Abstracts

Volume 45, No. 6

Abstracts to be presented at the meeting of the
Cordilleran Section
of The Geological Society of America and associated societies.
Fresno, California
20–22 May 2013

NOTE INDEXING SYSTEM
Numbers (2-4, 15-3) indicate session and order of presentation within that session.
Further information concerning the presented papers on which these abstracts are based should be obtained by contacting the authors of the abstracts.

SESSION NO. 1, 8:00 AM

Monday, 20 May 2013

T1. Tectonic Processes that Build the Stratigraphic and Structural Record of Ancient and Modern Convergent Margin

Radisson Hotel and Conference Center, Salon A1

1-1 **8:05 AM** Wakabayashi, John

MÉLANGES WITH HP METAMORPHIC ROCKS IN SUBDUCTION COMPLEXES: DEFORMED OLISTOSTROMES RATHER THAN EXHUMED SUBDUCTION CHANNELS?

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Many believe that the incorporation of high-pressure (HP) metamorphic rocks into mélanges results from large-scale return flow in a subduction channel, and that such mélanges represent exhumed subduction channels or plate interfaces. In the Franciscan Complex of California, the most striking examples of such mélanges are those with "high-grade", primarily metamafic, blocks, including HP amphibolite and eclogite. For examples with serpentinite-poor/free matrix, the blocks are clearly higher grade than the matrix, whereas this relationship is less clear for serpentinite matrix, due to the greater probability of retrogression of the latter. The high-grade metamorphic ages of the blocks are more than 50 million years older than the accretion age of the enclosing mélanges. The block-matrix metamorphic contrast, and the large difference between metamorphic and accretion ages, is difficult to explain with a simple subduction channel model. Franciscan mélanges with high-grade blocks display widespread evidence for a sedimentary (submarine sliding) origin rather than a subduction channel (tectonic) origin. The matrix comprises sedimentary breccia and conglomerate, including shale-rich, sandstone-rich, and serpentinite-rich examples. In several examples, the matrix metamorphism indicates subduction of the olistostromes to blueschist facies conditions. Many of the blocks in such units record at least two burial-exposure cycles to blueschist facies or greater depth. The first cycle involved exhumation of the blocks to the sea floor prior to olistostromal deposition, and the second involved subduction and exhumation of the olistostrome and the underlying block-free unit together. Metasomatic rinds around high-grade blocks apparently formed by reaction with surrounding ultramafic rocks. Ar-Ar ages of some rinds are less than 10 million years younger than high-grade metamorphic ages, indicating incorporation of the blocks in serpentinite mélanges 40 million years before the introduction of blocks into the oldest olistostromes. The first exhumation of the high-grade blocks may have taken place in the earlier serpentinite mélange(s). These older mélanges have yet to be found, so their origin (diapiric, shear zone, or sedimentary) remains unknown.

1-2 **8:25 AM** Rowe, Christie D.

THE THICKNESS OF PLATE BOUNDARY THRUST FAULTS: IMPLICATIONS FOR DEFORMATION MECHANISM AND THE ROCK RECORD OF SUBDUCTION

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The thickness of the actively deforming zone in a subduction thrust plate boundary fault is an important parameter for understanding the strength and spatial heterogeneity of plate boundary faults. Here we summarize observations of plate boundary faults at different depths from ocean drilling, seismic reflection studies, and structural measurements of exhumed ancient faults. These compiled measurements show that although cumulative deformation of subducting sediments may result in the development of sheared zones and mélanges hundreds of meters thick, that the active thickness of a plate boundary fault is likely much thinner (<50 m, usually 10-35 m). Anastomosing fault surfaces may be simultaneously active or alternating between earthquake cycles, for a total width of the geologically instantaneous plate boundary on order 100-400 meters. Sharp, smooth faults which are certain or possible earthquake rupture surfaces are found within or along the boundary of these ~10 m thick fault strands. Therefore, the effective deforming width of the plate boundary fault is at a minimum during earthquakes (<1-20 cm) but during afterslip and interseismic creep, the effective width is 2-3 orders of magnitude thicker. This compilation has implications for understanding the subduction and transference of material between tectonic plates and may be applied to constrain models which suggest material backflow within the plate interface.

1-3 **8:45 AM** Scholl, David

REEXAMINING THE CONCEPT OF THE LONG-TERM, PROGRESSIVE ACCRETIONARY WIDENING OF THE ALASKA FOREARC—DURING THE CENOZOIC IT EVOLVED AS A NARROWING (BY ~70-100 KM) AND THINNING OR EROSIVE MARGIN

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INTRODUCTION: The accretionary origin of the Franciscan complex was recognized in the 1970s as were similar rock bodies exposed around the rim of the north Pacific, e.g., the Chugach and Kodiak Fms of Alaska and the Shimanto of Japan. From this understanding it was posited that progressive accretion of material to the submerged forearc worked to widen the arc-trench gap. It was equally widely accepted that the Alaska forearc was an example of a progressively widening arc-trench gap. This supposition was not based on geological and geophysical observations of the submerged Alaska forearc. These data were unavailable until after the mid 1970s.

OBSERVATIONS: In the late 1970s and 1980s multichannel seismic reflection profiles and dredge samples collected by the USGS, MCS and refraction data by academia, and exploration drilling (COST wells) by industry, revealed the structural and tectonic fabric of the submerged Alaska forearc. These findings documented that coastal and island exposures of basement rock of Late Cretaceous and earliest Tertiary age extended seaward beneath the width of the forearc to near the Alaska Trench. Basement rock is the accretionary underplated complex and granite-intruded body of the exhumed Kodiak (and related) Fm. The wave-base unconformity cut across the beveled surface of the accretionary body can be traced seaward to the back of a ~20-30-km-wide frontal prism of offscraped trench sediment compiled along the inner wall of the trench. Dredge samples and stratigraphic continuity traceable to exposed units imply that since the early Eocene the submerged Alaska forearc has been subsiding and, with respect to fixed point on the upper plate, progressively narrowing.

INTERPRETATIONS AND IMPLICATIONS: We ascribe forearc subsidence and narrowing to the tectonic consequences of basal and frontal subduction erosion. During the Cenozoic accretionary processes built a small frontal prism and, based on limited reflection data, a thickening underplate beneath (20-30 km) the coastal area. Since 45-55 Ma accretion has thus dominantly been crustal thickening rather than crustal widening. Sediment subduction to build the posited underplate in turn smoothed the interplate decollement and favored the repeated rupturing of high-magnitude (>Mw8.0) megathrust earthquakes.

1-4 **9:05 AM** Raymond, Loren A.

TECTONOSTRATIGRAPHIC HISTORY OF THE UPPER FRANCISCAN (SUBDUCTION ACCRETIONARY) COMPLEX IN NORTHERN CALIFORNIA: ISSUES OF TERRANE DESIGNATION AND MAPPING

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Named units of the NE Diablo Range (NEDR) Franciscan Complex include coherent units, broken and dismembered formations, and various types of mélanges. Sedimentation on the seafloor of the drifting/subducting pre-Farallon (?) Plate and in the associated trench, followed both by subduction zone deformation and metamorphism and by later uplift, produced a distinct tectonostratigraphic sequence. Cretaceous Franciscan sedimentation in the eastern Diablo Range and NEDR (102 to 70 m.y –Joesten et al., 2004; Ernst, 2009) was followed in the NEDR by blueschist facies (BSF) metamorphism between 85 and 45 m.y. (Raymond et al., 1981) and uplift, perhaps between 40 and 30 m.y. (Dumitru, 1989). Yolla Bolly Terrane (YBT) type-area sedimentation was somewhat earlier (120 to 95 my – Dumitru, 2012; Ernst et al., 2012).

Similar tectonostratigraphic sequences with mappable units crop out below the Coast Range Ophiolite (CRO) and other serpentinite/peridotite (sp) units in the NEDR and Tiburon, Alpine Lake, Jenner Headlands, and YBT-type areas (Blake et al., 1982; Bero, 2010; 2013; Prohoroff et al., 2012; Wakabyashi, 1992; 2011). Downward, units include high-grade schist-bearing mélange +/- overlying schist units, foliated metawacke + metachert units, and broken and dismembered formational units. Most sub-CRO mélange and some mélange units have been assigned to the YBT. Structurally lower mélanges have been assigned to the Central Belt Terrane (CBT). Stratigraphies of "YBT" rocks vary regionally. Detrital zircon "YBT" ages cover a 50 my age range, but many YBT characteristics overlap those of the CBT. The YBT rubric seems to have been assigned primarily to metawacke-metachert and associated rock units of blueschist facies grade. Does the use of the terrane rubric as a proxy for detailed structural and stratigraphic mapping provide us with an adequate understanding of the accretionary complex architecture? Probably not. More detailed mapping and detrital zircon ages are needed.

1-5 **9:25 AM** Singleton, John

KINEMATIC ANALYSIS OF SYNSUBDUCTION SHEAR FABRICS IN FRANCISCAN COMPLEX MÉLANGE NEAR SAN SIMEON, CALIFORNIA

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Asymmetric fabrics in Franciscan Complex shale matrix mélange near San Simeon, central California, record synsubduction shear that has implications for the Late Cretaceous to early Tertiary tectonic evolution of the region. Outcrop-scale structural data including S-, C-, and C'-planes, slickenlines, block long axes, and offset blocks indicate that most asymmetric fabrics developed in a NE-dipping sinistral shear zone following Late Cretaceous chaotic mixing of the mélange. Approximately 70% of C-planes strike within ~45° of the major NW-striking structures in the region – the Neogene San Gregorio-Hosgri fault and the Late Cretaceous-early Tertiary Nacimiento fault zone. Slip vectors on these NW-striking C-planes consistently record sinistral or oblique sinistral shear. This dominant shear regime accommodated E-W to NE-SW shortening and N-S to NW-SE extension. Angles between S- and C-planes are typically ~25-35° and range up to ~45°, suggesting dominantly simple shear. Sinistral shear in the mélange is kinematically incompatible with Neogene to recent dextral faulting, indicating that these fabrics predate the early Miocene development of the Pacific-North America transform. We propose that sinistral shear in the mélange is related to Late Cretaceous to early Tertiary slip on the adjacent Nacimiento fault zone. These kinematic data are compatible with previous studies that have suggested the juxtaposition of the Salinian block against the Nacimiento block was accommodated by hundreds of kilometers of sinistral slip on the Nacimiento fault zone. This sinistral slip may have been driven by subduction of an aseismic ridge and/or oblique convergence between the Farallon and North America plates during Late Cretaceous to early Tertiary flat-slab subduction.

1-6 **9:45 AM** McLaughlin, Robert J.

TRANSTENSIONAL RIFTING ASSOCIATED WITH VOLCANISM DURING ACCRETION OF LATE CRETACEOUS-EOCENE SEAMOUNT REMNANTS IN THE FRANCISCAN COMPLEX COASTAL BELT, NORTHERN CALIFORNIA

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Small bodies of ocean floor entrained in the deformed Paleogene-Neogene Franciscan Complex Coastal Belt preserve a record of sea floor that otherwise was mostly subducted beneath North America. These basaltic rocks are expressed in aeromagnetic data indicating they are more widespread and structurally continuous than indicated by their mapped surface distribution (Langenheim et al., this meeting).

Foraminifer faunas of pelagic limestones intercalated with the basaltic rocks indicate mainly latest Cretaceous ages (Campanian-Maestrichtean) and a warm water, northern equatorial depositional setting. In the Wheatfield Fork terrane (WFT), however, Campanian-Maestrichtean basalts and limestones are overlain by a sequence of basalt and limestone containing a non-equatorial, late middle Eocene foraminifer fauna (about 45 ± 4 Ma).

We have compared the WFT geochemistry to other Coastal Belt basalts and to Paleogene (Siletz terrane) basalts in OR and WA, where pre-Paleogene basalts are not present. Trace and minor element scatter plots indicate a MORB to Ocean Island basalt origin for the Coastal Belt and most Siletz terrane basalts. The Eocene WFT basalt, however, has a chondrite-normalized rare-earth element (REE) pattern that is convex upward, with a maximum at Nd and Sm (Sm/Yb= 1.4; La/Sm=0.84). This pattern is comparable to basalts derived from a pyroxenitic melt source erupted during early Gulf of California rifting. Paleogene Siletz terrane basalts, in contrast, are strongly light REE- enriched, arguing against a compositional link with Paleogene Coastal Belt volcanism. We suggest that Late Cretaceous basalt entrained in the Coastal Belt was erupted on a seamount or plateau east of the Farallon-Kula and Farallon-Pacific ridges, which then collided with the California subduction margin north of 30° N in the Eocene (about 49-41 Ma). We speculate that deep extension or rifting occurred within the subducting seamount close to the Coastal Belt trench, producing Eocene (WFT) volcanism over the seamount.

1-7 **10:20 AM** Surpless, Kathleen DeGraaff

SEDIMENTARY GEOCHEMISTRY OF THE GREAT VALLEY GROUP, CALIFORNIA: RECORDS OF THE LOST ARC

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Where magmatic arcs have been deeply eroded, associated forearc basins may contain more complete records of arc evolution than the remnant arcs themselves. Geochemical analysis of fine-grained sedimentary rocks in the Great Valley Group (GVG) complement previous provenance studies to generate a more robust characterization of sediment sources. Although major-element sedimentary geochemistry is limited by the potential mobility of these elements, northern GVG (Sacramento Valley) samples consistently record more mafic signatures in the less-mobile Fe-, Mg-, and Ti-oxides than southern GVG (San Joaquin Valley) samples. Trace elements Cr, Ni, and V are also elevated in the northern relative to the southern GVG, reflecting more mafic, including ophiolitic, components in northern sources. The Sacramento Valley geochemical signature is remarkably consistent throughout deposition and between samples collected from the northeast, north, northwest and southwest sections of the valley. Samples from the Sacramento Valley and the basal, Lower Cretaceous San Joaquin strata fall between Mid-Ocean Ridge Basalt and Continental Arc andesite values on plots of compatible and incompatible trace elements, with basal San Joaquin samples showing the most juvenile signatures and high V/Sc ratios, suggesting increased mafic and volcanic detritus. In contrast, the Upper Cretaceous strata in the southern GVG are the most evolved in their trace-element signatures and have low V/Sc ratios indicative of limited volcanic input. The Upper Cretaceous San Joaquin samples plot closest to the North American Shale Composite and Upper Continental Crust values in compatible versus incompatible trace element plots. Northern GVG geochemical results are consistent with provenance limited to the accreted arc terranes of the Klamath Mountains and northern Sierra Nevada Mountains. The mafic provenance signal in the Early Cretaceous San Joaquin Valley may result from erosion of mafic rocks of the Early Cretaceous Sierran arc to the east, perhaps combined with removal of extensive volcanic cover from the southern Sierra Nevadan arc. Late Cretaceous exhumation of the southern Sierran arc provided a more felsic and evolved source for the southern GVG.

1-8 **10:40 AM** Saleeby, Zorka

GEOLOGIC DEVELOPMENT OF THE KERN ARCH, SE SAN JOAQUIN BASIN (SJB), CALIFORNIA

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We adopt the name Kern arch for the extensively faulted, broad W-plunging basement salient that has grown beneath eastern SJB over the past ~1 m.y., and which has been partly denuded of its Cenozoic cover strata. Subsurface apatite He thermochronometry, vitrinite reflectance, low-grade metamorphic paragenetic and thermal modeling studies show that 1 to 2 km of post 1 m.y. exhumation increased from west to east across the arch, and that ~1500 m of such strata has been exhumed off the adjacent Sierran basement. Seismological and geodynamic relations indicate that this active epeirogenic uplift is driven by the delamination of the underlying mantle lithosphere, and resulting asthenosphere ascent. Rock and surface uplift at mm/yr-scale is further indicated by contemporary vertical velocities measured in GPS monuments across the salient. Such rapid uplift is driving the incision of the lower Kern River gorge as well Poso Creek and the White River. Much of the Kern arch is characterized by widespread erosional lags, which commonly misguide workers into interpreting much of the arch as a series of alluvial fans.

In contrast to the misinterpretation of the Kern arch as a series of alluvial fans, some workers have misinterpreted it is an early Cenozoic uplift. This view may now be more clearly placed into the regional context of profound exhumation of the southern Sierra Nevada batholith and adjacent Great Valley forearc during the Late Cretaceous, which resulted in the rapid removal of ~10-15 km of crust off the area of the modern Kern arch, increasing to ~35 km of crust removed off the area of the Tehachapi Range. This exhumation gradient developed above the northern shoulder of the Shatsky Rise conjugate as it subducted beneath the southernmost Sierra-Mojave region. Complimentary to the southward increasing exhumation gradient, the mantle lithosphere was completely removed from beneath the Tehachapi-Mojave region by shallow flat subduction of the main rise conjugate. The uplift-subsidence patterns of the region were further confounded by the latest Oligocene-early Miocene opening of an underlying slab window, which drove epeirogenic transients and block faulting. Geodynamic relations suggest that the slab window instigated the recent delamination of the residual mantle lithosphere from beneath the Kern arch region.

1-9 **11:00 AM** Charvet, Jacques P.

MESOZOIC-CENOZOIC TECTONIC EVOLUTION OF SW JAPAN: REVALIDATION OF THE COLLISIONAL MODEL

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The Japanese Islands are often wrongly considered as a typical example of accretionary orogen. The model of "Pacific-type orogeny" of the 70s, emphasizing the purported absence of nappes, has been questioned in the 80s, with the discovery of the actual structure made of a pile of large thrust sheets and the proposal of collisional models, involving the intermittent underthrusting of buoyant blocks like micro-continents.

However, the revised plate tectonic interpretation of the history of the Japanese islands, considering new ocean plate stratigraphy and radiometric dating of metamorphic units acquired since the 1990s, is again presented by Japanese scientists in terms of accretionary processes linked to a steadily oceanic subduction, with an episodic ridge subduction: the so-called "Miyashiro-type orogeny".

The review of dataset leads to the following conclusions. The structure of SW Japan is made of a pile of polydeformed sub-horizontal nappes, similar to the one encountered in collisional orogens. The geodynamic mechanisms advocated for the tectonic building within the accretionary orogeny concept are inappropriate. A permanent oceanic subduction with the intermittent subduction of an active ridge or seamount chain is unable to build such structures, as it induces in fact an acceleration of the tectonic erosion; the underthrusting of a micro-continent or mature arc is likely needed. The exhumation of Sanbagawa HP schists suggests the setting of a continental subduction. The petrological and new geochemical data strongly support the existence, beneath the nappes of accretionary complexes, of continental bodies showing affinities with South China, from which they were once separated. The episodic underthrusting of such blocks was

responsible for the tectonic piling. Tectonic erosion plaid likely a major role in removing material during the intervening subduction stages.

A revised geodynamic model, implying the collision of buoyant blocks, is proposed for explaining the orogenic crises which took place respectively at around 240, 130, 80-60, and 20 Ma ago in SW Japan.

1-10 **11:20 AM** Ogawa, Yujiro

NEW SCOPE OF JAPAN TRENCH AND NANKAI TROUGH: MIOCENE TO RECENT TRENCH WEDGE HISTORY AND 2011 TOHOKU-OKI EARTHQUAKE

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The Japan trench and Nankai trough have been thought to be the best examples of subduction erosion type and an accretionary prism type trenches, respectively. More importantly, they were thought to be type examples of the Mariana type and Chilean type (without and with a large earthquake) margins, respectively. However, the 2011 Tohoku-oki Earthquake (Mw 9.0) along the Japan trench clearly shows that the previous classification was not the case but a new scope is needed for general understanding. The Tohoku-oki Earthquake recovered a back slip of 25 m at the hypocentral area (25 km depth) and much longer slip (50 m) at the trench area after 500 to 1000 years absence of the same scale subduction earthquake. A small, but typical, frontal prism of stacked thrusts is developed in front of a large listric normal fault submarine sliding body on the occasion of the great thrusting, as a result of the total trench slope stretching. By means of our submersible study, it has been known that in the upper part of this very frontal prism the lower trench slope is composed of Miocene diatomaceous, calcite cemented breccia, probably the exhumed Miocene accretionary prism. The mechanism of this exhumation is considered by surface gravitational collapse by frontal wasting as graben fill for tectonic (subduction) erosion. Also according to our submersible mapping on two submarine canyons which cut the total accretionary prism of the Nankai trough, the frontal part of the splay fault is composed of Quaternary beds, the present prism being as young as only 3 Ma. These two lines of recent researches indicate that the two trenches, Japan and Nankai, must be defined by a different way as repeated development of prism formation and erode type, in the latter case with large-scale sliding and collapsing of the toe area. The Miocene prism formation might be caused by trench outward proceed with massive sand supply to the trench, and the Quaternary collapse might be cause by volcanic ridge subduction in the Nankai, by large-scale thrusting which triggers a trench toe collapse. Thus the trench wedge is controlled by the total balance in island forearc, topographic and stress regime conditions, and this concept is in accordance with the wedge stability discussion in thrust belts.

1-11 **11:40 AM** Okay, Aral

EARLY CRETACEOUS SEDIMENTATION AND OROGENY ON THE SOUTHERN ACTIVE MARGIN OF EURASIA: CENTRAL PONTIDES, TURKEY

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The Pontides in northern Turkey constituted part of the southern active margin of Eurasian continent during the Mesozoic. In the Early Cretaceous, a large submarine turbidite fan, measuring 300 km by 60 km, covered most of the Central Pontides. New U-Pb detrital zircon data show that the major source of the turbidites was the East European Craton in the north. A large river, comparable to the present Nile, was draining the East European Craton south to the Tethyan Ocean. This implies that there was no Black Sea rift between the Pontides and the East European Craton during the Early Cretaceous. The Lower Cretaceous turbidites are bounded in the south by a large metamorphic area, the Central Pontide Supercomplex, which was considered as a pre-Jurassic basement. New geological mapping, petrology, U-Pb zircon and Ar-Ar muscovite ages indicate that the northern part of the Central Pontide Supercomplex consists of Lower Cretaceous distal turbidites deformed, metamorphosed and accreted in the north-dipping subduction zone in the Albian. The rest of the Central Pontide Supercomplex is made of Middle Jurassic, Lower Cretaceous and middle Cretaceous (Albian) metamorphic belts, each constituting distinct subduction-accretion units. They represent episodes of collision of oceanic volcanic arcs and oceanic plateaus with the Eurasian margin.

SESSION NO. 2, 9:20 AM

Monday, 20 May 2013

T5. Critical Zone I: Where Rock Meets Water and Life at Earth's Surface

Radisson Hotel and Conference Center, Salon A2

2-1 **9:20 AM** Wood, Jim

EARLY TERTIARY CLIMATE CHANGE AND ITS IMPACT ON THE MATRIX MINERALOGY OF "AURIFEROUS GRAVELS" IN THE SIERRA NEVADA FOOTHILLS

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"Early Tertiary auriferous gravels" is a non-descript early mining term that remains in use on modern maps of both the USGS and the California Geological Survey (CGS). Additional terms such as "lower gravel/upper gravel" and "channel gravel/bench gravel" all once held important economic connotations for 19th century miners but few modern geological studies have correctly characterized the physical and temporal nature of these important sedimentary deposits.

Recent field investigations and analytical data collected from several locations of the "auriferous gravels" throughout the Sierra foothills show this map unit to be a complex sedimentary assemblage comprised of at least two geologic units possessing drastically contrasting mineralogical and age relationships. Kaolinitic quartz-rich fluvial sandstones dominate the "lower or channel gravels" and represent the proximal Ione Formation fluvial system (≈50Ma). In contrast, the "upper or bench gravels" is a smectitic unit with complex sandstone matrix mineralogy and represents a much younger fluvial system (≥ 30 Ma). These smectitic sediments are best represented at Chalk Bluff in Nevada County. In addition, similar kaolinite/smectite mineralogical distinctions are observed in the paleosols buried immediately below these respective fluvial units.

The mineralogical record contained in these sedimentary and pedologic units collectively forms an important addition to other climatic data indicating major global climate change at the end of the Eocene period. Thus, the 19th century nomenclature spawned during the heyday of gold mining in California should be abandoned in favor of a new classification based upon important differences in matrix mineralogy Such revised classification will help more clearly define the character of these Early Tertiary sediments and their important role in understanding the complex geological evolution of the Sierran region as well as global climate change during this dynamic period.

2-2 **9:40 AM** Wood, Jim

THE NATURE OF EARLY TERTIARY SOILS AND SEDIMENTS—MINERALOGY AND PETROLOGY

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The mineralogy and petrology of soils and sediments in the Early Tertiary section of the Sierra Nevada foothills of Northern and Central California were influenced by global tropical and subtropical climatic regimens. Kaolinitic soils and sediments formed during the extremely warm/humid tropical climate of the Paleocene to Early Eocene, while smectite clay dominates the later Eocene to Early Oligocene soils and sediments. Micromorphological and micro-chemical investigations of both kaolinitic and smectitic sediments, large volumes of clay-rich materials were transported in these paleo fluvial systems as sand-sized aggregates derived from fluvial erosion of deeply weathered mature soils. The clay microfabric of the Early Tertiary paleosol clasts was stabilized by amorphous silica cement that precipitated in association with the intense chemical weathering in the warm/humid environment of the Early Tertiary. This pedogenic silica protected clay-rich aggregates from dispersion during fluvial transport in Early Tertiary rivers.

Today, the pedogenic silica cement that stabilizes the granular smectitic sediments creates problems for soil engineers that design for construction on the exposed smectitic soils and sediments. The silica-stabilized smectitic clay in soils engineered from Late Eocene/Early Oligocene deposits can not be characterized by conventional ASTM soil test methods. The standard soil engineering tests classify the smectitic sediments as having low expansion potential. Following placement in engineered soils for construction, the paleo silica cement in these clay materials is prone to incremental dissolution allowing the expansive clays to freely interact with cyclic soil moisture conditions. Failure to properly classify these potentially highly expansive soils has contributed to widespread cases structural damage throughout the urbanizing Sierra foothills and adjacent Sacramento Valley areas.

2-3 **10:00 AM** Granger, Darryl E.

EXHUMATION OF THE GRANITE MOUNTAINS, WYOMING, FROM COSMOGENIC DIPSTICK DATING

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Early Tertiary sedimentation in basins of Wyoming and northern Colorado buried large areas of the Rocky Mountain landscape that have since been re-exposed by Neogene exhumation. The Granite Mountains in central Wyoming are thought to be among the most recently exhumed, and may represent an intact Paleogene landscape over which deposition continued into the early Pliocene. The mountains are composed of erosionally resistant rock; there is little evidence of recent erosion and there is only a sparse colluvial apron capping Mio-Pliocene lake beds around the mountains. Preservation is enhanced due to the porous basin fill that limits surface drainage and thus also fluvial erosion. If the Granite Mountains are indeed a relict landscape with very little erosion, then their exhumation rate should be measurable by surface exposure dating of the newly exposed slopes. The mountains could be used for 'dipstick dating' in much the same way that nunataks can be used to date ice sheet ablation.

To determine the exhumation rate we collected 8 samples for exposure dating from bare rock slopes in a 184 m vertical transect at Lankin Dome. The lowest sample was from the present-day mountain base, within 1 m of where granite slopes emerge from basin fill, while the highest sample is from above the highest preserved lakebeds in the adjacent basin. Cosmogenic ^{10}Be concentrations increase systematically with elevation, and are consistent with a simple model of exhumation and slow bedrock erosion. The best-fit models constrain exhumation rates to a range of ~200-300 m/My and bedrock erosion rates to ~2.5-3.0 m/My. The data indicate that exhumation at Lankin Dome commenced recently, near 0.5-1.0 Ma, likely due to recent incision of the Sweetwater River and its tributaries.

2-4 **10:20 AM** Valenzuela, Rebecca A.

CONTRASTS IN DENUDATION RATES, CLIMATE, SUBDUCTION DIP ANGLES, AND PLATE CONVERGENCE RATES ALONG THE SOUTHWESTERN MEXICAN COAST

VALENZUELA, Rebecca A.[1], RIEBE, Clifford S.[1], and RAMÍREZ-HERRERA, M. Teresa[2], (1) Geology and Geophysics, University of Wyoming, 1000 E University Ave, Laramie, WY 82071, rcorbier@uwyo.edu, (2) Laboratorio Universitario de Geofísica Ambiental, CIGA, Universidad Nacional Autónoma de México, Morelia, Michoacán, 58190, Mexico

Erosion shapes landscapes and plays a crucial role in the interplay of climate and tectonics in Earth system dynamics. Quantifying erosion rates and how they vary with factors such as climate and tectonic setting is therefore important for understanding landscape evolution as well as Earth's long-term climate evolution. Here we use the southwestern Mexican coast as a natural laboratory for studying effects of climate and tectonics on erosion rates. Convergence rates, subduction dip angles, and average climate indices all vary sharply along the Middle America Trench (MAT), where the Cocos Plate subducts beneath the North American Plate. Convergence rates increase from ~2.0 cm/yr in the north, in the state of Jalisco, to 7.5 cm/yr in the south, in Chiapas. Average precipitation also increases to the south, spanning a greater than four-fold range across diverse ecosystems including desert lowlands and high-altitude tropical rainforests. The change in subduction dip angle is more localized, steepening to the south from ~15° to ~45° at the Tehuantepec Fracture Zone, which is near the middle of the MAT. We identified a series of catchments that span these natural gradients in tectonics and climate and measured concentrations of cosmogenic ^{10}Be in sediment from streams and in soils from ridge tops. This permits us to study how millennial-averaged erosion rates vary with tectonic and climatic factors. In Jalisco, in the north, we find that denudation rates are higher on ridge tops and lower within the surrounding catchments, consistent with relief decline. Conversely, in Chiapas, in the south,

denudation rates are lower on a ridge top than in the surrounding catchments, consistent with relief growth. Preliminary results suggest that erosion rates are lower in the north, where plate convergence rates are also lower, suggestive of tectonic control of erosion rates. We discuss how our results advance understanding of linkages among climate, tectonics, and Earth surface processes.

2-5 **10:40 AM** Beyssac, Olivier

TRACING FOSSIL PARTICULATE ORGANIC CARBON FROM BEDROCKS TO RIVER AND MARINE SEDIMENTS: IMPLICATIONS FOR THE GEOLOGICAL CARBON CYCLE

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Organic C (OC) exported by rivers is a mix of recent OC and fossil OC derived from erosion of rocks. Burial of fossil OC is a simple recycling of reduced carbon and has no effect on atmospheric CO2 and O2 levels. Conversely, its oxidation consumes atmospheric O2 and returns CO2 to the atmosphere. Addressing the role of continental erosion on the global carbon cycle thus requires assessing the fate of petrogenic OC during erosion. In large scale erosion systems (Himalaya, Amazon), it has been shown that only graphite resists to oxidation during river transport. We present new structural and geochemical data on a small-scale and extremely active erosion system (Taiwan) in which OC is massively and rapidly transferred to the ocean. The in situ structural characterization of fossil OC by Raman spectroscopy shows that all forms of fossil OC, from very disordered phases (kerogen-like) to graphite, are transported and preserved from the bedrocks to the marine sediments. Such small scale active systems therefore act as major carbon sinks on geological timescale. In turn, the Raman spectra of fossil OC may be used as a powerful tool for the provenance study of detrital sediments. The fate of fossil OC during erosion is a complex interplay between the burial history (diagenesis/metamorphism) of the OC-bearing source rock, the nature of the erosion system (transport, erosion dynamics, biological activity, climate. . .) and the sedimentation processes. Assessing the interactions of OC between the lithosphere and the atmosphere on geological timescale requires studies in various geological contexts to quantify the fluxes of fossil OC during erosion, but also studies dedicated to the processes controlling oxidation or preservation.

2-6 **11:00 AM** Hunsaker, Carolyn T.

HEADWATER STREAM SEDIMENT LOADS AND ASSOCIATED CARBON AND NITROGEN, SIERRA NEVADA, CALIFORNIA

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Knowing the spatial and temporal range of variability of soil erosion and stream sediment loads is important for understanding geomorphology processes and land management effects in forested mountains with changing climate. The Kings River Experimental Watersheds provide seven years of data for eight headwater watersheds with granite-derived soils in the southern Sierra Nevada, California. The average annual sediment loads range from 2 to 17 kg/ha with one watershed having a much higher load of 61 kg/ha. Annual sediment mass, carbon, and nitrogen fluxes were strongly correlated with streamflow and precipitation and have high interannual variation. Somewhat surprising is that snow-dominated streams transport similar loads as streams at the rain-snow transition zone. Also, the stream in the undisturbed watershed (no roads or timber harvest) carries as much sediment as the other streams. Current erosion rates are low compared to long-term erosion rates determined by cosmogenic nuclide analyses. Coarse and fine particulate organic matter makes up 30-50% of the material trapped in the sediment basins; this is expected for heterotrophic, low-order forest streams. Our results suggest that carbon and nitrogen are relatively less protected in material exported from watersheds with coarse-textured soils than in watersheds with finer textured soils, but more carbon and nitrogen overall are leaving the basins with finer textured soils.

2-7 **11:20 AM** Meadows, Matthew

USING LARGE-SCALE, SHALLOW SOIL WATER MEASUREMENTS TO ESTIMATE DEEPER SOIL WATER STORAGE IN A MIXED-CONIFER FOREST OF THE SOUTHERN SIERRA NEVADA

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Soil moisture was measured in the southern Sierra Nevada using cosmic-ray, time domain reflectometry (TDR), dielectric, neutron probe, and gravimetric or volumetric sampling techniques. These techniques are compared to: 1) develop a better understanding of shallow (0-50 cm) soil moisture from plot and hectare scales, and 2) determine the feasibility of estimating deep soil moisture using large-scale, shallow soil moisture measurements. Multiple embedded sensors (TDR and dielectric) were deployed across varying soil depths, aspects, and canopy covers to capture spatial and temporal variations of soil volumetric water content within the spatial range of a COsmic-ray Soil Moisture Observing Systems (COSMOS) and throughout a 4 km^2 headwater catchment. Through a one-year period, June 2011-June 2012, area-average volumetric water contents observed by COSMOS were compared to real-time, *in situ* observations of soil moisture using TDR and dielectric sensors, and with measurements of soil moisture taken periodically during surveys within the COSMOS footprint. Surveys of soil moisture in the upper 40 cm of soil were made along transects around the COSMOS with handheld TDR and gravimetric sampling techniques. A neutron probe was also used to measure soil moisture at 14 locations within the COSMSO footprint.

Results show that the COSMOS and the embedded sensor networks effectively observed trends of snow disappearance and soil drainage throughout the summer and fall, and track diurnal and seasonal trends in the near-surface soil profile. The addition of snow during the winter of water-year 2012 complicates the COSMOS signal. The COSMOS measurement was limited to approximately 6 cm of water and had an effective measurement depth between 15 and 30 cm. Throughout the basin 55% of the variability in the 90 cm water content observations on hillslopes was explained by the COSMOS observations during no-snow conditions. These data suggest that the COSMOS observations could be used for a watershed-scale soil moisture index for depths up to 90cm.

This research is part of the NSF-supported Southern Sierra Critical Zone Observatory, which is co-located within the U.S. Forest Service, Kings River Experimental Watershed.

2-8 **11:40 AM** Lucas, R. G.

GROUNDWATER-SURFACE WATER INTERACTIONS IN MONTANE MEADOWS OF THE SIERRA NEVADA, CALIFORNIA

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Meadows often lie in low gradient, groundwater fed terrain of the Sierra Nevada. These settings result in near saturated conditions for much of the year, shallow groundwater tables, and groundwater discharge to surface flow. Our hypothesis is that groundwater fluctuations integrate watershed processes rather than meadow specific processes. We utilize a series water column data from monitoring wells and piezometers in two meadows, soil moisture and snow depth data from nodes in the associated catchment, located within the Southern Sierra Critical Zone Observatory, from water years 2008-2012. Water samples from wells and associated streams were analyzed for major ions and stable water isotopes. Results from the monitoring wells and piezometers show groundwater tables and pressure heads that are highest during snowmelt and decrease over the summer growing season. Groundwater elevations exhibit diurnal fluctuations influenced by snowmelt and evapotranspiration (ET) processes in the spring, transitioning to an ET dominated signal during the summer growing season. These fluctuations are of greatest magnitude near the meadow-forest boundary and least near the center of the meadow. The piezometer data shows seasonal variation in the direction and magnitude of groundwater flux. Analysis of the geochemical data show that major ion concentrations vary little temporally; spatial variation is observed from the edge of the meadow to the center. Consistent groundwater discharge, with little variation in the geochemical profile of the groundwater, suggests a shallow groundwater source that is not being fully utilized by the adjacent forest landscape. These montane meadow systems provide a window for investigating groundwater surface water interactions in the catchments of the Southern Sierra Critical Zone Observatory.

SESSION NO. 3, 8:20 AM

Monday, 20 May 2013

T14. Quaternary Geology of California's Central Valley and Its Relevance to Water Infrastructure

Radisson Hotel and Conference Center, Salon D1

3-1 **8:20 AM** Sowers, Janet

QUATERNARY GEOLOGY AND GEOMORPHOLOGY A KEY TO ASSESSING LEVEE FOUNDATION CONDITIONS IN THE SACRAMENTO VALLEY, CALIFORNIA

SOWERS, Janet[1], PEARCE, Justin[1], BROSSY, Cooper C.[1], KELSON, Keith[2], and WILSON, Jennifer M.[1], (1) Fugro Consultants, Inc, 1777 Botelho Drive, Suite 262, Walnut Creek, CA 94596, j.sowers@fugro.com, (2) URS Corporation, 1333 Broadway, Suite 800, Oakland, CA 94612

Flood protection infrastructure in California's Sacramento Valley typically is founded on unconsolidated Late Quaternary fluvial, basin, and estuarine sediments. The stability of these sediments as foundation materials depends on characteristics such as grain size, sorting, density, permeability, bedding, and cementation. These characteristics are a reflection of the geologic origin and history of the sediments. Original 1:24,000 scale mapping of Quaternary geologic units was conducted to provide a framework for foundation assessments. The mapping builds on previous geologic mapping, and the interpretation of early topographic and soil maps, 1937 aerial photography, and limited drilling data.

The Sacramento Valley is divided into five major environments of deposition: Coast Range alluvial fans, Sierran alluvial fans, Sacramento River flood plain, flood basins, and the delta estuary. Coast Range alluvial fans are derived primarily from clastic sedimentary rocks and are clay-rich, especially in the distal fan reaches. Prominent natural levees form winding low ridges that may extend along the length of the fan. Sierran alluvial fans are derived from granitic and metamorphic rocks and are dominated by micaceous sands and silts. Coarse sediments derived from 1800s-era gold mining spoils form wide-spread deposits in several Sierran streams and alluvial fans, extending downstream to the Sacramento River and Sacramento – San Joaquin Delta. Alluvial fans from glaciated Sierran watersheds exhibit multiple older fan terraces at the mountain front. In the axis of the valley, the Sacramento River winds southward, flanked by silt-rich natural levees. Flood basins occupy the lowlands on either side of these natural levees, and their thick clays and silts interfinger with the coarser fan and levee deposits. Flood basins empty into the delta-- large marsh islands underlain by peat, clay, and silt, and bordered by winding sloughs and their natural levees.

Sacramento Valley sediments are longitudinally and laterally diverse reflecting the interplay of geomorphic process and depositional environment. This understanding provides a regionally continuous framework for estimating foundation conditions and facilitates identification of levee reaches for subsequent engineering characterization.

3-2 **8:40 AM** Wilson, Jennifer

DEVELOPING A GEOMORPHIC APPROACH TO ASSESSING LEVEE UNDERSEEPAGE

WILSON, Jennifer, PEARCE, Justin, and SOWERS, Janet, Fugro Consultants, Inc, 1777 Botelho Drive, Suite 262, Walnut Creek, CA 94596, jm.wilson@fugro.com

The migration of water through levee foundation materials by underseepage can lead to piping and levee instability during critical high-water stages. As part of regional levee evaluation studies, a geomorphic assessment approach was developed to identify areas of potential vulnerability to underseepage along levees within the Sacramento and San Joaquin Valleys. The approach integrated existing and new Quaternary geologic mapping with soil hydrologic classes and geomorphic data to develop a criteria matrix of relative underseepage susceptibility classes (very high, high, moderate, and low). These classes were assigned to levee segments according to the criteria matrix, with late Holocene and historical channel deposits judged to have very high susceptibility, late Holocene natural levee, overbank, and crevasse splay deposits having high susceptibility, and older alluvial fan and fine-grained, basin deposits having moderate to low susceptibility. Documented past levee performance issues were also evaluated and spatially analyzed using GIS and compared to the underseepage susceptibility mapping to help calibrate the susceptibility rankings based on historical events. The GIS analysis of past performance was designed to include discrete (point) data as well as continuous (line) data. Epistemic uncertainties include the completeness and locational accuracy of the levee performance data and precision in the surficial mapping. Preliminary results suggest a strong correlation between paleochannel, historical natural levee, and peat deposits and documented levee performance issues.

3-3 **9:00 AM** Barry, G. Robert

THE GEOLOGY AND ONGOING REPAIRS OF THE AGING CALIFORNIA AQUEDUCT IN THE CENTRAL VALLEY

BARRY, G. Robert and NICHOLS, Holly J., California Department of Water Resources, Project Geology Section, 3500 Industrial Blvd, West Sacramento, CA 95691, rob.barry@water.ca.gov

One of the major water conveyance systems through the Central Valley, the State Water Project's California Aqueduct, is an open canal that conveys about 1,500 gallons per minute every day to central and southern California. The California Aqueduct was built in the late 1960s and is approaching 50 years of age. The effects of that aging are evident as seeps, sinkholes, dribbles, depressions, leaks, and occasionally, major leaks. The underlying geology almost always plays a role in the problems manifest at the surface. Regional subsidence and locally poorly-consolidated to unconsolidated sedimentary debris flow deposits were recognized during the design phase of the California Aqueduct. Settlement ponds were constructed to consolidate the sediments and promote hydrocompaction. Shortly thereafter, the California Aqueduct embankments and other appurtenant structures were built. Since that time, a variety of problems have been encountered, including a few major leaks that required urgent repairs. These repairs nearly always must be completed without taking the California Aqueduct out of service, which would disrupt and potentially cause significant damages to agricultural, industrial, commercial, and residential users. This leads to a variety of repair alternatives, with no one-size-fits-all repair. Remedial repairs that have been used include excavating and re-compacting the embankment, injecting bentonite, compaction grouting, installing interlocking steel sheet piles, underwater grouting through the liner, permeation grouting, and re-lining the Aqueduct with an impermeable liner. This presentation will discuss a few of these canal repairs and how they relate to the underlying geology.

3-4 **9:20 AM** Sneed, Michelle

CORRELATING FINE-GRAINED DEPOSITS AND LAND SUBSIDENCE IN THE SAN JOAQUIN VALLEY, CALIFORNIA

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Extensive groundwater withdrawal in the San Joaquin Valley from 1926 to 1970 caused widespread aquifer-system compaction and resultant land subsidence. This subsidence was largely arrested by the importation of surface water through Federal and State Water Projects; however, both expanded agricultural land use and reduced availability of surface water have caused compaction to occur in the northwestern and central San Joaquin Valley. The resulting differential subsidence has reduced freeboard and flow capacity of the Delta-Mendota Canal, the Eastside Bypass, and other canals that deliver irrigation water and transport floodwater.

The location and magnitude of subsidence during 2006–12 were determined using Interferometric Synthetic Aperture Radar (InSAR), Global Positioning System (GPS), and other land-surveying techniques. Results of the InSAR analysis indicate that a 3,200 square-kilometer area was affected by at least 20 millimeters (mm) of subsidence during 2008–10. Within that area, InSAR analysis also indicates a localized maximum subsidence of at least 540 mm. Additional land-survey data indicate these high rates continued through 2012.

The Chowchilla River and Fresno River alluvial-fan deposits, which were derived from non-glaciated Sierra Nevada terrain and contain a higher fraction of fine-grained sediments than the adjacent fan deposits derived from glaciated terrain, underlie the maximum impacted area. Analysis of data from extensometers, continuous GPS stations, and groundwater levels indicates that nearly all of the aquifer-system compaction occurred below the top of the Corcoran Clay (CC). Results from a 1-D compaction model, constrained by lithological descriptions and consolidation tests of continuous core, indicate that less than 3 percent of the total compaction occurred within the CC, which was unexpectedly small. Accurate characterization of the lateral and vertical extents, mechanical properties, and flow regimes of fine-grained deposits is critical for development and calibration of numerical models and development of realistic simulated predictions of subsidence needed by agencies charged with maintaining the integrity of water-conveyance infrastructure in subsiding areas.

3-5 **9:40 AM** Brossy, Cooper C.

RE-VISITING AND REVISING THE QUATERNARY GEOLOGY OF THE LOWER AMERICAN RIVER

BROSSY, Cooper C.[1], WILSON, Jennifer[1], PEARCE, Justin[1], SOWERS, Janet[1], HUNTER, Lewis E.[2], and KYNETT, Michael N.[2], (1) Fugro Consultants, Inc, 1777 Botelho Drive, Suite 262, Walnut Creek, CA 94596, c.brossy@fugro.com, (2) U.S. Army Corps of Engineers, Sacramento District, 1325 J Street, Sacramento, CA 95814

Recent stratigraphic and geomorphic mapping along the Lower American River (LAR) downstream of Nimbus Dam in support of levee stability evaluations has refined existing geologic understanding and identified several American River paleochannels of potential engineering significance. The recent mapping synthesizes the results of field mapping and sampling as well as petrographic and pedogenic evaluations with existing and recently collected surface and subsurface data to investigate the origin, continuity, and extent of subsurface deposits constituting levee foundations. Collection of outcrop data and development of 3-D surface contour maps, geologic cross sections, and longitudinal correlations has helped resolve questions regarding the thickness, lateral and longitudinal extents, and contact relationships of key units. The results provide evidence that the Plio-Pleistocene-aged Fair Oaks formation, not the previously interpreted Riverbank- or Modesto-age formations, underlies much of the LAR channel bed. The formation is relatively fine-grained and hard, and appears to be laterally extensive and continuous beneath the levees, which may have implications for channel incision and lateral erosion. A variable thickness of unconsolidated modern and/or upper Modesto Formation-age gravels and cobbles unconformably overlies the Fair Oaks formation. The formation's top surface lies mostly at elevations too low to be exposed in the modern channel bed downstream of Watt Avenue. Synthesis of subsurface data suggests considerable relief of the eroded top of the formation, which may locally correspond with paleochannels identified via historical maps, as well as geophysical and LiDAR data.

3-6 **10:20 AM** Ponti, Daniel J.

QUATERNARY STRATIGRAPHY AND NEOTECTONICS OF THE SACRAMENTO-SAN JOAQUIN DELTA, CALIFORNIA: PRELIMINARY FINDINGS FROM RECENT COLLABORATIVE RESEARCH

PONTI, Daniel J.[1], TINSLEY, John C.[2], WAN, Elmira[3], PAGENKOPP, Mark[4], MAIER, Katherine[1], GATTI, Emma[1], OLSON, Holly[5], HADDON, Elizabeth[1], and ROSA, Carla[1], (1) U.S. Geological Survey, Earthquake Science Center, 345 Middlefield Road, Menlo Park, CA 94025, dponti@usgs.gov, (2) U.S. Geological Survey, 345 Middlefield Road, Menlo Park, CA 94025, (3) U.S. Geological Survey, 345 Middlefield Rd, MS-975, Menlo Park, CA 94025, (4) California Department of Water Resources, 3500 Industrial Blvd, West Sacramento, CA 95691, (5) U.S. Geological Survey, 345 Middlefield Rd, Menlo Park, CA 94025-3591

The U.S. Geological Survey and California Department of Water Resources (CDWR) are developing a 3D Quaternary chronostratigraphic model for the Sacramento-San Joaquin Delta area. Principal objectives of the study are to: a) identify and map subsurface unconformities and flooding surfaces that serve as tools for assessing tectonic deformation and the potential for seismic activity on faults in the region, b) provide a predictive tool for characterizing subsurface conditions to evaluate potential water conveyance system alignments, c) better characterize and map the 3D distribution of geotechnical parameters important for assessing levee vulnerability from earthquake ground shaking and liquefaction, and d) characterize the shallow seismic-velocity structure. Data for the model primarily consist of thousands of geotechnical boring logs and CPT soundings collected during the past six decades, including high-quality logs and core samples from several hundred boreholes and CPT soundings completed since 2008 by CDWR to depths up to 200 ft.

We have initially identified six mid-Pleistocene to Holocene sequences that can be regionally correlated based on log descriptions that suggest the presence of buried soils and measured variations in shear-wave velocity and soil density. Correlations have been aided by the discovery and identification of at least three distinct mid-lower Pleistocene age tephra horizons that occur within the section. Rates of sediment accumulation in the Delta are low, with perhaps >1 m.y of the sedimentary record preserved within ~300 ft of the ground surface. Initial evaluations of chronostratigraphic relations suggest a) middle and late Quaternary tectonic activity associated with the mapped trace of the West Tracy fault, b) post-lower Pleistocene structural relief likely associated with the South Midland fault, and c) possible Quaternary tectonic deformation within the central Delta not associated with any presently known structures.

3-7 **10:40 AM** Maier, Katherine

QUATERNARY TEPHROCHRONOLOGY AND STRATIGRAPHIC CORRELATION IN THE SACRAMENTO-SAN JOAQUIN DELTA, NORTHERN CALIFORNIA

WAN, Elmira[1], MAIER, Katherine[2], GATTI, Emma[2], OLSON, Holly[3], PONTI, Daniel J.[2], TINSLEY, John C.[2], and PAGENKOPP, Mark[4], (1) U.S. Geological Survey, Geology, Minerals, Energy, and Geophysics Science Center, 345 Middlefield Road, MS-975, Menlo Park, CA 94025, (2) U.S. Geological Survey, Earthquake Science Center, 345 Middlefield Road, MS-977, Menlo Park, CA 94025, kmaier@usgs.gov, (3) U.S. Geological Survey, Geology, Minerals, Energy, and Geophysics Science Center, 345 Middlefield Road, MS-975, Menlo Park, CA 94025-3591, (4) California Department of Water Resources, 3500 Industrial Blvd, West Sacramento, CA 95691

The Sacramento-San Joaquin Delta is the hub of a major water transport infrastructure that supplies a large part of California. Such infrastructures are vulnerable to levee failure and liquefaction hazards associated with the subsurface Delta stratigraphy. However, stratigraphy of Quaternary Delta deposits is partially constrained, especially for pre-Holocene strata. Three tephra have been identified thus far in 26 boreholes in the northern Delta and underpin chronostratigraphic correlations and paleoenvironmental interpretations. The U.S. Geological Survey Tephrochronology Project Laboratory analyzed three samples obtained from California Department of Water Resources (CDWR) boreholes near Hood and Walnut Grove, California. The major element compositions of the glass shards cluster tightly for the samples, indicating that these layers are composed of tephra from discrete volcanic eruptions. We correlate these samples to dated Cascades eruptions based on glass chemistry. The Rockland ash, which erupted from the southern Cascades near Lassen Peak ca. 0.575 Ma, was identified at depths between 132.25 and 143.5 feet from a borehole near Hood. Unanalyzed tephra have also been observed at similar depths from 11 boreholes drilled nearby. The Loleta ash, which erupted from the central Cascades, Oregon ca. 0.40-0.37 Ma (probably near the Three Sisters), was encountered at depths between 174.1 and 174.8 feet in a borehole along the Sacramento River southwest of Walnut Grove. A third unnamed tephra recovered at a depth of 197.3 feet from a borehole near the Mokelumne River northeast of Walnut Grove correlates geochemically with a volcanic ash layer from the Ferndale area, California, that is stratigraphically younger than the Rio Dell ash (1.45 Ma) and older than the ca. 0.78 Ma Brunhes/Matuyama paleomagnetic boundary. These ages and subsurface depths suggest that sedimentation rates are not consistent, and deposits may thicken in some areas. We use these ages to interpret stratigraphy and map chronostratigraphic surfaces in three dimensions. Tephra units in cores retained by CDWR provide evidence for environments of deposition and mechanisms of transport. This chronologic framework could provide additional insight into distribution of subsurface deposits in the Delta.

3-8 **11:00 AM** Hitchcock, Christopher

GEOLOGIC AND GEOMORPHIC CONSTRAINTS ON THE QUATERNARY SEPARATION RATE OF THE MIDLAND FAULT, SACRAMENTO-SAN JOAQUIN DELTA, CALIFORNIA

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The Midland fault is an approximately north to north-northwest-striking, west-dipping buried or "blind" fault zone underlying the central Sacramento-San Joaquin Delta. Structure contours of a late (?) Miocene unconformity beneath the Delta indicates uplift of the hanging wall of the Southern Midland fault between the towns of Brentwood and Rio Vista, terminating abruptly south of Lindsey Slough in Solano County. Structural relief on the Miocene unconformity is about 213 m +/- 61 m. These values suggest long-term average reverse slip rate on the Southern Midland fault ranging between about 0.07 mm/yr and 0.1 mm/yr, for an assumed range of fault dip from 45° to 75°. Comparison of historic and pre-historic drainage patterns in the Delta with structural relief on the Miocene unconformity provides evidence of possible Holocene uplift above the southern Midland fault. The complex network of streams and sloughs drained broad areas of swampy deposits and appears to have been extremely sensitive to topography and tidal levels. Small, sinuous sloughs in the Delta primarily developed east of the Midland fault converged abruptly westward across the fault into the major channels of the San Joaquin and Sacramento Rivers. Similarly, the thickest concentrations of Holocene peat are located directly east of the Midland fault. These relations suggest that west-side-up topographic relief was present in the hanging wall of the Midland fault during late Pleistocene to Holocene time and was sufficient to affect drainage patterns and peat thickness. Inferred structural relief on late Pleistocene deposits across the

fault estimated from borehole data suggests a possible late Quaternary vertical separation rate between 0.2 to 0.9 mm/yr. Variations in the thickness of Holocene peat deposits from subsurface borings suggests a minimum of 2 to 4 m of structural relief on the base of peat, with an implied a middle to late Holocene vertical separation rate of 0.3 to 0.6 mm/yr across the Midland fault. Based on the very low modern relief of the central Delta, we favor the lower values in the ranges of late Quaternary separation rates.

3-9 **11:20 AM** Kelson, Keith

ASSESSMENT OF LOCAL QUATERNARY STRATIGRAPHY AND POTENTIAL SEISMIC SOURCES NEAR SUCCESS DAM, CENTRAL CALIFORNIA

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The southeastern California Central Valley contains alluvial sediments from the Kaweah, Tule, and Kern River watersheds that have been deposited across the N-trending western margin of the Sierra Nevada between Visalia and Bakersfield. North of Visalia, the NW-trending edge of the Sierra Nevada is associated with low-slip-rate, normal dextral-oblique faults. South of Visalia, the range-margin faults are poorly characterized as potential seismic sources; this analysis was completed to update the seismic-source characterization and probabilistic seismic hazard analysis (PSHA) for Success Dam, which is 43 m (142 ft) high and impounds the Tule River upstream of Porterville. Previous stratigraphic interpretations along the western margin of the Sierra Nevada north of Tule River show the presence of Turlock Lake, Riverbank, and Modesto deposits of middle to late Quaternary age. Along the western range front south of Tule River, analysis of high-resolution LiDAR-derived shaded relief maps, aerial imagery, and field relationships delineates deposits that are probably correlative with Turlock Lake-, Riverbank-, and Modesto-age deposits. This analysis confirms geomorphic expression of fault-related lineaments associated with the previously mapped Rag Gulch fault, and extends the fault 58 km north from Poso Creek to the Tule River. The fault contains multiple strands in a 5-km-wide zone, and consists of a 17-km-long northern section and a 41-km-long southern section, which are demarked by changes in fault strike and width near Fountain Spring Gulch. Fault-related geomorphic features are restricted to areas underlain by middle Quaternary deposits (probable Turlock Lake Fm.), and are not developed on younger alluvial deposits (probable Riverbank and Modesto Fms.). Areas north of Tule River underlain by probable late Pleistocene alluvium do not contain distinct fault-related lineaments associated with the Rag Gulch fault. Other NW-trending, potentially fault-related topographic lineaments within the range block appear to be overlain by unfaulted Riverbank- or Modesto-age deposits. The PSHA assigns probabilities of activities for the Rag Gulch fault and other local potential seismic sources, and evaluates strong ground motions and response spectra for assessing the seismic stability of Success Dam.

3-10 **11:40 AM** Sawyer, Thomas L.

SEISMIC HAZARDS OF THE NORTHERN CALIFORNIA SHEAR ZONE TO WATER STORAGE, CONVEYANCE AND FLOOD PROTECTION INFRASTRUCTURE, NORTHERN CENTRAL VALLEY, CALIFORNIA

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Seismic hazards posed by the recently identified Northern California shear zone (Sawyer, this volume) have important implications for critical facilities in northern California, in particular water storage, conveyance and flood protection infrastructure in the northern Central Valley region. The westerly striking shear zone is comprised of Quaternary faults and fold-fault structures forming the highly complex structural transition between the Sierra Nevada-Great Valley (SN-GV) microplate on the south and the Oregon and Oregon Coast blocks on the north and northwest. The ≥225 km-long shear zone forms a large-scale left stepover within the evolving Pacific-North American transform margin that appears to accommodate the transpressional transfer of ≤6-8 mm/yr of shear strain from the northern Walker Lane westward across the northern Central Valley region to the primary plate margin in northwest California.

The southern extent of the Northern California shear zone splays from the Mohawk Valley fault zone as the WNW-striking Sierra Nevada-Cascade Range boundary zone (Sawyer, 2009), or eastern 'leg' of a 90 km-wide restraining left stepover across the Central Valley that appears to drive contractional deformation of the Inks Creek fold belt in the Red Bluff-Redding region. Partitioning of transpressional strain along the boundary zone provides a possible explanation for the orthogonal orientation of the fold belt to the Chico microcline-reverse-fault structure, which prominently delineates the linear eastern edge of the valley from Red Bluff to Oroville. The northward-bowing northern extent splays from or near the Honey Lake fault zone as an incipient shear zone largely superimposed on extensional structures of the Cascadia backarc rift. This zone transitions into a fold-and-thrust belt that cross-cut the active Cascade Range, in the Mt. Shasta-Pit River region, and widen westward apparently forming the distributed tectonic boundary between the Central Valley and the Klamath Mountains on the north.

The Northern California shear zone appears to accommodate up to 6-8 mm/yr of plate-boundary shear strain, involving regional contractional faults beneath and bordering the northern Central Valley, and thus, has important seismic hazard implications for critical water infrastructure in the region.

SESSION NO. 4, 1:30 PM

Monday, 20 May 2013

T2. Mélanges: Comparison and Contrast Between Circum-Pacific and Tethyan Chaotic Rock Bodies, and Modern Submarine Analogues

Radisson Hotel and Conference Center, Salon A1

4-1 **1:30 PM** Wakita, Koji

WHAT IS "A MÉLANGE"? - A COMPARATIVE STUDY ON UNITS OF MÉLANGES IN MINO AND SHIMANTO ACCRETIONARY COMPLEXES IN SOUTHWESTERN JAPAN

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Mélange is defined by its texture (block-in-matrix), components (exotic blocks) and size (mappability). This definition does not include its origin. However, various kinds of mélanges exist in the world that are described based on their origin. The definition of a unit of mélange is not clear until now. If mélange is formed by a single process, one unit of mélange must be clear. However, if mélange is formed by multiple processes, how could we define a melange unit? In order to discuss a unit of mélange, I will compare two types of mélanges in Japan. One is the Cretaceous mélanges in Shimanto accretionary complex (AC), and the other is the Jurassic mélanges in Mino accretionary complex (AC). The mélange of Shimanto AC is mainly caused by a single tectonic process in a convergent margin. Since the structural contrast is clear between these mélanges and their surrounding coherent units, a single unit of mélange is very distinct in Shimanto AC. The Oki and Mugi mélanges are good examples. On the other hand, the mélanges of Mino AC were formed by multiple processes such as sedimentary, diapiric and tectonic. It shows block-in-matrix texture in the outcrops, including exotic blocks of limestone, basalt and chert which were derived from ocean plate stratigraphy that were formed far from the trench. However, the Mino AC includes mélange-like parts, broken formations or coherent formations which were caused by multiple accretionary processes. Therefore, mélanges of Mino AC are sometimes too small based on the established definition of a mélange. Festa et al. (2012) recommended the use of the terms small-scale or meso-scale mélanges for such kinds of mélanges. The structure of mélanges of Mino AC is similar to the one drawn by Cowan (1985). Although the mélange unit in the outcrop scale is too small for the mélange definition, the Mino AC yields the mélange texture as a whole, and is big enough to be considered as mélange based on the definition. It would be confusing if we apply the same term "mélange" for the chaotic units at different scales in a single AC. In this study, the term"mélange complex" for the chaotic Mino AC is proposed.

4-2 **1:50 PM** Aalto, K.R.

FRANCISCAN COMPLEX: MAPPING OF MÉLANGES AND TERRANES IN THE NORTHERNMOST CALIFORNIA COAST RANGES, A RETROSPECTIVE

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Discrimination of mappable rock units reflects lithology, common ancestry and scale among rocks formally designated as *Franciscan Complex* (a 'superterrane'?) *Franciscan Eastern belt* (a composite terrane?) comprises the *Pickett Peak terrane* (*South Fork Mountain Schist, Redwood Creek schist, Patricks Point unit*) and *Yolla Bolly terrane* (*Eastern subterrane*: chiefly broken formation; *Western subterrane*: chiefly mélange). *Franciscan Central belt* (a composite terrane?) consists of NW-trending belts of intercalated mélange and broken formation. In the Cowan (1985) classification, broken formation is *Type I mélange* that has suffered layer-parallel extension prior to folding. *Type II mélange* (stratally-disrupted interbedded sequences of radiolarian chert, black argillite, hyaloclastite and pillow basalt) exists as mélange blocks and/or thrust fault-bounded slabs within all Franciscan terranes. Some slabs are extensive enough to be mapped at a 1/12,000 scale. Are they then subterranes? *Type III mélange* (block mixes of greenstone, chert, limestone, keratophyre, tonalite, turbidites and blueschist that originated as diapirs and/or olistostromes) are common in the *Western Yolla Bolly subterrane* and *Central belt. Type IV mélange* (block-in-matrix mixes developed along shear zones) with blocks of chert, greenstone, gabbro, sandstone and conglomerate exist in metapelitic gouge associated with major terrane-bounding faults. Omphacite-bearing tectonic blocks in serpentinite occur in an area of imbricate thrust faulting of *South Fork Mountain Schist* over *Eastern subterrane* broken formation, adjacent to the bounding *South Fork fault* of the Klamath Mountains *Western Jurassic belt*. This serp.-schist association has an affinity to the Coast Range ophiolite to the south and formed during western translation of the Klamath Mountains. The confusing mix of formal and informal unit nomenclature suggests need for revision of the stratigraphic code for the mapping of exhumed accretionary prisms.

4-3 **2:10 PM** Ogawa, Yujiro

NEW INTERPRETATION OF FRANCISCAN MÉLANGE AT SAN SIMEON COAST, CALIFORNIA: TECTONIC INTRUSION INTO AN ACCRETIONARY PRISM

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Many concepts and interpretations on the formation of the mélanges at San Simeon, California, have been proposed, but yet the topic remains a subject of debate since its first introduction by Ken Hsu followed by detail researches by Cowan, Cloos, Ernst, Ukar, and others. We aim here to show that the internal structures and textures of the chaotic rocks are characterized by various kinds of blocks from blue-or greenschist, oceanic rocks, including bedded chert, limestone, and particularly various kinds of sandstones. Interrelationships between the mélange blocks and the surrounding matrix materials suggest that all the features were produced by typical accretionary prism processes in which turbidites (both in the blocks and matrices) and oceanic rocks are in tectonic or diapiric (not sedimentary) contact with each other. The new interpretation is similar to that of Cloos, Becker, or Ukar, but different in a sense of the surrounding turbiditic formation (Cambria Slab) to be of an accretionary prism, not of the slope basin sediments. The turbiditic rocks display various kinds of structures associated with layer-parallel shortening or stretching by folds and faults. Way-up directions in turbiditic rocks are used to map to verify recumbent folds and thrust stacks, and repetitions of the slump beds for duplex structures. The "mélanges" are

commonly developed along the thrust faults between turbidite slices. We conclude that the entire Franciscan Complex at San Simeon consists of the Cambria Slab into which the mélange bodies were intruded. The exhumation of the blueschist blocks is still controversial, but the common extensional fractures and brecciation in most of the mélange blocks and further mixture of many fragments into one block, which is further enclosed into mélange matrices, must lead a story that once deep buried blocks were exhumed from considerable depths to the accretionary prism body, probably by return flow, to intrude either by thrusting or diapirism, or both, during when retrograde deformation occurred with retrograde metamorphism. The Recent examples of the accretionary prism and its gravitational collapse observed by submersible research in the Nankai trough of Japan must play the role in comparative study on mélange processes.

4-4 **2:30 PM** Pini, Gian Andrea

MASS-TRANSPORT PROCESSES AND SEDIMENTARY MÉLANGES: INTERNAL DEFORMATIONS, STRATAL DISRUPTION AND OCCURRENCE OF EXOTIC BLOCKS

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Detailed studies in recent years of mélanges and chaotic deposits in various mountain ranges around the world have resulted in the recognition of a large number of sedimentary mélanges. These sedimentary mélanges mostly originated from sedimentary mass-transport processes and flows, although they were strongly deformed by post-depositional, tectonic and mud-diapiric events. Therefore, they commonly represent excellent fossil examples of mass-transport deposits (MTDs) to investigate the processes involved in their origin. Large scale, basin-wide fossil MTDs, including sedimentary mélanges, are complex units involving the entire spectra of mass-transport processes. Their down-slope movement is facilitated by: 1) shear-dominated viscous flows within a muddy matrix, 2) mud-silt-sandy matrix sustained by fluid overpressure, 3) mm-thick shear zones with advection of grains/fluids. These three types of MTDs display different potential of stratal disruption depending on the sediment strength (composition and compaction), the activity of fluid (over)pressure, the length of *en-mass* transport and the rheology of the MTD-substratum interface. The potential of mixing of rocks of different ages and metamorphic degrees, and of diverse structural units and paleogeographic domains is conditioned by: 1) the geometry and evolution of slope failure, 2) the depth of the headwall surface, 3) the geometry and tectonic setting of sedimentary basins and basin margins, 4) the effectiveness of tectonic structures and serpentinite diapirs in exposing/exhuming deep-seated HP rocks.

We discuss here the potential of mass-transport processes in mélange formation, based on both on-land and seafloor examples and on their distribution and volumetric relevance in the sedimentary record of accretionary wedges.

4-5 **2:50 PM** Wakabayashi, John

WHAT IS AN EXOTIC BLOCK? IMPORTANCE IN EVALUATING ORIGINS OF MÉLANGE

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Distinguishing a block-in-mélange as “exotic” or “foreign” to the matrix versus “cogenetic” (part of broken formation) aids in evaluating mélange origins and convergent plate margin processes. However, this distinction is not easily made. For example, chert and/or basalt blocks may share a common ocean plate stratigraphy with their shale and/or sandstone matrix (“cogenetic”) or not (“exotic”). Serpentinite blocks in a sandstone and/or shale matrix are probably exotic, but the serpentinite may also be cogenetic, derived from ocean plate stratigraphy that included serpentinite (such as oceanic crust formed at oceanic core complexes or low magma supply ridge segments). Blocks of the same metamorphic grade as the matrix (“isofacial”) may be cogenetic or exotic, but a block of higher metamorphic grade than matrix (“high-grade”) is unambiguously exotic. Introduction of higher-grade metamorphic blocks into lower grade matrix cannot be easily explained by large-scale deformation or displacement because of the absence of high-grade equivalents of the matrix lithology; amphibolite and eclogite blocks in shale and sandstone matrix mélanges of the Franciscan Complex are good examples. Many exposures of mélange with such blocks in the Franciscan Complex show evidence of sedimentary origins with a gradation between undeformed sedimentary breccia and conglomerate with high-grade metamorphic clasts/blocks, and deformed mélange with the same block populations. Accordingly, introduction of high-grade blocks into matrix appears to have resulted from submarine sliding. An exotic origin can be recognized for many isofacial blocks if field relationships analogous to those seen for high-grade blocks are observed. Progressive deformation of parent strata results in formation of cogenetic isofacial blocks, such as sandstone blocks in shale matrix formed by deformation of interbedded sandstone and shale, or chert and basalt blocks in sandstone or shale matrix, or chert blocks in basalt matrix, formed by progressive deformation of ocean plate stratigraphy. Thus, “tectonic mélanges” have cogenetic blocks and are the equivalent of “broken formation” whereas exotic blocks suggest a sedimentary origin for the mélange.

4-6 **3:10 PM** Alonso, Juan Luis

MÉLANGES AND OTHER TYPES OF BLOCK-IN-MATRIX FORMATIONS IN THE CANTABRIAN ZONE (VARISCAN OROGEN, NW SPAIN): ORIGIN AND SIGNIFICANCE

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The block-in-matrix formations in the Variscan foreland of Spain (Cantabrian Zone) occur in two different geological settings. The major block-in-matrix formations are mélanges, which appear as carpets beneath submarine thrust systems and overlying flysch units. These mélanges may reach up kilometric thickness and are mostly composed of broken formations (tectonosomes) of Late Carboniferous age and scattered “exotic” blocks derived from older Palaeozoic formations. The source of the mélange blocks was the front of advancing nappes, chiefly the upper part of the nappe stacks. Therefore, the Cantabrian mélanges are interpreted as originated by submarine sliding and slumping associated with steep slopes at the orogenic front. The different types of rock bodies of these mélanges may be related to the degree of lithification of the sediments or rocks during slumping, since it depends on their age and composition. So, broken formations are boudinaged sequences where the boudins or blocks resulted from extensional faults developed in lithified or semilithified limestones and sandstones whereas the unlithified shaly matrix was undergoing continuous deformation. The scattered “exotic” blocks with a range of ages from Early Cambrian to Early Carboniferous came into the basin as individual slip blocks from competent well-lithified formations, originally located at the lower part of the nappe stacks. The mélanges in the Cantabrian Zone also intercalate minority debris flows with chaotic block-in matrix fabric (olistostromes). However, most of the olistostromes of the Cantabrian Zone occur in a different geological setting. They are usually intercalated into the normal marine deposits of the Variscan foreland basin. In contrast with the Cantabrian mélanges, these olistostromes are mostly related to the margins of carbonate platforms, ahead of moving nappes, and consist of intrabasinal (native) components.

4-7 **3:50 PM** Festa, Andrea

POLYGENETIC MÉLANGES IN THE LIGURIAN ACCRETIONARY WEDGE (NORTHERN APENNINES, ITALY)

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Interpretations on the origin of the External Ligurian Units in the Northern Apennines (Italy) range from a typical unmetamorphosed broken formation (chaotic rock unit without exotic blocks) to an undifferentiated chaotic complex, produced by offscraping–tectonic imbrication during the evolution of the Ligurian accretionary wedge (LAW). We report here on the internal structure of the late Cretaceous–late Oligocene LAW, which consists of polygenetic chaotic bodies of different scales formed by the superposition in time and space of tectonic, diapiric and sedimentary processes.

A *Broken Formation* is the oldest unit in the LAW, showing bedding-parallel boudinage structures developed due to layer-parallel extension at the toe of the LAW-front during the late Cretaceous–middle Eocene. This *Broken Formation* experienced an overprint of tectonic, diapiric and sedimentary processes as a result of the late Oligocene continental collision. Contractional deformation produced a structurally ordered block-in-matrix fabric through mixing of both native and exotic blocks, forming a *Tectonic Mélange*. Concentration of overpressurized fluids along thrust faults triggered the upward rise of shaly material, producing a *Diapiric Mélange*, which provided the source material for the downslope emplacement of the youngest, late Oligocene *Sedimentary Mélange*. Sedimentary Mélange units unconformably cover the thrust faults, constraining the timing of the youngest episode of contractional deformation in the LAW.

The interplay and superposition of tectonic, diapiric and sedimentary processes plays a significant role in the dynamic equilibrium of accretionary wedges. Our findings provide useful criteria to differentiate between different types of polygenetic mélanges in ancient and modern accretionary wedges.

4-8 **4:10 PM** Kato, Terence T.

PROGRESSIVE MELANGE EXHUMATION ALONG A PRE-ANDEAN TRANSPRESSIONAL FAULT SYSTEM, CORDILLERA DE LA COSTA, CHILE (26°S – 42°S)

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Mélanges occur as discontinuous mappable units along an extensive, North-South trending, steeply dipping zone of distributed shear along the coast of central Chile. Large mélange zones, from North to South, at Chañaral (26° S), Los Vilos (32°S), Pichilemu (36°S), and Chiloé Island (42.5°S) contain protolith variations, but are consistent in exhibiting cross cutting fabric features indicating progressive transition from earlier ductile to more brittle deformation. In the Infiernillo mélange near Pichilemu, where this transition is well preserved, Permian to early Triassic, sub-horizontal schistosity planes of the Western Series schist (WS) are disrupted and uplifted along high angle, N-S to NNE-SSW trending brittle-ductile shears . Exotic rock types, such as mafic blueschist, were incorporated within the mélange during diapiric piercement and exhumation of subjacent portions of the subduction complex. Small scale deformational features in mylonite and cataclasite zones within the mélange matrix indicate active lateral shear during exhumation from depths exceeding 12 Km [SAF geotherm].

Linkage between the mélange zones is inferred from extensive margin parallel alignment of late shear planes crosscutting low angle schistosity, margin parallel, sub-horizontal stretching lineations, and regional N-S truncation of horizontal to NW-SE striking regional fabric along the zone. Regional folding of schistosity in the WS in the southern portion of this zone indicates widespread NE-SW crustal shortening favoring dextral displacement along the N-S trending zone.

Mélange development and exhumation followed Permian to early Triassic greenschist metamorphism of the WS, and preceded the deposition of unconformably overlying, fossiliferous, late Triassic, rift deposits in the north. The length and extreme linearity of this zone of lateral movement, coincident with a general hiatus of regional arc magmatism, is consistent with large scale dextral transpression, or possible transform movement, during highly oblique convergence along the Pre-Andean margin. This may have weakened and uplifted the crust facilitating later fault localization, gravitational collapse, and subcrustal erosion during convergence along the subsequent Andean continental margin.

4-9 **4:30 PM** Okay, Aral

NEO-TETHYAN AND PALEO-TETHYAN MÉLANGES IN ANATOLIA

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Anatolian mélanges can be grouped broadly in two types based on age, lithology and structure. The Neo-Tethyan mélanges consist predominantly of oceanic crustal lithologies of basalt, radiolarian chert, pelagic shale with minor serpentinite and greywacke. They show locally an incipient high-pressure metamorphism with the formation of lawsonite, sodic pyroxene and aragonite. A matrix is hard to define in the Neo-Tethyan “mélanges”; they rather consist of chaotic thrust stacks. The age of the cherts in the Neo-Tethyan mélanges range from Middle Triassic to Cretaceous. With these features the Neo-Tethyan mélanges represent sediment starved subduction-accretion complexes; they were formed during the Cretaceous subduction of a Triassic to Cretaceous oceanic lithosphere.

The Paleo-Tethyan mélanges are made up mainly of greywacke and shale with exotic blocks of Permo-Carboniferous limestone, basalt and Devonian, Carboniferous and Permian radiolarian chert. A clastic matrix is well defined in the Paleo-Tethyan mélanges, which are associated with Late Triassic eclogites and blueschists. They were formed during the Triassic subduction of a Devonian to Triassic Tethyan oceanic crust. The lithological differences between these mélange types are related to the prevalent paleogeography; during the Late Cretaceous subduction, the magmatic arcs and the active margin of Eurasia were below sea-level and there was little influx of clastic material to the trenches, whereas during the Triassic subduction the active margin of Eurasia was uplifted probably through a collision with an oceanic plateau.

4-10 **4:50 PM** Wang, Junpeng

A LATE ARCHEAN TECTONIC MÉLANGE IN THE CENTRAL OROGENIC BELT, NORTH CHINA CRATON

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Laterally extensive belts of mélange characterize convergent margins, but are remarkably rare in Archean terrains. We document a late Archean mélange in the Zanhuang massif, southern Taihang Mountains, of the North China Craton (NCC). The mélange separates a passive margin sequence developed on the western edge of the Eastern Block of the NCC, from an arc terrane consisting of trondhjemitic, tonalitic and granodioritic (TTG) gneisses in the Central Orogenic Belt (COB) of the NCC. The mélange belt is 2-10 km wide, and contains a structurally complex tectonic mixture of metapelites, metapsammites, marble, metalimestone, and tectonic blocks of ultramafites and metagabbroic rocks, metabasites that locally include relict pillow lavas, and TTG gneisses. All units in the mélange have been intruded by mafic dikes that were subsequently deformed, and are now preserved as garnet-amphibolite boudins. We interpret the mélange to mark the suture zone between the Eastern Block and the arc terrane in the COB. Field relationships and geochemistry suggest that the exotic ultramafites-metagabbro-metabasaltic blocks are possible slivers of an intra-oceanic arc incorporated into the mélange during the arc/continent collisional process. A circa 2.5 Ga granitic pluton intrudes the mélange and undeformed circa 2.5 Ga pegmatites cut the mélange. Tectonic models for the evolution of the COB of the NCC are varied, but include models that favor collision at 2.5 Ga, 2.1 Ga, and 1.8 Ga. This work shows clearly, from field structural relationships and geochronology, that the first collision must have occurred prior to 2.5 Ga, favoring late Archean suturing of the western margin of the Eastern Block with an arc terrane (Fuping Terrane) during an arc/continent collision. The presence of an Archean mélange with exotic blocks in a suture zone between an Archean arc and continental margin is clear evidence for the operation of plate tectonics at circa 2.5 Ga.

4-11 **5:10 PM** Deng, Hao

GEOCHEMISTRY OF NEOARCHEAN MAFIC VOLCANIC ROCKS AND LATE MAFIC DIKES AND SILLS IN THE ZANHUANG COMPLEX, CENTRAL OROGENIC BELT, NORTH CHINA CRATON: IMPLICATIONS FOR GEODYNAMIC SETTING

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An Archean mélange belt has been recognized in the Zanhuang complex, Central Orogenic Belt (COB), North China Craton (NCC). All units of the mélange belt are intruded by a circa 2.5 Ga granite pluton and cross-cut by undeformed 2.5 Ga pegmatites, which constrains the Archean formation age of the mélange. Some exotic mafic-ultramafic blocks are tectonically dispersed in the metasedimentary matrix to the mélange and mainly consist of metabasaltic rocks, deformed pillow lavas with epidosite cores, gabbros, and ultramafic rocks. Both metabasalts and epidosites are characterized by enrichment in light rare earth elements (LREE) ($(La/Sm)_{cn}$=1.39-2.37, 1.89-2.76) and pronounced negative Nb (Nb/Nb*=0.29-0.72, 0.26-0.53) and Zr (Zr/Zr*=0.30-0.85, 0.58-0.82) anomalies on chondrite- and primitive mantle- normalized diagrams. These geochemical characteristics are consistent with supra-subduction zone geochemical signatures. Based on the pillow structures and seafloor hydrothermal alteration, combined with the geochemical characteristics, an intra-oceanic arc-forearc setting is proposed for the formation of these exotic blocks. Furthermore, a west-dipping intra-oceanic subduction zone is proposed to have formed in an ocean between the Eastern Block and an arc terrane prior to 2.5 Ga. The collision between the arc and the Eastern Block of the NCC happened at ~2.5 Ga, resulting in the formation of the Archean mélange belt in the Zanhuang complex, followed by intrusion of the granitic and pegmatitic melts of ~2.5 Ga.. All of the units of the mélange belt were then intruded by late mafic dikes and sills, which are present as bouninaged or lenticular shapes in the mélange and surrounding gneisses. Geochemical characteristics of the late mafic dikes are consistent with an arc-related mantle source region, rather than an OIB-like source. Accordingly, pending determination of their age, an arc-polarity reversal event is proposed to have occurred following the arc-continent collision, resulting in east-dipping subduction beneath the newly accreted arc and Eastern block, forming the swarm of arc-affinity mafic dikes, which were then deformed and metamorphosed when the remaining open part of the ocean between the arc-collision modified margin of the Eastern Block collided with the Western Block of the NCC.

SESSION NO. 5, 1:30 PM

Monday, 20 May 2013

T5. Critical Zone II: Where Rock Meets Water and Life at Earth's Surface

Radisson Hotel and Conference Center, Salon A2

5-1 **1:30 PM** Hartsough, Peter C.

CHARACTERIZATION OF WATER USE PATTERNS IN THE DEEP VADOSE ZONE THROUGH GEOPROBE DRILLING INTO WEATHERED BEDROCK

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The Sierra landscape is characterized by high variability in both soil and saprolite thickness. There is considerable uncertainty about the depth of water storage within these layers and the accessibility of these storage pools to roots within various layers of weathered bedrock material below the soil layers. Geoprobe drilling was used to collect cores from weathered bedrock material down to eleven meters depth. Drilling locations were chosen through interpretation of previous geophysical work. Analyses of these cores show considerable in situ porosity development, allowing for a large pool of stored water. Investigations into rooting depth of trees in the surrounding area show the majority of roots in the top two meters but indirect evidence points to a limited number of roots extending deeper into the saprolite. A physical root excavation and associated imaging and modeling of a White Fir tree show > 90% of the roots distributed from 30-150cm with limited roots available to access deeper soil water and water stored in the saprolite. This leaves open the question of how trees access deep saprolite water and to what extent this plays a role in late summer tree function. Tensiometer measurements down to 2.5 meters show gradients developing in late summer that drive flow toward the active root zone. Investigations of stable isotopes of water at depth and in vegetation at the surface, help to understand water use from different storage pools as conditions dry at the surface. Access to deeper water storage pools is also confirmed by results from coupled modeling across the soil/tree/atmosphere continuum. We seek to answer inter related questions of the role of vegetation distribution at the land surface, variable soil depth and locations of thick sequences of weathered bedrock.

This research is part of the NSF-supported Southern Sierra Critical Zone Observatory, which is collocated within the U.S. Forest Service, Kings River Experimental Watershed.

5-2 **1:50 PM** Wang, Zhi

HYDROLOGIC SENSITIVITY OF THE SOUTHERN SIERRA NEVADA CRITICAL ZONES TO CLIMATE CHANGE PROJECTIONS

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In order to examine the hydrological system sensitivity of the southern Sierra Nevada critical zone areas to climate change scenarios (CCS), five headwater basins of the snow-dominated Upper San Joaquin River Watershed (USJRW) were selected for hydrologic simulations using the Hydrological Simulation Program-Fortran (HSPF) model. A pre-specified set of CCS as projected by the Intergovernmental Panel on Climate Change (IPCC) were adopted as inputs for the hydrologic analysis. These scenarios include temperature increases between 1.5 and 4.5 C° and precipitation variation between 80% and 120% of the baseline conditions.

The historical meteorological data from a NOAA station at CA049855 were used, which were available for the period from 1970 to 2005. The measured data include precipitation, air temperature, wind speed, solar radiation, potential evapotranspiration (ET), dewpoint temperature and cloud cover. The daily discharge data were obtained from the USGS real-time stream gauging station No.11226500 which maintained a 47-year record from 1921 to 1991 with missing data from 1929 to 1951. Statistical analyses show that there is a strong and continuous temperature increase during the past few decades from 1970 to 2005. The 5-year running mean temperature increased from 10 C° to 12 C°.

The HSPF model was calibrated and validated with measured historical data. It was then used to simulate the hydrologic responses of the watershed to the projected CCS. Results indicate that the streamflow of USJRW is sensitive to the projected climate change. The total volume of annual streamflow would vary between -41% and +16% compared to the baseline years (1970–1990). Even if the precipitation remains unchanged, the total annual flow would still decrease by 8–23% due to temperature increases. A larger portion of the streamflow would occur earlier in the water year by 15–46 days due to the temperature increases, causing higher seasonal variability of streamflow.

5-3 **2:10 PM** Wang, Zhi

VAPOR FLOW CONTRIBUTIONS TO ECO-HYDROLOGY IN DRY LAND CRITICAL ZONES

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When the temperature of land surface and plants is lower than that of air and deeper soils and rocks, water vapor moves toward the ground and plant surfaces where dew maybe formed depending on prevailing dew point and wind speed. Some plants are able to directly absorb the dew and vapor flow while the soil can readily absorb both. Certain animals such as desert beetles and ants harvest water from the morning fog using their hydrophobic hairs on the back. Recently, it is also realized that the dew and vapor flow can be a life-saving amount of water for plant survival in at critical times in the critical zones, such as at the end of the dry season in southern Sierra areas of California, a Mediterranean climate zone where there is almost no precipitation from May to September.

Researches are being conducted to quantify the amount of dew and plant-absorbed water from near-surface vapor flow in arid and semi-arid regions. Quantitative leaf water absorption and desorption functions were derived based on laboratory experiments on turf grasses. Results show that plant leaves absorb and release water at different speeds depending on species and varieties. The "ideal" native plants in the dry climate zones can quickly absorb water and slowly release it. This water-holding capacity of plant is characterized by the absorption and desorption coefficients in the functions for plant physiology studies and water balance simulations.

Field studies are conducted to measure the dynamic vapor flow processes from atmosphere to soil surface and from groundwater table to soil surface in the vadose zone. Results show that dew is usually formed on soil and plant surfaces during the daily hours when the temperature gradients are inverted toward the soil surface. The amount of dew harvested using gravels on the soil surface was enough to support water melon agriculture on deserts. The vapor flow can be effectively intercepted by artificially seeded plants in semi-arid regions of China forming new forests.

5-4 **2:30 PM** Todd, Claire

MOUNT RAINIER GLACIAL MELTWATER HYDROCHEMISTRY AND MICROBIAL COMMUNITIES

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Mount Rainier is a geothermally active, glaciated peak. In this study, we analyze glacial meltwater hydrochemistry and microbial life as one way to characterize subglacial environments. We measure major ion concentrations in meltwater samples collected from streams at or near glacier termini in Mount Rainier National Park. Preliminary data show constant sulfate levels during the diurnal cycle, and low C-ratios (bicarbonate/[bicarbonate + sulfate]) at Tahoma and Emmons Glaciers, suggesting a subglacial source of sulfate at both locations. Carbon Glacier meltwater

contains relatively low levels of sulfate, with a significant decrease between the diurnal maximum and minimum and a high C-ratio, indicating a supraglacial source of sulfate. Tentative conclusions include that Tahoma Glacier meltwater is in contact with the mountain's hydrothermal system; this result confirms findings from previous work. Our work also suggests a subglacial source of sulfate at the Emmons Glacier; if confirmed, this result may identify a connection between the subglacial environment and the hydrothermal system. Since microbes are reliant on the chemistry of the water in which they reside, it is likely that a link between hydrochemistry, geothermal activity, and microbial life exists. Thus, we also use sequenced DNA of microbes found in glacial meltwater to provide additional insight into these complex environments.

5-5 **2:50 PM** White, Timothy S.

BIOTURBATION AND EROSION BY TREE THROW IN FORESTED LANDSCAPES, APPALACHIAN MOUNTAINS

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Tree throw, the upheaval of bedrock and soil in the root mass of a fallen tree, has been suggested to be a major process in the overturn and downslope transport of soil and shallow bedrock in mountainous regions. We report on an effort to quantify the effects of tree throw along a climosequence of five sites in the Appalachian Mountains associated with the Susquehanna-Shale Hills Critical Zone Observatory (SSHO) - sites were studied in central New York, central Pennsylvania, west central Virginia, eastern Tennessee, and northern Alabama. The study included field measurements of tree throws within a 120-meter diameter search area centered on soil pits on ridge tops on the Silurian Rose Hill Shale and coeval strata of similar composition. The following observations were made for each tree throw observed at each study site: GPS location, tree girth, relative tree age, tree type, dimensions of pit, azimuth of fall, and slope and azimuth of maximum slope. These observations allowed quantification of the volume and distance of transport of sediment per event, and the number of events/area/time.

The measurements of tree throw were made as part of a broader effort to characterize erosion rates on shale slopes, information that is applicable to understanding the evolution of topography and regolith thickness on shale landscapes. Specifically, the observations are used to verify formulations of sediment flux due to tree throw as presented in Gabet et al., 2003, The effects of bioturbation on soil processes and sediment transport, Annu. Rev. Earth Planet. Sci., 31, 249-73. The sediment fluxes reported here range from 1.8 X 10^{-5} m^2/m/y to 2.1 X 10^{-4} m^2/m/y. The higher values are comparable to those sediment flux rates from tree throw reported in the literature whereas the lower values compare well to long-term erosion rates for the Appalachian Mountains determined using cosmogenic radionuclide analyses.

5-6 **3:10 PM** Riebe, Clifford S.

THE INFLUENCE OF BEDROCK NUTRIENT CONCENTRATIONS ON LIFE AND TOPOGRAPHY IN THE SIERRA NEVADA BATHOLITH

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The breakdown of rock to regolith promotes erosion, liberates ions from minerals, and creates porosity, thus providing overlying ecosystems with access to life-sustaining water and nutrients. Understanding variations in regolith thickness and development across landscapes is a fundamental problem in critical zone science and management. Yet the factors that regulate regolith production, weathering, and thickness are poorly understood.

In granitic landscapes, for example, regolith cover is often mysteriously dichotomous. A case in point is the Sierra Nevada Batholith, where broad swaths of bare rock crop out immediately next to vegetated slopes with weathered regolith extending to depths of up to 40 m. Here we present evidence of a feedback in which this dichotomous presence/absence of regolith is regulated by bedrock nutrient content through its influence on vegetation. The concentrations of essential plant nutrients such as phosphorus (P) vary markedly in bedrock, changing abruptly at pluton contacts that coincide with ecotones between forest and bare rock. Moreover, we find that vegetative cover is strongly correlated with bedrock P in a multivariate, batholith-wide analysis that accounts for potentially confounding variations in climate and topography and excludes areas that were glaciated in the Pleistocene.

The paradigm for nutrient evolution in physically stable soils is that bedrock-derived P becomes depleted with time to the point that it limits productivity of overlying ecosystems. Our analysis of the Sierra Nevada presents a counterexample of an eroding landscape in which ecosystems developed on nutrient-poor granitic bedrock may experience P limitation under conditions of dynamic equilibrium and during incipient stages of weathering and pedogenesis. Our work challenges the common assumption that granitic bedrock can be viewed as a uniform substrate for pedogenesis and chemical weathering, irrespective of compositional differences from pluton to pluton; we find that differences in P, a minor element with concentration <0.01 g/g in bedrock throughout the batholith, appear to regulate the presence/absence of regolith and thus may also influence rates of soil formation, erosion, and landscape evolution.

5-7 **3:30 PM** Janes, M. Katy

HIGH VARIANCE OF PHYSICAL AND GEOCHEMICAL CHARACTERISTICS OF SALMONID SPAWNING RESTORATION SITES CREATES SUITABLE HABITAT WITHIN THE HYPORHEIC ZONE

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The Lower American River has historically provided natural spawning habitat for approximately one third of Northern California's salmon population. However, since the construction of Folsom and Nimbus Dams, downstream reaches have become sediment starved and periodic high outflow from the dam has caused channel armoring and incision, thereby degrading the natural spawning habitat. Restoration work on spawning sites in the Lower American River has consisted primarily of importing gravel to create riffles during periods of moderate flow. This is an effort to mitigate armoring of the riverbed and to rehabilitate salmonid spawning habitat by providing suitable grain size for all stages of spawning (redd construction, incubation, and emergence). Since restoration activities began, all rehabilitated sites have not been equally used for spawning. This study attempts to examine and compare the physical properties of each site in order to ascertain which characteristic create more suitable rehabilitated habitat. To do this, we compared restored areas to pre-restoration conditions through the assessment of three main aspects of the restored spawning habitat; grain size and its natural mobility, water flow in the surface and subsurface, and intragravel water quality. We found that some augmentation sites are more heterogeneous than others, and this correlates with higher spawning use. Most spawning was at fin height, and salmonids tend to use sites with higher depth variance (surface features) and higher variance in flow directions and velocities. With time, salmonids alter the spawning sites, creating small ridges and valleys perpendicular to flow. This creates more variable subsurface flow and generates hyporheic flow through the new gravel. This may have an effect on spawning as the more seasoned additions have a higher frequency of spawning than the newer augmentations. In order to efficiently rehabilitate a site and expedite the "seasoning process", creating variance through gravel contours during the gravel augmentation process may be effective as it mimics the small scale biophysical interactions.

SESSION NO. 6, 1:30 PM

Monday, 20 May 2013

T13. Irvingtonian Paleoecology of Western North America

Radisson Hotel and Conference Center, Salon D1

6-1 **1:35 PM** Bell, Christopher J.

63 YEARS OF OBFUSCATION: CONCEPTUAL, FAUNAL, SPATIAL, AND TEMPORAL USES OF THE TERM "IRVINGTONIAN"

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The Irvingtonian Land Mammal "Age" was proposed by Don Savage in 1951 as one of two mammal "ages" intended to encompass Pleistocene time in western North America. It was based on the fauna from the Irvington gravels in Alameda County, California, and, in Savage's words, was "marked by the absence of *Bison*." The operational definition of the Irvingtonian based on the absence of *Bison* resulted in considerable instability and a general lack of clarity in recognizing Irvingtonian faunas. Alternative definitions were offered in the literature for many decades, but no consensus emerged on a proper and widely applicable definition. As a result, the term still lacks clarity after 63 years of continuous usage. That lack of clarity stimulated alternative conceptual approaches to the definition of land mammal "ages," and sparked a discussion about the geographic extent of land mammal "ages" and their applicability along latitudinal, longitudinal, and elevational gradients.

Current proposals for the definition include single-taxon definitions (using various taxa) that are conceptualized as being applicable across the entire North American continent, the continent south of 55 degrees north latitude, or only to generalized (but not rigorously specified) geographic provinces on scales smaller than the continent. Irvingtonian faunas at high elevations in western North America are distinct, both in taxonomic associations and temporal durations of taxa, from Irvingtonian faunas from lower elevation sites elsewhere in the United States. Specific proposals for diachronous and spatially distinct boundaries exist and constitute fertile areas for future discussion.

Consensus on the definition of the Irvingtonian remains an elusive goal. Historical inertia, competing egos, apathy, ignorance, and inadequate data all contributed to a long-standing uncertainty about how to recognize, conceptualize, and discuss an interesting portion of mammalian faunal history in North America. Enhanced clarity of the conceptual bounds, spatial scope, taxonomic definition and characterization of the Irvingtonian will help future generations to resolve this long-standing problem. Broad discussions of these issues are needed, and might, possibly, benefit from insights from scientists in older generations.

6-2 **1:55 PM** Dundas, Robert G.

REVISITING IRVINGTON, TYPE FAUNA OF THE IRVINGTONIAN NORTH AMERICAN LAND MAMMAL AGE

DUNDAS, Robert G., Department of Earth & Environmental Sciences, California State University, Fresno, CA 93740, rdundas@csufresno.edu

Although it is the type fauna of the Irvingtonian North American Land Mammal Age (NALMA), Irvington is not well documented in the peer-reviewed literature. Vertebrate remains discovered in fluvial deposits of gravel quarries at three locations in the Irvington District of Fremont, California were brought to the attention of the University of California Museum of Paleontology (UCMP) in 1936. Stirton (1939) reported five taxa from UCMP localities V3602, V3604, V3605, including a new antilocaprid (*Tetrameryx irvingtonensis*). Following additional fossil collecting at Irvington by teacher Wes Gordon and his band of "Boy Paleontologists", Savage (1951) provided what remains the most thorough published account of the fauna, reporting 24 taxa (2 fish, 2 amphibians, 1 reptile, 1 bird, 18 mammals). Based on the fauna, Savage (1951) established the Irvingtonian NALMA. Further excavations during the 1950s and 1960s yielded significant remains which Firby (1968) described for her thesis, but never published. Firby (1968) more than doubled the Irvington fauna reported by Savage (1951), recognizing 54 taxa (5 mollusks, 4 fish, 4 amphibians, 3 reptiles, 8 birds, 30 mammals). Major excavations at Irvington ended in the 1960s following construction of State Route 680 through the gravel quarries. Age of the Irvington fauna and associated "Irvington Gravels" is not well constrained. Lindsay et al. (1975) determined that the fossil bearing strata are reversely magnetized. Coupled with biostratigraphy, the age of Irvington is typically inferred to be within the upper Matuyama magnetic polarity chron (i.e. greater than .78 Ma), however, maximum age of the fauna is unresolved. Bell and Bever (2006) note that consideration also must be given to the possibility that the fauna may be older than 1.21 Ma. Lack of fine-grained sedimentary exposures in the area at present prevents further evaluation of the site magnetostratigraphy. Apart from a paper by Rich (1977) reporting *Neophrontops americanus* from the site and a study of *Microtus* by Bell and Bever (2006), Irvington has received little attention from researchers in recent decades. In addition to the unpublished portion of the Irvington collection at the UCMP, the Math/Science Nucleus and Ohlone College in Fremont, California also have unstudied collections of Irvington specimens.

6-3 **2:15 PM** Chatters, James C.

PALEOECOLOGY OF THE IRVINGTONIAN FAIRMEAD LANDFILL SITE, MADERA COUNTY, CALIFORNIA

CHATTERS, James C., California State University Fresno Foundation, Fresno, CA 93740, paleosci@gmail.com and VAN DE WATER, Peter K., Department of Earth & Environmental Sciences, California State University, Fresno, CA 93740

Since the first fossil discoveries in 1993, Fairmead Landfill, located in the San Joaquin Valley of California, has produced thousands of vertebrate bone fragments, more than 3000 of which have been identified. Specimens collected between 1993 and 2008 comprise the Madera County Paleontology Collection (MCPC), which contains 2,964 identified elements. That collection, along

with fossil pollen extracted from 39 samples of the surrounding sediments, enables us to imagine the San Joaquin Valley ecosystem between 0.78 and 0.55 Ma. Bones in the MCPC, derived largely from distal alluvial fan sediments, come primarily from mammals, the remainder being of turtle and a small assortment of birds, amphibians, fish, and other reptiles. Whereas identification of larger taxa is complete, rodents remain largely unidentified. The assemblage consists primarily of grazers, including *Equus* (61% by NISP), *Mammuthus* (7%), and *Paramylodon* (3%), moderate frequencies of mixed feeders *Camelops* (15%), *Hemiauchenia* (2%) and the probable halophyte browser *Tetrameryx* (2%). *Odocoileus* and *Capromeryx*, thought to be browsers, are rare. Rodents and Leporids identified to date consist primarily of *Thomomys, Spermophilus, Microtus* and *Lepus*, with *Thomomys* by far the most common. Carnivores, which account for less than 2% of the assemblage, include *Canis dirus* (0.7%), *Smilodon* (0.4%), and rare specimens of *Lynx rufus*, *Canis latrans*, and *Taxidea*. Sediment samples, processed by Global Geolab, generally produced only small quantities of pollen, although counts as high as 240 were encountered. Poaceae (grass) is consistently the dominant type, followed by *Pinus*. Many samples also contain Cupressaceae (probably *Juniperus*) and Chenopodiceae/Amaranthaceae. Pollen from deciduous trees and aquatic habitats is rare. The assemblage is indicative of a mesic grassland with halophytic shrubs growing on small, seasonally dry basins and scattered juniper occupying rocky or protected settings. Pine occupied forested uplands. Taken together, the paleontological and palynological records indicate a flora not unlike that of the historic Central Valley, but lacking the characteristic oak savannahs and occupied by herds of horse and camel preyed upon by dire wolves and sabertooth cats.

6-4 **2:35 PM** Shaw, Christopher A.

PALEOECOLOGICAL CONSIDERATIONS REGARDING THE IRVINGTONIAN BIOTA FROM EL GOLFO DE SANTA CLARA, NORTHWESTERN SONORA, MEXICO

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Ancient Colorado River fluvio-deltaic deposits are exposed in northwestern Sonora, Mexico along the upper Gulf of California from which a diverse Irvingtonian paleobiota has been recovered. Fossils have been found in badlands that developed in response to late Pleistocene doming along the Cerro Prieto Fault. To date, over 7000 mapped vertebrate fossil localities are documented and over 120 species have been identified. The entire preserved paleobiota suggests the existence of four ecologic communities: freshwater aquatic, riparian galleria forest, shrub and brush woodland, and savannah-like grassland. A suite of specific species suggests that the Irvingtonian climate was quite different from the temperate desert that prevails in the area today. The recovery of fan palm (*Washingtonia* sp.), giant tortoise (*Hesperotestudo* sp.), crocodile (*Crocodylus* sp.), boa constrictor (*Constrictor constrictor*), crested guan (*Penelope* sp.), flamingo (*Phoenicopterus* sp.), capybara (*Neochoerus dicroplax*), giant anteater (*Myrmecophaga tidactyla*), and prehensile-tailed porcupine (*Coendou* sp.) remains implies that the annual regional temperature supported tropical to subtropical climates, and that areas existed within the region where at least partial shade prevailed.

6-5 **2:55 PM** Roeder, Mark A.

NEW RECORDS OF FRESHWATER FISH FROM IRVINGTONIAN DEPOSITS AROUND THE SALTON TROUGH, SOUTHERN CALIFORNIA AND NORTHWESTERN SONORA, MEXICO

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The El Golfo Badlands are located in the northwestern part of Sonora, Mexico. Although the El Golfo was collected as early as 1938 by Chester Stock of California Institute of Technology, the last 15 years, staff and volunteers from Reserva de la Biosfera–Alto Golfo de California y Delta del Rio Colorado (SMERNAP), Arizona Western College, and George C. Page Museum have made a concerted effort to survey exposures of Pleistocene-age Colorado River delta sediments for paleontological resources. Although the age of the El Golfo deposits is not well known, the fossil mammalian fauna correlates with the Irvingtonian -age section of the Anza Borrego Desert State Park stratigraphic sequence. At El Golfo, more than 3500 mapped vertebrate localities have yielded over 66 genera. In addition to the larger vertebrate fossils, several new microvertebrate localities have been identified. In conjunction with this work, the field survey and microvertebrate locality work, a small number of bony fish remains have been recovered. The bony fish remains consist primarily of isolated bones, teeth and vertebrae. At least three species of Colorado River fishes represented; razorback sucker (*Xyrauchen texanus*), pike minnow (*Ptychocheilus lucius*), chub (*Gila*).

Recently, paleontologists from the Department of Paleontology of the San Diego Natural History Museum (SDNHM) monitored ground disturbing activities during construction of the San Diego Gas and Electric Company Sunrise Powerlink Transmission Line for paleontological resources in western Imperial County, California. Near Seeley, at one of the tower locations, fossil-bearing fine-grained sediments of the Irvingtonian Brawley Formation , remains of at least four kinds of freshwater fish were recovered (*Gila*-chub, *Xyrauchen texanus*-razorback sucker, *Gasterosteus aculeatus*-threespine stickleback and a very small bony fish). Today, the threespine stickleback is not present in drainages the Salton Trough nor Colorado River. There are several possible explanations for this occurences

6-6 **3:15 PM** Ngo, My My

AVIFAUNAS OF THE MIDDLE PLEISTOCENE IRVINGTON AND FAIRMEAD LANDFILL LOCALITIES IN CALIFORNIA

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Two previously unpublished avifaunas, Irvington in the San Francisco Bay area and Fairmead Landfill in the San Joaquin Valley, provide insight into the middle Pleistocene birds of coastal and interior central California respectively. Specimens are curated in the University of California Museum of Paleontology (UCMP) and Madera County Paleontology Collection (MCPC). Located 10 miles north of Madera, California, Fairmead Landfill has yielded thousands of specimens from 0.78 Ma-0.55 Ma age alluvial fan deposits. The biota consists of 72 taxa (29 mammals, 6 birds, 3 reptiles, 2 amphibians, 2 fish, 1 bivalve, 1 gastropod, 12 plants/palynomorphs, 16 diatoms). Among the finds are 21 bird specimens, representing at least six taxa, including small goose cf. *Branta* sp. (MCPC A1102 synsacrum), Canada Goose *Branta canadensis* (MCPC A1103 left distal humerus), Common Shelduck *Tadorna tadorna* (UCMP 140414 right distal humerus, UCMP 141403 right humerus, UCMP 194432 right humerus), diving duck cf. *Aythya* sp. (UCMP 194433 right tarsometatarsus), Mourning Dove *Zenaida macroura* (MCPC A1560 left proximal tarsometatarsus), burrowing owl *Athene cunicularia* (MCPC A1300 left distal tarsometatarsus), and Tundra Swan *Cygnus columbianus* (MCPC A1086 right coracoid). Located in Fremont, California, the Irvington biota was recovered from fluvial deposits in a gravel quarry. Type locality of the Irvingtonian land mammal age, Irvington fossils were preserved in reversely magnetized strata representing the upper part of the Matuyama magnetic polarity chron (> 0.78 Ma). The Irvington biota includes 53 taxa (30 mammals, 7 birds, 4 fish, 4 amphibians, 3 reptiles, 5 mollusks). Seven bird taxa are represented by 17 specimens which include Ardeidae (UCMP 67817 distal ulna), Anatidae (UCMP 80995 left humerus, UCMP 67817 radius, UCMP 80997 distal ulna, UCMP 80996 proximal femur, UCMP 42292 coracoid), Canada Goose *Branta canadensis* (UCMP 38336 left humerus), American Neophron *Neophrontops americanus* (UCMP 80998 left humerus), Phasianidae (UCMP 80992 distal femur, UCMP 80994 left coracoid), Meleagridae (UCMP 80993 distal femur), and Passeriformes (UCMP 80986 carpometacarpus, UCMP 80988 left ulna, UCMP 80989 left humerus, UCMP 80990 coracoid, UCMP 80991 coracoid).

6-7 **3:50 PM** McDonald, H. Gregory

DIFFERENCES IN NORTH AMERICA XENARTHRAN DISTRIBUTION IN THE IRVINGTONIAN AND RANCHOLABREAN: AN APPROACH TO BETTER UNDERSTANDING THE GREAT AMERICAN BIOTIC INTERCHANGE

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Originating in South America, members of the Xenarthra (sloths, anteaters, armadillos, pampatheres, glyptodonts), dispersed into North America starting in the late Miocene. The first appearance of different taxa outside of South America is used to define the stages of the Great American Biotic Interchange (GABI). Given the diversity of Xenarthrans in South America, only a small subset were able to move northward into tropical Central and subsequently into temperate North America. A related question is why different taxa dispersed at different times? Was their dispersal northward facilitated or hindered directly by patterns of climate change during the Plio-Pleistocene or secondarily by the impact of climate change on the local ecology and habitats used by the different Xenarthrans as dispersal routes during the GABI? Are these differences reflective of differences in the ecology between the different taxa or merely a series of random events?

One approach to identifying climatic versus ecological parameters that affected the ecology and hence the distribution of the xenarthrans that did participate in the GABI is to compare their distribution in the Irvingtonian and Rancholabrean. For some taxa there is no change, while for others, the differences between their Irvingtonian and Rancholabrean distributions are significant and clearly indicate that each taxon responsed differently to changing climatic and ecological parameters during the Pleistocene. The patterns in how each taxon's range changed permit allow us to extrapolate some of the factors that allowed them to disperse out of South America. For example distributional changes that occur with longitude might indicate a response to changing rainfall patterns while changes in latitudinal distribution or in elevation may indicate a response to temperature change.

6-8 **4:10 PM** Howard, Carrie

A NEARLY COMPLETE SKULL OF THE BEAVER, *CASTOR CANADENSIS*, FROM THE IRVINGTONIAN BADLANDS OF GOLFO DE SANTA CLARA, SONORA, MEXICO

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Early to middle Pleistocene Colorado River Delta deposits exposed in the upper Gulf of California, northwestern Sonora, México are host to a diverse paleo-fauna and –flora, the El Golfo local paleobiota, which dates to the Irvingtonian North American Land Mammal Age. The fossiliferous exposures are found in badlands developed in fluvio-deltaic sediments that have been mildly deformed during late Pleistocene doming along the Cerro Prieto Fault. For the past two decades, the El Golfo Project has been part of a resource inventory for the Upper Gulf of California and Colorado River Delta Biosphere Reserve and has recovered over 7,000 fossils through joint efforts by Arizona Western College, the George C. Page Museum, and the Biosphere Reserve. The preserved paleobiota, now numbering over 120 species, suggests an Irvingtonian tropical to semitropical climate and the existence of four ecologic communities: freshwater aquatic, riparian gallery forest, shrub and brush woodland, and savannah-like grassland.

In 2011, a near-complete skull of *Castor canadensis*, was recovered as part of the ongoing El Golfo Project. The specimen lacks only the left second molar. To our knowledge, this is the most complete skull found at any Irvingtonian site in North America. The family Castoridae reached its highest diversity in the Oligocene and Miocene, but by the beginning of the Pleistocene only two genera are known and only one survives today, the genus *Castor*. There are two living species of *Castor*, the Eurasian *C. fiber* and the North American *C. canadensis*. Two North American fossil species are recognized as conspecific with *Castor canadensis*.

6-9 **4:30 PM** Scott, Eric

NEW RECORDS OF IRVINGTONIAN *TAPIRUS* FROM THE AMERICAN SOUTHWEST

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Middle Pleistocene vertebrate faunas from southwestern North America infrequently include fossil remains of the tapir, *Tapirus*. Fossils of this genus from Irvingtonian assemblages in northwestern Sonora, Mexico and inland southern California, US, can be separated into two size classes, large and small. Large tapir fossils from Sonora fall within the size range of *Tapirus haysii* Leidy, but are otherwise nondiagnostic. Small tapir fossils from California and Sonora fall in or near the size range of *Tapirus californicus* (Merriam) and *Tapirus veroensis* Sellards, based upon tooth measurements. Fossils from both regions also exhibit a dental morphology resembling the holotype of *T. californicus*, an isolated left m1 from California.

Newly recovered fossils of small Irvingtonian tapirs from Sonora include craniodental remains of multiple individuals. Based upon this material, small tapirs from Sonora can be distinguished from *Tapirus veroensis* based upon a number of cranial characters including: 1) the development of the posterodorsal process of the maxilla; 2) the width of the maxillary bar between the infraorbital foramen and the lacrimal; and 3) the morphology of the lacrimal.

The new tapir fossils from Sonora can also be distinguished from small Irvingtonian tapirs from inland southern California on the basis of: 1) the presence of strong anterolabial cingula on the upper premolars; 2) the morphology of the meatal diverticulum; 3) the orientation of the lacrimal foramina; and 4) the degree of development of the anterior lacrimal process. Whether these observed morphologic differences are sufficient to delineate two species, or instead represent variability within a single species, remains to be determined. If two small tapir species are present, the taxonomic validity of *Tapirus californicus* requires revision.

6-10 **4:50 PM** Asami, Rebecca

DETERMINING SPECIES OF *EQUUS* FROM THE MID IRVINGTONIAN FAIRMEAD LANDFILL LOCALITY, MADERA COUNTY, CALIFORNIA

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The mid Irvingtonian age (0.78 Ma to 0.55 Ma) Fairmead Landfill site in Madera County, California preserves a diverse fauna collected from fluvial channel, overbank, and lacustrine deposits of the upper unit of the Turlock Lake Formation. The fauna is dominated by large herbivorous mammals, with *Equus* representing nearly two-thirds of identified specimens. The horses include individuals of all ontogenetic ages, from juveniles to aged adults. The Fairmead Landfill collection provides ample material for comparison to other Pleistocene horses throughout North America. Metatarsals from the Fairmead Landfill were measured and compared to *Equus* from the following sites: *Equus* sp., Irvington, California; *E.* "*occidentalis*", McKittrick and Rancho La Brea, California; *E. scotti*, Rock Creek, Texas; *Equus* sp., Dalhart Horse Quarry, Texas; *E. conversidens*, San Josecito Cave, Mexico; *E. ferus*, Natural Trap Cave, Wyoming; and *Equus* sp., Natural Trap Cave, Wyoming. Horses from Fairmead Landfill fall in the low end of the *E.* "*occidentalis*"/ *E. scotti* distribution and in the upper end of the *E. conversidens* / *E. ferus* range. In addition to postcranial metrics, mandibles were examined for the presence or absence of infundibula, a character useful in distinguishing among horse species. The presence of infundibula in lower incisors of *Equus* at Fairmead Landfill indicates that these horses are neither *E.* "*occidentalis*" nor *E. conversidens*, since both these species lack infundibula in the lower incisors. This suggests the horse species from Fairmead Landfill may be either *E. scotti* or *E. ferus*, both of which possess infundibula. The infundibulum of the right 3rd incisor is open posteriorly, which also occurs in both *E. scotti* and Pleistocene North American *E. ferus*. Additional research is underway, using phalanges, in an attempt to further refine the species determination of Fairmead Landfill *Equus* specimens.

6-11 **5:10 PM** Trayler, Robin B.

STABLE ISOTOPE ECOLOGY AND DIETARY MODELING OF MAMMALIAN MEGAFAUNA FROM THE MIDDLE IRVINGTONIAN FAIRMEAD LANDFILL LOCALITY, CHOWCHILLA, CA

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Previous paleodietary studies of California megafauna have focused primarily on the coastal late Pleistocene Rancho La Brea tar seeps, while Irvingtonian sites remain understudied. We report $\delta^{13}C$ and $\delta^{18}O$ values measured from tooth enamel of mammalian megafauna from the mid Irvingtonian (.78-.55 Ma) Fairmead Landfill site, near Chowchilla. The assemblage is dominated by large herbivores, with *Equus*, *Camelops*, *Mammuthus* and *Paramylodon* the most prominent. Ten carnivore taxa are also present including *Canis dirus*, *Canis latrans*, *Smilodon*, *Homotherium*, and *Miracinonyx*.

We used stable isotope values of carnivore and herbivore tooth enamel to investigate paleodietary and paleoecological patterns. $\delta^{13}C$ values of tooth enamel are controlled by diet and can be used to investigate resource usage and partitioning among and between taxa. In large mammals $\delta^{18}O$ ratios are controlled by drinking water, and by proxy, climate. Ontogenetic serial tooth $\delta^{18}O$ and $\delta^{13}C$ reveal seasonal trends in resource usage, from which we can infer patterns of forage availability.

Fairmead Landfill $\delta^{13}C$ values are consistent with an environment dominated by C_3 vegetation. *Platygonus* and *Camelops* had the lowest and highest $\delta^{13}C$, respectively. *Camelops* exhibited the most variable $\delta^{13}C$ among herbivores, though several other taxa are represented by single individuals, thus lacking dietary ranges. Among carnivores, *Homotherium* had the lowest $\delta^{13}C$ values (-13.5‰) and *Canis latrans* the highest (-10.7‰). In addition to population level analysis (ANOVA, t-tests) we also used the Bayesian mixing model Stable Isotope Analysis in R (SIAR) to model carnivore diets against potential herbivore prey. Both canids and felids show generalist dietary patterns, however felids on average consumed *Mammuthus* than *Canis dirus*.

We serially sampled teeth from four taxa to investigate seasonality and temporal resource usage among megafauna. *Equus*, *Camelops* and *Tetrameryx* show little variation in $\delta^{13}C$ suggesting little turnover in Fairmead's floral community, on a seasonal scale. We also report a serial sampled *Homotherium* canine and a calculated growth rate of 3.4 mm/year; a growth rate intermediate between *Smilodon* and modern pantherine felids.

SESSION NO. 7, 1:30 PM

Monday, 20 May 2013

Mineralogy, Petrology, and Geochemistry (Posters)

Radisson Hotel and Conference Center, Salon B/C

7-1 **BTH 1** Brown, Howard J.

FLUORESCENT MINERALS AT THE OMYA WHITE KNOB QUARRY, LUCERNE VALLEY CALIFORNIA

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Omya, the leading global producer of ground calcium carbonate, produces white calcium carbonate from the White Knob quarry located on the north slope of the San Bernardino Mountains in the Lucerne Valley area of the Mojave Desert California. The quarry is developed in multiply folded, Paleozoic miogeoclinal carbonate rocks intruded by a variety of Mesozoic age plutonic rocks. The Monte Cristo Limestone of Mississippian age has been multiply metamorphosed to amphibolite grade, forming very coarse grained white calcite marble. Mining is by standard open pit methods. Ore is processed into fine grind calcium carbonate and utilized in hundreds of common consumer products.

Fluorescent minerals are common in waste rock and not in the high purity calcium carbonate ore. Fluorescent minerals respond to short wave ultra violet light. White Knob is the most prominent fluorescent mineral location in Southern California.

Fluorescent minerals have several modes of occurrence at the quarry. Most occur within the Arrowhead Member of the Mississippian Monte Cristo Limestone, originally an impure cherty limestone, metamorphosed to wollastonite calc-silicate marble. Several Mn bearing minerals are present. Fluorescent minerals are also common in the Arrowhead including orange fluorescing calcite, bright yellow wollastonite, lime green hyalite and aragonite, blue diopside, white dolomite and unknown minerals that fluoresce violet, azure blue, sky blue and shades of olive green. Another common fluorescent mineral occurrence is magenta fluorescing feldspar, within Jurassic granite dikes. When the dikes cut the fluorescent Arrowhead Member, spectacular multi color specimens are present. Other common fluorescent occurrences include highly phosphorescent travertine and caliche. Less common are skarn occurrences including metallic minerals such as powelite (a molybdenum mineral) which fluoresces as bright white snowflakes.

The presence of activator impurities in the host rock including Mn, U, Zn, Fe and REE are likely responsible for the fluorescence at the White Knob quarry. Fluorescent minerals occur in rocks of different ages and include primary minerals, metamorphic minerals, and secondary minerals. Genesis is related to inherent composition as well as other processes occurring over a range of geologic time.

7-2 **BTH 2** Kleck, Wallace D.

THE ABUNDANCE AND DISTRIBUTION OF THE RARE-EARTH ELEMENTS LA, CE, AND ND IN THE GEORGE ASHLEY BLOCK PEGMATITE BODY

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In the George Ashley Block pegmatite body four rare-earth elements are present in sufficient quantities to be measured (in ppm); these are La, Ce, Nd, and Yb. The elements Eu and Ho were looked for, but did not occur above the level of detection (2 and 4 ppm). The distribution of minerals in this pegmatite is not homogeneous. In particular, garnet (volume%) varies by a factor of at least 20 in different samples, and ≈80% occurs in the lower part (46%) of the pegmatite body. The abundances of three of the rare-earth elements (La, Ce, Nd) varies as does the abundance of garnet within the pegmatite body. The abundance of these elements also varies as does Mn, and garnet is the dominant Mn-bearing mineral. This data indicates that the La, Ce, and Nd are contained within the garnet in amounts of a few ppm and that their variation in rock samples is controlled by the variation in the abundance of garnet.

This data also indicates there is a tendency for these three elements to be, specifically, included in the garnet at a level of a few ppm. Note that in studies of thin sections and with the microprobe, there were no apparent blebs of melt or other inclusions in the garnet (grain size average ≈0.05 cm). Other minerals nucleated at the same time as garnet, and they show no tendencies to contain these rare-earth elements. This, then, indicates that these atoms (≈1.85Å, metallic radii) are present in a very few, scattered, large structural defects in the garnet--one such defect per 10^{10} structural sites should be sufficient to contain a few ppm of these rare-earth elements. The other possibility is that there were inclusions that favored garnet, and they are too small to observe. There is a vague indication that Yb behaves in a similar way, but with respect to muscovite.

7-3 **BTH 3** Baltzer, Suzanne M.

PETROCHEMISTRY OF A RARE EARTH OCCURRENCE WITHIN THE NORTHERN NEW YORK MOUNTAINS OF SOUTHERN NEVADA

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The northern New York Mountains, southern Clark County, Nevada contain anomalous concentrations of rare earth elements within a Proterozoic (1.6-1.8 Ga) orthogneiss. The host for the mineralization is a weakly alkaline granite, however, the highest rare earth concentrations occur in close proximity to the contact between granite and a more mafic intrusive phase varying in composition from granodiorite to diorite.

Four rare earth-bearing minerals have been identified. Small amounts of rare earths occur within the abundant fluorapatite of large aggregates that frequently enclose smaller grains of the other phosphates. Much higher concentrations of rare earth are present within monazite-Ce and xenotime. The monazite-Ce also contains significant amounts of lanthanum, neodymium, and thorium. Xenotime, in contrast, is enriched in gadolinium, dysprosium, and erbium. A thorium mineral species also contains small amounts of rare earth. The mineralization generally occurs as pods and disseminations within the host granite, however, some veining particularly of monazite was noted in thin section. Zoning of REEs and thorium within individual grains was common.

Alteration consists of widespread Na-metasomatism, in which k-spar has altered to albite and sodium clays, and more localized chloritization. The latter appears most commonly within breccia zones that likely were created by faulting. The relationship of the alteration to the rare earth mineralization remains enigmatic. Although some mineralization is present in areas of intense alteration other pods of rare earth mineralization have no associated alteration. The relationship is complicated by a Mesozoic copper-bearing intrusive near the north end of the New York Mountains. Fluid circulation associated with that event could account for some or all of the alteration associated with the rare earth mineralization.

SESSION NO. 8, 1:30 PM

Monday, 20 May 2013

Plutons: Evolution, Emplacement, and Deformation (Posters)

Radisson Hotel and Conference Center, Salon B/C

8-1 **BTH 4** Scudder, Christopher

STRUCTURE OF THE EOCENE GOLDEN HORN BATHOLITH, NORTH CASCADES, WASHINGTON

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The 48 Ma Golden Horn batholith is a ~310 km^2, shallow intrusion in the crystalline core of the North Cascades of Washington. It is the only large granite body in an orogen dominated by 96-45 Ma tonalite, and may have intruded during ridge subduction. Alkaline and calc-alkaline granites dominate, and include a hypersolvus biotite granite, a two-feldspar biotite granite, and a sodic amphibole-bearing alkaline granite containing large miarolitic cavities. Internal contacts are moderately steep and sharp between the alkaline and hypersolvus granite, whereas the latter

grades into the two-feldspar granite. Diorite forms a narrow, discontinuous belt along the SW margin, and the NW end of the intrusion is granodiorite and tonalite. The alkaline granites are inferred to be structurally highest and the NW end may represent the structurally deepest rocks, supporting the interpretation that the batholith is tilted NW-side-up and is more mafic with depth. Schlieren and enclaves are rare in the alkaline and hypersolvus granites, but are progressively more common in the two feldspar and relatively mafic rocks. The batholith displays a weak to moderately developed magmatic foliation, and a weaker lineation. It has a dominant NW-striking, typically SW dipping fabric and a weaker NE-striking fabric with both NW and SE dips, which is restricted to the center of the intrusion. Dips are moderate to steep. Foliations near the NW contact are coupled with the adjacent host rock, apparently recording regional strain. The weaker interior fabric probably reflects internal magmatic processes. Golden Horn dikes (n=61) intruding host rock are felsic and less commonly mafic, are typically ~1-m wide, but range up to 20 m. These steep dikes strike NW and E-W in roughly equal amounts. Their orientations may reflect regional transtension. Contacts of the batholith are typically steep. To the NW, the contact is a mixed zone, with Golden Horn dikes extending up to 100 m into the slightly older and deeper(?) Ruby Creek plutonic complex. At the southern contact, the ~90 Ma Black Peak pluton is highly fractured and incorporated into the Golden Horn rock as 10s-of-m-scale stoped blocks. The diking, stoping and lack of a ductile aureole are compatible with the shallow emplacement levels.

8-2 **BTH 5** Elkins, Scott W.

STRUCTURE AND CONSTRUCTION OF THE HIGHLY ELONGATE, CRETACEOUS SEVEN-FINGERED JACK PLUTON IN THE DEVIL'S SMOKESTACK AREA, NORTH CASCADES, WASHINGTON

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Within the Chelan block of the North Cascades crystalline core, a 20-25-km-wide region of 92-71 Ma, markedly elongate, and commonly internally sheeted plutons intrude amphibolite-facies host rocks. This study focuses on the structure of one of these elongate (50 km by 7 km) plutons, the ~92-90 Ma, mid-crustal (20-25 km) Seven-Fingered Jack (SFJ) pluton. Previous work suggests that large parts of the pluton are relatively homogeneous. Detailed mapping of three ~ 0.5-1.0-km^2 domains at a scale of 1:10,000 concentrated on internal heterogeneities, internal contacts, and magmatic fabric patterns with the goal of evaluating whether the apparently homogeneous rocks were constructed by multiple bodies with subtle contacts.

The pluton is dominantly tonalite, which is relatively homogeneous, particularly in the central and southern domains. Host rock xenoliths or rafts are rare. Schlieren and other layering are only locally developed. Schlieren are typically several meters long, thin (cm-scale), wispy, and biotite-rich. A ~15-cm wide zone of alternating mafic and felsic layers, which extends for ~10-15 m, may represent partially digested xenoliths or mingling between separate injections of melt. Textural and modal variations, although subtle, are gradational over several centimeters across internal contacts (traceable ≤ 10 m) and gradational at larger scales (10s to 100s of m). These contacts, schlieren, and the layered zone strike WNW and dip steeply to the ENE. Enclaves are abundant and were divided in the field into five types based on texture and color index. A ~5x5-m grid was used at each station to estimate enclave abundance, which ranged from 0 to 25 enclaves. Enclaves are elongate parallel to well-developed magmatic foliation, defined by hornblende and biotite; foliation strikes NW and has moderate to steep dips. Foliation orientations are less uniform in the northern domain, reflecting steeply plunging magmatic folds with 10s of m wavelengths.

These field results imply that the SFJ pluton was constructed by thin (< 1 m) and thicker (up to 500 m?) steeply dipping sheets, which strike parallel to the margins of the pluton and amalgamated into km-scale bodies with subtle internal contacts.

8-3 **BTH 6** Dustin, Kelly Nicole

CONSTRUCTION AND RELATIONSHIPS OF MAFIC AND TONALITIC ROCKS IN THE SEVEN FINGERED JACK PLUTON, NORTH CASCADES, WASHINGTON

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The crystalline core of the North Cascades preserves a crustal section through a Cretaceous continental magmatic arc and provides an excellent opportunity for study of a mid-to-deep-magmatic system. One pluton in this section, the 6-8 kb, Seven Fingered Jack pluton is an elongate body (~50 by 7 km), which has been previously mapped as a highly heterogeneous sheeted pluton in the NW, but largely as tonalite along strike to the SE. Previous U/Pb zircon geochronology on tonalite from the NW tip and pluton interior to the SE yielded ages of ~91 Ma, whereas mafic rocks in the NE margin are ~79 Ma. Detailed mapping was carried out on a southern part of the pluton in the Klone Peak area, which extends across strike from the margin SW into the pluton interior. Here, the eastern margin is very heterogeneous and sheeted, and the pluton is composed of: (1) a mafic complex mapped in three 50-600-m-thick sheets, which contain hornblendite xenoliths, patches, and enclaves enclosed in gabbro and diorite; (2) a heterogeneous diorite forming four 75-200-m-thick sheets, with less abundant gabbro and hornblendite enclaves and dikes; (3) a diorite mapped in two 100-700-m-thick sheets; and (4) a quartz diorite in two ~100 m-wide masses. To the SW of the ~1.5 km-wide mafic marginal units is a much larger (> 3 km wide) internal mass of relatively homogeneous hornblende-biotite tonalite. The tonalite contains abundant mafic and local felsic enclaves, minor xenoliths, and meter-wide felsic sheets. Two zones, 50-200 m wide, have abundant heterogeneities, which include concentrations of enclaves, hornblendite xenoliths, felsic sheets (5 cm-1 m wide), and schlieren, and most likely represent internal contacts between different tonalite bodies. The mafic units are on strike with the dated mafic rocks ~20 km to the NW, whereas the relatively homogeneous tonalite is probably part of the > 25 km-long interior belt of ~91 Ma tonalite. The mafic rocks intruded during a short-lived pulse of mafic magmatism in the area that includes the ~78 Ma Riddle Peak gabbro and mafic tip of the Cardinal Peak pluton. In summary, the composite mid-crustal Seven Fingered Jack pluton contains an internal mass of homogeneous tonalite and an eastern margin of younger heterogeneous mafic rocks that were constructed by multiple pulses of magma that dynamically interacted.

8-4 **BTH 7** Buerer, Brad

FOLIATION DEVELOPMENT AND INTRUSIVE RELATIONSHIPS IN THE CRETACEOUS WRIGHTS LAKE AND JURASSIC PYRAMID PEAK PLUTONS OF THE NORTHERN SIERRA NEVADA BATHOLITH, DESOLATION WILDERNESS, CALIFORNIA

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The structures of a Cretaceous and adjacent Jurassic pluton in the Sierra Nevada batholith near Lake Tahoe were studied to gain an understanding of the implications of magmatic foliation patterns and processes operating during pluton emplacement. The voluminous, poorly dated (ca. 106-92 Ma) Wrights Lake granodiorite is a generally homogeneous, medium- to coarse-grained hornblende-biotite granodiorite, with abundant enclaves and schlieren. It intrudes the Pyramid Peak granite (164±7 Ma) along a roughly N-S-trending contact. This older pluton is a coarse-grained quartz monzonite, but also features internal zones of diorite and gabbro, some of which form a sequence of gradational layers (Wiebe et al., 2002). Two overprinting, hornblende- and biotite-defined magmatic foliations and associated steeply plunging lineations are observed within the Wrights Lake granodiorite at the outcrop and map scale. A dominant, steeply dipping foliation of moderate to high intensity is parallel to the overall N-S trend of the pluton contact and bends to match a large recess in its eastern boundary, suggesting the influence of internal magma processes. A less intense fabric strikes ~E-W, discordant to both the pluton contact and to internal structures, and locally transposes the older foliation, associated enclaves, and schlieren. This orientation is similar to trends noted for the roughly coeval Tuolumne batholith (Žák et al., 2007), and is interpreted to reflect an interval of regional N-S shortening during final cooling, which is anomalous with respect to the rest of the Sierra Nevada batholith. Steep foliations within the Pyramid Peak granite, defined by coarse feldspar, strike consistently NNW and are interpreted to record WSW-ENE regional shortening in the Jurassic. The pluton contact is sharp and stepped in most places. Xenoliths occur only within 3m of the contact, and range from large, angular blocks to smaller, rounded pieces to zones of disaggregated feldspars. These suggest that brittle material transfer of the host helped accommodate emplacement. Solid-state deformation within the older pluton near the contact may indicate limited ductile flow also resulted from emplacement of the younger granodiorite.

8-5 **BTH 8** Miller, Robert B.

STRUCTURE OF THE YOSEMITE VALLEY INTRUSIVE SUITE: REGIONAL STRAIN FIELDS AND INFLUENCE ON EMPLACEMENT OF YOUNGER INTRUSIONS IN THE CENTRAL SIERRA NEVADA BATHOLITH

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The ~103-99 Ma Yosemite Valley Intrusive Suite (YVIS) formed during voluminous silicic (leucogranite to granodiorite) magmatism that predated the large zoned granodioritic suites of the Sierra Nevada batholith. The structure of the YVIS, although generally not considered in regional syntheses, provides insights into the regional strain field, and its rheology influenced the geometry and emplacement style of younger intrusions. The suite consists of older, generally coarser-grained, and higher-color-index rocks of the El Capitan Granite and similar units, the younger Taft Granite, and comagmatic diorites that are more abundant in the south. Thin (<10 m wide) metasedimentary screens to km-wide pendants separate the YVIS from younger plutons for ~35 km in the north, and form the eastern extent of the suite. The YVIS apparently acted as a rheological barrier to younger magmas of the Tuolumne Intrusive Suite, which only penetrate the YVIS for short distances. The YVIS is also extensively fractured and surrounded by younger intrusive rocks along parts of its eastern margin (cf. Calkins, 1985), a relationship not shown by other units in the region.

Steep magmatic foliation in the suite is commonly margin-parallel, but in some >10 km^2 domains, N- and NW-striking foliations are at high angles in map view to contacts with host rocks and are interpreted to record regional NE-SW shortening. This shortening direction is compatible with the overall Sierran strain field, but contrasts with that of the E-W-striking regional foliation in the Tuolumne suite and Cretaceous plutons in the Tahoe area. The major solid-state structures are ductile shear zones (~5 cm to >50 m thick) that formed at >450^{0}C and include NW-striking and larger NE-striking zones. They are much better developed in the El Capitan than the Taft Granite and indicate deformation shortly after emplacement and before ~98 Ma. The shear zones have moderate to steep dips, roughly down-dip lineations, and record reverse slip. Slightly younger (~98-80 Ma) map-scale reverse and dextral strike-slip zones in the region strike N to NNW in contrast to the large NE-striking zones in the YVIS. The anomalous NE strikes speculatively record strain refraction near NE-trending margins of the suite, but their origin remains a significant unanswered question.

8-6 **BTH 9** Brown, Kenneth

LATE CRETACEOUS ARC FLARE-UP IN NORTHWESTERN NEVADA: ELEMENTAL, ZIRCON HF ISOTOPE, AND U-PB ZIRCON GEOCHONOLOGY OF THE SANTA ROSA RANGE AND BLOODY RUN HILLS GRANITOIDS

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Recent work has emphasized the importance of the links between regional tectonics and magmatic arc flare-up in the Cordillera. In contrast to the well-studied batholiths, little is known about magmatism in NW Nevada, making it difficult to evaluate Cordillera-wide, spatio-temporal trends in crustal growth. Therefore, this contribution presents new data from granitoids exposed within the Santa Rosa Range (SRR) and Bloody Run Hills (BRH) of NW Nevada.

New U-Pb zircon geochronology via LA-ICP-MS yields two primary age groups within the SRR: the Santa Rosa/Andorno group (SRA) (Santa Rosa stock, 101.5 ± 1.6Ma; Andorno stock, 101.0 ± 1.0Ma) and the Granite Peak/Sawtooth group (GPS) (Granite Peak stock, 94.2 ± 1.4Ma; Sawtooth stock, 93.1 ± 1.2Ma). Within the BRH, however, U-Pb geochronology yields both an older pulse (Bloody Run Hill stock, 105.5 ± 1.3) and a pulse intermediate to the two primary pulses observed within the SRR (Flynn stock, 96.7 ± 1.5).

Despite within-sample variability, *in-situ* zircon Hf isotopic values via LA-ICP-MS show a consistent decrease in $\varepsilon Hf_{(t)}$ with time, mirroring the trend of whole-rock εNd values. Whereas zircon $\varepsilon Hf_{(t)}$ values for the older SRA pulse range from +8 to +1, the younger GPS pulse yields zircon $\varepsilon Hf_{(t)}$ values ranging from +3 to -5. Proterozoic inherited cores yield εHf values ranging from -14 to -25 at the time of SRA and GPS emplacement, suggesting that an ancient crustal component was involved in the evolution of these magmas.

Both pulses show high Sr (100-600ppm), high Sr/Y (30-90) and La/Yb ratios (15-65), low Y (8-15ppm), small to no Eu anomalies, and slightly concave-up REE patterns, consistent with signatures produced via melting of deep subarc crust in equilibrium with a feldspar-poor, garnet and amphibole-rich residue. Increasing whole-rock $Sr_{(i)}$, a correlated decrease in whole-rock εNd with zircon εHf, and an increase in inherited zircon cores within the younger GPS pulse, suggest a decreasing role for mantle derived melts and increasing involvement of crustal reservoirs through time. These same trends have been observed along much of the Cordilleran during high-magmatic flux periods (e.g. 120-80Ma), suggesting that magmatism in NW Nevada shared similar magmatic histories to the larger batholiths and was generated during the late Cretaceous arc flare-up (ca. 120-80 Ma).

8-7 **BTH 10** Bartley, John M.

GEOMETRY AND EMPLACEMENT MECHANISM OF LADDER DIKES IN THE CATHEDRAL PEAK GRANODIORITE, YOSEMITE NATIONAL PARK

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Ladder dikes (LDs)—crudely tabular arrays of nested, concave-up mafic-felsic layers, commonly 0.3-1 m thick—are sparse but relatively common in granitic plutons. Several recent papers interpret LDs to record subvertical plumes produced by small-scale convection in a magma chamber. Field observations from the Cathedral Peak Granodiorite (Kcp) clearly favor the migrating-pipe model of Weinberg et al. (2001); many LDs in Kcp terminate in a rod-shaped mass of leucocratic rock that fills the highest trough and records the final position of a pipe-like magma conduit. However, the geometry of LDs in Kcp is inconsistent with vertical plumes. At several widely dispersed locations in the Kcp, we measured orientations of >160 LDs and of the trough-shaped layers that record conduit orientation. The LDs generally strike at a high angle to the external contact of the pluton; troughs invariably plunge outward at an average angle of ~45°; and nesting of troughs uniformly indicates upward migration of the conduit. This pattern is difficult to reconcile with a subvertical original orientation and suggests that the conduits originally plunged away from the center of the pluton.

Wall-rock fragments are very sparse in Kcp but are common in LDs, indicating that the xenoliths were carried in by magma flow in the LD conduit. The xenoliths typically are ~2 -10 cm across and very fine-grained. Bulk-rock chemical analyses yield intermediate SiO_2 concentrations consistent with an andesitic protolith, but broad scatter of other major oxides suggests strong bulk-chemical modification.

Combined with chemical evidence that LD layering reflects liquid immiscibility (Glazner and Bartley, this volume), we suggest that LDs reflect conduits through which late-stage immiscible liquids migrated outward from the center of the growing pluton. The pipe-like shape of the conduits may reflect fingering of outward-propagating intrusive sheets during incremental growth of the pluton (Bartley et al., 2009). The descending trajectory of the conduits might result from negative buoyancy of the dense Fe-rich liquid component, which accumulated preferentially at the bottom of the conduit to form dark layers, while upward migration of the conduit may have been caused by the buoyancy of the felsic component.

8-8 **BTH 11** Ianno, Adam J.

CONSTRUCTION AND MAGMATIC EVOLUTION OF THE COMPOSITE PALMS GRANITE PLUTON, JOSHUA TREE NATIONAL PARK, CALIFORNIA

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The Palms pluton is representative of upper crustal granites found at Joshua Tree National Park. Our recent geologic mapping and geochronology work has shown this pluton to be composite, and we now are able to divide it into representative subunits. These units have varying textures (porphyritic to equigranular), mineral assemblages (± muscovite, garnet, relict hornblende), and a range of U-Pb zircon ages from 75-81 Ma. Unlike intrusive bodies beneath the Palms, the compositional range within each unit is restricted. There is only very minor evidence of host rock contamination at its external margins, preserved as schlieren, biotite clots, and rare host rock blocks. One unit (Keys Ranch) shows evidence of magma mingling, represented by rounded microdiorite enclaves.

Collectively, the mineral fabrics of the units are weakly developed and predominantly magmatic. Foliations are defined by biotite alignment and/or enclave orientation and are generally steep and northwest to north-striking. In map view, we observe more circular, blobby units in the center of the pluton, while outlying units are generally more linear. Units on the west and northwest sides become sheeted toward the external margins (with sheets both ~2 m and ~10 m in thickness), while those on the south to east margins form sharp contacts with the host rocks. Internal contacts vary locally, but most units exhibit sharp but mushy contacts. The contact between the Lost Horse and Keys Ranch units is gradational, and the Lost Horse unit lacks the characteristic enclaves. These internal contacts are often subvertical, although become obscured with the sheeting to the west. There appears to be a very weak fabric overprinting the contact between the Indian Cove and Lost Horse units, which likely occurred after significant cooling.

The Palms may have grown in at least two stages: one pulse at ~80-79 Ma and another at ~77-74 Ma. At 79 Ma, a blobby granite pluton (Lost Horse) intruded coevally with nearby diorites and hornblende gabbros, producing some enclaves in the central portions (Keys Ranch). At ~77 Ma, an elongate granite pluton (Indian Cove) intruded at the eastern side. At ~75 Ma, there may have been a great heat pulse at depth, with the possible remobilization of the southern Keys Ranch unit and small subunits showing evidence of host rock assimilation (Wall Street).

SESSION NO. 9, 1:30 PM

Monday, 20 May 2013

Volcanology, Volcanic Rocks, Volcanic Petrogenesis (Posters)

Radisson Hotel and Conference Center, Salon B/C

9-1 **BTH 12** Davidson, Blair

PETROLOGY AND GEOCHEMISTRY OF MINARET CONE, MAMMOTH MOUNTAIN, CA

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Approximately three dozen mafic vents surround Mammoth Mountain, a volcanic complex of 25-30 overlapping lava domes located in eastern California, including Minaret Cone on the northern flank. Mahood et al. (2010) determined an age of 94±9 ka based on $^{40}Ar/^{39}Ar$ analysis of Minaret Cone groundmass, which predates the 68-58 ka time period when the bulk of Mammoth Mountain lavas were erupted (Mahood et al., 2010). This study examines the mineralogy and chemical composition of basaltic material erupted from Minaret Cone. Minaret Cone lavas and scoria are plagioclase and clinopyroxene phyric with sparse olivine phenocrysts enclosed in an acicular groundmass composed mostly of plagioclase. Minaret Cone lavas and scoria yield bulk-rock trachybasaltic compositions that plot within the high-K calc-alkaline differentiation series, with 50.1-51.2 SiO_2, 1.58-1.69 TiO_2, 17.75-17.93 Al_2O_3, 8.20-8.49 Fe_2O_3, 5.42-5.81 MgO, 8.14-8.15 MnO, 8.77-8.99 CaO, 1.56-1.63 K_2O, 3.67-3.83 Na_2O, and 0.59-0.64 P_2O_5 (values in weight %). Modest modal olivine along with low concentrations of Ni (32-45 ppm) and Cr (42-73 ppm) require that Minaret Cone magmas are not primary mantle melts, but rather result from differentiation and assimilation in the lower crust. This interpretation is supported by trace element patterns in MORB-normalized spider diagrams, where Minaret Cone samples develop trends comparable to previously reported samples of Quaternary mafic lavas from the north moat region of Long Valley caldera (e.g., Bailey, 2004; Cousens, 1996). Interestingly, Minaret Cone samples share MORB-normalized trace element profiles to mafic enclaves contained in Mammoth Mountain trachyandesites and trachydacites in terms of immobile elements (e.g., Nb, Ce, Hf, and Ti), but are depleted in more mobile elements (e.g., K, Rb) compared to enclaves, suggesting that mafic magmas that intruded the Mammoth Mountain magma reservoir to form undercooled enclaves were more differentiated than those erupted from Minaret Cone.

9-2 **BTH 13** Browne, Brandon L.

AGE OF THE ALVORD PEAK BASALT, CENTRAL MOJAVE DESERT, CALIFORNIA

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The Alvord Mountains in the Central Mojave Desert of California consist of Paleozoic and Mesozoic igneous and metamorphic basement rock unconformably overlain by Tertiary sedimentary and volcanic rocks, the latter of which are exposed in the eastern Alvord Mountains. Over the past 60 years, attention has been paid to Tertiary rocks within the Alvord Mountains as recorders of basin development associated with Miocene extension in the central Mojave. The Tertiary stratigraphy remains in part unresolved, however, due to the limited distribution of some formations and the sparse number of radiometric dates of others. This study aims to resolve the position of the Alvord Peak Basalt (APB) in the Tertiary stratigraphy, which has eluded geologists due to the fact that critical contacts are often poorly exposed where the APB crops out.

New ages based on $^{40}Ar/^{39}Ar$ laser incremental heating of groundmass from samples collected south of Spanish Canyon and near Alvord Peak yield plateau ages of 17.2 ± 0.12 Ma and 18.1 ± 0.14 Ma, respectively. These ages are considerably older than Fillmore's (1993) interpretation that the APB be placed in the upper Barstow Formation (~13-14 Ma), but are more closely in agreement with Byers (1960) and Strona and Miller (2002), who argued for a position between the Clews and Spanish Canyon Formations. Our results suggest that the APB lies between Spanish Canyon and Barstow Formations, although it is possible that some of the upper APB flows are interbedded within the lower Barstow Formation. We prefer the former interpretation because APB flows are chemically distinct from two other basalt flows that clearly lie within the lower 100 meters of the Barstow Formation.

Dating of diabase from N30W trending dikes 1.7 km east of Spanish Canyon previously interpreted as feeder dikes of the APB (Byers, 1960) yield a plateau age of only 9.56 ±0.41 Ma, which disqualifies these features as the subvolcanic equivalent to the APB lava flows. Samples of the upper and lower basalt lava flows within the Spanish Canyon Formation were also dated, yielding plateau ages of 18.6 ±0.28 Ma and 19.1 ±0.20 Ma, respectively, which closely resemble the underlying Peach Springs Tuff, dated by Ferguson et al. (2013) at 18.78 ±0.02 Ma, exposed at the top of the Clews Formation (Byers, 1960; Fillmore, 1993).

9-3 **BTH 14** Haygood, Zachary

THE PYROCLASTIC SURGE DEPOSIT OF THE ~680 YR BP PANUM CRATER ERUPTION, EASTERN CALIFORNIA

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Panum Crater represents the youngest eruption of the Mono-Inyo Volcanic Chain in eastern California (Sieh and Bursik, 1986). Previous work by Sieh and Bursik (1986) determined a stratigraphy for this eruption characterized by a throat clearing breccia overlain by a pyroclastic flow deposit ("dune" flow), pyroclastic surge deposit, a block-and-ash-flow deposit found locally to the northwest of Panum Crater, capped by a tephra ring deposit and a rhyolite lava dome. This study investigates the "pyroclastic surge deposit" horizon of this stratigraphy along flow-parallel transects with increasing distance from vent in terms of thickness, internal stratigraphy, granulometry, and pyroclast morphology. Surge deposits within ~300 m of the crater rim are up to 4 meters thick and can be subdivided into 2 units, with a 3-meter-thick cross-bedded ash-rich unit at the base (P1) overlain by light beige ash-rich beds with cross-bedding and planar-bedding structures interbedded with 15 to 20-cm-thick reversely graded coarse-grained pumice lapilli and lithic fall deposits (P2). Surge deposits ~500 meters of the crater rim are 1 to 2 meters thick and can be subdivided into 3 units, with a dark beige fines-rich cross-bedded base unit (P1), a middle unit composed of beige fines-rich planar bedded layers interbedded with reversely-graded pumice fall (P2), overlain by a light tan fine-grained crystal-rich friable unit (P3). Surge deposits thin rapidly from 0.5 meters thick at distances of 700 meters from the crater rim to <4 cm thick at distances beyond 2 km from the crater rim. At these distances, only the upper friable and crystal-rich unit (P3) is observed. Granulometric analysis yields supportive data to the stratigraphic descriptions mentioned previously. For samples located ~500 meters from the Panum Crater rim, the percentage of fines decrease with stratigraphic height from 53% in P1 to 44% in P3, whereas median grain size increases slightly from 0.1 mm in P1 to 0.2 mm in P3. Sorting values range from 1.4 to 1.5 throughout the stratigraphy. We interpret this stratigraphy as the result of a dry, dilute, and turbulent pyroclastic density current (P1) followed by simultaneous deposition of fall and pyroclastic density current deposits (P2) capped by a co-ignimbrite ash fall (P3).

9-4 **BTH 15** Partridge, Molly E.

VOLCANO-TECTONIC HISTORY OF THE NORTHERN WARNER RANGE IN NORTHEASTERN CALIFORNIA

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The northwestern margin of the Basin and Range experienced a complex history of Tertiary volcanism and extension. Arc-volcanism produced Oligocene and mid-Miocene shield volcanoes that acted as barriers to later volcanic flows. Normal faulting occurred ca. 14-8 Ma. Late Miocene-Pliocene low-K, high-Al olivine tholeiites (LKOT) erupted ca. 8-3 Ma, filling topographic lows and obscuring the older volcanic history. All units were cut by normal faults ca. 3 Ma and extension continues today. The Warner Range (WR) exposes this entire sequence of events, providing an ideal location to study the geologic history of the margin.

New mapping in the Fort Bidwell quadrangle in the northern WR reveals volcanic rocks similar to those seen further south. At the base of the sequence is a series of interbedded mafic and silicic tuffs and basalt flows, with a total exposed thickness of ~550 m. The basalts contain ~1 cm euhedral or resorbed plagioclase phenocrysts and they have Ba and K_2O values similar to Oligocene basalts in the central WR. At the southern end of the new mapping, the sequence is 85% basalt and 15% tuff. The basalt thins to the north over 10 km to 15% of the sequence. Two late Miocene-Pliocene units overlie Oligocene units: diktytaxitic, low-K olivine tholeiite (LKOT) flows and lithic tuff. Unlike further south in the range, there are few mid-Miocene arc-volcanic rocks.

All units are cut by the Fandango Valley and Surprise Valley faults, suggesting that motion occurred primarily post-eruption of the closest dated unit, ~7.5 Ma. The ~13 km long Fandango Valley fault trends NW, parallel to a regional fabric whose origin is enigmatic, and does not appear to be active as it lacks fault scarps. In contrast, the NNE-trending Surprise Valley fault likely cuts the Fandango Valley fault, has visible fault scarps, and is likely active today. This new mapping does not reveal any new units, but the thickness of the late Miocene-Pliocene volcanic rocks here suggests that the northern Warner Range was a topographic low by the late Miocene. This may have been partially controlled in part by faulting, but pre-existing volcanic topography appears to be the primary factor influencing their distribution.

9-5 **BTH 16** Meade, Kyle

PETROLOGIC ANALYSIS OF RAILROAD VALLEY RHYOLITE, GRANT RANGE, NYE COUNTY, NV

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In the northern Grant Range, deposition of the Railroad Valley Rhyolite (33.0 to 33.4 Ma) marked the initiation of volcanism in the east-central Basin and Range province. Previously, the Railroad Valley Rhyolite was considered to be a lava flow with an autobrecciated top. However, this is unusual behavior for rhyolite, and field observations of the rhyolite did not indicate any solid flow-interior textures. A suite of samples were collected across the extent of this unit's exposures. Slabs and thin sections were made from these samples, and examined under magnification for textures that would indicate the eruptive style of the rhyolite. All samples showed clastic textures. None of the samples showed intact flow textures, making it unlikely that this unit had flowed cohesively at the time of eruption. In addition, the samples all lacked pumice fragments. Matrix and clastic fragments all appeared to be devitrified, so the original presence, or not, of volcanic ash could not be verified, but the absence of pumice makes an ignimbrite origin of the rhyolite unlikely, as well. High-silica eruptions frequently take the form of domes, which commonly undergo a series of building and collapse events over the course of an eruptive cycle. Therefore, given the assembly of textures, the best interpretation is that the Railroad Valley Rhyolite is the result of pyroclastic flows produced by dome collapse.

9-6 **BTH 17** Jenkins, Emily N.

$^{87}SR/^{86}SR$ OF MID-MIOCENE SILICIC VOLCANISM IN EASTERN OREGON: EVIDENCE FOR VARIABLE AND HIGH SR DOMAINS WEST OF THE TERRANE-CRATONIC LITHOSPHERE TRANSITION

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Widespread rhyolite volcanism mostly associated with voluminous mid-Miocene flood basalts of the Columbia River Basalt Province allows for mapping crustal domains using radiogenic isotopes. Here we use Sr isotopes but will supplement with other isotopic systems to study the source regions of rhyolites. Rhyolites of Oregon are thought to be mainly derived by partial melting of the crust and thus yield direct information of the make-up of the crust from which they are derived. Mid-Miocene rhyolite volcanism is expressed in the form of numerous silicic domes and tuffs that crop out over a wide area (~300 km in N-S dimension and ~100 km in E-W dimension) mostly west of the cratonic crust boundary located near the Oregon-Idaho state border. This boundary is delineated by geophysical methods and isotopic transitions. Our ongoing study is currently focused on determining the $^{87}Sr/^{86}Sr$ ratios of bulk rocks and mineral separates obtained from samples of mid-Miocene silicic volcanic centers in eastern Oregon.

Preliminary data indicate variable $^{87}Sr/^{86}Sr$ mostly along longitudinal sections, yet more similar values in latitudinal directions. In general, however, data indicate disagreement of isotopic ratios in relation to the long known 0.706 and 0.704 ($^{87}Sr/^{86}Sr$) boundaries. This calls into question how sharp the crustal transition really is or to what extent more radiogenic crustal domains exist west of the cratonic boundary that may well correlate with more radiogenic crust of select accreted terrane domains.

9-7 **BTH 18** McClaughry, Jason D.

THE HOOD RIVER GRABEN: A LATE PLIOCENE AND QUATERNARY INTRA-ARC HALF GRABEN IN THE NORTHERN OREGON CASCADE RANGE

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The High Cascade Range of northern Oregon occupies a segmented and structurally discontinuous, ~30-km-wide, arc-parallel graben that has propagated northward from central Oregon (Green Ridge) since 5.3 Ma at an overall rate of 4 cm/yr. Between Mount Hood and Mount Adams the High Cascade graben coincides with the Hood River graben, a late Pliocene and Quaternary half-graben that forms the Hood River Valley. The Hood River graben is defined by an ~20- to 25-km-wide zone of distributed east-west extension. The north-trending Hood River fault zone, extending from just north of Underwood Mountain to the east flank of Mount Hood (~50 km), defines the eastern boundary fault system of the graben. The fault zone may extend further to the southeast of Mount Hood where it joins more southern strands of the eastern boundary fault of the High Cascade graben, but its precise location in that area is not yet well constrained. The Hood River fault zone became active during the late Pliocene, and has accommodated the greatest amount of graben subsidence with at least 600 m of structural and topographic relief; south of Hood River lavas as young as 1.7 Ma are offset by at least 400 m along a strand of the Hood River fault. Cumulative displacement progressively decreases northward to ~130 m near the Columbia River. The western edge of the graben is topographically indistinct, but may be defined in part by a wide zone of parallel, north-northwest-trending, Quaternary extensional faults forming the Mount Hood fault zone. The Mount Hood fault zone extends at least 45 km from the northwest flank of Mount Hood and progressively down-drops a fold-warped, but generally eastward-dipping stratigraphic section from east to west. North-trending faults associated with the development of the Hood River graben have served as conduits for a number of late Pliocene and Quaternary volcanic vents that occur either within or adjacent to the structural basin. The timing of initial graben formation was contemporaneous with or closely followed a major pulse of mafic volcanism in the northern Oregon Cascades between 4.4 and 2.1 Ma. This pulse of mafic volcanism was distinctly younger than a similar episode that had culminated in central Oregon by ca. 5 Ma and contrasts with the preceding ten million years, when andesitic eruptions dominated the northern Oregon Cascade Range.

9-8 **BTH 19** Marcy, Phillip I.

REVISITING VOLCANOLOGY AND COMPOSITION OF RHYOLITES AND ASSOCIATED REE RICH MAFIC CLASTS OF THE THREE FINGERS CALDERA, SE OREGON

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Two adjacent caldera systems, the Mahogany Mountain and the Three Fingers caldera constitute voluminous rhyolitic volcanism on the eastern margin of the Oregon-Idaho graben during the mid-Miocene. Both calderas are part of the Lake Owyhee Volcanic Field, Oregon that in turn is part of widespread rhyolites associated with the Columbia River Basalt province. We focus on establishing relationships between intracaldera units of Three Fingers caldera and caldera-forming Spring Creek outflow tuff and assessing the distribution of entrained mafic clasts and their often anomalously high, ore-grade concentrations of rare earth elements (REE).

Previous mapping identified two intra-caldera rhyolite units: 1) intra-caldera Spring Creek Tuff and 2) younger rhyolite lavas (Trp). Our main reinterpretation is that devitrified Trp is equivalent to surrounding often glassy, pumiceous to dense or brecciated rhyolite mapped before as intra-caldera Spring Creek Tuff. In addition to field evidence, reinterpreted rhyolites lack vitroclastic textures and are geochemically distinct from outflow Spring Creek Tuff . Outflow tuff units are Fe-rich, low silica rhyolites (~74 wt.% SiO_2, and 3 wt.% FeO) as compared to less Fe rich, high-silica rhyolites (~77 wt.% SiO_2, 2 wt.% FeO) of intra-caldera units. We interpret the investigated area as a rhyolite dome field, erupting subsequent to caldera collapse. The proximity of vents resulted in a complex stratigraphic overlap of rhyolite flows and clastic debris issued from adjacent domes. The predominance of high-standing dome interiors reflects the more resistant nature of dense devitrified rhyolite as compared to pumiceous, glassy, or brecciated rhyolite. New $^{40}Ar/^{39}Ar$ data reveal intra-caldera rhyolites and outflow tuff to be indistinguishable at 15.64 ± 0.08 Ma yet field evidence indicates eruption of post-caldera rhyolites occurred after sedimentation within the caldera. Mafic clasts present in dense glassy or porous intra-caldera rhyolites are reworked fragments of preexisting lava flows that were entrained by subsequent eruptions. Ore-grade REE enrichment of over 2400 ppm Nd in these clasts is likely facilitated by mobilization of REE from earlier rhyolites during renewed rhyolite magmatism and subsequent deposition.

9-9 **BTH 20** Benson, T.R.

NEW GEOLOGIC AND GEOCHRONOLOGIC DATA ON THE LAKE OWYHEE VOLCANIC FIELD, OREGON: A SILICIC CENTER CONTEMPORANEOUS WITH FLOOD BASALT VOLCANISM

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Silicic volcanism concomitant with eruption of mid-Miocene Steens/Columbia River flood basalts spread across ~150,000 km^2 from northern Nevada to the Oregon/Idaho border. One of three major caldera centers in this region, the Lake Owyhee Volcanic Field in eastern Oregon, is the least studied due to difficult access and overprinting by younger Miocene volcanism, faulting, sedimentation, and alteration (Cummings et al., 2000). Rytuba et al. (1991) identified two calderas in the central part of this field: Mahogany Mountain and Three Fingers calderas, which they attributed to collapse on eruptions of the Tuff of Leslie Gulch (TLG) and Tuff of Spring Creek (TSC), respectively. Our new geologic and geochronologic data from this area suggest that there is a single ignimbrite sourced from a single caldera. We interpret the TSC as a later-erupted, more crystal-rich (10%) phase of the crystal-poor TLG, with the appearance of two units being (as suggested by M. Ferns, pers. comm., 2012) a result of alteration. New $^{40}Ar/^{39}Ar$ ages on intracaldera TSC (15.95 ± 0.06 Ma, 2σ) and what is mapped as extracaldera TLG (15.91 ± 0.05 Ma) are consistent with these units being the same ignimbrite (and agree with the Ekren et al. (1984) K-Ar age of 15.8 ± 0.6 Ma on the TLG).

We interpret the Three Fingers caldera of Rytuba et al. (1991) to be the northern part of a larger, ~25x30 km caldera. This part of the caldera preserves thin-bedded caldera lake sediments intruded by rhyolitic and trachytic lavas, including the 15.77 ± 0.11 Ma lava of eponymous Three Fingers Rock. In the southern part of the caldera, mapped by Vander Meulen (1989) and Rytuba et al. (1991) as Mahogany Mountain caldera, a slightly deeper level is exposed in which pervasively altered intracaldera ignimbrite is cut by numerous N-S-trending silicic and mafic dikes—feeders for postcaldera lavas preserved to the north. This new interpretation makes caldera formation contemporaneous with eruption of the ~15.9 Ma Dinner Creek Tuff (Streck et al., 2011; Nash and Perkins, 2012) from the Castle Rock area to the north, and with activity at two other flood-basalt-associated caldera centers: High Rock Caldera Complex, Nevada (15.8-16.4 Ma; Coble and Mahood, 2012), and McDermitt and Whitehorse centers (15.0-16.5 Ma; Rytuba and McKee, 1984; Henry et al., 2012) in northern Nevada and southern Oregon.

9-10 **BTH 21** Curry, Adam C.

THE ROLE OF SHEAR HEATING IN THE FORMATION OF OBSIDIAN

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With ~74-78 wt% SiO_2 and <1 vol% crystals, obsidian is the end-member of high-silica, crystal-poor volcanic rocks, making it ideal for evaluating current hypotheses of high-silica magmatism. In traditional models, high-silica melts are generated through liquid separation from a crystal mush in compositionally, thermally, and mineralogically zoned magma bodies. Such liquids should be saturated in quartz and one or two alkali feldspars at separation. However, due to its high viscosity (10^6-10^{12} Pa s), high-silica magma is difficult to separate from a crystal mush. An alternative method for producing crystal-poor liquids is via shear heating and resorption of crystals, because high-viscosity magmas are susceptible to shear heating. This effect has only recently been accounted for in thermal models of silicic magma flow, with possible temperature increases of 150 K. This study focused on modal analyses and crystal morphology of obsidian samples from the Long Valley and Coso volcanic areas east of the Sierra Nevada, California. To understand the potential for shear heating to create superliquidus conditions in silicic melts, petrographic analysis is combined with thermal models of conduit flow using composition to calculate temperature-dependent viscosity. Rounded crystals suggestive of heating dominate in obsidian from Coso, Mono Craters, the Long Valley resurgent dome, and Glass Mountain; crystal faces are rare. Samples have an average of 0.35 vol% phenocrysts and contain dominantly plagioclase (An_{14-48})

or anorthoclase (An_{9-12}, Or_{9-12}) with minor quartz or orthopyroxene (En_{54-57}). The high-silica content (74-78 wt%) of these rocks predicts saturation in quartz and sanidine, yet potassic feldspar (Or_{30-34}) is only present in trace amounts in one sample. These observations contradict mush-model predictions of silicic mineral assemblages and suggest crystal resorption via shear heating during ascent as a mechanism for the petrogenesis of obsidian.

SESSION NO. 10, 1:30 PM

Monday, 20 May 2013

T10. Reconstructing the Pacific-North America Plate Boundary Through Late Cenozoic Time (Posters)

Radisson Hotel and Conference Center, Salon B/C

10-1 **BTH 22** Duque, Jose

EARLY TO MIDDLE MIOCENE SYN-EXTENSIONAL MAGMATISM IN THE SOUTHERN GULF OF CALIFORNIA

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The Gulf of California (GoC) constitutes an example of crustal stretching leading to the birth of new oceanic basin at the site of a former convergent margin. In the southern Gulf the rifting process broke apart a Late Cretaceous to Paleocene batholitic belt, now exposed in southern Baja California and mainland Mexico, which is extensively covered by mid Eocene to Lower Miocene ignimbrites of the Sierra Madre Occidental silicic large igneous province (SMO). The intrusive part of SMO has been scarcely studied in the southern Gulf due to its limited exposure. Previous reports were limited to a few bodies in Sinaloa (mainland Mexico) and Bahia Concepcion (Baja California).

Here, we present the result of an extensive study of the Tertiary intrusive rocks of the southern Gulf sampled along its margins and in the submerged rifted blocks. Emplacement and cooling ages were determined on 66 samples by U-Pb and 40Ar/39Ar methods, and define two main magmatic pulses in Early and Middle Miocene. The Early Miocene magmatic pulse (22 to ~18 Ma) is observed across the entire southern GoC, from southern Baja California to Nayarit and Sinaloa, with a rapid cooling at ~18 Ma suggesting that emplacement was concurrent with crustal stretching and normal faulting forming the Gulf Extensional Province. The mid-Miocene magmatic pulse (16 to 13 Ma) tends to focus in the central part of the Gulf, around the Pescadero Basin. Granitoids emplaced in this area also show a rapid cooling with $^{40}Ar/^{39}Ar$ ages in the 13-12 Ma range. As a whole the age pattern suggest a transition from wide to a narrow rift mode during the Miocene.

It's widely known that ignimbrites of the last flare-up of the SMO (24 to 18 Ma) reached southern Baja California. Present results indicate that the early to middle Miocene magmatism (source of this silicic pulse), was not only located in northern Nayarit and Sinaloa but also in the area of the future Gulf and that this region was already under extension in the Early Miocene. Therefore, crustal stretching preceding the formation of oceanic crust in the GoC started significantly before the end of subduction and was likely the main factor controlling the genesis of magmatism.

10-2 **BTH 23** Umhoefer, Paul J.

BREACHING OF TRANSFORM FAULTS AND FLOODING OF PULL-APART BASINS TO INCREMENTALLY FORM THE EARLY GULF OF CALIFORNIA SEAWAY FROM ~8 TO 6.3 MA

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It has long been known that a seaway formed during the proto-Gulf of California stage of the oblique–divergent Pacific-North America plate boundary, but the processes that formed the seaway are poorly known. Microfossils and volcanic units date the first marine incursions at ~8 Ma at the mouth of the Gulf, ~7 Ma in the central Gulf, and 6.3 – 6.5 Ma in the northern Gulf to Salton Trough. Our GIS-based maps of the plate boundary at 8, 7, and 6 Ma, combined with the Guaymas basin history from seismic data from other workers, show that the evolution of pull-apart basins produced an incremental seaway encroachment. The critical parameter is the late Miocene length of the strike-slip faults between pull-apart basins, which we can approximate. Fault length indirectly controls when high topography of footwall blocks pass by. Breaching can then occur upon juxtaposition of adjacent basin lows or along narrow transtensional zones. The marine incursion history for the Gulf was pre-determined by the long strike-slip faults that bound the Guaymas pull-apart basin and produced a 3-stage seaway evolution. (i) By ca. 8 Ma, a seaway had formed from the mouth of the Gulf to the Pescadero basin, based on our maps and marine strata in the Cabo and Tres Marias basins. There was a short barrier to the Farallon basin that suggests it was either a terrestrial basin, or if breaching occurred, there may be 8 Ma salt or initial marine deposits in the basin. This early southern seaway formed in a transtensional setting. (ii) At ca. 7 Ma, a series of marine incursions breached the transform barrier between the Farallon and Guaymas basins. Our maps show that periodic breaching occurred along a 100 – 150 km long strike-slip or transtensional zone and was the precursor to the Carmen basins. Repeated breaching events and the isolation of the Guaymas basin in a sub-tropical setting caused the formation of a 2-km-thick salt deposit imaged in seismic data, similar to the facies history of the Santa Rosalia basin on the western margin. The rhomb shape of the Guaymas salt basin suggests that it was either a composite pull-apart basin or a transtensional basin. (iii) By 6.3 ± 0.2 Ma, two major breaches occurred that formed a permanent seaway through the Guaymas basin and to the Salton Trough; for the first time a narrow (50 – 100 km wide) sea formed along the 1500-km-long Gulf of California.

10-3 **BTH 24** Lomtatidze-Jimenez, Ekaterina

PROVENANCE AND GEOCHEMISTRY OF SEDIMENTS IN THE NORTHERN GULF OF CALIFORNIA: RESULTS FROM A DEEP STRATIGRAPHIC RECORD FROM WELL SAMPLES

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The age of the earliest deltaic deposits of the Colorado R. in the Salton Through is Early Pliocene (Dorsey et al., 2007). Deltaic deposits prograded over a latest Miocene marine section that includes relatively thick gypsum deposits, which likely predate the arrival of the Colorado R. sands. However, marine microfossils found in industry drill cores from PEMEX in the northern Gulf of California [GoC] suggest a mid Miocene marine incursion (Helenes et al., 2009). To constrain the provenance of sediments in the Wagner, Upper Delfin and Tiburon basins located in the northern GoC and the arrival of Colorado R. sand and mud to these basins, we analyzed trace element and Sm-Nd isotopic composition of 40 shale samples from three exploratory wells with depths ranging from ~5500 to 3200 m. Petrofacies analysis in 25 sandstone samples from wells and 9 samples from modern fluvial sediments from Sonora and Baja California were also accomplished. Three modern source end-members can be defined: (1) modern sediments from the Colorado R. have quartzose petrofacies, older Nd model ages (1666-1316 Ma) and highly negative εNd values (-15.45 - -12.5). Contrasting with sediments from NW Sonora (end-member 2) and from local sources in northern Baja (end-member 3), which include significant volcanic detritus from local syn-rift volcanic fields. End-members 2 and 3 are characterized by a decrease in quartz content, higher lithic fragments, younger Nd model ages (1292-889 Ma) and lower εNd values (-9.46 - -2.01). Sandstone petrofacies and Sm-Nd isotope ratios from well samples varies within a narrower range compared to modern end-members and suggest variation in the relative contribution of each end-member, and/or mixing of terrigenous sediments by marine processes, principally, tides, waves and long-shore currents. The Sm-Nd isotope composition and model ages indicate that modern Colorado R. muds are derived from a more enriched source compared to Pliocene Colorado R. muds. Our preliminary interpretation indicate that modern Colorado R. incise more ancient rocks from the Grand Canyon in Arizona. Older deposits may represent erosion of younger rocks in the Colorado Plateau. Additional petrofacies analysis in progress, will constrain the arrival of Colorado R. sand to the Wagner, Upper Delfin, and possibly to the Tiburon basins in the south.

10-4 **BTH 25** Parker, Michael Paul

MAJOR BUTTRESS DISCONFORMITY WITHIN THE MIOCENE SPLIT MOUNTAIN GROUP, SALTON TROUGH, SOUTHERN CALIFORNIA

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The Salton Trough underwent an episode of Late Neogene-Quaternary detachment faulting and subsidence that abruptly ended with the inception of the currently active Elsinore, San Jacinto and related right-lateral strike slip faults. Dorsey & others (2011) interpret the timing of detachment faulting as 8.0±0.4 to 0.95 Ma, based on the ages of the basin fill sediments. However, the oldest unit used to bracket this timing—the Elephant Trees Fm, an alluvial fan deposit in the Miocene Split Mountain Group—has been interpreted by Winker & Kidwell (1996) as interfingering with volcanic rocks of the 17 Ma (Morgan & others, 2012) Alverson Fm, implying an age much older than 8 Ma.

In an attempt to resolve this age discrepancy, we conducted field research in the southwestern Fish Creek Mountains, where Winker & Kidwell had reported the interfingering relationship. We observed two nearly identical alluvial fan deposits of distinctly different ages, separated by a buttress disconformity: (1) older primarily volcaniclastic conglomerates which fill isolated paleocanyons and are interbedded with the 17 Ma Alverson Fm, and (2) younger mixed clast conglomerates which we interpret as the Garnet Fm, an alluvial fan deposit within the Split Mountain Group that Winker & Kidwell (1996) correlate with the Elephant Trees Formation but do not report as occurring in the Fish Creek Mountains. Both of these conglomerates are composed of a mixture of volcanic clasts and "basement" (metamorphic and plutonic) clasts; thus neither resembles the Elephant Trees Fm, which is composed exclusively of metamorphic and plutonic clasts.

Thus there are, indeed, alluvial fan deposits interbedded with the 17 Ma Alverson Fm, but these alluvial fan deposits are not correlative with the Elephant Trees Fm. These older alluvial fan deposits are restricted to paleocanyons and thus predate detachment faulting and associated regional subsidence. The younger Elephant Trees Fm, as well as the Garnet Fm, both of which mark the beginning of regional extension in the area, could be as young as 8 Ma, as interpreted by Dorsey & others (2011).

Dorsey & others, 2011, GSA Bulletin, v. 123, p. 771-793.
Morgan & others, 2012, GSA Abstracts with Programs, Vol. 44, No. 3, p. 21.
Winker & Kidwell, 1996, Field Conference Guidebook, AAPG Annual Convention, p. 295–336.

10-5 **BTH 26** Price, Jason B.

UPDATED FIELD MAPPING IN THE LAVA HILLS, SAN BERNARDINO COUNTY, CALIFORNIA

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We present an updated field map for ~6 km²of the Lava Hills, San Bernardino County, California (Siberia 7.5' quad) centered at 34°39.3' N, 115°58.0' W. Cretaceous(?) monzogranite and Tertiary extrusive rocks were mapped at 1:10,000. Per Miller (1993), the volcanic section is a moderately southwest-dipping homocline of tuffaceous rocks divided in half by a prominent ridge of andesitic lava. The homocline rests nonconformably upon the granite. It is capped by locally-sourced, angularly unconformable dacite porphyry lava (22.4 ± 0.6 Ma, K/Ar on biotite; Miller, 1993). The volcanic package is unconformably overlain by Quaternary-Neogene cobble conglomerate. At the SW end of the map area, a high-angle, NW-striking fault with NE-side-down puts youngest tilted lapilli- and ash-tuffs against granite. This fault is cut by ENE-striking faults exhibiting left-lateral separation. Another NW-striking fault of unknown slip-sense cuts along the median lava ridge and may have been a conduit for the magma. No faults with definitive dextral motion were observed in the map area.

The Tertiary section comprises (bottom to top): 1. Friable, oxidized, coarse-grained arkose derived from underlying granite; ~6 m thick, 2. Fractured, incoherently-folded lacustrine limestone and minor planar-bedded arkose intercalated with ash- and lapilli-tuff and tuff-breccia; ~50 m thick, 3. Lithic lapilli- and ash-tuff with minor aphyric lava and volcanic breccia; ~90 m thick,

4. Purple hornblende andesite porphyry lava (phapl) with autobreccia; max ~30 m thick, 5. Dark green aphanitic basaltic andesite lava (gabal) that cuts phapl as a dike and also forms capping lava flows on older tuff; max ~50 m thick. Together, phapl and gabal form the prominent median ridge of the map area, 6. Sedimentary basin ~300 m long x 150 m wide x 40 m deep with lacustrine arkoses and water-lain tuffs that formed in a recessive part of the phapl-gabal lavas, 7. Varicolored unit of brick-red, white, brown, and grey lapilli- and ash-tuffs with layers <2 m thick containing minor arkose; ~85 m thick, 8. Tan pumiceous lapilli-tuff with laterally coextensive varicolored ash-tuff; ~275 m thick, 9. An angular unconformity marks the bottom of a volcanic cap rock sequence comprising a local diamictite overlain by reddish-grey dacite tuff-breccia and porphyritic lava; ~40 m thick.

10-6 **BTH 27** Murray, Bryan P.

EVIDENCE OF SYNEXTENSIONAL DEPOSITION OF THE PICKHANDLE AND JACKHAMMER FORMATIONS IN THE NORTHERN CALICO MOUNTAINS, CENTRAL MOJAVE DESERT, CALIFORNIA

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The precise timing of extension in the central Mojave metamorphic core complex (CMMCC) is unclear. Previous thermochronology studies suggest that extension occurred between ~21 -17.5 Ma, while stratigraphic studies suggests that extension was active between ~24 - 19 Ma. These previous stratigraphic interpretations imply that the timing of initial extension in the CMMCC is related to the depositional age of the volcanic and coarse-grained volcaniclastic deposits of the early Miocene Pickhandle Formation, inferred to represent synextensional supradetachment basin deposits. However, direct stratigraphic evidence of synextensional deposition has not yet been documented for this formation; therefore, the relation between deposition and inception of extension in the CMMCC warrants further investigation.

The Calico Mountains of the central Mojave Desert, CA are located on the hanging wall block of the Waterman Hills detachment fault in the CMMCC. New geologic mapping in the northern Calico Mountains has found direct evidence of synextensional deposition of the Pickhandle Formation and underlying Jackhammer Formation in an intra-hanging-wall half-graben basin bounded on the east by a high-angle NW-trending, SW-dipping normal fault. The Jackhammer Formation is deposited on nonmylonitic basement composed of Paleozoic metasedimentary and metavolcanic rocks and Mesozoic plutonic rocks. It is composed of fluvially-reworked tuff and lapilli tuff that transitions eastward into a welded ignimbrite, tuffaceous sandstone, and local conglomeratic sandstone, mafic lava, avalanche breccia, and lacustrine limestone. In the Calico Mountains, the Pickhandle Formation is deposited conformably over the Jackhammer Formation. It consists of a lower section of dacitic volcaniclastic breccia with a local dacitic block and ash flow deposits and an upper section of tuffaceous sandstone, conglomeratic sandstone, and fluvially-reworked tuff and lapilli tuff. Evidence of growth strata indicates synextensional deposition of both formations, including sedimentary and volcanic deposits that thicken and coarsen toward the basin-bounding normal fault to the east with some deposits thinning on the half-graben footwall, fanning bedding dips that decrease upsection, and internal angular unconformities.

10-7 **BTH 28** Hernandez, Janis L.

REVISED ALQUIST-PRIOLO EARTHQUAKE FAULT ZONE MAP FOR THE WHITTIER FAULT, YORBA LINDA 7.5' QUADRANGLE, ORANGE COUNTY, CALIFORNIA

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The California Geological Survey (CGS) first evaluated the Whittier Fault for potential fault zoning in 1977. A revised evaluation was prepared in 1979, concluding segments of the Whittier Fault Zone were “sufficiently active and well defined” to be included within an Alquist-Priolo Earthquake Fault Zone (APEFZ). In 1980, an Earthquake Fault Zone map was issued for the Yorba Linda 7.5' quadrangle. Since 1980, much development has taken place within the cities of Brea, Yorba Linda, and in the County of Orange accompanied by a number of geotechnical and fault studies within the mapped fault zone. Here we summarize the results of our current re-evaluation.

The Whittier Fault is a major structural element in the eastern Los Angeles basin. It is the longer of two northern extensions of the active Elsinore Fault Zone, the other being the Chino Fault. Primary sense of movement along this complex fault zone is right-lateral strike-slip, trending about N70°W, with dips ranging from 65 to 80°NE. Detailed paleoseismic studies have revealed complex fault characteristics at the Olinda Oil Field and Olinda Ranch sites. Gath et al. (1992) report the Whittier Fault consists of three active fault strands at Olinda Creek: the northern, central and southern strand. The central and southern strands form a positive flower structure: southern strand dipping northeast, central strand dipping southwest, with an elevated pressure ridge between the two faults. Work by Leighton and Associates reveals similar complex faulting relationships within Olinda Ranch. Patterson and Rockwell report Holocene sense of displacement is nearly pure strike-slip at Olinda Oil Field. Gath (1997) prepared a tectonic strip map along the Whittier Fault Zone, noting several geomorphic features indicative of active faulting, including an abundance of right-laterally deflected stream channels.

Detailed observations, made in these new studies and by CGS, provide a better understanding of the characteristics of active strands of this fault, which help with classification of geomorphic features recognized in other locations along the fault zone. CGS' revision of this zone map is prompted by the abundance of new geologic data that identify locations of “sufficiently active and well defined” fault segments located outside previously designated zone boundaries.

10-8 **BTH 29** Stanley, Richard G.

PROGRESS TOWARD UNDERSTANDING THE STRATIGRAPHY AND RIGHT-LATERAL DISPLACEMENT OF UPPER MIOCENE ROCKS ALONG THE SAN ANDREAS FAULT IN CENTRAL CALIFORNIA

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Recent field and biostratigraphic studies of upper Miocene strata in central California provide new information that bears on the history of right-lateral displacement along the San Andreas fault. Near Maricopa, the upper Miocene Bitterwater Creek Shale is exposed along the northeast side of the San Andreas fault and consists mainly of hard, siliceous shale with dolomitic concretions and turbidite sandstone interbeds. Diatom assemblages indicate that the Bitterwater Creek Shale was deposited about 8.0 to 6.7 Ma, coincident with the uppermost part of the Monterey Formation in other parts of California. The Bitterwater Creek Shale overlies fan-delta deposits of the upper Miocene Santa Margarita Formation, which in turn overlie siliceous shale of the Monterey Formation from which we obtained diatom assemblages dated at about 10.0 to 9.3 Ma. Huffman (1972, GSA Bulletin) noted that the Santa Margarita Formation contains granitic and metamorphic clasts derived from a source in the northern Gabilan Range, on the opposite side of the San Andreas fault, that has moved relatively northwestward by 254 ± 5 km of right-lateral displacement. Our new diatom ages suggest that this displacement occurred after 10 to 8 Ma.

Dibblee (1966, CDMG Bulletin 190) proposed that the Bitterwater Creek Shale near Maricopa was separated by about 80 km of right-lateral displacement from siliceous mudstone in the Pancho Rico Formation near Parkfield, on the opposite side of the San Andreas fault. However, we suggest that this hypothesis is incorrect because (1) diatoms from lower part of the Pancho Rico indicate deposition about 6.7 to 5.5 Ma, younger than the Bitterwater Creek Shale, and (2) the Pancho Rico Formation is lithologically unlike the Bitterwater Creek Shale.

In the upper Miocene Panorama Hills Formation of Dibblee (1962, Pacific Section AAPG Guidebook) on the northeast side of the San Andreas fault about 15 km west of Fellows, we found a new species of *Forreria*, a marine gastropod. The new species also occurs in the Pancho Rico Formation about 105 km to the northwest on the opposite side of the San Andreas fault. These *Forreria* localities were closer together prior to right-lateral motion along the fault, but whether they constrain the amount of displacement is uncertain because the paleogeographic distribution of *Forreria* is poorly known.

10-9 **BTH 30** Guillaume, Jonathan Kalani

TESTING THE STRUCTURAL ROLE OF THE SANTA MARIA BASIN IN THE ROTATION OF THE WESTERN TRANSVERSE RANGES, CALIFORNIA

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The onshore Santa Maria Basin (SMB) of southern California sits between the Southern Coast Ranges (SCR) and the Western Transverse Ranges (WTR). Past paleomagnetic studies conducted in the WTR from early Miocene rocks indicate that area rotated 90° clockwise since early Miocene time (e.g., Kamerling and Luyendyk, 1985; Hornafius, 1985). However, studies conducted in the SCR to the north of the SMB have determined that this area experienced an insignificant amount of rotation (e.g., Onderdonk, 2005) during the same time period. The SMB lies in between these two areas, and has not been previously sampled extensively to determine if it is rotated or not and where the boundaries of the rotated domain are located.

The primary goal of this study is to understand, using paleomagnetism, how differences in rotation across the SMB are distributed. This is significant because it will help define whether the western rotation boundary in the SMB is focused along one fault, or if the boundary exists as a more gradual fault zone across the western SMB. The paleomagnetic data for this study was collected from the middle to upper Miocene Monterey Formation. Because the Monterey Formation was deposited prior to deformation within the SMB it records the rotational history of the basin, and has also been used in previous studies (e.g., Hornafius, 1985; Khan et al. 2001) because the dolomite in the formation typically carries a well-preserved primary remanent magnetization. Samples were obtained from 6 sites in the SMB and were subject to step-wise alternating field and thermal demagnetization analysis. Uncorrected equal area diagrams indicate the samples have a remanence dominated entirely by the present day field, resulting in a failure to answer the main questions of the study. Remagnetization in the Monterey Formation probably occurred due to partial oxidation of the pyrite to magnetite as the rocks were lifted above sea level during the Pleistocene, causing flushing of the formation with meteoric groundwater (e.g., Hornafius, 1984). This process is commonly observed in rocks found in fold and thrust belts (eg., Hornafius, 1984; McCable and Elmore, 1989; McCabe and Channell, 1994; Stamatakos et at., 1996; Enkin et al., 2000).

10-10 **BTH 31** Hamilton, Douglas H.

LANDFORMS AND TECTONICS OF THE CENTRAL COAST REGION OF CALIFORNIA

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Understanding of the tectonics of the central coastal region of the Southern Coast Ranges of California has been significantly advanced by recent development of two general categories of geoscience knowledge. These are 1.) new developments in landform imaging at regional to detailed local scale, and 2.) imaging of the structure of the underlying crust by seismologic analysis of increasingly well recorded seismicity (eg. Hardebeck 2010) together with acquisition and modeling of gravity and magnetic potential field data (eg. Langenheim et. al. 2012) plus characterization by deep drilling and by geophysical techniques.

The general pattern of contemporary tectonism in the central Coast Ranges and adjacent near coastal offshore is clearly shown by the distribution and form of the principal mountain ranges in the region. Between Monterey Bay and the Transverse Ranges these local ranges mostly have discrete fault-controlled topographic boundaries and overlie zones of concentrated microseismicity. This indicates a characteristic structural form of uplifting “pop-up” wedge blocks for the mountain ranges of the region (as was determined by McLaren et.al., 2008 for the Santa Lucia Range source region of the 2003 San Simeon earthquake). The uplift of the wedge-block ranges represents accommodation to east-west, rotating southward to nearly north-south, regional compression. Earthquakes of M7.0-<7.5 appear possible on the reverse faults along which these ranges are being uplifted.

This general pattern of compressional tectonism onshore is bounded on the west by the 400 km long zone of active strike slip tectonism of the San Gregorio-Hosgri fault system. This system has produced no large earthquake during the 250 years of recorded history but exhibits local paleoseismic evidence of generating earthquakes of M>7.5.

It is suggested here that the evidence from the south central Coast Ranges seen in the terrain as well as in its tectonic underpinning, indicates a level of tectonism and consequent seismic potential that exceeds that now accepted for design and safety analysis of major infrastructure features in the region.

10-11 **BTH 32** Grove, Karen

GEOPHYSICAL AND SEDIMENTOLOGIC EVIDENCE FOR PLIO-PLEISTOCENE DEFORMATION IN THE OFFSHORE SAN ANDREAS FAULT ZONE BETWEEN GUALALA AND SAN FRANCISCO, NORTHERN CALIFORNIA

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Sedimentary sequences in the offshore region of northern California between Gualala and San Francisco record the transition from a convergent to a transform plate boundary during the Miocene Epoch. Since the transition, the geologic record shows varying tectono-stratigraphic conditions that included episodes of contraction and subsidence. We analyzed two sets of seismic reflection data that have recently become available—multichannel (deep-penetration) seismic reflection data, with associated offshore exploratory well logs, that were collected for petroleum companies; mini-sparker (high-resolution) seismic reflection data collected within the 3-miles limit by the U.S. Geological Survey.

North of the Golden Gate entrance to San Francisco Bay, converging strands of the San Andreas fault (SAF) system have produced a Holocene graben east of the SAF, and a contractional region west of the SAF. Marine terraces on the south end of the Point Reyes Peninsula have been uplifted ~1 mm/yr; this rate accelerated as the contractional zone migrated north and began to impinge on the peninsula. Farther north, near the Point Reyes headland, Miocene units have been vertically offset at least 2 km on the Point Reyes fault (PRF). Deformation began during the Late Miocene, probably in response to a change in relative plate motions. Our analyses suggest that the PRF was most active at this location 5–0.5 Ma.

North of the peninsula, multiple Quaternary sequences formed above a subsiding Plio-Pleistocene unconformity (PPU) during eustatic sea-level fluctuations. The mechanism for subsidence may be related, in part, to isostatic loading from thick Pleistocene deposits derived from the Russian River. West of the Gualala block, preserved sequences have been folded, probably starting ~500 ka, by transpressional structures associated with the Gualala fault. South and adjacent to the headland, few Pleistocene sediments are preserved. The PPU and overlying Holocene deposits are undeformed, suggesting that the PRF has become increasingly inactive since the Middle Pleistocene and that its hazard potential in current fault and tsunami hazard models should be reduced.

10-12 **BTH 33** Hoirup, Don F.

GEOMORPHIC AND STRUCTURAL ANALYSIS OF THE VERONA-WILLIAMS-PLEASANTON FAULT ZONE AND IMPLICATIONS FOR SEISMIC HAZARD, EASTERN SAN FRANCISCO BAY AREA, CALIFORNIA

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Folds and thrust faults adjacent to and beneath the Livermore Valley accommodate Quaternary crustal shortening between major faults of the eastern San Andreas fault system. The Verona and Williams faults are NE-dipping thrust or reverse faults that have uplifted the Pliocene-Pleistocene Livermore gravels along the western and southern margins of the valley. The Williams fault extends ~13 km northwest from the Mt. Lewis seismic trend to the sinistral Las Positas fault, which forms the southern margin of the valley. A 3-km left step along the Las Positas fault separates the surface traces of the Verona and Williams faults. The Verona fault extends ~8 km northwest from the stepover to southwestern Livermore Valley. The Las Positas fault may extend to the base of the seismogenic crust separating the Verona and Williams faults into two independent structures. Alternatively, the Verona and Williams faults may merge downdip into a common thrust fault plane, with the Las Positas fault confined to the hanging wall as a tear fault. The Verona and Williams faults exhibit geomorphic evidence for late Quaternary fault rupture propagating to or very near the ground surface. The Williams fault tightly folds and overturns the Livermore gravels, and appears to form scarps that impound late Quaternary alluvium and cross Holocene landslide deposits. Many Holocene(?) alluvial fans exhibit distinct convex longitudinal profiles across the fault trace suggesting active folding above the Verona fault. The geomorphic position of a stream-terrace remnant suggests that >7 m of tectonic uplift is possible across the Verona fault during the late Quaternary. Surficial geologic mapping and geomorphic analysis of the ancestral Arroyo Valle drainage system reveals numerous paleochannels that generally decrease in elevation (age) to the northwest, and provide useful isochronous markers delineating a subtle tectonic uplift in western Livermore Valley. This newly recognized uplift has lateral dimensions comparable to those of the Verona homocline, but generally is centered on or near the inferred trace of the Pleasanton fault. The paleochannels record tectonic uplift of the newly recognized “Pleasanton” anticline (or homocline) and reveal approximately 5 km of north-northwest fold propagation during the late Quaternary.

10-13 **BTH 34** Hoirup, Don F.

LIDAR-BASED MAPPING OF LATE QUATERNARY FAULTING, GRIZZLY VALLEY FAULT WALKER LANE SEISMIC BELT, PLUMAS COUNTY, CALIFORNIA

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The Grizzly Valley fault (GVF) is located within the northern Walker Lane seismic belt, a zone of right-lateral shear between the Sierra Nevada and the Basin and Range in Plumas County. The GVF extends southeasterly from near Mt. Ingalls along the eastern side of Lake Davis to Loyalton on the southern end of the Sierra Valley with an approximate length of 50 km. Comparison of high-resolution topography developed from LiDAR data with published bedrock geologic mapping documents the presence of geomorphic features that provide information on fault activity of the GVF. Field mapping verified tectonically deformed and offset late Quaternary surfaces identified on bare-earth LiDAR imagery across the GVF within glacial deposits on the eastern margin of Lake Davis, and alluvial deposits in Sierra Valley. Along the GVF, conspicuous geomorphic and hydrologic features include scarps in alluvial surfaces, elongated depressions aligned with adjacent linear escarpments, truncated bedrock spurs, closed depressions, linear swales, right-lateral deflections of creeks and river courses, and shutter ridges, as well as springs and linear seeps consistent with right-lateral strike-slip faulting. The discontinuous nature of observed fault traces combined with the apparent down-to-the-west offset of alluvial surfaces at the southern and northern ends of the eastern margin of Lake Davis are consistent with a broad bend or step over in the fault. Scarp profiles of apparently faulted surfaces extracted from LiDAR data document vertical offsets of up to 14 m. Our study suggest that the GVF is an oblique, right-lateral fault that has been active in the late Quaternary. This study complements on-going investigations by the California Department of Water Resources (DWR) to assess the impact of seismic hazards on State Water Project (SWP) infrastructure.

10-14 **BTH 35** Jones, Shelby A.

CORRELATION AND ANALYSIS OF PALEOCHANNELS IN THE SIERRA NEVADA, CALIFORNIA, AS DISPLAYED BY THE STANISLAUS GROUP; TOWARDS UPDATING LATE CENOZOIC UPLIFT ESTIMATES

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The proposed Neogene uplift of the Sierra Nevada has been debated amongst geologists for several decades. Although multiple lines of evidence indicate substantial uplift of the Sierran crest over the last ten million years, new isotopic and paleobotanical methods have called into question the validity of these calculations. This study focuses on the discontinuous units of the Miocene Stanislaus Group: Table Mountain Formation lavas, Dardenelles Formation lavas, and Eureka Valley Tuff lavas and tuffs. These units are significant because they have been used as a tilt indicator to calculate the uplift of the Sierra Nevada crest since their emplacement, 9.0-10.2 million years ago.

This study involves detailed field research to increase the quantity of primary data, which will be used to develop and verify a digitally-derived model of the paleodrainage systems of the ancient Sierra Nevada. The field localities, Dorrington, Pikes Peak, Rancheria Mountain, Sonora Pass, and Three Chimneys, are of significant importance because they may represent the few remaining outcrops of previously unmapped paleodrainage channels. To test this hypothesis, geochemical and paleomagnetic data were used to correlate the localities and thereby reconstruct the paleochannels.

Outcrops near Dorrington contain biotite, display eutaxitic textures and are characterized by a reverse polarity indistinguishable from the Tollhouse Flat Member of the Eureka Valley Tuff. Although previously mapped as Table Mountain Latite, we reclassify these units Tollhouse Flat Member and eliminate the hypothesis that the units were once part of a potentially lava-back-flooded tributary of the paleo-Stanislaus River. Columnar jointed Pikes Peak lavas record normal polarity, characteristic of most flows within the Table Mountain Formation. Research conducted on Rancheria Mountain verifies the presence of Stanislaus Group lavas and tuffs previously mapped by Huber et al. (1989). This project tests Huber’s (1990) hypothesis that lavas and tuffs flowed southwest from the Buckeye Pass area in paleo-creeks of the paleo-Tuolumne drainage basin, but have been almost completely eroded away since emplacement. We tentatively correlate at least one lava flow found near Rancheria Mountain to outcrops documented by Carlson (2012) in the Bridgeport area.

10-15 **BTH 36** Carlson, Chad W.

ONE VERSUS TWO LATE CENOZOIC UPLIFT EVENTS, SIERRA NEVADA, CALIFORNIA, RECORDED IN DRAINAGE GEOMORPHOLOGY

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Long known for differences in topography and volcanic cover between northern and southern regions, the topography of the Sierra Nevada of California also appears to reflect a similar temporal and spatial variation of tectonic history. For example, the landscape of the San Joaquin River drainage forms topographic highs of basement exposures positioned above projected ~10 Ma paleothalwegs with latest Miocene-Pliocene volcanic remnants inset below the ~10 Ma paleo datum, whereas the northernmost Sierra topographic highs are predominantly volcanic draped peaks and interfluves capped by Mio-Pliocene andesites. Positioned at the transition between these disparate regions, the drainages of the Tuolumne and San Joaquin rivers display geomorphic characteristics of their respective regions to the north and south.

As stream incision outpaces erosion rates in a drainage system due to a lowering of base-level, incised stream-channel walls form a steeper gradient than channel walls above the pre-incision stream position. These gradient changes or ‘breaks-in-slope’ are preserved in the interfluve crests of tributary reaches oriented at high angles to main stream courses. The San Joaquin River drainage displays two breaks in slope. The higher one coincides with the 10 Ma paleothalweg of Huber (1981). New Ar/Ar ages, paleomagnetism and field-relationships show that ~3.6 Ma volcanics are inset on basement benches (straths) on the rim of the lower break in slope. Thus the first incision event took place between 10 and 3.6 Ma and the second after 3.6 Ma. The Kings River drainage and other river drainages to the south exhibit two breaks in slope in their canyon walls, and two knickpoints in some streams. In contrast, the Tuolumne River drainage has a single break in slope. The geomorphology suggests two periods of late Cenozoic incision and inferred uplift from the San Joaquin drainage southward, versus one for the Sierra Nevada from the Tuolumne River drainage northward. Thermochronologic data suggests that the first period of stream incision began at about 20 Ma in the Kings to Kern River drainage, much earlier than in the San Joaquin River drainage, whereas the second period of incision appears approximately coeval (ca. 3.5 Ma) from the San Joaquin River southward.

10-16 **BTH 37** Knott, Jeffrey R.

LATE NEOGENE DEPOSITION IN THE LAST CHANCE RANGE, EASTERN CALIFORNIA

KNOTT, Jeffrey R.[1], MANOUKIAN, David[1], NUNEZ, Ernest Jr[1], WHITMER, Daniel[1], HATHAWAY, Jeffrey[1], REHEIS, M.C.[2], WAN, Elmira[3], LACKEY, Jade Star[4], and DEINO, Alan[5], (1) Department of Geological Sciences, California State Univ, Fullerton, Box 6850, Fullerton, CA 92834, jknott@fullerton.edu, (2) U.S. Geol. Survey, MS 980, Federal Center, Denver, CO 80225, (3) U.S. Geological Survey, 345 Middlefield Rd, MS-975, Menlo Park, CA 94025, (4) Geology Department, Pomona College, 185 E. 6th St, Claremont, CA 91711, (5) Berkely Geochronology Lab, 2455 Ridge Road, Berkeley, CA 94709

Hypotheses regarding the paleo-Owens River include possible flow from Owens Valley east into Eureka Valley. If true, then the Last Chance Range (LCR) is the only barrier to direct flow of the Owens River into Death Valley to the east. Previous geologic studies identified Cenozoic conglomerate with intercalated basalt flows both atop and along the western flank of the LCR. We present detailed geologic mapping, $^{40}Ar/^{39}Ar$ dating, geochemical, and provenance data for these late Neogene deposits to determine the age and paleocurrent directions. Atop the LCR, tilted conglomerate, sandstone and a 3.5 Ma rhyolite ash bed are overlain by flat-lying basalt flows. Clast provenance is consistent with depositional source areas on top of the LCR; geomorphic evidence indicates that the basalt flowed east to west. On the western flank, the late Neogene deposits are mapped as one unit with conglomerate surrounding rhyolite ash beds and a basalt flow. Mapping indicates that there are two separate conglomerate deposits. We dated an ash bed in the east-tilted conglomerate by $^{40}Ar/^{39}Ar$ at 3.5 Ma. Clast provenance indicates an east-to-west paleocurrent that records exposure of Mississippian bedrock. The second, west-flank conglomerate also has east-to-west paleocurrent indicators and an ash bed. Glass shard composition correlates this ash bed with the 0.77 Ma Bishop ash bed. X-ray fluorescence analysis of the basalt flows atop and on the west flank of the LCR indicates that the two flows have the same source. Our conclusions are that the LCR was a topographic high at least since 3.5 Ma depositing sediments into Eureka Valley; the Eureka Valley fault zone is stepping basinward progressively uplifting basinal deposits.

10-17 **BTH 38** Nunez, Ernest

FAULT SCARP MORPHOLOGY ALONG THE EUREKA VALLEY FAULT ZONE, EASTERN CALIFORNIA, U.S.A

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Eureka Valley, CA, in northwestern Death Valley National Park, is one of a series of valleys formed by oblique extension within the Eastern California shear zone and Walker Lane belt. In

Eureka Valley, extension is accommodated by the normal-oblique, north-south trending Eureka Valley fault zone (EVFZ) that bounds the valley's east side at the foot of the Last Chance Range and has visible Quaternary fault scarps. A M_w 6.1 earthquake on May 17, 1993 near the west side of Eureka Valley did not produce substantial ground rupture. In Northern Eureka Valley, the EVFZ offsets Quaternary alluvial-fan deposits with an age ~2-12 ka that display subdued bar and swale morphology and light desert varnish. Three scarp profiles were surveyed showing two events. Scarp profile 1 displays a right lateral offset of 3.2 m and a vertical offset of 0.7 m. Scarp profiles 2 and 3 show vertical offsets of 1 m and 1.5 m, respectively, with no horizontal offset. Results indicate minimum slip rates of 0.26 – 1.6 mm/yr over the last 2-12 ka. These results correlate with the geodetic slip rates of 0.2 mm/yr; however, EVFZ slip rates determined on scarps to the south were 0.04 – 0.13 mm/yr whereas the southernmost EVFZ is inactive over the last 30 ka. Based on the parallel trends of the northern scarps and the 1993 event we suggest that the cross-valley fault in Eureka Valley is the more active fault strand. The development of a cross-valley fault is consistent with clay models and field observations of a basin in the late extension phase.

10-18 **BTH 39** Fredrickson, Shelby M.

KINEMATICS OF DEFORMATION IN WEST-CENTRAL WALKER LANE; PALEOMAGNETIC TESTING OF FAULT-BLOCK ROTATION AND DOMING MODELS, EASTERN CALIFORNIA AND WESTERN NEVADA

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Walker Lane (WL) is a broad (~100-200 km) zone of dextral shear lying between the Sierra Nevada Microplate and the Basin and Range Province. Bodie Hills is considered a part of WL as it has experienced clockwise, vertical-axis rotation of crustal blocks due to dextral shear accommodation. This strain is variable, resulting in rotations ranging from 10° to nearly 60°, depending on specific location. The Eureka Valley Tuff (EVT) of the Stanislaus Group (10.4-9.4 Ma) and the Tuff of Jack Springs (TJS) are ideal strain markers, as they are geologically instantaneous and laterally extensive units. We use paleomagnetic analysis of these ignimbrites to improve the resolution of strain domain boundaries as well as test for doming in Bodie Hills.

EVT site mean directions were compared to reference directions of Tollhouse Flat and By Day Members collected from the stable Sierra Nevada to determine vertical-axis rotations. EVT collected from Clark Canyon exhibits 40.5°±7.1° of clockwise rotation, improving the definition of a high-strain domain centered on Bridgeport Valley. More data are needed to assess whether strain boundaries are gradual or sharp. Near Mormon Meadow, EVT has undergone about 90° of tilting since emplacement, whereas some localities may demonstrate original dips, complicating interpretations of some sites. New and previously collected paleomagnetic data from the EVT will be used to perform a fold test to assess the presence of doming centered on Potato Peak. Rejection of doming would require that the ignimbrites flowed about 2000 ft upslope over Potato Peak or that vertical crustal displacements have occurred without doming. The duration of tectonic rotation in Bodie Hills is unknown. Paleomagnetic investigation of the TJS (12 Ma), a sanidine and biotite phyric rhyolitic ignimbrite, will be used to extend the spatial coverage of rotation measurement and better constrain duration of rotation. Since it has thus far not been found on a stable crustal block, we tentatively establish a reference direction for TJS in a location with known minimal rotation measured using EVT. Testing these hypotheses will provide vital constraints on the kinematics of deformation in the region. This study enhances the general understanding of the kinematics of crustal deformation and sheds light on the tectonic history of Bodie Hills.

10-19 **BTH 40** Makovsky, Kyle A.

JUST WHERE IS THE NORTHERN TERMINATION OF THE WALKER LANE? POSSIBLE ASSOCIATIONS TO DEXTRAL OBLIQUE-STRIKE SLIP FAULTING IN NORTHERN CALIFORNIA AND SOUTHEASTERN OREGON

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The numerous NW-SE trending faults of southeastern Oregon could be the result of the same tectonic driver as that producing the Walker Lane. The faults in southeastern Oregon have NW-SE orientations and display dextral oblique to strike-slip relative motions, similar to structures in the Walker Lane (Pezzopane and Weldon, 1993; Crider, 2001; Jordan et al., 2004; Trench et al., 2012). The question then becomes how are they related to Walker Lane structures? By definition, Walker Lane structures have been created from the northwest translation of the Sierra Nevada crustal block relative to North America and therefore accommodate 15%-20% relative motion between these two plates (Faulds et al., 2005). So, if this block is translating northwestwards, then could there be deformation not only adjacent to this crustal block (i.e., Walker Lane per se) but also in front of it (i.e., northern California and southeastern Oregon)? Conversely (or perhaps not), there has been much evidence for the clockwise rotation of the Cascadia forearc (e.g., Wells and Simpson, 2001) and resultant clockwise rotation in the back-arc region of Oregon (Trench et al., 2012). Blakely et al. (1997) postulate that strain is being transferred from dominantly strike-slip domains of the Walker Lane northwards to E-W directed extension in the High Cascades via N-S and NW-SE trending normal and strike-slip faults, respectively, associated with Quaternary volcanic centers of the southern High Cascades, also alluded to by Oldow (2001), Figure 1. How much of this rotation is due to oblique convergence between the Juan de Fuca and North American plates versus the northward translation of the Sierra Nevada crustal block? The origin of the faulting in southeast Oregon is thus problematic in that it could be related to Basin and Range tectonics, the rotation of the Cascade forearc, and/or the forces that are generating the Walker Lane.

SESSION NO. 11, 10:00 AM

Tuesday, 21 May 2013

Sedimentary Geology

Radisson Hotel and Conference Center, Salon D1

11-1 **10:00 AM** Weinman, Beth

SEDIMENTOLOGICAL AND GEOMORPHOLOGICAL PERSPECTIVES ON GRAINSIZE DISTRIBUTIONS: HOW SEDIMENTS GET THEIR SIZE IN THE SIERRA NEVADA, CALIFORNIA

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Traditionally, grainsize distributions are used to infer sedimentological paleoenvironments and past flow regimes. Rather than just being an indicator of flow, new work on sediment production views grainsize as a product of both physical and chemical processes. Yet, the relative roles of physical breakdown and/or chemical weathering (i.e., kaolinization and secondary mineral production) in producing a deposit's resulting grainsize distribution remains poorly understood. In order to quantify the physical and chemical effects that act to produce a grainsize distribution, we couple sediment residence times with geochemical mass balances and grainsize distributions to describe the evolution of grainsize along hillslopes within the Feather River basin of the Sierra Nevada, California. Our results show that particle sizes increase with both hillslope slope gradient and soil-depth. The average grainsize of particles at the soil-saprolite boundary increases with slope from 78 to 181 to 275mm. Using Zr as an immobile element, hillslope sediments appear virtually identical to the underlying saprolite, which indicates that sediment production and the mechanisms that determine particle size distribution is mostly a physical process. Additionally, turnover times calculated from slope-based erosion rates for the basin (Riebe et al., 2000) indicate that once in the soil, particles physically breakdown at rates of 0.9, 10, and 27mm/kyr (in order of increasing slope) along the three measured hillslopes (above, at, and below the river's knickpoint, respectively). The fact that the particles in the three hillslopes are breaking down at different rates means that the higher-sloped colluvium is fining faster, even though it has an overall coarser grainsize than soils on shallower slopes with higher degrees of chemical weathering. Taking this as one of the first steps towards quantifying the relative roles of physical and chemical weathering on grainsize distributions, we should be able to one day use grainsize distributions from the sedimentary record to calculate the rates of paleo-soil formation, past sediment production, and previous regimes of chemical and physical weathering.

11-2 **10:20 AM** Lowey, Grant

INTEGRATED PROVENANCE ANALYSIS OF THE DEZADEASH FORMATION (JURA-CRETACEOUS), YUKON, CANADA: CONSTRAINING THE ACCRETIONARY TECTONIC HISTORY OF THE WRANGELLIA COMPOSITE TERRANE IN THE NORTHERN CORDILLERA OF NORTH AMERICA

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The Wrangellia composite terrane (WCT) was the last major terrane accreted to the western margin of North America, which consisted of the Yukon composite terrane (YCT). Accretion was accompanied by the formation of Mesozoic magmatic arcs (Talkeetna, Chitna and Chisana), and the collapse of intervening 'flysch' basins (Gravina belt, Nutzotin Mountains sequence, Dezadeash Formation, and Kahiltna assemblage).

The 3000 m thick Dezadeash Fm, located north of the Denali fault system and closer to YCT, is interpreted as being deposited in a backarc basin, whereas the 3000 m thick Nutzotin Mountains sequence, located south of the fault system and farther from YCT, has recently been interpreted as forming in a retroarc foreland basin. As both units represent the same basin displaced by ~370 km of dextral movement on the Denali fault system in post-Early cretaceous time, evidence linking strata of the Nutzotin-Dezadeash basin with the YCT is critical to the retroarc model.

Integrated provenance analysis of the Dezadeash Fm reveals that conglomerates are dominated by clasts derived from WCT (basalt, limestone, chert, andesite) and roots of the Chitna arc (diorite, granodiorite); sandstones include litharenites and feldspathic litharenites ($Q_{12}F_{26-62}L_{62}$) that are dominated by volcanic lithic grains ($Lv_{93}Ls_6Lm_1$) and Mesozoic detrital zircons (94%), with minor Paleozoic (1%) and Precambrian (5%) zircons; and sandstones and mudstones have a chemical index of alteration similar to unweathered igneous rocks (CIA ≈ 50), Th/Sc ratios of ≈ 0.2, and display parallel, listric-shaped profiles with moderate enrichment of LREE and no Europium anomaly (Eu/Eu* ≈ 1.0) on chrondrite-normalized multi-element diagrams; and sandstones and mudstones have Nd-Sm systematics suggesting mixing of a depleted mantle source and an older crustal source ($\varepsilon_{Nd}{}^{(0)} \approx 0$ to +3.4).

The provenance data indicates that the Dezadeash Fm consists of first-cycle volcanogenic material derived from a young undifferentiated arc that was undissected to partly dissected (i.e., transitional), as well as older crustal material, all of which originated from the coeval Mesozoic arcs and the WCT. These results, combined with paleocurrent data that indicates *only* a westerly source, do not support a retroarc foreland basin interpretation for the Nutzotin-Dezadeash basin.

11-3 **10:40 AM** Buesch, David C.

PRE-, SYN-, AND POST- MIOCENE VOLCANIC SOURCES AND DEPOSITIONAL ENVIRONMENTS IN SEDIMENTARY ROCKS AT CRASH HILL, NELSON LAKE VALLEY, CALIFORNIA

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Crash Hill in Nelson Lake valley, California, contains a >230-m thick, conformable, Miocene sedimentary basin sequence deformed into a domed structure along the Nelson Lake fault. Volcanism occurred west of the area 18-12 Ma, and the section is divided into three general groups relative to volcanism: pre-, syn-, and post-volcanic.

Pre-volcanic rocks derived from Cretaceous granitic rocks form >50 m of arkosic sandstone and conglomerate. Beds are 0.05-1.0-m thick, fine-grained sandstone to pebble conglomerate, tabular to lenticular, many with crossbeds. Many conglomerate beds have subrounded clasts up to

30 cm, and a few ~80 cm. Fallout tephra beds, 4-15-cm thick, are in the upper 40 m and increase in number and thickness up section.

Syn-volcanic deposits are ~100 m of medium- to coarse-grained tuffaceous sandstone to pebble conglomerate, interbedded with siltstone to fine-grained tuffaceous sandstone and fine-grained ash. The tuffaceous and volcanic lithic materials were probably derived from the volcanic center to the west. Many 1-2-m thick bedsets contain cycles that coarsen upwards, from fine-grained, structureless sandstone to coarse-grained sandstone or pebble conglomerate. Many tuffaceous beds have grains of glass shards or pumice clasts, many altered to clay. Many beds have calcite cement, especially the well sorted, coarser-grained sandstones. Some siltstone to fine-grained sandstone beds have root casts. Fine-grained, 10-30-cm thick, ash beds are mostly vitric glass and small pumice grains with small fragments of quartz, feldspar(?), and biotite.

Post-volcanic rocks are >80 m of sandstone and conglomerate that include volcanic lithic clasts, minor amounts of tuffaceous material as epiclasts, and rare granitic clasts. Beds are 4-40-cm thick, fine-grained sandstone to cobble conglomerate, and internally they are laminated, trough crossbedded, or have normal size grading. The matrix is mostly fine-grained, epiclastic grains similar to the larger clasts along with a small component of fine-grained clay minerals.

Depositional environments for pre-volcanic deposits are interpreted as basin margin, medial to distal, alluvial fan, syn-volcanic deposits as basin axis, distal fluvial to lacustrine (marsh?), and post-volcanic deposits as basin axis, distal to medial alluvial fan.

11-4 **11:00 AM** Harwood, Cara L.

CLOTTEDNESS IN CAMBRIAN MICROBIALITES: EXAMINING TEXTURAL VARIATIONS IN THE DEFINING CHARACTERISTIC OF THROMBOLITES

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Thrombolites reflect the interplay between microbial communities, sedimentation, and lithification, and therefore provide a record of sediment-organism interactions through much of Earth history. Although thrombolites are defined as internally clotted microbialites, the character of clottedness is difficult to define and describe. Thus, 'thrombolites' include many dissimilar structures, including both those with a distinct clotted framework and those with irregular, patchy textures, which makes it difficult to interpret their significance. This study describes microbialites in Cambrian carbonates of the southern Great Basin, CA and NV. Specifically, we categorized internal textures of microbial buildups typically described as 'thrombolites' and 'cryptic microbial boundstones' by examining the features that impart a clotted, or patchy, character. Microbialites were described in the field in a stratigraphic context, and further studied in polished slabs. We examined the presence and distribution of different components (e.g. calcimicrobial clusters, dense micrite, coarse spar, skeletal material), their organization and distribution, and the relationships between them. Some mounds are composed of distinct micritic mesoclots with peloidal microfabrics in a framework structure. The clotted appearance of these mounds likely reflects a primary growth structure. Other mounds lack a framework structure, and a patchy texture is defined by intermixed light and dark micrite in irregularly shaped patches with smooth margins. In this case, the clotted appearance likely reflects intermixing of two sediment types following deposition, possibly from bioturbation. Other densely micritic mounds lack a distinct internal structure, and appear patchy from discontinuous zones of coarse spar. These mounds all share a 'clotted' or patchy appearance, yet are made up of different components with different geometries. This indicates that the character of clottedness is produced from a wide range of processes. Recognizing variations in clotted and patchy textures will allow identification of different types of thrombolites and will improve interpretations of ancient thrombolite environments and ecosystems.

11-5 **11:20 AM** Morgan, George

EVIDENCE OF FRESH WATER LIMESTONE (BOUSE FORMATION EQUIVILENT?) IN THE TRANSGESSIONAL-REGRESIONAL MARINE AND NON-MATINE IMPERIAL GROUP SEDIMENTS, COYOTE MOUNTAINS, IMPERIAL COUNTY, SALTON TROUGH, SOUTHERN CALIFORNIA

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Within two of the six+ transgressional and regressional sequences of the Imperial Group found in the Coyote Mountains are what appear to be two fresh water limestones. The first and lowest appears at the bottom of the Garnet Formation, a non-marine fanglomerate in the Imperal Group, and is approximately two+ meters thick with a tuffa cap. In other areas of the Garnet Formation, this limestone is much thinner. The second and highest limestone appears in the next higher non-marine fanglomerate in the Imperial Group, is less than a meter thick and exposed in only one location. No fossils are seen in either limestones.

Using Winker and Kidwell (1996) figure 2, a reconstruction of the Salton Tough, the Coyote Mountains and the deposition environment of the Imperial Group sediments would be south of Yuma, Arizona and south of the mouth of the Colorado River. With the Coyote Mountains in this location, the Colorado River could supply fresh water to the depositional environments of the non-marine fanglomerates. The limestones that are found in the Coyote Mountains represent a environment south of Yuma, Arizona that is similar to the environment that produced the Bouse Formation north of Yuma Arizona.

11-6 **11:40 AM** Brady, Mara

EVALUATING THE STRATIGRAPHIC COMPLETENESS OF DEEP-TIME RECORDS: A NEW QUANTITATIVE APPROACH

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Thick stratigraphic records reflect both high accommodation, typically created by greater subsidence, and high sediment supply, such that a relatively temporally complete record of deposition is preserved. However, thin records can form through multiple possible interactions between accommodation and sediment supply. Thin records can be (1) miniaturized, i.e. thinner, but equally complete; (2) comparable in thickness and quality where the sedimentary record is preserved, but certain portions of the record are notably absent; or (3) so invariably preserved that the stratigraphic packages are qualitatively different compared to a coeval thick record.

Here, I present a method for discriminating among these distinct modes of stratigraphic thinning, which each have different consequences for the quality and temporal resolution of the preserved sedimentary record. Starting with stratigraphic building blocks of lithofacies and meter-scale cycles, this quantitative approach can be used to compare two (or more) ancient sedimentary records, which differ in terms of net rock accumulation rates (typically measured over 10^6-year time scales), but not in terms of completeness given available chronostratigraphic resolution. The methodological approach is as follows: First, assess the relative contribution of (1) different average cycle thickness between the two records versus (2) differences in the numbers of cycles preserved over the entire stratigraphic interval. Next, evaluate the degree to which differences in cycle thickness can be accounted for by (3) differences in facies thickness versus (4) numbers of facies per cycle. Finally, (5) consider how the composition of facies and meter-scale cycles contributes to the observed differences in thickness.

When applied to Devonian carbonate sedimentary records, this quantitative analysis revealed the important role of suppressed subtidal sedimentation rates in creating a thin cratonic interior record relative to a coeval record on the continental margin. This approach can be applied to other geologic time periods and settings to better constrain the resolution of stratigraphic, paleoenvironmental, and paleobiological information available and the comparability of studies conducted across distinct basins.

SESSION NO. 12, 8:15 AM

Tuesday, 21 May 2013

T3. Oceanic Petrogenesis of Pacific-Type Convergent Margins

Radisson Hotel and Conference Center, Salon A1

12-1 **8:20 AM** Liou, Juhn G.

RECYCLING OF UHP-UHT MINERALS — THE FATE OF SUBDUCTED CONTINENTAL CRUST

LIOU, Juhn G., Department of Geological and Environmental Sciences, Stanford University, Stanford, CA 94305-2115, jliou@stanford.edu and TSUJIMORI, Tatsuki, Institute for Study of the Earth's Interior, Okayama University, Misasa, Tottori, 682-0193, Japan

New occurrences of UHP minerals in UHT felsic granulites from NW Africa and the Bohemia Massif and earlier findings of microdiamond, coesite and nano-size α-PbO2–structured TiO2 polymorph in pelitic gneisses of the central Erzgebirge suggest that a big segment of crustal basement has been exhumed from mantle depths > 150 km. Inclusions of microdiamond and coesite occur in Grt, Ky and zircon of felsic granulites; those in Africa have much higher P-T estimates of P > 4.3 GPa and T > 1100°C, exhibit topotaxial overgrowths of diamond and coesite, lack palisade Qtz around relict coesite, and have intergrowths of coesite and phengite possibly after K-cymrite. These UHP–UHT granulites are closely associated with mantle-derived Grt peridotites that were interdigitated with deeply subducted continental crust rather than being tectonically emplaced at shallow depths.

UHP minerals have also been discovered in podiform chromitite associated with ophiolite. Diamond, moissanite, possible coesite pseudomorphs after stishovite, Fe-Ti alloys, osbornite, cubic boron nitride, TiO2 II, and zabonite occur as nano- to micro-scale inclusions in podiform Luobusa chromitite, Tibet. In-situ microdiamond (± moissanite) inclusions in chromite grains have been recognized in numerous ophiolitic massifs along the 1400-km-long Yarlung-Zangbo suture between India and Asia, and in the Polar Ural Mountains. These UHP minerals and chromite containing exsolution lamellae of coesite + diopside suggest that the chromitites formed at P > 9–10 GPa at depths of > 250–300 km. Thin lamellae of pyroxene in chromite also occur in chromitites of the northern Oman ophiolite. These chromitities and associated peridotites contain rare zircon, corundum, feldspar, Grt, Ky, sillimanite, Qtz and rutile, and have much older U-Pb zircon ages than the formation ages of ophiolites. Apparently, these UHP mineral-bearing chromitites had a deep-seated evolution prior to the formation of overlying ophiolite complexes at shallow depths. These findings lead to speculation about supracrustal materials being recycled through deep subduction, mantle upwelling and return to the Earth's surface supported by crustal mineral inclusions in diamonds and possible 'organic' light carbon isotopes of diamond and moissanite in both UHP terranes and kimberlitic xenoliths.

12-2 **8:40 AM** Beyssac, Olivier

CARBON CYCLING IN SUBDUCTION ZONES: THE IMPORTANCE OF METASOMATISM

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Subduction zones play a key role in the long-term carbon cycle as they transfer carbon from the Earth's surface to the deep Earth. In the downgoing slab, carbon is present as solid reduced organic (graphitic carbons and diamond) and oxidized inorganic (carbonates) phases, as well as in fluids. The respective stability of these phases during subduction, particularly carbonates, is the subject of intense research, but we have a poor knowledge on the possible exchanges between the C reservoirs and on the influence of local redox and chemical gradients on the stability of C-bearing phases during subduction. Alpine Corsica (France) provides a unique window on subduction processes with no retrograde alteration as attested by the widespread presence of lawsonite eclogites and blueschists. Two examples of metasomatism involving C-bearing phases at lithological contacts will be discussed based on detailed field, petrological and geochemical observations. At a first locality where impure marbles are at direct contact with serpentinites, complete calcite reduction is observed generating graphite and secondary wollastonite. Conversely, at a second locality, graphite is completely leached from the matrix in metasediments at direct contact with a gabbro, and only remains as inclusions in secondary lawsonite in the reaction zone. Both localities illustrate metasomatic processes during subduction affecting C-bearing phases in metasediments at contact with mafic or ultramafic lithologies. The global implications of such metasomatic reactions on the long-term carbon cycle will be discussed.

12-3 **9:00 AM** Vitale Brovarone, Alberto

THERMAL REGIME AND TECTONO-STRATIGRAPHY ACROSS THE BLUESCHIST-ECLOGITE TRANSITION: INSIGHTS FROM VARIOUS HP BELTS OF TETHYAN AND PACIFIC TYPE

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The blueschist-eclogite transition of fossil and present day subduction zones deserves broad interest in the Earth Sciences because of its central role in subduction dynamics. In fold-thrust belts, blueschist and eclogite-facies rocks commonly occur in different terrnanes separated by tectonic contacts, and lack pristine continuity. We compared the nature of the blueschist-

eclogite transition in different orogenic belts including both Tethyan-type (Alpine Corsica, the Western Alps and Oman) and Pacific-type (New Caledonia). Our first aim was to compare the thermal regime of these HP belts by means of the same petrological techniques, namely Raman Spectroscopy of Carbonaceous Material (RSCM) and PT pseudosections. All these belts show comparable Pressure-Temperature (PT) estimates and PT path, and testify a rather equivalent thermal regime independently from the above-mentioned initial setups. Blueschist-facies terranes are metasediment-rich and show a constant metamorphic gradient increasing from ca. 300 °C and 1 GPa to ca.480-500 °C and 1.8-2.0 GPa toward the blueschits-eclogite boundary, and preserve progressive metamorphic mineral isograds (e.g. carpholite-, lawsonite-, Na-amphibole-, chloritoid-, garnet-in). Eclogite-facies terranes are otherwise metaophiolite-rich (or continental basement-rich in the case of Oman), and show a narrower PT estimates increase from ca. 490-500 to ca. 550 °C and rather constant P estimates at and 2.3-2.5 GPa. On the field, the blueschist-eclogite transition occurs at ca. 480-500 °C, and corresponds to a sharp P gap in the range of ca. 0.4-0.6 GPa. Importantly, no significant Tmax gap is observed across the blueschist-eclogite boundary.

Tectonostratigraphic data indicate that the two metamorphic terranes originated in different paleogeographic contexts, structure of which possibly controls their tectonometamorphic evolution during subduction and mountain building.

We conclude that the blueschist-eclogite transition shows precise metamorphic and tettonostratigraphic patterns in HP belts originated in both Tethyan and Pacific subduction zones, and that structural inheritance plays a crucial role in selective accretion of subducting material and mountain building.

12-4 **9:20 AM** Vitale Brovarone, Alberto

THE IMPORTANCE OF LAWSONITE METASOMATISM IN BLOCK-IN-MATRIX STRUCTURES: FIELD AND GEOCHEMICAL FINGERPRINTS FROM ALPINE CORSICA

VITALE BROVARONE, Alberto, Institut de Minéralogie et Physique des Milieux Condensés (IMPMC), Université Pierre et Marie Curie (UPMC) Paris, 4, Place Jussieu, case courrier 115, Paris, 75005, France, alberto.vitalebrovarone@gmail.com and BEYSSAC, Olivier, CNRS IMPMC Paris, Campus Jussieu, Case courrier 115, 4 place Jussieu, Paris, 75005, France

Fluid-rock interaction at High-Pressure (HP) has been shown to represent a fundamental process for recycling elements such as REE and LILE during subduction and a source for arc magmatism. Chaotic units, including block-in-matrix structures, are a perfect environment for metasomatism and are the locus of intense chemical exchange between contrasting lithologies and circulating fluids at HP (e.g. Bredding et al., 2004, Geology 32, 1041-1044).

We present spectacular examples of lawsonite-bearing metasomatism affecting contacts between metaophiolite blocks (mafic, ultramafic or ophicalcite) and the surrounding metapelites in blueschist-facies terranes of Alpine Corsica (France), a classical type-locality for well-preserved lawsonite. Lawsonite metasomatites, often lawsonitite, form at the expense of metapelitic protolith, and range in size from a few cm to about 25 m depending on the size of the "allochthonous" body. Lawsonite forms mm-size idiomorphic blasts that include trails of the protolith's fabric, most notably carbonaceous material (CM) and acicular rutile. Lawsonite compositional zoning and bulk rock geochemistry show a systematic REE and LILE (most notably Ca and Sr) enrichment in lawsonitites compared to the metapelite protolith, thus indicating strong variation in the bulk rock composition during lawsonite growth. Different geochemical patterns characterize retrogressed lawsonitites, where REE and LILE are strongly depleted compared not only to the lawsonite metasomatite, but also to the metapelitic protolith. We conclude that lawsonite metasomatites formed by fluid-rock interaction represent an important reservoir for (C)OH volatiles and elements like REE and LILE and for their recycling at greater depth at the lawsonite breakdown, and a possible source of these elements for arc magmatism. Block-in-matrix structures, which are common in many orogenic belts (e.g. Corsica, Franciscan complex, Syros, New Caledonia), represent the perfect environment for widespread metasomatic lawsonite precipitation, and suggest its relevance at global scale.

12-5 **9:40 AM** Flores, Kennet E.

CONTRASTING PROTOLITH GEOCHEMICAL SIGNATURES OF JURASSIC PACIFIC-RELATED METABASITES NORTH AND SOUTH OF THE CHORTÍS BLOCK (GUATEMALA AND NICARAGUA)

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The NW edge of the modern Caribbean Plate is a jig-saw puzzle of displaced continental slivers, tectonically sandwiched between highly deformed oceanic crust assemblages, and as assigned to the Chortís Block. The oceanic crust assemblages consist of slices of metavolcanic sequences, partially serpentinized ultramafic bodies and serpentinite-matrix mélanges within metabasite blocks including high-pressure–low-temperature (HP–LT) rocks. At the northern margin of the Chortís Block these assemblages have been grouped as the El Tambor Complex (ETC) and the South Motagua Mélange (SMM), and in the south as the Siuna Serpentinite Mélange (SSM). The ETC and the SMM contain slivers of Jurassic Pacific-related radiolarites in original sedimentary contact with metabasalts. HP–LT blocks from the SMM and SSM have yielded Late Jurassic metamorphic peak and Early Cretaceous exhumation ages suggesting a similar, if not a contemporary origin.

New geochemical data from these metabasites show major contrasts in signature and geotectonic setting. Low to medium grade spilite, greenschist, and amphibolite facies metabasites as well as HP–LT blocks show trace elements patterns that resemble those of (1) MORB, OIB, and BABB, and (2) typical IAT and CAB with large enrichments in the most fluid mobile elements (Rb, Ba, K and U), strong depletion of Nb and moderate depletion of Th and Ti.

Typical arc lava signatures in HP–LT blocks are expected due to the metasomatic overprint in the subduction channel. However, such large variations in tectono-magmatic origin of the other metabasites evidence a tectonic scenario that includes an island arc setting encountering a back-arc basin, as well as oceanic islands and normal oceanic crust. The latter scenario can be compared to the modern tectonic setting of the Izu-Bonin-Mariana (IBM) arc system and suggest the occurrence of a paleo-Pacific intra-oceanic island arc system accreted or collided into the continental active margin of the Americas.

12-6 **10:20 AM** Ernst, W.G.

MID-MESOZOIC TO MIOCENE CLASTIC SEDIMENTATION ALONG THE NORTHERN CALIFORNIA MARGIN—PROVENANCE AND PLATE-TECTONIC IMPLICATIONS

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Based on relationships among volcanic-plutonic arc rocks, HP/LT metamafic rocks, westward relative migration of the Klamath Mountains salient, and the locus of the Mariposa-Galice, Great Valley Group (GVG), and Franciscan depo-basins, I infer the following geologic evolution for northern California: (1) At ~175-170 Ma, onset of transpressive plate underflow generated an emergent igneous arc along the margin. By ~165 Ma and continuing to ~150-140 Ma, erosion provided volcanogenic debris to proximal Mariposa-Galice ± Myrtle overlap strata. (2) Mafic rocks were metamorphosed at HP/LT in an inboard subduction zone from ~170-155 Ma. Except for the Red Ant blueschists, such rocks remained at depth; most HP/LT mafic tectonic blocks returned surfaceward only during Late Cretaceous time entrained in circulating, buoyant Franciscan mélange. (3) At the end-of-Jurassic time, before onset of Franciscan and GVG ± Hornbrook deposition, the Klamath salient was deformed and began to be offset ~100-200 km westward relative to the Sierran arc. (4) After this step-out of the Farallon-North American convergent plate junction—which stranded pre-existing oceanic crust on the south as the Great Valley Ophiolite—terrigineous debris began to arrive at the Franciscan trench + intervening Great Valley forearc by ~140 Ma. The most voluminous sedimentation/accretion of Franciscan Eastern + Central Belt and GVG detritus took place during paroxysmal igneous activity and rapid, nearly orthogonal plate convergence at ~125-85 Ma. (5) Andean-type arc volcanism-plutonism ceased at ~85 Ma in northern California, signaling a transition to nearly subhorizontal plate underflow attending Laramide orogeny far to the east. (6) Paleogene-Miocene Franciscan Coastal Belt sedimentary strata were deposited in a tectonic realm practically unaffected by HP/LT subduction. (7) Grenville detrital zircons are completely missing from the post-125 Ma Franciscan section, whereas detritus from the Idaho Batholith, Challis volcanics, and Cascade Range appear in progressively younger Paleogene-Miocene Coastal Belt sediments. Although not conclusive, this suggests the possibility of gradual, post-depositional NW dextral offset of Franciscan trench deposits (~1600 km) relative to the GVG forearc and basement terranes of the SW conterminous U. S.

12-7 **10:40 AM** Barnes, Calvin G.

THE WESTERN HAYFORK TERRANE: MIDDLE JURASSIC ARC WITH ADAKITIC AFFINITIES IN THE KLAMATH MOUNTAIN PROVINCE, OR AND CA

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The western Hayfork terrane (wHt) is a thick sequence of arc-related volcanogenic sandstone and siltstone (arc apron) with sparse mafic to intermediate lavas and air-fall deposits that crop out from the southern Klamath Mountain province to the latitude of Grants Pass, OR. It was deposited on ophiolitic mélange of the Rattlesnake Creek terrane and depositional ages determined by $^{40}Ar/^{39}Ar$ dating of detrital (magmatic) hornblende range from 179 to 169 Ma[1]. The end of wHt magmatism is coincident with a regional high-grade (~9–10 kbar, 965–980°C)[2] metamorphic event.

The bulk of the wHt consists of fine to coarse metasandstone with clasts of volcanic rock fragments, plagioclase, augite, and hornblende. Graded bedding is common and is locally truncated by channels filled with volcanic cobble-rich lahar deposits. The lack of volcanic rocks in the wHt makes characterization of Middle Jurassic arc magmatism difficult. However, magmatic compositions of the arc may be characterized by major and trace element analysis of augite and hornblende phenocrysts and detrital grains. Augite is relative calcic (Wo > 0.4) and magnesian (mg# 0.79–0.92). Most augites have strongly concave-downward REE patterns with highest chondrite-normalized abundance at Nd; most lack a Eu anomaly. Normalized heavy REE abundances are variable from as much as 20x to as little as 1.5x chondrites. Augite with low HREE also has low Y and high Sr contents (to 110 ppm) and calculation of magmatic trace element patterns of these samples shows an affinity to mafic adakite, with Sr/Y ratios suggestive of both slab melting and deep-crustal melting[3]. Among the numerous proposed origins for adakites, the wHt examples are best explained as slab melts modified by interaction with the mantle wedge. If this was the case, then the wHt arc was evidently related to subduction of a young, hot slab. It is possible that wHt magmatism ended as a spreading ridge reached the trench. Subduction of the trailing edge of the slab could then have resulted in a slab window which provided heat for the subsequent high-grade metamorphism.

[1]Hacker et al., Tectonics *14*, 677. [2]Medaris et al., GSA Abst. Prog. *41*, 590. [3]Drummond & Defant, JGR *95*, 21503.

12-8 **11:00 AM** Maekawa, Hirokau

SERPENTINITE DIAPIR AND BLUESCHIST METAMORPHISM IN THE MARIANA FOREARC, WESTERN PACIFIC

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A large number of seamounts of serpentinized peridotites are widely distributed in the Mariana forearc. They are commonly dome-like in shape, and up to 30 km in diameter with up to 2 km of relief. Serpentinite blocks of varying sizes are scattered in a fractured and crushed serpentinite mud matrix on the surface of the seamounts. The degree of serpentinization of the blocks varies from 30% to 100%. Drilled samples of serpentinites from Conical Seamount during ODP Leg 125 are highly sheared, and show "block-in-matrix" fabrics, which are typical in on-land serpentinite mélanges. As hydrated pelagic sediments on the top of the subducting plate supply water to wedge mantle peridotites, the peridotites react with water to form serpentinites. Voluminous low-density serpentinites generated just above the subducting slab have uplifted along faults to form a huge chain of seamounts on the ocean floor. Blueschist-facies rocks have been found from some of serpentinite seamounts. Together with abundant serpentinized peridotites, the 2-3 cm clasts of blueschist-facies rocks were recovered from one of serpentinite seamounts, i.e., Conical Seamount, during the ODP Leg 125. Many sand-sized fragments of blueschists were found from South Chamorro Seamount at the southern part of the Mariana forearc during the ODP Leg 195. Recently, we carried out the geological expedition of Twin Peaks Seamount which is situated at the central part of the Mariana forearc by means of ROV "KAIKO 7000II" and submersible vessel "Sinkai 6500" during KR06-15 and YK08-08 cruises (JAMSTEC), respectively. Blueschist-facies blocks of more than several meters are exposed in the large fault scarp, which develops at the central part of the seamount. These blueschist-facies rocks are thought to have been entrained by uprising fluidized serpentinite materials from depth in the subduction zone, and extruded onto the seafloor. The presence of high-pressure rocks in these seamounts confirms that blueschist-facies metamorphism actually took place beneath the forearc in the Mariana subduction system. Serpentinite diapir is one of the potentially important mechanisms for uplifting blueschist-facies rocks from subduction zones to forearc surface.

12-9 **11:20 AM** Okamoto, Kazuaki

ZIRCON CHRONOLOGY AND GARNET CHEMISTRY RELATED TO DEHYDRATION MELTING IN A DEEP SUBDUCTION ZONE: CASE STUDY FROM THE SANBAGAWA QUARTZ-BEARING ECLOGITE

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The Sanbagawa high P–T metamorphic rocks have been considered as typical cold oceanic material subducted during the Cretaceous. However, we have discovered an eclogite outcrop exhibiting partial melting texture. In order to confirm the age of partial melting of Sanbagawa metamorphic rocks, we dated zircons from both the melted portion and the host eclogite using the U–Pb SHRIMP age-dating at the Korean Basic Science Institute. Zircons from the melted portion are rounded and have sector zoning. The core and mantle yield U–Pb age in the 130–113 Ma range (120 Ma average), and the rim ages are in the 115–104 Ma range. Zircons from the eclogite have a homogenous core with thin mantle and rims. The U–Pb ages are concentrated at 123–112 Ma. These pieces of evidence suggest that the eclogite metamorphism occurred at about 120 Ma and subsequent partial melting happened at about 110 Ma. REE concentration of the zircon core and mantle indicates the eclogite facies recrystallization. Rims of the zircons decrease HREE and increase MREE, suggesting decomposition of phengite and omphacite and formation of melt and garnet. Garnet REE signature supports the dehydration reaction.

12-10 **11:40 AM** Tsai, Chin-Ho

AMPHIBOLE COMPOSITIONS AND TECTONIC IMPLICATIONS OF THE WANJUNG SERPENTINITE COMPLEX, YULI BELT, EASTERN TAIWAN

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The Wanjung serpentinite complex mainly consists of serpentinite, mafic schist, and metagabbro. Rare metarodingite, serpentinized peridotite, and omphacite-bearing metabasite have also been reported (Lan and Liou, 1981; Yui and Lo, 1989; Beyssac et al., 2008). This complex and two other serpentinite-metabasite suites in Juisui (Tamayen) and in Yuli (Chinshuichi) have been interpreted as part of a dismembered and metamorphosed ophiolite, which represents foreign oceanic materials tectonically transported to the Yuli metamorphic belt (Liou, 1981; Lin, 1999). Recently we discovered a new occurrence in which omphacite-diopside bearing metabasite exists near the contact between serpentinite and mafic schist. The representative omphacite-rich rock contains omphacite, diopside, Mg-rich chlorite, zoisite, albite and titanite, but lacks quartz. Rare rutile and ilmenite are included in titanite. BSE imaging and EPMA mapping reveal that omphacite always contains patchy diopside, implying coexistence of these two phases (cf. Tsujimori, 1997). Mafic schist, metagabbro, and some ultramafic rocks contain amphibole and show compositional zoning. The amphibole core in mafic schist is barroisite, whereas that in metagabbro is edenite to magnesiohornblende. The amphibole rim in both meta-mafics is actinolite. A serpentine-rich "hybrid rock" contains amphibole with relict pargasite-edenite replaced by tremolite. One serpentinized metaperidotite contains olivine, talc, chromite, tremolite, and anthophyllite. The studied amphibole compositions of mafic rocks lie within the range of medium-pressure series on a Na/(Na+Ca) vs. Al/(Al+Si) diagram (Laird and Albee, 1981). Except the omphacite-bearing rock, metamorphic evolution from epidote-amphibolite (or amphibolite) facies to greenschist facies can be inferred for the mafic rocks. The Wanjung complex is a metamorphosed mélange but differs from the Tamayen and the Chinshuichi mélanges in metamorphic facies series, because glaucophane exists in the latter two but not in the former (Liou et al., 1975; Lin et al., 1984; Tsai et al., 2013). These three metamorphosed mafic-ultramafic complexes in the Yuli belt may have been of multiple origins and through different metamorphic histories.

SESSION NO. 13, 8:00 AM

Tuesday, 21 May 2013

T10. Reconstructing the Pacific-North America Plate Boundary Through Late Cenozoic Time I

Radisson Hotel and Conference Center, Salon A2

13-1 **8:05 AM** Atwater, Tanya M.

CONSTRAINTS ON THE HISTORY OF THE LATE CENOZOIC PACIFIC-NORTH AMERICAN PLATE BOUNDARY FROM MARINE MAGNETIC ANOMALIES AND GLOBAL PLATE CIRCUITS

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Round-the-world plate tectonic reconstructions, when combined with offshore California seafloor patterns of magnetic anomalies, supply strong constraints on the origin and development of the San Andreas plate boundary, its deformation budget, and the configurations of subducted slabs beneath it.

Circuit solutions provide tight estimates of the total deformation across western North America for four different times (2.6 Ma, 11.1 Ma, 19.7 Ma, and 33.2 Ma) and less precise estimates for many more times. Because of possible unknown displacements along the continent-ocean join, these estimates provide only upper limits for the on-land deformation budget, but they appear to approximate the actual deformation values for times younger than 20 Ma. The on-land deformation budget totals include both near-coast offsets on the San Andreas and Gulf of California systems and interior deformations on the Walker-Lane and Eastern California Shear Zone and in the Basin and Range provinces of the U.S. and Mexico. Interior deformations in the coast-parallel direction are particularly tricky since they imply substantial extensions/shortenings at the edges of the region. Motions of the Great Valley-Sierra Nevada block define the partitioning of deformation for central and northern California and cause the plate boundary region to extend far north of the Mendocino triple junction. Details of the transfer of Baja California to the Pacific plate dictates the late Miocene tectonic history of Southern California.

Offshore magnetic anomaly patterns help describe the breakup events that occurred during the demise of the Farallon plate and the origin of Pacific-North American plate contact. In most cases, the spreading center at the edge of the Pacific plate never reached the subduction zone, but rather, it slowed and stalled offshore because the main subducting plate broke away at depth, abandoning a surface microplate. These breakups and microplates, in turn, dictated the locations and shapes of resulting "slab windows" in the subducting plate and drove and localized patterns of volcanism and other events on the overriding plate.

13-2 **8:25 AM** Stock, Joann M.

EVOLUTION OF THE SALTON TROUGH-GULF OF CALIFORNIA PART OF THE PACIFIC-NORTH AMERICA PLATE BOUNDARY: AN UPDATE

STOCK, Joann M., Seismological Laboratory, California Institute of Technology, 1200 E California Blvd, MC 252-21, Pasadena, CA 91125, jstock@gps.caltech.edu and MARTIN-BARAJAS, Arturo, Div. Ciencias de la Tierra, CICESE, Carretera Ensenada-Tijuana No. 3918, Ensenada, B.C, C.P. 22860, Mexico

Tectonic knowledge of the Gulf of California - Salton Trough region has improved greatly from geological and geophysical studies by many workers. We highlight key new results that are published or in press.

The northern Gulf basins, onland and offshore, have been imaged by Mexican researchers using PEMEX data. This reveals detailed basin geometry and development, including the role of low-angle normal faults within the marine basins, and inactive basins east of the Cerro Prieto fault. High heat flow along active basin-bounding faults constrains processes of crustal formation in the northern Gulf where true seafloor spreading is still absent.

Details of timing and amount of rifting remain controversial. Detailed studies of the N Gulf coastal regions indicate that at 12.5 Ma the area had low topographic relief, allowing deposition of a widespread subaerial ignimbrite, with faulting and basin formation starting at ~9-7 Ma. However, middle Miocene nannofossils from adjacent marine drill holes are interpreted as primary (Helenes et al 2009), suggesting that considerable pre-12 Ma lithospheric thinning should be found. Earlier estimates of ~270 km of net plate boundary slip within the N Gulf agree well with San Andreas system displacements and with a new correlation of evaporites from the Guaymas margin to Santa Rosalia in Baja California Sur, with offset of ~280 km since 7 Ma (Miller & Lizarralde 2013). Buried faults of inland Sonora may accommodate up to 100 km additional offset of ~12 Ma volcanic rocks (Vidal-Solano et al., in press). Geophysical estimates of total plate boundary slip are larger for the southern Gulf than for the northern Gulf.

Major changes in deformation at ~8 Ma in the southern Gulf and peninsula are interpreted from seismic evidence for basin development (Sutherland et al. 2012) and uplift (Brothers et al. 2012). Changes at 8-7 Ma along most of the modern Gulf may eventually be reconciled into a coherent kinematic model for plate boundary deformation linked to increased transtensional motion of the Pacific plate relative to North America at ~ 8 Ma. Entrance of seawater into the Gulf basins may not have been simultaneous along the entire length of the Gulf. The effect of ~5.5 Ma arrival of Colorado River water and sediment into the Northern Gulf still remains to be integrated into the history of plate margin development.

13-3 **8:45 AM** Ferrari, Luca

LATE OLIGOCENE TO MIDDLE MIOCENE RIFTING AND SYN-EXTENSIONAL MAGMATISM IN THE SOUTHWESTERN SIERRA MADRE OCCIDENTAL, MEXICO: THE BEGINNING OF THE GULF OF CALIFORNIA RIFT

FERRARI, Luca[1], MARTINEZ-LOPEZ, Margarita[2], OROZCO ESQUIVEL, Maria Teresa[3], BRYAN, Scott[4], DUQUE, Jose[3], and LONSDALE, Peter[5], (1) Instituto de Geología, Universidad Nacional Autonoma de Mexico, Circuito Investigacion Cientifica, Ciudad Universitaria, Mexico City, 04510, Mexico, luca@unam.mx, (2) Centro de Investigacion Cientifica y de Educacion Superior de Ensenada, Ensenada, Baja California, 22860, Mexico, (3) Centro de Geociencias, Universidad Nacional Autonoma de Mexico, Campus Juriquilla, Blvd. Juriquilla 3001, Queretaro, 76230, Mexico, (4) Earth, Environmental and Biological Sciences, Queensland University of Technology, GPO Box 2434, Brisbane, 4001, Australia, (5) Scripps Institution of Oceanography, UCSD, 9500 Gilman Drive, La Jolla, CA 92093

Although Basin and Range-style extension affected several areas of western Mexico since the Late Eocene, extension in the Gulf of California region (the Gulf Extensional Province GEP) is thought to have started as subduction waned and ended at ~14-12.5 Ma. A general consensus also exists in considering the mid-Miocene Comondú group as a supra-subduction volcanic arc. Our new integration of the geology of the southeast Gulf region, backed by 43 new Ar-Ar and U-Pb mineral ages and geochemical studies, document a widespread phase of extension in the southern GEP between latest Oligocene and Early Miocene that subsequently focused in the region of the future Gulf in the Middle Miocene. Upper Oligocene to Lower Miocene rocks across the southern Sierra Madre Occidental (SMO) (northern Nayarit and southern Sinaloa) were affected by major ~N-S to NNW striking normal faults prior to ~21 Ma. Then, between ~21 and 11 Ma, a system of NNW-SSE high angle extensional faults continued extending the southwestern side of the SMO. Rhyolitic domes, shallow intrusive bodies, and lesser basalts were emplaced along this extensional belt at 20-17 Ma. In northern Sinaloa, large grabens were floored by huge dome complexes at ~21-17 Ma and filled by continental sediments with interlayered basalts dated at 15-14 Ma, a setting and timing very similar to Sonora. Early to Middle Miocene volcanism, including the largely volcaniclastic Comondú strata in Baja California Sur, was thus emplaced in rift basins and was likely associated to decompression melting of upper mantle (inducing crustal partial melting) rather than to fluxing by fluids from the young subducting plate. Along the Nayarit and Sinaloa coast, flat-lying basaltic lava flows dated at 11-10 Ma are exposed just above the present sea level. Here, crustal thickness is almost half that in the unextended core of the SMO, implying significant lithosphere stretching before ~11 Ma. Our study shows that rifting began much earlier than Late Miocene and provided a fundamental control on the style and composition of volcanism from at least 30 Ma. We envision a sustained period of lithospheric stretching and magmatism during which the pace and breadth of extension changed at ~20-18 Ma to be narrower and likely more rapid, and again at ~12.5 Ma, when the kinematics of rifting became more oblique.

13-4 **9:05 AM** Gans, Phillip B.

LATE MIOCENE (12-6 MA) TRANSTENSIONAL FAULTING, BLOCK ROTATIONS, AND VOLCANISM DURING INCEPTION OF THE GULF OF CALIFORNIA OBLIQUE RIFT, SOUTHWESTERN SONORA, MEXICO

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The history of late Miocene (Proto-Gulf) deformation on the Sonoran margin of the Gulf of California is key to understanding how Baja California was captured by the Pacific plate and how strain was partitioned during early stages of this transtensional rift system. Geologic mapping and paleomagnetic investigations in southwestern Sonora and 40Ar/39Ar dating of pre-, syn-, and post-tectonic volcanic units indicate that late Miocene deformation was largely restricted to a NW-SE 100-120 km wide coastal belt. Extension inboard of this area is older (>15 Ma) and occurred in an intra-arc setting. In the coastal belt, deformation is profoundly transtensional, with NW-SE striking, dextral strike slip faults operating in concert with N-S and NNE-SSW striking normal and sinistral-normal faults, producing large-scale rotations about both horizontal and vertical axes, and yielding an overall NW to WNW extension direction. This fundamentally triaxial strain field produced clockwise vertical axis rotations of up to 112° and tilts of up to 90° on blocks bound by arrays of antithetic sinistral-normal faults. The total amount of mid- to late- Miocene NW

directed extension is still poorly constrained, but likely exceeds several hundred km. Within this late Miocene Sonoran coastal belt, deformation and volcanic activity migrated NW. Inboard (Sierra Libre and Sierra El Bacatete) volcanism commenced at ~13.0 Ma and peaked at 12.0 Ma, with deformation largely bracketed between 12.0 and 10.6 Ma. In the Sierra El Aguaje, volcanic activity commenced at 11.0 Ma and peaked at 10.5 Ma, with most faulting and tilting tightly bracketed between 10.7 and 9.3 Ma. On the coastal mountains north of San Carlos, faulting and tilting continued after 8.5 Ma. Voluminous and compositionally diverse (basalt to rhyolite) late Miocene (13-8 Ma) volcanic rocks within the Sonoran coastal belt were erupted from several large centers (e.g. Sierra Libre, Sierra El Aguaje). This eruptive activity was closely associated in space and time with tectonic activity, with transtensional deformation apparently triggered and localized by pulses of magmatic activitiy. The Sonoran coastal belt represents a spectacular example of distributed transtension that ultimately led to rupturing of the continental lithosphere.

13-5 **9:25 AM** Bennett, Scott E.K.

TIMING AND MAGNITUDE OF TRANSFORM FAULTING IN THE NORTHERN GULF OF CALIFORNIA: IMPLICATIONS FOR OBLIQUE RIFT LOCALIZATION AND RECONSTRUCTIONS OF THE PACIFIC-NORTH AMERICA PLATE BOUNDARY

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The Gulf of California oblique rift has accommodated dextral-oblique Pacific-North America (PAC-NAM) plate divergence since Miocene time. Its rifted margins preserve a rare onshore record of early continental break-up processes from which to investigate the role of rift obliquity in strain localization. We integrate structural mapping and basin analysis of syn-tectonic sedimentary basins with geochronology of pre- and syn-rift volcanic units to estimate the timing of rift-related fault activity and basin formation on Isla Tiburón, an exposure of the North America margin proximal to the rift axis. On southern Isla Tiburón, an early phase of east-west extension initiated sometime after ~19 Ma and was ongoing by ~12.3 Ma, when deposits of the Tuff of San Felipe were emplaced. Extensional faults and basins were subsequently buried by younger deposits of the La Cruz basin, which accumulated along the La Cruz fault ca. ~8 - 4 Ma due to 5 ± 2 km of dextral motion. On northeastern Isla Tiburón, transtension also commenced in the latest Miocene, recorded by <7.1 Ma Tecomate basin deposits that accumulated above the hanging wall of the Kunkaak normal fault. Strike-slip faulting along the Yawassag fault truncated Tecomate basin-fill and the Kunkaak fault via ≥8 km of post-6.4 Ma dextral offset. Onset of strike-slip faulting on Isla Tiburón was synchronous with the onset of transform faulting along a significant length of the PAC-NAM plate boundary ca. 9 - 7 Ma. This event was coeval with a 15 - 20° clockwise azimuthal shift in PAC-NAM relative motion that enhanced the obliquity of the rift, and immediately preceded strain localization ca. 6 Ma. The restored, latest Miocene positions of focused transtensional activity are restricted to a ~50 - 100 km-wide, NNW-trending belt, embedded within the western Mexican Basin and Range. A paleomagnetic transect across the plate boundary at the latitude of Isla Tiburón shows that only drill sites within this belt have experienced large magnitude clockwise vertical-axis block rotations. The proto-Gulf of California illustrates how highly oblique rift geometries, where transform faults develop and are kinematically linked to large-offset normal faults in pull-apart basins, enhance the ability for rupturing continental lithosphere and, ultimately, hasten the formation of new oceanic rift basins.

13-6 **10:00 AM** Martín, Arturo

EXTENT AND COMPOSITION OF THE NEW CRUST BENEATH RIFT BASINS IN THE NORTHERN GULF OF CALIFORNIA

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The rupture of continental lithosphere in the northern Gulf of California occurs across the Wagner, Upper Delfin and Lower Delfin basins. Structural mapping on a 5-20 km grid of seismic reflection lines obtained by PEMEX constrains the maximum length of new crust in the Upper Delfin basin to <40 km based on the lack of an acoustic basement and the absence of a lower sedimentary sequence beneath the >5 km thick, wedge-shaped upper sequence. Numerous magmatic intrusives, volcanic edifices and their pyroclastic deposits are imaged within the Upper and Lower Delfin basins in both the PEMEX (6 s of TWTT) and the Ulloa 99-5 (2 s of TWTT) seismic lines. Samples of submarine and subaerial Quaternary volcanoes are rhyolitic to andesitic with geochemical characteristics and Sr-Nd isotope ratios that suggest a MORB-type parent magma. We infer that basaltic melts intrude the base of Late Miocene sedimentary deposits, whereas differentiated magma rise to shallower levels within the sediments and produce submarine volcanic eruptions. In order to investigate the effects of the thick sedimentary lid in the ascent of magma we constructed a simple hydraulic model to calculate the neutral buoyancy level of basaltic melts (2.68 g/cc), andesite (2.45), and rhyolite (2.25). The structure of the lithosphere is constrained with the wide-angle seismic refraction profile of González-Fernández et al. (2005). Density of sediments is constrained with well density logs, and magma pressure is controlled by density contrast and tensile strength of rocks (9 to 1 MPa). The model predicts that basaltic magma may reach a maximum of 1-1.3 km beneath the seafloor within the axial trough in the Upper Delfin basin. Only andesite to rhyolite magma reaches shallower levels, where they exsolve volatiles and produce submarine eruptions. Our results indicate that thick sedimentary deposits control magma ascent and differentiation in rift basins and contribute to produce a hybrid type of crust composed of basaltic and differentiated intrusive-extrusive rocks and meta- to unmetamorphosed sedimentary rocks.

13-7 **10:20 AM** Nourse, Jonathan A.

HOW DOES THE EASTERN CALIFORNIA SHEAR ZONE PROJECT INTO SONORA, MEXICO?

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Much discussion on reconciling the Late Cenozoic North American-Pacific relative plate motion budget has addressed the Walker Lane and Eastern California Shear Zone. An important piece of the story resides along the SE projection of these zones in Mexico. One broad constraint from latitudes 31°-33° N involves 370±50 km dextral offset of the Eocene Poway conglomerate from its northern Sonora bedrock source (Abbot and Smith, 1989). Only ~250 km of this displacement can be accommodated by the San Andreas-San Gabriel-Gulf of California fault system, implying that significant missing slip has accumulated on faults between the Gulf and central Sonora since Eocene time. Several candidate structures are identified in the Arizona-Sonora border region SE of Yuma. Across a 50 km–wide belt between Cerro Pinto, Sonora and Sierra Pinta, Arizona, distinctive geologic contacts are dextrally offset along five hypothetical NW-trending faults. Cumulative distributed displacement across this shear zone is 50±10 km. One structure records ~21km of dextral displacement of an Eocene(?) river channel and overlying Mid-Miocene volcanic strata from bedrock sources composed of distinctive Proterozoic and Cretaceous units. Other offset markers include various Late Cretaceous-Proterozoic intrusive contacts. This dextral shear zone projects SE into the Quaternary Pinacate volcanic field and does not appear to disrupt it. Farther SE near Caborca, Sonora, cryptic evidence for additional pre-Quaternary, post-Mid Miocene dextral faulting and associated vertical-axis block rotation is preserved. Jurassic arc strata of the Juarez-San Francisco mining district are broken into diamond-shaped blocks by NW dextral faults and NE sinistral faults that disrupt brittle structures related to Mid Miocene detachment faulting. Easterly mylonitic lineation of the 15 Ma Cerro Carnero core complex are misaligned from the regional N60E trend, suggesting block rotation between two NW-trending dextral faults transecting the Caborca-Altar valley. Such field relationships and the relative seismic quiescence of NW Sonora support existence of a significant dextral shear zone operative during the important Late Miocene time period within a region where 100+ km of right slip is needed to balance the relative plate motion budget.

13-8 **10:40 AM** Singleton, John

POST-MIDDLE MIOCENE DEXTRAL FAULTING IN THE LOWER COLORADO RIVER EXTENSIONAL CORRIDOR: INSIGHTS FROM THE BUCKSKIN-RAWHIDE CORE COMPLEX, WEST-CENTRAL ARIZONA

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Structural data from the Buckskin-Rawhide metamorphic core complex in west-central Arizona document the Miocene transition from large-magnitude, NE-directed extension to distributed dextral shear along NW-striking faults. The Buckskin detachment fault locally records a clockwise rotation of the slip direction from dominant top-NE-directed slip to ENE- and E-directed slip during the late stages of activity. New (U-Th)/He thermochronology of lower plate mylonites and $^{40}Ar/^{39}Ar$ geochronology of postdetachment volcanic rocks indicate that detachment faulting ceased ca. 12-11 Ma. Postdetachment deformation was dominated by E-W extension and associated dextral-normal faulting. At least ten NE-dipping postdetachment faults record ~0.1-1 km dextral or oblique dextral displacement. The cumulative amount of dextral shear across the core complex is probably 7-9 km, which is the amount needed to restore the topographic trend of lower plate corrugations into alignment with the dominant extension direction. Geologic mapping confirms that the misalignment between the lower plate topography and the corrugation axis in the Little Buckskin Mountains is due to dextral faulting. Postdetachment dextral/transtensional faulting across the core complex reflects the increasing influence of the diffuse Pacific-North American transform plate boundary towards the end of the middle Miocene. Although strike-slip faulting associated with this plate boundary is not well recognized in the lower Colorado River extensional corridor, post-middle Miocene dextral faults appear to be widespread across the region and most likely account for at least 15 km of dextral shear.

13-9 **11:00 AM** Darin, Michael H.

CUMULATIVE DEXTRAL STRAIN ACROSS THE MIOCENE-PRESENT PACIFIC-NORTH AMERICA PLATE BOUNDARY: EASTERN CALIFORNIA SHEAR ZONE TO THE NORTHERN GULF OF CALIFORNIA

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Late Cenozoic Pacific-North America (PAC-NAM) plate motion has been accommodated by a combination of localized and distributed shear, transtension, transpression and rotation of crustal-scale faults blocks. At the latitude of the Gulf of California (GOC), a global plate circuit model requires 600-650 km of cumulative northwestward displacement of the Pacific plate relative to the North America plate since 12.3 Ma, distributed in an uncertain way on faults both west and east of the stable Baja California microplate. Existing kinematic models estimate from as little as 300 km to as much as 450-500 km of cumulative dextral shear east of the Baja California microplate, with transtensional structures west of Baja California accommodating the residual component of PAC-NAM dextral shear. We compile late Cenozoic fault displacement data from the northern GOC, Salton Trough and Eastern California Shear Zone to test the compatibility of these kinematic models with known dextral displacements. Because no large-offset, trans-peninsular dextral faults cut the stable Baja California microplate, cumulative dextral shear across the northern GOC should be consistent with cumulative dextral shear along plate boundary strike across southern California and Arizona. Summation of dextral displacements across several onshore transects, perpendicular to the PAC-NAM plate boundary, consistently reveal ~320-380 km of total intracontinental shear. These findings suggest that previous models for relatively small offset (300 km) underestimate known geologic offsets, while larger offset models (450-500 km) require an additional 70-180 km of dextral plate motion that is currently undocumented in the northern GOC and southwestern United States. Thus, we propose a moderate-offset model in which ~320-380 km of dextral shear occurred across the northern GOC and southwestern United States, while ~220-330 km of shear occurred offshore southern California and northern Baja California. Discrepancies with larger post-12.3 Ma estimates across the southern GOC could be partially resolved if some PAC-NAM motion occurred west of the Magdalena fan. Additionally, several tens of km more dextral shear likely occurred along transform faults in the southern GOC than in the north because the southern GOC is farther from the PAC-NAM Euler pole.

13-10 **11:20 AM** Umhoefer, Paul J.

RECONSTRUCTING THE GULF OF CALIFORNIA-SALTON TROUGH OBLIQUE PLATE BOUNDARY WITH GIS MAPS SINCE 12 MA

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We present GIS-based reconstructions for the Pacific-North America (PAC-NAM) oblique plate boundary. Our maps track PAC-NAM deformation since 12 Ma, at 1-2 Myr intervals, and use existing data to close basins, restore slip on faults, and restore rotated blocks. We use modern-day GPS motion between the Baja California microplate (BCM) and North America (NAM) (from R. Malservisi) for the BCM and intervening tectonic blocks. Extrapolation of these rates back to 7 Ma produces maps that agree well with many aspects of the southern and northern Gulf. GPS-based rates in the north result in ~320 km of BCM-NAM motion since 7 Ma, and ~300 km since 6.5 Ma. These rates agree with geologic tie points across the northern Gulf and with the latest

geologic evidence along a transect of dextral offsets from the northern BCM to coastal Sonora, east of Tiburon Island. In the southern Gulf, the 7 Ma model results in ~340 km of BCM-NAM offset at San Jose del Cabo and ~330 km at Loreto. Cross-Gulf geologic tie points are lacking in the southern Gulf, but the 7 Ma map fits many documented geologic aspects. At 7 Ma, we model an enclosed Guaymas basin similar to the salt basin observed in seismic data and on the conjugate Santa Rosalia coastline. At ~7 Ma, Guaymas basin was isolated from the northern Gulf basins, and from the Farallon basin to the south, then the north end of a ~100 km-wide seaway. This incipient seaway was co-located with a longer, nascent transtensional belt that developed from the northern end of the Maria Magdalena rise to the Salton Tough. In order to match the full 51 mm/yr PAC-NAM budget, we add 21 km of dextral offset west of the BCM in the south and 35 km in the north since 7 Ma. The proto-gulf maps from 7 to 12 Ma are much less constrained. PAC-NAM motion requires ~610 km total offset since 12 Ma. This suggests that there must be 250-300 km of dextral offset outside the Gulf axis prior to 7 Ma, distributed in the borderland west of the BCM and/or in mainland Mexico. Our preferred model accommodates ~200 km proto-gulf motion west of the BCM. This preferred model shows ~400 km BCM-NAM offset in the south, and ~360 km offset in the north since 12 Ma; the north-south discrepancy is due to variable Euler pole distance along plate boundary strike. Maximum allowable offset is ~450 km in the south and ~400 km in the north, as any further offset produces unacceptable overlap of crust.

SESSION NO. 14, 8:00 AM

Tuesday, 21 May 2013

Engineering and Environmental Geology (Posters)

Radisson Hotel and Conference Center, Salon B/C

14-1 **BTH 1** Testa, Stephen M.

FROM AGGREGATE AVAILABILITY TO SUSTAINABILITY IN CALIFORNIA

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California leads the nation in the production of sand and gravel, and ranks second behind Texas in the production of portland cement. Under the California Surface Mining and Reclamation Act of 1975 (SMARA), the State Geologist classifies mineral resources solely on geologic factors, and without regard to existing land use and land ownership. Following classification, the State Mining and Geology Board (SMGB) may consider “designating” such lands should the classified area contain mineral resources of regional or statewide economic significance and that may be needed to meet future demands. Maps and descriptions of the designated mineral lands were placed in the California Public Resources Code and officially transmitted to those lead agencies having permitting authority over those lands. CGS’s statewide Aggregate Availability Map, commonly referred to as Map Sheet 52, was developed in 2002 and updated in 2006. The purpose of Map Sheet 52 was to compare projected aggregate demand for the next 50 years with currently permitted aggregate resources in 31 “production-consumption” regions of the state, and flag regions where there were less than 10 years of permitted aggregate supply remaining. The 31 P-C aggregate study areas covered about 25 percent of the State’s geography, but about 90 percent of California’s population. It was shown that in the next 50 years, California was projected to need approximately 13.5 billion tons of aggregate. Map Sheet 52 demonstrated the need for additional permitting of mineral resources, but did not address the overall effectiveness of the state’s efforts to protect aggregate resources, or aggregate sustainability. To address the effectiveness of the state’s overall efforts to conserve and address aggregate sustainability, new maps are being considered. These maps may incorporate other factors to reflect the pace of urbanization, quality of the mineral resource, and environmental factors (i.e., sensitive habitat, wildlife refuge, etc.), material haul distances, infrastructure (suitability of roads and bridges) condition, and greenhouse gas emissions.

14-2 **BTH 2** Rubin, Ron S.

NEW REGULATORY FAULT RUPTURE HAZARD ZONES BY STATE OF CALIFORNIA

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The California Geological Survey (CGS) has released new and revised Alquist-Priolo Earthquake Fault Zone (APEFZ) maps in Alameda and Ventura Counties. APEFZ maps are regulatory documents defining zones in which detailed fault investigations are required for property development. The zones are intended to preclude construction across Holocene-active faults. Completed Fault Evaluation Reports (FER) evaluated geomorphology and available subsurface data, and faults are zoned based the criteria ‘sufficiently active’ and ‘well-defined’, as per CGS SP 42. As part of these new map releases, CGS now combines APEFZ maps with Seismic Hazard Zone (SHZ) maps in one product, when both are available.

In Alameda County, the existing APEFZ in the Hayward Quadrangle is revised to include two branches of the Hayward Fault (HF). The Ashland Fault (AF) branches northwest from the HF and extends approximately 2 km through an area of extensive residential development. It is interpreted to be an oblique reverse fault that merges with the Hayward at relatively shallow depths. The AF was previously encountered during local construction and subsequently zoned by the County. Evidence for Holocene activity on the AF includes a curvilinear scarp in Holocene alluvium, and bedrock juxtaposed against Holocene soils. Scarp heights range from 3 m to over 8 m. The HF APEFZ is also revised to include a smaller branch to the northeast, which occupies an area of mostly public land with the exception of an abandoned quarry where a multi-unit development was previously proposed.

In Ventura County, the existing Piru Quadrangle SHZ map now incorporates a new APEFZ for the San Cayetano Fault (SCF). The SCF is a major east-west-trending north-dipping reverse fault, extending from Upper Ojai Valley eastward to Fillmore, then along the base of the Topatopa Mountains where it terminates approximately 5 km east of Piru. Within the quadrangle, the SCF bifurcates into the Main and Piru strands. South-facing scarps up to 8 m high within alluvium were interpreted as evidence that portions of the Main and Piru strands were Holocene-active. Two paleoseismic trenches previously excavated across a prominent scarp along the Piru strand indicate 4.3 to 5 m of apparent offset related to the most recent event.

14-3 **BTH 3** Sutherland, Michelle Allison

CORRELATING SURFACE GEOLOGY WITH 1913-VINTAGE AS-BUILT GEOLOGY ACROSS THE SAN ANDREAS FAULT FOR SEISMIC ENHANCEMENT OF THE ELIZABETH TUNNEL, LOS ANGELES AQUEDUCT

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Vulnerability of the five-mile-long Elizabeth Tunnel to earthquake hazards was recognized by the City of Los Angeles in 1913 when it was constructed across the San Andreas Fault Zone (SAFZ) as part of the initial Los Angeles Aqueduct (LAA). In 1970, the second LAA went into service, in the same tunnel crossing the SAFZ. Currently, 50% of the City’s water is imported through this tunnel. Viable mitigation alternatives are difficult to identify and to date no hazard mitigation measures have been implemented, However, the City plans to install a 30” HDPE pipe in the 9x11’ concrete-lined tunnel to enhance the likelihood that water will get through following a SAFZ earthquake. The initial pipe segment will cross the 2000’-wide SAFZ, with additional segments added during annual maintenance shutdowns. As-built tunnel records revealed reasonably good rock quality in the SAFZ , whereas poor-quality rock was 3500-4000’ to the south. A laser survey in 2012 demonstrated no creep deformation. Four subparallel faults cross the tunnel, including the SAFZ which is near the tunnel midpoint. Published geologic maps show gneissic and granitic rocks along the alignment. “Quaternary-Tertiary crushed granitic rocks” is mapped in fault contact with Cretaceous quartz monzonite and quartz diorite above the poor-quality rock in the tunnel about 900’ below ground. Field observations revealed minor differences between crushed and non-crushed granitic rocks, suggesting most rock in SAFZ proximity has been tectonized. One small zone of gneiss mapped against crushed granitic rock is a reminder of the scale of faulting and potential for variable conditions at depth. As-built geologic conditions within the tunnel are consistent with surface geology. The highest hazard to the tunnel is fault displacement, followed by roof collapse in the poor-quality rock. These considerations are guiding seismic enhancement to allow water flow following a major SAFZ earthquake.

14-4 **BTH 4** Kennedy, Drew G.

OPEN CANAL SOLUTION FOR ADDRESSING THE STABILITY OF AN UNSUPPORTED WATER CONVEYANCE TUNNEL

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A non-pressurized water conveyance tunnel on a critical irrigation canal in the lower Sierra Nevada foothills exhibited signs of crown instability, and raised concerns regarding the potential for a large-scale failure that could completely block canal flow, resulting in millions of dollars of crop losses. The tunnel is on the Upper Main Canal, a 70 cubic meter/second canal that conveys water from the Tuolumne River to Turlock Lake for agricultural irrigation in California’s fertile Central Valley. The approximately 110-meter-long tunnel was originally constructed in 1891, and was later enlarged in 1914 to a typical cross section of 9 meters wide and 7 meters tall. The tunnel was excavated primarily within a sandstone unit of the Mehrten Formation. The concrete-lined invert and sidewalls performed well with no evidence of instability, but a large domed cavity had formed in the unsupported crown near the center of the tunnel. The cavity extended approximately 5 meters above the original crown, exposing an alluvial paleochannel filled with a low-strength conglomerate unit. Detailed crown mapping combined with six exploratory borings and seismic refraction surveys indicated that the conglomerate unit was unfavorably positioned within 4.5 meters above the crown along much of the tunnel. Tunnel rehabilitation options considered included stabilizing the tunnel crown via mechanical support, and daylighting (open cutting) the tunnel. Internally-braced crown support systems, such as steel ribs and lagging, were evaluated. However, given to the position of the conglomerate unit, the daylighting option was found to be best suited to meet the owner’s objective for a long-term reliable solution. Following extensive environmental permitting efforts, the tunnel crown was removed during an annual outage in late 2012. The contractor opted to excavate the crown using conventional grading equipment rather than blasting to minimize damage to the canal lining. The tunnel crown was removed over five weeks with minimal damage to the canal lining and within the outage window. This project presents a unique case study of addressing the potential vulnerability of a critical irrigation canal to tunnel failure by daylighting, and the lessons learned may translate to similar projects throughout the western United States.

14-5 **BTH 5** Drew, Dennis

AN INVESTIGATION OF THE USE OF MOBILE LIDAR ON THE LEVEE SYSTEM OF CALIFORNIA DURING AN EMERGENCY FLOOD

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The purpose of this project is to show that the Levee system will always need monitoring in an emergency situation. LiDAR will be able to assist emergency engineers in detecting boils as well as showing the contours of the terrain. LiDAR or light detecting and ranging is a tool used by surveyors to give a three-dimensional view of the terrain. Levee failure can be detected by the observance of boils. Boils are the results of leeway seepage and piping usually caused by small creatures such as sand crabs and snakes. This experiment used a water sustained box that was filled with soil from the Chowchilla bypass. Traditional plumbing was used to imitate the piping process. Through a steady-state of water, boils were created in an environmentally controlled situation. Using the Lycia 3000 it was possible to take a LiDAR scan of a boil. A comparison of experimental data is made to Twichel Island.

This project investigated the need for continuous monitoring of levee and boils during the event of a flood emergency using LiDAR (Light Detection and Ranging). This project was engendered by the April 2006 high water event around the city of Firebaugh and the Chowchilla bypass. Outdated maps led to incorrect information which might lead to incorrect decisions. LiDAR (Light Detection and Ranging) is used extensively in air and also can be used as a land-based and mobilized scanner. LiDAR not only sees the contours of the terrain but also can be used for the detection of the formation of boils on the landward side of the Levees. This project also looked at the occurrences and behaviors of boils which are the primary indicator of possible catastrophic failure to the Levee system. A boil is the result of head pressure forcing its way through sand. Piping is the avenue from which a boil is created and can cause levee failure. Levee failure can cost many millions of dollars in damage as well as loss of life. Failure to detect boils will result in possible failure of the Levee system such as witnessed in the Jones tract breech and the Fallon flood. Using LiDAR it is possible to realize boils in a timely manner.

14-6 **BTH 6** Lindsey, Kassandra O.

RADON HOT SPOTS IN OREGON AND THE UNDERLYING GEOLOGY

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Radon exposure in homes is a huge concern because it is the leading cause of lung cancer in non smokers. In order to determine which areas in Oregon are at risk, the maximum and average radon reading and the percent of reports with a reading greater than 4 pCi/L were recorded, and the radon potential was calculated for 265 ZIP codes. Statewide, 232 ZIP codes have long term data and 207 have short term data. Based on long term data there are three ZIP codes with a high radon potential: 97281 (Silverton), 97630 (Lakeview), and 97862 (Milton-Freewater). Additionally, 42 ZIP codes have moderate radon potential, 46 have low radon potential, and 141 are uncategorized. Based on short term data there are 10 ZIP codes with high radon potential: 97002 (Aurora), 97103 (Astoria), 97304 (West Salem), 97306 (Salem), 97338 (Dallas), 97831 (Silverton), 97392 (Turner), 97457 (Myrtle Creek), 97850 (La Grande), and 97862 (Milton-Freewater). Additionally, 27 ZIP codes have moderate radon potential, 38 have low radon potential, and 132 are uncategorized. There are 33 ZIP codes for which short and long term test data conclude the same level of radon potential. Some increased or decreased a level or two from long to short term test types. There are 11 ZIP codes that increase by a level, 9 ZIP codes that decrease by a level, and 1 that decreased from high to low. Some moderate and high radon potential readings in Oregon are caused by structural weaknesses in rocks that allow radon to travel to the surface, like faults. Others occur where there are unconsolidated sediments like Missoula Flood deposits or landslide deposits. The higher permeability of these deposits allows radon to be released into the air easily. Rocks like granites release radon into the air, so areas with granitic terranes and intrusions are at risk of higher radon exposures.

14-7 **BTH 7** Whitney, Hilary

RADON IN HOMES IN THE PORTLAND, OREGON AREA: RADON DATA FROM LOCAL RADON TESTING COMPANIES COLLECTED BY CRM (CONTINUOUS RADON MEASUREMENT) MACHINES

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Students from the Department of Geology at Portland State University paired up with the Oregon Health Authority to better understand radon gas values in homes of the Portland metropolitan area. This study focuses on radon values collected by continuous radon measurement (CRM) machines, taken by local radon testing companies. The local companies participating in this study include Alpha Environmental Services, Inc., Cascade Radon, Environmental Works, The House Detectives, LLC, and Soil Solutions Environmental Services, Inc. In total, 2491 radon readings spanning across 77 zip codes were collected from local companies in the Portland metropolitan area. The maximum value, average value, percentage of homes greater than 4 pCi/L and total rank sum was calculated and used to determine the overall radon potential for each zip code (Burns et al., 1998). A list and four maps were produced showing the results from each category. Out of the total records, 24 zip codes resulted in high radon potential and the average reading for the entire Portland Metropolitan area was 3.7 pCi/L. High potential zip codes are thought to be a result of sand and gravel (Missoula Flood deposits) and faults present in the subsurface. The CRM data was compared with both long-term and short-term data provided by the Oregon Health Authority to validate radon potentials in each zip code. If a home is located in a zip code with high or moderate radon potential across 2 types of data sets, it is recommended that those homes be tested for radon gas.

14-8 **BTH 8** Linde, Tamara C.

A COMPARISON OF GEOLOGY TO RADON TEST DATA IN PORTLAND, OREGON

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In recent research, radon has been identified as the second leading cause of lung cancer. Radon gas exists naturally at low levels; it is when the gas becomes concentrated in living spaces that a health hazard arises. Radon distribution in the Portland area was last performed in 2003 for long-term test data. The intent of this examination is to provide an update to the 2003 data and for the first time examine short-term testing data. The raw data was limited to tests performed in living areas only, and the highest reading for a given address. Radon distribution is based on zip code geographical boundaries. This examination adds 65 zip codes to the 2003 dataset. Each zip code was examined for maximum radon reading, average radon reading, and percent greater than 4 pCi/L. These four values combined determine the radon potential for each zip code. Based on the long-term data, nearly 90% of homes in the Portland area have moderate to high radon potential. The short-term data indicates that nearly 98% of homes are within these ranges. There is some variation in the distribution of radon levels within the Portland metro area and one of the reasons for this is that zip codes cut across geologic boundaries. Geologic examination shows that the moderate and high potential areas are associated with porous Missoula Flood deposits or landslide deposits that allow for easier release of radon gas. Radon hazard potential can be better understood with an examination of the underlying geology.

14-9 **BTH 9** Burns, Scott F.

ARSENIC IN SOILS OF NORTHWESTERN OREGON

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186 soil samples from Northwest Oregon were tested for arsenic content. The highest values measured were 13.9 ppm in the A horizon (site C4) and 20.4 ppm in the B horizon (Site P4). Arsenic was not detected in 28 A horizon samples and 23 B horizon samples. Data are grouped based on the age and rock type of underlying bedrock. Lithologic groups with six or more data points were compared statistically to ascertain if groups are distinct. Analysis of Variance (ANOVA) multiple comparison tests indicate that the arsenic content of the Marine Sediments and Sedimentary Rocks group samples is distinguishable from the Quaternary Basalts group in the A horizon and all other groups in the B horizon. Kruskal-Wallis multiple comparison tests indicate that the arsenic content of the Marine Sediments and Sedimentary Rocks group is distinguishable from the Quaternary Basalts, Quaternary/ Tertiary Sediments and Sedimentary Rocks and Volcanic Sediments groups in both the A and B soil horizons. The ANOVA and Kruskal-Wallis tests compared A and B horizon data by lithologic group. The ANOVA shows the Marine Sediments and Sedimentary Rocks group in the A horizon is distinct from the Quaternary Basalts in the A and B horizon. The KruskalWallis test yielded the same result. Per the ANOVA, the Marine Sediments and Sedimentary Rocks in the B horizon are distinct from all other tested groups. The Kruskal-Wallis test shows the Marine Sediments and Sedimentary Rocks group in the B horizon as distinct from the Quaternary Basalts, Quaternary/ Tertiary Sediments, and Volcanic Sediments groups in the A and B horizon. Three, four, and five group analyses were conducted, and the results of these tests were compared to the data grouped by underlying rock type. This analysis supports the creation of a map distinguishing arsenic content in the soils above Marine Sediments and Sedimentary Rocks group units from arsenic content in all other tested lithologic groups. The mean and standard deviations of these groups (in ppm) are: A horizon: Marine Sediments (6.09 ±2.66); other groups (3.10 ±3.19); B horizon: Marine Sediments (10.26 ±4.65); other groups (3.13 ±2.52). This analysis indicates that geologic context must be taken into account when determining background levels of naturally occurring arsenic in soils.

14-10 **BTH 10** De Graff, Jerome V.

OBSERVATIONS DEMONSTRATING THE RUNOFF-INITIATION OF THE JULY 12, 2008 PIUTE WILDFIRE DEBRIS FLOWS, SIERRA NEVADA, CALIFORNIA

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On July 12, 2008, the Piute Mountains south of Lake Isabella, CA experienced a period of intense rainfall. At Piute Peak, a remote automated weather station recorded a rainfall intensity rate of 16.2 and 20.4 mm/h during a thirty minute period (De Graff et al., 2011). The rainfall triggered three large debris flows which passed down Erskine Creek, Clear Creek, and Thompson Canyon respectively (De Graff et al., 2011). Much of the headwater source areas for these debris flows were burned by the Piute wildfire eleven days earlier. Within a week of the storm event, field observations were made of extensive rilling throughout the burned area. This indicated debris flow generation was due to erosion and entrainment of material by surface runoff, a process well documented in other parts of the western United States (Parise and Cannon, 2012). Examination at two areas, one in the headwaters of Thompson Creek and the other within a major tributary to the South Fork of Erskine Creek, verified this process in the generation of the July 12th debris flows. The first area was within the first order channels in the headwaters of Thompson Creek near Piute Peak. Numerous rills spaced approximately 5 feet apart and incised up to 6 inches deep were noted in this area which experienced high to moderate soil burn severity. The rills discharged to a defined ephemeral channel. While sediment-laden water clearly flowed in the upper channel reach, its transformation into a debris flow due to progressive sediment bulking was evident by incision into channel sediments bordered by a mud veneer. This same transformation process was visible along the main channel within the headwaters of a tributary to the South Fork of Erskine Creek. Moderate to high soil burn severity was experienced within this area, too. Along this channel, small debris flows issued from minor tributary channels along the length of the main channel and contributed additional material to the main channel debris flow. Matrix-supported levees were present along many of these contributing debris flows. Evidence of more than one surge was seen at the junction between one of these contributing debris flows and the main channel debris flow. One small headwater debris flow failed to reach the main channel and instead ended in a deposit of matrix-supported material.

14-11 **BTH 11** Wagner, David L.

THE OAK CREEK WATER-SEDIMENT FLOWS OF JULY 12, 2008, INYO COUNTY, CALIFORNIA: A HAZARDOUS RESPONSE TO SIERRAN UPLIFT

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Alluvial fans in Owens Valley form at rates on the order of 0.1 to 0.2 mm/year in response to subsidence of the valley. They are the result of debris flows that occur about once in several hundred years in individual drainages. On July 12, 2008 over 32 mm/hr (1.25 in/hr) of precipitation fell on the Oak Creek drainage north of Independence, in Inyo County, California. The drainage had been burned during the Inyo Complex fire of July 6, 2007. Debris and hyperconcentrated flows ran out 6 to 7 km from the mountain front, destroying 17 homes and severely damaging the historic Mt. Whitney Fish Hatchery. Traffic was disrupted on State Highway 395 for nearly a week. Although slopes were extensively rilled, most of the estimated 1-2 million cubic meters of sediment was scoured from channels and deposited over an area of more than 3 km^2, mostly on younger alluvial fans. Flow surges moved down the North Fork of Oak Creek at estimated speeds of 2 m/sec (~6 mi/hr) to 5.4 m/sec (~12 mi/hr) and were one to three meters high. Sand-rich, hyperconcentrated flows followed the active channel of the north fork of Oak Creek and abandoned channels on the fan filling them, and spread laterally across the interfluves. On the south fork of Oak Creek, boulder-rich debris flows clogged the active channel, leaving a boulder field of at least 1500 m long and 75 m wide, blocking the channel and forcing the south fork to a new course to the west. The largest boulders moved during the storm ranged from 3300 kg (~1300 lbs) to 17,000 kg (11,800 lbs). Older uplifted alluvial fans were unaffected while younger fans were greatly affected. The Oak Creek water-sediment flow is typical of the events that have formed the alluvial fans in the Holocene. Events during late Pleistocene glaciations were probably larger and more frequent.

14-12 **BTH 12** Lancaster, Jeremy T.

OBSERVATIONS DEMONSTRATING THE RUNOFF INITIATION OF THE AUGUST 26, 2010 POSTFIRE DEBRIS FLOWS, HAIWEE CREEK, INYO COUNTY, CALIFORNIA

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On August 26, 2010 in southern Inyo County, CA, at about 2:30pm, a thick slurry of boulders, trees, ash, soil, and water issued out of Haiwee Creek after an intense, short duration cloud burst on a drainage basin that was partially burned by the Clover Fire in July 2008. The wildfire burned 766 acres (3.1 km^2), or 21.6 % of the South Fork Haiwee drainage basin, with <2 %of the watershed burned at low severity, and 19.7 percent at moderate to high severity. From the topographic apex of the Haiwee alluvial fan, the debris flow traveled in surges for over 4.8 kilometers before carrying a semi-tractor and trailer off US Highway 395 at approximate Post Mile 23.7. Flows overwhelmed highway drainage structures and overtopped both the south and northbound lanes with 0.9 to 1.2 meters of debris. The flows proceeded east past the highway continuing another 1.6 kilometers to the valley floor.

Rainfall affecting the Haiwee Creek watershed resulted from a convective system traveling from the southwest, inundating the burn area first and unburned slopes second. The debris flows originated from the burn area in the south fork of Haiwee Creek, developing as concentration of runoff caused progressive increase in flow depth (and channel shear stress) leading to channel scour, bank collapse and the entrainment of sediment and debris. Limited channel scour and debris generation occurred in the unburned portion of the watershed. Within the rugged upland area along Haiwee Creek, east of the confluence of the south and north forks, the debris flows deposited a 1.4 meter thick marginal levee composed of matrix supported cobble and boulder clasts. In contrast, where the flow became unconfined and more broadly distributed near US 395,

deposits lack internal stratification, are relatively thin (up to 0.60 meter) and consist of clayey silt with sand and gravel, including scattered cobbles and boulders with numerous 1-2 millimeter size voids. These contrasting sedimentological characteristics underscore the spatial and temporal variation in flow behavior commonly observed in other debris flow studies. The deposit distribution and textural characteristics coupled with radar rainfall distribution suggest a rainfall runoff sequence that initially generated viscous granular debris flows, followed by a recessional stage dominated by fluidized debris flows.

14-13 **BTH 13** Lancaster, Jeremy T.

ALLUVIAL FAN FLOODING HAZARDS: AN ENGINEERING GEOLOGIC APPROACH FOR REGIONAL PLANNING AND PRELIMINARY DESIGN

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Alluvial fans form where streams emerge from mountain fronts onto relatively flat valley bottoms. Within a mountain range, particularly in areas experiencing tectonic uplift, a stream is often steeply inclined and confined to a single channel by narrow canyon walls. Once a stream reaches the mountain front its gradient typically flattens and waters may spread into a distributary network of channels, both of which reduce the depth and velocity of stream waters and reduce size and volume of sediment that the stream is capable of carrying. Debris flows and hyperconcentrated flows are a common component of actively building alluvial fans. They respond to these diverging channel patterns and lack of channel confinement by avulsing or splaying on to the surface of the alluvial fan, inundating areas that are not typically perceived to be hazardous. To assist regional planning efforts it is important to identify the general distribution and age of alluvial fans, and to characterize the potentially hazardous processes in advance, as development continues to encroach on alluvial fan surfaces. However, the analysis of flood hazards on alluvial fans is complex. A three stage analysis approach developed by the National Research Council (NRC, 1996) uses geologic information, including the review of historic imagery, to assist in establishing alluvial fan boundaries, and relative state of activity. These data provide a physical basis for detailed hydrologic/hydraulic modeling of the design flood on the active fan surfaces.

To address the both necessary information for planning, and in part the first two stages of the NRC analysis approach, the California Geological Survey has developed a engineering geologic approach for assessing the alluvial fan depositional environment as a preliminary means of identifying areas susceptible to alluvial fan flooding. Engineering geologic maps developed from surficial geologic maps and field investigations are used to identify the general distribution of alluvial fans, the relative age of alluvial deposits, and the relative likelihood of alluvial fan flooding. These maps may then form the engineering geologic basis for communicating the potential distribution of alluvial fan flooding from both a planning and preliminary design perspective as well as help frame more detailed geologic studies.

14-14 **BTH 14** Hausback, Brian P.

LANDSLIDE HAZARDS ALONG THE INTERSTATE 80 CORRIDOR ASSOCIATED WITH THE EARLY OLIGOCENE SEDIMENTARY AND VOLCANIC DEPOSITS IN THE SIERRA NEVADA

HAUSBACK, Brian P., Geology, California State University, Sacramento, 6000 J Street, Sacramento, CA 958l9-6043, hausback@csus.edu, WOOD, Jim, Sierra Geological Services, Colfax, CA 95713, HENRY, Christopher D., Nevada Bureau of Mines and Geology, University of Nevada, Reno, NV 89557, and MCCRINK, Timothy P., California Geological Survey, 801 K Street , MS 12-32, Sacramento, CA 95814

Prehistoric to active slope failure near Alta, California threatens important trans-Sierran transportation infrastructure. Eocene to Miocene sedimentary and volcanic deposits unconformably overlie Paleozoic and Mesozoic accreted basement terrains in the highlands between the Bear River and North Fork of the American River. Regional Tertiary units, best illustrated at Chalk Bluff, Nevada County, include the Eocene Ione Fm (auriferous) gravels, Oligocene rhyolitic ash-flow tuffs and interbedded smectitic sediments, and Middle to Late Miocene Mehrten Fm intermediate-composition lahars and alluvial deposits. Tuffs near I-80 were mapped as Valley Springs Fm (VS), but $^{40}Ar/^{39}Ar$ dating and stratigraphic correlations place them between 31.5 and 25.4 Ma, older than the 23 Ma KAr dates at the VS type section (Dalrymple, 1964). All Tertiary units were derived from easterly sources and accumulated in paleochannels. The Ione and smectitic sediments with interbedded tuffs were derived from upland and caldera sources in west and central Nevada, and the Mehrten from ancestral Cascade volcanoes in eastern California and western Nevada.

Widespread slope failure and foundation settling/heaving are associated with smectite clay in the Oligocene section and have occurred through a wide area of the Sierran foothills and adjacent lowlands in the Sacramento Valley. The California Geological Survey issued a Geologic Hazard Notice in 2010 warning of geohazards associated with the smectitic unit.

Slope failure in the smectitic sedimentary section is exacerbated at some locations by interbedded primary and reworked rhyolitic tuff beds. The enveloping clay causes the tuff beds to become confined aquifers. During wet periods the tuff beds with inherent microporosity fill with water resulting in excessive pore pressure. The upper surfaces of the tuff beds at the clay bed contacts become preferred landslide planes.

Preliminary landslide reconnaissance mapping shows that the I-80 roadway, UP railway, and a petroleum pipeline all traverse extensive areas of prehistoric landslide terrain. All transportation lines have suffered repeated historic failures. Better mapping and analysis of hazardous slope failure zones will help in preventative efforts along transportation routes to minimize future economic loss.

14-15 **BTH 15** Wood, Jim

GEOLOGIC HAZARDS IN THE EARLY TERTIARY SEDIMENTS OF THE SIERRA NEVADA FOOTHILLS OF CALIFORNIA

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In 2010 the California Geological Survey issued a Geologic Hazard Notice to warn engineering and building departments in affected cities and counties over concern of problematic smectitic clay fluvial sediments occurring in the Sierra Nevada foothills and adjacent areas of the Sacramento and San Joaquin Valleys. The Geohazard Notice was warranted based on preliminary data and on-going investigations that show the potential for serious engineering problems associated with this fluvial unit including landsliding and expansive soil behavior that leads to severe foundation distress.

The geologic unit in question has been variously mapped in the Sierra Nevada as the upper part of the legendary "Early Tertiary auriferous gravels," while in the Sierra foothills and adjacent lowland valley areas the smectite-rich detrital materials superficially resemble, and are often mapped as the quartzose-kaolinitic Ione Formation sediments. Throughout the region, it has been mapped as the Valley Springs Formation where coherent rhyolitic tuffs are interbedded, yet recent age dates show most tuffs in the Sierra to be considerably older than those in Valley Springs type locality. Traditional reliance on the presence of rhyolite to mark the bottom of the Valley Springs has resulted in the mis-location of the contact between it and the underlying Ione Formation which is part of the reason some recent residential developments have been built on highly expansive smectitic clay without appropriate foundation design in the Sacramento region.

Another contributing factor is that despite careful scrutiny by numerous geotechnical professionals, the smectitic sediments are often classified as reasonably stable and suitable for use as engineered soils. ASTM soil tests often classify these sediments as having low or no expansion potential due to the occurrence of the smectite clay in a cemented granular form. The smectite clasts are stabilized largely by ephemeral amorphous silica as well as other pedogenic cements. Thus, the expansive behavior is latent, and significant soil heaving behavior can be delayed for years following its use as engineered soil. Recent investigations show that X-ray diffraction (XRD) and thin section petrography are other analytical techniques that can reliably assess the expansion potential of these sediments.

14-16 **BTH 16** Stansbeary, Ann M.

INVESTIGATION OF RISING GROUNDWATER LEVEL OBSERVED AT MCMENAMINS EDGEFIELD IN TROUTDALE, OREGON

STANSBEARY, Ann M.[1], JENKINS, Emily N.[1], CARNES, Austin[2], and CONRATH, Kysa[3], (1) Dept. of Geology, Portland State University, Portland, OR 97207, ann.m.stansbeary@gmail.com, (2) Dept. of Environmental Science and Management, Portland State University, Portland, OR 97207, (3) Dept. of Civil and Environmental Engineering, Portland, OR 97207

Located twenty kilometers east of Portland, McMenamins Edgefield is a resort complete with guestrooms, restaurants, vineyards, golf courses, and a spa. Over the past twenty years, head gardener, Kim Kincaid, has noticed an increase in the number of wet areas on the grounds of McMenamins Edgefield. The main elements of concern are production in the Syrah vineyard, mortality of trees surrounding the manor, and saturation of the wedding grove. Several changes have occurred over this twenty-year period that we hypothesized may be the cause of the rising groundwater level: 1) a golf course was constructed on the property in 1998 and expanded in 2007, 2) a neighborhood was developed on a hill up-gradient from the property in 1993, 3) an earth flow occurred in 1993, and 4) the Pacific Decadal Oscillation changed from a warm phase to a cool phase around 1996, resulting in increased precipitation. Site reconnaissance conducted in November 2012 ruled out the golf course and neighborhood development as potential causes of the rising groundwater level. Two soil cores, taken at depths of 1.5 meters, confirmed the presence of ML soils with redoximorphic features, indicating that the soil is poorly drained. The NRCS Soil Survey also specifies these soils can be poorly drained. We concluded that a combination of poorly drained soils and increased precipitation is most likely responsible for the increase in water level. Our recommendations include establishing five strategically placed monitoring wells to better define the subsurface stratigraphy and to observe the seasonal changes in water table depth across the property, increasing drainage in problem areas, and replacing dead trees with wetland facultative species.

SESSION NO. 15, 8:00 AM

Tuesday, 21 May 2013

T5. Critical Zone: Where Rock Meets Water and Life at Earth's Surface (Posters)

Radisson Hotel and Conference Center, Salon B/C

15-1 **BTH 17** Stacy, Erin M.

DECOMPOSABILITY OF ORGANIC MATTER IN SEDIMENTS ERODED FROM EIGHT LOW-ORDER CATCHMENTS, SIERRA NEVADA, CALIFORNIA

STACY, Erin M.[1], BERHE, Asmeret Asefaw[2], JOHNSON, Dale W.[3], HUNSAKER, Carolyn T.[4], and HART, Stephen C.[2], (1) SSCZO & Sierra Nevada Research Institute, University of California, Merced, Merced, CA 95340, estacy@ucmerced.edu, (2) University of California, Merced, Merced, CA 95340, (3) University of Nevada, Reno, Reno, NV 89557, (4) US Forest Service, Pacific Southwest Research Station, Fresno, CA 93710

Erosion laterally distributes soil organic matter across a landscape and may result in a net C sink if eroded OM is relatively more protected from decomposition after deposition in lower-lying depositional landform positions through organomineral associations or burial. Conversely, erosion can disrupt aggregates and expose previously protected material. To determine the net impact of erosion on the C balance, we need to know the magnitude of material transported, as well as its composition and potential to decompose. Predictive erosion models incorporate meteorological variation into estimates of sediment detachment and transport. However, little is known about how these drivers impact the composition of sediment, which could drastically alter its potential to decompose. In conjunction with a study on the magnitude of annual sediment transport, we assessed the decomposability of soil and eroded sediment from eight low-order watersheds in the southern Sierra Nevada to evaluate differences in composition over time and space. Decomposability was approached from two directions: (1) carbon dioxide evolution and changes in inorganic nitrogen during a soil incubation (43 days) at field capacity, and (2) a suite of extracellular enzyme assays, including potentials for C-, N-, and P-rich compounds. The ultimate fate of the OM will depend on when and where it is deposited, but the combination of total transport with decomposability estimates what can potentially decompose in a short period of time, when the direct feedback of land management decisions to the ecosystem can be monitored and adjusted.

15-2 **BTH 18** Bean, Jessica A.

PERFORMANCE OF GRAVEL AUGMENTATION ON THE LOWER AMERICAN RIVER, LOWER SAILOR BAR 2012

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The decline of salmon spawning on the Lower American River is connected to streambed degradation. Segments of river where no spawning occurs is the result of low permeability, armored streambed, and excess large gravel (Horner, 2005). This study looks at the performance of the newest spawning gravel restoration project on the Lower American River by comparing physical conditions before and after augmentation. The ability of salmonid species to successfully spawn is dependent on the physical environment; water depth and velocity, gravel size distribution, and dissolved oxygen (D.O.) each play a role in the spawning process. Experiments were conducted to characterize a salmon spawning habitat before and after restoration. Surface water depth and velocity were measured using USGS stream gauging procedures (USGS, 1980). Pre-restoration depth and velocity were nearly immeasurable because water depth across the site was too deep for accurate measurements. Post-restoration data showed water depths from 0.6 ft. to 3 ft., and velocity values from 0.7 ft./sec. to 6.4 ft./sec., both well within optimal conditions. Wolman pebble counts and bulk samples were used to characterize gravel before and after augmentation. Preliminary estimates project a decrease in median grain size and qualitative field observations confirm less streambed armoring post-restoration. D.O. was measured by inserting a mini-piezometer approximately 1 ft. into the streambed, where salmonids construct redds, and pumping water from the gravel into a flow-through cell to avoid sample contamination. Due to severe streambed armoring only two successful D.O. measurements were taken pre-augmentation. Results showed the average D.O. level before restoration to be 38%, well below optimal conditions. After gravel augmentation, 13 D.O. measurements were taken across the site and showed a low degree of variability with a high average D.O. content of 93.7%. Analysis of the site is still underway. Preliminary data shows a 250% increase in usage of the site by salmon after gravel augmentation. High resolution aerial images pre-restoration show 52 redds. Images taken post-restoration show 133 redds. It is anticipated that further study will support the finding that gravel augmentation is conducive to the success of salmon spawning on the river.

15-3 **BTH 19** Steinert, Tiffany

EVIDENCE FOR FRACTIONATION OF RARE EARTH ELEMENTS DURING SOIL FORMATION ALONG FEATHER RIVER BASIN HILLSLOPES IN THE CALIFORNIA SIERRA NEVADA

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Are rare earth elements (REE) immobile or do they fractionate overtime? This study presents soil data from an ongoing study that examines how REEs fractionate as rock weathers into soil. The Middle Fork Feather River in Northern California, the location of the study site, takes advantage of an erosional signal propagating through the basin and compares traditional methods of REE normalization then contrasts them with elemental losses based on mass balance calculations (tau). Analyzed by ICP-MS using the whole-rock Li-borate dissolution method, soil sample collection took place along two differentially eroding hill slopes (a shallow slope above the knick-point and a more inclined slope below the knick-point). Using Zr as an immobile element, the mass-balance method clearly portrays REE fractionation occurring within the soils, whereas traditional REE normalization patterns do not clearly display fractionation relative to the parent material. While REEs fractionate approximately to the same extent in the topmost soils of both hill slopes, the more actively eroding hill slope fractionates REEs faster because of a faster rate of soil chemical weathering. While the full meaning of this work is still underway, current progress indicates that significant REE fractionation occurs during chemical weathering, implying that using REEs as tracers for surfaces processes requires significant care.

SESSION NO. 16, 8:00 AM

Tuesday, 21 May 2013

Geomorphology and Quaternary Geology (Posters)

Radisson Hotel and Conference Center, Salon B/C

16-1 **BTH 20** Thibodeaux-Yost, Singleton

DELINEATION OF DRYLAND EPISODIC STREAM PROCESSES FOR THE RIDGECREST SOLAR POWER PROJECT, KERN COUNTY, CALIFORNIA

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Large-scale renewable energy projects are being developed in the California desert region on large tracts of predominantly undeveloped land (total area of developed land for individual project sites vary from 327 acres to 8,230 acres). The absence of a standard method of identifying and accounting for episodic streams in arid and semi-arid (dryland) regions is an area of conflict between project developers and the government agencies responsible for protecting natural resources and permitting renewable energy projects. There is a need for an accurate dryland stream delineation protocol that is consistent, efficient, accessible, and accurately reflects the extent and distribution of streams on a site. Dryland stream delineation protocol based on a scientific, geomorphic and ecological understanding of dryland stream processes will help ensure dryland streams are accurately identified for the purposes of environmental impact assessments and project permitting. Such a method is currently being developed by the California Energy Commission (CEC) and the Department of Fish and Wildlife (CDFW). This thesis work critically evaluates the stream delineation and stream impact assessment previously completed by the developer for the proposed renewable energy project in El Paso Fan, El Paso Mountains, Ridgecrest, Kern County, California. This evaluation is then compared and contrasted with the results achieved in the field using the CEC/CDFW stream delineation methods and protocols and mobile GIS mapping technology.

16-2 **BTH 21** Kaphle, Rameshwor

ESTIMATING SHEAR STRESS OF STREAM BED USING ACOUSTIC DOPPLER VELOCIMETERS

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Fluid shear stress, an index of fluid force per unit area on the stream bed, is a very important parameter in flume/river studies, especially in the areas of sediment transport and biofilm erosion. This parameter is a linkage of flow conditions to sediment mobilization and transport along with biofilm development and erosion. Therefore, the estimation of shear stress on stream bed, which is fairly complex in natural flow fields, plays a key role in sediment and biofilm studies. Generally, instead of being measured directly, shear stress is determined by the velocity profiles near stream bed using logarithmic methodology. Impact of shear stress in erosion and development of biofilm has been extensively investigated using three dimensional physical/mathematic models. The accuracy of shear stress significantly depends of the measurement of velocity profiles. The objective of this research is to estimate shear stress for future investigations of biofilm erosion and sediment transport in stream/river using flume experiment and mathematical modeling methods. A straight hydraulic flume with unidirectional turbulent flow is used to simulate a natural river in the laboratory. The 20 feet long flume was marked at equally divided 4 feet interval to obtain 5 points where Acoustic Doppler Velocimeters (ADVs) are placed to measure velocities in three dimensions. The logarithmic equation is used to translate velocities to shear stresses at the bottom of the flume. Similar experiment will be conducted in the south fork of Tule River for comparison purpose. A selected 20 feet stretch of Tule River was marked at 5 points equally separated by 4 feet and velocity profiles at each point will be measured using ADV as well. For the verification purpose, an Acoustic Doppler Current Profiler (ADCP) mounted on a moving boat will be used to validate the velocity profiles obtained by ADV. Summaries of the estimated values for the bottom shear stress, shear velocity, and the coefficient of friction are presented. Confidence intervals about the shear stress estimates are provided.

16-3 **BTH 22** Cordes, Shaun E.

SUPPORTING EVIDENCE FOR A LARGE ROCK FALL 9.6 ± 1 KA FROM GLACIER POINT IN YOSEMITE VALLEY, CALIFORNIA

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Large boulders exceeding 10 m^3 in exposed volume are widely scattered throughout Upper Pines Campground in eastern Yosemite Valley, Yosemite National Park, California. These enigmatic boulders rest up to 330 m from the base of adjacent talus slopes but lack geomorphic expressions typical of other large rock fall, debris flow, or glacial deposits in Yosemite. We evaluated four hypotheses for boulder deposition: (1) glacial deposition during ice retreat (~15-17 ka), (2) fluvial deposition during high discharge flood events, (3) debris flow deposition, and (4) rock fall deposition. We utilized field mapping, spatial analysis, cosmogenic ^{10}Be exposure dating, and X-ray fluorescence analysis to investigate possible modes of deposition. A mean boulder exposure age of 9.6 ± 1 ka considerably postdates glacial retreat from Yosemite Valley, effectively ruling out glacial deposition. Discharge and bed stress calculations indicate that flooding was capable of entraining boulders at confined upstream locations, but it is unlikely to have transported boulders >500 m farther to Upper Pines. Slope comparisons and evaluation of surface morphology of debris flow fans in Yosemite Valley suggest that the boulders did not result from debris flows. Geochemical results identify a majority of boulders in Upper Pines as granodiorite of Glacier Point, corresponding to bedrock samples located at the summit of Glacier Point. We interpret boulders in Upper Pines Campground to result from a single large rock fall event originating from the east face of Glacier Point circa 9.6 ± 1 ka, and subsequently partially buried by alluvial fan aggradation, modifying the original geomorphic expression.

16-4 **BTH 23** Ahlstrom, Martha Peggye

POST-STATION FIRE DEBRIS FLOW ANALYSIS IN THE SAN GABRIEL MOUNTAINS

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Debris flows are a source of substantial erosion in mountainous areas; consequently, their occurrence, spatial density, and characteristics provide essential data for understanding erosion rates and volumes. The 2009 Station Fire in the San Gabriel Mountains burned an extensive area (649.75 square kilometers), and thus destabilized the slopes setting them up for subsequent debris flows. GIS mapping of post-fire debris flows within the burn area, combined with field mapping, allowed the calculation of area and volume calculations and the spatial density of these flows. Most debris flows initiated from burned, previously undisturbed, upper channel hill slopes averaging 28° and have a spatial density of one flow per every two square kilometers. Total flow material deposited is 715,071 cubic meters and affected 2.5% of the total burn area. The relationship between the area affected by each debris flow and the volume deposited in each flow reveals a positive linear correlation and suggests that as the area affected by a debris flow increases, so does the depositional volume of the flow. Assuming a 30 year recurrence of fires and subsequent debris flows, these flows account for 0.12 ± 0.03 mm/yr of erosion within the burn area. This erosion rate accounts for 7.5 -13.3% of the total erosion rate in the San Gabriel Mountains, according to the erosion rate of 0.9 -1.6 mm/yr (Lavé and Burbank, 2004), despite flows covering only 2.5% of the area. This new data demonstrates that debris flows are more efficient in causing significant erosion compared to typical erosion processes. This data provides an empirical dataset for future debris flow hazard analysis, as well as providing a quantitative assessment of post-fire erosion rates in the San Gabriel Mountains.

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20–22 May 2013 ◆ Radisson Hotel and Conference Center ◆ Fresno, California, USA

Looking north toward Mount Whitney and the Sierra Nevada from Mount Langley, California, USA. Photo by Mel Stoutsenberger; used with permission via Wikimedia Commons.

THE GEOLOGICAL SOCIETY OF AMERICA®

CORDILLERAN SECTION

2013 Program ◆ Volume 45, Number 6 ◆ ISSN 0016-7592

109th Annual Meeting
Cordilleran Section of The Geological Society of America

Hosted by

Department of Earth and Environmental Sciences,
California State University, Fresno

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General Information

Welcome to the 109th Annual Meeting of the Cordilleran Section of The Geological Society of America, hosted by the Department of Earth and Environmental Sciences of California State University, Fresno. The technical program truly reflects the meeting theme of "Local Geology, Global Connections", for the meeting features presentations on both the geology of the Cordillera and of other regions of the world that share similar research interests, and our presenters include many international researchers as well as those based in the Cordillera. In addition, the more literal meaning of the theme is embodied in presentations proposing direct geologic correlations between parts of the Cordillera and regions far removed. The technical program has very little time overlap between topics of shared interests, so that meeting participants can attend what amounts to their own "meetings within the meeting". Moreover, with the thematic linkage between our theme sessions and field trips, participants can "build their own field forum" by viewing theme sessions and going on related field trips.

Fresno, California, is ideally located for exploring the best of Cordilleran geology. It is nestled at the foot of the Sierra Nevada famed for its granitic batholith, but also having long been a global focal point for studies of landscape evolution. The pre-batholithic rocks include some of the oldest ophiolites in the Cordillera, the nearest outcrops of which are a half hour drive from the meeting site, as well as many other rock units that record several hundred million years of active plate margin orogenesis. An hour to the west rise the California Coast Range, not as lofty in elevation as the Sierra Nevada, but including what is probably the world's most famous transform fault system, the San Andreas fault system, as well as the world's best-known subduction complex, the Franciscan. The field trips for this meeting visit these world-class geologic localities and mesh with the international character of the theme sessions.

Venue and Lodging

The meeting will be held at the at the Radisson Hotel and Conference Center, 2233 Ventura Street, Fresno, CA 93721, USA. A free shuttle connects the hotel with the airport, Amtrak, and bus station (6 am to 9 pm).

Dining, by Steve Lewis

The Radisson Hotel and Conference Center has a restaurant and bar, so participants who do not wish to wander far for their meals will be well taken care of. Several notable restaurants within walking distance of the Radisson span a good range of cuisine and are listed below.

Joe's Steakhouse & Grill, 831 Van Ness Avenue (559) 486-3536. Five minute walk from the Radisson (see map). Joe's Steakhouse offers a pleasant, inviting atmosphere that is perfect for casual dining with families and friends. The menu features an extensive array of selections, with something sure to please every member of your group. Joe's Steakhouse also features a professional staff of friendly people, who will ensure that your visit is a pleasant one. They also have a good wine cellar.

Los Panchos Mexican Restaurant, 1000 Fulton Mall (see map), (559) 497-9999. Mexican food with a good bar.

Mediterranean Grill & Café, 1031 U St., (559) 441-7050. About 15 minutes walking from the Radisson (see map). Armenian/Mediterranean restaurant.

Shepherd's Inn, 935 Santa Fe Ave,: 559-266-2228, http://www.shepherdsinnfresno.com/page/page/8384539.htm. Across from the AMTRAK train station (see map). Basque-style food and meal and a great bar.

Tokyo Garden, 1711 Fulton Street (559)268-3596. A 15-minute walk from the Radisson (see map). Japanese food, but best known for the bar and as headquarters for the local Fresno music scene.

BEER, by John Wakabayashi

Below are personal reviews by your meeting chair, an amateur brewer for 19 years.

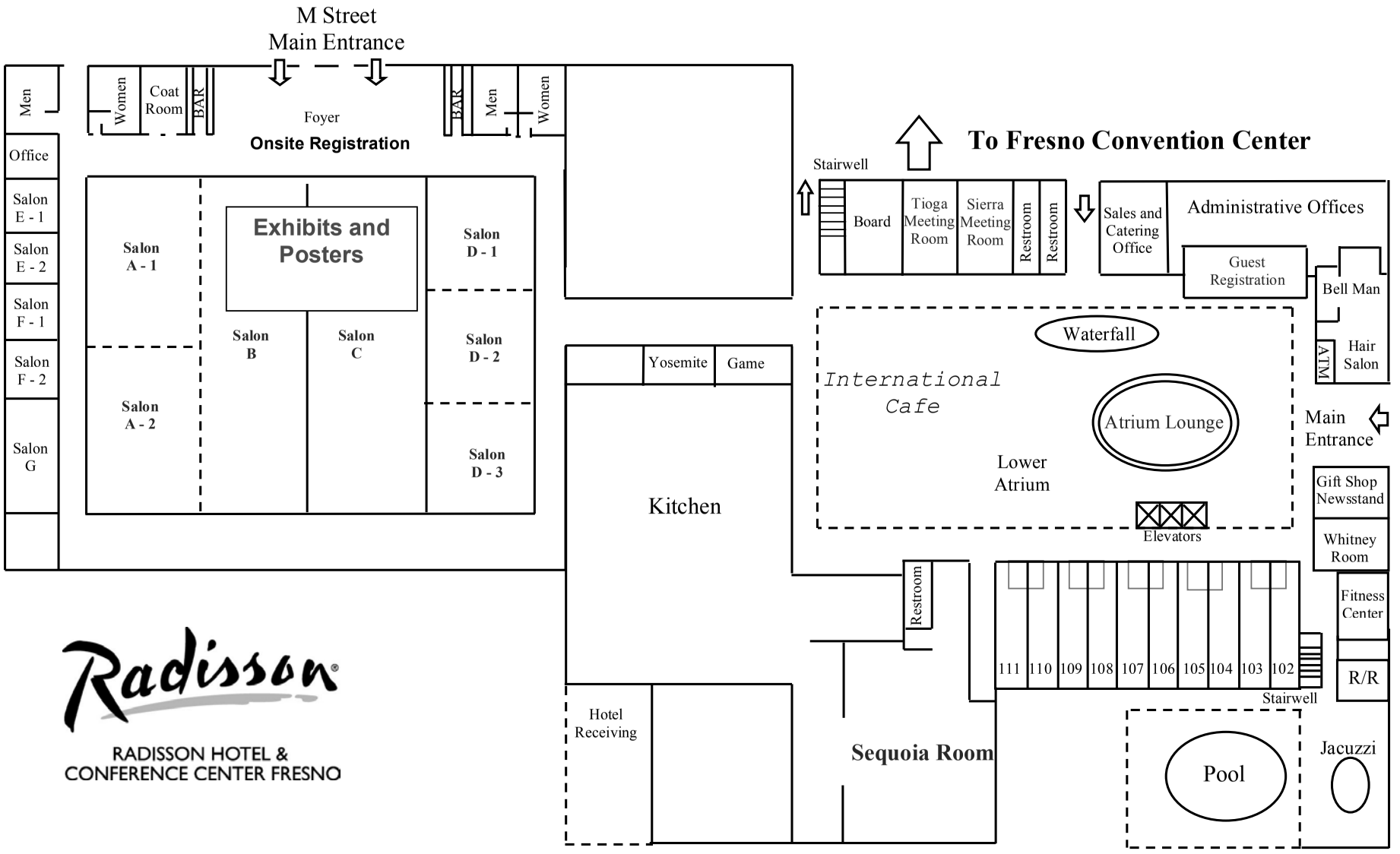
Within walking distance from meeting.

Fresno Brewing Company, 1243 Fulton Mall. (559) 393-0260. This is on the Fulton Street Mall between Fresno Street and Tuolumne Street, approximately 1 km west-northwest of the Radisson (see map). This superb pub has a terrific tap list of microbrewed beer, as well as a wide selection of bottled beer, and a friendly, knowledgeable staff. Some students in our geology department work there, so you may see one of your fellow meeting participants behind the bar. This is also the premier coffee house in the downtown area.

Atrium Lounge, Radisson Hotel and Convention Center, The current tap list at this bar that includes the locally brewed Tamarack Amber by Sequoia Brewing Company, as well as the standby Sierra Nevada Pale Ale. I am working with the Radisson to get two special taps at the bar, including at least one of my favorite West Coast IPAs or double IPAs.

Full Circle Brewing Company, 620 F Street, (559) 264-6323. http://fullcirclebrewing.com/. This small brewery, located about one km SW of the Radisson (see map) features a variety of beers, including some high gravity ones, and tends to steer clear of the hyper hopped brews that West Coast brewers such as myself tend to be rather addicted to. They also make mead and wine. Although they do not serve food, they are well known as a live music venue.

Radisson Hotel - Fresno



A bit beyond walking distance (cab or shuttle needed).

Sequoia Brewing Company, 777 E Olive Ave, Fresno, CA 93728 (559) 264-5521, http;//sequoiabrewing.com. About 3.7 km (2.3 miles) from the Radisson.This is the nucleation point of the fine beer scene in Fresno, for it began life as the first southern San Joaquin Valley microbreweries under the name Butterfield, and it has continued the tradition of quality and innovation. Known in our geology department as "Southern Headquarters" (our campus is located north of it), their quality lineup of beers spans a range of styles, but I consider their Big Horn Red IPA to be the finest red IPA I have had, hence my efforts to get this installed at the Radisson for the meeting. Worth seeking out, should our meeting schedule prove so fortunate, are some of their seasonal specialty beers, particularly those in what I consider their ultrahighgravity "UHG" class. The latter tend to have immense flavor, aroma, and length and go down the hatch unusually well for their strength. The Buzzsaw double IPA is an example, and their Matterhorn imperial red ale is so good that other imperial reds, including extremely accomplished ones from legendary breweries simply can't measure up.

Spokeasy Public House, 1472 N Van Ness Avenue. (559) 492-7765. About 3.7 km (2.3 mi.) (NW) from the Radisson. This recent addition to the Fresno brew scene has drawn well-deserved rave reviews from my colleagues and students for their rapidly rotating selection of high quality taps and bottled beer. For example, Green Flash's legendary Palate Wrecker double IPA has appeared there multiple times in recent months.

BC's Pizza and Beer, 1315 Shaw Avenue, Clovis. (559) 297-7800 http://bcspizzaandbeer.com/. About 16 km (10 miles) (NE) from the Radisson. BC's features an excellent selection of fine microbrews and imports (including a fine Belgian ale selection), on tap and in bottles, and a knowledgeable staff that is very enthusiastic about craft beer. There almost always seems to be some sort of beer festival or special event happening here. This is my personal go to spot here, although during the meeting, my preferences will shift closer to the venue (including the venue itself).

Eureka Burger, 7775 N Palm Ave. (559) 320-1300 http://www.eurekaburger.com/ About 16 km (N) of the Radisson. Eureka Burger features a great selection of high quality beers on tap in addition to an unusually good selection of distilled spirits from small American distilleries. This "gourmet" burger and brew establishment indeed serves some superior burgers. A local legend is the Fresno Fig Burger, which is my go to burger here, along with my "usual" round of Stone Sublimely Self Righteous Ale.

Registration

Onsite registration and badge pick-up is located in the Foyer of the Radisson Hotel and Conference Center. Registration is required for anyone attending technical sessions, field trips, short courses, or exhibits.

Onsite Registration Hours:

Sunday, 19 May, 5–8 p.m.
Monday, 20 May, 7 a.m.–5 p.m.
Tuesday, 21 May, 7 a.m.–5 p.m.
Wednesday, 22 May, 7–10 a.m.

On-site registration fees:	Standard	
	Full Mtg.	**One day**
Professional member	$195	$115
Professional nonmember	$220	$170
Professional 70+	$70	$60
Student member	$80	$55
Student nonmember	$110	$80
K–12 Teacher	$60	$40
Guest/Spouse	$60	N/A
Field trip/workshop only	$45	N/A

Travel Information

The Radisson Hotel and Convention Center Fresno is about 10 minutes away from the Fresno-Yosemite International Airport (FAT), and a free shuttle will take you to the Radisson. Fresno is also reached by Amtrak. The Amtrak station is within walking distance of the Radisson Hotel and Conference Center. The hotel is also easily reached by car via State Highway 99 by taking the Ventura Avenue exit eastbound. The Radisson Hotel and Conference Center is located on the NW corner of Ventura Ave. and M Street (see www.radisson.com/fresno-hotel-ca-93721/cafresno/area/map).

Note to international travelers: Depending on the flight packages available, it can be much less expensive to book two connected round trips rather than a combination round trip package to Fresno-Yosemite International Airport. The best combinations are round-trip to Los Angeles (LAX) or San Francisco (SFO) and then booking a separate round-trip ticket from LAX or SFO to Fresno. This tends to vary considerably depending on the time you book your ticket.

Weather

Fresno weather in late May is usually sunny and mild, with occasional hot spells. Weather on field trips will vary more because a wide range of elevations and microclimates will be traversed by the field trips, so participants should prepare according to additional guidance for each field trip.

Special Events

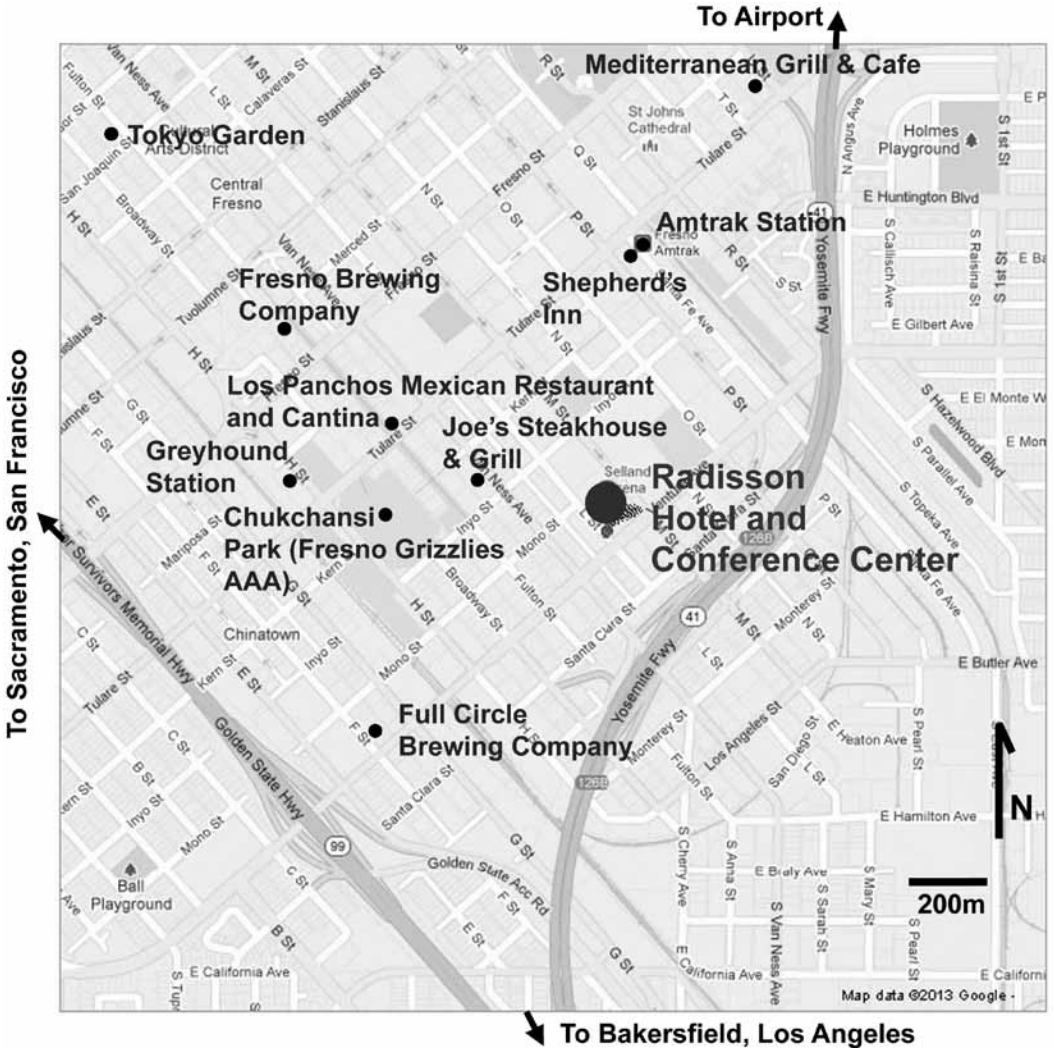
Ice Breaker Party. Sunday, 19 May, 6–8 p.m., Salon B/C Lounge, Radisson Hotel and Conference Center.

Cordilleran Section Management Board Meeting. Tuesday, 21 May, 7–8 a.m. International Cafe.

Cordilleran Section Business Meeting. Salon D2, Tuesday, 21 May, 6:30–8 p.m.

National Association of Geoscience Teachers (NAGT) Far West Section (FWS) Business Meeting, Tuesday, 21 May, 6:30-8p.m. Sierra Room.

Fresno State Geology Alumni Reception, Tuesday, 21 May, 6:30-10 p.m. Sequoia Room.



Exhibits

Exhibits are located in Salon B/C of the Radisson Hotel and Conference Center and area open at the following times:

Sunday, 19 May, 6–8 pm
Monday, 20 May, 8 a.m.–5:30 p.m.
Tuesday, 21 May, 8 a.m.–5:30 p.m.
Wednesday, 22 May, 8 a.m.–noon

Field Trips

1. **A Look at Critical Zone Processes in the NW Sierra Nevada.** Sat.–Sun. 18–19 May. Cost: $205. Beth Weinman, California State University, Fresno, bweinman@csufresno.edu.

In this trip, we will travel up the valley, stopping to look at sites that highlight the effect of differential erosion on soil formation in the northwest Sierra Nevada. The incision of the Middle Fork Feather River into the Bald Rock Pluton in the northern Sierra Nevada gives some of the first insight on how transient basins are responding to differential erosion. Taking advantage of an erosional gradient, this trip highlights ongoing critical zone work in the Feather River area and will familiarize trip-goers with soil formation processes in response to differential river incision in several sub-basins. Just across the river from the soil-mantled hillslopes being used in current critical zone-type studies lies Big Bald Rock, a piece of the same pluton—with no obvious differences in aspect or slope gradient—that remains curiously bare of soil. Why soil occurs where it does and why soil production is not continuous along the landscape will be just a couple of the topics up for debate while hiking along the Big Bald Rock Trail and camping in Feather Falls campgrounds during the excursion.

2. **Granite, Glaciation, and Rockfall in Yosemite Valley, California.** Sat.–Sun., 18–19 May. Cost: $205. Roger Putnam, Dept. of Geological Sciences, University of North Carolina at Chapel Hill, rputnam@live.unc.edu; Greg Stock, National Park Service, Yosemite National Park, greg_stock@nps.gov; Allen Glazner, Dept. of Geological Sciences, University of North Carolina at Chapel Hill, afg@unc.edu; John Bartley, Dept. of Geology and Geophysics, University of Utah, john.bartley@utah.edu.

Since the days of John Muir, the striking topography of Yosemite Valley, California, has been understood to have been generated by Pleistocene glaciers, then modified in the Holocene mainly by rockfall. The distribution of bedrock units has been used to track glacier movements and to determine the source areas of rock avalanches. On this trip, we

will discuss recent studies of the glacial history and bedrock geology of Yosemite Valley, including detailed mapping of intrusive relations exposed on the cliff face of El Capitan. El Capitan presents an unparalleled exposure of the interior of a granitic plutonic system at a locus of interaction between multiple intrusive suites and two mafic dike swarms. Mapping of this 1-km-high cliff was accomplished using remote sensing techniques ground-truthed by climbing and rappelling. The character and distribution of the various units affected El Capitan's extensive rockfall history, including a huge post-glacial rock avalanche at 3.6 kya. This two-day field trip will present new observations and data on the bedrock, glacial, and rockfall history of Yosemite and apply them to some of the other classic cliffs such as Glacier Point and Half Dome. We will present the new map of El Capitan and discuss the intrusive relationships exposed on the face while visiting several rockfall deposits and some of the classic vistas of Yosemite Valley, including El Capitan Meadow, Glacier Point, Taft Point, and Cook's Meadow.

3. **From Deep to Modern Time along the Western Sierra Nevada Foothills between the San Joaquin and Kern River Drainages.** Sat.–Sun., 18–19 May. Cost: $240. Jason Saleeby, Zorka Saleeby, Frank Sousa, Div. of Geological and Planetary Sciences, California Institute of Technology.

The western Sierra Nevada Foothills preserve ~500 m.y. of diverse geologic history initiating with the interaction of Panthalassa abyssal lithosphere with the passive margin of the SW Cordillera and accented today by rapidly evolving epeirogenic displacements arising from the ongoing removal of the mantle lithosphere that formed beneath the Cretaceous Sierra Nevada batholith. Our field trip will survey basement exposures that display key stages in western Sierra Nevada lithospheric evolution and geomorphic-stratigraphic relations that reflect geologically recent mobilization of the underlying mantle lithosphere. Key elements surveyed in the basement include (1) a deformed abyssal Moho section interpreted to represent an oceanic spreading ridge-transform intersection core complex; (2) a regional ophiolitic mélange interpreted to have formed along a major transform zone that truncated the SW Cordilleran margin and along which the California Mesozoic convergent margin nucleated; and (3) Early Cretaceous mafic intrusions that are typical of the western Sierra Nevada batholith and its extension into the Great Valley subsurface. Key geomorphic-stratigraphic elements include (1) An exhumed end of Cretaceous pediment surface and its implications on the remnants of Cretaceous paleo-relief throughout the greater Sierra Nevada; (2) anomalous subsidence along the eastern margin of the southern Great Valley interpreted to have arisen from initial mobilization of the underlying mantle lithosphere; and (3) rapid Quaternary uplift and hydrothermal fluxing along part of the southeastern Great Valley arising from the most recent focused phase of mantle lithosphere detachment from the lower crust.

4. **Middle Irvingtonian Fairmead Landfill Fossil Site and Fossil Discovery Center of Madera County, California.** Sun., 19 May. Cost: $50. Robert G. Dundas, CSU Fresno, rdundas@csufresno.edu; James C. Chatters, CSU Fresno Foundation, paleosci@gmail.com; Eric Scott, San Bernardino County Museum, escott@sbcm.sbcounty.gov.

Celebrating the 20th anniversary of the Fairmead Landfill fossil locality's discovery, participants will visit the Madera County Fairmead Landfill, the corresponding Madera County Paleontology Collection, and end at the Fossil Discovery Center of Madera County. The middle Irvingtonian aged (0.78 to .55 Ma) Fairmead Landfill fossil site was discovered in May 1993 during excavations for a new expansion cell at the landfill. Paleontological monitoring since 1993 has yielded thousands of fossil specimens representing 71 taxa (two fish, two amphibians, three reptiles, five birds, 29 mammals, one bivalve, one gastropod, 12 plants, and 16 diatoms). Fossils occur in distal alluvial fan channel, distal fan overbank flood or sheetflood, and marsh/lacustrine deposits of the upper unit of the Turlock Lake Formation. Fossils have been collected from a geographic area of more than 40 acres and stratigraphically from depths of 4 m to 20+ m below ground surface. The vertebrate fauna include *Archoplites interruptus*, *Catostomus occidentalis*, Caudata, Anura, *Clemmys marmorata*, *Xerobates agassizi*,Colubridae, *Athene cunicularia*, *Branta canadensis*, *Tadorna tadorna*,cf. *Aythya* sp., *Zenaida macroura*, *Sorex* sp., *Paramylodon harlani*, *Nothrotheriops shastensis*, *Megalonyx wheatleyi*, *Canis latrans*, *Canis dirus*, *Vulpes velox*, *Homotherium* sp., *Smilodon* sp., *Miracinonyx* sp., *Lynx rufus*, *Panthera* sp., *Taxidea taxus*, *Arctodus* sp., *Spermophilus* sp., *Neotoma* sp., *Peromyscus* sp., *Microtus* sp., *Thomomys* sp., cf. *Dipodomys* sp., *Lepus* sp., *Mammuthus columbi*, *Equus* sp., *Camelops* sp., *Hemiauchenia* sp., *Tetrameryx irvingtonensis*, *Capromeryx* sp., *Odocoileus* sp., and *Platygonus vetus*. The fauna is dominated by large herbivorous mammals, particularly open-country grazers and mixed feeders such as *Equus*, *Camelops*, *Mammuthus columbi* and *Paramylodon harlani*. Fairmead Landfill represents an age not well documented in the terrestrial vertebrate record of North America and helps to fill the gap in knowledge about the middle Irvingtonian.

5. **LOCKED ROCKS: Hard-to-Access Outcrops of the Mesozoic Metasedimentary Framework and Gabbroids of the Early Cretaceous Sierra Nevada Batholith.** Thurs., 23 May. Cost: $70. Diane Clemens-Knott, Dept. of Geological Sciences, CSU Fullerton; Jason Saleeby, Div. of Geological and Planetary Sciences, California Institute of Technology.

This one-day trip will begin/end with a one-hour highway commute from Fresno to the greater Visalia area. As we travel back roads through private ranchlands of the Stokes Mountain region, we will track the Mesozoic evolution of depositional environments as recorded in the batholith's metamorphic framework, progressing from (1) the Triassic ribbon cherts, carbonates, and distal turbidites of the Calaveras Complex; to (2) the Jurassic turbidites of the Kings Sequence; to (3) the Early Cretaceous siliciclastic and volcanic rocks of the Goldstein Peak Formation, which were deposited in a nonmarine, intra-arc basin during the earliest stage of Cretaceous arc activity. As we travel, we will inspect various Early Cretaceous rock types of the Stokes Mountain ring dike complexes, with the trip culminating at a spectacular outcrop of layered olivine-plagioclase cumulates—the most primitive rocks of the Cretaceous Sierra Nevada batholith. Various

isotopic (igneous and detrital zircon U-Pb; Hf-Nd-Sr-O), geochemical, and geophysical data will be integrated into reconstructions of Mesozoic paleogeography, tectonics, and the dominantly gabbroic-to-tonalitic Early Cretaceous Sierra Nevada batholith.

6. **New Views on the Evolution of the San Andreas Fault Zone in Central California and the Carrizo Plain.** Thur.–Sat., 23–25 May. Cost: $310. Sinan Akciz, University of California, Irvine, sakciz@uci.edu; Ramon Arrowsmith, Arizona State University, School of Earth and Space Exploration, ramon.arrowsmith@asu.edu.

On this three-day field trip, we will examine the evidence for slip along the San Andreas fault as expressed over different temporal and spatial scales. At the largest scales, we will discuss the ~320-km-long term offset of the Pinnacles-Neenach volcanic complex with a stop at Pinnacles National Monument. Working along the San Andreas fault to the southeast, we will traverse a fundamental change in strain release from the creeping section through Parkfield to the Cholame and Carrizo sections. At Parkfield, we will discuss the history of repeated M6 earthquakes and the significant monitoring instrumentation available that provide a high-resolution view of fault zone behavior and the earthquake cycle. A highlight of the trip will be our examination of classic localities in the Carrizo Plain where we plan to review new results from Wallace Creek, Bidart, the Dragon's Back pressure ridge, and the Elkhorn Hills. We will also present recent results of paleoclimate research from Soda Lake at the sink of the Carrizo Plain and their constraints on the formation of offset landforms.

7. **Mélanges, HP Metamorphism, Subduction Accretion and Erosion, Subduction Megathrusts, and Ophiolites: The Franciscan and Related Rocks.** Thur.–Fri., 23–24 May. Cost: $205. John Wakabayashi, California State University, Fresno, jwakabayashi@csufresno.edu.

We will visit exposures that highlight the rock record of convergent plate margin processes on round-trip from Fresno through Panoche Pass to the San Francisco Bay area. The trip will feature multiple stops with exceptional exposures of mélange matrix of Franciscan subduction complex showing evidence for sedimentary origins of block in matrix fabric and introduction of exotic blocks/clasts, as well evidence of two and possibly three burial-exposure cycles to blueschist facies or greater depth. At least one of these stops will view exposures that may represent the exhumed subduction megathrust. We will see the large-scale architecture of the preserved trench-forearc system and its implications for non-accretionary versus accretionary episodes, preserved ocean plate stratigraphy within different parts of the system, and the high-grade metamorphism that may record Franciscan subduction initiation. We will also view exposures of the Coast Range ophiolite, considered a good example of a supra-subduction zone ophiolite, along with the forearc basin cover of the Great Valley Group, including the basal olistostrome of the latter that includes high-grade metamorphic blocks.

8. **Debris Flows in Recently Burned Watersheds in the Southeastern Sierra Nevada.** Thur.–Sat., 23–25 May. Cost: $250. Dave Wagner, California Geological Survey, dave.wagner@suddenlink.net; Jerry DeGraff, Sierra National Forest; Jeremy Lancaster, California Geological Survey.

Research in recently burned mountainous watersheds in California, Colorado, and Utah shows that most post-fire debris flows are initiated by runoff and erosion and grow in size through erosion and scour in channels. Most commonly, post-fire debris flows occur within two years after a fire. On this trip, we will visit three such occurrences in the southeastern Sierra Nevada as well as debris flows in the arid Inyo Mountains. On 12 July 2008, tropical moisture moved across the American southwest and stalled against the eastern Sierra. Local convective cells simultaneously produced brief periods of intense rainfall on steep-sloped, burned watersheds near the towns of Lake Isabella and Independence, about 155 km to the north. Both communities sustained significant damage and infrastructure disruption. On 10 August 2010, intense rain fell on the Haiwee Creek drainage that was burned in 2008, producing a debris flow that swept a semi tractor-trailer off of Highway 395, caused overnight traffic delays, and damaged infrastructure. Leaders will present findings of detailed investigations of each of these events. Trip will depart Fresno at 8 a.m. on Thursday, 23 May, and return to Fresno at ~6 p.m. on Saturday, 25 May.

Opportunities For Students

Mentoring Programs

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Cosponsored by the GSA Foundation.

Roy J. Shlemon Mentor Program in Applied Geoscience Luncheon, Monday, 20 May, noon–1:30 pm Sierra Room.

John Mann Mentors in Applied Hydrogeology Program Luncheon, Tuesday, 21 May, noon–1:30 pm Sierra Room

Technical Session Program Calendar

Session Title	Start Time	Room
MONDAY, 20 MAY 2013		
MORNING		
T1. Tectonic Processes that Build the Stratigraphic and Structural Record of Ancient and Modern Convergent Margin	8 a.m.	Salon A1
T5. Critical Zone I: Where Rock Meets Water and Life at Earth's Surface	9:20 a.m.	Salon A2
T14. Quaternary Geology of California's Central Valley and Its Relevance to Water Infrastructure	8:20 a.m.	Salon D1
AFTERNOON		
T2. Mélanges: Comparison and Contrast Between Circum-Pacific and Tethyan Chaotic Rock Bodies, and Modern Submarine Analogues	1:30 p.m.	Salon A1
T5. Critical Zone II: Where Rock Meets Water and Life at Earth's Surface	1:30 p.m.	Salon A2
T13. Irvingtonian Paleoecology of Western North America	1:30 p.m.	Salon D1
Posters *Authors present 2:30–4:30 p.m.*		
Mineralogy, Petrology, and Geochemistry (Posters)	1:30 p.m.	Salon B/C
Plutons: Evolution, Emplacement, and Deformation (Posters)	1:30 p.m.	Salon B/C
Volcanology, Volcanic Rocks, Volcanic Petrogenesis (Posters)	1:30 p.m.	Salon B/C
T10. Reconstructing the Pacific-North America Plate Boundary Through Late Cenozoic Time (Posters)	1:30 p.m.	Salon B/C
TUESDAY, 21 MAY 2013		
MORNING		
T10. Reconstructing the Pacific-North America Plate Boundary Through Late Cenozoic Time I	8 a.m.	Salon A2
T3. Oceanic Petrogenesis of Pacific-Type Convergent Margins	8:15 a.m.	Salon A1
Sedimentary Geology	10 a.m.	Salon D1
Posters *Authors present 9–11 a.m.*		
Engineering and Environmental Geology (Posters)	8 a.m.	Salon B/C
T5. Critical Zone: Where Rock Meets Water and Life at Earth's Surface (Posters)	8 a.m.	Salon B/C
Geomorphology and Quaternary Geology (Posters)	8 a.m.	Salon B/C
T14. Quaternary Geology of California's Central Valley and Its Relevance to Water Infrastructure (Posters)	8 a.m.	Salon B/C
T7. Hydrogeologic Issues of Irrigated Agricultural Regions- Problems and Solutions (Posters)	8 a.m.	Salon B/C
T13. Irvingtonian Paleoecology of Western North America (Posters)	8 a.m.	Salon B/C

Session Title	Start Time	Room
AFTERNOON		
Geomorphology and Quaternary Geology	1:30 p.m.	Salon D2
T4. Ophiolites and Suture Zones	1:30 p.m.	Salon A1
T9. AFC Processes in the Formation of Intermediate Magmas from Mantle to Crust	1:30 p.m.	Salon D1
T10. Reconstructing the Pacific-North America Plate Boundary Through Late Cenozoic Time II	1:30 p.m.	Salon A2
Posters *Authors present 2:30–4:30 p.m.*		
Geologic Maps and Geologic Mapping (Posters)	1:30 p.m.	Salon B/C
Geoscience Education and Communication (Posters)	1:30 p.m.	Salon B/C
Sedimentary Geology (Posters)	1:30 p.m.	Salon B/C
T6. Using Detrital Zircon Age Data to Reassemble the Cordilleran Jigsaw Puzzle (Posters)	1:30 p.m.	Salon B/C
T15. Undergraduate Research (Posters)	1:30 p.m.	Salon B/C
WEDNESDAY, 22 MAY 2013		
MORNING		
T7. Hydrogeologic Issues of Irrigated Agricultural Regions–Problems and Solutions	8 a.m.	Salon A2
T6. Using Detrital Zircon Age Data to Reassemble the Cordilleran Jigsaw Puzzle	8:40 a.m.	Salon A1
Posters *Authors present 9–11 a.m.*		
Structural Geology and Tectonics (Posters)	8 a.m.	Salon B/C
T1. Tectonic Processes that Build the Stratigraphic and Structural Record of Ancient and Modern Convergent Margin (Posters)	8 a.m.	Salon B/C
T2. Mélanges: Comparison and Contrast Between Circum-Pacific and Tethyan Chaotic Rock Bodies, and Modern Submarine Analogues (Posters)	8 a.m.	Salon B/C
T3. Oceanic Petrogenesis of Pacific-Type Convergent Margins (Posters)	8 a.m.	Salon B/C
T4. Ophiolites and Suture Zones (Posters)	8 a.m.	Salon B/C

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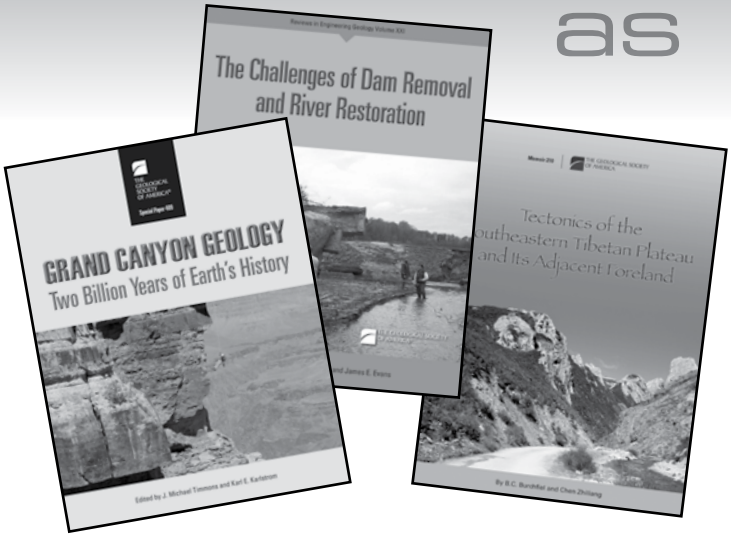

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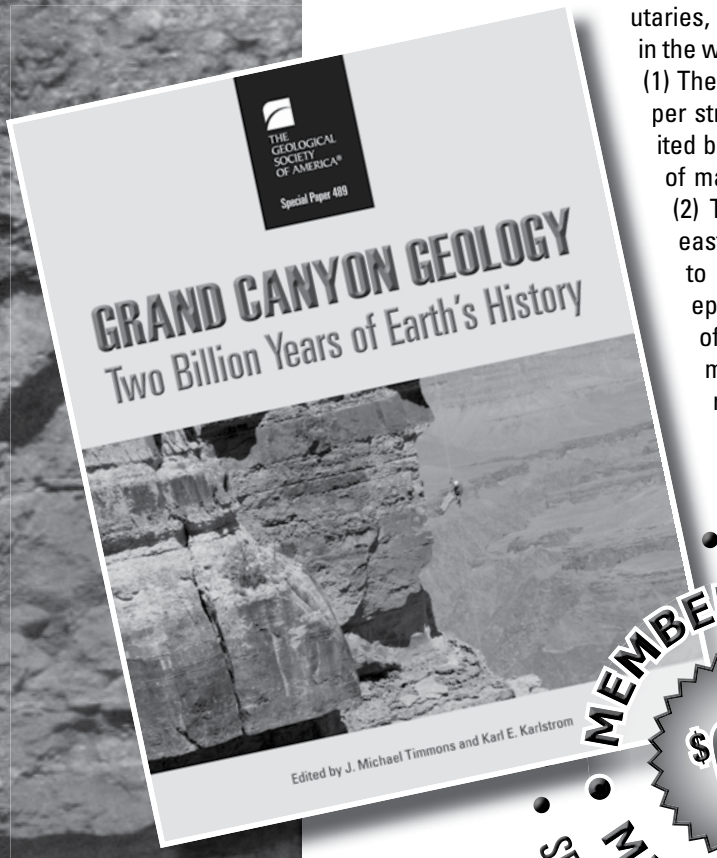

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A no-smoking policy has been established by the Programme Committee and will be followed in all meeting rooms for technical sessions.

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In the interest of public information, The Geological Society of America provides a forum for the presentation of diverse opinions and positions. The opinions (views) expressed by speakers and exhibitors at these sessions are their own and do not necessarily represent the views or policies of The Geological Society of America.

NOTE INDEX SYSTEM
Numbers (3-4, 15-3) indicate session and order of presentation within that session.

*denotes speaker

MONDAY, 20 MAY 2013

ORAL TECHNICAL SESSIONS

SESSION NO. 1

T1. Tectonic Processes that Build the Stratigraphic and Structural Record of Ancient and Modern Convergent Margin

8:00 AM, Radisson Hotel and Conference Center, Salon A1

David Scholl, Roland von Huene, Trevor Dumitru, and John Wakabayashi, Presiding

8:00 AM **Introductory Remarks**

1-1 8:05 AM Wakabayashi, John*: **MÉLANGES WITH HP METAMORPHIC ROCKS IN SUBDUCTION COMPLEXES: DEFORMED OLISTOSTROMES RATHER THAN EXHUMED SUBDUCTION CHANNELS?**

1-2 8:25 AM Rowe, Christie D.*; Moore, Casey; Remitti, Francesca; Science Party, IODP Exp. 343: **THE THICKNESS OF PLATE BOUNDARY THRUST FAULTS: IMPLICATIONS FOR DEFORMATION MECHANISM AND THE ROCK RECORD OF SUBDUCTION**

1-3 8:45 AM Scholl, David*; von Huene, Roland: **REEXAMINING THE CONCEPT OF THE LONG-TERM, PROGRESSIVE ACCRETIONARY WIDENING OF THE ALASKA FOREARC—DURING THE CENOZOIC IT EVOLVED AS A NARROWING (BY ~70-100 KM) AND THINNING OR EROSIVE MARGIN**

1-4 9:05 AM Raymond, Loren A.*: **TECTONOSTRATIGRAPHIC HISTORY OF THE UPPER FRANCISCAN (SUBDUCTION ACCRETIONARY) COMPLEX IN NORTHERN CALIFORNIA: ISSUES OF TERRANE DESIGNATION AND MAPPING**

1-5 9:25 AM Singleton, John*; Cloos, Mark: **KINEMATIC ANALYSIS OF SYNSUBDUCTION SHEAR FABRICS IN FRANCISCAN COMPLEX MÉLANGE NEAR SAN SIMEON, CALIFORNIA**

1-6 9:45 AM McLaughlin, Robert J.*; Blake, M.C. Jr.; Sliter, William V.; Wentworth, Carl M.; Langenheim, V.E.; Jachens, R.C.; Sawlan, M.G.: **TRANSTENSIONAL RIFTING ASSOCIATED WITH VOLCANISM DURING ACCRETION OF LATE CRETACEOUS-EOCENE SEAMOUNT REMNANTS IN THE FRANCISCAN COMPLEX COASTAL BELT, NORTHERN CALIFORNIA**

10:05 AM **Break**

1-7 10:20 AM Surpless, Kathleen DeGraaff*: **SEDIMENTARY GEOCHEMISTRY OF THE GREAT VALLEY GROUP, CALIFORNIA: RECORDS OF THE LOST ARC**

1-8 10:40 AM Saleeby, Zorka*; Saleeby, Jason; Cecil, M. Robinson: **GEOLOGIC DEVELOPMENT OF THE KERN ARCH, SE SAN JOAQUIN BASIN (SJB), CALIFORNIA**

1-9 11:00 AM Charvet, Jacques P.*: **MESOZOIC-CENOZOIC TECTONIC EVOLUTION OF SW JAPAN: REVALIDATION OF THE COLLISIONAL MODEL**

1-10 11:20 AM Ogawa, Yujiro*; Kawamura, Kiichiro: **NEW SCOPE OF JAPAN TRENCH AND NANKAI TROUGH: MIOCENE TO RECENT TRENCH WEDGE HISTORY AND 2011 TOHOKU-OKI EARTHQUAKE**

1-11 11:40 AM Okay, Aral*; Sunal, Gursel; Sherlock, Sarah; Altiner, Demir; Tuysuz, Okan; Kylander-Clark, Andrew; Aygul, Mesut: **EARLY CRETACEOUS SEDIMENTATION AND OROGENY ON THE SOUTHERN ACTIVE MARGIN OF EURASIA: CENTRAL PONTIDES, TURKEY**

SESSION NO. 2

T5. Critical Zone I: Where Rock Meets Water and Life at Earth's Surface

9:20 AM, Radisson Hotel and Conference Center, Salon A2

Clifford S. Riebe, Leonard S. Sklar, and Kate Maher, Presiding

2-1 9:20 AM Wood, Jim*; Glasmann, J. Reed: **EARLY TERTIARY CLIMATE CHANGE AND ITS IMPACT ON THE MATRIX MINERALOGY OF "AURIFEROUS GRAVELS" IN THE SIERRA NEVADA FOOTHILLS**

2-2 9:40 AM Wood, Jim*; Glasmann, J. Reed: **THE NATURE OF EARLY TERTIARY SOILS AND SEDIMENTS—MINERALOGY AND PETROLOGY**

2-3 10:00 AM Granger, Darryl E.*; Reid, Casey R.; Riebe, Clifford S.: **EXHUMATION OF THE GRANITE MOUNTAINS, WYOMING, FROM COSMOGENIC DIPSTICK DATING**

2-4 10:20 AM Valenzuela, Rebecca A.*; Riebe, Clifford S.; Ramírez-Herrera, M. Teresa: **CONTRASTS IN DENUDATION RATES, CLIMATE, SUBDUCTION DIP ANGLES, AND PLATE CONVERGENCE RATES ALONG THE SOUTHWESTERN MEXICAN COAST**

2-5 10:40 AM Beyssac, Olivier*: **TRACING FOSSIL PARTICULATE ORGANIC CARBON FROM BEDROCKS TO RIVER AND MARINE SEDIMENTS: IMPLICATIONS FOR THE GEOLOGICAL CARBON CYCLE**

2-6 11:00 AM Hunsaker, Carolyn T.*; Stacy, Erin M.; Berhe, Asmeret Asefaw; Hart, Stephen C.: **HEADWATER STREAM SEDIMENT LOADS AND ASSOCIATED CARBON AND NITROGEN, SIERRA NEVADA, CALIFORNIA**

2-7 11:20 AM Meadows, Matthew*; Hartsough, Peter; Bales, Roger C.; Hopmans, Jan W.; Malazian, Armen: **USING LARGE-SCALE, SHALLOW SOIL WATER MEASUREMENTS TO ESTIMATE DEEPER SOIL WATER STORAGE IN A MIXED-CONIFER FOREST OF THE SOUTHERN SIERRA NEVADA**

2-8 11:40 AM Lucas, R. G.*; Conklin, M.H.: **GROUNDWATER-SURFACE WATER INTERACTIONS IN MONTANE MEADOWS OF THE SIERRA NEVADA, CALIFORNIA**

SESSION NO. 3

T14. Quaternary Geology of California's Central Valley and Its Relevance to Water Infrastructure

8:20 AM, Radisson Hotel and Conference Center, Salon D1

Justin Pearce, Janet Sowers, Jennifer Wilson, and Cooper C. Brossy, Presiding

3-1 8:20 AM Sowers, Janet*; Pearce, Justin; Brossy, Cooper C.; Kelson, Keith; Wilson, Jennifer M.: **QUATERNARY GEOLOGY AND GEOMORPHOLOGY A KEY TO ASSESSING LEVEE FOUNDATION CONDITIONS IN THE SACRAMENTO VALLEY, CALIFORNIA**

3-2 8:40 AM Wilson, Jennifer*; Pearce, Justin; Sowers, Janet: **DEVELOPING A GEOMORPHIC APPROACH TO ASSESSING LEVEE UNDERSEEPAGE**

3-3 9:00 AM Barry, G. Robert*; Nichols, Holly J.: **THE GEOLOGY AND ONGOING REPAIRS OF THE AGING CALIFORNIA AQUEDUCT IN THE CENTRAL VALLEY**

3-4 9:20 AM Sneed, Michelle*; Faunt, Claudia C.; Phillips, Steven; Solt, Mike; Brandt, Justin T.; Traum, Jonathan A.: **CORRELATING FINE-GRAINED DEPOSITS AND LAND SUBSIDENCE IN THE SAN JOAQUIN VALLEY, CALIFORNIA**

3-5 9:40 AM Brossy, Cooper C.*; Wilson, Jennifer; Pearce, Justin; Sowers, Janet; Hunter, Lewis E.; Kynett, Michael N.: **RE-VISITING AND REVISING THE QUATERNARY GEOLOGY OF THE LOWER AMERICAN RIVER**

10:00 AM **Break**

3-6 10:20 AM Ponti, Daniel J.*; Tinsley, John C.; Wan, Elmira; Pagenkopp, Mark; Maier, Katherine; Gatti, Emma; Olson, Holly; Haddon, Elizabeth; Rosa, Carla: **QUATERNARY STRATIGRAPHY AND NEOTECTONICS OF THE SACRAMENTO-SAN JOAQUIN DELTA, CALIFORNIA: PRELIMINARY FINDINGS FROM RECENT COLLABORATIVE RESEARCH**

3-7 10:40 AM Wan, Elmira; Maier, Katherine*; Gatti, Emma; Olson, Holly; Ponti, Daniel J.; Tinsley, John C.; Pagenkopp, Mark: **QUATERNARY TEPHROCHRONOLOGY AND STRATIGRAPHIC CORRELATION IN THE SACRAMENTO-SAN JOAQUIN DELTA, NORTHERN CALIFORNIA**

3-8 11:00 AM Hitchcock, Christopher*; Unruh, Jeffery: **GEOLOGIC AND GEOMORPHIC CONSTRAINTS ON THE QUATERNARY SEPARATION RATE OF THE MIDLAND FAULT, SACRAMENTO-SAN JOAQUIN DELTA, CALIFORNIA**

3-9 11:20 AM Kelson, Keith*; Kozlowicz, Benjamin; Hunter, Lewis; Simpson, David; Terra, Fabia; Rose, Ronn: **ASSESSMENT OF LOCAL QUATERNARY STRATIGRAPHY AND POTENTIAL SEISMIC SOURCES NEAR SUCCESS DAM, CENTRAL CALIFORNIA**

3-10 11:40 AM Sawyer, Thomas L.*: **SEISMIC HAZARDS OF THE NORTHERN CALIFORNIA SHEAR ZONE TO WATER STORAGE, CONVEYANCE AND FLOOD PROTECTION INFRASTRUCTURE, NORTHERN CENTRAL VALLEY, CALIFORNIA**

SESSION NO. 4

T2. Mélanges: Comparison and Contrast Between Circum-Pacific and Tethyan Chaotic Rock Bodies, and Modern Submarine Analogues

1:30 PM, Radisson Hotel and Conference Center, Salon A1

Yildirim Dilek, Andrea Festa, and Yujiro Ogawa, Presiding

4-1 1:30 PM Wakita, Koji*: **WHAT IS "A MÉLANGE"? - A COMPARATIVE STUDY ON UNITS OF MÉLANGES IN MINO AND SHIMANTO ACCRETIONARY COMPLEXES IN SOUTHWESTERN JAPAN**

4-2 1:50 PM Aalto, K.R.*: **FRANCISCAN COMPLEX: MAPPING OF MÉLANGES AND TERRANES IN THE NORTHERNMOST CALIFORNIA COAST RANGES, A RETROSPECTIVE**

4-3 2:10 PM Ogawa, Yujiro*; Mori, Ryota: **NEW INTERPRETATION OF FRANCISCAN MÉLANGE AT SAN SIMEON COAST, CALIFORNIA: TECTONIC INTRUSION INTO AN ACCRETIONARY PRISM**

4-4 2:30 PM Pini, Gian Andrea*; Festa, Andrea; Ogata, Kei; Camerlenghi, Angelo; Dilek, Yildirim; Strasser, Michael: **MASS-TRANSPORT PROCESSES AND SEDIMENTARY MéLANGES: INTERNAL DEFORMATIONS, STRATAL DISRUPTION AND OCCURRENCE OF EXOTIC BLOCKS**

4-5 2:50 PM Wakabayashi, John*: **WHAT IS AN EXOTIC BLOCK? IMPORTANCE IN EVALUATING ORIGINS OF MÉLANGE**

4-6 3:10 PM Alonso, Juan Luis*; Marcos, Alberto; Villa, Elisa; Súarez, Angela; Merino-Tomé, Oscar A.: **MÉLANGES AND OTHER TYPES OF BLOCK-IN-MATRIX FORMATIONS IN THE CANTABRIAN ZONE (VARISCAN OROGEN, NW SPAIN): ORIGIN AND SIGNIFICANCE**

3:30 PM **Discussion**

4-7 3:50 PM Festa, Andrea*; Dilek, Yildirim; Pini, Gian Andrea: **POLYGENETIC MÉLANGES IN THE LIGURIAN ACCRETIONARY WEDGE (NORTHERN APENNINES, ITALY)**

4-8 4:10 PM Kato, Terence T.*; Godoy, Estanislao: **PROGRESSIVE MELANGE EXHUMATION ALONG A PRE-ANDEAN TRANSPRESSIONAL FAULT SYSTEM, CORDILLERA DE LA COSTA, CHILE (26°S – 42°S)**

4-9 4:30 PM Okay, Aral*: **NEO-TETHYAN AND PALEO-TETHYAN MÉLANGES IN ANATOLIA**

4-10 4:50 PM Wang, Junpeng*; Kusky, Timothy M.; Polat, Ali; Wang, Lu; Deng, Hao; Wang, Songjie; Wang, Zhensheng; Alhousseyni, Traore: **A LATE ARCHEAN TECTONIC MÉLANGE IN THE CENTRAL OROGENIC BELT, NORTH CHINA CRATON**

4-11 5:10 PM Deng, Hao*; Kusky, Timothy M.; Polat, Ali; Wang, Lu; Wang, Junpeng; Wang, Songjie: **GEOCHEMISTRY OF NEOARCHEAN MAFIC VOLCANIC ROCKS AND LATE MAFIC DIKES AND SILLS IN THE ZANHUANG COMPLEX, CENTRAL OROGENIC BELT, NORTH CHINA CRATON: IMPLICATIONS FOR GEODYNAMIC SETTING**

SESSION NO. 5

T5. Critical Zone II: Where Rock Meets Water and Life at Earth's Surface

1:30 PM, Radisson Hotel and Conference Center, Salon A2

Clifford S. Riebe, Leonard S. Sklar, and Kate Maher, Presiding

5-1 1:30 PM Hartsough, Peter C.*; Malazian, Armen; Meadows, Matthew; O'Geen, Anthony T.; Hopmans, Jan W.: **CHARACTERIZATION OF WATER USE PATTERNS IN THE DEEP VADOSE ZONE THROUGH GEOPROBE DRILLING INTO WEATHERED BEDROCK**

5-2 1:50 PM Wang, Zhi*; Suen, C. John; He, Zili: **HYDROLOGIC SENSITIVITY OF THE SOUTHERN SIERRA**

NEVADA CRITICAL ZONES TO CLIMATE CHANGE PROJECTIONS

5-3 2:10 PM Wang, Zhi*: **VAPOR FLOW CONTRIBUTIONS TO ECO-HYDROLOGY IN DRY LAND CRITICAL ZONES**

5-4 2:30 PM Todd, Claire*; Lapo, Kristiana; Harris, Amanda; Hegland, Matthew; Siegesmund, Amy: **MOUNT RAINIER GLACIAL MELTWATER HYDROCHEMISTRY AND MICROBIAL COMMUNITIES**

5-5 2:50 PM White, Timothy S.*; Sharkey, Sarah; Dere, Ashlee: **BIOTURBATION AND EROSION BY TREE THROW IN FORESTED LANDSCAPES, APPALACHIAN MOUNTAINS**

5-6 3:10 PM Riebe, Clifford S.*; Hahm, W. Jesse: **THE INFLUENCE OF BEDROCK NUTRIENT CONCENTRATIONS ON LIFE AND TOPOGRAPHY IN THE SIERRA NEVADA BATHOLITH**

5-7 3:30 PM Janes, M. Katy*; Horner, Timothy: **HIGH VARIANCE OF PHYSICAL AND GEOCHEMICAL CHARACTERISTICS OF SALMONID SPAWNING RESTORATION SITES CREATES SUITABLE HABITAT WITHIN THE HYPORHEIC ZONE**

SESSION NO. 6

T13. Irvingtonian Paleoecology of Western North America

1:30 PM, Radisson Hotel and Conference Center, Salon D1

Robert G. Dundas and Eric Scott, Presiding

1:30 PM **Introductory Remarks**

6-1 1:35 PM Bell, Christopher J.*: **63 YEARS OF OBFUSCATION: CONCEPTUAL, FAUNAL, SPATIAL, AND TEMPORAL USES OF THE TERM "IRVINGTONIAN"**

6-2 1:55 PM Dundas, Robert G.*: **REVISITING IRVINGTON, TYPE FAUNA OF THE IRVINGTONIAN NORTH AMERICAN LAND MAMMAL AGE**

6-3 2:15 PM Chatters, James C.*; Van de Water, Peter K.: **PALEOECOLOGY OF THE IRVINGTONIAN FAIRMEAD LANDFILL SITE, MADERA COUNTY, CALIFORNIA**

6-4 2:35 PM Shaw, Christopher A.*; Croxen, Fred W. III.; Sussman, David R.: **PALEOECOLOGICAL CONSIDERATIONS REGARDING THE IRVINGTONIAN BIOTA FROM EL GOLFO DE SANTA CLARA, NORTHWESTERN SONORA, MEXICO**

6-5 2:55 PM Roeder, Mark A.*: **NEW RECORDS OF FRESHWATER FISH FROM IRVINGTONIAN DEPOSITS AROUND THE SALTON TROUGH, SOUTHERN CALIFORNIA AND NORTHWESTERN SONORA, MEXICO**

6-6 3:15 PM Ngo, My My*; Canchola, Joe A.; Dundas, Robert G.: **AVIFAUNAS OF THE MIDDLE PLEISTOCENE IRVINGTON AND FAIRMEAD LANDFILL LOCALITIES IN CALIFORNIA**

3:35 PM **Break**

6-7 3:50 PM McDonald, H. Gregory*: **DIFFERENCES IN NORTH AMERICA XENARTHRAN DISTRIBUTION IN THE IRVINGTONIAN AND RANCHOLABREAN: AN APPROACH TO BETTER UNDERSTANDING THE GREAT AMERICAN BIOTIC INTERCHANGE**

6-8 4:10 PM Howard, Carrie*; Shaw, Christopher A.; Croxen, Fred W. III.: **A NEARLY COMPLETE SKULL OF THE BEAVER, *CASTOR CANADENSIS*, FROM THE IRVINGTONIAN BADLANDS OF GOLFO DE SANTA CLARA, SONORA, MEXICO**

6-9 4:30 PM Scott, Eric*; Farrell, Aisling B.; Croxen, Fred W. III.; Shaw, Christopher A.; Hulbert, Richard C.: **NEW RECORDS OF IRVINGTONIAN *TAPIRUS* FROM THE AMERICAN SOUTHWEST**

6-10 4:50 PM Asami, Rebecca*; Espino, Yesenia; Scott, Eric; Haack, Kelsey; Dundas, Robert G.: **DETERMINING SPECIES OF *EQUUS* FROM THE MID IRVINGTONIAN FAIRMEAD LANDFILL LOCALITY, MADERA COUNTY, CALIFORNIA**

6-11 5:10 PM Trayler, Robin B.*; Dundas, Robert G.; Fox-Dobbs, Kena; Van de Water, Peter K.: **STABLE ISOTOPE ECOLOGY AND DIETARY MODELING OF MAMMALIAN MEGAFAUNA FROM THE MIDDLE IRVINGTONIAN FAIRMEAD LANDFILL LOCALITY, CHOWCHILLA, CA**

POSTER TECHNICAL SESSIONS

SESSION NO. 7

Mineralogy, Petrology, and Geochemistry (Posters)

1:30 PM, Radisson Hotel and Conference Center, Salon B/C

Authors will be present from 2:30 to 4:30 PM

Booth #

7-1 1 Brown, Howard J.*: **FLUORESCENT MINERALS AT THE OMYA WHITE KNOB QUARRY, LUCERNE VALLEY CALIFORNIA**

7-2 2 Kleck, Wallace D.*: **THE ABUNDANCE AND DISTRIBUTION OF THE RARE-EARTH ELEMENTS LA, CE, AND ND IN THE GEORGE ASHLEY BLOCK PEGMATITE BODY**

7-3 3 Baltzer, Suzanne M.*; Jessey, David R.; Housley, Robert M.: **PETROCHEMISTRY OF A RARE EARTH OCCURRENCE WITHIN THE NORTHERN NEW YORK MOUNTAINS OF SOUTHERN NEVADA**

SESSION NO. 8

Plutons: Evolution, Emplacement, and Deformation (Posters)

1:30 PM, Radisson Hotel and Conference Center, Salon B/C

Authors will be present from 2:30 to 4:30 PM

Booth #

8-1 4 Scudder, Christopher*; Miller, Robert: **STRUCTURE OF THE EOCENE GOLDEN HORN BATHOLITH, NORTH CASCADES, WASHINGTON**

8-2 5 Elkins, Scott W.*; Miller, Robert: **STRUCTURE AND CONSTRUCTION OF THE HIGHLY ELONGATE, CRETACEOUS SEVEN-FINGERED JACK PLUTON IN THE DEVIL'S SMOKESTACK AREA, NORTH CASCADES, WASHINGTON**

8-3 6 Dustin, Kelly Nicole*; Miller, Robert B.: **CONSTRUCTION AND RELATIONSHIPS OF MAFIC AND TONALITIC ROCKS IN THE SEVEN FINGERED JACK PLUTON, NORTH CASCADES, WASHINGTON**

8-4 7 Buerer, Brad*; Miller, Robert: **FOLIATION DEVELOPMENT AND INTRUSIVE RELATIONSHIPS IN THE CRETACEOUS WRIGHTS LAKE AND JURASSIC PYRAMID PEAK PLUTONS OF THE NORTHERN SIERRA NEVADA BATHOLITH, DESOLATION WILDERNESS, CALIFORNIA**

8-5 8 Miller, Robert B.*; Johnson, Brendon; Van Dyne, Ashley; Petsche, Joseph: **STRUCTURE OF THE YOSEMITE VALLEY INTRUSIVE SUITE: REGIONAL STRAIN FIELDS AND INFLUENCE ON EMPLACEMENT OF YOUNGER INTRUSIONS IN THE CENTRAL SIERRA NEVADA BATHOLITH**

8-6 9 Brown, Kenneth*; Hart, William K.: **LATE CRETACEOUS ARC FLARE-UP IN NORTHWESTERN NEVADA: ELEMENTAL, ZIRCON HF ISOTOPE, AND U-PB ZIRCON GEOCHONOLOGY OF THE SANTA ROSA RANGE AND BLOODY RUN HILLS GRANITOIDS**

8-7 10 Bartley, John M.*; Glazner, Allen; Law, Bryan; Coleman, D.S.: **GEOMETRY AND EMPLACEMENT MECHANISM OF LADDER DIKES IN THE CATHEDRAL PEAK GRANODIORITE, YOSEMITE NATIONAL PARK**

8-8 11 Ianno, Adam J.*; Norwood, Christopher W.; Paterson, Scott R.: **CONSTRUCTION AND MAGMATIC EVOLUTION OF THE COMPOSITE PALMS GRANITE PLUTON, JOSHUA TREE NATIONAL PARK, CALIFORNIA**

SESSION NO. 9

Volcanology, Volcanic Rocks, Volcanic Petrogenesis (Posters)

1:30 PM, Radisson Hotel and Conference Center, Salon B/C

Authors will be present from 2:30 to 4:30 PM

Booth #

9-1 12 Davidson, Blair*; Browne, Brandon L.: **PETROLOGY AND GEOCHEMISTRY OF MINARET CONE, MAMMOTH MOUNTAIN, CA**

9-2 13 Browne, Brandon L.*; Foster, John; Jicha, Brian R.: **AGE OF THE ALVORD PEAK BASALT, CENTRAL MOJAVE DESERT, CALIFORNIA**

9-3 14 Haygood, Zachary*; Browne, Brandon L.: **THE PYROCLASTIC SURGE DEPOSIT OF THE ~680 YR BP PANUM CRATER ERUPTION, EASTERN CALIFORNIA**

9-4 15 Partridge, Molly E.*; Egger, Anne E.: **VOLCANO-TECTONIC HISTORY OF THE NORTHERN WARNER RANGE IN NORTHEASTERN CALIFORNIA**

9-5 16 Meade, Kyle*: **PETROLOGIC ANALYSIS OF RAILROAD VALLEY RHYOLITE, GRANT RANGE, NYE COUNTY, NV**

9-6 17 Jenkins, Emily N.*; Streck, Martin J.; Ramos, Frank C.: **^{87}SR/^{86}SR OF MID-MIOCENE SILICIC VOLCANISM IN EASTERN OREGON: EVIDENCE FOR VARIABLE AND HIGH SR DOMAINS WEST OF THE TERRANE-CRATONIC LITHOSPHERE TRANSITION**

9-7 18 McClaughry, Jason D.*; Wiley, Thomas J.; Conrey, Richard M.; Jones, Cullen B.; Lite, Kenneth E. Jr.: **THE HOOD RIVER GRABEN: A LATE PLIOCENE AND QUATERNARY INTRA-ARC HALF GRABEN IN THE NORTHERN OREGON CASCADE RANGE**

9-8 19 Marcy, Phillip I.*; Streck, Martin J.; Ferns, Mark L.: **REVISITING VOLCANOLOGY AND COMPOSITION OF RHYOLITES AND ASSOCIATED REE RICH MAFIC CLASTS OF THE THREE FINGERS CALDERA, SE OREGON**

9-9 20 Benson, T.R.*; Mahood, Gail A.; Grove, Marty: **NEW GEOLOGIC AND GEOCHRONOLOGIC DATA ON THE LAKE OWYHEE VOLCANIC FIELD, OREGON: A SILICIC CENTER CONTEMPORANEOUS WITH FLOOD BASALT VOLCANISM**

9-10 21 Curry, Adam C.*: **THE ROLE OF SHEAR HEATING IN THE FORMATION OF OBSIDIAN**

SESSION NO. 10

T10. Reconstructing the Pacific-North America Plate Boundary Through Late Cenozoic Time (Posters)

1:30 PM, Radisson Hotel and Conference Center, Salon B/C

Authors will be present from 2:30 to 4:30 PM

Booth #

10-1 22 Duque, Jose*; Ferrari, Luca; Lopez Martinez, Margarita; Orozco Esquivel, Maria Teresa; Lonsdale, Peter: **EARLY TO MIDDLE MIOCENE SYN-EXTENSIONAL MAGMATISM IN THE SOUTHERN GULF OF CALIFORNIA**

10-2 23 Umhoefer, Paul J.*; Skinner, Lisa A.; Bennett, Scott E.K.; Oskin, Michael E.; Dorsey, Rebecca; Darin, Michael H.: **BREACHING OF TRANSFORM FAULTS AND FLOODING OF PULL-APART BASINS TO INCREMENTALLY FORM THE EARLY GULF OF CALIFORNIA SEAWAY FROM ~8 TO 6.3 MA**

10-3 24 Lomtatidze-Jimenez, Ekaterina*; Martin-Barajas, Arturo; Weber, Bodo; Pérez-Arvizu, Ofelia: **PROVENANCE AND GEOCHEMISTRY OF SEDIMENTS IN THE NORTHERN GULF OF CALIFORNIA: RESULTS FROM A DEEP STRATIGRAPHIC RECORD FROM WELL SAMPLES**

10-4 25 Parker, Michael Paul*; Bykerk-Kauffman, Ann: **MAJOR BUTTRESS DISCONFORMITY WITHIN THE MIOCENE SPLIT MOUNTAIN GROUP, SALTON TROUGH, SOUTHERN CALIFORNIA**

10-5 26 Price, Jason B.*; Harvey, Janet C.; Hamon, Jennifer L.; Stock, Joann M.: **UPDATED FIELD MAPPING IN THE LAVA HILLS, SAN BERNARDINO COUNTY, CALIFORNIA**

10-6 27 Murray, Bryan P.*: **EVIDENCE OF SYNEXTENSIONAL DEPOSITION OF THE PICKHANDLE AND JACKHAMMER FORMATIONS IN THE NORTHERN CALICO MOUNTAINS, CENTRAL MOJAVE DESERT, CALIFORNIA**

10-7 28 Hernandez, Janis L.*: **REVISED ALQUIST-PRIOLO EARTHQUAKE FAULT ZONE MAP FOR THE WHITTIER FAULT, YORBA LINDA 7.5' QUADRANGLE, ORANGE COUNTY, CALIFORNIA**

10-8 29 Stanley, Richard G.*; Barron, John A.; Powell, Charles L. II.; Graymer, Russell W.; Brabb, Earl E.: **PROGRESS TOWARD UNDERSTANDING THE STRATIGRAPHY AND RIGHT-LATERAL DISPLACEMENT OF UPPER MIOCENE ROCKS ALONG THE SAN ANDREAS FAULT IN CENTRAL CALIFORNIA**

10-9 30 Guillaume, Jonathan Kalani*: **TESTING THE STRUCTURAL ROLE OF THE SANTA MARIA BASIN IN THE ROTATION OF THE WESTERN TRANSVERSE RANGES, CALIFORNIA**

10-10 31 Hamilton, Douglas H.*: **LANDFORMS AND TECTONICS OF THE CENTRAL COAST REGION OF CALIFORNIA**

10-11 32 Grove, Karen*; Stozek, Brian: **GEOPHYSICAL AND SEDIMENTOLOGIC EVIDENCE FOR PLIO-PLEISTOCENE DEFORMATION IN THE OFFSHORE SAN ANDREAS FAULT ZONE BETWEEN GUALALA AND SAN FRANCISCO, NORTHERN CALIFORNIA**

10-12 33 Hoirup, Don F. Jr.*; Sawyer, Thomas L.; Unruh, Jeffrey: **GEOMORPHIC AND STRUCTURAL ANALYSIS OF THE VERONA-WILLIAMS-PLEASANTON FAULT ZONE AND IMPLICATIONS FOR SEISMIC HAZARD, EASTERN SAN FRANCISCO BAY AREA, CALIFORNIA**

10-13 34 Hoirup, Don F. Jr.*; Hitchcock, Christopher: **LIDAR-BASED MAPPING OF LATE QUATERNARY FAULTING, GRIZZLY VALLEY FAULT WALKER LANE SEISMIC BELT, PLUMAS COUNTY, CALIFORNIA**

10-14 35 Jones, Shelby A.*; Pluhar, Christopher J.; Farner, Michael: **CORRELATION AND ANALYSIS OF PALEOCHANNELS IN THE SIERRA NEVADA, CALIFORNIA, AS DISPLAYED BY THE STANISLAUS GROUP; TOWARDS UPDATING LATE CENOZOIC UPLIFT ESTIMATES**

10-15 36 Carlson, Chad W.*; Wakabayashi, John: **ONE VERSUS TWO LATE CENOZOIC UPLIFT EVENTS, SIERRA NEVADA, CALIFORNIA, RECORDED IN DRAINAGE GEOMORPHOLOGY**

10-16 37 Knott, Jeffrey R.*; Manoukian, David; Nunez, Ernest Jr.; Whitmer, Daniel; Hathaway, Jeffrey; Reheis, M.C.; Wan, Elmira; Lackey, Jade Star; Deino, Alan: **LATE NEOGENE DEPOSITION IN THE LAST CHANCE RANGE, EASTERN CALIFORNIA**

10-17 38 Nunez, Ernest Jr.*; Knott, Jeffrey R.; Zepeda, Anthony; Schlom, Tyanna M.: **FAULT SCARP MORPHOLOGY ALONG THE EUREKA VALLEY FAULT ZONE, EASTERN CALIFORNIA, U.S.A**

10-18 39 Fredrickson, Shelby M.*; Lindeman, Justin R.; Pluhar, Christopher J.; Carlson, Chad W.: **KINEMATICS OF DEFORMATION IN WEST-CENTRAL WALKER LANE; PALEOMAGNETIC TESTING OF FAULT-BLOCK ROTATION AND DOMING MODELS, EASTERN CALIFORNIA AND WESTERN NEVADA**

10-19 40 Makovsky, Kyle A.*: **JUST WHERE IS THE NORTHERN TERMINATION OF THE WALKER LANE? POSSIBLE ASSOCIATIONS TO DEXTRAL OBLIQUE-STRIKE SLIP FAULTING IN NORTHERN CALIFORNIA AND SOUTHEASTERN OREGON**

TUESDAY, 21 MAY 2013

ORAL TECHNICAL SESSIONS

SESSION NO. 11

Sedimentary Geology

10:00 AM, Radisson Hotel and Conference Center, Salon D1

Mara Brady and Cara Harwood, Presiding

11-1 10:00 AM Weinman, Beth*; Yoo, Kyungsoo; Mudd, Simon Marius; Attal, Mikael; Maher, Kate; Kouba, Claire; Singhvi, Ashok: **SEDIMENTOLOGICAL AND GEOMORPHOLOGICAL PERSPECTIVES ON GRAINSIZE DISTRIBUTIONS: HOW SEDIMENTS GET THEIR SIZE IN THE SIERRA NEVADA, CALIFORNIA**

11-2 10:20 AM Lowey, Grant*: **INTEGRATED PROVENANCE ANALYSIS OF THE DEZADEASH FORMATION (JURA-CRETACEOUS), YUKON, CANADA: CONSTRAINING THE ACCRETIONARY TECTONIC HISTORY OF THE WRANGELLIA COMPOSITE TERRANE IN THE NORTHERN CORDILLERA OF NORTH AMERICA**

11-3 10:40 AM Buesch, David C.*: **PRE-, SYN-, AND POST- MIOCENE VOLCANIC SOURCES AND DEPOSITIONAL ENVIRONMENTS IN SEDIMENTARY ROCKS AT CRASH HILL, NELSON LAKE VALLEY, CALIFORNIA**

11-4 11:00 AM Harwood, Cara L.*; Sumner, Dawn Y.: **CLOTTEDNESS IN CAMBRIAN MICROBIALITES: EXAMINING TEXTURAL VARIATIONS IN THE DEFINING CHARACTERISTIC OF THROMBOLITES**

11-5 11:20 AM Morgan, George*: **EVIDENCE OF FRESH WATER LIMESTONE (BOUSE FORMATION EQUIVILENT?) IN THE TRANSGESSIONAL-REGRESIONAL MARINE AND NON-MATINE IMPERIAL GROUP SEDIMENTS, COYOTE MOUNTAINS, IMPERIAL COUNTY, SALTON TROUGH, SOUTHERN CALIFORNIA**

11-6 11:40 AM Brady, Mara*: **EVALUATING THE STRATIGRAPHIC COMPLETENESS OF DEEP-TIME RECORDS: A NEW QUANTITATIVE APPROACH**

SESSION NO. 12

T3. Oceanic Petrogenesis of Pacific-Type Convergent Margins

8:15 AM, Radisson Hotel and Conference Center, Salon A1

Tatsuki Tsujimori, W.G. Ernst, and John Wakabayashi, Presiding

8:15 AM **Introductory Remarks**

12-1 8:20 AM Liou, Juhn G.*; Tsujimori, Tatsuki: **RECYCLING OF UHP-UHT MINERALS — THE FATE OF SUBDUCTED CONTINENTAL CRUST**

12-2 8:40 AM Beyssac, Olivier*; Galvez, Matthieu E.; Vitale Brovarone, Alberto: **CARBON CYCLING IN SUBDUCTION ZONES: THE IMPORTANCE OF METASOMATISM**

12-3 9:00 AM Vitale Brovarone, Alberto*; Picatto, Miro; Agard, Philippe; Beyssac, Olivier: **THERMAL REGIME AND TECTONO-STRATIGRAPHY ACROSS THE BLUESCHIST-ECLOGITE TRANSITION: INSIGHTS FROM VARIOUS HP BELTS OF TETHYAN AND PACIFIC TYPE**

12-4 9:20 AM Vitale Brovarone, Alberto*; Beyssac, Olivier: **THE IMPORTANCE OF LAWSONITE METASOMATISM IN BLOCK-IN-MATRIX STRUCTURES: FIELD AND GEOCHEMICAL FINGERPRINTS FROM ALPINE CORSICA**

12-5 9:40 AM Flores, Kennet E.*; Brueckner, Hannes K.; Harlow, George E.: **CONTRASTING PROTOLITH GEOCHEMICAL SIGNATURES OF JURASSIC PACIFIC-RELATED METABASITES NORTH AND SOUTH OF THE CHORTÍS BLOCK (GUATEMALA AND NICARAGUA)**

10:00 AM **Break**

12-6 10:20 AM Ernst, W.G.*: **MID-MESOZOIC TO MIOCENE CLASTIC SEDIMENTATION ALONG THE NORTHERN CALIFORNIA MARGIN—PROVENANCE AND PLATE-TECTONIC IMPLICATIONS**

12-7 10:40 AM Barnes, Calvin G.*; Barnes, Melanie A.: **THE WESTERN HAYFORK TERRANE: MIDDLE JURASSIC ARC WITH ADAKITIC AFFINITIES IN THE KLAMATH MOUNTAIN PROVINCE, OR AND CA**

12-8 11:00 AM Maekawa, Hirokau*: **SERPENTINITE DIAPIR AND BLUESCHIST METAMORPHISM IN THE MARIANA FOREARC, WESTERN PACIFIC**

12-9 11:20 AM Okamoto, Kazuaki*: **ZIRCON CHRONOLOGY AND GARNET CHEMISTRY RELATED TO DEHYDRATION MELTING IN A DEEP SUBDUCTION ZONE: CASE STUDY FROM THE SANBAGAWA QUARTZ-BEARING ECLOGITE**

12-10 11:40 AM Tsai, Chin-Ho*; Lan, Ching-Hung: **AMPHIBOLE COMPOSITIONS AND TECTONIC IMPLICATIONS OF THE WANJUNG SERPENTINITE COMPLEX, YULI BELT, EASTERN TAIWAN**

SESSION NO. 13

T10. Reconstructing the Pacific-North America Plate Boundary Through Late Cenozoic Time I

8:00 AM, Radisson Hotel and Conference Center, Salon A2

Scott E.K. Bennett, Rebecca Dorsey, Michael Oskin, and Michael H. Darin, Presiding

8:00 AM **Introductory Remarks**

13-1 8:05 AM Atwater, Tanya M.*; Stock, Joann: **CONSTRAINTS ON THE HISTORY OF THE LATE CENOZOIC PACIFIC-NORTH AMERICAN PLATE BOUNDARY FROM MARINE MAGNETIC ANOMALIES AND GLOBAL PLATE CIRCUITS**

13-2 8:25 AM Stock, Joann M.*; Martin-Barajas, Arturo: **EVOLUTION OF THE SALTON TROUGH-GULF OF CALIFORNIA PART OF THE PACIFIC-NORTH AMERICA PLATE BOUNDARY: AN UPDATE**

13-3 8:45 AM Ferrari, Luca*; Martinez-Lopez, Margarita; Orozco Esquivel, Maria Teresa; Bryan, Scott; Duque, Jose; Lonsdale, Peter: **LATE OLIGOCENE TO MIDDLE MIOCENE RIFTING AND SYN-EXTENSIONAL MAGMATISM IN THE SOUTHWESTERN SIERRA MADRE OCCIDENTAL, MEXICO: THE BEGINNING OF THE GULF OF CALIFORNIA RIFT**

13-4 9:05 AM Gans, Phillip B.*; Herman, Scott; MacMillan, Ian: **LATE MIOCENE (12-6 MA) TRANSTENSIONAL FAULTING, BLOCK ROTATIONS, AND VOLCANISM DURING INCEPTION OF THE GULF OF CALIFORNIA OBLIQUE RIFT, SOUTHWESTERN SONORA, MEXICO**

13-5 9:25 AM Bennett, Scott E.K.*; Oskin, Michael E.; Iriondo, Alexander: **TIMING AND MAGNITUDE OF TRANSFORM FAULTING IN THE NORTHERN GULF OF CALIFORNIA: IMPLICATIONS FOR OBLIQUE RIFT LOCALIZATION AND RECONSTRUCTIONS OF THE PACIFIC-NORTH AMERICA PLATE BOUNDARY**

9:45 AM **Break**

13-6 10:00 AM Martín, Arturo*; Hurtado, Juan Carlos; Cañón, Edgardo; Weber, Bodo; Schmitt, A.K.: **EXTENT AND COMPOSITION OF THE NEW CRUST BENEATH RIFT BASINS IN THE NORTHERN GULF OF CALIFORNIA**

13-7 10:20 AM Nourse, Jonathan A.*: **HOW DOES THE EASTERN CALIFORNIA SHEAR ZONE PROJECT INTO SONORA, MEXICO?**

13-8 10:40 AM Singleton, John*: **POST-MIDDLE MIOCENE DEXTRAL FAULTING IN THE LOWER COLORADO RIVER EXTENSIONAL CORRIDOR: INSIGHTS FROM THE BUCKSKIN-RAWHIDE CORE COMPLEX, WEST-CENTRAL ARIZONA**

13-9 11:00 AM Darin, Michael H.*; Bennett, Scott E.K.; Oskin, Michael E.; Dorsey, Rebecca J.: **CUMULATIVE DEXTRAL STRAIN ACROSS THE MIOCENE-PRESENT PACIFIC-NORTH AMERICA PLATE BOUNDARY: EASTERN CALIFORNIA SHEAR ZONE TO THE NORTHERN GULF OF CALIFORNIA**

13-10 11:20 AM Umhoefer, Paul J.*; Bennett, Scott E.K.; Skinner, Lisa A.; Darin, Michael H.; Oskin, Michael E.; Dorsey, Rebecca J.: **RECONSTRUCTING THE GULF OF CALIFORNIA-SALTON TROUGH OBLIQUE PLATE BOUNDARY WITH GIS MAPS SINCE 12 MA**

11:40 AM **Discussion**

POSTER TECHNICAL SESSIONS

SESSION NO. 14

Engineering and Environmental Geology (Posters)

8:00 AM, Radisson Hotel and Conference Center, Salon B/C

Authors will be present from 9 to 11 AM

Booth #

14-1 1 Testa, Stephen M.*; Parrish, John G.: **FROM AGGREGATE AVAILABILITY TO SUSTAINABILITY IN CALIFORNIA**

14-2 2 Rubin, Ron S.*; Olson, Brian P.E.: **NEW REGULATORY FAULT RUPTURE HAZARD ZONES BY STATE OF CALIFORNIA**

14-3 3 Sutherland, Michelle Allison*; Keaton, Jeffrey R.; Heron, Christopher: **CORRELATING SURFACE GEOLOGY WITH 1913-VINTAGE AS-BUILT GEOLOGY ACROSS THE SAN ANDREAS FAULT FOR SEISMIC ENHANCEMENT OF THE ELIZABETH TUNNEL, LOS ANGELES AQUEDUCT**

14-4 4 Kennedy, Drew G.*; Pascoe, Jerry S.; Smith, Casey D.; Braun, Kurt N.; Koehn, Brad A.: **OPEN CANAL SOLUTION FOR ADDRESSING THE STABILITY OF AN UNSUPPORTED WATER CONVEYANCE TUNNEL**

14-5 5 Drew, Dennis*: **AN INVESTIGATION OF THE USE OF MOBILE LIDAR ON THE LEVEE SYSTEM OF CALIFORNIA DURING AN EMERGENCY FLOOD**

14-6 6 Lindsey, Kassandra O.*; Whitney, Hilary; Linde, Tamara C.; Burns, Scott: **RADON HOT SPOTS IN OREGON AND THE UNDERLYING GEOLOGY**

14-7 7 Whitney, Hilary*; Lindsey, Kassandra O.; Linde, Tamara C.; Burns, Scott: **RADON IN HOMES IN THE PORTLAND, OREGON AREA: RADON DATA FROM LOCAL RADON TESTING COMPANIES COLLECTED BY CRM (CONTINUOUS RADON MEASUREMENT) MACHINES**

14-8 8 Linde, Tamara C.*; Lindsey, Kassandra O.; Whitney, Hilary; Burns, Scott F.: **A COMPARISON OF GEOLOGY TO RADON TEST DATA IN PORTLAND, OREGON**

14-9 9 Ricker, Tracy R.; Burns, Scott F.*: **ARSENIC IN SOILS OF NORTHWESTERN OREGON**

14-10 10 De Graff, Jerome V.*; Gallegos, Alan J.: **OBSERVATIONS DEMONSTRATING THE RUNOFF-INITIATION OF THE JULY 12, 2008 PIUTE WILDFIRE DEBRIS FLOWS, SIERRA NEVADA, CALIFORNIA**

14-11 11 Wagner, David L.*: **THE OAK CREEK WATER-SEDIMENT FLOWS OF JULY 12, 2008, INYO COUNTY, CALIFORNIA: A HAZARDOUS RESPONSE TO SIERRAN UPLIFT**

14-12 12 Lancaster, Jeremy T.*: **OBSERVATIONS DEMONSTRATING THE RUNOFF INITIATION OF THE AUGUST 26, 2010 POSTFIRE DEBRIS FLOWS, HAIWEE CREEK, INYO COUNTY, CALIFORNIA**

14-13 13 Lancaster, Jeremy T.*; Spittler, Thomas E.; Short, William R.: **ALLUVIAL FAN FLOODING HAZARDS: AN ENGINEERING GEOLOGIC APPROACH FOR REGIONAL PLANNING AND PRELIMINARY DESIGN**

14-14 14 Hausback, Brian P.*; Wood, Jim; Henry, Christopher D.; McCrink, Timothy P.: **LANDSLIDE HAZARDS ALONG THE INTERSTATE 80 CORRIDOR ASSOCIATED WITH THE EARLY OLIGOCENE SEDIMENTARY AND VOLCANIC DEPOSITS IN THE SIERRA NEVADA**

14-15 15 Fingerson, Rob; Glasmann, J. Reed; Hausback, Brian P.; Henry, Christopher D.; Loyd, Ralph; McCrink, Timothy P.; Wood, Jim*: **GEOLOGIC HAZARDS IN THE EARLY TERTIARY SEDIMENTS OF THE SIERRA NEVADA FOOTHILLS OF CALIFORNIA**

14-16 16 Stansbeary, Ann M.*; Jenkins, Emily N.; Carnes, Austin; Conrath, Kysa: **INVESTIGATION OF RISING GROUNDWATER LEVEL OBSERVED AT MCMENAMINS EDGEFIELD IN TROUTDALE, OREGON**

SESSION NO. 15

T5. Critical Zone: Where Rock Meets Water and Life at Earth's Surface (Posters)

8:00 AM, Radisson Hotel and Conference Center, Salon B/C

Authors will be present from 9 to 11 AM

Booth #

15-1 17 Stacy, Erin M.*; Berhe, Asmeret Asefaw; Johnson, Dale W.; Hunsaker, Carolyn T.; Hart, Stephen C.: **DECOMPOSABILITY OF ORGANIC MATTER IN SEDIMENTS ERODED FROM EIGHT LOW-ORDER CATCHMENTS, SIERRA NEVADA, CALIFORNIA**

15-2 18 Bean, Jessica A.*: **PERFORMANCE OF GRAVEL AUGMENTATION ON THE LOWER AMERICAN RIVER, LOWER SAILOR BAR 2012**

15-3 19 Steinert, Tiffany*; Weinman, Beth; Yoo, Kyungsoo; Mudd, Simon Marius; Kouba, Claire; Maher, Kate: **EVIDENCE FOR FRACTIONATION OF RARE EARTH ELEMENTS DURING SOIL FORMATION ALONG FEATHER RIVER BASIN HILLSLOPES IN THE CALIFORNIA SIERRA NEVADA**

SESSION NO. 16

Geomorphology and Quaternary Geology (Posters)

8:00 AM, Radisson Hotel and Conference Center, Salon B/C

Authors will be present from 9 to 11 AM

Booth #

16-1 20 Thibodeaux-Yost, Singleton*; Brady, Roland H. III.; Vyverberg, Kris A.; Weinman, Beth: **DELINEATION OF DRYLAND EPISODIC STREAM PROCESSES FOR THE RIDGECREST SOLAR POWER PROJECT, KERN COUNTY, CALIFORNIA**

16-2 21 Kaphle, Rameshwor*; Liu, Lubo: **ESTIMATING SHEAR STRESS OF STREAM BED USING ACOUSTIC DOPPLER VELOCIMETERS**

16-3 22 Cordes, Shaun E.*; Stock, Greg M.; Schwab, Brandon Edward; Glazner, Allen F.: **SUPPORTING EVIDENCE FOR A LARGE ROCK FALL 9.6 ± 1 KA FROM GLACIER POINT IN YOSEMITE VALLEY, CALIFORNIA**

16-4 23 Ahlstrom, Martha Peggye*; Heermance, Richard V.: **POST-STATION FIRE DEBRIS FLOW ANALYSIS IN THE SAN GABRIEL MOUNTAINS**

16-5 24 Short, Lauren E.*; Gabet, Emmanuel J.: **THE RELATIONSHIP BETWEEN LARGE WOODY DEBRIS AND A DECREASE OF MEDIAN BED MATERIAL SIZE IN A GRAVEL BED CHANNEL AFTER POST-FIRE DEBRIS FLOWS**

16-6 25 Swanson, Brian J.*: **NEW LANDSLIDE MAPPING OF THE PITAS POINT AND VENTURA QUADRANGLES, VENTURA COUNTY, SOUTHERN CALIFORNIA**

16-7 26 Sundberg, Paul Robert*: **REFINING GEOLOGIC MAPPING OF THE MAD RIVER FAULT ZONE BETWEEN FIELDBROOK VALLEY AND MCKINLEYVILLE, CALFORNIA USING HIGH-RESOLUTION TOPOGRAPHIC DATA AND SPATIAL ANALYSIS TOOLS**

16-8 27 Short, William R.*; Bedrossian, Trinda L.; Hayhurst, Cheryl A.; Lancaster, Jeremy T.: **COMPILATION OF SURFICIAL GEOLOGIC MAPPING IN SOUTHERN CALIFORNIA**

SESSION NO. 17

T14. Quaternary Geology of California's Central Valley and Its Relevance to Water Infrastructure (Posters)

8:00 AM, Radisson Hotel and Conference Center, Salon B/C

Authors will be present from 9 to 11 AM

Booth #

17-1 28 Springhorn, Steven T.*; Hightower, Nicholas; Bedegrew, Tad; Bonds, Christopher L.: **BASE OF FRESH GROUNDWATER IN THE SACRAMENTO VALLEY, CALIFORNIA**

17-2 29 Gutierrez, Carlos*; Dawson, Timothy E.: **RECENT GEOLOGIC COMPILATIONS IN CALIFORNIA'S CENTRAL VALLEY BY THE CALIFORNIA GEOLOGICAL SURVEY AND THE DEVELOPMENT OF A NEW DIGITAL GEOLOGIC MAP OF CALIFORNIA**

17-3 30 Haydon, Wayne D.*: **QUATERNARY SURFICAL DEPOSITS OF THE SOUTHERN SAN JOAQUIN VALLEY**

SESSION NO. 18

T7. Hydrogeologic Issues of Irrigated Agricultural Regions-Problems and Solutions (Posters)

8:00 AM, Radisson Hotel and Conference Center, Salon B/C

Authors will be present from 9 to 11 AM

Booth #

18-1 31 Han, Jong Youn*; Lubo, Liu: **EFFICIENCY OF SOIL VAPOR EXTRACTION AS A GROUNDWATER REMEDIAITON TOOL FOR OIL REFINERIES IN THE CENTRAL VALLEY OF CALIFORNIA**

18-2 32 Rieth, Dale*; Holcomb, Ronald E.; Hishida, Kassandra; Wang, Zhi: **SOIL ORGANIC MATTER CONTENTS IN THE SHALLOW SALINE AQUIFER BELOW NAS LEMOORE IN WESTERN SAN JOAQUIN VALLEY, CALIFORNIA**

18-3 33 Hishida, Kassandra*; Rieth, Dale; Holcomb, Ronald E.; Wang, Zhi: **SOIL VERSUS GROUNDWATER SALINITY AT NAS LEMOORE IN WESTERN SAN JOAQUIN VALLEY, CALIFORNIA**

18-4 34 Halopoff, David D.*; Liu, Lubo: **NITRATE FATE AND TRANSPORT IN A LARGE SOIL AND GROUNDWATER-MODELING TANK**

18-5 35 Cassel Sharma, Florence*; Goorahoo, Dave; Yadavali, Prasad: **ENVIRONMENTAL AND AGRONOMIC MANAGEMENT STRATEGIES FOR IMPROVING TOMATO PRODUCTION IN SALT-AFFECTED SOILS OF THE SAN JOAQUIN VALLEY, CA**

SESSION NO. 19

T13. Irvingtonian Paleoecology of Western North America (Posters)

8:00 AM, Radisson Hotel and Conference Center, Salon B/C

Authors will be present from 9 to 11 AM

Booth #

19-1 36 Del Castillo, Christopher*; Espino, Yesenia; Dundas, Robert G.: **AMERICAN BADGER (*TAXIDEA TAXUS*) FROM THE MID-IRVINGTONIAN FAIRMEAD LANDFILL LOCALITY, MADERA COUNTY, CALIFORNIA**

19-2 37 Tovar, Danny H.*; Dundas, Robert G.: **FELIDAE FROM IRVINGTONIAN DEPOSITS AT FAIRMEAD LANDFILL AND IRVINGTON IN CALIFORNIA**

ORAL TECHNICAL SESSIONS

SESSION NO. 20

Geomorphology and Quaternary Geology

1:30 PM, Radisson Hotel and Conference Center, Salon D2

Greg M. Stock and Jessica A. Thompson, Presiding

20-1 1:30 PM Shlemon, Roy*: **PLEISTOCENE CHANNELS IN THE CENTRAL VALLEY OF CALIFORNIA: POTENTIAL CONTAMINANT PATHWAYS, AND EXPLOITATION FOR GROUNDWATER AND MINERALS (GOLD, AGGREGATES)**

20-2 1:50 PM Sousa, Frank J.*; Saleeby, Jason B.; Farley, Kenneth A.; Unruh, Jeffery: **THE SOUTHERN SIERRA NEVADA FOOTHILLS BEDROCK PEDIMENT**

20-3 2:10 PM Stock, Greg M.*; Anderson, Robert S.; Devine, Pete: **RETREAT AND STAGNATION OF LITTLE ICE AGE GLACIERS IN YOSEMITE NATIONAL PARK**

20-4 2:30 PM Thompson, Jessica A.*; Stock, Greg M.; Frankel, Kurt L.; Rood, Dylan H.: **COSMOGENIC NUCLIDE EXPOSURE DATING OF ROCK AVALANCHE DEPOSITS IN YOSEMITE VALLEY, CALIFORNIA**

2:50 PM **Break**

20-5 3:10 PM Caskey, S. John*; Reheis, Marith C.; Paces, James B.: **NEW SHORELINE AGES AND OIS-6 LAKE-LEVEL HISTORY OF LAKE MANLY, DEATH VALLEY**

20-6 3:30 PM Medley, Erica; Burns, Scott F.*: **ANCIENT CATACLYSMIC FLOODS IN THE PACIFIC NORTHWEST: ANCESTORS TO THE MISSOULA FLOODS**

20-7 3:50 PM Bishop, Kim M.*: **THE KOHALA LANDSLIDE: A NEW MEGA-LANDSLIDE INTERPRETATION REGARDING THE NORTHEAST FLANK OF KOHALA VOLCANO, HAWAII**

20-8 4:10 PM Brady, Roland H. III.*; Vyverberg, Kris A.; Thibodeaux-Yost, Singleton: **DEVELOPING A PROTOCOL TO DESCRIBE AND DELINEATE EPISODIC STREAM PROCESSES ON ARID LANDSCAPES FOR PERMITTING SOLAR POWER PLANTS**

SESSION NO. 21

T4. Ophiolites and Suture Zones

1:30 PM, Radisson Hotel and Conference Center, Salon A1

Yildirim Dilek, John Wakabayashi, and John Shervais, Presiding

21-1 1:30 PM Moores, Eldridge M.*: **NORTH AMERICAN OPHIOLITES AND SUTURES: ANALOGUES WITH SW PACIFIC AND ALPINE-MEDITERRANEAN BELTS**

21-2 1:50 PM Dilek, Yildirim*: **SSZ OPHIOLITES AS ARCHIVES OF SUBDUCTION INITIATION AND MELT EVOLUTION IN CONVERGENT MARGIN SETTINGS**

21-3 2:10 PM Jean, Marlon M.*; Shervais, John W.: **ASSESSING THE LIGHT ELEMENT CYCLE: THE FORE-ARC CONNECTION**

21-4 2:30 PM Yoshinobu, Aaron*; Salisbury, Mike; Andreas, Kaitlyn; Whitesides, Andrew; Gates, Katie M.; Deans, Jeremy; Miranda, Elena A.: **LINKING DEFORMATION IN THE MANTLE WEDGE AND CRUSTAL ACCRETION IN THE SUPRA-SUBDUCTION ZONE JOSEPHINE OPHIOLITE**

21-5 2:50 PM Shimabukuro, David H.*; Alvarez, Walter; Wakabayashi, John; Moores, Eldridge M.: **AN OCEANIC CORE COMPLEX PRESERVED IN OPHIOLITIC FRAGMENTS IN CALABRIA, SOUTHERN ITALY**

21-6 3:10 PM Flores, Kennet E.*; Harlow, George E.: **GEODYNAMIC EVOLUTION AND TECTONIC HISTORY OF THE OPHIOLITES AND SERPENTINITE MÉLANGES IN THE GUATEMALA SUTURE ZONE**

3:30 PM **Break**

21-7 3:50 PM Kusky, Timothy M.*; Wang, Lu; Dilek, Yildirim; Robinson, Paul T.: **APPLICATION OF THE MODERN OPHIOLITE CONCEPT WITH SPECIAL REFERENCE TO PRECAMBRIAN OPHIOLITES**

21-8 4:10 PM Topuz, Gültekin*; Çelik, Ö. Faruk; Sengör, A.M. Celâl; Alténtas, Ì. Emir; Zack, Thomas; Rolland, Yann: **JURASSIC OPHIOLITE FORMATION AND EMPLACEMENT AS A BACKSTOP TO A SUBDUCTION-ACCRETION COMPLEX IN THE NORTHEAST TURKEY AND POSSIBLE RELATION TO BALKAN OPHIOLITES**

21-9 4:30 PM Lindsley-Griffin, Nancy*; Griffin, John R.: **THE POLYGENETIC TRINITY OPHIOLITIC COMPLEX, AN OCEANIC COLLAGE, EASTERN KLAMATH MOUNTAINS, CALIFORNIA**

21-10 4:50 PM Xiao, Wenjiao*: **SUTURES IN THE ALTAIDS**

21-11 5:10 PM Li, Yuan*; Yang, Jing-Sui; Dilek, Yildirim: **OPHIOLITES AND ULTRAHIGH PRESSURE ZONES IN THE CENTRAL OROGENIC BELT OF CHINA: TECTONIC HISTORY OF A COMPOSITE OROGENIC BELT**

SESSION NO. 22

T9. AFC Processes in the Formation of Intermediate Magmas from Mantle to Crust

1:30 PM, Radisson Hotel and Conference Center, Salon D1

Michael Farner and Cin-Ty Lee, Presiding

1:30 PM **Introductory Remarks**

22-1 1:35 PM Lackey, Jade Star*; Cecil, M. Robinson; Miller, Jonathan S.; Sendek, Callie L.; Eisenberg, Jane L.; Economos, Rita; Davies, Gareth R.: **SMALL VOLUME PERALUMINOUS**

GRANITES AS WINDOWS INTO ANATECTIC CONVERSION OF ACCRETED TERRANES TO CRUST IN CONTINENTAL ARCS

22-2 1:55 PM Gevedon, Michelle L.*; Clemens-Knott, Diane: **ZIRCON HAFNIUM AND OXYGEN ISOTOPIC ANALYSIS OF SIERRA NEVADA GABBROS: EVIDENCE FOR MAJOR COMPOSITIONAL VARIATION IN THE MESOZOIC MANTLE**

22-3 2:15 PM Putirka, Keith*; Canchola, Joe A.; Torrez, Gerardo; Smith, Oscar; Paterson, Scott; Ducea, Mihai N.: **INCREMENTAL GROWTH OF GRANITIC MAGMA BODIES: THE GUADALUPE IGNEOUS COMPLEX, SIERRA NEVADA BATHOLITH, CALIFORNIA**

22-4 2:35 PM Canil, Dante*: **GENERATION OF INTERMEDIATE CRUST:VIEW THROUGH THE PLUTONIC WINDOW OF THE JURASSIC BONANZA ARC SECTION, VANCOUVER ISLAND, CANADA**

2:55 PM **Break**

22-5 3:05 PM Farner, Michael J.*; Lee, Cin-Ty A.; Putirka, Keith: **MAGMA MIXING LIMITED BY REACTIVE PROCESSES**

22-6 3:25 PM Putnam, Roger L.*; Glazner, A.F.; Law, Bryan: **UNDERSTANDING PLUTONISM IN THE VERTICAL: FIELD AND GEOCHEMICAL RELATIONS ON THE SOUTHEAST FACE OF EL CAPITAN, YOSEMITE VALLEY, CALIFORNIA**

22-7 3:45 PM Glazner, Allen F.*; Bartley, John M.: **EVIDENCE FOR LIQUID IMMISCIBILITY IN LADDER DIKES AND LAYERED GRANODIORITES, SIERRA NEVADA, CALIFORNIA**

22-8 4:05 PM Kleck, Wallace D.*: **EVIDENCE FOR A CRYSTAL-SETTLING MODEL FOR THE FORMATION OF LAYERED-PEGMATITE-APLITE INTRUSIVES (LPAI)**

SESSION NO. 23

T10. Reconstructing the Pacific-North America Plate Boundary Through Late Cenozoic Time II

1:30 PM, Radisson Hotel and Conference Center, Salon A2

Scott E.K. Bennett, Rebecca Dorsey, Michael Oskin, and Michael H. Darin, Presiding

23-1 1:30 PM Graymer, R.W.*; Stanley, R.G.; Roberts, M.A.; Barron, John A.; McPhee, Darcy K.: **GEOLOGIC MAPPING, GRAVITY, AND PALEONTOLOGICAL STUDIES IN THE PINNACLES NATIONAL PARK REGION, CENTRAL CALIFORNIA, REVEAL ~14 TO ~6 MA TRANSTENSIONAL HISTORY OF THE SAN ANDREAS FAULT SYSTEM**

23-2 1:50 PM Faulds, James E.*; Henry, Christopher D.; Hinz, Nicholas H.; Carlson, Chad W.: **LATE MIOCENE TO RECENT EVOLUTION OF THE WALKER LANE: AN INCIPIENT TRANSFORM FAULT WITH KINEMATIC GROWING PAINS**

23-3 2:10 PM Lifton, Zachery M.*; Frankel, Kurt L.; Lee, Jeffrey; Newman, Andrew V.: **SUMMATION OF DISTRIBUTED SLIP ACROSS THE WALKER LANE**

23-4 2:30 PM Ucarkus, Gulsen*; Shaopeng, Dong; Wesnousky, Steven G.; Maloney, Jillian; Kent, Graham; Driscoll, Neal W.: **STRIKE-SLIP FAULTING ALONG THE WASSUK RANGE OF THE NORTHERN WALKER LANE, NEVADA**

23-5 2:50 PM Carlson, Chad W.*; Pluhar, Christopher J.; Glen, Jonathan; Farner, Michael: **CHANGES IN CENTRAL WALKER LANE STRAIN ACCOMMODATION NEAR BRIDGEPORT, CA**

3:10 PM **Break**

23-6 3:30 PM Busby, Cathy J.*; Putirka, Keith; Renne, Paul; Melosh, Benjamin L.; Koerner, Alice A.; Hagan, Jeanette C.: **A TALE OF TWO WALKER LANE PULL-APARTS**

23-7 3:50 PM Henry, Christopher D.*; Faulds, James E.: **IGNIMBRITE-FILLED PALEOVALLEYS: KEY MARKERS FOR THE STRUCTURAL DEVELOPMENT OF THE PACIFIC-NORTH AMERICAN PLATE BOUNDARY**

23-8 4:10 PM Unruh, Jeffrey*; Humphrey, James: **SEISMOGENIC DEFORMATION BETWEEN THE SIERRAN MICROPLATE AND OREGON COAST BLOCK, CALIFORNIA, AND THE NORTHERN TERMINATION OF THE WALKER LANE BELT**

23-9 4:30 PM Trench, David*: **TERMINATION OF THE NORTHWESTERN BASIN AND RANGE PROVINCE INTO A CLOCKWISE ROTATING REGION OF TRANSTENSION AND VOLCANISM, SOUTHEAST OREGON**

23-10 4:50 PM Sawyer, Thomas L.*: **THE NORTHERN CALIFORNIA SHEAR ZONE—MISSING LINK IN THE PACIFIC-NORTH AMERICAN PLATE TRANSFORM MARGIN?**

5:10 PM **Discussion**

POSTER TECHNICAL SESSIONS

SESSION NO. 24

Geologic Maps and Geologic Mapping (Posters)

1:30 PM, Radisson Hotel and Conference Center, Salon B/C

Authors will be present from 2:30 to 4:30 PM

Booth #

24-1 1 Brown, Howard J.*: **GEOLOGY OF THE STODDARD RIDGE AREA, WEST CENTRAL MOJAVE DESERT, SAN BERNARDINO COUNTY CALIFORNIA**

24-2 2 Brown, Howard J.*: **GEOLOGY OF THE SIDEWINDER MOUNTAIN AND BLACK MOUNTAIN AREA, WEST CENTRAL MOJAVE DESERT, SAN BERNARDINO COUNTY CALIFORNIA**

24-3 3 Wills, Chris J.*; Delattre, Marc P.: **PROGRESS IN GEOLOGIC MAPPING AT THE CALIFORNIA GEOLOGICAL SURVEY**

24-4 4 Wiegers, Mark O.*; Holland, Peter J.: **GEOLOGIC MAPPING IN SAN LUIS OBISPO COUNTY ON THE CENTRAL COAST OF CALIFORNIA**

24-5 5 Hernandez, Janis L.*; Olson, Brian: **GEOLOGIC MAP OF THE SLEEPY VALLEY 7.5' QUADRANGLE, LOS ANGELES COUNTY, CALIFORNIA**

24-6 6 Irvine, Pamela J.*; Wills, Chris; McCrink, Timothy P.: **SEAMLESS DIGITAL LANDSLIDE INVENTORY AND GEOLOGIC DATABASES OF THE SANTA MONICA MOUNTAINS, SOUTHERN CALIFORNIA**

SESSION NO. 25

Geoscience Education and Communication (Posters)

1:30 PM, Radisson Hotel and Conference Center, Salon B/C

Authors will be present from 2:30 to 4:30 PM

Booth #

25-1 7 Boryta, Mark*; Walker, Becca; Carlos, Richard; Carrizal, Jonathan T.; Chi, Brian; de Martinez, Levi; Diaz, Miguel Angel; Hoffmann, Adam; Ketting-Olivier, Amanda; Villanueva, Lorenzo: **SUSTAINABLE AND MEANINGFUL RESEARCH OPPORTUNITIES FOR COMMUNITY COLLEGE STUDENTS**

25-2 8 Greene, David C.*: **TEACHING EARTHQUAKE-RESISTANT BUILDING PRACTICES IN GUATEMALA: DISSEMINATING EXISTING KNOWLEDGE TO THE PEOPLE WHO NEED IT MOST**

25-3 9 MartÍnez-Sacristán, Hernando*: **MINING PUBLIC POLICY WOULD INCREASE NATURAL AND SOCIAL RISKS IN COLOMBIA: FAR FROM RHETORIC CLOSER TO REALITY**

SESSION NO. 26

Sedimentary Geology (Posters)

1:30 PM, Radisson Hotel and Conference Center, Salon B/C

Authors will be present from 2:30 to 4:30 PM

Booth #

26-1 10 Morgan, George*; Morgan, J.R.: **RECENT GEOLOGICAL MAPPING OF THE COYOTE MOUNTIANS, WESTERN SALTON TROUGH, IMPERIAL COUNTY, CALIFORNIA**

26-2 11 Fleming, Monte Alain*; Nick, Kevin E.; Urbina, Mario; Poma, Orlando: **SEDIMENTOLOGY OF MARINE VERTEBRATE BURIAL IN THE MIOCENE PISCO FORMATION, PERU**

SESSION NO. 27

T6. Using Detrital Zircon Age Data to Reassemble the Cordilleran Jigsaw Puzzle (Posters)

1:30 PM, Radisson Hotel and Conference Center, Salon B/C

Authors will be present from 2:30 to 4:30 PM

Booth #

27-1 12 Koplitz, Trevor*; Surpless, Kathleen DeGraaff: **PROVENANCE ANALYSIS OF MID-CRETACEOUS STRATA IN THE METHOW BASIN, SOUTHERN BRITISH COLUMBIA: EVIDENCE FOR RAPID ARC EXHUMATION**

27-2 13 Soboleva, A.; Udoratina, O.*; Miller, Elizabeth L.; Grove, Marty: **NEW LOOK AT NEOPROTEROZOIC ROCKS OF THE YREKA TERRANE, KLAMATH MOUNTAINS, N. CALIFORNIA**

27-3 14 Lund Snee, Jens-Erik*; Miller, Elizabeth L.: **GEOLOGIC MAPPING, GEOCHEMISTRY, AND DETRITAL ZIRCON GEOCHRONOLOGY IN HUNTINGTON VALLEY AND THE EASTERN PIÑON RANGE, NORTHEAST NEVADA: IMPLICATIONS FOR THE PALEOGEOGRAPHIC EVOLUTION OF THE ELKO BASIN AND SURROUNDINGS**

27-4 15 Fagin, Brittany*; Mattinson, Christopher G.: **ZIRCON AND APATITE SEPARATION USING A SPIRAL PANNING TABLE: EVALUATION OF TIME AND YIELD EFFICIENCY**

SESSION NO. 28

T15. Undergraduate Research (Posters)

1:30 PM, Radisson Hotel and Conference Center, Salon B/C

Authors will be present from 2:30 to 4:30 PM

Booth #

28-1 16 Engberg, Christopher*; Shimabukuro, David H.; Saekow, Roland; Alvarez, Walter; Rohde, Robert; Berezin, Sergey; Kalygin, Michael: **DIVING INTO 540 MILLION YEARS OF CLIMATE WITH CHRONOZOOM**

28-2 17 Olson, Christopher*; Thomas, Carrie; Sklar, Leonard S.; Goodfellow, Bradley: **EFFECT OF CHEMICAL WEATHERING ON SEDIMENT RESISTANCE TO MECHANICAL WEAR IN STREAMS**

28-3 18 Harris, Cornelius; Cathcart, Eric M.; Christensen, Vanessie; Weis, Dan; Schwabe, Stephanie J.*: **NATURALLY OCCURRING CONCENTRATIONS OF SEVENTEEN METALS IN THE BAY POINT FORMATION, SAN DIEGO, CALIFORNIA**

28-4 19 Olsen, Erik*; Olaivar, Adrienne; Van De Water, Peter; Singhvi, Ashok; Gulliot, Stephane; Weinman, Beth: **ADDING POLLEN TO THE RECORD: REFINING HOW SEDIMENTARY AQUIFERS FORM USING SEDIMENTOLOGY, PALYNOLOGY, AND OSL AGE DATING IN NEPAL'S TERAI**

28-5 20 Al-Safwani, Zahra*; Weinman, Beth: **DETERMINING WATER QUALITY IN BANGLADESH GROUNDWATER**

28-6 21 Karasaki, Kenzi; Lopez, Robin*: **CHARACTERIZATION OF FAULT ZONES THROUGH HYDROGEOLOGIC METHODS**

28-7 22 Kucker, Kyle*; Mookerjee, Matty: **CONSTRUCTING A GEOLOGICAL SQUEEZEBOX TO MODEL FAULT ASPERITY KINEMATICS**

28-8 23 Canada, Andrew*; Mookerjee, Matty: **EBSD AND THREE-DIMENSIONAL STRAIN ANALYSIS OF TRANSPRESSIONAL THINNING WITHIN THE ROSY FINCH SHEAR ZONE**

28-9 24 Melcon, Alexa*; Thomason, Katie; Mookerjee, Matty: **EXHUMATION PROCESSES WITHIN THE BITTERROOT LOBE DETACHMENT, NORTH AMERICAN CORDILLERA, A THREE-DIMENSIONAL STRAIN AND KINEMATIC VORTICITY ANALYSIS**

28-10 25 Davies, Robert I.; Almand, John, M.*: **UNMAPPED OCCURRENCE OF CHIASTOLITE SCHIST IN WESTERN MARIPOSA COUNTY, CALIFORNIA, EXTENDING THE RANGE OF METAMORPHISM FOR INCLUSION IN SMALL SCALE GEOLOGIC MAPS OF CALIFORNIA**

28-11 26 Walters, Jesse*; Mattinson, Christopher G.: **MODELING P-T PATHS FOR A GT-KY GNEISS FROM THE N. QAIDAM HP/UHP BELT WESTERN CHINA**

28-12 27 Kenney, Michael J.S.*; Gans, Phillip B.; Wong, Martin S.; Wilch, Joe: **MICROSTRUCTURAL ANALYSIS OF QUARTZ MYLONITES AND NEW U-PB ZIRCON AGES OF CRETACEOUS INTRUSIONS IN THE CENTRAL PART OF THE NORTHERN SNAKE RANGE METAMORPHIC CORE COMPLEX, NEVADA**

28-13 28 Monroe, Evan*; Gans, Phillip B.; Wong, Martin S.; Bender, Will: **GEOCHRONOLOGY AND STRAIN ANALYSIS OF THE JURASSIC PLUTONIC COMPLEX ON THE SOUTHERN FLANK OF THE NORTHERN SNAKE RANGE, NEVADA**

28-15 30 Scheftner, Tonya Renee*; Giaramita, Mario: **STRATIGRAPHIC, PETROGRAPHIC, GEOCHEMICAL, AND STRUCTURAL ANALYSIS OF PILLOW LAVAS AND OVERLYING METASEDIMENTS: COLEBROOKE SCHIST, SOUTHWESTERN OREGON**

28-16 31 Jean, Marlon M.; Alonzo, Benigno*; Schwartz, Joshua; Christiansen, Eric H.; Phillips, William M.; Vetter, Scott K.; Shervais, John W.: **NEW CHEMICAL RELATIONSHIPS FROM DRILL CORE IN THE SNAKE RIVER PLAIN, IDAHO**

28-17 32 Shaddox, Heather Rose*; Barrera, Angelica Yuridia; Giaramita, Mario Joseph: **A NEWLY DISCOVERED SHEETED DIKE COMPLEX ON THE WESTERN MARGIN OF THE IRON MOUNTAIN PERIDOTITE, WITHIN EASTERN ELK OUTLIER OF THE WESTERN KLAMATH TERRANE, SOUTHWESTERN OREGON**

28-18 33 Raisis, Alyssa*; Hausback, Brian P.: **HYDROVOLCANISM IN THE HIGH ROCK CALDERA, NORTHWESTERN NEVADA**

28-19 34 Rodd, Rebecca L.*; Verosub, Kenneth L.; Nicolaysen, Kirsten P.: **A PALEOMAGNETIC RECONNAISSANCE STUDY OF THE POWDER RIVER VOLCANIC FIELD, UNION COUNTY, OREGON**

28-20 35 Choi, Na Hyung*; Wright, James E.: **THE ORIGIN OF UNUSUAL PHOSPHATE DEPOSITS ON THE VENEZUELAN ISLAND OF GRAN ROQUE, LEEWARD ANTILLES**

WEDNESDAY, 22 MAY 2013

ORAL TECHNICAL SESSIONS

SESSION NO. 29

T6. Using Detrital Zircon Age Data to Reassemble the Cordilleran Jigsaw Puzzle

8:40 AM, Radisson Hotel and Conference Center, Salon A1

Trevor Dumitru and Elizabeth L. Miller, Presiding

29-1 8:40 AM Ingersoll, Raymond V.*; Grove, M.; Jacobson, Carl E.; Kimbrough, David L.; Hoyt, Johanna F.: **MESOZOIC-CENOZOIC DRAINAGE DIVIDES FOR SOUTHERN CALIFORNIA RIVERS, AS DETERMINED BY DETRITAL ZIRCONS, WITH IMPLICATIONS FOR EVOLUTION OF GRAND CANYON, THE COLORADO RIVER AND THEIR PRECURSORS**

29-2 9:00 AM Hollis, Natalie*; Gevedon, Michelle L.; Clemens-Knott, Diane: **AGE, PROVENANCE, AND LATERAL VARIATION OF DETRITAL ZIRCON POPULATIONS IN THE PENINSULAR RANGES FOREARC BASIN, ORANGE COUNTY, CA**

29-3 9:20 AM Saleeby, Jason*; Saleeby, Zorka: **DETRITAL ZIRCON U/PB AGES OF UPPER MIOCENE TO PLEISTOCENE STRATA OF THE SE SAN JOAQUIN BASIN (SJB) IN COMPARISON TO ZIRCON AGE PATTERNS OF THE SOUTHERN SIERRA NEVADA BATHOLITH (SNB)-IMPLICATIONS FOR LATE CENOZOIC SEDIMENT PROVENANCE AND DISPERSAL PATTERNS**

29-4 9:40 AM Johnston, Scott M.*: **DETRITAL ZIRCON GEOCHRONOLOGY OF THE TORO FORMATION, NACIMIENTO BLOCK, CENTRAL CALIFORNIA COAST**

29-5 10:00 AM Clemens-Knott, Diane*; Martin, Michael W.; Buchen, Christopher: **DETRITAL ZIRCON EVIDENCE FOR LINKAGES BETWEEN MESOZOIC SEDIMENTARY SYSTEMS ALONG THE WESTERN FLANK OF THE SIERRA NEVADA ARC**

10:20 AM **Break**

29-6 10:40 AM Linde, Gwen M.*; Cashman, Patricia H.; Dickinson, William R.; Trexler, James H. Jr.: **THE PROVENANCE CHALLENGE OF THE HARMONY FORMATION IN CENTRAL NEVADA: AN ENIGMATIC PIECE IN THE CORDILLERAN JIGSAW PUZZLE**

29-7 11:00 AM Schmidt, Keegan L.*; Schwartz, Darin M.; Lewis, Reed S.; Vervoort, Jeffrey D.; LaMaskin, Todd A.; Wilford, Diane E.: **NEW DETRITAL ZIRCON AGES CONSTRAIN THE ORIGIN AND EVOLUTION OF THE RIGGINS GROUP ASSEMBLAGE ALONG THE SALMON RIVER SUTURE ZONE, WESTERN IDAHO**

29-8 11:20 AM LaMaskin, Todd A.*: **REASSESSING TERRANE BOUNDARIES IN THE BLUE MOUNTAINS PROVINCE OF EASTERN OREGON USING DETRITAL ZIRCON U-PB AGES**

29-9 11:40 AM Miller, Elizabeth L.*; Soloviev, A.V.; Gottlieb, E.S.: **THE SECRET LIVES OF MOUNTAIN BELTS REVEALED BY U-PB DATING OF DETRITAL ZIRCON SUITES: THE LATE JURASSIC-EARLY CRETACEOUS BROADER BROOKS RANGE-VERKOYANSK OROGEN, ARCTIC ALASKA AND NE RUSSIA**

SESSION NO. 30

T7. Hydrogeologic Issues of Irrigated Agricultural Regions–Problems and Solutions

8:00 AM, Radisson Hotel and Conference Center, Salon A2

C. John Suen and Dong Wang, Presiding

30-1 8:00 AM Suen, C. John*; Wang, Dong: **WATER SUPPLY ISSUES OF THE SAN JOAQUIN VALLEY IN CALIFORNIA**

30-2 8:20 AM Cehrs, David*: **WATER DEMAND VS. SUPPLY, KINGS RIVER BASIN CALIFORNIA: IMPLICATIONS FOR CALIFORNIA AND THE AMERICAN WEST**

30-3 8:40 AM Green, Sargeant*: **ATTAINING SUSTAINABLE USE OF SAN JOAQUIN VALLEY GROUNDWATER FOR AGRICULTURE, TECHNICAL AND INSTITUTIONAL ISSUES**

30-4 9:00 AM Jitan, Mohd A.*; Evett, Steve; Shaqir, Ibrahim: **WATER POLICIES, STRATEGIES AND IRRIGATION WATER MANAGEMENT IN JORDAN**

30-5 9:20 AM Anderson, Ray G.*; Wang, Dong; Lund, Christopher P.; Melton, Forrest S.; Johnson, Lee F.; Prueger, John H.; Alfieri, Joseph G.; McKee, Lynn; Kustas, William P.: **ASSESSING EVAPOTRANSPIRATION, BASAL CROP COEFFICIENT, AND IRRIGATION EFFICIENCY IN PRODUCTION PEACH ORCHARD IN CALIFORNIA'S SAN JOAQUIN VALLEY**

30-6 9:40 AM Zhang, Huihui*; Wang, Dong: **DEVELOPMENT OF DEFICIT IRRIGATION STRATEGIES FOR PEACH PRODUCTION**

10:00 AM **Break**

30-7 10:20 AM Sartono, Ori*; Suen, C. John; Lili, Gao: **ESTIMATING THE PROPORTION OF CHEMICAL FLUX FROM AGRICULTURAL SOURCES IN THE GROUND WATER OF THE SAN JOAQUIN VALLEY BASED ON PRINCIPAL COMPONENT ANALYSIS OF MAJOR MINERAL CONCENTRATIONS**

30-8 10:40 AM Holtz, Marianne L.*; Esser, Bradley K.; Hillegonds, Darren J.; Moran, Jean E.; Roberts, Sarah K.; Singleton, Michael J.; Visser, Ate: **INVESTIGATING THE SOURCE OF NITRATE IN A SALINAS VALLEY DRINKING WATER SUPPLY WELL WITH ISOTOPIC TRACERS**

30-9 11:00 AM Schmidt, Kenneth D.*: **THE RELATION BETWEEN CONFINING BEDS AND THE VERTICAL EXTENT OF DEEP PERCOLATION IN THE SAN JOAQUIN VALLEY, CALIFORNIA**

30-10 11:20 AM Holcomb, Ronald E.*; Rieth, Dale; Hishida, Kassandra; Wang, Zhi: **CHARACTERIZATION OF THE SHALLOW SALINE AQUIFER AT NAS LEMOORE IN WESTERN SAN JOAQUIN VALLEY, CALIFORNIA**

30-11 11:40 AM Wang, Zhi*; Holcomb, Ronald E.; Rieth, Dale; Hishida, Kassandra: **SHALLOW SALINE AQUIFER MONITORING AT NAVAL AIR STATION LEMOORE IN WESTERN SAN JOAQUIN VALLEY, CALIFORNIA**

30-12 12:00 PM Ramirez, Joaquin D.*; Liu, Lubo: **MODELING SAN JOAQUIN RIVER FLOW PATH ALTERATIONS FOR RESTORATION PROJECT**

POSTER TECHNICAL SESSIONS

SESSION NO. 31

T1. Tectonic Processes that Build the Stratigraphic and Structural Record of Ancient and Modern Convergent Margin (Posters)

8:00 AM, Radisson Hotel and Conference Center, Salon B/C

Authors will be present from 9 to 11 AM

	Booth #	
31-1	1	Langenheim, V.E.*; Jachens, R.C.; Wentworth, C.M.; McLaughlin, R.J.: **INSIGHTS INTO STRUCTURE WITHIN A SUBDUCTION-ZONE COMPLEX FROM SIMPLE, CURVILINEAR MAGNETIC ANOMALIES IN THE COASTAL BELT OF THE FRANCISCAN COMPLEX, NORTHERN CALIFORNIA**
31-2	2	Stanley, Richard G.*; Haeussler, Peter J.; Benowitz, Jeff A.; Goodman, David K.; Ravn, Robert L.; Shellenbaum, Diane P.; Saltus, Richard W.; Lewis, Kristen A.; Potter, Christopher J.: **NEW STRATIGRAPHIC REVELATIONS IN THE SUBSURFACE SUSITNA BASIN, SOUTH-CENTRAL ALASKA, FROM RECENT ISOTOPIC AND BIOSTRATIGRAPHIC RESULTS**
31-3	3	Park, Yong*; Jung, Haemyeong: **DEFORMATION MICROSTRUCTURES OF OLIVINE AND PYROXENE IN MANTLE XENOLITHS AND IMPLICATIONS FOR SEISMIC ANISOTROPY**
31-4	4	Bero, David A.*: **GEOLOGY OF RING MOUNTAIN AND TIBURON PENINSULA, MARIN COUNTY, CALIFORNIA**

SESSION NO. 32

T2. Mélanges: Comparison and Contrast Between Circum-Pacific and Tethyan Chaotic Rock Bodies, and Modern Submarine Analogues (Posters)

8:00 AM, Radisson Hotel and Conference Center, Salon B/C

Authors will be present from 9 to 11 AM

	Booth #	
32-1	5	Platt, John P.*: **ORIGIN OF BLUESCHIST-BEARING MELANGE AT SAN SIMEON, CENTRAL CALIFORNIA COAST RANGES**
32-2	6	Mori, Ryota; Ogawa, Yujiro*; Tsunogae, Toshiaki: **DUCTILE AND BRITTLE DEFORMATION STRUCTURES IN THE BLOCKS OF FRANCISCAN (CALIFORNIA) AND MINEOKA (JAPAN) MÉLANGES: IMPLICATIONS FOR RETROGRADE DEFORMATION DURING EXHUMATION OF DEEP-BURIAL ROCKS**
32-3	7	Vitale Brovarone, Alberto*; Agard, Philippe: **FIELD-BASED CONSIDERATIONS ON THE NATURE OF THE HP "MÉLANGE" OF NEW CALEDONIA**
32-4	8	Festa, Andrea*; Pini, Gian Andrea; Dilek, Yildirim: **MÉLANGES AND GEODYNAMIC SETTINGS OF THEIR FORMATION**
32-5	9	Moclock, Leslie G.*; Roeske, Sarah M.; Benowitz, Jeff A.; Coble, Matthew A.: **TIMING AND KINEMATICS OF DEFORMATION IN THE NORTHERN BEAR MOUNTAINS FAULT ZONE, SIERRA NEVADA FOOTHILLS, CALIFORNIA**

SESSION NO. 33

T3. Oceanic Petrogenesis of Pacific-Type Convergent Margins (Posters)

8:00 AM, Radisson Hotel and Conference Center, Salon B/C

Authors will be present from 9 to 11 AM

Booth #

33-1 10 Stovall, Jesse*; Shimabukuro, David H.: **POSSIBLE COUNTERCLOCKWISE P-T-T PATH FROM THE FORT JONES TERRANE NEAR YREKA, CALIFORNIA**

33-2 11 Haxel, Gordon B.*; Jacobson, Carl E.: **ALPINE PERIDOTITE IN THE ARIZONA DESERT: NEW DISCOVERY OF OROCOPIA SCHIST AND INCLUDED SERPENTINIZED PERIDOTITE IN SOUTHWEST ARIZONA**

33-3 12 Holk, Gregory J.*; Jacobson, C.E.; Grove, Marty: **STABLE ISOTOPE EVIDENCE FOR A TWO-STAGE FLUID HISTORY THE OROCOPIA SCHIST AT THE OROCOPIA MOUNTAINS AND GAVILAN HILLS, SOUTHEASTERN CALIFORNIA**

33-4 13 Wills, Marci A.*; Hoisch, Thomas D.; Vervoort, Jeff; Wells, Michael L.; Camilleri, Phyllis A.: **AGE OF METAMORPHISM AND PRESSURE-TEMPERATURE PATH FROM METAMORPHOSED DUNDERBERG SHALE IN THE WOOD HILLS, EASTERN NEVADA**

33-5 14 Lacy, Alison C.*; Wells, Michael L.; Hoisch, Thomas; Vervoort, Jeff D.: **EARLY EOCENE METAMORPHISM IN THE SEVIER HINTERLAND CONSTRAINED BY LU-HF GARNET GEOCHRONOLOGY**

33-6 15 Regel, Megan E.*; Mattinson, Christopher G.: **INCREASING THE SPATIAL RESOLUTION OF AGES AND PEAK PRESSURE-TEMPERATURE CONDITIONS OF ULTRAHIGH-PRESSURE ECLOGITES AND HIGH-PRESSURE GRANULITES IN DULAN UHP TERRANE, NORTHWESTERN CHINA**

SESSION NO. 34

T4. Ophiolites and Suture Zones (Posters)

8:00 AM, Radisson Hotel and Conference Center, Salon B/C

Authors will be present from 9 to 11 AM

Booth #

34-1 16 Masutsubo, Nobuaki*; Wakabayashi, John: **DIVERSE METAMORPHIC TRAJECTORIES, IMBRICATED OCEAN PLATE STRATIGRAPHY, AND FAULT ROCKS, YUBA RIVER AREA, FEATHER RIVER ULTRAMAFIC BELT, CALIFORNIA**

34-2 17 Eck, Dennis S.*; Wakabayashi, John: **THE DEVIL'S GATE OPHIOLITE, NORTHERN SIERRA NEVADA, CALIFORNIA: NOT AN OPHIOLITE OR METAMORPHIC SOLE?**

34-3 18 Luo, Jun*; Wakabayashi, John: **AN UPPER CRUSTAL OPHIOLITE REMNANT WITHIN THE FEATHER RIVER ULTRAMAFIC BELT, NORTHERN SIERRA NEVADA, CALIFORNIA: UNSUBDUCTED, BUT AFFECTED BY RIDGE SUBDUCTION?**

34-4 19 Ao, Songjian*; Xiao, Wenjiao; Zhang, Ji'en: **CAMBRIAN TO EARLY SILURIAN OPHIOLITE AND ACCRETIONARY PROCESSES IN THE BEISHAN COLLAGE**

34-5 20 Sarifakioglu, Ender*; Sevin, Mustafa; Dilek, Yildirim: **REMNANT OF A JURASSIC BACKARC OCEAN BASIN (KÜRE OPHIOLITE) IN THE CENTRAL PONTIDE BELT, TURKEY**

34-6 21 Moore, Diane E.*: **VARIATION WITH CREEP RATE IN THE MINERALOGY AND TEXTURES OF FAULT GOUGE FROM THE SAN ANDREAS FAULT OBSERVATORY AT DEPTH (SAFOD)**

34-7 22 Jung, Haemyeong*; Lee, Jaeseok; Ko, Byeongkwan; Jung, Sejin; Park, Munjae; Cao, Yi; Song, Shuguang: **NATURAL TYPE-C OLIVINE FABRICS IN GARNET PERIDOTITES IN NORTH QAIDAM UHP COLLISION BELT, NW CHINA**

34-8 23 Kim, Dohyun*; Jung, Haemyeong: **LATTICE PREFERRED ORIENTATION AND WATER CONTENT OF OLIVINE IN PERIDOTITES FROM ALMKLOVDALEN IN WESTERN GNEISS REGION, SW NORWAY**

34-9 24 Moss, Benjamin T.*; Miranda, Elena A.; Yoshinobu, Aaron S.: **MICROSTRUCTURAL ANALYSIS OF HYPERSOLIDUS FOLIATIONS AT THE ATLANTIS BANK OCEANIC CORE COMPLEX, SOUTHWEST INDIAN RIDGE**

SESSION NO. 35

Structural Geology and Tectonics (Posters)

8:00 AM, Radisson Hotel and Conference Center, Salon B/C

Authors will be present from 9 to 11 AM

Booth #

35-1 25 Anderson, R. Ernest*: **HYDROGEOLOGY OF THE ZUCCALE DETACHMENT FAULT, ELBA ISLAND, ITALY**

35-2 26 Greene, David C.*: **THE CONFUSION RANGE "SYNCLINORIUM": A WESTERN UTAH THRUST BELT ANALOGOUS TO THE CENTRAL NEVADA THRUST BELT**

35-3 27 Fang, Yi*; Holk, Gregory J.: **A STABLE ISOTOPE STUDY OF FLUID-ROCK INTERACTIONS IN THE SAN GABRIEL FAULT ZONE AND ITS RELATIONSHIP TO SEISMIC PROCESS**

35-4 28 Giallorenzo, Michael A.*; Wells, Michael L.; Stockli, Daniel F.: **TWO EXHUMATION EVENTS OF THE WHEELER PASS THRUST SHEET IN THE SOUTHERN SEVIER OROGEN FROM (U-TH)/HE ZIRCON THERMOCHRONOLOGY**

35-5 29 Crane, Jake*; Huerta, Audrey; Winberry, Paul: **THE ROLE OF HETEROGENEITIES IN CRUSTAL STRENGTH DURING CONTINENTAL RUPTURE: A NUMERICAL MODELING APPROACH**

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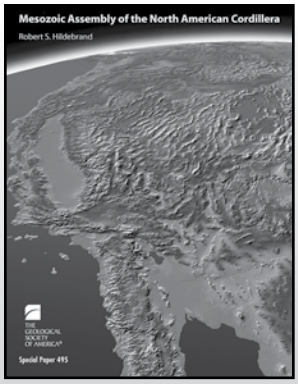

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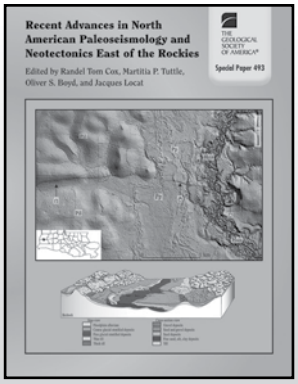

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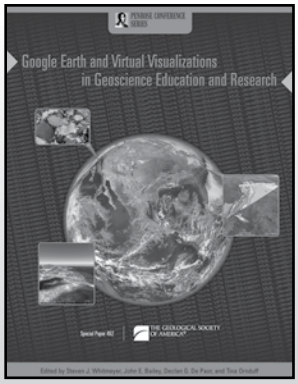

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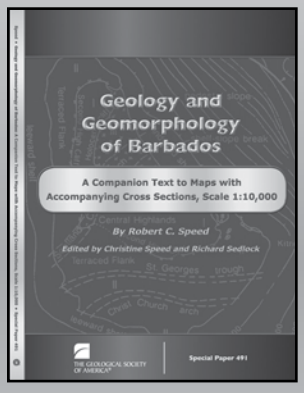

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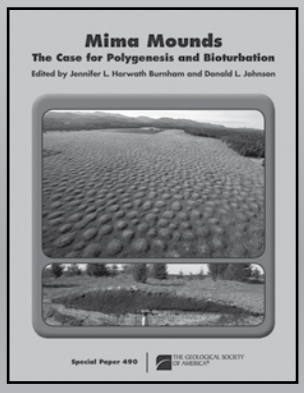

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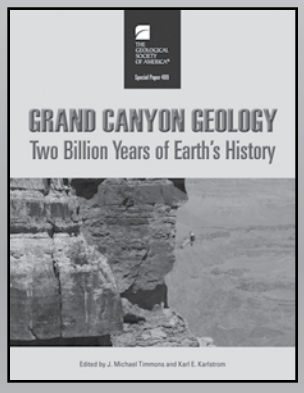

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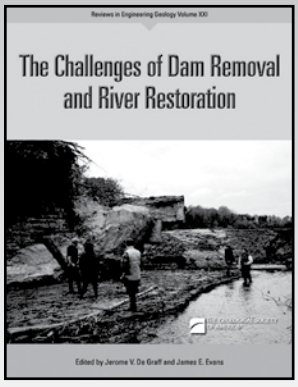

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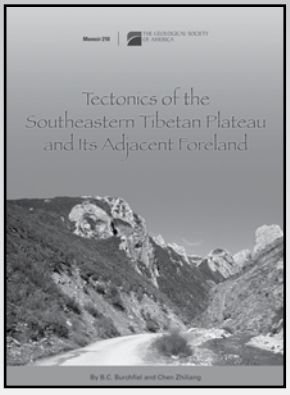

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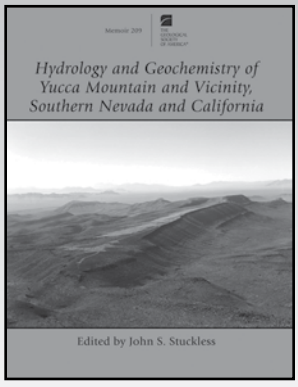

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16-5 **BTH 24** Short, Lauren E.

THE RELATIONSHIP BETWEEN LARGE WOODY DEBRIS AND A DECREASE OF MEDIAN BED MATERIAL SIZE IN A GRAVEL BED CHANNEL AFTER POST-FIRE DEBRIS FLOWS

SHORT, Lauren E. and GABET, Emmanuel J., Department of Geology, San Jose State University, One Washington Square, San Jose, CA 95192, leshort@gmail.com

To further the understanding of how rivers process an instantaneous increase in sediment supply, a study was conducted of a gravel bed channel affected by post fire debris flows. Sleeping Child Creek, a tributary of the Bitterroot River, is located in the Sapphire Mountains of west central Montana. In the summer of 2000, a large fire burned 1500 acres of the watershed. The following summer, thunderstorms brought intense rainfall to the area, triggering a series of debris flows originating from the main tributaries that had burned. Along the 10-kilometer study reach, cross sections and pebble counts were taken near six debris flow fans. A channel survey of large woody debris was also conducted. The initial hypothesis was that the fine sediment would disperse downstream, exposing coarse bed material. Comparing the cross sections with previous measurements has shown that the river has aggraded throughout most of the site. The bed material has become finer and there is about ten times more large woody debris than conducted six years ago. The aggradation and the finer bed material can be attributed to the increase in large woody debris in the channel. The response documented in Sleeping Child Creek informs our understanding of channel evolution after large sediment pulses. In burned landscapes, the role of large woody debris could be instrumental in modulating the storage and release of the post-fire sediment pulse.

16-6 **BTH 25** Swanson, Brian J.

NEW LANDSLIDE MAPPING OF THE PITAS POINT AND VENTURA QUADRANGLES, VENTURA COUNTY, SOUTHERN CALIFORNIA

SWANSON, Brian J., California Geological Survey, Los Angeles, CA 90017, brian.swanson@conservation.ca.gov

The California Geological Survey (CGS) recently completed new landslide mapping of the Pitas Point and Ventura quadrangles as part of the Seismic Hazards Zonation Program. These 1:24,000-scale maps will be published online in the CGS Landslide Inventory Map Series. The inventory maps were prepared by geomorphic analysis and interpretation of stereo-paired aerial photographs, LiDAR and NAIP imagery, on-line oblique photo-mosaics on Bing™, and topographic maps, as well as limited field observations and review of previous mapping. Landslide deposit and source (scarp) areas were digitally compiled and key attributes were assigned to each landslide.

Landslides are a significant geologic hazard in the Pitas Point and Ventura area, having caused the disruption of the road and railway along the coast as far back as 1865, damage to oil wells along the Ventura Avenue-Rincon anticline trend, and the destruction of homes in the town of La Conchita in 1995 and again in 2005, when 10 lives were lost. Landslides are common throughout the area because it is underlain primarily by weak, fine-grained, sedimentary strata that have undergone rapid, late Quaternary tectonic uplift, folding, faulting and subsequent erosion, resulting in the development of steep-sided canyons and coastal bluffs. Landslides, including local earth flows, are most concentrated in the "Mud Pit shale." The distribution and failure mechanism of bedrock landslides are controlled primarily by the underlying geologic structure and its relationship to slope gradient and orientation. Translational and compound failures are dominant near fold axes and on dip slopes. Several large, dormant old landslides occur in the Sespe Formation on the flanks of the Red Mountain anticline. Rotational and wedge-type failures are the dominant mechanisms where neutral or antidip bedding is exposed in high steep slopes. Shallow debris slides and flows commonly develop in colluvium, weathered rock, and existing slide debris after periods of heavy rainfall, particularly in the Pico and Rincon Formations. Extensive Late Pleistocene debris deposits on the southwest side of Rincon Mountain are largely a combination of debris flow sheets and long-runout landslides that are unique in the area and have been designated as debris fans on the inventory map.

16-7 **BTH 26** Sundberg, Paul Robert

REFINING GEOLOGIC MAPPING OF THE MAD RIVER FAULT ZONE BETWEEN FIELDBROOK VALLEY AND MCKINLEYVILLE, CALFORNIA USING HIGH-RESOLUTION TOPOGRAPHIC DATA AND SPATIAL ANALYSIS TOOLS

SUNDBERG, Paul Robert, Geology, Humboldt State University, 1 Harpst Street, Arcata, CA 95521, prs.geo@gmail.com

Initial mapping of the Mad River Fault Zone, the onland fold and thrust belt of the southern Cascadia subduction zone, was at a scale of 1:24,000, at reconnaissance level with limited land access for field verification. 1m LiDAR hillshades and private timber company access provided improvements to mapping of the fault zone, while GPS and LiDAR improve map detail. I identified three Pleistocene marine terrace groups in coastal hills between McKinleyville, CA and Fieldbrook, CA. An assumed uplift rate of 1 m/ky correlates these three terrace flights to sea level high stands of Oxygen Isotope Stage (OIS) 5 (120 ka to 80 ka). Additionally, alluvial/fluvial terraces, north of Fieldbrook, are present at elevations consistent with sea level highs of OIS 5a and 5c. These terraces most likely developed from base level changes during the last inter-glacial period.

Using LiDAR, I mapped compression features near the identified trace of the McKinleyville fault. Evidence for the fault include linear scarps, swales and drainages and offset terraces. The OIS 5e and 5c terraces in the footwall of the fault are offset by secondary discontinuous 5 m scarps. These scarps may be related to compression along the Mad River fault to the southwest.

The Trinidad fault exists in the north part of the map area in Mather Creek, a drainage that flows into Fieldbrook Valley. The fault is characterized by low-lying, discontinuous linear ridges, juxtaposing Cretaceous-Jurassic Franciscan formation against Pleistocene marine sand. The fault appears to be an erosional remnant lacking "fresh" scarps in the young deposits of Mather Creek. To the northwest, surface expression of this trace diminishes in the OIS 5c marine terrace. Lack of fault expression may indicate a relative low level of activity on this portion of the Trinidad fault. The OIS 5 coastline was much different from that of today. Hills between McKinleyville and Fieldbrook may have persisted as an island during the initial OIS 5 sea level highs. Fieldbrook Valley was a marine embayment throughout OIS 5 time. The alluvial/fluvial terraces and surface inclinations indicate that Little River, flowed south into the north end of Fieldbrook Valley during OIS 5. Stream piracy redirected Little River to the west. Precise timing for this piracy event is unknown.

16-8 **BTH 27** Short, William R.

COMPILATION OF SURFICIAL GEOLOGIC MAPPING IN SOUTHERN CALIFORNIA

SHORT, William R., BEDROSSIAN, Trinda L., HAYHURST, Cheryl A., and LANCASTER, Jeremy T., California Geological Survey, 801 K Street, MS 13-40, Sacramento, CA 95814, Bill.Short@conservation.ca.gov

The California Geological Survey (CGS), with funding from the Department of Water Resources (DWR), has completed an update of a GIS-based compilation of high-resolution geologic maps of Quaternary age and older deposits in southern California. The compilation provides a consistent classification of surficial deposits that cover approximately 35,000 square miles of a 10-county area currently of interest to DWR and the Governor's Alluvial Fan Task Force (AFTF), including San Bernardino, Riverside, Los Angeles, Ventura, Santa Barbara, San Luis Obispo, Kern, Orange, Imperial and San Diego counties.

Over the past two decades, alluvial fans have experienced rapid growth and high development pressures in southern California. Due to the unique flood hazards associated with alluvial fans, the AFTF was charged in 2007 to review the state of knowledge regarding alluvial fan floodplains and develop recommendations that would be specific to alluvial floodplain management. The CGS geologic compilation was designed as a regional-scale planning tool to assist DWR, the AFTF, other state and local agencies, local communities, consultants, and geologists in evaluating hazards as well as locating future development on alluvial fans.

The project merges new mapping and existing digital geologic data by various authors at CGS and the U.S. Geological Survey into a common seamless format that normalizes and differentiates alluvial fan deposits, related Quaternary deposits, and various older deposits into 40 derivative units at a scale of 100,000 for the entire area. Quaternary surficial deposits are divided into four main age categories: late Holocene=most recent; Holocene to late Pleistocene=young; late to middle Pleistocene=old; and middle to early Pleistocene= very old. CGS Special Publication 217 (SP 217) includes both a GIS-based dataset and a Portable Document File (PDF) version of the 100,000 scale derivative maps. An online web map viewer is in progress. The data is provided to assist elected officials, local floodplain managers, representatives from various governmental agencies, developers, environmental groups, consultants, geologic investigators, and the public in the rapid identification of areas subject to previous and potential future flooding and other geologic hazards on alluvial fans and floodplains.

SESSION NO. 17, 8:00 AM

Tuesday, 21 May 2013

T14. Quaternary Geology of California's Central Valley and Its Relevance to Water Infrastructure (Posters)

Radisson Hotel and Conference Center, Salon B/C

17-1 **BTH 28** Springhorn, Steven T.

BASE OF FRESH GROUNDWATER IN THE SACRAMENTO VALLEY, CALIFORNIA

SPRINGHORN, Steven T., HIGHTOWER, Nicholas, BEDEGREW, Tad, and BONDS, Christopher L., California Department of Water Resources, 3500 Industrial Blvd, West Sacramento, CA 95691, steven.springhorn@water.ca.gov

A base of fresh groundwater (BFW) contour map was created to identify the approximate lower limit and the thickness of the fresh groundwater aquifer system in the Sacramento Valley. The BFW map is useful for groundwater resource and storage analyses, groundwater modeling, and delineating structural geologic features in the Sacramento Valley.

Two BFW maps covering the Sacramento Valley were previously created; Olmsted and Davis (1961) and Berkstresser (1973). The BFW map in this study relies on a substantial amount of new subsurface geophysical and water quality data that has been collected since the earlier BFW maps.

Fresh groundwater is defined in this study as water containing less than 1,000 mg/l total dissolved solids (TDS), approximately 1,550 µmhos/cm specific conductance, instead of 2,000 mg/L TDS used in the earlier studies. The BFW was estimated based on a comparative analysis of geophysical logs and lithologic data from approximately 2,800 geophysical logs from water resource wells and CA Division of Oil and Gas well records. The BFW selection criteria were calibrated using water chemistry data and constrained by comparing multiple well-logs and lithologic information in the same geographic area.

The BFW boundary occurs primarily in late Tertiary to Quaternary unconsolidated sediments at depths near land surface to more than 3,500 feet below ground surface. The BFW is an uneven boundary that in some places reflects the major geologic structures underlying the Sacramento Valley, and in other areas, transgresses underlying geologic structures. In some areas, the BFW boundary is well above the base of post-Eocene marine strata. This is most likely caused by high artesian pressures and upward vertical gradients in deep aquifers in the Sacramento Valley, which have been documented in DWR monitoring wells. This suggests that migration of poor quality water into continental sediments that previously contained freshwater has occurred over geologic time. This finding has implications for brackish and saline water upconing beneath areas of prolonged groundwater pumping in the Sacramento Valley.

17-2 **BTH 29** Gutierrez, Carlos

RECENT GEOLOGIC COMPILATIONS IN CALIFORNIA'S CENTRAL VALLEY BY THE CALIFORNIA GEOLOGICAL SURVEY AND THE DEVELOPMENT OF A NEW DIGITAL GEOLOGIC MAP OF CALIFORNIA

GUTIERREZ, Carlos, California Geological Survey, 801 K Street, MS 12-32, Sacramento, CA 95814, carlos.gutierrez@conservation.ca.gov and DAWSON, Timothy E., California Geological Survey, 345 Middlefield Road, MS 520, Menlo Park, CA 94025

The California Geological Survey (CGS) has recently completed geologic compilations of the Sacramento, Lodi, and Stockton 30x60-minute quadrangles in the southern Sacramento Valley and northern San Joaquin Valley. This work was performed as part of the STATEMAP program, an ongoing cooperative effort with the USGS to produce geologic maps of 7.5-minute and 30x60-minute quadrangles in California. The area covered by these new maps includes a large portion of the Sacramento-San Joaquin River Delta, critical infrastructure related to flood control and the State Water Project, and several densely populated urban areas. The new maps, prepared by various authors, represent a digital compilation of the best available geologic mapping for the region, and provide a consistent geologic framework that can be utilized as a basis for the analysis of a host of concerns in California, including seismic hazards to infrastructure, environmental management, and groundwater issues.

CGS also plans to use the digital data developed for these maps as the foundation for building a new digital geologic map of California based on the most detailed geologic information available. Once established, digital geologic datasets developed for other STATEMAP and CGS products can be migrated into the new statewide digital geologic map. This new map and associated database will support CGS's goals to bring new and existing map information into standardized data and cartographic formats, and to release the new maps for public use as downloadable images and GIS data, as well as for viewing on an interactive web-based Google Map platform.

17-3 **BTH 30** Haydon, Wayne D.

QUATERNARY SURFICAL DEPOSITS OF THE SOUTHERN SAN JOAQUIN VALLEY

HAYDON, Wayne D., California Geological Survey, 135 Ridgway Avenue, Santa Rosa, CA 95401, Wayne.Haydon@conservation.ca.gov

As part of the California Geological Survey's (CGS) Alluvial Fan Mapping Program, we mapped Quaternary surficial deposits and digitally compiled bedrock mapping, structure and landslides in the southern San Joaquin Valley near Bakersfield and Arvin for the Department of Water Resources (DWR). DWR is working to identify areas more susceptible to flooding on alluvial fans in urbanizing areas. This mapping is also a first step towards an evaluation of seismic shaking amplification, liquefaction, and collapsible soils. Four relative ages of alluvial fans (early/late Pleistocene, early/late Holocene) were interpreted from topographic data, geomorphic expression and imagery. Recent to early Pleistocene alluvial units mapped at 1:24,000 include wash, fans, axial-valley, lacustrine and eolian deposits. USDA soil surveys helped delineate flatland deposits. Mapping criteria included topographic expression, dissection, texture, slope, and profile development. Quaternary age flatland alluvial deposits near the southern end of the San Joaquin Valley are dominated by late Holocene Kern River, Caliente Creek and Tejon Creek alluvial fans emanating from bedrock uplands and spreading out toward the valley center. Early Holocene alluvial fans were interpreted between or at distal ends of the younger fans. Typically, Holocene fan deposits lie adjacent to the major drainages and near the mountain fronts, while early and late Pleistocene alluvial fans are located along the topographically higher margins of valleys and at distal ends of younger fans. Isolated remnants of early Pleistocene fans occupy the tops of many side ridges within several west-draining drainages. These early Pleistocene to late Holocene age alluvial fan and wash deposits include historic debris-flow deposits. Holocene wind-blown sand dunes are present south of Arvin. The valley center is underlain by the Buena Vista and Kern lake bed deposits, with alluvial valley deposits in interconnecting sloughs. The alluvial flatland deposits are surrounded on three sides by tectonically active mountains experiencing deformation resulting in uplift, displacement, tilting or folding, and erosion of the older Quaternary sediments at basin margins, narrowing the southern San Joaquin Valley and forcing younger sediments to prograde toward valley center.

SESSION NO. 18, 8:00 AM

Tuesday, 21 May 2013

T7. Hydrogeologic Issues of Irrigated Agricultural Regions- Problems and Solutions (Posters)

Radisson Hotel and Conference Center, Salon B/C

18-1 **BTH 31** Han, Jong Youn

EFFICIENCY OF SOIL VAPOR EXTRACTION AS A GROUNDWATER REMEDIAITON TOOL FOR OIL REFINERIES IN THE CENTRAL VALLEY OF CALIFORNIA

HAN, Jong Youn and LUBO, Liu, Civil and Geomatics Engineering, California State University, Fresno, Fresno, CA 93740, hanjong@mail.fresnostate.edu

Many of the old petroleum oil refineries in the Central Valley of California caused soil contamination and groundwater degradation problems with petroleum hydrocarbons generated over the years from their aboveground storage tanks (ASTs) and underground crude oil delivery pipelines operations. Most refineries in the area adopted soil vapor extraction (SVE) technique as their main soil and groundwater remediation tool probably due to the SVE's reputation as an already accepted, recognized, and cost-effective technology. Our review of the historical site characterization and remediation reports indicate that SVE technique was highly effective in remediating groundwater impacted with chlorinated hydrocarbons (such as TCE and PCE) in some industrial sites of this region such as former Dow Chemical Company in Fresno of Fresno County and former Sprague Electric Company in Visalia of Tulare County. However, SVE was much less effective in other sites such as Bakersfield Refinery in Bakersfield of Kern County for the petroleum hydrocarbon cleanup. At the refinery, SVE operation started in 1992 and the SVE system is still being operated in conjunction with other remediation technique (air sparge) to clean up the benzene and total petroleum hydrocarbon groundwater plumes. The effectiveness of SVE needs to be quantified for different scenarios.

The objective of this research is to utilize available data collected from the three sites mentioned above to evaluate the effectiveness of the SVE as a sustainable soil (and subsequently groundwater) remediaiton tool, and to verify its application range from the hydrogeological point of view. The evaluation will also include the type of contaminants and their values of vapor pressure, water solubility, and Henry's Law constant. The challenges of this research lie on the complex composition of petroleum and petroleum products and also on the contaminants occasionally being added to the site soils through the leaks and spills occurring by the on-going refinery operations.

18-2 **BTH 32** Rieth, Dale

SOIL ORGANIC MATTER CONTENTS IN THE SHALLOW SALINE AQUIFER BELOW NAS LEMOORE IN WESTERN SAN JOAQUIN VALLEY, CALIFORNIA

RIETH, Dale, HOLCOMB, Ronald E., HISHIDA, Kassandra, and WANG, Zhi, Dept. of Earth & Environmental Sciences, California State Univ, Fresno, 2576 E. San Ramon Ave., M/S ST24, Fresno, CA 93740, drrieth@gmail.com

The Naval Air Station Lemoore (NASL) is located in the western central part of California's San Joaquin Valley which has long been affected by soil and groundwater salinization due to drainage of irrigated agricultural fields. The soil organic matter content of the shallow saline aquifer at NASL is physically delineated in this study in conjunction with a larger study that was conducted to evaluate soil and groundwater conditions.

In arid soils, the natural soil organic matter content (OMC) is usually small (less than 2%), but its effect on soil functions are profound. Soil organic matter provides much of the soil's cation exchange capacity. It is largely responsible for the formation of soil aggregates which increases soil aeration and water-holding capacity. It also contains large quantities of plant nutrients and acts as slow-releasing nutrients. Furthermore, organic matter supplies energy and body-building constituents for most of the microorganisms. For all these reasons, it is necessary to measure the soil OMC in order to determine the soil quality.

The soil OMCs were measured using the oven and furnace drying methods in the lab. Samples were taken from 450 soil cores obtained from 28 newly installed groundwater observation wells drilled to depths of 20-25 ft. The measuring results were plotted in 2D and 3D software to assess the spatial patterns of soil OMC at NASL.

Results show that the soil OMC is generally high in the surface soil (> 3%). It decreases along the depth of the aquifer but never become less than 2%. The soil texture within the 20-ft depth varies from sand to silt clay but mostly loams. All indicators show that the soil has good texture, high organic matter and nutrients, thus is suitable for growing shallow- and deep-rooted plants if soil and groundwater salinity is controlled.

18-3 **BTH 33** Hishida, Kassandra

SOIL VERSUS GROUNDWATER SALINITY AT NAS LEMOORE IN WESTERN SAN JOAQUIN VALLEY, CALIFORNIA

HISHIDA, Kassandra, RIETH, Dale, HOLCOMB, Ronald E., and WANG, Zhi, Dept. of Earth & Environmental Sciences, California State Univ, Fresno, 2576 E. San Ramon Ave., M/S ST24, Fresno, CA 93740, keh511425@mail.fresnostate.edu

The San Joaquin Valley is one of the most productive agricultural regions in the world. Although practice of irrigation has helped make this possible, it has also caused severe salinization of soil in this region. Due to strong evapotranspiration, salt ions accumulate in the soil, which is then leached to groundwater during rainfall or irrigation events. Conversely, the groundwater table may rise to levels close to soil surface, thereby contributing salt to the surface soil by soil capillarity. To best manage soil salinity, it is essential to understand the relationship between soil salinity and groundwater salinity as well as the long-term impacts of irrigation farming.

The shallow saline aquifer at NAS Lemoore is chemically characterized in this study in conjunction with a larger study that was conducted to evaluate soil and groundwater conditions. Soil and groundwater salinity parameters such as electrical conductivity (EC), pH, and total dissolved solids (TDS) were measured either in the field or from 450 soil cores, drilled to depths of 20-25 ft. Soil paste solutions were prepared and measured to obtain soil pH and EC data.

By comparing the new data with historical records, it has been found that the surface soil of the region has progressed from saline and severely saline levels (EC = 4-12 dS/m) in 1999 to non-saline (EC < 2 dS/m) in 2010 due to land leasing for irrigated crop production. The soil chemistry profile shows that the top 5-ft of soil is non-saline or slightly saline. Soil salinity sharply increases at the depth of groundwater table. Thus, in order to use the soil sustainably in the future, the groundwater table must be closely monitored and maintained at depths well below 5-ft bgs through management and engineering measures.

18-4 **BTH 34** Halopoff, David D.

NITRATE FATE AND TRANSPORT IN A LARGE SOIL AND GROUNDWATER-MODELING TANK

HALOPOFF, David D. and LIU, Lubo, Lyles College of Engineering, California State University - Fresno, 2320 E. San Ramon Ave, Fresno, CA 93740, dhalopoff@mail.fresnostate.edu

Conventional fate and contaminant framework assumes that as water and contaminants travel through the ground surface, the vadose zone, and eventually the groundwater table, the infiltration is uniform and an average hydraulic conductivity for the strata is used. However, as more recent research has demonstrated, this framework is not adequate; water passes through the vadose zone through the soil strata's macropores, referred to as preferential pathway flow. These preferential pathways transport both water and contaminants at much higher rates and through less area, drastically reducing travel time and soil attenuation. This study focuses on the investigation of interaction between macropores and preferential pathway flow and nitrate fate and transport to the groundwater table through the vadose zone. The methods used in this research include a lab experiment using a soil-groundwater tank and mathematic modeling with GMS (Groundwater Modeling System). This study will result in a better understanding of the controlling factors of contaminant fate and transport through the vadose zone and allow for the proper nitrate mitigation framework to be implemented.

18-5 **BTH 35** Cassel Sharma, Florence

ENVIRONMENTAL AND AGRONOMIC MANAGEMENT STRATEGIES FOR IMPROVING TOMATO PRODUCTION IN SALT-AFFECTED SOILS OF THE SAN JOAQUIN VALLEY, CA

CASSEL SHARMA, Florence[1], GOORAHOO, Dave[2], and YADAVALI, Prasad[1], (1) Department of Plant Science, California State University, Fresno, 2415 E. San Ramon Ave. M/S AS 72, Fresno, CA 93740, fcasselss@csufresno.edu, (2) Plant Science Department, California State University, Fresno, 2415 E. San Ramon Ave., M/S AS72, Fresno, CA 93740

Production of processing tomatoes (*Solanum lycopersicum* L*)* is a major challenge in salt-affected soils of western San Joaquin Valley (SJV). Environmental and agronomic strategies need to be implemented to improve yields and reduce salt built-up in the root zone. Such strategies include acidifying the irrigation water to reduce soil pH and implementing fertigation of important nutrients, such as calcium, to improve their availability to plants. In this study, we evaluated the environmental and economic benefits of irrigation water acidification and calcium (Ca) fertigation on the yield and quality of processing tomatoes grown in saline soils, incidence of blossom end rot (BER-a physiological disorder attributed to Ca deficiency), plant calcium levels and soil chemical properties. The experiment was conducted during a two-year period in a conventional processing tomato field in Kettleman City, CA. The four fertilizer/acidification treatments were (1) ammonium nitrate (AN-20), (2) urea sulfuric acid (US-15) + AN-20, (3) calcium ammonium nitrate (CAN-17) and (4) calcium thiosulfate (CTS) + AN-20 which were replicated four times. A randomized complete block design was utilized and each treatment plot consisted of 5 beds of 300-ft length. In year 1, fertilizer treatments had a significant effect on the yield of tomatoes. Yields were highest under the calcium thiosulfate (CTS) treatment. Plants treated with CTS+AN-20 had 10 to 15% greater total and marketable yield as compared to tomatoes receiving the other fertilizers. In year 2, no significant yield differences were observed among the treatments. Plants treated with CTS exhibited the lowest incidence of BER in both years. Correlation analysis indicated that elevated sodium (Na) and Sodium Adsorption Ratio (SAR) in soil had a negative effect on tomato yields and contributed to greater incidence of BER in both the seasons, regardless of fertilizer treatments. Results suggest that efforts should be directed towards soil Na amelioration using management practices such as proper irrigation methods and gypsum application rather than using Ca fertilizers only.

SESSION NO. 19, 8:00 AM

Tuesday, 21 May 2013

T13. Irvingtonian Paleoecology of Western North America (Posters)

Radisson Hotel and Conference Center, Salon B/C

19-1 **BTH 36** Del Castillo, Christopher

AMERICAN BADGER (*TAXIDEA TAXUS*) FROM THE MID-IRVINGTONIAN FAIRMEAD LANDFILL LOCALITY, MADERA COUNTY, CALIFORNIA

DEL CASTILLO, Christopher, ESPINO, Yesenia, and DUNDAS, Robert G., Department of Earth & Environmental Sciences, California State University, Fresno, CA 93740, christopherdelcastiilo59@yahoo.com

Badgers (*Taxidea taxus*) first appeared in North America during the late Pliocene. Several Blancan and Irvingtonian localities record the species and badgers are common in Rancholabrean faunas of western North America. Three badger specimens from Fairmead Landfill are curated in the collections of the University of California Museum of Paleontology (UCMP) and Madera County Paleontology Collection (MCPC). The mid-Irvingtonian aged (0.78–.55 Ma) Fairmead Landfill site has yielded thousands of fossils representing 72 taxa (2 fish, 2 amphibians, 3 reptiles, 6 birds, 29 mammals, 1 bivalve, 1 gastropod, 12 plants/palynomorphs, and 16 diatoms). Fossils are preserved in sediments representing distal alluvial fan channel, distal fan overbank flood or sheetflood, and marsh/lacustrine deposits of the upper unit of the Turlock Lake Formation. Badger specimens from Fairmead Landfill include UCMP 156954 (left maxilla with P3-P4), MCPC A2197 (skull), and MCPC A1182 (parietals and other cranial fragments). UCMP 156954 compares well morphologically with modern badger specimens. Although the P4 has slight posterior damage, the minimum labial carnassial length is 11.1 mm, about the mean size of modern male badgers in the West. The dental characteristics of MCPC A2197 cannot be studied because the jaw and cranium cannot be disarticulated without causing significant damage to the specimen. However, measurements of the cranium indicate a very large individual, bigger than modern male badgers in the West. Zygomatic breadth is 107 mm, labial length of the upper carnassial is 12.5 mm, alveolar length of the maxillary tooth row is 50.5 mm, postorbital breadth is 47+ mm (slight damage to one postorbital process), and greatest length of the cranium is 145+ mm (significant damage to the occipital condyles). Occurrence of badgers at Fairmead Landfill is not unexpected. The species' historical range includes the central San Joaquin Valley. The fossil locality's biota indicates a predominantly grassland habitat, with some scrubland and sparse trees. The site's rodent taxa, including ground squirrel, pocket gopher, voles, rats and mice would have provided adequate prey. The Fairmead Landfill specimens are significant in documenting the presence of badgers in the central San Joaquin Valley by at least the mid Pleistocene.

19-2 **BTH 37** Tovar, Danny H.

FELIDAE FROM IRVINGTONIAN DEPOSITS AT FAIRMEAD LANDFILL AND IRVINGTON IN CALIFORNIA

TOVAR, Danny H. and DUNDAS, Robert G., Department of Earth & Environmental Sciences, California State University, Fresno, CA 93740, dht79@yahoo.com

In general, felids are rare in Pleistocene localities. When present, felid specimens are often fragmentary and the ability to identify them to species level is difficult due to a lack of diagnostic characters. The sites of Fairmead Landfill and Irvington in central California are significant in that they record a diversity of mid Irvingtonian felids, with some specimens exhibiting intermediate morphologic traits between early and late Pleistocene members of their respective lineages. Fairmead Landfill and Irvington have *Homotherium*, *Smilodon* and *Panthera* in common, with *Lynx* and *Miracinonyx* also present at Fairmead Landfill. Fairmead Landfill felid specimens include *Homotherium* (UCMP 140390 cranium, UCMP 140391 upper canine), *Smilodon* (MCPC A9 left proximal femur, MCPC A2210 cranium), *Miracinonyx* (UCMP 140618 maxilla fragment with P4), *Panthera* (MCPC A2200 partial cranium), and *Lynx rufus* (MCPC A2198 left proximal ulna, MCPC A2199 left proximal ulna). Irvington specimens include *Homotherium* (UCMP 39228 partial cranium), *Smilodon* (UCMP 38338 posterior cranium, UCMP 67859 left dentary with partial m1), and *Panthera* (UCMP 71237, juvenile jaw with p3-m1). *Lynx* from Fairmead Landfill is indistinguishable from modern specimens of bobcat. The *Miracinonyx* agrees morphologically with mid Pleistocene specimens of the taxon. *Panthera* from both Irvington and Fairmead Landfill share many similarities with *Panthera onca,* although further evaluation is necessary to resolve some observed differences in comparison to the extant species. The *Homotherium* crania from Irvington (UCMP 39228) and Fairmead Landfill (140390) compare well to *Homotherium serum* from Friesenhahn Cave, Texas, but the presence of an internal root (protoradix) on the P4, a primitive character, precludes their assignment to the late Pleistocene taxon. The Fairmead Landfill *Smilodon* cranium (MCPC A2210) is morphologically intermediate between early Pleistocene *Smilodon gracilis* and late Pleistocene *Smilodon fatalis*. The Fairmead Landfill cranium compares best with *Smilodon* crania from the Irvingtonian Camelot fauna of South Carolina. Overall, Fairmead Landfill and Irvington represent diverse felid records, with evolutionarily transitional features present in some members.

SESSION NO. 20, 1:30 PM

Tuesday, 21 May 2013

Geomorphology and Quaternary Geology

Radisson Hotel and Conference Center, Salon D2

20-1 **1:30 PM** Shlemon, Roy

PLEISTOCENE CHANNELS IN THE CENTRAL VALLEY OF CALIFORNIA: POTENTIAL CONTAMINANT PATHWAYS, AND EXPLOITATION FOR GROUNDWATER AND MINERALS (GOLD, AGGREGATES)

SHLEMON, Roy, Geology, UC Davis, One Shields Ave, Davis, CA 95616, rshlemon@jps.net

Major rivers in the California Central Valley are underlain by multiple, generally gravel-filled buried channels produced by regional climatic change (mainly Sierra Nevada glaciations) and by local tectonics. Buried lower American and Mokelumne river channels are traced to ~35 m below sea level where they graded to glacio-eustatic base levels in the California Delta. Upstream, the channels are surficially expressed by inset terraces; downstream they are traced mainly in water-well logs, and are relatively dated to at least ~600 ka bp by soil profile development and by association with the late Quaternary isotope stage chronology.

Buried channels in the northern Sacramento Valley and the southern San Joaquin Valley similarly reflect Pleistocene climatic change, but their depths and downstream trends are largely controlled by local regional subsidence, particularly in the Tulare Basin. Historically, many Pleistocene channels were exploited for gold mostly by dredging and hydraulic mining. The buried channels are also important aquifers for domestic and agricultural water. Where expressed as terraces, the channels have long supplied sand and gravel for aggregate, an increasing valuable commodity for urban development. But the buried channels are also potential pathways for contaminants moving into the subsurface where downstream migration is not readily predictable owing to complex hydraulic connection via local fracture and fault systems.

20-2 **1:50 PM** Sousa, Frank J.

THE SOUTHERN SIERRA NEVADA FOOTHILLS BEDROCK PEDIMENT

SOUSA, Frank J.[1], SALEEBY, Jason B.[1], FARLEY, Kenneth A.[1], and UNRUH, Jeffery[2], (1) Division of Geological and Planetary Sciences, California Institute of Technology, Pasadena, CA 91125, frank@caltech.edu, (2) Lettis Consultants International, Inc, 1981 No. Broadway, Suite 330, Walnut Creek, CA 94596

A bedrock landscape present in the western Sierran Foothills between 36°N and 37°N is here interpreted to be an exhumed Late Cretaceous to early Tertiary pediment. Based on field reconnaissance, the pediment landscape is divided into three main geomorphic zones: a sub-horizontal bedrock pediment surface; a multi-scale set of bedrock tors (~ 1 meter scale relief), monadnocks and hilly ranges (~ 100 meter scale relief); and the transition between these two zones marking the slope to pediment plane transition, lacking lithologic change. Relief of hill slopes adjacent to the modern pediment locally exceeds 500 m, which serves as a minimum constraint on paleo-relief above the Late Cretaceous pediment surface. Analysis of water-well logs indicates that the pediment extends at least several kilometers west of the Foothills in the San Joaquin Valley subsurface, where it is overlain by 100 m or less of middle to late Pleistocene glacial outwash fan deposits. Lithology of the bedrock pediment generally is granitoid, but locally includes pendants of ultramafic rocks of the Kings-Kaweah ophiolite belt. Apatite U-Th-Sm/He thermochronometric data from 10 samples collected from this landscape document 74.6 Ma +/- 7.4 Ma rapid exhumation of the bedrock. The pediment surface is overlain by Eocene Ione Formation at Little Table Mountain in the north and by Eocene Walker Formation near Fountain Springs in the south. These relations indicate a Late Cretaceous to Eocene age for the pediment. Where exposed as part of the pediment landscape, individual monadnocks of ophiolite are covered with a Si and Fe-rich rind of highly weathered and indurated rock, which possibly developed during the oxic (tropical) Eocene climate and weathering regime in this part of California. These thermochronometric, geomorphic, and stratigraphic data define a roughly range-parallel joint pre-Eocene relict landscape and Late Cretaceous apatite U-Th-Sm/He isochronal swath that extends along strike at least from Fountain Springs to Little Table Mountain. This relict landscape correlates with a set of surfaces that mimic both the western shoulder of a regional orogenic plateau called the Nevadaplano, which characterized the U.S. Cordillera in Late Cretaceous to mid-Cenozoic time, and the basal Late Cretaceous nonconformity beneath the adjacent Great Valley.

20-3 **2:10 PM** Stock, Greg M.

RETREAT AND STAGNATION OF LITTLE ICE AGE GLACIERS IN YOSEMITE NATIONAL PARK

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The high peaks of Yosemite National Park in the Sierra Nevada, California, retain small (<1 km^2) glaciers dating back to the Little Ice Age. The largest of these glaciers, the Lyell and Maclure, form the headwaters of the Tuolumne River and are an important source of late summer runoff. The Lyell and Maclure glaciers have been the subject of scientific study and documentation since the late 19th century and thus offer opportunities for comparative studies of their response to climate change. Beginning in 2007, we repeated a set of historical photographs, topographical surveys, and velocity measurements of the glaciers. By tracking the movement of stakes over a four year period (2009-2012), we found the average horizontal velocity of the Maclure Glacier to be 7.2 m/yr, or 1.9 cm/day. The noted conservationist John Muir first measured the velocity of the Maclure Glacier between 21 August and 6 October of 1872. In 2012, we reproduced Muir's measurements over the same time period and found the glacier to be moving at the same rate, about 2.6 cm/day. This consistency in velocity occurs despite an approximate 60% reduction in glacier surface area and about 30 m of thinning. Much of the movement of the Maclure Glacier occurs as sliding at the bed, which may be enhanced by greater amounts of meltwater. In contrast, we found that the adjacent Lyell Glacier displayed virtually no movement over the same four year period, suggesting that it has stagnated. As velocity measurements by the National Park Service in 1935 indicated that the east lobe of the Lyell Glacier was moving at about 3.2 m/yr, stagnation has occurred since that time, and perhaps within the past decade. A time series of surface elevation surveys across the width of the Lyell Glacier shows that the Lyell Glacier surface has lowered by as much as 40 m since 1932, with about 3 m of thinning in the past five years; this thinning is likely why the glacier has stagnated. The surface area of the Lyell Glacier has diminished by about 62% since 1903. Ongoing work involving numerical modeling of glacier mass balance from the Little Ice Age into the next century will help to predict the future fate of these glaciers.

20-4 **2:30 PM** Thompson, Jessica A.

COSMOGENIC NUCLIDE EXPOSURE DATING OF ROCK AVALANCHE DEPOSITS IN YOSEMITE VALLEY, CALIFORNIA

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Rock falls commonly occur from the glacially-steepened walls of Yosemite Valley, with smaller rock falls up to hundreds of cubic meters in volume occurring on an annual basis. Larger rock falls up to tens of thousands of cubic meters in volume occur less frequently, but have been documented in the past 150 years. Deposition of these rock falls is typically limited to the active talus slopes beneath the cliffs. However, the floor of Yosemite Valley preserves at least six extremely large rock fall deposits, here termed rock avalanches, up to several million cubic meters in volume. These deposits extend far beyond the base of active talus slopes onto the valley floor, and have occurred since the retreat of Last Glacial Maximum glaciers circa 15-17 ka. We mapped these

rock avalanche deposits in the field and in ArcGIS, using airborne LiDAR data that resolves individual boulders. Minimum exposed volumes range from hundreds of thousands to several million cubic meters. To assess the frequency of rock avalanche occurrence, we employed cosmogenic beryllium-10 surface exposure dating of large (>10 m^3) boulders embedded within the deposits. Rock avalanches in Yosemite are ideal targets for cosmogenic exposure dating, as they are essentially instantaneous failures that excavate deep-seated quartz-rich granitic rocks, and once they are deposited on the flat valley floor they are essentially immune to subsequent modification. Exposure ages show remarkable consistency across the width of the deposits, with as little as 3% variation between samples located tens to hundreds of meters apart. Mean exposure ages indicate that failures occurred at 1.0, 1.8, 2.3, 3.7, 4.4, 6.4, and 11.6 ka. At least three of the deposits appear to represent two or more failures, separated in time by hundreds to thousands of years. Synchronous rock avalanches (within the uncertainty of the exposure ages, or <200 yrs) at different locations within the valley appear to have occurred at 3.7 ka, and possibly at 2.3 ka, suggesting coseismic triggering. Age correlations tentatively identify large earthquakes originating from the eastern Sierra Nevada as triggers for at least some of the rock avalanches. These unique and robust age data provide key information for quantifying recurrence intervals for rock avalanches in Yosemite Valley.

20-5 **3:10 PM** Caskey, S. John

NEW SHORELINE AGES AND OIS-6 LAKE-LEVEL HISTORY OF LAKE MANLY, DEATH VALLEY

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Despite a long history of Lake Manly research, a well-dated core record of the last two major lake cycles [186-120 ka (OIS-6) and 35-10 ka (OIS-2)], and numerous attempts to date shoreline deposits, the pluvial history as recorded in the ages and elevations of Lake Manly shorelines has remained controversial and unresolved. To this end, we initiated a basin-wide survey of high-level shorelines in areas of relative tectonic stability. We see remarkable consistency in elevations of two distinct high-level shorelines spanning northern, central (west side), and southern Death Valley. The highest formed at ~60 m above sea level (masl). Slightly lower, and notably prominent shorelines mark lake levels at ~46 masl. Similarities in degree of preservation suggest shorelines at both levels formed during the same pluvial cycle. New U-series tufa ages from 46-m shorelines on Johnson Canyon fan and a basalt hill (BH) on the north side of Blackwater fan (BF) are best bracketed between 129.5 ± 1.6 ka and 122.4 ± 1.1 ka, and indicate a high lake level late in the OIS-6 pluvial. Further details of OIS-6 lake fluctuations are recorded on BF where a high beach ridge (57 m) built onto the south flank of the BH during (what we now take as) the OIS-6 high stand. Following lake regression from the high stand, the 57-m beach ridge was deeply incised on the flank of the BH and inset by a younger fan. The timing of lake regression isn't known. Remarkably, however, the fan that was inset during lake regression records a later transgression of Lake Manly in the way of shorelines and overlying beach deposits that can be traced on the fan to a maximum elevation of 46 m. Importantly, the relations show that the late OIS-6 lake at 46 masl was a late-transgressional phase, not a recessional lake level and thus implies an earlier OIS-6 age for the high stand. Our new observations and age constraints agree well with the lacustrine record from CORE DV93-1. We interpret that: 1) the 60 m shorelines mark the original, quasi-stable, highstand of Lake Manly reached in the earlier part of the OIS-6 pluvial (186-166 ka interval); 2) lake regression (recorded at BF) likely occurred during a time of higher lake salinities (166-144 ka interval); and 3) late OIS-6 transgression to 46 masl matches a deep lake interval at 122 ka, but perhaps more likely correlates to the deep lake interval ending at 128 ka.

20-6 **3:30 PM** Burns, Scott F.

ANCIENT CATACLYSMIC FLOODS IN THE PACIFIC NORTHWEST: ANCESTORS TO THE MISSOULA FLOODS

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The Missoula Floods left erosional and depositional features behind in eastern Washington, now termed the scablands. At least 89 floods occurred when Glacial Lake Missoula's ice dam repeatedly ruptured and re-formed between 15 to 18 thousand years ago, with 40 of the floods reaching Wallula Gap (Allen et al., 2009). Evidence of older deposits have been wiped out by the Missoula Floods in most places. By searching geological literature evidence of older flood deposits can be found. Geologists have sited magnetic reversals in flood sediments that date some paleosols to at least 780,000 years before present. Further evidence can be found in the formation of caliche, which takes longer than 15,000 years to form. This project will involve visiting every site referenced in literature to look for evidence of older flood deposits. Each site will be described and samples will be taken and analyzed for color, particle size, cementing, caliche, and dates where possible. Flood deposits from the sites will be correlated to each other to begin to form a chronology of the Ancient Cataclysmic Floods.

20-7 **3:50 PM** Bishop, Kim M.

THE KOHALA LANDSLIDE: A NEW MEGA-LANDSLIDE INTERPRETATION REGARDING THE NORTHEAST FLANK OF KOHALA VOLCANO, HAWAII

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With respect to the Pololu mega-landslide off the northeast coast of the island of Hawaii, two interpretations have been proposed for the anomalously eroded subaerial northeast slope of Kohala Mountain between Waipio and Pololu Valleys. The older interpretation is that the slope forms the upper part of the landslide (Moore et al., 1989), whereas the more recent model is that the slope is not part of the landslide and that the head of the Pololu landslide is located at the high coastal cliffs below the subaerial slope (e.g., Smith et al., 2002).

Contour analysis of the slope supports the following two conclusions: 1) the subaerial slope has experienced landslide movement; and 2) that this landslide is separate from the Pololu landslide. Evidence for the first conclusion is recognition that the trends of contours lines north and south of Pololu Valley, interpreted to delineate the northern lateral boundary of the landslide, are misaligned. Contours south of the valley are shifted seaward from those to the north. This misalignment is readily explained by landslide displacement along a slide plane that dips less steeply seaward than the topographic slope.

The second conclusion derives from analysis of summit area contours. At the crest of Kohala volcano are 3 sizeable faults that bound grabens. Assuming these grabens developed from movement at the head of the landslide, mass balance analysis of a topographic profile suggests that the slide displacement in this area is 225 m and that the slide plane is 1000 m below the summit surface. Using this depth and the constraint that the slide plane is less steep than the topographic slope (noted above), the slide plane is projected to daylight at the base of the coastal cliffs. Daylighting of the low gradient slide plane at this location indicates the slide cannot be part of the Pololu landslide further offshore and must be a separate landslide. The proposed name for this newly recognized landslide is the Kohala slump/debris avalanche.

The volcanic mass missing from the area northeast of the cliffs is proposed to be a part of the Kohala landslide that mobilized into a debris avalanche and travelled far offshore, thereby creating the coastal cliffs. The difference in behavior of the upper and lower parts of the Kohala landslide might be explained by buoyancy affects of ocean water on the lower part.

20-8 **4:10 PM** Brady, Roland H.

DEVELOPING A PROTOCOL TO DESCRIBE AND DELINEATE EPISODIC STREAM PROCESSES ON ARID LANDSCAPES FOR PERMITTING SOLAR POWER PLANTS

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Like their perennial, temperate-region counterparts, episodic streams in arid and semi-arid (dryland) areas transport and disperse water, sediment, seed and organic matter, and provide refugia – processes that collectively produce habitat values and biodiversity that are considerably higher than in adjacent uplands. But episodic streams are more prone to flash floods, debris flows, rapid channel switching, and rapid bank erosion.

Large-scale solar power plants will eventually cover thousands of acres in dryland regions of California. Drainage reconfigurations for these projects greatly modify the watershed's morphology often with detrimental impacts to associated ecosystems. As well, projects that fail to incorporate the site's fluvial processes into their designs face costly remediation measures to protect the project's performance and capital investments.

Industry and public partners recognize the need to minimize the negative impacts from solar power plant projects in dryland areas. Although the relationship between habitat and physical/hydrological processes is much better understood in perennial than in episodic stream systems, and few reliable protocols exist for describing and delineating processes in dryland streams, nevertheless, many of the concepts, theories, and practices used in design and described in permit applications for sites in ephemeral landscapes is based on those used in perennial systems. This problematic information gap often overlooks or misinterprets critical ecological or physical factors, leading to delays in the permitting process or inappropriate project designs.

To address this shortcoming, this project, funded by the California Energy Commission, will: 1) produce a scientifically based, geomorphic and ecological stream delineation method for project applicants to use to design and develop sustainable, low-impact projects in dryland environments; 2) provide oversight agencies a rigorous and consistent method to evaluate proposed projects and mitigation; and 3) provide a formalized tool with broad application for use in siting and permitting any development project, developing land use and resource management plans, or evaluating land use and resource management practices in ephemeral stream environments.

SESSION NO. 21, 1:30 PM

Tuesday, 21 May 2013

T4. Ophiolites and Suture Zones

Radisson Hotel and Conference Center, Salon A1

21-1 **1:30 PM** Moores, Eldridge M.

NORTH AMERICAN OPHIOLITES AND SUTURES: ANALOGUES WITH SW PACIFIC AND ALPINE-MEDITERRANEAN BELTS

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Ophiolites are formed at oceanic spreading centers and emplaced principally by collision of a continental or island arc crustal margin with a subduction zone dipping away from it. Nonaccretionary subduction zones recycle old oceanic lithosphere, including sediments, into the mantle to be recycled as new suprasubduction-like oceanic crust.

Western North American ophiolites may form as in the western Pacific--complex intra-arc rifting and closure (e.g. Philiippines: Encarnacion, 2004) or multiple rifting, sutures, collisions, rapid plate margin changes, and extensive transform faulting (e.g., Indonesia-Philiippines: Hall and Wilson, 2000). Alpine-Mediterranean nappes, sutures, ophiolites, thrust-belt and subduction parallism, collisions, and subduction polarity flips also provide insight into Cordilleran tectonic events.

In northern California-western Nevada, possible sutures--some involving westward subduction--include the following boundaries: *1.* Franciscan Coastal-Central belts; *2.* Coast Range/Great Valley Ophiolite-Western Jurassic belt; *2.* Western Jurassic Belt-Central Belt; *3.* Central Belt-Feather River Peridotite; *4.* Feather River Peridotite--"Cedar" rocks; *5.* "Cedar" rocks-Eastern Belt. Also, *6.* Pre-380 Ma serpentinite-Shoo Fly contact; *7.* Intra Jurassic-Cretaceous oceanic-continental volcanic rock boundary; and *8.* A late Mesozoic suture between the Philippine-like northern Sierra Nevada and the ribbon continent "Rubia" (Hildebrand, 2009, 2013). Some sutures may continue into the southern Sierra-Nevada; they may also be loci of younger major strike-slip faults. Contemporaneous regions north and south show broadly similar relations. Irving, et al. were right 40 years ago about northward movement of the Canadian Cordillera. Any traces of the 80-60 Ma northward migration of Wrangellia-Stikinia past California will be found between the Franciscan Coastal and Central Belts. Smartville ophiolite and younger topographically higher pluton surfaces model the southern San Joaquin sub-basement.

21-2 **1:50 PM** Dilek, Yildirim

SSZ OPHIOLITES AS ARCHIVES OF SUBDUCTION INITIATION AND MELT EVOLUTION IN CONVERGENT MARGIN SETTINGS

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The internal structure-stratigraphy and geochemical signatures of most suprasubduction zone (SSZ) ophiolites display structural, petrological, geochemical and geochronological evidence, recording different stages of subduction initiation-related magmatism, material flux, metasomatism and deformation in forearc-incipient arc settings. There is a well-developed magmatic stratigraphy in the extrusive sequences of these ophiolites from older MORB-like lavas at the bottom towards younger island arc tholeiite (IAT) and boninitic lavas in the upper parts. A similar progression of the lava chemistry also occurs in crosscutting dike swarms and sheeted

dikes, indicating increased subduction influence in the evolution of ophiolitic magmas through time. Lherzolitic peridotites in structurally lower parts of the upper mantle sequences of these ophiolites represent the residue after MORB melt extraction. Harzburgite and harzburgite-dunite associations higher up in the mantle sequences and below the transitional Moho are crosscut by networks of orthopyroxenite (opxt) veins, which include hydrous minerals (amphibole). These orthopyroxenite veins represent a reaction product between the host harzburgite (depleted, residual peridotite) and the migrating Si-rich (boninitic) melt. The harzburgite-dunite-opxt suites characterize melt-residua relationships and melt migration patterns in the mantle wedge during the initial stages of subduction and incipient arc construction. Thus, SSZ ophiolites show a lateral and vertical progression of melt evolution in their crustal and upper mantle components that traces different stages of subduction initiation-related magmatism, reminiscent of the forearc magmatism in some of the modern arc-trench rollback systems as in the Izu-Bonin-Mariana and Tonga-Kermadec subduction factories.

21-3 **2:10 PM** Jean, Marlon M.

ASSESSING THE LIGHT ELEMENT CYCLE: THE FORE-ARC CONNECTION

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One of the most significant cycles that define Earth's various chemical systems are those that include the light elements. Li, Be, and B are the three most important elements that fall into this category. It is known that altered oceanic mantle is a repository for these elements, and subduction zones carry these elements into the lower mantle - a plausible explanation for the HIMU-isotopic signature. However, the concentrations of these elements have hardly been explored or quantified in mantle peridotite. Estimates of the light element content of primitive mantle and depleted mantle imply very low abundances in whole rock samples and major mantle phases - around 1 ppm for Li and B, consistent with C1-chondrite, and Be being extremely low (< 0.07 ppm).

The Coast Range Ophiolite, a Jurassic fore-arc ophiolite that preserves mantle lithologies formed in response to hydrous melting, light element compositions are highly enriched, e.g., Li up to 10x DMM, B up to 600x DMM, and Be are also present above detection limits. The concentrations for most of the light elements should effectively be zero after partial melting, however, upon analysis were enriched by factors of up to ~10^5 to ~10^{40}; therefore any enrichment observed in our samples must be due solely to fluid addition within the mantle wedge. To model this enrichment a new algorithm was derived, which modeled the fluid enrichment process and represents the total addition of material to the mantle wedge source region. This calculation can be applied to any refractory mantle peridotite that has been modified by melt extraction and/or metasomatism. Application of this new method shows that the amount of fluid added to a DMM-source was in the 10's of ppm range for each light element.

It has been demonstrated that other fore-arc ophiolites, e.g., Oman, Troodos, Bay of Islands, among others, display enriched light element signatures. These ophiolites, however, have been shown to have subduction origins. One of the critical issues to understanding this cycle is finding other repositories for light elements. We posit that lower oceanic crust (peridotites and gabbros) and eclogites could represent such reservoirs. Demonstrating enriched light elements in these two domains would be an important component for understanding mantle dynamics and the cycling of light elements since accretion.

21-4 **2:30 PM** Yoshinobu, Aaron

LINKING DEFORMATION IN THE MANTLE WEDGE AND CRUSTAL ACCRETION IN THE SUPRA-SUBDUCTION ZONE JOSEPHINE OPHIOLITE

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The Josephine peridotite comprises > 800 km^2 of tectonized/variably serpentinized harzburgite, dunite, and pyroxenite that represent the upper mantle exposures of the Middle Jurassic Josephine ophiolite (JO). Published results indicate that the JO was generated in a supra-subduction zone, trans-extensional marginal basin setting that evolved by rupturing and rifting of a contemporaneous Middle Jurassic calc-alkaline arc. Published overlapping ages suggest that the rifted arc may have been active along portions of both margins of the JO basin. Thus, the JO and peridotite represent an excellent locality to study the dynamics of mantle flow and accretion of marginal basin crust in the context of rifting and concomitant arc magmatism.

New mapping, structural analysis and olivine LPO data from two regions provide a framework to evaluate potential links between mantle flow patterns and plate separation. Region 1 (latitude of Cave Junction) is underlain by harzburgite with sub-horizontal OPX layers, plastic foliations parallel, oblique and discordant to layers, folds, and outcrop-scale shear zones. Lineations and fold hinges are generally shallowly-plunging with no significant azimuthal clustering. Poles to foliations are moderately plunging also with no significant azimuthal clustering. Domains of sub-horizontal layering are bounded by high-angle plastic shear zones, some of which are characterized by steep dunite bodies. Region 2 (Chrome Ridge) is underlain by foliated peridotite, with a conspicuous lack of OPX layering. Steep, tabular dunites are common. Foliations form a variety of orientations with moderate to shallow dips. Olivine LPO data from region 1 document the 'high-temperature' (010)[100] slip system as dominant during deformation and recrystallization, but other slip systems including (100)[001] were operative.

Domains of mantle harzburgite are bounded by dunite shear zones that accommodated movement of individual blocks in relation to each other and acted as zones of basalt accumulation/transport through the upper mantle to the JO spreading axis. Mantle foliation/lineation orientation data are geometrically compatible with hypersolidus flow patterns in the lower crustal sequence of the JO, indicating a link between mantle flow in the wedge and plate separation in the crust.

21-5 **2:50 PM** Shimabukuro, David H.

AN OCEANIC CORE COMPLEX PRESERVED IN OPHIOLITIC FRAGMENTS IN CALABRIA, SOUTHERN ITALY

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Dismembered fragments of Jurassic Alpine Tethys ocean crust are exposed in the Cenozoic accretionary complex of Calabria, Southern Italy. Most of the ophiolite consist of prehnite-pumpellyite to lawsonite-blueschist-facies metabasalt and associated sedimentary cover. However, in the southernmost exposures, at Gimigliano and Monte Reventino (above Lamezia Terme), greenstone metabasalt is closely associated with serpentinite and ophicarbonate. At Gimigliano, serpentinite underlies a thick sequence of metabasalt, while at Monte Reventino, the contact between the two units is has been folded by Alpine deformation, with serpentinite at the core of a 200-m fold. The close relationship between metabasalt and serpentinite requires an explanation.

At Monte Reventino, rodingite dikes within the serpentinite are truncated at the metabasalt-serpentinite contact, suggesting that the contact is a fault. Serpentinite in the footwall of the fault has been altered to tectonic ophicarbonate by subseafloor fluid flow and further altered to talc-tremolite schist near the fault surface. At Gimigliano serpentinite breccias forms lenses within the metabasalt, indicating that serpentinite was exposed on the ocean floor when basalt was being erupted. These observations are similar to what has been reported from the Chenaillet Ophiolite (French-Italian Alps), where low-angle normal faulting and a reduced magma supply suggest an original tectonic setting of an oceanic core complex at a slow-spreading paleoridge.

It is not clear whether the overlying basalt was deposited on the detachment surface of a low-angle fault, or if the basalts were juxtaposed against serpentinite by slip along a normal fault. However, similar outcrops near Terranova di Pollino in Northern Calabria expose pillow basalt and radiolarian chert that appear to be in depositional contact with a serpentinite, suggesting that at that locality basalt was erupted onto an exhumed fault surface.

21-6 **3:10 PM** Flores, Kennet E.

GEODYNAMIC EVOLUTION AND TECTONIC HISTORY OF THE OPHIOLITES AND SERPENTINITE MÉLANGES IN THE GUATEMALA SUTURE ZONE

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The Guatemala Suture Zone (GSZ) is the fault-bound region in central Guatemala that contains the present North American–Caribbean plate boundary. It is bounded by the Maya Block to the north and Chortís Block to the south and contains a variety obducted "ophiolites", high-grade schist and gneisses, serpentinite mélanges, accreted metavolcanic bodies, low-grade schist and metasediments. This major composite geotectonic unit contains four major oceanic crust bodies and two serpentinite mélanges bearing high-pressure–low-temperature (HP–LT) rocks. The latter assemblages were previously defined as "ophiolites" and are thrust north and south of the active left-lateral transform, the Motagua fault system (MFS).

Classically, the GSZ has been interpreted as the result of a single progressive collision between an island arc related to the Chortís Block and the Maya Block passive margin. This model was based on the geochemical signatures of basaltic rocks from the "ophiolitic" sequences. Our research results challenge this geodynamic scenario because multiple metamorphic ages and PT paths recorded in the HP–LT rocks. Moreover, there are major contrasts in the geochemical signatures and geotectonic settings recorded by the "ophiolites" from both sides of the MFS.

Our new data suggest two major tectonic events occurred within the GSZ: first a Jurassic-Early Cretaceous oceanic accretion/collision and exhumation in the active margin, and second a Late Cretaceous island arc-passive margin collision-exhumation and subsequent obduction probably related to a back-arc closure. This two suture zone system was modified by a major Cenozoic left-lateral displacement along the then active margin which restructured the original tectonic arrangement into the present complex. Important distinctions in these interpretations are based on multiple lines of evidence, including the difference between ophiolite and serpentinite mélange, a sometimes overlooked or under-appreciated differentiation.

21-7 **3:50 PM** Kusky, Timothy M.

APPLICATION OF THE MODERN OPHIOLITE CONCEPT WITH SPECIAL REFERENCE TO PRECAMBRIAN OPHIOLITES

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Much has been learned in the past 40 years about the great diversity of the internal structure and geochemical compositions of Phanerozoic ophiolites, indicating that these on-land fragments of ancient oceanic lithosphere formed in distinctly different tectonic settings during their igneous evolution. Recent studies in Archean and Proterozoic greenstone belts have shown that the Precambrian rock record may also include exposures of a diverse suite of ophiolite complexes as part of craton development in the early history of the Earth. We review the salient features of the Precambrian ophiolite record to highlight what has been learned about Precambrian oceanic spreading systems since the original Penrose definition of ophiolites in 1972. Some of the diagnostic, characteristic, typical, and rare aspects of ophiolites of all ages are presented in order to help determine if tectonically deformed and metamorphosed sequences in Precambrian shield areas may be considered as ophiolites. The results of this comparative analysis are important in that they enable researchers to more realistically characterize allochthonous mafic/ultramafic rock sequences as ophiolitic or non-ophiolitic. This approach is more deterministic in contrast to some other arbitrary classification schemes requiring three or four of the Penrose-style ophiolitic units to be present in the Precambrian record for a specific rock sequence to be considered ophiolitic. Once these tectonic fragments are recognized as remnants of ancient oceanic lithosphere, great progress shall be made in understanding early Earth history. We discuss the significance and implications of the Precambrian ophiolite record to constrain the mode and nature of the plate tectonics that operated in deep time.

21-8 **4:10 PM** Topuz, Gültekin

JURASSIC OPHIOLITE FORMATION AND EMPLACEMENT AS A BACKSTOP TO A SUBDUCTION-ACCRETION COMPLEX IN THE NORTHEAST TURKEY AND POSSIBLE RELATION TO BALKAN OPHIOLITES

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The eastern Mediterranean region within the Tethyan realm shows a high concentration of ophiolites with contrasting diverse times of formation and emplacement along the belt: In

the Balkans, the ophiolites formed during the early to medial Jurassic, and were emplaced during late Jurassic time, whereas the known ophiolites in Turkey, Cyprus and Syria have late Cretaceous formation and emplacement ages. Here we report a previously unknown large ophiolite body of early Jurassic age from NE Turkey, the Refahiye ophiolite, located close to the suture zone between the Eastern Pontides and the Menderes-Taurus block. The ophiolite body within the studied section is made up of mantle peridotite (clinopyroxene-bearing harzburgite and minor dunite) crosscut by up to 20 cm thick veins of clinopyroxenite and later dikes/pods/stocks of gabbro ranging in size from 2 m to several hundreds of meters. The gabbro is represented by two distinct types: (i) cumulate gabbro, and (ii) non-cumulate gabbro with locally well-developed igneous foliation. Within the non-cumulate gabbro or enclosing peridotite, there are up to 5 m and 50 cm-thick veins of trondjemite and pegmatitic gabbro, respectively. Formation in a suprasubduction-zone setting is inferred from (i) wide-ranging pyroxene and spinel compositions in the peridotites as documented in most suprasubduction-zone ophiolites, and (ii) arc tholeiitic signature of the intrusive non-cumulate gabbros. LA-ICP-MS dating on zircons from two trondjemite samples yielded weighted mean ages of 182 ± 3 Ma and 175 ± 4 Ma (2σ), respectively, suggesting formation during early Jurassic time. Thus, the Refahiye ophiolite represents the first example of a non-mélanged, true Jurassic ophiolite in Turkey, thus filling the long-sought missing link between the Jurassic ophiolites in the Balkans and those in the Lesser Caucasus. Field relationships, e.g. (i) intimate association with nearly coeval metamorphosed accretionary complexes, (ii) absence of unambiguous relationship to the southern Atlantic-type continental margin, and (iii) absence of any stratigraphic indications for the ophiolite obduction in the southern Atlantic-type continental margin during the Jurassic time point to emplacement of a trapped forearc ophiolite above its own subduction-accretion complex as a backstop.

21-9 **4:30 PM** Lindsley-Griffin, Nancy

THE POLYGENETIC TRINITY OPHIOLITIC COMPLEX, AN OCEANIC COLLAGE, EASTERN KLAMATH MOUNTAINS, CALIFORNIA

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The Trinity Complex (TC) includes four geologic components formed over a 200 m.y. period from late Neoproterozoic to Middle Devonian. A 5th component sometimes correlated with TC is a separate terrane. Each has a different age, composition, and tectonic history. **1) SRB**: "Scott River block" – intensely deformed, synformal late Neoproterozoic ophiolite consisting of serpentinized harzburgite, amphibole metagabbro (579-556 Ma), plagiogranite (571-565 Ma) cut by dikes and sills, and pillow basalt along Scott River's East Fork. A ductile shear zone sutures this block to: **2) TRB**: "Trinity River block" – Cambrian peridotite consisting of harzburgite and lherzolite with subordinate dunite and feldspathic lherzolite exposed along the Trinity River and east to I-5. Feldspathic partial melt dikes dated 472 ± 32 Ma (Sm-Nd) crosscut mantle tectonite structures and are boudinaged, indicating late syntectonic deformation during Early Ordovician uplift from mantle depths. Undeformed layered gabbro and microgabbro that intrude both SRB and TRB range from 480 to 470 Ma and suggest ductile deformation and juxtaposition of SRB and TRB ended by Early Ordovician. Thus mantle tectonite structures in the TRB formed in the Cambrian. **3) SSZ**: Siluro-Devonian supra-subduction zone ophiolite that intruded/erupted over the composite SRB/TRB. Undeformed SSZ components (435-412 Ma) consist of pegmatitic gabbro and associated pyroxenite, hornblende gabbro, diorite, and plagiogranite that extensively intrude the two older entities, locally overlain by sheeted dikes and pillow basalts. **4) TAB**: "Trinity Alps block" – Middle Devonian non-feldspathic harzburgite with dunite and minor orthopyroxenite, metamorphosed and interfolded with the Central Metamorphic terrane (CMT). The CMT underthrust TAB ~380 Ma along Irwin's (1981) Trinity Fault, which is not traceable north into the Yreka and Fort Jones terranes. TAB is faulted against TRB along a tremolite schist shear zone. Because SSZ intrusions occur only east of the shear zone, this block joined the collage between 412 ± 10 and 380 Ma. **5) FMT**: Forest Mountain ophiolite terrane – a thin belt of harzburgite, dunite, and minor lherzolite extends from Callahan to Yreka east of Scott Valley. It steeply underthrust the composite Trinity-Yreka terrane ~407-391 Ma, Early Devonian.

21-10 **4:50 PM** Xiao, Wenjiao

SUTURES IN THE ALTAIDS

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Ophiolites are remnants of vanished oceans in orogenic belts; therefore they are very important for defining sutures and plate reconstruction. However, most ophiolites are actually ophiolitic fragments which do not have the full trinity of a classical ophiolite. Ophiolitic fragments can be formed at different tectonic settings as illustrated in the Altaids. The Altaids records the convergence and interactions among the three orogenic systems, the Siberia and Tarim Cratons, and the Kazakhstan composite arc chain, showing multiple accretionary orogenesis.

Some ophiolites in the Altaids may be substrate of oceanic island arcs or accreted fragments. Others are blocks or slices in accretionary prisms. As ophiolites should be used to constrain the existence of ancient oceans, they pre-date the accretionary process afterward and should not necessarily represent real sutures. Some ophiolitic fragments in Central Asia such as the Tianshan predate an accretion/collision event and may reflect merely one small accretion/convergent /rifting event.

Paleomagnetic data and tectonic analysis enable us to conduct palinspastic reconstructions and can help define the real suture as a main cryptic plane separating the Tarim Craton to the south and the accretionary collages to the north from the early Paleozoic to the early Triassic. During most of the Paleozoic time, the Siberia was distributed in the northwest and the Tarim Craton was in the southeast, while the Kazakhstan arc chain was in the west. The active margin of the Siberia Craton had wide accretionary complexes and accreted intraoceanic arcs and terranes, the Kazakhstan arc chain was characterized by multiple subductions, while the northern margin of the Tarim Craton remained mostly as a passive margin. The multiple convergence and accretion among these three orogenic systems generated huge orogenic collages in the late Paleozoic and even early Triassic, in which occurs orogenic oroclinal stacking of the Kazakhstan arc chain and parallel amalgamation of the Altai, East Junggar, and Tianshan arcs.

21-11 **5:10 PM** Li, Yuan

OPHIOLITES AND ULTRAHIGH PRESSURE ZONES IN THE CENTRAL OROGENIC BELT OF CHINA: TECTONIC HISTORY OF A COMPOSITE OROGENIC BELT

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The Central Orogenic belt (COB) between the North China (NCB) and South China blocks (SCB) represents the northernmost orogenic collage of the Tethys domain that experienced a series of early Paleozoic and early Mesozoic subduction-accretion events, and an intracontinental orogenic event in the Cretaceous. It is bounded by the early Paleozoic tectonic belt in the north (N-COB) and the early Mesozoic tectonic belt in the south (S-COB). The North Qilian and the North Qinling oceanic-type suture zones, the North Qaidam continental-type suture zone and the east Kunlun arc-type suture zone in the western segment of N-COB indicate multiple events of terrane accretion via subduction-collision processes in the early Paleozoic (550-420 Ma). The North Qilian and the North Qinling orogenic belts form a continuous, early Paleozoic suture zone between the NCB and SCB as evidenced by (1) the occurrence of rock assemblages of common origin and ages, with similar tectonic structures, and (2) southward getting younger multiple arc terranes accreted to the continental margin between 540 Ma and 450 Ma as small forearc basins collapsed and closed. Following the closure of the Proto-Tethys Ocean in the Carboniferous, the A'nyemaqen-Mianlue basin evolved into a small ocean separating the south Qinling micro-plate from SCB. The discovery of two phases of UHP metamorphic zones in the early Paleozoic (505-440 Ma) and early Mesozoic (240-220 Ma) segments of COB reveals that both the NCB and SCB experienced deep oceanic/continental subduction processes in the early Paleozoic and Triassic, respectively.

SESSION NO. 22, 1:30 PM

Tuesday, 21 May 2013

T9. AFC Processes in the Formation of Intermediate Magmas from Mantle to Crust

Radisson Hotel and Conference Center, Salon D1

22-1 **1:35 PM** Lackey, Jade Star

SMALL VOLUME PERALUMINOUS GRANITES AS WINDOWS INTO ANATECTIC CONVERSION OF ACCRETED TERRANES TO CRUST IN CONTINENTAL ARCS

LACKEY, Jade Star[1], CECIL, M. Robinson[2], MILLER, Jonathan S.[3], SENDEK, Callie L.[1], EISENBERG, Jane L.[1], ECONOMOS, Rita[4], and DAVIES, Gareth R.[5], (1) Geology Department, Pomona College, 185 E. 6th St, Claremont, CA 91711, JadeStar.Lackey@pomona.edu, (2) Department of Geological Sciences, California State University Northridge, 18111 Nordhoff St, Northridge, CA 91130-8266, (3) Geology, San Jose State University, San Jose, CA 95192-0102, (4) Earth and Space Sciences, University of Southern California, Los Angeles, CA 90095-1577, (5) Department of Petrology, VU University Amsterdam, De Boelelaan 1085, Amsterdam, 1081HV, Netherlands

Small-volume peraluminous granitoid rocks from the 124–105 Ma Fine Gold Intrusive Suite preserve important records of magma source and mixing processes during initiation of the Sierran magmatic arc. In particular, they record abundant inheritance of Early Cretaceous zircon cores (130–143 Ma) that are overgrown by at least two younger (124–118 Ma) domains. Such temporal and textural information is typically absent from zircons in the Sierra, presumably because inherited zircon is dissolved in the largely metaluminous magma compositions. Using in situ O (SIMS) and Hf (LA-ICP-MS) isotope analyses of the different textural domains in these zircon grains, we document the following patterns: (1) Inherited zircon cores have high and variable $\varepsilon Hf_{(t)}$ (3–13) and low to moderately elevated $\delta^{18}O$ (5.0–6.3‰), reflecting derivation from sources that were mantle-like with variable crustal input; 2) First-stage overgrowths show high and variable $\delta^{18}O$ (8.0–13.4‰), and more restricted $eHf_{(t)}$ = 3–7 than cores. The $\delta^{18}O$ values are the highest yet reported for zircon in the Sierra Nevada; (3) Rims on zircons have lower and less variable $\delta^{18}O$ (7.0–8.0‰) and lower but still variable $\varepsilon Hf_{(t)}$ (1–7.5) values. Overall, the isotopic variations in these zircons are interpreted as recording partial melting of hydrothermally altered accretionary complex rock (volcanic?) because older cores are overgrown by domains crystallized from melts with high $\delta^{18}O$, but minimally changed $\varepsilon Hf_{(t)}$. Lower and less variable $\delta^{18}O$ values, and slight lowering of εHf in the last stages of grain growth is taken as evidence of homogenization within the overall magma, averaging contributions from mixtures of small-volume partial melts. With a span of at most 10 million years between original deposition of these rocks, melting, and homogenization of the melts, the peraluminous granites of the Fine Gold Suite suggest efficient recycling of accreted terranes into granitic crust.

22-2 **1:55 PM** Gevedon, Michelle L.

ZIRCON HAFNIUM AND OXYGEN ISOTOPIC ANALYSIS OF SIERRA NEVADA GABBROS: EVIDENCE FOR MAJOR COMPOSITIONAL VARIATION IN THE MESOZOIC MANTLE

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Hafnium isotope (εHf) analyses of zircon separated from gabbros confirm the existence of compositional variation within the mantle source region of the Mesozoic Sierra Nevada arc. Oxygen isotope ($\delta^{18}O$) values of these zircons indicate this heterogeneity originated in the mantle. Most zircon isotopic studies focus on granitoids, and non-mantle-like values are often interpreted as reflecting variable crustal input during magma differentiation. In contrast, gabbros are better suited for discerning geochemical variations originating in the mantle because mafic rocks have undergone minimal differentiation.

Zircons were separated from 7 gabbros collected from two locations at ~36° N latitude, close to the western and eastern edges of the Sierra Nevada batholith (SNB) ~100 km apart. The Stokes Mountain region of the western SNB is an ideal site for a zircon Hf-O study because previous work has documented variations within whole rock O-Sr-Nd isotopic values likely attributable to small-scale mantle heterogeneity. Zircon eHf data from these western Early Cretaceous gabbros range from +15.9 to +2.7 ε-units, with the highest e-values approaching that of the modeled Cretaceous depleted mantle. In stark contrast, zircons from the late Jurassic Summit Gabbro of

the eastern SNB Kern Plateau have εHf values ranging from +0.3 to -11.4 ε-units. Typical mantle-like zircon $\delta^{18}O$ values (i.e. +5.0‰ to +5.6‰) in both the western and eastern gabbros rule out the possibility that the ~27 ε-unit Hf variation is due to variable crustal assimilation. The disparity in εHf values suggests heterogeneity was present in the SNB mantle source region as early as the latest Jurassic, and supports earlier proposals for an enriched mantle end-member below the eastern arc flank.

Minor zircon $\delta^{18}O$ variation suggests the limited role of hydrothermally- or metasomatically-altered source material in the production of these gabbros. Within the western zircon population, $\delta^{18}O$ varies from typical mantle to values elevated by ~1‰. In contrast, the $\delta^{18}O$ of the eastern zircon population varies from typical mantle signatures to values lowered by ~1‰. The magnitude and depth of such an interaction is constrained by the undifferentiated character of the gabbroic host magma.

22-3 **2:15 PM** Putirka, Keith

INCREMENTAL GROWTH OF GRANITIC MAGMA BODIES: THE GUADALUPE IGNEOUS COMPLEX, SIERRA NEVADA BATHOLITH, CALIFORNIA

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The 153 Ma Guadalupe Igneous Complex (GIC) is a remarkably bi-modal pluton that represents the first of a series of Late Jurassic-Early Cretaceous plutons that record the birth of the Sierra Nevada Batholith. Due to ~30° of tilting, the GIC provides rare exposures of the mafic roots of the system (Heaussler and Paterson, 1992). Targeted, high-density sampling and new isotope data from the GIC provide clues regarding granite magma genesis and pluton assembly. For example, lower crust partial melting can be rejected because unaltered samples from the GIC fall on a single Rb-Sr isochron with an age of 152±7 Ma, matching single crystal zircon ages (Ernst et al., 2009) within error; this isochron cannot be generated by partial melting of the Mid-Jurassic and earlier metabasalts of the region. In addition, alumina saturation indices of the upper crust Mariposa Formation (the sedimentary framework into which the GIC was intruded) are far too high to explain GIC compositions. Compositional relationships and mass balance calculations, however, support Best's (1963) idea of *in situ* differentiation, and especially the differentiation mechanism of Bachmann and Bergantz (2004), which explains the GIC's bi-modality. In the latter model, crystal settling is hindered as interstitial liquids evolve to high SiO_2 compositions, and melt is segregated from its crystalline residue only when melt fractions approach 50%. Our evidence indicates, however, that granite magma chambers grow by small increments of such differentiation events: the, lower mafic part of the system is emplaced as a sequence of sills that differentiate and feed felsic magmas upward into an overlying, convective felsic magma cap. Pluton growth and convection in the felsic cap ends when basaltic inputs cease. We posit that the GIC preserves its bi-modality in part due to its smaller size and shorter lifespan, compared to larger, well-mixed systems, such as the Bass Lake Tonalite and Tuolumne Intrusive Complex.

22-4 **2:35 PM** Canil, Dante

GENERATION OF INTERMEDIATE CRUST:VIEW THROUGH THE PLUTONIC WINDOW OF THE JURASSIC BONANZA ARC SECTION, VANCOUVER ISLAND, CANADA

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The Jurassic Bonanza arc exposed in oblique section on Vancouver Island, Canada has a structural thickness of at least 15 km and an average bulk composition of basaltic andesite (57% SiO_2, Mg# = 48) similar to bulk continental crust. The most abundant component in this and other arcs is, unremarkably, 'intermediate plutonic rock'. It is by no means universally known to what extent the addition of new material versus recycling of older material is involved in the generation of crust in arcs. New U-Pb zircon ages for heterogeneous mafic – felsic rocks in the mid-crustal plutonic component of the arc were used to examine the consanguinity of volcanism and plutonism and processes in production of intermediate crust in this arc. The intermediate mid-crustal plutons were emplaced between 197 and 174 Ma, overlapping in time with a more felsic upper crustal (< 10 km depth) plutonic component of the arc. A 12 km thick plutonic arc crust was built as a series of sheets at a rate of ~ 0.003 $km^3\ a^{-1}$ partly into a substrate of pre-Jurassic supracrustal rocks. Deformation focussed in the mid-crust is syn-magmatic, with no obvious relationship between age and differentiation. Our petrological studies of all rock types show intermediate crust of the evolved plutonic section can be explained by Hbl+Plag fractionation; the former as a cryptic intercumulus phase economical in producing evolved liquids by in-situ fractionation (in molar ratio 0.65:1). There is ample field evidence for intermingling and cross-cutting of felsic, intermediate and even mafic magmas at various scales, but no profound Nd-Sr isotopic or field evidence for assimilation and 'mixing' of partial melts of country rock. Previously described 'migmatites' or melted country rock are re-interpreted as strained (re-intruded) intermediate plutonic rocks. In this sense the Bonanza arc may be an extreme – a 'clean' end member example in production of intermediate continental crust in arcs.

22-5 **3:05 PM** Farner, Michael J.

MAGMA MIXING LIMITED BY REACTIVE PROCESSES

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Mafic enclaves are common in many felsic plutons and are suggestive of magma mixing. However, compositional and rheological contrasts between enclaves and host magma indicate that mixing is inefficient. Additionally, enclaves are often mantled by fine-grained rims, which form during entrainment in the host magma. These have been interpreted as chill rinds, thereby implying that mixing occurs between solidified enclaves and host magma. Collectively this indicates that such mixing is a minor petrogenetic process. However, previous studies show mixing is an important means of generating intermediate rocks.

We present evidence from the Bernasconi Pluton in the Peninsular Ranges, southern California that mixing is, in part, driven by reaction between enclaves and host magma. Field observations show that enclave rinds are K-rich and biotite-rich, thus requiring reaction origin between enclaves and host magma. Geochemcial modeling with MELTS, JavaMELTS, and binary mixing equations show that measured rind compositions cannot be achieved by mixing between enclaves and a hypothetical interstitial felsic melt.. We propose that biotite-rich enclave rinds formed by reaction between K-rich aqueous fluids and enclave material and that such reaction enables mechanical mixing by reducing viscosity contrasts between enclave material and host magma. Strain accumulation in enclaves is accompanied by delamination of biotite rinds from enclaves, further supporting this notion. Mineralogical and textural similarities between biotite rinds and schlieren suggest that rinds develop into schlieren with additional strain accumulation.

22-6 **3:25 PM** Putnam, Roger L.

UNDERSTANDING PLUTONISM IN THE VERTICAL: FIELD AND GEOCHEMICAL RELATIONS ON THE SOUTHEAST FACE OF EL CAPITAN, YOSEMITE VALLEY, CALIFORNIA

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Because erosional surfaces are dominantly horizontal, most studies of magmatic systems are inherently two dimensional. The 1 km vertical section of granitic rock exposed on the southeast face of El Capitan in Yosemite Valley, CA provides a crucial third dimension for the study of plutonism. Many hypotheses for the generation of silicic melts are based on gravitational separation of melt from crystals and predict upward accumulation of liquids rich in silica and incompatible elements. This study focused on detailed mapping of the spatial extents of exposed rock units in order to determine the chronology and geometry of emplacement, coupled with a study of the vertical variation in mineralogy and whole-rock chemistry. Field relations revealed by this mapping display a complex intrusive history at the point of interaction between separate intrusive suites and two sets of mafic dike swarms. The Leaning Tower granodiorite, a member of the little-studied intrusive suite of Buena Vista Crest, crosses the southeast face of El Capitan yet was not previously mapped in this area of Yosemite Valley. Mapping also revealed two sets of aplite dikes, one of which displays a variety of sense of separation indicators, suggesting an episode of late-stage deformation. All aplites have trace element compositions indicative of local derivation. Within the two dominant granitioids, the El Capitan and Taft granites, 62 samples were taken over multiple km-tall transects and analyzed for major- and trace-element abundances. The ordered vertical variation in mineral composition and element abundances predicted by traditional models of pluton evolution were not found. This suggests that a process other than in-situ gravitational crystal-liquid fractionation was responsible for the petrochemical variations in granitoids exposed on El Capitan.

22-7 **3:45 PM** Glazner, Allen F.

EVIDENCE FOR LIQUID IMMISCIBILITY IN LADDER DIKES AND LAYERED GRANODIORITES, SIERRA NEVADA, CALIFORNIA

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Ladder dikes (LDs) and laterally continuous modal layers (MLs) are common features of granodiorites worldwide. Although a variety of explanations have been offered for these phenomena, all invoke standard processes of crystal-liquid separation such as gravitational settling and shear flow. Here we show, based on field work, whole-rock geochemistry, and microprobe analysis, that the geochemistry of LDs and modal layering is inconsistent with crystal-liquid separation but bears a striking resemblance to mafic liquids produced by liquid immiscibility.

LDs are roughly tabular bodies, <1m thick, composed of nested, concave-up, mafic-felsic troughs with an overall tabular, dike-like form (see Bartley et al., this volume). MLs are decimeter-scale couplets composed of a sharp-sided mafic layer that grades into a felsic layer that is in turn in sharp contact with another mafic layer. Both LDs and MLs are greatly enriched in mafic minerals, including biotite, hornblende, magnetite, titanite, apatite, and zircon, leading to extreme enrichments in many elements including REE, Fe, Zr, P, and Ti; $Fe_2O_3^t$ in some LD mafic layers approaches 35 wt%, and La approaches 1000x chondrite. Mafic layers in LDs and MLs also have low Mg numbers (typically <0.4). In contrast, crystallizing assemblages in granodioritic magmas should be low in these elements and have high Mg numbers owing to preferential incorporation of Mg over Fe in the crystallizing assemblage. Biotite and hornblende crystals are typically more Fe- and apatite-rich than those of the host plutons. All of these features argue that the minerals in the layers were not derived from the surrounding pluton by crystal-liquid separation.

Fe-enrichment trends are dramatically different from predictions of crystal-liquid equilibria but match observed segregation of Fe, REE, P, etc. into Fe-rich immiscible liquids in both experiments and in volcanic rocks on the earth and moon. Although immiscibility is difficult to detect in plutonic rocks owing to crystallization of the immiscible liquids, it has been proposed for several layered mafic complexes, and LDs and MLs carry the same geochemical fingerprint. The immiscibility hypothesis cannot explain all the peculiar field relations of LDs and MLs, but neither can other explanations advanced to date.

22-8 **4:05 PM** Kleck, Wallace D.

EVIDENCE FOR A CRYSTAL-SETTLING MODEL FOR THE FORMATION OF LAYERED-PEGMATITE-APLITE INTRUSIVES (LPAI)

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LPAI are characterized by horizontal*, tabular forms and range in thickness from approximately 1 to 20 m. They have two major layers--a top of cm-grained, pegmatite rock and a base of mm-grained, multilayered aplite. The core zone separates the two major layers and ranges in thickness from 0 to about 0.5 m. The pegmatite bodies in the Pala Pegmatite District, San Diego Co., CA are of this type. Such bodies are neither rare nor common and typically occur in groups.

A number of textures and features strongly suggest homogeneous nucleation plus an accumulation of grains (sedimentary process) for the formation of the multilayered aplite. Features of interest in this part are:

- drop-block xenoliths;
- draping of layers over xenoliths;
- graded bedding (uncommon);
- individual layers usually consist of garnet±tourmaline+quartz+feldspar;
- squeeze-ups;
- 'comb-structure' layers (irregularly present);
- great linear extent of individual aplite layers;
- euhedral garnet and tourmaline grains.

Features of interest in the total pegmatite body are:

- isolated, scattered, dm-grained, tear-drop-shaped K-feldspar in the upper part;
- non-uniform distribution of K-feldspar grains;
- anhedral grains of garnet and tourmaline in the upper part vs. euhedral grains in the lower, aplitic part;
- symmetrical compositional variation of the garnet across the body coupled with asymmetric abundance;

- symmetrical occurrence of tourmaline about the core zone coupled with a statistically horizontal attitude of this euhedral, elongate-habit mineral in the aplitic part;
- brown-clay and rubble-filled 'former' miarolitic cavities;
- asymmetric location of the core zone;
- consistent location of multilayered aplite in the lower and cm-grained rock in the upper part.

Other features are:

- consistent low-Si composition of adjoining, igneous country-rock;
- extensive alteration halos*;
- thin, horizontal*, tabular bodies of km length and breadth.

A complex part of the history of these bodies is the hypothesized variations in the water content which results in a number of 'odd' features.

Note that this model for the formation of LPAI bodies is in direct contrast to the diffusion models of several geologists as summarized in London (2008-Can. Min. Spec. Pap. 10).

SESSION NO. 23, 1:30 PM

Tuesday, 21 May 2013

T10. Reconstructing the Pacific-North America Plate Boundary Through Late Cenozoic Time II

Radisson Hotel and Conference Center, Salon A2

23-1 **1:30 PM** Graymer, R.W.

GEOLOGIC MAPPING, GRAVITY, AND PALEONTOLOGICAL STUDIES IN THE PINNACLES NATIONAL PARK REGION, CENTRAL CALIFORNIA, REVEAL ~14 TO ~6 MA TRANSTENSIONAL HISTORY OF THE SAN ANDREAS FAULT SYSTEM

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Middle and late Miocene strata occupying a down-dropped fault block west of the present San Andreas fault and east of Pinnacles volcanics record releasing bend extension on an early set of San Andreas system faults, accumulation of coarse clastics derived from volcanic and granitic rocks to the west, and subsequent folding, erosional truncation, and sedimentary overlap as the releasing bend was abandoned. These conclusions arise from new geologic studies in and around Pinnacles National Park undertaken in cooperation with the National Park Service. Reconnaissance mapping and new gravity-data collection extend the study area to the south and east. Siliceous shale from two units yielded age-diagnostic Miocene diatoms. The new data reveal the following geologic history:

~14-8 Ma, the San Andreas fault system occupied a releasing step that included faults west of the present San Andreas. A tectonic escarpment was formed and uplifted volcanic and granitic sources west of the escarpment contributed coarse detritus that was transported generally eastward and deposited as arkosic sandstone and boulder conglomerate, with angular to subrounded clasts in places larger than 1 m. Transport and deposition of coarse sediment was episodic and mostly by sediment gravity flows in marine environments, perhaps on parts of one or more fan-deltas. Interbedded with the coarse-grained strata are diatomaceous mudstone layers representing periods of quiet-water deposition.

Between ~8-6 Ma, the accumulated strata were folded, eroded, and overlain in angular unconformity by unsorted shallow marine and nonmarine deposits of sand, gravel, and cobbles, again sourced from uplifted granitic and volcanic rocks to the west. We take these changes to signify that activity on the releasing step was tapering off, resulting in one or more periods of compression and erosion and lower energy depositional environments.

Gravity data reveals that the east-facing escarpment is at least ~60 km long, suggesting at least that much offset through the releasing bend between ~14-6 Ma.

After ~6 Ma, the transtensional faults were abandoned and overlapped by shallow marine deposits. The sedimentary rocks of the transtensional depocenter have been offset northward by slip on San Andreas and other faults to the east (~165 km since ~5.5 Ma based on studies elsewhere).

23-2 **1:50 PM** Faulds, James E.

LATE MIOCENE TO RECENT EVOLUTION OF THE WALKER LANE: AN INCIPIENT TRANSFORM FAULT WITH KINEMATIC GROWING PAINS

FAULDS, James E., HENRY, Christopher D., HINZ, Nicholas H., and CARLSON, Chad W., Nevada Bureau of Mines and Geology, University of Nevada, Reno, NV 89557, jfaulds@unr.edu

In the late Miocene, the southern part of the North American-Pacific transform shifted east into the Gulf of California (~13-6 Ma), the Big Bend of the San Andreas developed, and plate motions changed from ~N60°W to N37°W (~8 Ma). Coincidentally (~11-6 Ma), dextral shear initiated in the Walker Lane and eastern California shear zone (WLSZ) from southern California to west-central Nevada and has since propagated NW-ward to NE California in concert with the N-ward propagation of the Mendocino triple junction. Plate-boundary dextral shear was favored in the western Great Basin because it paralleled the new plate motion, aligned more directly with the Gulf of California, and avoided the Big Bend bottleneck. Analogous to the Gulf of California, the WLSZ developed directly east of large coherent Mesozoic batholiths (Sierra Nevada vs. Baja), approximately along the axis of a retreating magmatic arc and cuts across the batholiths where weakened by the Cascade arc. Today, the WLSZ accommodates ~20% of the plate motion (~1 cm/yr).

In contrast to the Gulf of California, the WLSZ has had kinematic growing pains. It consists of many disparate domains, some composed of discontinuous NW-striking dextral fault arrays with negligible vertical-axis rotation (e.g. Pyramid Lake and Walker Lake domains) and others consisting of NE- to E-striking sinistral fault systems that accommodate significant clockwise rotation (e.g. Mina deflection and Carson domain). Within the broadly transtensional setting, individual strike-slip faults in both domain types commonly end in normal fault systems rather than link with other strike-slip faults. The length of individual strike-slip faults is generally <100 km and does not exceed ~250 km. Thus, the WLSZ lacks through-going strike-slip faults that cross and link domains. A resultant conundrum is how strain kinematically transfers between disparate domains. For example, the system of ENE- to E-striking sinistral faults accommodating up to 90° of clockwise rotation in the Carson domain gives way abruptly to dextral faults of the Pyramid Lake and Walker Lake domains. Understanding these strain transfer mechanisms and how such boundaries are eventually breached by through-going dextral faults may be key to understanding how incipient strike-slip fault systems ultimately achieve transform status.

23-3 **2:10 PM** Lifton, Zachery M.

SUMMATION OF DISTRIBUTED SLIP ACROSS THE WALKER LANE

LIFTON, Zachery M.[1], FRANKEL, Kurt L.[1], LEE, Jeffrey[2], and NEWMAN, Andrew V.[1], (1) School of Earth and Atmospheric Sciences, Georgia Institute of Technology, 311 Ferst Drive, Atlanta, GA 30332, zach.lifton@eas.gatech.edu, (2) Department of Geological Sciences, Central Washington University, 400 East University Way, Ellensburg, WA 98926

Continental strike-slip plate boundaries tend to accommodate slip through a complex network of faults that evolve over time. Observations along some fault systems suggest a discrepancy between long- and short-term slip rates, which must be attributed to fluctuations in strain over time, broadly distributed strain, and/or an incomplete geologic record. We investigate such a discrepancy in the Walker Lane, a dextral shear zone in eastern California and western Nevada that participates in the Pacific-North America plate boundary and acts as the transition between the Basin and Range province and the Sierra Nevada block. Our observations include GPS time series, high-resolution lidar topography and field mapping of offset landforms, and ^{10}Be cosmogenic nuclide exposure ages. Taken together, these observations show that: 1) the Walker Lane currently accommodates 9.7±0.3 mm/yr of right-lateral motion toward N37°W; 2) slip is very evenly distributed across the entire shear zone; 3) extension in the Silver Peak-Lone Mountain extensional complex (SPLM) appears to have increased through the late Pleistocene, while right-lateral slip on the White Mountains Fault appears to have decreased during that same time; 4) long- and short-term extension rate estimates for the SPLM are in agreement; 5) there remains a discrepancy between long- and short-term slip rates that we suggest occurs across Owens Valley. Future work to fully resolve the discrepancy should focus on faults to the west of White Mountains Fault, including Owens Valley Fault, Round Valley Fault, and the faults that offset the Volcanic Tableland.

23-4 **2:30 PM** Ucarkus, Gulsen

STRIKE-SLIP FAULTING ALONG THE WASSUK RANGE OF THE NORTHERN WALKER LANE, NEVADA

UCARKUS, Gulsen[1], SHAOPENG, Dong[2], WESNOUSKY, Steven G.[3], MALONEY, Jillian[1], KENT, Graham[4], and DRISCOLL, Neal W.[1], (1) Scripps Institution of Oceanography, University of California, San Diego, 9500 Gilman Dr, La Jolla, CA 92093, gucarkus@ucsd.edu, (2) Key Laboratory of Active Tectonics and Volcanoes, Institute of Geology, Beijing, 100029, China, (3) Center for Neotectonic Studies, University of Nevada, Reno, MS 169, Reno, NV 89557, (4) Nevada Seismological Laboratory, University of Nevada Reno, 1664 N. Virginia St. MS 0174, University of Nevada Reno, Reno, NV 89557-0174

Walker Lake is a fault-controlled basin along the Wassuk Range front in the Walker Lane shear zone. Geologic observations suggest that motion along the range-bounding faults of Walker Lake is predominately dip-slip. Nevertheless, geodetic measurements indicate that the right-lateral strike-slip motion is equal to or greater than the extensional component of slip. New terrestrial and submarine observations adjacent to the Wassuk Range and within Walker Lake show the presence of a strike-slip fault zone outboard and subparallel to the Wassuk rangefront. The remnant shorelines of pluvial Lake Lahontan that reached its highstand about 15,475 ± 720 cal. yr B.P. are displaced between about 12 - 15 m and lead to a right-lateral slip rate estimate of the fault approaching 1 mm/yr or greater. A record of strike-slip displacement is also preserved in high quality CHIRP seismic profiles acquired in Walker Lake about 15 km south of the observed shoreline offsets. The data image intense folding consistent with strike-slip deformational patterns observed elsewhere. Based on sedimentation rates, the onset of the strike-slip deformation is ~15, 300 yrs BP with the cessation of deformation being ~10, 140 yrs BP. Sediment divergence along the western portion of the lake records tectonic deformation along the Wassuk rangefront; the most recent episode of deformation is dated as 3000 yrs BP. The analysis of conventional low-sun angle photography, LiDAR, and seismic CHIRP imagery provides another example of the partitioning of slip between primarily normal and strike-slip faults that occurs in regions of oblique extension. These observations begin to reconcile what has been a mismatch between geodetically predicted deformation rates and geological fault slip rate studies along the Wassuk rangefront.

23-5 **2:50 PM** Carlson, Chad W.

CHANGES IN CENTRAL WALKER LANE STRAIN ACCOMMODATION NEAR BRIDGEPORT, CA

CARLSON, Chad W., Nevada Bureau of Mines and Geology, University of Nevada, Reno, NV 89557-0178, ameanchad@hotmail.com, PLUHAR, Christopher J., Department of Earth & Environmental Sciences, California State University, Fresno, 2576 E. San Ramon Ave., Mail Stop ST-24, Fresno, CA 93740, GLEN, Jonathan, U.S. Geological Survey, MS989, 345 Middlefield Road, Menlo Park, CA 94025, and FARNER, Michael, Department of Earth Science, Rice University, 6100 Main Street MS-126, Houston, TX 77005

The Walker Lane (WL) is an elongate, NW oriented, region of active tectonics positioned between the northwesterly-translating Sierra Nevada microplate and the east-west extension of the Basin and Range (Fig. 1). This region of transtension presently accommodates ~20% of the dextral-motion between the Pacific and North American plates on regional-scale strike-slip fault systems. West of the NW oriented dextral fault systems of the central Walker Lane is a region of crustal-scale blocks bounded by wedge-shaped depositional-basins and normal-fault systems, here defined as the west-central Walker Lane (WCWL). Devoid of obvious strike-slip faulting, the presence of tectonic-block vertical-axis rotations in the WCWL represents unrecognized components of dextral-shearing and/or changes of strain-accommodation over time. We use paleomagnetic reference directions for Eureka Valley Tuff members of the late Miocene Stanislaus Group as spatial and temporal markers for documentation of tectonic-block vertical-axis rotations near Bridgeport, CA.

Study-site rotations produced discrete rotational-domains of mean vertical-axis rotation ranging from ~10°-30° with heterogeneous regional distribution. Additionally, the highest measured magnitudes of vertical-axis rotation (~50°-60° CW) define a 'Region of High Strain' that includes the wedge-shaped Bridgeport Valley (Basin). We present a kinematic model based on mean rotation magnitudes of ~30° CW for the Sweetwater Mountains and Bodie Hills that accounts for rotational-strain accommodation of dextral-shear in the WCWL since the late Miocene. This model considers rotational magnitudes, paleostrain indicators, basin development, and strain-accommodating structures of rotating crustal-blocks to represent changes in regional strain accommodation over time. The results and models presented here elucidate the complicated and evolving nature of the WCWL, and further understanding of variations in strain accommodation for the Walker Lane.

23-6 **3:30 PM** Busby, Cathy J.

A TALE OF TWO WALKER LANE PULL-APARTS

BUSBY, Cathy J.[1], PUTIRKA, Keith[2], RENNE, Paul[3], MELOSH, Benjamin L.[4], KOERNER, Alice A.[1], and HAGAN, Jeanette C.[1], (1) Department of Earth Science, University of California, Santa Barbara, Santa Barbara, CA 93106-9630, cathy@eri.ucsb.edu, (2) Department of Earth and Environmental Sciences, California State University - Fresno, 2345 E. San Ramon Ave, MS/MH24, Fresno, CA 93720, (3) Berkeley Geochronology Ctr, 2455 Ridge Rd, Berkeley, CA 94709-1211, (4) Department of Earth Science, University of California, Santa Barbara, CA 93106-9630

The Sierra Nevada - Walker Lane region is an archetype for early rupturing of continental lithosphere. Trantensional rifting was initially focused in thermally-weakened, partially extended crust of the Ancestral Cascades arc (~ 12 Ma), producing a large volcanic center at a releasing stepover, the Sierra Crest – Little Walker volcanic center. Here, "flood andesite" lavas erupted from fault-controlled fissures within a series of grabens that we call the "Sierra Crest graben-vent system". This system consists of a single ~27 km long, ~ 8-10 km wide ~N-S full graben that lies along the modern Sierran crest between Sonora Pass and Ebbetts Pass, with a series of ~N-S half grabens on its western margin, and a ~30 km-wide NE transfer zone emanating from the NE boundary of the full graben on the modern range front. The N-S faults rare dextral oblique and the NE faults are sinistral oblique; the geometry and kinematics of these ~ 11 – 9 Ma faults are clearly Walker Lane (not Basin and Range) in style.

The transtensional rift tip then propagated northward, following the Mendocino triple junction, to form a younger, newly-recognized intra-arc pull-apart we call the Ebbetts Pass volcanic center. This formed at a series of right-stepping N-S dextral oblique down-to-the-east normal faults on the modern Sierra crest and range front. The oldest volcanic rocks in the pull-apart are Late Miocene, 6.305 +/-0.017 Ma ($^{40}Ar/^{39}Ar$ hornblende, on a 2-pyroxene biotite quartz dacite lava flow at Elder Creek), but most of the pull-apart fill is Pliocene, and somewhat bimodal, perhaps indicating a transition from subduction to rift magmatism. The earliest volcanic rocks include a rhyolite flow at Nobel Lake (4.581 +/-0.018 hornblende) and a biotite sanidine hornblende quartz rhyolite ultra-welded ignimbrite near Silver Peak (4.636 +/-0.014 on 14 sanidine crystals). Later basaltic andesites form a large cone (4.85 +/-0.02 plagioclase), but the youngest parts of the cone are silicic, with block-and-ash-flow tuffs and central intrusions, including a hornblende biotite sanidine quartz dacite intrusion dated at 4.434 +/-0.007 (sanidine).

We predict that any <12 Ma large volcanic centers identified by future workers in the Sierra Nevada-Walker Lane region will be sited at major releasing bends or step-overs, like Lassen and Long Valley are today.

23-7 **3:50 PM** Henry, Christopher D.

IGNIMBRITE-FILLED PALEOVALLEYS: KEY MARKERS FOR THE STRUCTURAL DEVELOPMENT OF THE PACIFIC-NORTH AMERICAN PLATE BOUNDARY

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Voluminous Cenozoic ash-flow tuffs erupted from a belt of calderas in central Nevada and along much of western North America to the southern Sierra Madre Occidental during the late Eocene through early Miocene (~37-19 Ma). This Ignimbrite Flare-up was the most intense magmatism in western North America, and the widespread tuffs are key units for analyzing the tectonic and magmatic evolution of the Great Basin and Sierra Nevada. Our detailed and reconnaissance mapping, geochemistry, geochronology, and paleomagnetic investigations show that the tuffs erupted onto mountainous country with deep paleovalleys that drained westward to the Pacific Ocean, in the Great Valley at the time. The tuffs were channelized into these paleovalleys, which were as much as 1.2 km deep and 8 to 10 km wide in Nevada but shallowed westward into the Sierra Nevada where they are the famed gold-bearing gravel channels. The most widespread tuffs almost certainly reached the ocean, and ash was reworked extensively in the then coastal plain.

The distribution of paleovalleys and ash-flow tuffs reveal that the Basin and Range – Sierra Nevada structural and topographic boundary did not exist before 23 Ma, the age of the youngest tuff we currently can correlate across the boundary. What is now relatively low Basin and Range country was at higher elevation than the Sierra Nevada at the time. Although major normal (Basin and Range) and strike-slip faulting (the Walker Lane and eastern California shear zone) has been proposed to have begun in western Nevada at about 25-26 Ma, any faulting before 23 Ma was insufficient to disrupt the paleodrainages other than temporarily.

Offset of tuff-filled paleovalleys, the best piercing points to determine displacement, reveal that the northern Walker Lane (north of ~39.5°) has ~25 km total dextral slip (~10 km on individual faults). Numerous tuff-filled paleovalleys also cross the central Walker Lane (~39-37.5°) and can be used to determine total displacement, which is so far poorly constrained. Tuff distribution has been used to determine displacement across the northern Gulf of California and is applicable all along the Gulf. Although access to some regions is difficult, delineation of paleovalleys and correlation of specific tuffs potentially can provide precise displacements along much of the transform boundary.

23-8 **4:10 PM** Unruh, Jeffrey

SEISMOGENIC DEFORMATION BETWEEN THE SIERRAN MICROPLATE AND OREGON COAST BLOCK, CALIFORNIA, AND THE NORTHERN TERMINATION OF THE WALKER LANE BELT

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The Sierran microplate, which comprises much of central California, is a northwest-translating block entrained in distributed motion east of the Pacific plate. To the north, the Oregon Coast block (OCB) moves northward in the hanging wall of the Cascadia subduction zone, above the obliquely converging Juan de Fuca plate. The motions of the Sierran and OCB microplates relative to North America (NA) are described by distinct Euler poles, and the western US velocity field reveals that that these motions extend well east into the Walker Lane belt (WLB) and northern Basin and Range of California, Nevada and Oregon. Geodetic data locate the boundary between the Sierran microplate and OCB in northern California near the southern end of the Cascadia subduction zone. Analysis of regional seismicity indicates that distributed deformation occurs in a NE-trending transition zone between the nominally rigid microplates and is characterized by approximately east-west-directed dextral shear, consistent with differential Sierran-OCB motion. In addition, dextral motion likely steps west from the northern WLB to the subduction zone, driving oblique shortening in the northern Sierran microplate. Because the Sierran-NA and OCB-NA motions are locally identical at the transition, small circles about their respective Euler poles must be tangent there as well. This geometric requirement accurately predicts the location and orientation of the Sierran-OCB transition zone, as well as the northern boundary of the Walker Lane belt and the transition from distributed NW dextral shear east of the Pacific plate to CW microplate rotation above the Juan de Fuca plate. These boundaries also are tied to the position of the Mendocino triple junction on the west, which lies at the northwestern corner of the Sierran microplate. The triple junction is migrating to the northwest with the velocity of the Pacific plate, which is about four times that of the Sierran microplate. Thus the Sierran-OCB transition and the northern end of the Walker Lane belt are moving to the north relative to these two microplates. These relationships imply rapidly migrating and changing patterns of late Cenozoic deformation in northern California as the plate boundary to the west evolves.

23-9 **4:30 PM** Trench, David

TERMINATION OF THE NORTHWESTERN BASIN AND RANGE PROVINCE INTO A CLOCKWISE ROTATING REGION OF TRANSTENSION AND VOLCANISM, SOUTHEAST OREGON

TRENCH, David, Fugro Consultants, Inc, 1777 Botelho Drive, Suite 262, Walnut Creek, CA 94596, d.trench@fugro.com

New data indicate that northeast-directed extensional faulting characterizes slip across the Brothers fault zone (BFZ), which marks the northern limit of the northwestern Basin and Range (NWBR) extensional province in southeastern Oregon. Structural separation across individual north-northeast striking NWBR faults decreases to zero south of the BFZ. Field relationships and cross-sections demonstrate limited kinematic linkage and independent evolution of the two fault systems since ~7 Ma. West-directed extension accumulated on NWBR faults at 0.01 mm/yr and lengthened northward after 7.05 Ma. BFZ faults accumulated northeast-directed extension at rates of 0.01 mm/yr since 5.68 Ma. Deformation coincides with periods of heightened basaltic magmatism in the High Lava Plains, implying that volcanism weakened the crust and promoted extension in the BFZ. In a new model, we reconcile the observed northward diminishing rate and clockwise motion of the modern NWBR deformation field with regional geology. The BFZ defines a small circle about the pole of rotation and separates a stable block to the NE from the extending region to the south. Faults to the south are growing northward, consistent with the northward decrease in rate and magnitude of extension in the NWBR.

23-10 **4:50 PM** Sawyer, Thomas L.

THE NORTHERN CALIFORNIA SHEAR ZONE—MISSING LINK IN THE PACIFIC-NORTH AMERICAN PLATE TRANSFORM MARGIN?

SAWYER, Thomas L., Piedmont GeoSciences, Inc, 10235 Blackhawk Drive, Reno, NV 89508, tom@piedmontgeosciences.com

Within the distributed P-NA plate transform margin and translating 10-11 mm/yr to the NW through a CCW arc relative to interior NA, is the Sierra Nevada-Great Valley (SN-GV) microplate. Motion of the microplate is accommodated by dextral shear across the Walker Lane shear zone (WL), extension in the Basin and Range, crustal shortening across the Coast Range boundary zone and, as previously suggested, by transpressional shear along unknown structures north of the microplate (e.g., Unruh et al., 2003; Williams et al., 2006). The northern WL accommodates 6-8 mm/yr of dextral shear at the latitude of Mohawk Valley, but there is little if any shear strain measured further north in the Mt. Shasta-Medicine Lake region (e.g., Hammond and Thatcher, 2007) particularly after removing CW rotation of the Oregon block (Poland et al., 2006). This northern limit of significant shear strain, coupled with microplate motion recorded near the southern end of the Cascadia subduction zone (Williams et al., 2006), seemingly requires a zone of deformation between about latitude 40°-41°N to accommodate westward translation of the microplate and transfer ≤6-8 mm/yr of regional shear strain.

More than two decades of seismic hazard research reveals a distributed zone of Quaternary faults and fold-fault structures, the "Northern California shear zone", that extends >225 km westward from the northern WL and forms a large-scale left stepover across much of northern California. The structurally integrated southern extent of the shear zone splays W-NW from the Mohawk Valley fault zone, delineating the northern edge of the microplate and forming a 90 km-wide restraining stepover that drives crustal shortening in the Inks Creek fold belt. The arcuate northern extent splays from or near the Honey Lake fault zone and cross-cuts the Cascadia volcanic arc as a fold-and-thrust belt, south of Mt. Shasta. The belt widens westward and appears to define the structural boundary between the Oregon Coast block and the northern Central Valley. Thus, the structurally complex Northern California shear zone apparently accommodates westward translation of the northern SN-GV microplate, and thereby transfers ≤6-8 mm/yr of WL shear strain across the Central Valley-Klamath Mountains region to the primary plate margin in northwestern California.

SESSION NO. 24, 1:30 PM

Tuesday, 21 May 2013

Geologic Maps and Geologic Mapping (Posters)

Radisson Hotel and Conference Center, Salon B/C

24-1 **BTH 1** Brown, Howard J.

GEOLOGY OF THE STODDARD RIDGE AREA, WEST CENTRAL MOJAVE DESERT, SAN BERNARDINO COUNTY CALIFORNIA

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Stoddard Ridge is a prominant landmark south of Barstow California in the west central Mojave Desert area. The 35 square mile area was mapped in detail at a scale of 1:12,000. The geology is far more complex than depicted on all older published maps. The new mapping adds significant new data regarding the variety of rocks present, and adds new details on the geologic structure and complex geologic history of the area.

Several packages of rocks are exposed. At the east end of the ridge the oldest rocks are exposed and include PreCambrian basement gneiss complex, metamorphosed intrusive rocks, and possible Late Proterozoic metasedimentary rocks (schist units). The central part of the ridge exposes several sequences of steeply dipping Mid Jurassic Lower Sidewinder volcanic (JLSV) rocks, and younger (JLSV) rhyolite dome complex that includes extrusive, flow banded and massive hypabyssal intrusives. The western portion of Stoddard Ridge is largely heterogeneous Mid Jurassic plutonic rocks (post JLSV) which form a steeply dipping sheeted intrusive complex, that includes diorite, granodiorite, quartz monzonite and felsite. Plutonic and to a lesser degree volcanic rocks are cut by numerous younger mafic and felsic dikes correlated with the Independence dike swarm of Late Jurassic age. The eastern part of the ridge has been intruded by homogeneous Mid Jurassic plutonic rocks, and Cretaceous granitic intrusive rocks are

exposed along the southwestern base of Stoddard Ridge. Several ages of Late Cenozoic alluvial units were also differentiated in mapping.

Geologic structure is complex, the result of several deformational events including shearing, folding, faulting, intrusion and metamorphism of pre Mid Jurassic age, followed by multiple Mid Jurassic age volcanic, intrusive and deformation (folding and faulting) events, and younger Cenozoic age faulting. Most bedrock units have a northwest trending structural grain which likely formed in Jurassic time. Suspected concealed faults are present under alluvium. Several prominant young northwest trending high angle faults are present on the south side of the ridge and can be seen to cut alluvium.

24-2 **BTH 2** Brown, Howard J.

GEOLOGY OF THE SIDEWINDER MOUNTAIN AND BLACK MOUNTAIN AREA, WEST CENTRAL MOJAVE DESERT, SAN BERNARDINO COUNTY CALIFORNIA

BROWN, Howard J., Omya California, 7225 Crystal Creek Road, Lucerne Valley, CA 92356, howard.brown@omya.com

The Sidewinder Mountain, Black Mountain area is located in the west central Mojave Desert area, and was mapped at a scale of 1:6,000. This work presents the most detailed mapping of the area, and provides additional details regarding bedrock units and complex geologic structures.

Bedrock includes roof pendants of Late Proterozoic and Paleozoic miogeoclinal metasedimentary formations, and is the type location of the unconformably overlying Fairview Valley Formation (FVF), unconformably overlying quartzite, and unconformably overlying Lower Sidewinder volcanic rocks (LSV) all Early to Mid Jurassic age. Triassic, Jurassic and Cretaceous plutonic rocks and dikes are also exposed. Alluvial units of PrePleistocene to recent age are also present.

Structure includes multiple Mesozoic age metamorphic, intrusive, contractional and extensional deformational events, and younger deformation that continued to present time. Mesozoic deformation includes polyphase folding, faulting and metamorphism of Paleozoic rocks likely during Permo-Triassic time, followed by intrusion of Triassic monzonite, uplift and erosion. Lower Jurassic FVF unconformably overlies deformed Paleozoic metasediments and Triassic intrusive. The FVF was faulted and folded prior to unconformably overlying quartzite. Unconformably overlying quartzite is Mid Jurassic LSV, hypabyssal intrusives and subordinate sedimentary rocks. During and following deposition of the LSV were multiple caldera collapse events and associated faulting, intrusion of hypabyssal intrusives and unconformities. Several generations of extensional deformation occurred prior to and after intrusion of Late Mid Jurassic plutonic rocks. Northwest trending felsic and mafic dikes correlate with the Late Jurassic Independence dikes and cut older rocks. Late Jurassic Upper Sidewinder volcanics followed. Quartz monzonite plutonic rocks were intruded during Cretaceous time.

A prominant feature is the northwest trending Helendale fault zone. The fault zone is postulated to have several miles of movement. Alluvial and bedrock units indicate right lateral faulting. Gravity data suggest right stepping en echelon fault strands may have formed a pull apart basin up to two miles wide in which many faults are present, some of which have been active during recent time.

24-3 **BTH 3** Wills, Chris J.

PROGRESS IN GEOLOGIC MAPPING AT THE CALIFORNIA GEOLOGICAL SURVEY

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In California, almost all land-use planning and building decisions are made at the local level, but few local governments have the staff, funding, or expertise to interpret critical details of geologic hazards and resources from available geologic mapping. To accommodate this need, the California Geological Survey (CGS) prepares maps specifically for use in hazard and resource evaluation by local government. Those maps are derivatives of geologic maps and contain only the information needed by land-use planners and decision-makers.

CGS derives hazard or resource maps from geologic maps, so needs regionally consistent geologic maps to form the basis for analysis of a host of concerns in California, from seismic hazards to infrastructure engineering, environmental management, and groundwater issues. CGS aims to bring new and existing map information into a standardized cartographic format and release the new maps for public use in downloadable image and GIS file formats, as well as for viewing on an interactive Google Map platform.

Geologic mapping at CGS is partly supported by grants through the USGS STATEMAP program. Mapping projects are selected each year based on development pressures and geologic hazard potential with input from an independent advisory committee. Each year STATEMAP supports mapping of several 7.5’ quadrangles and compilation of existing mapping for a 30' x 60' quadrangle. CGS also prepares geologic maps for specific hazard mapping projects, such as the recent mapping of Quaternary deposits for evaluation of alluvial fan flood hazard. These maps can be combined with others, in this case with maps showing more detail of the bedrock, to develop complete geologic maps. Over the long term, CGS plans to complete 1:24,000-scale geologic mapping in urbanizing areas of the state and complete compilation of the 115 30' x 60' quadrangles that preserves the detail of the original mapping.

CGS can help other geologists get their work out to the public by providing GIS and cartographic support and publication. Examples include the Geologic Map of the North Lake Tahoe – Donner Pass Region, compiled by faculty and students of U.C. Santa Barbara, and mapping of four 30’ x 60’ quadrangles in northeastern California by T.L.T. Grose. New maps are announced on the CGS website as they are released.

24-4 **BTH 4** Wiegers, Mark O.

GEOLOGIC MAPPING IN SAN LUIS OBISPO COUNTY ON THE CENTRAL COAST OF CALIFORNIA

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The California Geological Survey (CGS) is engaged in a multi-year project to prepare a seamless onshore/offshore geologic map and geologic database of the San Luis Obispo 30 x 60-minute quadrangle in the Central Coast region of California. So far, four 7.5-minute quadrangle geologic maps have been completed (Morro Bay South, San Luis Obispo, Pismo Beach and Atascadero). Two quadrangles are in preparation and will be released in June, 2013 (Arroyo Grande NE and Oceano). Two more quadrangles are scheduled for release in 2014 (Nipomo and Santa Margarita). This project is funded by the STATEMAP component of the National Cooperative Geologic Mapping Program.

Coastal San Luis Obispo County is a region of active crustal deformation and high seismicity caused by transpressive movement between the Pacific and North America Plates. Deformation is accommodated by a number of active and potentially active faults that extend through the area, including the Rinconada, Oceano, Los Osos, and West Huasna Faults and the Southwest Boundary Fault Zone of the San Luis Range. The active Hosgri and Shoreline Faults lie just offshore. In addition to earthquakes, parts of the region are underlain by weak bedrock subject to landslides and alluvial and estuarine deposits subject to liquefaction. CGS will use the new geologic maps to prepare Seismic Hazard Zone Maps delineating Zones of Required Investigation for Liquefaction and Earthquake-induced Landslides. The maps will also be useful for evaluating aggregate and groundwater resources and geologic conditions for City and County planning and public works projects.

In addition to CGS's mapping activities, western San Luis Obispo County is currently the focus of extensive seismic hazard studies by Pacific Gas & Electric (PG&E) for a twenty year renewal of their license to operate Diablo Canyon Nuclear Power Plant, about 8 miles southwest of San Luis Obispo. Following detailed guidelines adopted by the Nuclear Regulatory Commission, extensive new onshore and offshore data are being generated by PG&Es geosciences staff, their consultants, the USGS and the Seafloor Mapping Lab at CSU Monterey Bay. These data will be incorporated into the San Luis Obispo 30 x 60-minute quadrangle geologic database as they become available.

24-5 **BTH 5** Hernandez, Janis L.

GEOLOGIC MAP OF THE SLEEPY VALLEY 7.5’ QUADRANGLE, LOS ANGELES COUNTY, CALIFORNIA

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The California Geological Survey (CGS) recently completed geologic mapping of the Sleepy Valley 7.5' quadrangle in northeastern Los Angeles County as part of STATEMAP, an ongoing cooperative effort with the USGS to produce seamless geologic maps of 7.5' and 30'x60' quadrangles in California. This map presents a digital compilation of the best available geologic mapping augmented by new 1:24,000-scale bedrock field mapping and petrographic analysis by CGS, resulting in better lithologic descriptions and differentiation of the igneous and metamorphic units. CGS also utilized available LiDAR data, aerial photography, and field reconnaissance to complete new detailed mapping of Quaternary units and to more accurately locate major pre-Holocene faults. This detailed geologic mapping allows for an improved understanding of the geologic framework in this tectonically active area.

The San Andreas Fault Zone crosses obliquely through the northeast corner of the Sleepy Valley quadrangle, with distinctive rock units found north of, within, and south of the fault zone. North of the fault, the area is primarily underlain by Upper Cretaceous to Lower Tertiary Portal Schist. Breccia, arkosic sandstone, and clay shale of the Pliocene Anaverde Formation are exposed on a ridge within the fault zone. South of the fault, the dominant bedrock rock unit is the Upper Cretaceous to Lower Tertiary Pelona Schist, which is exposed in the Sierra Pelona, a westward-plunging antiform in the center of the map area. Other basement rocks include a Proterozoic quartzo-feldspathic and amphibolite gneiss complex, the San Gabriel Mountains anorthosite-gabbro-syenite complex, and Cretaceous gneissic granite and tonalite units. Mylonitic rocks mapped at the contact between the Pelona Schist and the Cretaceous gneissic granite formed as a result of movement along the south-dipping Vincent Thrust. The intrusive and metamorphic rocks are locally overlain by fluvial and volcaniclastic rocks of the Upper Oligocene Vasquez Formation. This formation marks the earliest sedimentation in the Soledad basin, which developed as a result of crustal extension associated with incipient development of the San Andreas transform margin. This basin was transrotated and tectonically inverted along preexisting normal faults during the Miocene.

24-6 **BTH 6** Irvine, Pamela J.

SEAMLESS DIGITAL LANDSLIDE INVENTORY AND GEOLOGIC DATABASES OF THE SANTA MONICA MOUNTAINS, SOUTHERN CALIFORNIA

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The California Geological Survey (CGS) has developed two separate seamless digital databases of landslide inventories (LSI) and geologic maps of the Santa Monica Mountains National Recreation Area (SAMO). This work was part of a cooperative effort with the National Park Service (NPS) to provide NPS with two of the essential datasets of geologic and hazards information to include in their Geologic Resources Inventory of SAMO.

SAMO is in the Transverse Ranges Province, a tectonically active area where uplift, folding and faulting have produced steep slopes composed of deformed and weakened rocks, resulting in the widespread occurrence of landslides. CGS prepared LSI maps of the area as part of the Seismic Hazards Zonation Program (SHZP) in 1996 to 2002. For the NPS SAMO LSI project, CGS completed the digital database of landslide attributes, reconciled landslide mapping across quadrangle boundaries, and reviewed the maps for completeness. The 14 individual 7.5’ LSI maps will be published online as part of the CGS LSIM Series.

The NPS SAMO geologic map project involved reconciling geologic contacts and stratigraphic nomenclature between the Los Angeles 30’x60’ quadrangle by Yerkes and Campbell (2005) and the Santa Barbara 30'x60' quadrangle by Gutierrez et al. (2008) to the west. CGS worked with Russell Campbell (USGS – retired) to update bedrock mapping and reconcile map-boundary issues between the 30'x60' quadrangles. Quaternary units in the area were updated with detailed mapping by CGS for SHZP. Landslides are not included in this database except where the landslide deposits obscure the underlying bedrock to the point where the underlying bedrock contacts cannot be inferred.

Development of the two SAMO databases represents a major step toward the CGS goal of completing a new seamless geologic map database covering the Los Angeles 30'x60' quadrangle. Campbell is continuing to update maps of the 7.5' quadrangles, which will be published online as CGS Preliminary Geologic Maps. The new compilation will substantially update the previous compilation of Yerkes and Campbell (2005) with new Quaternary mapping, more detailed mapping of crystalline units, and more consistent stratigraphic nomenclature within the quadrangle and with adjacent maps. CGS welcomes comments and additional data from the geologic community.

SESSION NO. 25, 1:30 PM

Tuesday, 21 May 2013

Geoscience Education and Communication (Posters)

Radisson Hotel and Conference Center, Salon B/C

25-1 **BTH 7** Boryta, Mark

SUSTAINABLE AND MEANINGFUL RESEARCH OPPORTUNITIES FOR COMMUNITY COLLEGE STUDENTS

BORYTA, Mark, WALKER, Becca, CARLOS, Richard, CARRIZAL, Jonathan T., CHI, Brian, DE MARTINEZ, Levi, DIAZ, Miguel Angel, HOFFMANN, Adam, KETTING-OLIVIER, Amanda, and VILLANUEVA, Lorenzo, Department of Earth Sciences and Astronomy, Mt. San Antonio College, 1100 N. Grand Ave, Walnut, CA 91789, mboryta@mtsac.edu

Science classes generally teach students to question assumptions. In order to best prepare our community-college students for careers in the geosciences, we have created an ongoing student-led research project that provides opportunities to develop skills necessary for geological field work as well as experience with decision-making and collaborating. Students may participate for up to two semesters in the study; returning students are expected to mentor incoming students.

The project involves testing the logical assumption that sediments undergo changes along the length of a given stream. Trabuco Creek is a tributary of San Juan Creek in southern Orange County, CA. In past semesters, students have been mapping the bedrock and the creek, conducting both longitudinal and cross-sectional profiles, sampling sediment from the creek bed, and performing sieve analyses. This semester's work, defined by the team, is to continue mapping the bedrock and to analyze sediments for changes in roundness, sphericity and compositional distribution among different size fractions, as related to stream position and tributary input, in an effort to test standard assumptions.

Students will present both scientific and academic returns. Instructors will also report on lessons learned, including involvement of faculty, procuring of resources, strategies for assessment of students at various levels in the project, and addressing the challenges of course repeatability.

25-2 **BTH 8** Greene, David C.

TEACHING EARTHQUAKE-RESISTANT BUILDING PRACTICES IN GUATEMALA: DISSEMINATING EXISTING KNOWLEDGE TO THE PEOPLE WHO NEED IT MOST

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Most geoscience professors have spent years teaching about the geology of earthquakes, but geologic knowledge alone does not prevent fatalities: building collapse in response to shaking accounts for most casualties. Though earthquake-resistant building techniques have been developed using the concrete frame and masonry block construction typical in the developing world, a major challenge remains in disseminating these known best practices to the amateur builders and local contractors who are responsible for most housing and small scale commercial construction in rural areas. The principal earthquake-resistant technique – Confined Masonry – is highly effective for these non-engineered buildings, and it requires only modest changes in customary design and building practices.

Recently I had the opportunity to teach earthquake-resistant building techniques in rural Guatemala, although I am neither a builder nor an engineer. My experience suggests that effective teaching, a skill that most geoscientists have and practice every day in their classrooms and workplaces, is the most critical tool for providing meaningful assistance with this and many other geoscience-related issues. Expert knowledge, fluency in local languages, years of local experience and cultural insight are all useful but can be provided or developed through relationships with local partners.

I developed a 1-hour presentation using a laptop computer and small portable projector. I used photographs of local buildings and simple graphics with minimal captions to illustrate best/poor practices with yes/no labels, and breakable models to demonstrate basic design principals. Manuals with additional information and examples were provided to each attendee, for later reference and the possibility of propagating this information forward. Most remote villages had access to sufficient electricity to run a small projector, and the general underemployment of even educated individuals meant that there was little difficulty in finding partners capable of providing running translation into local language(s). The most challenging aspect of this project was developing a working relationship with a local organization willing and able to assist with scheduling, publicity, and generally connecting me with appropriate audiences.

25-3 **BTH 9** MartÍnez-Sacristán, Hernando

MINING PUBLIC POLICY WOULD INCREASE NATURAL AND SOCIAL RISKS IN COLOMBIA: FAR FROM RHETORIC CLOSER TO REALITY

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During the last four decades, several mistakes of public policies for mining have occurred as a consequence of short public policy implemented for each government during the four years in office without continuity in this administrative process. Both bureaucratic and technical methods have been unsatisfactory showing lack of efficacy and efficiency as well.

The Colombian government has diverse rhetorical documents from different administrative organization and institutions such as National Council of Economic and Social Politic (CONPES), National Development Plan Prosperity for All 2010-2014, National Plan for Mining Development up to 2019- UPME, and others. All of them are representing short time interests, except the theoretical plan from Planning Mining Energy Unit-UPME, which has not power because its dependant from the Mining and Energy Ministry.

In opposite, another National Council of Economic and Social Politic (Consejo Nacional de Política Económica y Social-CONPES) sector policies and documents from the Ministry of the Environment, Housing and Territorial Development; also, Law 99/1993, Colombian Natural Resources Code, and others sometimes disagree with the Mines and Energy Ministry creating confusion. Sometimes it is a limb where publicly through media every day unusual opposition of legal normative is remarked.

On the other, it is easy to find controversial documents from Colombian government but it is difficult to find funding for natural resources exploration and safeguarding. The Mining Development Plan 2019 has a fantastic scope. A technical plan without funds means a scientific-political dichotomy.For instance, the Colombian government needs field activities of geology such as structural geology, stratigraphy, tectonic, and geophysics for basic information more than abstract planning, legal aspects, taxes, intangible safety and others. In addition, it is necessary to provide adequate basic articulation of this information.

The Colombian government's Vision and Mission regarding natural resources and/or mining policies represent lack of preparation from administrative people, politicians, scientists, technicians, and population as well.

SESSION NO. 26, 1:30 PM

Tuesday, 21 May 2013

Sedimentary Geology (Posters)

Radisson Hotel and Conference Center, Salon B/C

26-1 **BTH 10** Morgan, George

RECENT GEOLOGICAL MAPPING OF THE COYOTE MOUNTIANS, WESTERN SALTON TROUGH, IMPERIAL COUNTY, CALIFORNIA

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Some of the results from several years of geological mapping of the Coyote Mountains, an on-going geological project, show the following: 1). Active left-lateral faulting and reactivation of older faults in a right-lateral stress field, 2). Landslides and several terraces associated with the uplift of the Coyote Mountains; 3). Pliocene Imperial Group marine transgressions and regression with non-marine sediments, 4) Fresh water limestones (Bouse Formation equivalent?), 5). New interpretation of the Garnet Formation in relationship with the Imperial Group; 6). Cenozoic thrust and detachment faults; 7). Miocene volcanic plug and cinder cones with dated tuffs(17 +/-2Ma); 8). Cretaceous and Jurassic igneous dated rocks; 9). Folded and faulted metamorphic rocks made up of: marbles, schists, gneisses, banned cherts, cherts, quartzites and amphibolites with pillow basalts.

26-2 **BTH 11** Fleming, Monte Alain

SEDIMENTOLOGY OF MARINE VERTEBRATE BURIAL IN THE MIOCENE PISCO FORMATION, PERU

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The Miocene Pisco Formation on the central coast of Peru is known for a remarkable abundance of well preserved, articulated, marine mammals. The goal of this project is to provide a better sedimentological model to explain how such large carcasses could be buried and preserved so well. Because of the unusual abundance of the fossils in the Pisco basin, combined with numerous, readily-accessible outcrops in canyons and hills, we were able to find several specimens in cross section. This provided us with a special opportunity for sedimentological studies of the cross sections, and comparison with the previous taphonomic research done in the Pisco Formation. Going into this study, we planned to test models that included burial in channels and submergence in the sediment by liquefaction.

We studied 11 large marine vertebrate cross sections, ranging in size from dolphins to whales. All of them were fully articulated, and only one whale and the dolphin skeleton were not encased in a concretion. We have organized the sites into three categories: 1) burial in channels, probably during storms, 2) near-shore storm deposits, and 3) storm deposits in deeper water on the shelf. Four whales and the dolphin were buried in channels. Sediments are diatomaceous, tuffaceous, and contain silt-size clastic grains. One whale was buried in a near-shore storm deposit of coarse, fossiliferous sediments associated with shallow water facies. Three whales were deposited in a shelf environment in diatom-rich, tuffaceous, and silty sediments. The burial of these whales before decomposition required substantial advection of sediment and in some cases included volcanic ash deposition. Two of the whale skeletons were on distinct bedding surfaces suggestive of hiatuses in deposition. Other whales were on indistinct contacts. We found no evidence that liquefaction was a mechanism for burial. This study suggests that storms were the primary process driving burial and were effective in at least three different depositional settings.

SESSION NO. 27, 1:30 PM

Tuesday, 21 May 2013

T6. Using Detrital Zircon Age Data to Reassemble the Cordilleran Jigsaw Puzzle (Posters)

Radisson Hotel and Conference Center, Salon B/C

27-1 **BTH 12** Koplitz, Trevor

PROVENANCE ANALYSIS OF MID-CRETACEOUS STRATA IN THE METHOW BASIN, SOUTHERN BRITISH COLUMBIA: EVIDENCE FOR RAPID ARC EXHUMATION

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Accretionary events, abundant deformation, and subsequent erosion and burial of Mesozoic topography mean that the sedimentary record may contain the most complete account of complex North American Cordilleran paleogeography. Sandstone petrography and detrital zircon U-Pb and Lu-Hf analysis of east-derived strata of the Methow Basin in southern British Columbia suggest that the basin received sediment from a nearby, high-standing plutonic source throughout the mid-Cretaceous period of deposition. The east-derived strata of the Methow Basin in Manning Provincial Park include the Albian-Cenomanian Jackass Mountain Group (JMG) and the Cenomanian-Turonian Winthrop Formation (WF). All 12 JMG and WF samples have an entirely Mesozoic detrital zircon age signature, with no Precambrian or Paleozoic ages, and only a few

Triassic ages. All samples contain an Aptian-Albian (125-105 Ma) age peak, which includes 82% of the detrital zircon dated from the WF (637 of 777grains). A Middle to Late Jurassic (170-145 Ma) peak occurs in the JMG samples, and is most significant in the older JMG. Detrital zircon ε_{Hf} values determined for 125-105 Ma and 170-145 Ma grains range from +6 to +12, regardless of age or location within the basin, indicating a juvenile source. Sandstone petrography indicates low potassium feldspar and volcanic lithic content, along with consistently poor sorting. Taken together, these data suggest that east-derived strata in Manning Park came from a largely tonalitic plutonic source that was isotopically juvenile. This plutonic source experienced active magmatism during the Middle to Late Jurassic and Early Cretaceous, and was uplifted and exposed by the mid-Cretaceous. The arc source must have remained a topographic barrier throughout the mid-Cretaceous, shedding abundant sediment into the Methow basin and blocking westward transport of Precambrian continental detritus. Potential large-scale post-Cretaceous translation of the Methow Basin means possible source areas include magmatic arcs along the length of western North America. However, the relatively proximal Coast Plutonic Complex (CPC) in the Southern Canadian Cordillera provides a close match with the Methow provenance data, whereas other potential sources do not match the zircon ages, ε_{Hf} values, and/or petrography of the Methow strata.

27-2 **BTH 13** Udoratina, O.

NEW LOOK AT NEOPROTEROZOIC ROCKS OF THE YREKA TERRANE, KLAMATH MOUNTAINS, N. CALIFORNIA

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Interest in the "Baltic" elements of Cordillera terranes and their possible origin in the current Arctic led to a closer look at parts of the eastern Klamath Mountains. Here, Ordovician blueschists and Devonian sandstones of the Yreka terrane are enriched in non-western Laurentian detrital zircon (DZ) populations including 1.46- 1.55 Ga U-Pb ages specifically linked to Baltica. Wallin et al. (1988; 1995) dated adjacent Neoproterozoic (565-570Ma) intrusive rocks, ages common to the ~ 750-550 Ma arc complexes accreted to the margin of Baltica during the Timan orogeny (~ 550 Ma) and in possibly displaced parts of this belt in the Arctic Alaska and Alexander terranes.

We investigated the contact relationships between map units in the region near Kangaroo Lake and Lover's Leap to sample additional rocks and strata for U-Pb geochronology, geochemistry and detrital zircon studies. We confirmed that undated ultramafic rocks of the Trinity terrane and the coarse-grained Silurian gabbros that intrude them (Wallin et al., 1995) are in fault contact with the Neoproterozoic igneous rocks. The Neoproterozoic consists of structurally intact intrusive, extrusive and hypabyssal rocks. Intrusive rocks vary from hornblende gabbros through diorites to quartz diorites. Tonalite and plagiogranite veins cut this succession. Geochemistry indicates a basalt-andesite-dacite calc-alkaline assemblage with island arc affinities– low Ti, low K, low Zr, and LILE concentrations relatively higher than HFSE. Mafic rocks are depleted in Ta and Nb. Following Rohr et al (1975), we observed that the Neoproterozoic complex is unconformably overlain by conglomerates and sandstones, basalt and limestone of Ordovician and Silurian age. Conglomerates, perhaps coeval with carbonate buildups, contain mainly limestone and volcanic rock clasts (ranging from basalt to dacite). The limestone clasts have yielded mostly Ordovician fauna (Rohr et al., 1975). All of the rocks appear to be overlain (or overthrust) by the adjacent Devonian Gazelle Fm.

Detrital zircon geochronology of Paleozoic sediments overlying the Neoproterozoic arc sequence are compared to those to the Yreka terrane and to established DZ signatures of coeval strata of the Arctic region.

27-3 **BTH 14** Lund Snee, Jens-Erik

GEOLOGIC MAPPING, GEOCHEMISTRY, AND DETRITAL ZIRCON GEOCHRONOLOGY IN HUNTINGTON VALLEY AND THE EASTERN PIÑON RANGE, NORTHEAST NEVADA: IMPLICATIONS FOR THE PALEOGEOGRAPHIC EVOLUTION OF THE ELKO BASIN AND SURROUNDINGS

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The Ruby Mountains–East Humboldt Range (RMEH) is a classic example of a metamorphic core complex, which exposes deep crustal levels providing insight into the complex Tertiary and Mesozoic magmatic and deformational history of the Cordillera. The extensional history of the RMEH has been controversial for decades but comparatively little study has focused on the surrounding supracrustal rocks and sedimentary basins, which record an impressively complete history of Cenozoic sedimentation and volcanism, thus revealing insight into the paleogeographic and paleotopographic evolution of what was once the cover sequence for the RMEH.

Depositional rates in the Elko Basin were relatively minor from Cretaceous to Oligocene time, and changed to rapid sedimentation in the Middle Miocene. The Eocene Elko Formation is only ~125 m thick (maximum ~850 m thick regionally; Haynes, 2003) and sediments within the Eocene–Oligocene Indian Well Formation are significantly less voluminous than previously reported. Detrital zircon signatures recording erosion of the metamorphic and igneous rocks of the RMEH arrive in the Middle Miocene, suggesting that the RMEH was not exposed to erosion prior to that time. A small number of Jurassic zircons in the Elko Formation are likely derived from plutons in the nearby Cortez Range to the west, and a population of ~46 Ma zircons may represent air fall from the Challis volcanic field in Idaho.

The ~40–31 Ma calcic to calc-alkalic Robinson volcanic field records early peraluminous to weakly metaluminous "ignimbrite flare-up" volcanism of basaltic andesite to trachydacite and rhyolite composition. Minor ~E–W-striking faults are observed during or immediately following eruption of 38–37 Ma volcanic rocks. A gentle (10–15º) angular unconformity is mapped between ~37 Ma volcanics and a ~31.5 Ma ignimbrite, the Tuff of Hackwood. Between ~31.5–16 Ma another unconformity is developed at the base of the Miocene section that is not well constrained from the mapping but could be as little as 5º or as much as 45º. An east-dipping, range-bounding normal fault system between Huntington Valley and the Piñon Range to the west is inferred to have slipped after 31 Ma and may be synchronous with deposition of the Miocene Humboldt Formation, as is the major W-dipping fault that bounds the RMEH (Colgan et al., 2010).

27-4 **BTH 15** Fagin, Brittany

ZIRCON AND APATITE SEPARATION USING A SPIRAL PANNING TABLE: EVALUATION OF TIME AND YIELD EFFICIENCY

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Mineral separations concentrate the heavy minerals apatite and zircon necessary to accurately date rock samples, but current methods are time-consuming, toxic, expensive, and have unknown yield efficiencies. To evaluate and improve separation methods, I processed five, ~1.4 kg samples (hornblende-biotite tonalite, 65.47 wt % SiO_2, 137 ppm Zr, 0.138 wt % P_2O_5, collected from the Mt. Stuart Batholith near Leavenworth, WA; expected yields per kg, calculated from CIPW-norm: 30 g zircon; 320 g apatite) with a new procedure using a spiral panning table (panner) to wash and pre-concentrate heavy minerals before magnetic, lithium polytungstate (LST) and methylene iodide (MEI) heavy liquid separations. The control sample (#3) was hand washed, separated magnetically, and processed with LST and MEI, resulting in 34 mg zircon and 155 mg apatite. Panner trial #1 used a fast sample feed rate (58.4 g/min) and slow rotation speed (13.7 rpm), resulting in 3.7 mg zircon and 1.0 mg apatite. Panner trial #2 used a slow sample feed rate (11.5 g/min), the same slow rotation speed as trial #1, and yielded 6.1 mg zircon and 6.0 mg apatite. Surfactant was used in panner trial #4 to cut surface tension along with a slow feed rate of 9.1 g/min and the same slow rotation speed as trial #1, yielding 6.9 mg zircon and 3.4 mg apatite. Last, panner trial #5 used a faster rotation speed (24.7 rpm) and a fast feed rate (36.2 g/min), which produced the highest yields: 13.2 mg zircon, 12.9 mg apatite. Compared with the expected yields (above), the yields from both control (~50% purity separates containing 34 mg zircon, 155 mg apatite) and panner trials (high-purity separates containing 3.7-13.2 mg zircon, 1.0-12.9 mg apatite) were much less, likely due to the loss of small grains and inclusions. The panner technique yielded 10x the concentration of zircon than the control, so toxic MEI would ideally not be needed to separate apatite from zircon in future projects, making this project's protocol safer than current methods. The experimental process took ~7 hours per sample, compared to ~38 hours for the control. The greater speed, improved zircon concentration, and avoidance of toxic heavy liquids are significant advantages of the methods in this project similar to the larger, more expensive Gemeni table, and further development will improve recovery efficiency.

SESSION NO. 28, 1:30 PM

Tuesday, 21 May 2013

T15. Undergraduate Research (Posters)

Radisson Hotel and Conference Center, Salon B/C

28-1 **BTH 16** Engberg, Christopher

DIVING INTO 540 MILLION YEARS OF CLIMATE WITH CHRONOZOOM

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ChronoZoom is an open-source visualization tool for exploring all of the past using an intuitive and friendly zoomable user interface. We have recently added the ability to display large time-series data sets across the 13.7 billion years capable in ChronoZoom.

As a demonstration of the new time-series capability, we have assembled a temperature history of the Earth for the last 540 million years. Many different paleoclimate proxies are available, however, each covers vastly different time scales, making synthesis and display of trends across these datasets difficult. The zoomable interface of ChronoZoom is an ideal way of visualizing, exploring and comparing these paleoclimate data sets.

We have compiled the most commonly used paleoclimate proxy data from the literature based on oxygen isotopes from the fossil record (last 540 Myr), oxygen isotopes in benthic foraminifera compiled from ocean cores (last 65 Myr), high-resolution oxygen isotopes from ocean cores (last 5.3 Myr), oxygen isotopes from Greenland and Antarctica ice cores (up to last 720 kyr), multi-proxy records (last 2000 years), and compiled instrumental records (last 250 years). For oxygen isotope records we use a method to convert an isotopic value to an estimated temperature. We realize that there are many interpretations and have made an effort to allow the user to choose their preferred data.

This newly formed data set has a combined resolution that spans ten orders of magnitude. Exploring paleoclimate data within ChronoZoom enables educators and students to better communicate and understand global climate at all scales, ranging from months to billions of years.

28-2 **BTH 17** Olson, Christopher

EFFECT OF CHEMICAL WEATHERING ON SEDIMENT RESISTANCE TO MECHANICAL WEAR IN STREAMS

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Bedload sediments are reduced in size by mechanical wear during downstream transport through river networks. The rate of size reduction varies with rock type, and has been shown experimentally to scale with the inverse square of rock tensile strength. Chemical weathering reduces rock tensile strength, so that for a given rock type, strength, and thus rock resistance to mechanical wear, should depend on the degree of chemical weathering. Here we test this hypothesis using granitic rocks from the Santa Cruz Mountains, which have undergone various degrees of chemical weathering. We use a laboratory barrel tumbler to simulate downstream transport of gravel, and quantify the fractional mass loss to silt as a function of circumferential distance traveled. We combine these measurements with tests of rock tensile strength and indices of chemical weathering. With these data, we can determine whether the strength reduction due to chemical weathering in a uniform rock type has the same effect on particle wear rates as strength variation among different rock types. These results will be useful in understanding the interactions between chemical weathering, sediment durability, and the dynamics of river incision into bedrock.

28-3 **BTH 18** Schwabe, Stephanie J.

NATURALLY OCCURRING CONCENTRATIONS OF SEVENTEEN METALS IN THE BAY POINT FORMATION, SAN DIEGO, CALIFORNIA

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The natural variability of metals in the native formations of San Diego County is poorly understood. Specific formation studies are critical in identifying the spatial variability of metals and concentrations that are anthropogenic and what may be naturally occurring. Few studies of the concentrations of metals within the native sediments of San Diego County exist. The existing studies are regional in nature and formation specific studies in the San Diego Embayment are not readily available. The concentrations of metals in soils is a fundamental criteria regarding remediation and potential disposal options for soils removed from contaminated or potentially contaminated properties in San Diego County.

We present the results of distinct geogenic soil samples representing the *in-situ* Bay Point Formation (upper and lower facies) of San Diego, California. The location for this project is in downtown San Diego and consists of an area of approximately 1.3 square miles (3.34 km). All of the soil samples collected were analyzed by a California Certified Analytical Laboratory for various metals following Environmental Protection Agency 6000 / 7000 Series Methods on a ICP Mass Spectrometer.

The naturally occurring Arsenic concentrations detected during this study exceed commonly used health risk soil screening levels and other risked-based corrective action guidelines utilized by many regulatory agencies on contaminated sites in California. The other metals concentrations do not exceed any such published criteria. Additional research is needed to assess the bio-availability of the Arsenic, the potential impact to human health and the environment, and the impact these results may have on current regulatory thresholds for assessing soils on residential and commercial properties.

Ultimately, this project will include the uploading of all raw analytical data to a central database for public use. Further research is currently underway to identify the range of concentrations of metals in additional formations throughout the San Diego Embayment (e.g. San Diego Formation, Torrey Sandstone, Mission Valley Formation). Additional data will be collected from specific locations so that a comprehensive study of the concentration of naturally occurring metals in San Diego County sediments can be published.

28-4 **BTH 19** Olsen, Erik

ADDING POLLEN TO THE RECORD: REFINING HOW SEDIMENTARY AQUIFERS FORM USING SEDIMENTOLOGY, PALYNOLOGY, AND OSL AGE DATING IN NEPAL'S TERAI

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Like many of the other heterogeneously-afflicted arsenic regions of Asia, shallow aquifer sediments in the Nepalese Terai display extremely high variances of groundwater arsenic. Given that the degree of groundwater heterogeneity is often on the order of meters to 10's of meters, understanding the small-scale aquifer differences and the evolutionary processes behind how these sedimentary units form is becoming increasingly necessary for managing and using local supplies of ground water—especially in developing countries like Nepal. Coupling previous sedimentological, geochronological and groundwater arsenic results from a 1-km transect in Parasi, Nepal with new palynological work, an effort is made to refine our understanding of how several processes (i.e., changes in climate and ecology) can affect modern groundwater arsenic distributions. Combining aquifer depositional dates with detrital zircon and titanite ages, stable O and C isotopes, and palynological separates, a more refined story of aquifer evolution emerges, with evidence suggesting that changes in source rock and climate can account for some of the arsenic heterogeneity we see today in Parasi's shallow aquifer. While this work is still underway, the preliminary findings show that differences in climate (i.e., arid vs. humid periods) as well as sediment provenance (Siwalik vs. Crystalline Himalayan, etc.) can play a significant role in the distribution of Asia's groundwater arsenic.

28-5 **BTH 20** Al-Safwani, Zahra

DETERMINING WATER QUALITY IN BANGLADESH GROUNDWATER

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The focus of this research is to analyze the results of shallow groundwater data already measured throughout two 1 km transects in Araihazar, Bangladesh. Using an already existing geochemical dataset of groundwater quality, we compare vast quantities of elemental data to provisional and recommended standards set by agencies such as the WHO and EPA. In doing so, we test whether more (i.e., Be, Na, Al, Cr, Mn, Fe, Ni, Cu, Zn, As, Se, and Cd) and less (such as Li, Mg, Si, S, K, Ca, Ti, V, Co, Sr, Mo, etc.) traditionally tracked elements comply with existing (if any) recommended water quality standards. Excess levels of elements like arsenic, iron, chromium, and mercury in water is poisonous, and together with the presence or absence of other critical/detrimental elements, we use the already existing dataset to make more contextual and meaningful conclusions about water quality and groundwater geochemical heterogeneity in Araihazar, Bangladesh.

28-6 **BTH 21** Lopez, Robin

CHARACTERIZATION OF FAULT ZONES THROUGH HYDROGEOLOGIC METHODS

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Hydrogeology is a very specific field of study that focuses on the flow, transport, and distribution of ground water. The research team has attempted to implement hydrogeologic methods in characterizing fault zones, by studying and observing the ground water flow in the Wildcat Fault-zone region along the East Canyon of the Lawrence Berkeley National Laboratory. By testing, observing and analyzing ground water flow and permeability along the fault plane, it is believed that a fault zone can be in fact characterized. Five boreholes were drilled along the East Canyon, to help in collecting and analyzing ground water data to better interpret our theories of how the fault zone is affecting the groundwater flow near the fault. The boreholes are monitored regularly and equipped with several sensors each, for data logging. The exact location of the fault plane is still disputed amongst those involved in the research project. Yet, the methods utilized in this project, can be transcended into future work and understanding for regions with similar tectonic environments, such as Japan.

28-7 **BTH 22** Kucker, Kyle

CONSTRUCTING A GEOLOGICAL SQUEEZEBOX TO MODEL FAULT ASPERITY KINEMATICS

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The geological squeezebox has been used to model deformation in analogue materials (usually sand and/or clay) ever since Henry Cadell's experiments in 1888. We have modified the basic squeezebox model in an attempt to yield quantifiable data with respect to the flow of material as it encounters a deep fault asperity. We have chosen a viscoplastic analog material of spherical wax beads in order to record the kinematics of the ductile deformations associated with fault motion. These wax spheres are themselves "cemented" by a lower melting temperature wax matrix.

Our deformation rig consists of an aluminum framed box with a movable push-plate at one end. A modified trailer jack is attached to the push-plate which receives a constant displacement from a stepper motor. Heating coils line the exterior of the aluminum box to provide the requisite heat to facilitate plastic deformation. The bottom of the squeezebox is fitted with a removable aluminum asperity. Additional overburden can be simulated with the addition of water bladders on top of the deforming wax.

A single experiment includes three successive runs with the squeezebox. At the end of an experiment, the cooled wax is sectioned in order to preform strain analysis on the deformed wax beads. Strain measurements are taken from three mutually perpendicular sections and combined to yield three-dimensional strain ellipsoids.

We anticipate that the strain distributions will incorporate large amounts of material flow perpendicular to the compression direction and that the deforming material within the fault system will need to compensate for this material flow by transmitting strain to material farther from the fault surface. We hypothesize that the strains associated with irregularities along fault surfaces are the major contributing factors in whether a fault continues to be active versus the initiation of a new fault.

28-8 **BTH 23** Canada, Andrew

EBSD AND THREE-DIMENSIONAL STRAIN ANALYSIS OF TRANSPRESSIONAL THINNING WITHIN THE ROSY FINCH SHEAR ZONE

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Kinematic analysis of the Rosy Finch Shear Zone (RFSZ) via three-dimensional strain data and Electron Backscatter Diffraction (EBSD) analysis, has allowed for the calculation of the vorticity number, which relates the relative amounts of pure shear and simple shear within the zone and ultimately can be used to estimate the amount of across-the-zone thinning. The RFSZ is a 3.5 km wide NNW trending transpressional zone along the eastern margin of the Sierra Nevada mountain range, and the southernmost shear zone within the Sierra Crest Shear Zone (SCSZ). Oblique subduction along the western coast of the North American Plate, combined with westward-directed compression, is concentrated within the shear zone. Highly deformed metasedimentary rocks within the zone have a prominent foliation with a mean dip, dip direction of 233°, 79°. These rocks also have a relatively steeply plunging and penetrative stretching lineation with a trend and plunge of 63°, 177°. A mean Flinn's k-value of 0.845, and Lode's Ratio of 0.058, indicate the predominance of plane strain deformation within this zone. Samples collected along an E-W transect of the field area provide crystallographic axes orientation data from EBSD, which further supplement the three-dimensional strain data in determining the dynamics of the shear zone. The transpressional nature of this obliquely convergent boundary, represented by the RFSZ, has resulted in vertical extrusion of material. Preliminary data, measured from samples that were collected during a 2007 field campaign, have yielded a mean shortening of nearly 21%, or approximately 135 m of the 0.65 km zone of interest.

28-9 **BTH 24** Melcon, Alexa

EXHUMATION PROCESSES WITHIN THE BITTERROOT LOBE DETACHMENT, NORTH AMERICAN CORDILLERA, A THREE-DIMENSIONAL STRAIN AND KINEMATIC VORTICITY ANALYSIS

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Collisional events form mountain belts and thicken the continental crust. Overthickened crust is gravitationally unstable and collapses in order to regain typical crustal thickness by vertical shortening of up to ~50%. Understanding the kinematics and evolution of large-scale, normal-detachment zones associated with the collapse and exhumation of mountain belts is essential for understanding orogenesis at the first-order. Despite their importance, we know comparatively little about the kinematics and evolution of these detachment zones.

The Bitterroot Lobe Detachment (BLD) marks the eastern edge of the Bitterroot metamorphic core complex, a kilometer-thick mylonitic shear zone created during the orogenic collapse of the North American Cordillera. Using a combination of three-dimensional strain analysis of deformed quartz grains and crystallographic texture analysis via electron backscatter diffraction (EBSD), we estimate how much vertical shortening of this mylonite zone has experienced and whether that thinning has affected the rate of exhumation in the region.

The vorticity number is particularly useful kinematic indicator because it relates the relative amount of pure shear experienced by a deformed material to the relative amount of simple shear. These measurements can be integrated over the entire deforming zone in order to estimate the amount of total vertical shortening. We have measured quartz crystallographic axes orientations from mylonitized granodiorites collected along a transect through the BLD. These data have been combined with measurements of strain geometry, axes orientation, and strain magnitudes to yield a vorticity number and to ultimately be able to calculate the amount of zone-perpendicular thinning incurred within the BLD. Preliminary data for the BLD yield an estimated 67% vertical shortening.

28-10 **BTH 25** Almand, John, M.

UNMAPPED OCCURRENCE OF CHIASTOLITE SCHIST IN WESTERN MARIPOSA COUNTY, CALIFORNIA, EXTENDING THE RANGE OF METAMORPHISM FOR INCLUSION IN SMALL SCALE GEOLOGIC MAPS OF CALIFORNIA

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The Chiastolite variety of Andalusite is identified by dark colored inclusions of carbonaceous material making a distinctive cross-shaped figure in cross section. Andalusite is typically formed in the contact aureole of igneous intrusions into argillaceous rocks. Our study is to better resolve the

extent of this metamorphic locale, with the goal of including this as an update to future geologic maps of the area.

The location we studied is currently included on the Geologic Map of California (Jennings, 1977, updated in 2010 by Gutierrez, Bryant, Saucedo and Wills). Previous workers (Taliaferro et.al., 1930, Best, 1961, Bortugno, 1983, Wagner et.al., 1991) map our location as Upper Jurassic-Lower Cretaceous marine sandstone and shale, minor conglomerate, chert, slate, limestone, and minor pyroclastics. The region mapped is approximately one mile wide and 6 miles long. Other occurrences reported include Turner (1892) who reported chiastolite, sillimanite and mica; and Butler and Gale (1912) identify Tres Cerritos Buttes, approximately 1-2 km northwest of our site as containing Chiastolite associated with meta-greenstone and metamorphosed augite-andesite tuff.

Our study extends this region of metamorphism by 30 kilometers to the south east, with the farthest occurrence outcropping at Deadman Creek in Mariposa County, California.

The majority of the field work was completed at Bear Creek California, with other investigations at Owens Creek, Mariposa Creek, and Deadman Creek.

We collected over sixty orientations of the foliations in outcrops along a property that has, according to the property owner, not been studied in 150 years. Samples were collected for further optical and geochemical study.

Our findings increase the extent of the metamorphic range, in area, to the scale that inclusion in future maps is possible.

28-11 **BTH 26** Walters, Jesse

MODELING P-T PATHS FOR A GT-KY GNEISS FROM THE N. QAIDAM HP/UHP BELT WESTERN CHINA

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A Gt-Ky paragniess from the Dulan region, N. Qaidam HP/UHP, belt contains the assemblage Bt + Pl + Kfs + Gt + Ky + Qtz + Rt + Ap. A pseudosection constructed for the sample's bulk composition predicts the observed assemblage to form at ~11-15 kbar and ~810-870 °C, which is consistent with previously determined peak conditions of 13-17 kbar and 790-880 °C for mafic granulite pods hosted by the gneiss. The pseudosection predicts ~2-8 vol % melt coexisting with the observed assemblage. Predicted abundances also closely match observed values, with 8-18 vol % Gt and 0-10 vol % Bt in the pseudosection, and 10-15 vol % Gt and 10 vol % Bt in the sample.

Compositional isopleths intersect at lower T than the above values predicted for the observed assemblage field. Pl isopleths intersect at 12.5 kbar , ~700 °C, and Gt rim isopleths converge at ~12-12.3 kbar and ~660-670 °C. This agrees with previous P-T estimates of 13-15 kbar and 730-775 °C for the gneiss using the Gt-Bt thermometer and GASP barometer. Average Gt size is 0.2 mm, and exhibits limited zoning with average core values of $Alm_{58}Prp_{17}Grs_{23}$ and rim values of $Alm_{69}Prp_{19}Grs_{16}$. This suggests Gt re-equilibrated ~190 °C down T, representing a segment of the P-T path from the observed assemblage to the isopleth intersections.

To model melt loss potential, a melt-reintegrated bulk composition is estimated by calculating the composition of the initial (low-T) melt, and adding it to the sample's bulk composition until the melt-in reaction is bounded by H_2O saturated fields. The melt-reintegrated pseudosection predicts a maximum of ~20-35 vol % melt in coexistence with the observed assemblage, ~ 80-85 % of which is lost during peak metamorphism. Melt loss is supported by the lack of retrograde Ms and field evidence for melt escape.

The reintegrated pseudosection displays a Kfs-in reaction, which is consistent with reaction textures in thin section that display Kfs growing around Pl. The prograde P-T path passes through the Kfs-in reaction (~15.5 kbar, 750 °C) to the observed assemblage (~12 kbar, 850 °C), after which melt is lost. This is supported by Gt growth over fields containing Ms, which occurs as inclusions in Gt. This two part P-T path for the host gneiss is consistent with estimates for mafic granulites, supporting a shared P-T history.

28-12 **BTH 27** Kenney, Michael J.S.

MICROSTRUCTURAL ANALYSIS OF QUARTZ MYLONITES AND NEW U-PB ZIRCON AGES OF CRETACEOUS INTRUSIONS IN THE CENTRAL PART OF THE NORTHERN SNAKE RANGE METAMORPHIC CORE COMPLEX, NEVADA

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The northern Snake Range (NSR) in eastern Nevada is a classic metamorphic core complex with a footwall composed largely of mylonitic quartzite, schist, marble and assorted intrusive rocks. The timing of mylonitization is poorly constrained but was previously attributed to the same extensional event that produced rapid cooling of the footwall and large-scale slip on the northern Snake Range Decollement (NSRD) at 15-20Ma. Intrusions in the central part of the NSR include: the Horse Canyon orthogneiss (Khg) and abundant leucogranite dikes and sills. New LA-ICPMS U-Pb zircon ages of 101Ma for Khg and 85Ma, 85Ma and 84Ma for 3 different leucogranite bodies generally confirm previous dating by Miller et al. (1989-Rubey Vol VII). A fine-grained 2-mica granite that cuts some of the leucogranite sills yielded a distinctly younger age of 76.1 ± 1.5 Ma signaling a protracted late K magmatic history.

Mylonitic quartzites from Smith Creek, Horse Canyon, and Deadman Creek possess a conspicuous L-S fabric with a consistent ESE trending stretching lineation and gently E-dipping foliation. Thinning of stratigraphic units and aspect ratios on stretched pebbles indicate high strains (X/Z > 10). Ubiquitous kinematic indicators (S-C fabric, mica fish, sigma clasts, oblique grain shape foliations, CPOs) consistently indicate top-to-SE shear sense. . EBSD analyses of quartz CPOs indicate predominantly prism<a> slip with variable amounts of rhomb<a> slip and alternating dominance of regime I and regime II. Recrystallization textures are dominated by subgrain rotation, with lessor grain boundary migration and bulging recrystallization, Together, these observations suggest temperatures of deformation between 400-500°C. New and previously published argon thermochronologic data indicates that most of the footwall had cooled below 350°C by 20Ma, suggesting mylonitic deformation occurred prior to the Miocene unroofing event. We suggest that the mylonitic deformation of the footwall occurred during an earlier (Eocene) unroofing evnt following late Cretaceous thickening.

28-13 **BTH 28** Monroe, Evan

GEOCHRONOLOGY AND STRAIN ANALYSIS OF THE JURASSIC PLUTONIC COMPLEX ON THE SOUTHERN FLANK OF THE NORTHERN SNAKE RANGE, NEVADA

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The Jurassic Silver Creek and Old Man's Canyon plutonic complex (Miller et al, 1999 –NBMG MFS Map#21) is exposed in the footwall of the Northern Snake Range Decollement along the southern flank of the range. The Old Man's Canyon pluton generally grades westward from hornblende diorite to two mica granite over 10 km. Three new LA-ICPMS U-Pb zircon ages indicate an emplacement age of this entire compositional spectrum at 159-160 Ma. The Silver Creek 2 mica granite is compositionally more homogeneous and clearly cuts the Old Man's Canyon plutonic complex. Two new LA-ICP-MS U-Pb zircon ages suggest a more protracted but distinctly younger emplacement age of 154.21±0.76 to 151.6±0.48 Ma. The plutonic complex and adjacent meta-sedimentary wall rocks are variably deformed by a mylonitic ESE trending mineral stretching lineation and weakly developed subhorizontal foliation. Grain shape fabrics in the plutons and stretched pebbles in metasedimentary pendants consistently indicate a strongly constrictional strain with top-to-SE sense of shear. Microstructural analysis of >20 samples of plutonic rock and mylonitized quartzite pendants within the pluton suggests that strain is extremely heterogeneous; some samples show little or no evidence of deformation while others have strongly developed mylonitic fabrics and crystallographic preferred orientations. EBSD analyses reveal a variety of CPO patterns for quartzite samples including Type II crossed girdle and single Y-axis maxima, suggesting activity of basal <a> slip, rhomb <a> slip, and prism <a> slip. Ubiquitous synkinematic growth of biotite, dynamic recrystallization of k-spar, grain boundary migration, and subgrain rotation recrystallization all suggest that deformation occurred at 450-550°C (Regime I or II). The mylonitic fabric is interpreted to be late Eocene or early Oligocene and distinctly older than the rapid Miocene slip event on the NSRD based on (a) new 36 Ma (U-Pb zircon) age on a granodiorite dike that is at least partially involved in the mylonitization and (b) a new U-Pb zircon age of 23.3±0.09 Ma age on an undeformed rhyolite dike in the Silver Creek drainage that cuts all of the mylonitic fabric.

28-15 **BTH 30** Scheftner, Tonya Renee

STRATIGRAPHIC, PETROGRAPHIC, GEOCHEMICAL, AND STRUCTURAL ANALYSIS OF PILLOW LAVAS AND OVERLYING METASEDIMENTS: COLEBROOKE SCHIST, SOUTHWESTERN OREGON

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The Colebrooke Schist (CS) is part of the Late Mesozoic-Cenozoic Franciscan Complex. It consists of metamorphosed shale and sandstone with minor pillow lava (PL), tuff and chert of blueschist-greenschist grade. We examined a quarry in the CS, 7.3 km NW of Agness, Oregon, 1 km south of Upper Jurassic Galice metasediments, to obtain a detailed history of the Colebrooke sea floor. The quarry exposes a shallowly NW-plunging anticline, cored by flattened PL and pillow breccias overlain by foliated metasediments. The rocks are cut by steep quartz-epidote veins and faults. Locally, a distinct, dark-colored, metalliferous metasediment (MM) overlies the PLs.

PLs contain relict augite, altered plagioclase, and secondary pumpellyite, chlorite, quartz, and sphene, calcite, chlorite, and stilpnomelane or biotite. Pillow breccias have altered pillow fragments in a fine matrix of augite grains, basalt fragments, and secondary calcite, quartz, biotite, pumpellyite, epidote, and blue amphibole. The overlying metasediments are foliated cherts and argillites with varying amounts of opaque minerals and randomly oriented biotite or stilpnomelane.

The MM and a PL , located 2 cm beneath it, were analyzed geochemically. The PL is LREE-depleted, has 16.55 wt. % FeO* 3.62 wt.% TiO_2making it a Fe-Ti basalt, has a MORB-like Ti/V of 41, plots in the MORB field within the mantle array on a plot of Th/Yb vs Ta/Yb. The MM contains 28.4 wt% FeO*, 8.9 wt.% MnO, 1567 ppm Cu, 342 ppm Zn, 264 ppm Ni and 1531 ppm V; however, the extremely high concentrations of Cu, Mn, and V exceed the lab's highest calibration standards. In addition, sulfur-loss on heating led to low totals. Although the results are semi-quantitative, the high metal concentrations are typical of modern metalliferous sea-floor sediments.

The MM's location immediately above the PLs is evidence for on-axis hydrothermal activity suggesting a ridge-transform intersection rather than a propagating rift-tip where metal-rich layers would be higher in the section although such sediments occur in both environments. The chert and argillite evidence a pelagic environment with pulses of terrigenous mud. The folded foliation records two episodes of deformation. Pumpellyite, greenschist- and blueschist-facies metamorphic minerals suggests progressive metamorphism and indicates subduction.

28-16 **BTH 31** Alonzo, Benigno

NEW CHEMICAL RELATIONSHIPS FROM DRILL CORE IN THE SNAKE RIVER PLAIN, IDAHO

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Scientific and exploratory test wells and core holes dot the landscape of the Snake River Plain (SRP). Over the last 25 years, this has been mainly carried out at Idaho National Laboratory (INL). Unlike the extensive drilling at INL, the stratigraphy and geochemistry of subsurface lava flows from the margins of the SRP and the CSRP has been less reported. We report whole rock major and trace elements from the rhyolite section of Sugar City geothermal test well, near Rexburg, ID and major and trace elements in olivine from the Wendell (RASA) hydrologic test well, near Wendell, ID.

The Sugar City geothermal test well, near Rexburg, ID, cored basalts, rhyolite lava flows, and tuffs from the western margin of the Heise caldera complex. Analyses from the basalt section have been previously presented (Jean and Shervais, 2010). This new work focuses on the rhyolite and welded tuff section of this core, which constitutes 520 meters of core. Our new work demonstrates a large increase in LOI for depths between 500-600 meters, coupled with changes in major elements, i.e., decrease in SiO_2 and Na_2O and increase in Fe_2O_3, MgO, and Al_2O_3. While REE composition for our rhyolite samples is still being analyzed, lanthanum and cerium show relatively large ranges.

The Wendell (RASA) hydrologic test well penetrated an upper basalt unit from 0.305 to 122.8 m (Snake River Group) and a lower basalt unit from 179.8 to 327.1 m (Idaho Group). Average olivine concentrations include; SiO_2=37.48 wt.%; TiO_2=0.02 wt.%; Al_2O_3=0.05 wt.%; FeO=21.50 wt.%; MgO=40.00 wt.%; CaO=0.10 wt.%. Magnesium decreases with depth, while SiO_2 increases with depth. These relationships suggest the possible occurrence of magma recharge and fractionation. Investigating REE's by the use of LA-ICP-MS shows promise in determining similarities in REE concentration to other standards, such as NMORB, primitive mantle, and OIB. Although this phase of the study is still currently in process, some preliminary correlations are suggested. The general trend for REE concentration appears to be an increase in REE content with depth. Our data shows a spike in Gadolinium (Gd) when normalized to all standards with an enrichment factor of up to 30.8 when normalized to C1-Chondrite. The frequently appearing spike in Gd suggests that a more careful approach to analyzing REE concentrations is needed.

28-17 **BTH 32** Shaddox, Heather Rose

A NEWLY DISCOVERED SHEETED DIKE COMPLEX ON THE WESTERN MARGIN OF THE IRON MOUNTAIN PERIDOTITE, WITHIN EASTERN ELK OUTLIER OF THE WESTERN KLAMATH TERRANE, SOUTHWESTERN OREGON

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The Western Klamath terrane (WKT) consists of the ca. 162 Ma Josephine Ophiolite (JO) conformably overlain by the Upper Jurassic Galice Formation. Both are intruded by 150 to145 Ma calc-alkaline intrusives and are unconformably overlain by Lower Cretaceous strata. The Elk outlier (EO) of the WKT, in the southern Oregon Coast Range, has geology similar to the WKT except for the absence of a complete ophiolite. Sheeted dikes in the western EO tentatively correlate with the JO. This study concerns what we interpret to be foliated sheeted dikes, and dikes cutting both gabbro and cumulate ultramafic rocks exposed in a 4.5-km long, north-trending belt east of the Iron Mountain peridotite and west of the Galice Formation in the eastern EO.

A 300 m east-to-west traverse reveals vertically faulted, variably serpentinized cumulate ultramafics, diabase dikes cutting gabbro, and mafic schist. The cumulate ultramafics contain primary augite, opaques, serpentine pseudomorphs, and secondary uralite, tremolite, chlorite and prehnite. The gabbro contains augite, brown hornblende, plagioclase altered to epidote(?) opaques, secondary actinolite, tremolite, and rare serpentine. Diabase dikes cut gabbro, are roughly parallel (ca. N25°E, 75°E) and contain plagioclase altered to albite, and secondary uralite, epidote, and sphene. A steep foliation in the mafic rocks increases in intensity to the west where gabbro is absent. Here, the rocks are chlorite-actinolite schists consisting of aligned albitized plagioclase, uralite, and chlorite, with minor epidote, sphene and opaques. The presence of a chilled margin in the schist and its similarity in mineralogy and texture to a deformed dike cutting gabbro suggest that the schists are deformed sheeted dikes.

Geochemical analysis of two samples reveals that dike I, which cuts gabbro, is LREE-depleted, plots in the island arc tholeiite (IAT) field on Ti vs V, Cr vs Y, and Th/Yb vs Ta/Yb diagrams. The dike has IAT affinity. Schist P is LREE-enriched, has higher REE concentrations, plots in the MORB field on a Ti vs V diagram, within the IAT field on a Th/Yb vs Ta/Yb diagram, and is a transitional IAT-MORB derived from more enriched mantle than dike I. The rocks are part of a suprasubduction zone ophiolite and are geochemically and petrographically very similar to the two types of intrusives from the JO.

28-18 **BTH 33** Raisis, Alyssa

HYDROVOLCANISM IN THE HIGH ROCK CALDERA, NORTHWESTERN NEVADA

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Hydrovolcanic tuff cones are scattered throughout the interior of the High Rock Caldera, in northwestern Nevada. One set of tuff cones, at latitude 41.487° N, longitude 119.433 ° W., informally named "the Bear Paws" was chosen for study. The cone assemblage is about 1.4 km x 0.6 km, elongated north-south. Aerially, the Bear Paws appear to be two cones, North and South Paw. The tuff cones erupted through caldera-filling lacustrine deposits and are likely to be the youngest magmatic event of the approximately 16 Ma High Rock Caldera, one of the oldest calderas along the NE-trending Yellowstone hotspot path.

Stratigraphic and textural evidence reveals that the Bear Paws tuff cone eruptions were emergent to subaerial. Only the innermost vent facies is preserved with the uppermost and exterior portions of the cones eroded away. There is one emergent and two subaerial stratigraphic units surrounded by older, interbedded caldera fill and lacustrine deposits. The matrix of the cones has been moderately to highly palagonized and is weathered, with many volcanic clasts also showing secondary alteration. Hyaloclastite beds dip 45-68° towards the vent, vastly greater than typical tuff cones, which dip 20-25°. Soft sediment deformation and repeated slip failure back into the vents accounts for the steep dips with subsequent cementation by palagonitization. Dike swarms along the periphery of both cones appear to have slumped outward from the interior of the cone.

The Bear Paws are basalt composition and erupted after siliceous and intermediate volcanism ended at the High Rock Caldera. The Bear Paws vented along a migrating path from south to north, producing the double cone morphology. The migration may have followed the course of a dike. After the hydrovolcanic eruptions, lake levels rose and fluctuated creating two wave-cut platforms and eroding much of the upper and outer parts of the cones.

Geochemical and petrographic analyses show that the Bear Paws are the most mafic magmas erupted at the High Rock Caldera, with juvenile clast silica content as low as 43%. On major and trace element variation diagrams the basalt lies along linear and curvilinear differentiation trends of High Rock Caldera magma compositions. The basalt appears to represent a parental composition that may have evolved to form the entire High Rock Caldera magmatic suite.

28-19 **BTH 34** Rodd, Rebecca L.

A PALEOMAGNETIC RECONNAISSANCE STUDY OF THE POWDER RIVER VOLCANIC FIELD, UNION COUNTY, OREGON

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The Powder River Volcanic Field is a series of middle Miocene extension-related lava flows exposed along the margins of the Grande Ronde Valley in northeastern Oregon. Oriented samples for a paleomagnetic reconnaissance study were collected from nine units at three sites in the PRVF. Samples were subjected to progressive alternating field demagnetization to determine primary paleomagnetic directions and to study the general magnetic behavior of the PRVF. Five of the units were lava flows; one was a volcaniclastic deposit: and three represented different horizons below a baked contact. Three of the lava flows and one of the units beneath the baked contact demagnetized smoothly and showed uni-vectorial decay toward the origin. Two of these units have normal inclinations (~65°), but southern declinations ranging from -105° to -140°. The other two units have reversed inclinations (~-70°) and southern declinations ranging from 140° to 200°. The median destructive fields (MDFs) ranged from 20mT to 30mT. The other lava units did not demagnetize fully, but also have normal inclinations and southern declinations. The volcaniclastic unit and other units beneath the baked contact did not demagnetize fully, but have reversed inclinations and southern declinations. Magnetic directions from the unit immediately below the baked contact indicate the unit had been heated above the Curie temperature by the overlying flow. The paleomagnetic results appear to be reliable but the normal inclinations/ southern declinations are anomalous. One possibility is that these units were deposited during a geomagnetic reversal or excursion. Another possibility is that we sampled a small tectonic block that has been significantly rotated. These results indicate the PRVF is suitable for further paleomagnetic study and that additional work is needed to resolve the origin of the anomalous directions.

28-20 **BTH 35** Choi, Na Hyung

THE ORIGIN OF UNUSUAL PHOSPHATE DEPOSITS ON THE VENEZUELAN ISLAND OF GRAN ROQUE, LEEWARD ANTILLES

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The bedrock geology of the Leeward Antilles island of Gran Roque has long been interpreted to be exposures of the Caribbean Plate, which formed when existing Pacific oceanic crust was thickened by oceanic plateau mafic magmatism. The mafic complex on Gran Roque consists of older amphibolite facies rocks derived from a diabase protolith and younger coarse-grained gabbros containing a low-grade static metamorphic overprint of prehnite ± actinolite. The gabbros have yielded an 87.0 ± 4.1 Ma U-Pb micro-zircon age. The age, petrography, and geochemistry of the mafic complex are consistent with a Caribbean Plate origin, supported by their similarity to those of other Caribbean Plate exposures on nearby islands Aruba and Curaçao. In the mafic complex, the older amphibolites may represent an earlier phase of plateau magmatism or the pre-existing Pacific oceanic crust. We interpret the intrusion of the gabbros to have been the heat source for amphibolite facies metamorphism. The mafic complex was then intruded by a quartz diorite (65.6 ± 1.4 Ma U-Pb zircon age) with island arc geochemistry and associated dikes and sills of hornblende dacite, pegmatite (65.3 ± 0.91 Ma U-Pb zircon age), and granophyre.

Also within the mafic complex are visually striking phosphate deposits. The best exposures are on the western part of the island, where rinds of green phosphate surround spheroidally weathered corestones of gabbro. X-ray diffraction indicates that the deposits principally consist of the unusual minerals variscite, phosphosiderite, and strengite. The quartz diorite and its associated dikes and sills are not phosphatized and sharply cross-cut the phosphatized rocks of the mafic complex. Thus, the spheroidal weathering and phosphate formation occurred between ca 87-66 Ma. This period of subaerial weathering is broadly consistent with those documented on Aruba and Curaçao. We attribute the phosphate formation to rainwater leaching Cretaceous guano deposits and subsequently reacting with the weathered mafic complex. Similar modern processes have been observed and described from other localities.

SESSION NO. 29, 8:40 AM

Wednesday, 22 May 2013

T6. Using Detrital Zircon Age Data to Reassemble the Cordilleran Jigsaw Puzzle

Radisson Hotel and Conference Center, Salon A1

29-1 **8:40 AM** Ingersoll, Raymond V.

MESOZOIC-CENOZOIC DRAINAGE DIVIDES FOR SOUTHERN CALIFORNIA RIVERS, AS DETERMINED BY DETRITAL ZIRCONS, WITH IMPLICATIONS FOR EVOLUTION OF GRAND CANYON, THE COLORADO RIVER AND THEIR PRECURSORS

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Central to debate about the age, origin and evolution of Grand Canyon is the history of the Colorado River and its precursors. Reversal of dextral slip along the San Andreas fault system restores southern California to a position at the downstream end of the Early Pliocene course of the Colorado River. If the Colorado River flowed across southern California to the Pacific prior to 6 Ma, then sand deposited by it would have distinctive detrital-zircon age distributions reflecting erosion of upper Paleozoic and lower Mesozoic strata of the Colorado Plateau. The latter contain 300-1100 Ma zircon that was originally transported from orogenic belts along southeastern Laurentia. Lower Paleozoic, upper Paleozoic, Triassic, Lower to Middle Jurassic, and Upper Jurassic to Cretaceous sandstone of the Colorado Plateau contains average concentrations of 300-1100 Ma zircon of 4%, 32%, 46%, 44% and 30%, respectively. Not surprisingly, Plateau-derived sand in the modern Colorado River averages 29% 300-1100 Ma zircon. Triassic to lowest Cretaceous metasedimentary wallrocks of the mid-to-Late Cretaceous southern California magmatic arc contain 34% 300-1100 Ma zircon, indicating that sand similar to that on the Plateau reached the Pacific Ocean. In contrast, only trace amounts of 300-1100 Ma zircon occur in younger southern California sandstone. Stratigraphic groupings of age distributions of 6662 detrital zircons from 167 broadly distributed sandstone samples from coastal deposits of southern California average 44-88% Cretaceous, but only 0.4-1.3% 300-1100 Ma grains, most of which can be attributed to recycling from older deposits. No individual Upper Cretaceous to Pliocene sandstone sample contains greater than 3% 300-1100 Ma zircon. Although Paleogene headwaters of southern California rivers extended into the eastern Mojave Desert, Sonora and Mogollon Highlands, our observations indicate that these headwaters did not extend as far inland as the Colorado Plateau. This conclusion conflicts with the model of a SW-flowing Arizona River during the Paleogene, but supports rapid Late Miocene-Pliocene drainage reorganization and integration of the Colorado River coincident with development of the Salton Trough and Gulf of California.

29-2 **9:00 AM** Hollis, Natalie

AGE, PROVENANCE, AND LATERAL VARIATION OF DETRITAL ZIRCON POPULATIONS IN THE PENINSULAR RANGES FOREARC BASIN, ORANGE COUNTY, CA

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U-Pb detrital zircon (DZ) data from Late Cretaceous sediments of the Peninsular Ranges (PR) forearc basin display lateral and outcrop-scale variation in the proportions of zircons derived from the arc and its metamorphic framework, as well as extra-regional sources. Sandstone samples were collected along two traverses across the Late Cretaceous Ladd and Williams Formations, exposed along the western flank of the Santa Ana Mountains: (1) a northern traverse along Silverado and Williams Canyons; and (2) a southern, along the Ortega Highway, ~23 km to the south. The Arizona LaserChron Center's LA-ICP-MS was used to measure the U-Pb dates of 87 to 99 DZs from six samples. Maximum depositional ages (MDA) estimated from the DZ data are compared to biostratigraphic estimates of sediment age. MDAs of the stratigraphically lowest sample (Baker Canyon mbr, Ladd Fm) from the north and south transects are indistinguishable (97.9+3.0 Ma (N); 97.0+1.6 Ma (S)), but are significantly older than the stratigraphic age of 91-89 Ma. Samples from the overlying Williams Fm (Schulz Ranch mbr) also exhibit differences between the estimated MDAs and stratigraphic age (83-75 Ma), as well as differences in MDA along strike: 97.3+1.4 Ma (N) and 88.5+1.4 Ma (S). Two samples of the stratigraphically highest unit, (Pleasants mbr, Williams Fm), also display lateral variations in MDA: 75.3+1.8 Ma (N) and 84.0+1.2 Ma (S), though both MDAs fall within the unit's stratigraphic age of 83-75 Ma. The stratigraphically lowest samples have the greatest amount of arc-derived DZs, while the stratigraphically highest sample contains a significant population of extra-regional DZs. Possible origins of these extra-regional DZs include ≈83 Ma plutons exposed in the northeastern PR batholith and ≈75 Ma plutons exposed in western Arizona. These data suggest that the northern and southern drainage basins were isolated, with differing amounts of metamorphic framework contributing to the detritus. These mismatches between MDAs and stratigraphic ages suggest that the arc may have been dormant between ≈95 and 91 Ma, or possibly later (≈83 Ma) in the vicinity of Silverado Canyon. The appearance of extra-regional DZs in the Pleasants mbr indicates that the arc crest was breached by ≤83 Ma fluvial systems that transported zircons from Laramide-aged uplifts east of the PRB.

29-3 **9:20 AM** Saleeby, Jason

DETRITAL ZIRCON U/PB AGES OF UPPER MIOCENE TO PLEISTOCENE STRATA OF THE SE SAN JOAQUIN BASIN (SJB) IN COMPARISON TO ZIRCON AGE PATTERNS OF THE SOUTHERN SIERRA NEVADA BATHOLITH (SNB)-IMPLICATIONS FOR LATE CENOZOIC SEDIMENT PROVENANCE AND DISPERSAL PATTERNS

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Detrital zircon (dz) ages from upper Cenozoic strata of the SE SJB are compared to a large database on southern SNB zircon ages as a means of better resolving sediment provenance and dispersal patterns as well as the incision history of the lower Kern River basement gorge. Recent stratigraphic and depth of burial studies show that ~1500 m of SJB strata sat nonconformably above the low relief basement surface that the lower Kern gorge incised through over the past ~1 m.y., calling into question the Kern River as the principal source channel for the Kern River Fm. We focused our studies on the Kern River Fm., and adjacent units such as the Bena and Chanac, which are partly equivalent to the Kern River Fm. These strata all constitute a distinct plutonoclastic lithosome that based on dz data and distinct clasts of Neogene andesite/dacite, was derived from the extreme SE Sierra Nevada. The Neogene clasts were derived from the Cache Peak volcanic center, whose basal ignimbrites contributed distinct ca. 21 Ma volcanic zircon to the SE SNB-dominated dz population. This lithosome was delivered to the SE SJB through a major river trunk that we call the Caliente River, whose terminal channel is clearly expressed in DEMs, issuing westwards into the SJB ~10 km south of the lower Kern gorge. The Pleistocene channel walls of the lower Caliente River consist of the same lithosome, which we further trace into the subsurface as the principal lobes of the Stevens submarine fan. The Kern River-Bena-Chanac lithosome represents an upper middle Miocene through Pliocene fluvial-deltaic system that was delivered into the SE SJB through a structural trough that we call the Edison graben. The principal lobes of the Stevens submarine fan formed directly off the delta front. Greater Kern River drainage basement ages and matching dz ages from terrace sands within the lower Kern River are distinct from those of the Caliente lithosome. The Kern drainage dz signal is present in green mudstones and siltstones of latest Miocene-early Pleistocene age, and which replace the Caliente lithosome north of the lower Kern River. These strata are more akin to the Etchegoin and San Joaquin Fms. In parallel, the northern (Rosedale) lobe of the Stevens fan system contains the Kern drainage dz, signaling the deflection of the Kern drainage lithosome by the more voluminous Caliente lithosome.

29-4 **9:40 AM** Johnston, Scott M.

DETRITAL ZIRCON GEOCHRONOLOGY OF THE TORO FORMATION, NACIMIENTO BLOCK, CENTRAL CALIFORNIA COAST

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The California Mesozoic arc is commonly cited as the archetypal example of a convergent margin tectonic setting, although the juxtaposition of Nacimiento Block subduction mélanges and Salinian Block arc rocks across the enigmatic Sur–Nacimiento Fault in the central California coast serves as a reminder of the complexity of the Cordilleran Mesozoic forearc. Prior to Cenozoic slip along the San Andreas Fault, these central California coast terranes restore to a position near the present-day latitude of San Diego, although earlier slip along the Sur–Nacimiento Fault is poorly understood, and alternate models for its evolution call for either sinistral strike-slip, dextral strike-slip or thrust displacement. Here, we present detrital zircon ages from the Toro Formation as part of a broader study investigating the provenance of Nacimiento Block sediments that is designed to place new paleogeographic constraints on the evolution of the Sur–Nacimiento Fault.

The Late Jurassic–Early Cretaceous Toro Formation is dominated by mudstone interlayered with sandstone and rare conglomerate that rests unconformably above Jurassic ophiolite, and 4 sandstone samples were selected for detrital zircon geochronology by LA-ICPMS at the UC Santa Barbara. The youngest zircons from each sample indicate Tithonian and Valanginian maximum depositional ages that are consistent with fossil ages in adjacent outcrops, while Cordilleran-aged grains cumulatively define probability maxima at 140–150, and ~168 Ma, and a lesser peak at ~258 Ma. Pre-cordilleran zircons comprise ~60% of the analyzed grains, and broad probability peaks occur at 1.0–1.2, ~1.45, and 1.6–1.8 Ga. Toro Formation conglomerate clasts are dominated by chert, although quartzite and sandstone clasts are not uncommon; detrital zircon results from 7 individual conglomerate clasts reveal a suite of Triassic sandstones, and quartzites that are dominated by pre-Cordilleran ages with 1.0–1.2, 1.4 and 1.6–1.8 Ga ages. These initial results suggest that Late Jurassic and Early Cretaceous Nacimiento Block sediments were dominated by input from miogeoclinal source terranes in the continental interior and from the growing Middle–Late Jurassic Sierran/Salinian arc, and mixed with a minor, but measureable component derived from early Cordilleran arc terranes.

29-5 **10:00 AM** Clemens-Knott, Diane

DETRITAL ZIRCON EVIDENCE FOR LINKAGES BETWEEN MESOZOIC SEDIMENTARY SYSTEMS ALONG THE WESTERN FLANK OF THE SIERRA NEVADA ARC

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Detrital zircon U-Pb data from pendants in the SW Sierra Nevada batholith and from sediments exposed along the western Great Valley (all sites ~36°N latitude) document linkages between marine and nonmarine deposition along the western flank of the Mesozoic arc and the Great Valley forearc regions. Linkages are supported by statistically similar provenance data from (1) rare, fine-grained siliciclastic horizons associated with ribbon cherts and carbonates of the Early Triassic Calaveras Complex; (2) medium-grained turbiditic sandstones of the Early Jurassic Kings Sequence; (3) fluvial conglomerates and sandstones of the Early Cretaceous Goldstein Peak Formation; and (4) Early to Late Cretaceous turbidites of the Gravelly Flat formation at the base of the Great Valley Group. These Mesozoic sediments document the transition from Triassic deep marine to Jurassic arc apron to Early Cretaceous marine forearc and nonmarine intra-arc environments, and together reflect the emergence of the mid-Cretaceous continental margin arc. Similarities between Goldstein Peak fluvial deposits and lowermost Gravelly Flat forearc deposits, each comprising subequal contributions from the Mesozoic arc and pre-Mesozoic sources, support a linkage between the Early Cretaceous Goldstein Peak intra-arc basin and deposits in the nascent forearc basin. In addition, statistical similarities between the pre-Mesozoic zircon populations in the Early Cretaceous fluvial conglomerates from the western arc flank and in the forebasin to the east (Buckthorne Conglomerates; Lawton et al., 2010) suggest overall similarities between pre-arc zircon populations that were mobilized during the Early Cretaceous on both sides of the arc axis. Moreover, statistical similarities between zircon populations in Permo-Triassic sediments on both sides of the arc suggest transport of North American zircons westward across the arc axis, possibly in part by aolian transport, and tie Permo-Triassic marine sediments exposed in the western Sierra Nevada foothills to the western North American zircon system. Possible extension of the foothills metamorphic-Early Cretaceous igneous complex westward into the eastern basement of the Great Valley forearc basin would extend linkages of the eastern forearc basement to North America back to the early Mesozoic.

29-6 **10:40 AM** Linde, Gwen M.

THE PROVENANCE CHALLENGE OF THE HARMONY FORMATION IN CENTRAL NEVADA: AN ENIGMATIC PIECE IN THE CORDILLERAN JIGSAW PUZZLE

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The Harmony Formation is a poorly understood unit within the Roberts Mountains allochthon (RMA) of northern Nevada: it is structurally highest in a stack of nappes derived from the west, its age is equivocal (Cambrian or possibly Devonian?), and it comprises two distinct petrofacies with different detrital zircon (DZ) age spectra. Our new samples and mapping highlight the enigmatic nature of the Harmony Formation and place some limits on its origins.

The two petrofacies record very different provenance. Harmony A is a quartzose wacke with DZ ages mainly in four groups: 980 Ma-1.2 Ga, 1.3-1.5 Ga, 1.6-1.8 Ga, and 2.4-2.5 Ga. These are consistent with derivation from the Grenville orogeny, the midcontinent region, the Mazatzal Province, Yavapai Province, and the Archaean craton, respectively. The DZ age spectra of the Harmony A are dissimilar from those of any known RMA or western Laurentian passive margin unit, but are similar to those in Laurentian Cambrian passive margin strata of the (present-day) Arctic. Harmony B is an immature arkosic wacke with DZ ages mainly in two groups: 1.7-1.9 Ga and 2.5-2.6 Ga. These are consistent with derivation from the Yavapai Province, Trans-Hudson Orogen, and the Archean craton, respectively. Although its arkosic composition is distinctive, the DZ age spectra of Harmony B are similar to those of coeval western Laurentian passive margin units, as well as Laurentian Cambrian passive margin strata of the (present-day) Arctic. Our mapping indicates the two units are conformable, and Harmony B is much more widespread.

Several alterative origins for the Harmony Formation are possible, including derivation on the Arctic Laurentian margin during Cambrian time. This would require subsequent tectonic transport to a position outboard of the RMA strata, with all then thrust onto the Laurentian craton.

29-7 **11:00 AM** Schmidt, Keegan L.

NEW DETRITAL ZIRCON AGES CONSTRAIN THE ORIGIN AND EVOLUTION OF THE RIGGINS GROUP ASSEMBLAGE ALONG THE SALMON RIVER SUTURE ZONE, WESTERN IDAHO

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Hornblende gneiss, calc-silicate quartzite, and uncommon marble of the Riggins Group assemblage comprise a nearly continuous high-grade metamorphic belt west of, and adjacent to, the north-south trending Salmon River suture zone in western Idaho. This assemblage, which attained lower-crustal metamorphic conditions during coeval intrusion of magmatic epidote-bearing tonalite-trondhjemite plutons in the Early Cretaceous (ca. 122 to 111 Ma), is sandwiched between lower metamorphic grade assemblages of the North American craton to the east and accreted Wallowa island arc terrane to the west. The origin and placement of the Riggins Group in the collage of Cordilleran tectonic terranes has been controversial for decades. Recent geologic mapping and new detrital zircon analyses provide constraints on the evolution of this important tectonic belt. Results from U/Pb LA-ICPMS detrital zircon analyses of two samples of amphibolite-grade hornblende gneiss yielded well-defined age modes of 202 Ma (+32, -50 Ma) and 198 Ma (+32, -19 Ma). In the former sample, zircon rims with low Th/U ratios yielded an additional mode

of 113 Ma (+12, -8 Ma) and are as young as 83 Ma. This age mode is similar to Lu/Hf garnet ages in the same sample. Significantly, no reliable ages older than 235 Ma were recovered from either sample. We interpret these data as follows: 1) sedimentary protoliths of the Riggins Group are Early Jurassic to Early Cretaceous deposits; 2) the dominant ca. 200 Ma age mode represents detrital zircon derived from early Mesozoic igneous source rocks; 3) the ca. 113 Ma age mode represents peak metamorphism coincident with tonalite-trondhjemite pluton emplacement; and 4) younger ages represent continued rim growth during mid- to Late-Cretaceous plutonism. The Riggins Group contains clastic material eroded from igneous sources and deposited in a basin that was isolated from cratonal input. Likely protolith rocks in accreted terranes to the west include the Jurassic Weatherby Fm. of the Izee terrane and the Triassic–Jurassic Hurwal Fm. of the Wallowa terrane.

29-8 **11:20 AM** LaMaskin, Todd A.

REASSESSING TERRANE BOUNDARIES IN THE BLUE MOUNTAINS PROVINCE OF EASTERN OREGON USING DETRITAL ZIRCON U-PB AGES

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One of the most complete and least deformed early Mesozoic stratigraphic records in the western U.S. Cordillera is present in the terranes of the Blue Mountains Province of eastern Oregon and western Idaho. Here, in marine rocks of Late Triassic through Cretaceous age, many unambiguous sedimentary structures, depositional contacts, and map relationships are preserved, allowing for detailed analysis of depositional and tectonic history. Traditionally defined terranes in the Blue Mountains Province include the Wallowa, Baker, Olds Ferry, and Izee terranes. The Wallowa and Olds Ferry terranes contain late Paleozoic to early Mesozoic igneous and sedimentary rocks that formed in two facing magmatic arcs. The intervening Baker terrane represents a deformed subduction-accretion complex and the Izee terrane consists primarily of Late Triassic–late Middle Jurassic sedimentary rocks. Detrital zircon U-Pb data challenge these traditional terrane definitions and provide unique insight into possible connections between areas previously considered distinct terranes. In the John Day region of central Oregon, Permo-Triassic rocks of the Baker terrane and Triassic rocks of the Izee terrane (Vester Fm.) contain an identical age distribution of Late Paleozoic and ca. 1.8–2.7 Ga grains. In contrast, structurally adjacent Late Triassic rocks of the Aldrich Mountains Group, typically mapped as Izee terrane contain a distinct age distribution of Silurian and 1.0–2.0 Ga grains. Structural and stratigraphic intercalation of these two age distributions has been used to argue for a northwestern-derived, Laurentian-Baltican origin for numerous subduction-accretionary complexes in the Cordillera. These data indicate a provenance affinity between rocks of the Baker terrane and *pre*-Early Jurassic rocks of the Izee terrane (Vester Fm. and Aldrich Mountains Group). In contrast, data from the Baker terrane (Burnt River Schist) and Izee terrane in the Huntington region of eastern Oregon are unimodal with ages centered on ca. 200 Ma. These data indicate a provenance affinity between rocks of the Baker terrane and *post*-Early Jurassic rocks of the Izee terrane (Weatherby Fm.). In both regions, new detrital zircon data suggest that the traditional terrane distinction between Baker and Izee terrane rocks is invalid.

29-9 **11:40 AM** Miller, Elizabeth L.

THE SECRET LIVES OF MOUNTAIN BELTS REVEALED BY U-PB DATING OF DETRITAL ZIRCON SUITES: THE LATE JURASSIC-EARLY CRETACEOUS BROADER BROOKS RANGE-VERKOYANSK OROGEN, ARCTIC ALASKA AND NE RUSSIA

MILLER, Elizabeth L.[1], SOLOVIEV, A.V.[2], and GOTTLIEB, E.S.[1], (1) Geological and Environmental Sciences, Stanford University, Stanford, CA 94305, elmiller@stanford.edu, (2) Russian Academy of Sciences, Geological Institute, Pyzhevsky 7, Moscow, 119017, Russia

The Brooks Range thrust belt is a classic N-vergent orogen with a telescoped S-facing continental margin sequence and structurally overlying oceanic and ultramafic allochthons. However, the driver or collider for orogenesis is missing, having rifted southward away from the orogen and subsequently buried by deep water basinal successions shortly after thrust faulting. These same relationships characterize a much broader sector of the Arctic for an along strike distance of more than 3000 km including the northern paleo-Pacific margin of NE Russia, where continental margin fold -thrust belts and syn-orogenic sedimentary rocks shed towards the exterior of the belt are coeval based on fossil control and cross-cutting relationships.

Detrital zircon studies from syn-orogenic sedimentary rocks along this belt show remarkable similarities and reveal the age range of the now missing arc system involved in orogenesis. Youngest zircons range from ~ 140-180 Ma, indicating that shortening between a Jurassic arc and the continental margin ultimately drove this orogenic event. The next older group of zircons ranges from ~ 250-320 Ma on the west to 200-320 on the east, with most of the population between 230 and 320 Ma. The colliding arc in the Russian sector included crystalline basement dated at ~1.8-2.0 Ga. In the Bering Strait region and Alaska, older components are more variable, represented by Siluro-Ordovician (420-480 Ma), Neoproterozoic (550-750 Ma) and 1-2 Ga and older zircons.

This data set suggests that it might be possible to locate and determine which terranes of the paleo-Pacific margins of NE Russia and the Cordillera could represent the remaining fragments of this arc terrane. In the inner zone of the Verkoyansk fold belt, upper Paleozoic and Mesozoic arc volcanic sequences have been identified. Similarly, in Alaska, the Jurassic Talkeetna arc was likely built upon an upper Paleozoic arc within the greater Wrangelia-Alexander Terrane.

SESSION NO. 30, 8:00 AM

Wednesday, 22 May 2013

T7. Hydrogeologic Issues of Irrigated Agricultural Regions–Problems and Solutions

Radisson Hotel and Conference Center, Salon A2

30-1 **8:00 AM** Suen, C. John

WATER SUPPLY ISSUES OF THE SAN JOAQUIN VALLEY IN CALIFORNIA

SUEN, C. John, Dept of Earth & Environmental Sciences, California State Univ, Fresno, 6014 N. Cedar Ave., Mail Stop OF-18, Fresno, CA 93710, john_suen@csufresno.edu and WANG, Dong, USDA Agricultural Research Service, San Joaquin Valley Agricultural Sciences Center, 9611 South Riverbend Ave, Parlier, CA 93648

The San Joaquin Valley of California is undoubtedly one of the most productive agricultural regions of the United States, and of the world. The valley was a Miocene epicontinental sea bounded by the Sierra Nevada igneous arc in the east and the Coast Range accretionary terrane in the west. It is now filled with thick layers of Neogene and Quaternary sediments derived from rocks with marine origin in the west and continental origin in the east. The valley encompasses 4 million hectares of rich farmland and has an annual production exceeding US$25 billion of fruits, nuts, vegetables, and livestock products, comprising approximately 20% of the U.S. agricultural production. However, the climate is semi-arid with average annual precipitations ranging from only 5 inches in the south to 13 inches in the north. Due to the warm dry climate and high evapotranspiration rates, irrigation is essential for all crops. On the east side of the valley, irrigation water is mostly derived from the Sierra snow melt. On the west side, water used for irrigation is imported from the more humid region in the northern part of the state through a network of canals and aqueducts built by both Federal and State government water projects. Ground water is also used for both east and west sides of the valley to supplement surface water sources. After years of intense irrigation, a number of water supply and water quality issues emerged. They include groundwater overdraft, land subsidence, water contamination by agricultural drainage laden with selenium, salinity buildup in soil and water, water contamination by nutrients from fertilizers and livestock production, competition for water supply with California's megalopolis, and also with environmental use and restoration. All these problems are intensified by the effect of climate change that has already taken place and other geological hazards, such as earthquakes that can bring the water supply system to a complete halt. To find practical and achievable solutions for these complex problems, scientists must employ a holistic approach. Towards this end, we cannot just rely on scientific research and technology development alone; we must also take into consideration of the social and economic contexts, and work with governments, stakeholders, and the community.

30-2 **8:20 AM** Cehrs, David

WATER DEMAND VS. SUPPLY, KINGS RIVER BASIN CALIFORNIA: IMPLICATIONS FOR CALIFORNIA AND THE AMERICAN WEST

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Water demand has exceeded supply in the Kings River Basin since 1945, with chronic groundwater overdrafts. Precipitation and surface water deliveries for irrigation have increased through time and all surface water is used, on average, in three out of four years. The best correlation with declining groundwater levels is with Fresno County population increases, which are projected to double by 2050. The economic base for the area is irrigated agriculture which uses the vast majority of the available water. Several water management scenarios are shown that would achieve basin wide water sustainability and include or consider retirement of irrigated land, irrigation efficiency, soil salinity, and domestic water use cuts. Climate change will exacerbate the water management options for achieving basin sustainability. The ultimate solutions for sustainable basin management will be based on societal choices carried out by political and judicial decisions.

30-3 **8:40 AM** Green, Sargeant

ATTAINING SUSTAINABLE USE OF SAN JOAQUIN VALLEY GROUNDWATER FOR AGRICULTURE, TECHNICAL AND INSTITUTIONAL ISSUES

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San Joaquin Valley agriculture is dependent on groundwater supplies for over 40% of total water needs. Declining availability of surface water imported into the area from the northern part of the State has returned the extraction rate to accelerated overdraft. Coincidentally, recent information on groundwater quality has shown that certain edaphic and hydrogeologic areas are contributing high levels of nitrates to shallow groundwater. Changes are needed in how to recharge groundwater and manage the lands, facilities and activities that have the greatest contribution to both supplies and quality. This discussion will present some of the current and proposed technical and institutional needs to optimize quantity and quality. Many of the tools are available but need to be implemented at the practical level by the agencies and authorities that have the site specific conditions that provide the opportunity for sustainable practices.

30-4 **9:00 AM** Jitan, Mohd A.

WATER POLICIES, STRATEGIES AND IRRIGATION WATER MANAGEMENT IN JORDAN

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Jordan is facing a chronic imbalance in the population-water resources equation. Despite the huge investment in the water sector, a considerable water deficit is still facing Jordan; where the annual water consumption has reached an average of 935 MCM for the last few years, about 63% of which is used for agricultural purposes. It is expected that the water deficit for all uses to be more than 360 MCM/year by year 2020. During the last 15 years the government of Jordan, under the umbrella of the Ministry of Water and Irrigation, has initiated and developed two water policies and strategies. In 2002, the MWI published the Jordan water policy and strategy consisting of: (1) a water strategy for Jordan, (2) a groundwater management policy, (3) a water utility policy, (4) an irrigation water policy, and (5) a wastewater management policy. The issues covered by the irrigation water policy are the sustainability of irrigation water resources, development and use, research and technology transfer, farm water management, irrigation water quality, management and administration, water pricing, regulation and control and irrigation efficiency. Specific and practical strategies of water saving are introduced and recommended in this paper under the arid conditions of Jordan and the Middle East region.

From the irrigation point view, management of irrigation water requires new ways of thinking since the subject is multi disciplinary and has different approaches to the various technical, economic and social aspects. For the technical part, determining the actual evapotranspiration of different crops in Jordan's irrigation projects is essential to estimate the plant water requirements for different plant growth stages. The paper also discusses an irrigation management information system approach developed by NCARE researchers with the help of USDA-ARS. The system is capable of providing farmers with online crop water requirements based on automated meteorological data published on the internet (www.ncare.gov.jo/imis, and www.merimis.org). This Middle Eastern Regional Irrigation Management Information Systems (MERIMIS) project, which started in 2003, has focused on improving irrigation scheduling in Jordan, Palestine, and Israel with cooperators from the region and the U.S.

30-5 **9:20 AM** Anderson, Ray G.

ASSESSING EVAPOTRANSPIRATION, BASAL CROP COEFFICIENT, AND IRRIGATION EFFICIENCY IN PRODUCTION PEACH ORCHARD IN CALIFORNIA'S SAN JOAQUIN VALLEY

ANDERSON, Ray G.[1], WANG, Dong[1], LUND, Christopher P.[2], MELTON, Forrest S.[2], JOHNSON, Lee F.[2], PRUEGER, John H.[3], ALFIERI, Joseph G.[4], MCKEE, Lynn[4], and KUSTAS, William P.[4], (1) USDA-Agricultural Research Service, San Joaquin Valley Agricultural Sciences Center, Water Management Research, USDA-ARS-SJVASC-WMRU, 9611 S. Riverbend Ave, Parlier, CA 93648-9757, ray.anderson@ars.usda.gov, (2) California State University, Monterey Bay, Seaside, CA 93955, (3) USDA-ARS, National Lab for Agriculture and the Environment, 2110 University Blvd, Ames, IA 50011-3120, (4) USDA-ARS Hydrology & Remote Sensing Laboratory, Bldg. 007 Rm. 104, Beltsville, MD 20705

Accurate field scale observations of crop water use are necessary to maximize crop productivity with limited water resources and to parameterize regional and continental satellite models to estimate near real-time crop water use. However, rapid, continuous observations of field-scale water use in California's diverse cropping systems have been historically limited. Here we present an integrated framework to assess crop water use in a mature peach orchard in California's San Joaquin Valley that combines micrometeorological, radiometric, and soil observations. We compared evapotranspiration (ET) measured with an Eddy Covariance tower to soil water balance observations (SM), precipitation (P), and irrigation (I) measurements. Data from our first year of observation indicates a relatively high irrigation efficiency (ET>85% of P+I+ΔSM). Crop coefficient (Kc) had a peak value (~1.2-1.3 of reference ET) that was similar, but more variable than reported for lysimeter-grown peaches in California and which reached an elevated level (Kc>1) earlier in the season. Transpiration (T) was >80% of ET during midday in the growing season. Our preliminary results highlight the need for better quantification of water extraction by mature peach trees from deeper soil layers. Additional observations in the upcoming year from the recently launched Landsat Data Continuity Mission should further enable additional quantification between orchard water use and remotely sensed observations.

30-6 **9:40 AM** Zhang, Huihui

DEVELOPMENT OF DEFICIT IRRIGATION STRATEGIES FOR PEACH PRODUCTION

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The San Joaquin Valley in California is one of the most productive agricultural regions in the world. However, crop production replies on irrigation due to the hot and dry weather and lack of rainfall in the summer. In recent years, water supply for irrigation was decreased because of the competition for water demands from residential, industrial, and environmental usages. It is necessary to find management methods to optimize the usage for the limited supply of irrigation water.

Deficit irrigation has been studied for perennial crops to help alleviate water shortage. At certain growing stages, crops which are not sensitive to water stress can receive less than full irrigations. For early-maturing peach cultivars, it has been demonstrated that established peach trees are not sensitive to moderate water stress in the postharvest growth. Field studies were conducted since 2007 to evaluate deficit irrigation management in a 1.6-ha peach orchard in USDA-ARS, Parlier, CA. A wired network of infrared temperature sensors was installed above the orchard for monitoring canopy temperature, which has been used as an indicator of crop water stress. In the first two-years of the study, canopy temperature response from different irrigation treatments was investigated. Mid-day canopy to air temperature difference was found to be most sensitive to water stress. Then we used mid-day canopy to air temperature as a primary input for irrigation scheduling for the peach trees. The relationship between fruit weight and postharvest irrigation amount indicated that up to 50% water savings could be achieved without impacting fruit size. Our findings on peach tree deficit irrigation and thermal infrared sensors for guiding irrigation scheduling can provide growers with a practical tool to save water without reduction in yield and fruit quality.

30-7 **10:20 AM** Sartono, Ori

ESTIMATING THE PROPORTION OF CHEMICAL FLUX FROM AGRICULTURAL SOURCES IN THE GROUND WATER OF THE SAN JOAQUIN VALLEY BASED ON PRINCIPAL COMPONENT ANALYSIS OF MAJOR MINERAL CONCENTRATIONS

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Groundwater samples from the eastern San Joaquin Valley represent mixtures of waters from different sources. The source of the natural ground water is mainly from the recharge by precipitation in the Sierra Nevada. Because the area is predominantly agricultural, natural ground water is mixed with irrigation waters drained from farmlands due to deep percolation. In addition, nutrient (nitrate) contaminated water from numerous confined animal facilities, septic systems, municipal waste treatment facilities of cities and towns also contribute significantly to the compositions of the groundwater samples. We collected 125 groundwater samples from agricultural and domestic water-supply wells in a mixed suburban and agricultural area, and analyzed them for major minerals. The data were subjected to statistical correlation and principal component analyses. The results indicate that no significant spatial distribution pattern of groundwater compositions can be identified. However, apparently they are mainly dependent on their original sources and the mixing proportions among the different possible components. Three principal components are identified and they account for 84% of the sample variances. Compositions of some samples cannot be explained by the 3-component mixing model. They are likely influenced by local contamination sources of specific compositions. Based on these analyses, the ratios of mixing and the proportion of chemical flux due to groundwater recharge derived from agricultural and other anthropogenic sources can be estimated.

30-8 **10:40 AM** Holtz, Marianne L.

INVESTIGATING THE SOURCE OF NITRATE IN A SALINAS VALLEY DRINKING WATER SUPPLY WELL WITH ISOTOPIC TRACERS

HOLTZ, Marianne L.[1], ESSER, Bradley K.[2], HILLEGONDS, Darren J.[2], MORAN, Jean E.[1], ROBERTS, Sarah K.[2], SINGLETON, Michael J.[2], and VISSER, Ate[2], (1) Department of Earth and Environmental Sciences, California State University, East Bay, 25800 Carlos Bee Boulevard, Hayward, CA 94542-3088, mholtz@horizon.csueastbay.edu, (2) Chemical Sciences Division, Lawrence Livermore National Laboratory, L-231, 7000 East Avenue, Livermore, CA 94550

Nitrate-loading is a pervasive water quality problem in the Salinas Valley due to its rich agricultural history. Row crops, including strawberries and lettuce, are grown in the area immediately surrounding the drinking water supply well in this study. The application of fertilizers to these crops is compounded because the crops are irrigated with nutrient-rich agricultural return fed groundwater. The nitrate impacted drinking water supply well in this small agricultural labor co-operative community has been warranted unsafe for human consumption because nitrate concentrations were well above the MCL. A new water supply has recently replaced the former well. The former drinking water supply well, located in the Salinas Valley Groundwater Basin - Eastside Sub-basin, was completed at a depth of 450 ft. under semi-confined conditions of the alluvial Paso Robles Formation.

One of the goals of the study is to unravel the complex dynamics associated with local and regional source loading, recharge, and discharge, and make a definitive statement about the source of the nitrate contamination in order to recommend best management practices into the future. This study implements an interdisciplinary approach to investigate the source of nitrate. Stable isotope ratios of water (δ^2H,$\delta^{18}O$-H_2O) and nitrate ($\delta^{15}N$, $\delta^{18}O$-NO_3) were analyzed as source indicators. Additionally the study utilized dissolved oxygen content, dissolved nitrogen and argon gas concentrations, selected anions (F^-, Cl^-, NO_2^-, Br^-, NO_3^-, SO_4^{2-}), and tritium-helium groundwater age-dating to examine the processes taking place in the subsurface. A high-resolution time-series dataset of pumping volumes and nitrate concentrations also provided invaluable insight into the changes in nitrate concentration that are observed seasonally.

30-9 **11:00 AM** Schmidt, Kenneth D.

THE RELATION BETWEEN CONFINING BEDS AND THE VERTICAL EXTENT OF DEEP PERCOLATION IN THE SAN JOAQUIN VALLEY, CALIFORNIA

SCHMIDT, Kenneth D., 600 W. Shaw Avenue, Fresno, CA 93704, classotovitch@gmail.com

Historically, only laterally extensive clay layers were normally mentioned as confining beds in the San Joaquin Valley. In particular, the widespread Corcoran Clay has been noted for many decades beneath the western and central parts of the valley. In addition, the shallower A-Clay has been extensively discussed. The east side of the valley was often considered to be underlain by an unconfined aquifer. When many of the U.S. Geological Survey reports were done in the 1950's and 1960's, most of the test holes and wells on the east side of the valley were less than about 300 feet deep. Coarse-grained deposits were often predominant. However, in recent decades many holes have been drilled to depths of 800 feet or deeper. This deeper information indicates that there are significant thick confining beds beneath most parts of the east side of the valley.

Evidence on the vertical extent of deep percolation from irrigation can be obtained by evaluating concentrations of salinity, nitrate, DBCP, and 1,2,3-TCP in the groundwater. The uppermost part of the groundwater beneath irrigated parts of the valley usually has higher total dissolved solids (TDS) concentrations than are in the deeper groundwater. In general, one or more significant confining beds separate the upper higher TDS groundwater from the deeper lower TDS groundwater. Nitrate concentrations in the shallow groundwater beneath irrigated areas are often due to historical irrigation and fertilizer practices. The vertical distribution of nitrate generally is similar to that of TDS in these areas.

Beneath parts of the east side of the valley, DBCP and 1,2,3-TCP are also present in the shallow groundwater. DBCP was first applied to control nematodes in about 1950 and its use was subsequently banned in 1977. Concentrations of these two trace organics delineate the vertical extent in the groundwater of deep percolation that originated in recent decades.

Understanding of the relation between significant confining beds, the extent of deep percolation, and geochemical factors that affect naturally derived constituents in the groundwater has been used to successfully design and develop new public supply wells in the valley for more than three decades.

30-10 **11:20 AM** Holcomb, Ronald E.

CHARACTERIZATION OF THE SHALLOW SALINE AQUIFER AT NAS LEMOORE IN WESTERN SAN JOAQUIN VALLEY, CALIFORNIA

HOLCOMB, Ronald E., RIETH, Dale, HISHIDA, Kassandra, and WANG, Zhi, Dept. of Earth & Environmental Sciences, California State Univ, Fresno, 2576 E. San Ramon Ave., M/S ST24, Fresno, CA 93740, holcombron@hotmail.com

The physical attributes of the shallow aquifer at NAS Lemoore were characterized in conjunction with a larger study that was conducted to evaluate soil and groundwater conditions. Increasing salinity in the groundwater of the Tulare Lake Basin is a growing threat to long-term sustainability of use for drinking and irrigation. Characterization of this aquifer is an attempt to understand the dynamics and evolution of a small aquifer subject to salinization.

The aquifer lithology was determined with well log data from 23 irrigation wells and 25 newly constructed observation wells. Additionally, core samples obtained during drilling operations to install the observation wells were analyzed for particle size distribution using a Beckman Coulter LS Particle Size Analyzer located at Moss Landing Marine Laboratories. Deeper aquifer structures were researched in the literature.

The texture of the soil samples varied from sand to silty clay, but the majority of the soil samples were loam. Grain size distributions were analyzed with the HYDRUS 1D computer model to determine the hydraulic conductivity of the soil in each sample. Hydraulic conductivities ranged from 10^{-3} cm/sec to 10^{-5} cm/sec.

Future analysis will include three-dimensional simulations of the aquifer dynamics using Rockware computer software.

30-11 **11:40 AM** Wang, Zhi

SHALLOW SALINE AQUIFER MONITORING AT NAVAL AIR STATION LEMOORE IN WESTERN SAN JOAQUIN VALLEY, CALIFORNIA

WANG, Zhi, HOLCOMB, Ronald E., RIETH, Dale, and HISHIDA, Kassandra, Dept. of Earth & Environmental Sciences, California State Univ, Fresno, 2576 E. San Ramon Ave., M/S ST24, Fresno, CA 93740, zwang@csufresno.edu

The Naval Air Station Lemoore (NASL) is located in the western central part of California's San Joaquin Valley which has long been affected by soil and groundwater salinization due to drainage of irrigated agricultural fields. The drainage problem is caused by naturally saline soils and imported water, as well as the valley's distinctive geological makeup which prevents effective natural drainage in certain areas.

A DoD supported field monitoring project was carried out to: (1) evaluate the existing monitoring system and update it with modern technologies; (2) develop recommendations for planting, soil amendments and groundwater management based on soil physics and chemistry studies; and (3) develop program recommendations based on scientific analyses and management needs. A total of 94 observation wells were monitored in 10 field surveys in 2010-12 water years, 28 new wells were installed from which core samples were taken for lab study.

The overall results show that the groundwater salinity was highly variable in space, with electric conductivity (EC) varying from 0.3 dS/m (fresh water) to 100 dS/m (similar to sea water or brine). But the seasonal variation was minimal. The average EC values varied in a narrow range between 7.8 and 9.5 dS/m (brackish water) over the entire 2010-2012 monitoring period. By the end of 2012, the saline groundwater area (EC = 4-12 dS/m) was wide spread and the groundwater

table elevated to within 5-ft below surface which can cause soil salinization. The severely saline groundwater areas (EC > 12 dS/m) were invariably located deep beneath the paved areas where there is limited groundwater recharge. Lab studies were conducted to delineate the material composition, physics and chemistry of the aquifer based on 450 core samples obtained from 28 new wells. Three-dimensional solid models of the aquifer were developed using Rockware, which will be used in hydraulic simulations. Results of these studies will be reported separately in this meeting.

30-12 **12:00 PM** Ramirez, Joaquin D.

MODELING SAN JOAQUIN RIVER FLOW PATH ALTERATIONS FOR RESTORATION PROJECT

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The San Joaquin River (SJR) is one of the most vital natural resources to the residents and industries within central California. Along with human necessities, the river is crucial for the propagation and survivability of Chinook salmon and other aquatic and wildlife. However, Indigenous salmon populations have been degraded over the years due to insufficient flows and anthropogenic activities. Many water resources management operations such as dam construction, gravel extraction, and water diversion have altered the flow current and water stage of the SJR, resulting unfavorable living conditions for salmon. Currently, the SJR is undergoing a major evaluation by state and federal agencies as part of a legal settlement. In 2006, the San Joaquin River Restoration Project (SJRRP) was established with different alternative plans to restore flows to the SJR from Friant dam to the confluence of the Merced River. The salmon population is expected to be sustainable by restoring adequate flow to the subjected area through the project.

The objective of the research project is to characterize the stream conditions of each proposed alternative of SJRRP using a modeling method. By simulating and predicting flow conditions of each alternative, this project may offer an insightful understanding of the hydrodynamic occurrence of river alterations and aid in the best passage for Chinook salmon. In this research, a two-dimensional mathematic model is developed to simulate the hydrodynamic conditions (e.g., current velocity, water surface elevation, etc.) of different alternatives, incorporating the disengaged portion of the SJR along the current path proposed in the SJRRP. The 2-D model will facilitate model flow features which are essential to the SJRRP. Flow simulation will allow for the exploration of flow patterns and enable the user to compare each alternative. The research domain extends from Sack Dam to Highway 140, downstream of the Salt Slough confluence. In this area, a portion of the SJR's flow has been diverted and presently courses through an engineered bypass, excluding flow from entering an original stretch of the SJR. SMS11.0 (Surface water Modeling System) and finite element models RMA2 and RMA10 are used in the model development.

SESSION NO. 31, 8:00 AM

Wednesday, 22 May 2013

T1. Tectonic Processes that Build the Stratigraphic and Structural Record of Ancient and Modern Convergent Margin (Posters)

Radisson Hotel and Conference Center, Salon B/C

31-1 **BTH 1** Langenheim, V.E.

INSIGHTS INTO STRUCTURE WITHIN A SUBDUCTION-ZONE COMPLEX FROM SIMPLE, CURVILINEAR MAGNETIC ANOMALIES IN THE COASTAL BELT OF THE FRANCISCAN COMPLEX, NORTHERN CALIFORNIA

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Magnetic anomalies provide surprising structural detail within the Coastal Belt, the westernmost, youngest, and least metamorphosed part of the Franciscan Complex. Although the Coastal Belt consists almost solely of arkosic greywacke and minor shale, of mainly Eocene age, new aeromagnetic data indicate that it is pervasively marked by long, narrow and regularly spaced magnetic anomalies. These anomalies arise from relatively simple tabular bodies containing magnetic basalt or greywacke confined mostly to the top couple of km, even though metamorphic grade indicates these rocks had been more deeply buried, at depths of 5-8 km. This implies surprisingly uniform uplift of these rocks. The basalt (and associated Cretaceous limestone) occurs largely in the northern part of the Coastal Belt; the greywacke is recognized only in the southern Coastal Belt and is magnetic because it contains andesitic grains. The magnetic grains were not derived from the basalt, and thus require a separate source. The anomalies form simple patterns that can be related to folding and faulting within the Coastal Belt. This apparent simplicity belies complex structure mapped at outcrop scale, a contrast that implies the relatively simple tabular magnetic bodies are internally deformed, fault-bounded slabs. One mechanism that might explain thin basalt-bearing layers of wide areal extent is peeling up of oceanic crust into the accretionary prism, controlled by porosity and permeability contrasts produced by alteration in the upper part of the subducting slab. It is not clear, however, how such a mechanism might apply to the fault-bounded layers containing magnetic greywacke, nor is the source of the magnetic greywacke evident. We propose that structural domains defined by differing magnetic anomaly trend, wavelength, and source, reflect local plate interactions as the Mendocino Triple Junction migrated north, a hypothesis that should be tested by more detailed structural studies.

31-2 **BTH 2** Stanley, Richard G.

NEW STRATIGRAPHIC REVELATIONS IN THE SUBSURFACE SUSITNA BASIN, SOUTH-CENTRAL ALASKA, FROM RECENT ISOTOPIC AND BIOSTRATIGRAPHIC RESULTS

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New isotopic and palynological data from wells in the Susitna basin of south-central Alaska indicate the presence of Paleogene nonmarine sedimentary and volcanic strata that provide a record of the tectonic history of the area. The Susitna basin is located north of the Castle Mountain fault and the petroliferous Cook Inlet basin. Seven exploratory wells drilled in the Susitna basin during 1964-2005 found no commercial amounts of oil or gas.

The deepest wells in the Susitna basin are the Trail Ridge Unit 1 (latitude 61.843˚, longitude -151.084˚) and Pure Kahiltna Unit 1 (62.041˚, -150.756˚), which reached measured total depths of 4,178 m and 2,214 m, respectively, and are 27 km apart. Both wells bottomed in a package of interstratified sedimentary and volcanic rocks of late Paleocene to early Eocene age. The ages are based on late Paleocene palynomorphs and $^{40}Ar/^{39}Ar$ step-heating ages on andesite and basalt of 57.3 ± 0.2 Ma, 56.9 ± 0.4 Ma, and 54.3 ± 0.4 Ma. This package is about the same age as the Arkose Ridge Formation in the Talkeetna Mountains and volcanic rocks on the eastern flank of the Tordrillo Mountains.

The volcanic-bearing package is overlain by a nonmarine sequence of sandstone, siltstone, and coal that has an apparent thickness of about 1,400 m and contains early to middle Eocene palynomorphs. This sequence, in turn, is unconformably overlain by a nonmarine interval of primarily conglomerate and sandstone with apparent thicknesses of about 2,500 m in the Trail Ridge well and 150 m in the Pure Kahiltna well; this interval contains early to middle Miocene palynomorphs in its lower part and Quaternary palynomorphs in the upper part.

We infer that late Paleocene and Eocene strata in the Susitna basin record volcanism, subsidence, and sedimentation that accompanied eastward passage of a slab window related to subduction of the hypothesized Resurrection-Kula spreading ridge. The Miocene-on-Eocene unconformity is not precisely dated but may represent uplift and erosion that accompanied the initiation of Yakutat microplate subduction beneath south-central Alaska. The mechanisms of subsidence that accommodated the thick Miocene to Quaternary deposits are unclear but may have included sediment loading, faulting, and lithospheric flexure associated with subduction of the Yakutat microplate.

31-3 **BTH 3** Park, Yong

DEFORMATION MICROSTRUCTURES OF OLIVINE AND PYROXENE IN MANTLE XENOLITHS AND IMPLICATIONS FOR SEISMIC ANISOTROPY

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We studied lattice preferred orientations (LPOs) of olivine, orthopyroxene (Opx; enstatite), and clinopyroxene (Cpx; diopside) in mantle xenoliths at Shanwang, eastern China to understand deformation microstructures and seismic anisotropy in the upper mantle. The Shanwang area is located across the Tan-Lu fault that was formed due to the collision between the northern and southern China blocks. Petrologically, all of the samples are spinel lherzolite and wehrlite, which consist of mainly olivine (58 – 83 %), Cpx (13 – 37 %), Opx (16 – 27 %), and minor minerals such as magnetite and spinel. LPOs of minerals were determined by using electron backscattered diffraction (EBSD) in SEM. Two types of LPOs of olivine were found: type-E and type-B. Enstatite showed two types of LPOs (type-BC and type-AC), and diopside showed three different types of LPOs. Since LPO of olivine is influenced by water, water content was determined by using the Nicolet 6700 Fourier transformation infrared (FTIR) spectroscopy. The FTIR data showed that all of the olivine in samples contained some amount of water (20 – 570 ppm H/Si). Enstatite and diopside, however, contained much more water than olivine (50 – 3600 ppm H/Si and 530 – 14000 ppm H/Si, respectively). Water is considered to be escaped from olivine after formation of type-B and -E fabrics because of fast diffusion of H in olivine.

Seismic anisotropy was calculated using the LPO of minerals. The seismic anisotropy of P-wave (V_p) was in the range of 2.2 – 11.6 % for olivine, 1.2 – 2.3 % for enstatite, and 2.1 – 6.4 % for diopside. The maximum anisotropy of the shear wave (AV_s) was in the range of 1.93 – 7.53 % for olivine, 1.53 – 2.46 % for enstatite, and 1.81 – 6.57 % for diopside. As a result, the seismic anisotropy of olivine was stronger than both enstatite and diopside. Furthermore, the thickness of anisotropic layer was calculated for three geodynamic models to understand the origin of seismic anisotropy in the study area by using delay time from shear wave splitting and S-wave velocity & anisotropy from LPOs of minerals. Finding the type-B LPO of olivine in nature is important because trench-parallel seismic anisotropy of fast S-wave found in many subduction zones can be attributed to the type-B LPO.

31-4 **BTH 4** Bero, David A.

GEOLOGY OF RING MOUNTAIN AND TIBURON PENINSULA, MARIN COUNTY, CALIFORNIA

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Detailed geologic mapping and petrographic analysis reveal that Ring Mountain and the adjoining NW-trending Tiburon Peninsula are underlain by three distinct terranes (T). The structurally highest terrane, T1, consists of partially serpentinized harzburgite underlain by a relatively thin serpentine-matrix mélange. The mélange matrix, composed of lizardite with minor antigorite and chrysotile, has a pervasive shear-fracture fabric characterized by anastomosing shear-fracture surfaces enclosing small, disk-shaped serpentinite phacoids. Entrained within, or eroded from, the mélange matrix are blocks of variable size and shape, including blocks of blueschist, amphibolite, and eclogite grade rock. T1 is underlain by T2, which consists of schistose metagreywacke, metachert, greenstone, and minor metaconglomerate units of blueschist grade. Although individual units of T2 are somewhat discontinuous at Ring Mountain, they are more laterally continuous in the central and southern Tiburon Peninsula. Metagraywacke, the dominant rock type of T2, is fine- to medium–grained with a semi-planar foliation and common, foliation-normal quartz veins. Cleavage is defined by anastomosing chlorite, white mica ± stilpnomelane. The phyllosilicates enclose porphyroclasts of relict quartz elongated by deformation and fabric-parallel overgrowths together with neoblasts of the blueschist facies assemblage lawsonite ± albite ± jadeite ± glaucophane. T3, the structurally lowest terrane, is dominated by prehnite-pumpellyite grade meta-litharenite with minor metashale. The meta-litharenite of T3 has modal mineral content and QFL ratios (for 32 litharenite samples) confirming that it represents part of the

Alcatraz Terrane of Jayko and Blake (1984). At Ring Mountain, the three distinct, stacked terranes are separated by low-angle faults. Southeast of Ring Mountain, along Tiburon Peninsula, that terrane sequence is offset by later NE- and NW-trending high-angle normal faults that juxtapose portions of the three terranes.

SESSION NO. 32, 8:00 AM

Wednesday, 22 May 2013

T2. Mélanges: Comparison and Contrast Between Circum-Pacific and Tethyan Chaotic Rock Bodies, and Modern Submarine Analogues (Posters)

Radisson Hotel and Conference Center, Salon B/C

32-1 **BTH 5** Platt, John P.

ORIGIN OF BLUESCHIST-BEARING MELANGE AT SAN SIMEON, CENTRAL CALIFORNIA COAST RANGES

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Mud-matrix melanges at San Simeon have been variously interpreted as deformed olistostromes or as subduction-channel flow melanges. Detailed examination shows that seven types of melange can be distinguished, with transitions among them. All types contain exotic clasts of greenstone, chert, and more rarely blueschist, in addition to greywacke sandstone, and the same materials occur as blocks meters to tens of meters in diameter immersed in melange. The seven types are (1) bedded conglomerate, (2) structureless conglomerate, (3) pebbly mudstone, (4) sandy block melange, (5) broken formation, (6) mud-matrix melange without deformational fabric, (7) sheared melange. Types (1) to (3) are clearly sedimentary in origin. Types (4) and (5) were clearly formed from unconsolidated sediment. Transitional types suggest that the mud-matrix melange (6) formed by disruption of types (1) to (5). Disruption took place while the sediment was unconsolidated, either on the trench slope or at very shallow levels in the accretionary wedge. Sheared melange (7) was formed by low-temperature post-consolidational deformation of all other types, which produced shear bands and a crude fabric transitional between slaty cleavage and gouge fabric. Kinematic indicators of shear direction are rare, but assuming the fabric and shear planes are coeval, the shear direction and sense can be determined from their intersection. Most shear planes are gently dipping and have normal sense displacements. Shear directions are highly variable, with the highest concentrations between WNW and S. This suggests that the main phase of shearing took place during a phase of vertical shortening and extension, rather than during accretion. Post-accretionary dextral shearing on NNW-trending vertical planes, and sinistral shear on a variety of trends, are likely related to Neogene transform tectonics. The simplest interpretation of these relationships is that the disrupted character of the melanges formed primarily by sliding down the trench inner slope of unconsolidated sediment, including clasts and blocks of previously accreted and exhumed greenstone, chert, and blueschist. The deformational fabric is largely unrelated to the disruption, and was formed during late-stage extension in the accretionary wedge.

32-2 **BTH 6** Ogawa, Yujiro

DUCTILE AND BRITTLE DEFORMATION STRUCTURES IN THE BLOCKS OF FRANCISCAN (CALIFORNIA) AND MINEOKA (JAPAN) MÉLANGES: IMPLICATIONS FOR RETROGRADE DEFORMATION DURING EXHUMATION OF DEEP-BURIAL ROCKS

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Tectonic blocks of metamorphic, igneous and oceanic rocks, in both the Franciscan (California) and Mineoka (Japan), show widespread cataclastic and mylonitic structures. The mélanges, formerly interpreted as debris flow deposits of a sedimentary origin, display systematic fracture patterns with certain orientations as below, so that not of sedimentary in origin. The boundaries between clasts and the matrix materials are generally pulverized, and Riedel shears form sharp planes in the rocks. The fracture planes are plotted in great or small circles on a stereographic projection. Such structural features indicate a tectonic origin, rather than sedimentary for their formation. We interpret that all these brittle to ductile structures formed during the exhumation of the rocks. The metamorphic mineral phases suggest their crystallization at 10-20 to 50 km within subduction zones with low to intermediate thermal gradients. The rock exhumation involved volumetric expulsion via dilatant shear deformation, and formation of quartz, calcite, zeolite and other low-pressure minerals, in most cases associated with quartz, calcite, zeolites or other low-pressure or low-temperature minerals. Block shapes are commonly phacoidal with fish tails, or turtle-like, surrounded by pelagic matrices or serpentinite. Some blocks are metamorphosed into either blueschist (Franciscan case), or amphibolites (Mineoka case), superimposed by later veins or rinds of epidote-amphibolite or greenschist facies assemblages, suggesting retrograde metamorphism. Serpentine minerals, lizardite-chrysotile and rare antigorite, indicates vast amount of volume increase by hydration that may have played a significant role in exhumation through diapiric or intrusive emplacement of the retrograde metamorphic blocks. Tonalitic igneous bodies have similar deformation features of retrograde metamorphism. These blocks within the both mélanges strongly support the concept of subduction channel of return flow for the exhumation processes, whose modern analogues occur in the Paleogene Izu forearc.

32-3 **BTH 7** Vitale Brovarone, Alberto

FIELD-BASED CONSIDERATIONS ON THE NATURE OF THE HP “MÉLANGE” OF NEW CALEDONIA

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The eclogitic Pouébo unit of New Caledonia is considered a good example of HP mélange formed by intense deformation along the plates interface. Serpentinites within the mélange structure are alternatively interpreted as lower- or upper plate material variably mixed with subducting mafic and sedimentary rocks.

We provide new field observations that clarify the geological meaning of the Pouébo unit. The unit comprises a spatially discontinuous lithostratigraphy that includes variably serpentinized ultramafics, metagabbro, metabasalt and metasediments including (radiolarian) metachert, siliceous metatuff and micaschist. Ultramafics commonly preserve primary peridotite textures. Metavolcanics and metasediments are primarily associated and form repeated intercalations ranging in thickness from a few cm to several meters. Thicker metabasalt (>10m) bodies commonly show pillowed structure, while thinner (ca. 1-2m) layers intercalated within siliceous metasediments commonly show hyaloclastite textures (eruptive tectono-sedimentary structures) or in-situ cooling fracturing typical of oceanic lavas. Mafic polygenic breccias, also including minor clasts of radiolarian metachert, are equally found and locally show rounded shapes. This lithological association is variably deformed, from the rather pristine sequence to intensely disrupted structures. The most intense deformation is localized in the structurally upper part of the units, close to the contact with the overlying blueschist-facies metasediment-rich accretionary complex (i.e. the Diahot terrane). In this zone, all terms of the primary lithostratigraphic sequence are found as blocks of variable size (cm to tens of m) embedded in a metasomatized ultramafic/sedimentary matrix. Blocks commonly show intense deformation, and in many cases likely formed by intense folding/boudinage. No “exotic” blocks were found.

We propose that the Pouébo unit represents a coherent segment of Pacific lithosphere that only locally underwent intense tectonic disruption, probably favored by primary lithological intercalations and rheological contrasts along localized HP shear zones. Consequently, this terrane should not be considered as an HP mélange structures formed by intense mixing of lower- and upper plate material along the plates boundary.

32-4 **BTH 8** Festa, Andrea

MÉLANGES AND GEODYNAMIC SETTINGS OF THEIR FORMATION

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Mélange formation commonly occurs through the interaction and/or overlapping of different processes acting during a continuum of stratal disruption and mixing. At shallow structural levels in tectonically active environments, sediments are subject to small-scale deformation immediately after deposition, at rates and in ways dependent on the interplay between gravitational deformation and tectonic burial. Here, gravitational deformation favors mixing processes forming different types of sedimentary mélanges. With the downward increase in the degree of consolidation/lithification of buried sediments, tectonic forces gradually become predominant forming broken formations. Tectonic mélanges (with exotic blocks included), however, are restricted to fault zones, plate boundaries and subduction channels. Formation of diapiric mélanges is strongly controlled by the presence of fluid overpressure, consolidation rate of sediments, and the state of stress.

A comparison of the Circum-Pacific and Tethyan mélanges shows that the internal structure of different mélange-types is controlled by tectonic, sedimentary and diapiric processes operating in their environment of origin. Discrete evolutionary stages of mélange formation, from stratal disruption to mixing, are constrained by the tectonic setting of their formation, state of consolidation of the original coherent succession, metamorphic degree, rheological contrast between component layers, strain rate, and shallow vs. deep crustal deformation. The most common mechanisms-processes of strata disruption-mixing and the tectonic setting of mélange formation are linked by a causal relationship, which we use to subdivide mélanges into six types, associated with (i) extensional tectonics, (ii) passive margin evolution, (iii) strike-slip tectonics, (iv) convergent margin–subduction tectonics, (v) continental collision, and (vi) intra-continental deformation.

32-5 **BTH 9** Moclock, Leslie G.

TIMING AND KINEMATICS OF DEFORMATION IN THE NORTHERN BEAR MOUNTAINS FAULT ZONE, SIERRA NEVADA FOOTHILLS, CALIFORNIA

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The N-S trending Bear Mountains Fault Zone (BMFZ) in the Sierra Nevada foothills is a 300 km long by ~10 km wide mélange zone with local high strain zones. It separates two lithotectonic belts and has been variably interpreted as a suture zone, an intra-arc reverse fault, and a transverse “mega-shear” zone. Previous work also suggests the timing of ductile deformation along the BMFZ may vary significantly along strike, from prior to ~160 Ma in the north to as young as ~123 Ma in the south.

This study examines the timing and deformation history of the northern BMFZ near Auburn, where excellent exposure occurs along the American River. This area is dominated by a zone of foliated greenschist-facies serpentine matrix mélange up to 11 km wide. Blocks include gabbro, pillow basalt and breccia, massive metabasite, chert, and limestone, with lesser volcaniclastic rocks and clastic sediment. One higher-grade block consists of strongly foliated hornblende amphibolite. Metadiorite plutons that intrude the mélange have been strongly deformed into wide zones of uniform greenschist that previous workers mapped as metavolcanic rocks.

Anastamosing foliation dips steeply east and contains a weak to moderately-developed down-dip lineation. Rootless isoclinal folding at the cm-scale is ubiquitous. A 4 km-wide high strain zone has deformed the BMFZ up to its border with an intact, less-deformed volcanic and plutonic sequence previously dated to ~162 Ma. Kinematic indicators from the high strain zone show that flattening strain is dominant. Both reverse and normal motion are also indicated, likely due to large-scale folding. Of note, no conclusive evidence of transverse motion is present.

New isotopic ages bracket the timing of ductile deformation in this area to the Early and Middle Jurassic. Hornblende from the amphibolite block has a $^{40}Ar/^{39}Ar$ age of 195.9±2.4 Ma, and a weakly-deformed pluton intruding the high strain zone has a SHRIMP U/Pb zircon age of 160.9±1.3 Ma. Dikes and sills with $^{40}Ar/^{39}Ar$ muscovite and biotite ages of ~124 Ma are undeformed. Based on these results and structural interpretations, we infer that the northern BMFZ is a middle Jurassic or older feature that incorporates syndeformational plutonism and high strain, rather than an upper Jurassic-lower Cretaceous feature as seen in the south.

SESSION NO. 33, 8:00 AM

Wednesday, 22 May 2013

T3. Oceanic Petrogenesis of Pacific-Type Convergent Margins (Posters)

Radisson Hotel and Conference Center, Salon B/C

33-1 **BTH 10** Stovall, Jesse

POSSIBLE COUNTERCLOCKWISE P-T-T PATH FROM THE FORT JONES TERRANE NEAR YREKA, CALIFORNIA

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The Klamath Mountains preserve a Devonian to late Jurassic accretionary complex emplaced beneath the Eastern Klamath Terrane. At the latitude of Yreka, California, the structurally highest lower-plate unit is the Central Metamorphic Belt, which is underlain by the Fort Jones Terrane (FJT). Although the amphibolite-facies Central Metamorphic Belt has been considered to be a Devonian metamorphic sole based on old K/Ar dates, recently published Ar/Ar hornblende to the south yield a Triassic age, leaving open the possibility that these rocks are not related to the early history of the subduction zone.

The underlying FJT, usually considered to be an extension of the Stuart Fork Terrane to the south, consists of a diverse assemblage of phyllite, quartzite, chert, and metabasalt, in both coherent and mélange tectonic textures. These rocks were affected by a widespread blueschist-facies metamorphic event, presumably of Triassic age. Good exposures of the block-in-matrix fabric of the FJT exist in the Soap Creek Valley, just west of Yreka. Here, we individually describe blocks mapped by previous workers, finding lawsonite-blueschist and omphacite-lawsonite metabasalt, actinolite schist, and amphibolite. In addition, eclogite has been reported in the literature.

One metabasalt block has late glaucophane overprinting early hornblende, suggesting a blueschist-facies overprint on an amphibolite protolith. Furthermore, widespread late lawsonite overprints omphacite-rich rocks that likely co-existed with garnet. These observations, indicative of a higher-temperature event followed by a lower-temperature event, may indicate a counterclockwise pressure-temperature-time path, one which may record the early stages of subduction in the Klamath Mountains. If so, geochronology on these rocks may provide the best opportunity to date of initiation of this subduction zone. Alternately, the blueschist-over-amphibolite metamorphic relationship could be explained by the blocks having undergone two cycles of subduction.

33-2 **BTH 11** Haxel, Gordon B.

ALPINE PERIDOTITE IN THE ARIZONA DESERT: NEW DISCOVERY OF OROCOPIA SCHIST AND INCLUDED SERPENTINIZED PERIDOTITE IN SOUTHWEST ARIZONA

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The latest Cretaceous to early Tertiary Orocopia Schist (OS) records subduction of continental-margin supracrustal rocks beneath southwest North America. Heretofore, all known exposures of OS lay along the Chocolate Mountains anticlinorium. This structure extends from the Orocopia Mountains (southern California) southeastward to Neversweat Ridge, 65 km east of the Colorado River in southwest Arizona. In 2012 we found an additional body of OS significantly farther inland—at Cemetery Ridge (CR), 90 km east of the Colorado River and 90 km west of the outskirts of greater Phoenix.

The quartzofeldspathic schist at CR possesses four features diagnostic of OS: porphyroblasts of bluish-gray to black graphitic albite, layers of Fe-Mn metachert and amphibolite schist (metabasalt), and pods of coarse-grained actinolite rock.

OS at CR is remarkable because it includes at least 17 blocks of serpentinized mantle peridotite, 200–400 m to < 30 m long. These blocks, aligned in a diffuse trend ≈ 2 km long, may be dispersed fragments of a single peridotite slab. Field relations indicate that the peridotite at CR was serpentinized but otherwise unmetamorphosed when it was emplaced into the sedimentary protolith of the OS, and was subsequently partially metamorphosed with the schist. Premetamorphic textures and fabrics are preserved in several of the blocks. Here the peridotites are serpentinized harzburgite and olivine orthopyroxenite, commonly with bastite texture and locally with probable mantle tectonite fabric; and subordinate black serpentinized dunite, typically forming dikes cutting harzburgite. We've found one small mass of probable chromite-serpentine rock. As two of the peridotite bodies are closely associated with metachert, the peridotite incorporated into the OS is probably oceanic mantle, possibly detached from the subducting plate, rather than continental mantle.

Thick actinolite veins in and around the peridotite reveal the origin of the enigmatic actinolite rock that is ubiquitous in the Orocopia and related schists.

OS and alpine peridotite at CR provide the farthest-inland in situ evidence for low-angle subduction beneath the Southwest. Studies of detrital-zircon and metamorphic-mineral ages will relate this outlying exposure of OS to similar schists nearer to the continental margin to the west.

33-3 **BTH 12** Holk, Gregory J.

STABLE ISOTOPE EVIDENCE FOR A TWO-STAGE FLUID HISTORY THE OROCOPIA SCHIST AT THE OROCOPIA MOUNTAINS AND GAVILAN HILLS, SOUTHEASTERN CALIFORNIA

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A two-stage fluid history of the Orocopia Schist at the Gavilan Hills and Orocopia Mountains in SE California is documented with mineral oxygen and hydrogen isotope data and $^{40}Ar/^{39}Ar$ geochronology (Jacobson et al., 2002; 2007). The first event is related to prograde metamorphism followed by subduction refrigeration at ~50 Ma. This event is evidenced by quartz, muscovite, amphibole, and biotite $\delta^{18}O$ values from Orocopia Schist in the lower plate of the Orocopia/Chocolate Mountains detachment fault(s) and Gatuna normal fault in apparent equilibrium at 450-550°C with metamorphic water ($\delta^{18}O$ ~ +8.5). A few high D/H muscovites and biotites from the Orocopia Schist suggest these metamorphic fluids had δD ~ –40. The second event is associated with final exhumation, syn-detachment fault chlorite alteration and the influx of meteoric-hydrothermal fluids at 28-24 Ma. This event is evidenced by low biotite (–90 to –122‰), amphibole (–100 to –119‰), and muscovite (–75 to –107‰) dD values from almost all structural levels at the Orocopia Mountains and Gavilan Hills that indicate D/H exchange involving meteoric fluids with δD values between –60 and –80‰. Muscovite from detachment fault-related mylonites have the lowest δD values, suggesting that these faults were an enhanced zone of meteoric fluid circulation. More variable δD values in lower plate Orocopia Schist from both the chlorite and biotite zones indicate a lesser degree of interaction with meteoric-hydrothermal fluids. The preservation of high-temperature oxygen isotope fractionations (T ~ 500°C) in upper plate rocks indicates low water-rock ratios for the second event. Low biotite $\delta^{18}O$ values (+3.4 to +4.5) in the upper plate at the Orocopia Mountains are out of isotopic equilibrium with coexisting quartz ($\delta^{18}O$ ~ +10‰). This indicates a more vigorous meteoric-hydrothermal system at the Orocopia Mountains Fault relative to that related to the Chocolate Mountains/Gatuna fault system at Gavilan Hills.

33-4 **BTH 13** Wills, Marci A.

AGE OF METAMORPHISM AND PRESSURE-TEMPERATURE PATH FROM METAMORPHOSED DUNDERBERG SHALE IN THE WOOD HILLS, EASTERN NEVADA

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The Wood Hills, located in eastern Nevada in the hinterland of the Sevier orogenic belt, includes sedimentary rocks of Cambrian to Devonian age that underwent burial, folding, and metamorphism associated with Sevier orogenesis. We studied the metamorphosed Cambrian Dunderberg Shale, a pelitic schist with the mineral assemblage garnet-staurolite-kyanite-plagioclase-muscovite-biotite-quartz, to determine the age of garnet growth, the conditions of metamorphism, and pressure-temperature path. Garnets are generally <2 mm and comprise about 3% of the rock's volume. Determinations of pressure-temperature (P-T) conditions were evaluated using isochemical plots (pseudosections) calculated using DOMINO and the thermodynamic dataset of Holland and Powell, and GASP/garnet-biotite thermobarometry (calibrations of Holdaway). Thermobarometry indicated conditions of 610-630 °C and pressures of 6.8-7.1 kb. The pressures determined are about 1 kb higher than estimated by plotting the isopleths for the garnet core compositions (Xpy, Xgr, Xal, and Xsp) on an isochemical plot. Conditions of 625 °C and 6.6 kb, consistent with thermobarometry within uncertainties, fall inside the rock's mineral assemblage field on an isochemical plot, and were used as starting conditions for garnet growth simulations to determine P-T paths. Using the program GIBBS, which performs calculations based on Duhem's theorem, and selecting as monitors the changes in mole fraction of grossular (ΔXgr) and moles garnet (ΔMgar), it was determined that garnets grew core-to-rim during 10 °C of temperature increase while pressure decreased 500 bars then increased 400 bars. The path suggests that garnets grew during a transition from exhumation to burial. The timing of this path was determined using the Lu-Hf method of garnet dating. Four garnet fractions and two whole rocks yielded an isochron age of 82.8 ± 1.1 Ma (MSWD=15). Approximately 130 km to the northeast, in the Basin Creek area of the Grouse Creek Mountains, previously studied garnets in Neoproterozoic metasedimentary rocks (schist of Steven's Spring) preserve a P-T path indicative of prograde burial and yielded a similar age of 85.5 ± 1.9 Ma. The similar age supports the hypothesis from previous studies that both areas experienced burial by the Windermere thrust at 82-86 Ma.

33-5 **BTH 14** Lacy, Alison C.

EARLY EOCENE METAMORPHISM IN THE SEVIER HINTERLAND CONSTRAINED BY LU-HF GARNET GEOCHRONOLOGY

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The hinterland of the Sevier orogen experienced alternating shortening and extension during development of the foreland fold-thrust belt, prior to a terminal transition from shortening to extension that affected the entire orogen. The timing of the terminal transition between shortening and extension, while well documented in the Idaho-Utah-Wyoming salient of the Sevier fold-thrust belt between ca. 50 and 48 Ma, remains poorly constrained within the hinterland. To address the timing of this kinematic transition in the hinterland, we take advantage of a rare opportunity to determine a P-T-t-d path provided by the occurrence of garnet within the schist of Upper Narrows in the western Raft River Mountains, where it is metamorphosed to amphibolite facies. The 1-2 cm diameter garnets are datable and preserve growth zoning, and are thus amenable to thermodynamic modeling to produce pressure-temperature (P-T) paths. They also preserve sigmoidal inclusion trails indicating synkinematic growth. Here we present results of Lu-Hf isochron dating of two samples of garnet schist in the schist of Upper Narrows, from the type locality in the Upper Narrows of the Raft River in the western Raft River Mountains. Lu-Hf isochron ages of 51.0 ± 2.0 and 53.3 ± 2.2 Ma are each defined by 3 garnet fractions + whole rock on two samples. Garnets grew during top-to-NW shear, similar to the kinematics preserved within the Middle Mountain shear zone, which is exposed along the western margin of the Grouse Creek, Raft River and Albion Mountains. Prior studies have interpreted a polyphase extensional history for the Middle Mountain shear zone, with earliest extension responsible for 45 Ma cooling ages in its footwall. Thermodynamic modeling including pseudosection and Gibbs Method approaches are currently in progress to constrain P-T changes associated with Early Eocene top-to-NW shear. The results will better constrain the timing of the terminal transition phase from contraction to extension of the Sevier orogeny.

33-6 **BTH 15** Regel, Megan E.

INCREASING THE SPATIAL RESOLUTION OF AGES AND PEAK PRESSURE-TEMPERATURE CONDITIONS OF ULTRAHIGH-PRESSURE ECLOGITES AND HIGH-PRESSURE GRANULITES IN DULAN UHP TERRANE, NORTHWESTERN CHINA

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The North Qaidam ultrahigh-pressure (UHP) terrane in northwestern China contains the ~140 km^2 Dulan UHP region, with UHP eclogites outcropping in the east and high-pressure (HP) granulites

outcropping in the west. Previous Fe^{2+} - Mg exchange thermometry suggests temperatures ranging from ~620 – 800 °C and pressures between 27 and 32 kbars in the eclogites and 750 - 950 °C and pressures of ~14 kbars in the granulites; this large range of temperatures and uncertainty prevented a detailed understanding of P-T histories and exhumation paths. Zirconium-in-Rutile (Zr-in-Rt) thermometry of 5 representative eclogites provides a temperature range of ~670 - 710 ± 10 °C, which suggests a westward-increasing thermal gradient of 3 - 5 °C/km. Rutile inclusions from two samples show temperatures ~40 - 50°C lower than the matrix rutiles, which suggests increasing temperatures during prograde and peak metamorphism. Rutiles from one representative granulite show two much higher temperature populations: 1) ~775 ± 10 °C and 2) ~740 ± 10 °C. The lower temperature population occurs along an amphibolite facies retrogressed fracture, and likely records exhumation conditions. The ~775 °C granulite temperatures are likely underestimated; current pseudosection and past P-T work on the granulite sample suggests peak temperatures of ~810 - 870 °C. Zircon U-Pb SHRIMP-RG geochronology of the 5 eclogites used for Zr-in-Rt thermometry give ages of 432.6 ± 4.0 Ma, 433.9 ± 2.5 Ma, 436 ± 3.0 Ma and 432.4 ± 2.4 Ma. These ages are the same within error. REE analyses of dated zircons show depleted HREE due to concurrent garnet growth and no negative Eu anomaly due to a lack of plagioclase in the system, which suggests that these ages record eclogite facies. These data show that the temperatures recorded by Zr-in-Rt thermometry are a “snapshot” of the P-T conditions rather than an artifact of crystallization times. The temperature discontinuity between the eclogites and granulites supports the presence of an unmapped fault, which could suggest tectonic juxtaposition after peak metamorphic conditions, after which the granulites and eclogites underwent amphibolite facies retrogression concurrently.

SESSION NO. 34, 8:00 AM
Wednesday, 22 May 2013
T4. Ophiolites and Suture Zones (Posters)
Radisson Hotel and Conference Center, Salon B/C

34-1 **BTH 16** Masutsubo, Nobuaki

DIVERSE METAMORPHIC TRAJECTORIES, IMBRICATED OCEAN PLATE STRATIGRAPHY, AND FAULT ROCKS, YUBA RIVER AREA, FEATHER RIVER ULTRAMAFIC BELT, CALIFORNIA

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The Feather River ultramafic belt (FRB), extends for more than 150 km along strike within the basement of the northern Sierra Nevada. Geologic relationships along the FRB in the Yuba River area illustrate the complexity of a suture zone and likely complexity of its tectonic evolution. In the North Yuba River area, thin slabs of ilmenite-bearing, redbrown-amphibole (high Ti,low Al) amphibolites, apparently formed by high-temperature, low to medium pressure (LP-HT) metamorphism, structurally underlie ultramafic rocks, and overlie the high-pressure, low-temperature (HP-LT) blueschist facies RAS. The RAS includes a mélange zone with blocks of rutile-bearing, green-amphibole (low Ti, high Al) rutile-bearing amphibolite, indicative of HP-HT metamorphism, that have been heavily overprinted with blueschist facies assemblages. Amphibolite grade rocks in the Forest City area, directly south of North Yuba River, occur structurally beneath serpentinite and comprise imbricates of ocean plate stratigraphy represented by repeated sheets of metabasites, metacherts, and metaclastics. Fault rocks consisting of cataclastically deformed amphibolite and possible pseudotachylites crop out, and in Alleghany is adjacent to serpentinite. The amphibolites appear to structurally overlie the RAS. In the Alleghany area, south of Forest City in the Middle Fork Yuba drainage, there appear to be two amphibolite slabs with distinct metamorphic histories, each comprising imbricated ocean plate stratigraphy and structurally overlying the RAS. In one slab, olive green amphibole, apparently representing HP-HT metamorphism (rutile cores in ilmenite) is overgrown by redbrown amphibole formed during LP-HT conditions whereas the other slab has redbrown amphibole cores mantled by olive green amphibole. One slab may record ridge subduction followed by renewed subduction (LP-HT before HP-HT) whereas the other may record subduction initiation in young oceanic lithosphere (HP-HT) followed by ridge subduction (LP-HT). Other amphibolites along strike in the FRB record only LP-HT or HP-HT. The high temperature events were followed by subduction of long enough duration to develop HP-LT metamorphism. Some HP-HT rocks were exhumed to the sea floor, shed into the trench and resubducted with the RAS.

34-2 **BTH 17** Eck, Dennis S.

THE DEVIL’S GATE OPHIOLITE, NORTHERN SIERRA NEVADA, CALIFORNIA: NOT AN OPHIOLITE OR METAMORPHIC SOLE?

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The Devil's Gate Ophiolite (DGO), a 10 km by 15 km large, oblong mass of amphibolite, is associated with the Feather River ultramafic belt (FRB), a 150-km-long belt of ultramafic and mafic rocks in the northern Sierra Nevada of California. The DGO has been interpreted as comprising mainly sheeted dikes with some pillow basalts on the periphery of the exposures and small bodies of gabbro in the interior. Inspection of the outcrops, however, reveals ubiquitous siliceous metasediment layers (<1 m thick) throughout the interpreted dike and gabbro parts of the DGO. The metasediment layers suggest that the metabasites of the DGO are almost entirely sea floor basalts rather than being primarily intrusive rocks. Metamorphic grain sizes increase towards the interior of the body. No igneous minerals or textures are preserved. Rutile is present in most of the DGO except for the finest grained peripheral units. Al2O3 content of the calcic amphiboles range from 4-9.7 % in the peripheral units to 11.2-12.1% for those of intermediate grain size (formerly called sheeted dikes) to13.6-14.1. % in the coarsest grained rocks formerly called metagabbros. TiO2 content of calcic amphiboles ranges from 0.20 % in the finest grained rocks to 0.56% in the coarsest amphibolites. Plagioclase ranges from albite (An 2-4) in the finest grained peripheral metabasites to An 16-18 for medium-grained, and An 18-22 for the coarsest grained metabasites. Glaucophane (Al2O3 10.6-11.7%) locally rims calcic amphibole in the finest-grained metabasites. The three dimensional shape of the body appears bowl-like with the stucturally highest and highest grade rocks in the center and the structurally lowest and lowest grade rocks on the periphery. The mineral assemblages and compositions appear to reflect high-pressure (HP) metamorphism (1 GPa or more) at medium to high temperature (M/HT) (480-610°C) and an inverted pressure as well as inverted temperature gradient, apparently reflecting internal imbrication within the amphibolite body. Whereas the DGO does not resemble a true ophiolite, it also differs from a HP-HT metamorphic soles found beneath ophiolites because it is much thicker (>1km) than typical metamorphic soles (≤0.5 km). The origin of the DGO remains enigmatic, but the metamorphism suggests that is was partly subducted.

34-3 **BTH 18** Luo, Jun

AN UPPER CRUSTAL OPHIOLITE REMNANT WITHIN THE FEATHER RIVER ULTRAMAFIC BELT, NORTHERN SIERRA NEVADA, CALIFORNIA: UNSUBDUCTED, BUT AFFECTED BY RIDGE SUBDUCTION?

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The 150-km-long Feather River ultramafic belt (FRB), of the northern Sierra Nevada, California, consists of serpentinized ultramafic rocks, with lesser amounts of amphibolite-grade metabasites. The amphibolites are completely recrystallized, with a strong tectonite fabric, lack relict igneous minerals, and record a range of metamorphic conditions from high-pressure, high-temperature (HP-HT) to low-pressure, high-temperature (LP-HT), with some rocks showing overprinting of one high temperature event on another. The amphibolites are intepreted to represent partially subducted oceanic crust recording subduction initiation and ridge subduction events (possibly multiple events of each). Unsubducted “upper plate” ophiolitic rocks are rare in the FRB, but such rocks crop out along La Porte Road in the southern Feather River region. These rocks include gabbroic, diabasic, and possibly basaltic rocks. Preliminary geochemical results suggest a supra subduction zone origin for these rocks. In contrast to the amphibolites, these rocks preserve igneous textures and minerals and lack a penetrative fabric although local shear zones are present. The gabbroic rocks display LP-HT metamorphism, however, recorded by red-brown amphibole that rims actinolite that rims relict igneous clinopyroxene. Diabasic or basaltic rocks have metamorphic actinolite and pumpellyite and record much lower grade metamorphism. This suggests either an exceptionally steep metamorphic gradient in this ophiolite remnant or, more likely, significant post metamorphic faults within the ophiolite. The metamorphism of this ophiolite remnant may reflect ridge subduction beneath it that preferentially metamorphosed the lower crustal levels of the upper plate, or it may record metamorphism associated with oceanic core complex formation near a spreading center. The latter, however, would not be expected to result in prograde metamorphism recorded by hornblende rimming actinolite. The juxtaposition of these upper plate ophiolitic rocks with the amphibolites reflects the complex nature of tectonic processes associated with the development of the FRB suture zone.

34-4 **BTH 19** Ao, Songjian

CAMBRIAN TO EARLY SILURIAN OPHIOLITE AND ACCRETIONARY PROCESSES IN THE BEISHAN COLLAGE

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The mechanism of continental growth of the Altaids is currently under debate between models invoking continuous subduction-accretion or punctuated accretion by closure of multiple ocean basins. We use the Yueyashan-Xichangjing ophiolite belt of the Beishan Collage (southern Altaids) to constrain the earliest oceanic crust in the southern Paleoasian Ocean.We present a structural analysis of the accretionary complex, which is composed of the incoherent ophiolitic melange and coherent sedimentary rocks, to work out the tectonic polarity. A new weighted mean $^{206}Pb/^{238}U$ age of 534.4 ± 3.4 Ma from a plagiogranite in the Yueyashan-Xichangjing ophiolite indicates that the ocean floor formed in the early Cambrian. Furthermore, we present new geochemical data to constrain the tectonic setting of the Yueyashan-Xichangjing ophiolite. The Yueyashan-Xichangjing ophiolite was emplaced as a result of northward subduction of an oceanic plate beneath the Mazongshan island arc to the north in the late Ordovician to early Silurian. Together with data from the literature, our work demonstrates that there were multiple overlapping periods of accretion existed in the Palaeozoic in the northern and southern Altaids. Therefore, a model of multiple accretion by closure of several ocean basins is most viable.

34-5 **BTH 20** Sarifakioglu, Ender

REMNANT OF A JURASSIC BACKARC OCEAN BASIN (KÜRE OPHIOLITE) IN THE CENTRAL PONTIDE BELT, TURKEY

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We report here on the Jurassic Küre ophiolite in the Central Pontide belt of northern Turkey. This ophiolite is a remnant of a backarc ocean that opened during the pre-Lias and closed in the early Dogger as part of the Tethyan realm. It is tectonically imbricated with the mid-Late Paleozoic Devrekani metamorphic units and the Triassic Cangaldag Complex. The Küre Ophiolite consists of harzburgite, lherzolite and dunite, layered to isotropic gabbros, sheeted dolerite and plagiogranite dikes, and pillow-massive lava flows, volcanic breccias and hyaloclastites. Basaltic lavas are the hostrock of massive sulphide deposits. The upper mantle rocks in Küre include both depleted mantle and abyssal peridotites. The SiO_2 contents (46.97-68.84 wt.%) and alkali (Na_2O+K_2O) values (3-6 wt%) of the volcanic units show basalt, basaltic andesite, trachybasalt, basaltic trachyandesite and dacite compositions with tholeiitic and calc-alkaline affinities. Their Ti/V ratios (12.08-32.12) indicate IAT- and MORB-like compositions. Plagiogranite dikes in the ophiolite have Si_2O (68-69 wt%), K_2O (0.36 wt%), Nb (1-2 ppm), Th (0.6 ppm), displaying VAG characteristics. Ophiolitic pillow lavas are overlain by the Liassic pelitic rocks (Akgöl Formation) that grade upwards into black shales. Elsewhere, the ophiolite is unconformably overlain by an Upper Jurassic-Lower Cretaceous neritic limestone starting with a basal conglomerate. The Dogger granitoids, composed of granite, granodiorite, diorite and syeno-diorite with metaluminous and peraluminous characteristics, represent a continental arc development in the Central Pontides as a result of northward subduction of the Küre marginal basin.

34-6 **BTH 21** Moore, Diane E.

VARIATION WITH CREEP RATE IN THE MINERALOGY AND TEXTURES OF FAULT GOUGE FROM THE SAN ANDREAS FAULT OBSERVATORY AT DEPTH (SAFOD)

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The SAFOD deep drillhole, located 14 km northwest of Parkfield, CA, crosses the central creeping section of the San Andreas Fault where measured creep rates are ~25 mm/yr. Coring

at 2.65–2.70 km vertical depth successfully sampled two zones of foliated gouge where creep is localized: the 2.6-m-wide central deforming zone (CDZ) and the 1.6-m-wide southwest deforming zone (SDZ). The CDZ takes up most of the creep, as evidenced by the more pronounced well-casing deformation associated with it. The gouge zones are the product of shear-enhanced metasomatic reactions between sedimentary wall rocks of the Great Valley Group and serpentinite that was tectonically entrained in the fault from a source in the Coast Range ophiolite. Although the CDZ and SDZ are closely similar in character, consisting of porphyroclasts of serpentinite and sedimentary rock dispersed in a foliated matrix of Mg-rich clay minerals, they exhibit differences in texture and mineralogy that can be attributed to different shearing rates. In addition, a ~0.2-m-wide sector of the CDZ located at its northeastern margin (NE-CDZ) is essentially identical in texture and Mg-clay chemistry to the SDZ, possibly due to a gradient in creep rate across the CDZ. The SDZ and NE-CDZ core samples contain a larger proportion of porphyroclasts than the majority of the CDZ, and average porphyroclast sizes are also larger. Narrow veinlets of calcite up to 5 mm in length and oriented parallel to the foliation were observed only in the matrices of the SDZ and NE-CDZ gouges. The gouge matrix clays in the SDZ and NE-CDZ consist of saponite (trioctahedral, Mg-rich smectite) and corrensite (1:1 ordered, interstratified saponite-chlorite), whereas those in the rest of the CDZ are largely saponite. Where age relations can be determined, saponite is always later than corrensite. Larger sizes and greater abundances of serpentinite and sedimentary clasts in the SDZ and NE-CDZ are consistent with a lesser degree of shear-enhanced reaction to form the Mg-rich clays. The temporal differences in clay-mineral compositions may reflect a change in physico-chemical conditions such as temperature or fluid chemistry, with clays in the more actively deforming portions adjusting more completely to the new conditions than those in more slowly creeping portions.

34-7 **BTH 22** Jung, Haemyeong

NATURAL TYPE-C OLIVINE FABRICS IN GARNET PERIDOTITES IN NORTH QAIDAM UHP COLLISION BELT, NW CHINA

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Water is known to change the lattice-preferred orientation (LPO) of olivine, which significantly affects seismic anisotropy in the Earth's upper mantle. Research into the LPO of olivine in the deep interior of the Earth has been limited due to inadequate specimens. We report both the water-induced LPOs of olivine and the presence of large quantities of water inside olivine, enstatite, and garnet in garnet peridotites from the North Qaidam ultrahigh-pressure (UHP) collision belt in NW China. We show that the [001] axis of olivine is aligned subparallel to the lineation and that the [100] axis is strongly aligned subnormal to the foliation. This alignment is a known feature of type-C LPO of olivine formed experimentally under water-rich conditions (≥700 ppm H/Si) at high pressure and temperature. Enstatite possessed an LPO with the [001] axis aligned parallel to the lineation and the [100] axis aligned normal to the foliation. FTIR analysis of this specimen revealed that olivine contained concentrations of water up to 1130 ± 50 ppm H/Si in clean areas, whereas olivine, enstatite, and garnet contained considerably more water, i.e., 2600 ± 100 ppm H/Si, 5000 ± 100 ppm H/Si, and 21000 ± 200 ppm H/Si, respectively, when exsolved inclusions were visible. Confocal micro-Raman spectroscopy of these exsolved inclusions revealed that they were composed of hornblende and amphiboles. Straight dislocations were also commonly observed in olivine and are characteristic of olivine that had been experimentally deformed under hydrous conditions. These observations suggest that the type-C LPO of olivine in the North Qaidam UHP belt formed under water-rich conditions.

34-8 **BTH 23** Kim, Dohyun

LATTICE PREFERRED ORIENTATION AND WATER CONTENT OF OLIVINE IN PERIDOTITES FROM ALMKLOVDALEN IN WESTERN GNEISS REGION, SW NORWAY

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Almklovdalen is a part of Norwegian Western Gneiss Region, located in SW Norway. Six garnet peridotites from Almklovdalen were studied to understand deformation processes and seismic anisotropy in the upper mantle. These peridotites were metamorphosed at high pressure and high temperature and contained chlorite up to ~20 %. Lattice preferred orientation (LPO) of olivine was determined by using electron backscattered diffraction (EBSD) in SEM. Water content of olivine was measured using the Nicolet 6700 Fourier transformation infrared (FTIR) spectroscopy.

Six samples showed various LPOs of olivine. The garnet peridotite with the highest garnet content (19 %) showed that [100] axes of olivine are aligned subparallel to the lineation and [010] axes aligned normal to the foliation, which is known as A-type LPO. Two samples showed that [001] axes are aligned subparallel to the lineation and [010] axes aligned normal to the foliation, which is known as B-type LPO. One sample showed that [100] axes are aligned subparallel to the lineation and [001] axes aligned normal to the foliation, which is known as E-type LPO. Another sample showed that [001] axes are aligned subparallel to the lineation and [100] axes aligned normal to the foliation, which is known as C-type LPO. Water content of olivine obtained from FTIR analysis was in the range of 250 – 660 ppm H/Si. The garnet peridotite with the highest garnet content (19 %) showed a small amount (250 ppm H/Si) of water in olivine. Samples with olivine LPOs of B-, C-, and E-type showed high water contents in olivine. In contrast, samples with olivine A-type LPO showed low water content which is consistent with the result of previous experimental studies at high pressure and high temperature. Seismic anisotropy of different LPOs of olivine was calculated and will be presented.

34-9 **BTH 24** Moss, Benjamin T.

MICROSTRUCTURAL ANALYSIS OF HYPERSOLIDUS FOLIATIONS AT THE ATLANTIS BANK OCEANIC CORE COMPLEX, SOUTHWEST INDIAN RIDGE

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To investigate the initiation of detachment faulting at "hot detachment" oceanic core complexes, we focus on the Atlantis Bank oceanic core complex, Southwest Indian Ridge, where abundant high-temperature hypersolidus fabrics (i.e., those developed at high temperatures in the presence of melt) in the footwall rocks are assumed to have recorded the onset of detachment faulting and strain localization during magmatism. We examine hypersolidus fabrics in lower crust gabbro from the footwall of the Atlantis Bank core complex using drilling core samples from Ocean Drilling Program (ODP) Hole 735B. We use petrographic and microstructural analyses to describe the variation in hypersolidus fabric development, and we observe two primary fabric types that we designate as Fabric Type I and Fabric Type II.

In Fabric Type I, subhedral and elongate plagioclase laths define a strong foliation where plagioclase grains display microstructures such as undulose extinction and tapered deformation twins, which are indicative of very minor strain. In contrast, clinopyroxene grains display microstructures indicative of slightly more strain relative to plagioclase, as subgrains are common and systematically oriented perpendicular to foliation. In Fabric Type II, a moderate foliation is defined by subhedral and elongate plagioclase laths that exhibit undulose extinction and deformation twins, and smaller grains that show curved or lobate grain boundaries indicative of recovery through grain boundary mobility and minor recrystallization. Both clinopyroxene and olivine display evidence of minor strain such as undulose extinction, but olivine exhibits rare subgrains that are systematically oriented perpendicular to foliation. Late-stage igneous brown hornblende mantles clinopyroxene grains and displays straight extinction. Fabric Types I and II have strong to moderate foliations, yet the constituent minerals show relatively minor evidence of internal crystal plasticity, suggesting both fabrics formed in the presence of melt. However, the fabrics are differentiated by relative abundances of microstructures indicative of strain and recovery, where Type II fabrics may indicate more intense deformation associated with the onset of strain localization, possibly due to decreasing melt fraction approaching the solidus.

SESSION NO. 35, 8:00 AM
Wednesday, 22 May 2013
Structural Geology and Tectonics (Posters)
Radisson Hotel and Conference Center, Salon B/C

35-1 **BTH 25** Anderson, R. Ernest

HYDROGEOLOGY OF THE ZUCCALE DETACHMENT FAULT, ELBA ISLAND, ITALY

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Elba Island consists of a west-dipping stack of east-directed pre-extension thrust sheets invaded by 6-8 Ma Miocene syn-extension plutons emplaced at depths ranging from 6-3 km. The plutons, now at sea level, are younger and emplaced at shallower depth in the west than in the east. The space-depth relationship is opposite the relationship expected if exhumation were by the east-vergent Zuccale detachment fault (ZF). The ZF has a strongly domed shape in eastern Elba Island, and that shape has been interpreted as having formed at depth during plutonism, an interpretation also at odds with pluton exhumation by subsequent ZF displacement. These relationships warrant consideration of alternative modes of uplift. The ZF separates contrasting paleohydrologic regimes; strong oxidative alteration, dissolution, and iron and carbonate replacement in upper-plate rocks vs. sulfide mineralization and silicification in lower-plate rocks. Excellent exposures in numerous open-pit iron-mine excavations in altered upper plate rocks reveal wholesale destruction of primary schistose fabric and widespread secondary srtuctures formed by dissolution and collapse. Those relations, together with the form and contact relations of sub-grade iron-bearing masses remaining in the pits, support a hydrogeologic model of iron ore formation as residues of protracted karst activity. Karst volume loss could have kept pace with uplift protracted over a few Ma. In this open-system model, diapiric uplift during thermal relaxation fed the pluton and its country rock into a corrosive zone of interaction between hot acidic lower-plate waters and oxidative cooler upper-plate waters. Corrosion was aided by sulphuric acid derived from the breakdown of pyrite in the presence of carbonic acid streaming upward from the mantle, a process currently active beneath central Italy. Exposures of the ZF in the Punta di Zuccale and Spiaggia Nere area mark the hydrogeologic boundary zone between the two fluid systems, a zone from which the loss of several km^3 of predominantly silicic rock by karsting is postulated.

35-2 **BTH 26** Greene, David C.

THE CONFUSION RANGE "SYNCLINORIUM": A WESTERN UTAH THRUST BELT ANALOGOUS TO THE CENTRAL NEVADA THRUST BELT

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The Confusion Range in west central Utah has been considered a broad structural trough or synclinorium with little overall shortening. However, new balanced cross sections indicate that the Confusion Range is more accurately characterized as an east-vergent, fold-thrust belt with ~10 km of horizontal shortening during the late Mz to Paleogene Sevier orogeny. Subsurface structure is dominated by a series of frontal and lateral ramps in lPz strata on the west side of the range. Ramp anticlines and anticlinal duplexes characteristic of lPz strata are balanced by faulted and rotated detachment folds in uPz strata, with a major detachment zone in shales of the Chainman and Pilot formations. The apparently synclinal aspect of the Confusion Range results from two different sets of thrust structures that uplift and expose lower Paleozoic strata on the flanks of the range. The east-dipping Snake Range decollement projects under the Confusion Range at a depth of 5 to 10 km or more, and may truncate deeper level structures of the fold-thrust belt.

Fold-thrust structures and structural style are continuous southward into the Burbank Hills and Mountain Home Range for more than 130 km of total strike length. Thus the "Confusion Range synclinorium" of previous authors is a fold-thrust belt of regional extent, herein informally named the western Utah thrust belt (WUTB). To the south the WUTB merges with the Wah Wah thrust and related structures of the Sevier frontal thrust zone near the south end of the Indian Peak Range. To the north, restoring 47 km of displacement on the Sevier Desert Detachment aligns the Confusion Range with uPz strata and fold-thrust structures in the Cedar Mountains. These structural correlations suggest that the WUTB is a coherent fold-thrust belt that diverges from the Sevier frontal zone in southwestern Utah and can be traced northward into west central Utah for at least 250 km.

The western Utah thrust belt is similar in size and structural style to the central Nevada thrust belt. Together these thrust belts and related structures in eastern Nevada indicate significant, broadly distributed Mz shortening. The Sevier hinterland is thus not an undeformed interior zone as originally envisioned, but instead preserves an important component of Mz fold-thrust deformation during the Sevier orogeny.

35-3 **BTH 27** Fang, Yi

A STABLE ISOTOPE STUDY OF FLUID-ROCK INTERACTIONS IN THE SAN GABRIEL FAULT ZONE AND ITS RELATIONSHIP TO SEISMIC PROCESS

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The Plio-Pleistocene uplift and erosion of the San Gabriel Mountains allows us to directly observe the seismogenic paleodepths of San Gabriel Fault and to determine its fluid history using stable isotopes. Integrated petrographic, geochemical and structural studies indicate that fluids have played a significant role in weakening the fault zone by two interrelated processes: 1) Mechanical weakening of the fault zone as rock failure is induced by elevated pore-fluid pressure in response to reduced pore-space volume, resulting in the reduction of friction along the fault. 2) Chemical weakening due to alteration that resulted as fluids reacted with fine-grained cataclasites, resulting in weaker foliated phyllosilicate-rich fault rocks. This process is evidenced by occurrences of fracture-controlled chlorite, epidote, clay minerals and zeolites, veins of carbonate and slickenside surfaces filled with calcite and/or zeolites that cut through brecciated zones. Stable isotopes provide evidence of fluid sources and temperatures of fluid-rock interaction during deformation. δD values of biotite (–67 to –95‰), hornblende (–72 to –81‰), and chlorite (–73 to –76‰) indicate hydrous minerals have been altered with local meteoric water (δD ≈ –40 to –50‰). High temperature oxygen isotope fractionations ($\Delta^{18}O_{BIO/HBL-H2O}$ = 6) indicate high temperature $^{18}O/^{16}O$ equilibrium (T ~ 475°C) with rock-buffered $\delta^{18}O_{H2O}$ values (~+8‰), but this also suggests a low water-rock ratio system involving meteoric-hydrothermal waters as some mineral pairs display non-equilibrium $^{18}O/^{16}O$ fractionations ($\Delta^{18}O_{BIO/HBL-H2O}$ = 2). A reinterpretation of published carbonate vein $\delta^{13}C$ and $\delta^{18}O$ values (Pili et al, 2011) also indicates meteoric water dominant in the evolution of the San Gabriel Fault Zone. Similar processes that involve weakening by alteration due to circulation of small amounts of external meteoric water may be responsible for the weakening of the San Andreas Fault.

35-4 **BTH 28** Giallorenzo, Michael A.

TWO EXHUMATION EVENTS OF THE WHEELER PASS THRUST SHEET IN THE SOUTHERN SEVIER OROGEN FROM (U-TH)/HE ZIRCON THERMOCHRONOLOGY

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The Wheeler Pass (WP) thrust sheet is a major structural feature that played a key role in the development of the southern Sevier orogenic belt, now discontinuously exposed across several mountain ranges in the Mojave Desert. This regionally extensive sheet of Neoproterozoic and Paleozoic rocks from the passive margin of western North America experienced ~6 km of stratigraphic throw and >30 km of lateral displacement. The timing of motion of the WP thrust fault is poorly bracketed by stratigraphy between the Pennsylvanian and Late Cenozoic. Proposed correlative thrusts to the south, including the Winters Pass and Pachalka thrusts, permit additional constraints that late motion on the fault system occurred at ~146 Ma. The large thickness (9+ km) of the WP sheet and stratigraphic throw permit the application of zircon (U-Th)/He (ZHe) thermochronometry to date cooling related to erosional exhumation due to rock uplift over thrust ramps. Here we present new ZHe data from two key sections of the WP thrust sheet that represent different stratigraphic depth intervals: Neoproterozoic to Devonian strata in the NW Spring Mountains, and Paleoproterozoic basement through Cambrian strata in the southernmost Nopah Range. Our results indicate that the WP thrust sheet in the northwest Spring Mountains underwent moderate cooling rates in the Late Jurassic at ~155 Ma, followed by slow cooling and development of a ZHe Partial Retention Zone (PRZ) between ~150 Ma and ~50 Ma. In contrast, ZHe results from the southern Nopah Range section show a preserved Cretaceous PRZ followed by moderate cooling rates beginning at ~100 Ma. We interpret these two seemingly disparate cooling histories as reflecting separate cooling events from different structural levels of the thrust sheet and different initial positions relative to a complex WP thrust ramp. ZHe thermochronometry of the WP thrust sheet indicates Late Jurassic motion on the WP thrust followed by mid Cretaceous passive uplift and exhumation due to thrusting along a structurally lower ramp related to the frontal Keystone and Red Springs-Wilson Cliffs-Contact thrust system that lies to the east.

35-5 **BTH 29** Crane, Jake

THE ROLE OF HETEROGENEITIES IN CRUSTAL STRENGTH DURING CONTINENTAL RUPTURE: A NUMERICAL MODELING APPROACH

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Subduction zones often transition into continental rifts with accreted terranes becoming the locus of extension. The lateral variations in crustal strength associated with these accreted terranes must play a role in the patterns of the subsequent extensional evolution. To explore the affect of heterogeneities in crustal strength on the evolution of continental rifting we use a 2-D geodynamic model to simulate the evolution of a lithospheric cross section of accreted terranes juxtaposed to a craton. The model domain consists of a thick, strong craton on the right side and a thinner, weaker lithosphere of accreted terranes on the left side. A stronger crustal block is emplaced within the accreted terranes to simulate the affect of strength heterogeneities of accreted terranes.

The experiment looked at the impact of varying three factors: i) the location of the strong block, ii) the rate of crustal heat production in the strong block, and iii) the spreading velocity. Model results fall into three different extensional styles; 1) rifting and eventual rupture of the lithosphere occurs at the left edge of the model 2) lithospheric rupture is located between the strong block and the craton 3) the locus of extension migrates from the edge of the model to the region between the strong block and the craton.

All model simulations begin with extension at the left edge of the model. In all cases with a high heat production within the strong block, regardless of location or spreading rate, extension eventually migrates to the region between the strong block and the craton. Simulations with moderate to low heat production in the strong block, and with the strong block located nearer the model edge, the extension immediately migrates to the region between the strong block and the craton. Simulations with moderate to low heat production in the strong block, and with the strong block located far from the model edge, with high spreading velocity, extension and lithospheric rupture occurs at the model edge.

The results of this study suggest that strength heterogeneities systematically control the evolution and final geometry of a continental rift and should be addressed when studying continental rupture. These results may provide insights to the evolution of complex continental rifts such as the Basin and Range Province and the West Antarctic Rift System.

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