Colorado Scientific Society

The objective of the Society is to promote the knowledge and understanding of Earth science, and its application to human needs

Newsletter of the Society – September, 2018

September Meeting, Thursday, Sept. 20, 2018
Short Talks & Poster Session Evening

Join us for a selection of talks and poster papers from past or upcoming geologic meetings, on a wide variety of topics!

Arbor House, Maple Grove Park,
14600 W. 32nd Ave., Golden (Applewood area)
Complimentary refreshments!*

5:30 p.m. social time and poster viewing (authors present)
7:00 p.m. oral presentations (four 15-minute talks)

Oral presentations: (See abstracts of all talks after the body of the Newsletter)

The effects of geological structure and clay on landslides in the Teklanika Formation in Denali National Park and Preserve, Alaska, Michael Frothingham, PhD student, CU Boulder

Insight into incipient motion of blocks on a river bed from Computation Fluid Dynamics modeling, Aaron Hurst, PhD student, CU Boulder

Seasonality of a Sub-Alpine Lake: Understanding evolving physical and biogeochemical controls on aquatic ecosystem structure under ice cover. Rocky Mountain National Park, Colorado USA, Garrett Rue, PhD Candidate, CU Boulder

The role of flashing in the formation of high-grade, low-sulfidation epithermal deposits: a case study from the Omu Camp in Hokkaido, Japan, Lauren Zeeck, MS Candidate, Colorado School of Mines

Poster presentations: see next page.

**including our thank-you to Golden City Brewery!*

Poster presentations: (See abstracts of all presentations after the body of the Newsletter)

Evidence of rapid incision within tributary box canyons during historical times, South Platte River corridor, northeastern Colorado, Margaret E. Berry, U.S. Geological Survey

The importance of mineralogy for deciphering the evolution of alkali-basaltic magmas: a case study of Dotsero volcanics (Eagle County, central Colorado) , Anton Chakhmouradian , Geological Sciences, University of Manitoba, and Peter Modreski, USGS

Evolution of an interbasin mountain-block extensional accommodation zone within the central Colorado Rio Grande rift, USA, Scott A. Minor, Jonathan Saul Caine, Chris J. Fridrich, Mark R. Hudson, and Cal Ruleman, U.S. Geological Survey

Geology of the upper Arkansas River valley, Colorado - a field mapper's perspective, Colorado Scientific Society, Field Trip, Sept 15-16, 2018
Trip leaders: Karl Kellogg (USGS emeritus), Cal Ruleman (USGS), and Scott Minor (USGS)

U-Th Geochronology using hydrogenic and biogenic materials, James B. Paces, USGS, Elizabeth M. Niespolo, Dept. Earth & Planetary Science, Univ. of California, Berkeley, and Warren D. Sharp, Berkeley Geochronology Center, Berkeley, CA

Mineralogy and petrogenesis of the California Blue mine aquamarine- and topaz-bearing pegmatite deposit, San Bernardino County, California, Carolyn Pauly, MS student, CSM

Pleistocene lakes and paleohydrologic environments of the Tecopa Basin: Constraints on the drainage integration of the Amargosa River, Marith Reheis, John Caskey, Jordon Bright, and Jim Paces, U.S. Geological Survey

Understanding geomorphic response to floods: the role of scale and gradients, Joel Sholtes, US Bureau of Reclamation

Indigenizing water resources on the Navajo Nation: A water policy analysis and critique, Andrew Swanson, Undergraduate student, CU Boulder

The basement tapes: Mapping the Precambrian beneath the Colorado Plateau, D.S. Sweetkind, U.S. Geological Survey

A paleoseismic investigation of the Northern Teton fault at the Steamboat Mountain trench site, Grand Teton National Park, Wyoming.
Mark S. Zellman, BGC Engineering, Inc., and Christopher B. DuRoss, Glenn D. Thackray, Richard W. Briggs, Nicole Cholewinski, Tyler Reyes, Nick Patton, and Shannon A. Mahan, USGS

President's Message, Sep. 2018

This summer I participated in a field trip to the Ouray area that replicated one I had been on ten years ago. It caused me to ponder the changes that have occurred over the past ten years. While the geology has not changed, our views of it have.

This year many of us navigated to Ouray following the lure of the blue dot. This telephone mapping application was only dimly contemplated ten years ago. Now we use it world-wide, and from aircraft. Mapping apps and sites like Avenza that allow you to load USGS geologic maps onto your phone and Flyover Country that allow you to learn about the geology you are flying over (developed by Shane Loeffler at U. Minnesota) are making us all more digital.

Mantle tomography:
Deep seismic tomographic imaging of low velocity materials in the upper mantle allows us to see the roots of volcanic systems like Yellowstone and to image the character of subducted slabs beneath western North America. These data sets are being used to provide context for the vast Tertiary eruptions of the San Juan Mountains.

'Shale gale' and US oil imports:
Refinement of drilling and completion techniques have resulted in vast increases in gas production from Colorado's Cretaceous Interior Seaway hydrocarbon system. A by-product of this is the reduced price of gas vs. coal and a dramatic shift in electrical generation in the US. This has the happy effect of halving CO_2 production per kilowatt. On a national basis, fracking has also dramatically increased oil production: doubling over the past ten years from about 5 to about 11 MMBO/day (highest ever). Oil imports have fallen slightly from about 9 to about 8 MMBO/day; (we are not self sufficient in oil). As noted in a front-page article in the WSJ on 11 July, the doubling of US oil production has seen an employment base little changed due to technological innovation and efficiency gains.

Ghost forests, temperature and low reservoir levels:
Warmer winters, resulting from increased greenhouse gas in the atmosphere (CO_2 has risen from 382 to 408 ppm in past ten years), have resulted in a change in the elevation constraints on a variety of bark beetle species. The resultant death of conifer forests from Alaska to New Mexico was locally manifest in the upper reaches of the Ouray valley. Year 2008 was the peak of the mountain pine beetle infestation; by 2018 we were dealing with the later effects of the spruce bark beetle
See graph at:
https://csfs.colostate.edu/forest-management/common-forest-insects-diseases/mountain-pine-beetle/
During our field trip there were water restrictions in both Ouray and Ridgway; the entire Colorado River drainage is water-challenged as the west warms. The global temperature has risen 0.2 degrees C in the past ten years.

Population and sea level:
Despite the fact that peak baby was about 1990, global population has increased from about 6.8 B to about 7.8 B over the past ten years; this is equivalent to the population of North America and South America combined. We are heavier; 34% of American adults were overweight in 2008, now it is closer to 38%.
Sea level rose by 3 cm as measured by satellite radar data. Global ice melting (documented by the Grace satellite system) is responsible for 2 cm, thermal expansion of seawater for about 1 cm of this rise. You can see the temperature data at:
https://en.wikipedia.org/wiki/Global_temperature_record

BTW: ten years ago Wikipedia was a suspect venue to many, today it is recognized as perhaps the single greatest innovation of mankind after the taming of fire.

Digital geology movies:
Paul Weimer's Interactive Geology Project team at CU Boulder has produced a series of videos showing the evolution of Colorado using digital virtual reality. Several of these videos are available on YouTube, for example look for: 'A brief history of Colorado through time'.
See web page at: igp.colorado.edu

Digital stratigraphy:
Steve Cumella has perfected his technique of jamming color-coded (corrected and calibrated) electric logs using Petra and other software packages. His log sections now resemble seismic transects with the wonderful benefit of being in depth, not time.

Working with James Hagadorn at the Denver Museum I have compiled a digital stratigraphic chart covering all of Colorado's sedimentary rocks. See web page at Coloradostratigraphy.org

Regional stratigraphy

Cutler Formation:

Don Rasmussen has improved his correlation from the axial Paradox basin to its proximal eastern margin. His regional sections now show the Cutler Formation to be a proximal facies of elements of the late fill of the Paradox Basin. The Hermosa is characterized by intervals of carbonate; the overlying Cutler lacks them. Defining the boundary between the Hermosa and the Cutler, like that of the boundary between the Minturn and the overlying Maroon is a quixotic quest.

Telluride Conglomerate:

One of the most enigmatic units in the region. This thin coarse conglomerate of basement clasts is tentatively placed into a regional context by correlation to the Bishop, Tallahassee Creek and the Castle Rock Conglomerate of the Front Range. These conglomerates may in turn have genetic correlations to similar aged enigmatic conglomerates in the Wind River Basin of Wyoming. Interpreted ten years ago as valley-fill deposits by Bob Weimer, these conglomerates represent high energy flow (flood deposits?) from basement sources that accumulated in the absence of significant accommodation on or near the Rocky Mountain Erosion Surface.

Rocky Mountain Erosion Surface:

The RMES has been mapped state-wide by Ned Sterne and has been locally studied by Donahue (2016) and Ewing (2017). Here in Ouray, it is lightly mantled by the mysterious Telluride Conglomerate,

Detrital zircon dating:
Led by folks in Arizona (Dickinson and Gehrels) the clastic sedimentary rocks of western North America are being seen in new light as we learn of the age spectra of detrital zircons and their implications for regional dispersal patterns. Many of Colorado's Mesozoic eolian rocks (including the Entrada Sandstone) have components derived from the eastern US, presumably transported west by large rivers and subsequently reworked by eolian processes.

Pleistocene ice:
The Pleistocene started about 2.5 MY ago and witnessed many tens of glacial episodes. We know only the last three or four in any detail. Vince Matthews is accumulating data on the distribution of Colorado's past glaciers and learning that the moraine record is a complicated set of superimposed signals, now coming to light through the use of OSL dating.

Bob Raynolds, 2018 President, Colo. Sci. Soc.

CSS Meetings for the rest of 2018:

Please make note of the dates; we'll have more info available in our next newsletter and by email:

Thurs., Sept. 20, Colorado Scientific Society September meeting: Poster Session + Short Talks; a selection of invited poster + short oral presentations by CSS members and by graduate students. Arbor House, Maple Grove Park, 14600 W. 32nd Ave., Golden CO. All are invited; complimentary refreshments (including beer!). For more information see http://coloscisoc.org .

Thurs., Oct. 18, 7:00 p.m., Colorado Scientific Society October meeting, **"Structural Geology of Colorado"** by Ned Sterne, plus "**Electric log cross sections of Colorado"** by Steve Cumella. Shepherd of the Hills Church, 11500 W. 20th Ave., Lakewood; all are welcome.

Sun., Oct. 21, 4:00-6:00 p.m., **CSS Family Night at the Colorado School of Mines Geology Museum.**

Thurs. Nov. 15, 7:00 p.m., Colorado Scientific Society November meeting, **"Geothermal Energy**", by Jeff Winick, DOE, plus a possible 2nd speaker. Shepherd of the Hills Church, Lakewood.

Thurs., Dec. 13, (plans still tentative), **CSS Annual Meeting and President's Address**, tentatively to be held in the Denver Museum of Nature and Science, Gates Planetarium.

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***It's ALWAYS a good time to* renew your membership in the Colorado Scientific Society!** Get a jump on 2019 and renew now. Dues are $25 for regular members (discount rate of $20 if paid before the end of January), $10 for corresponding members (outside the Colorado Front Range area) and $5 for students. A Lifetime Membership is $395.00. Mail a check to the CSS or pay with a credit card using PayPal on the CSS website, http://coloscisoc.org/membership-payment/. Send payments to **Colorado Scientific Society, P.O. Box 150495, Lakewood CO 80215-0495.**
For more news & information about the Society, always check our website, **www.coloscisoc.org**, or see our facebook page, **https://www.facebook.com/groups/511533159044226/** .

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Calendar of Coming Events

Thurs., Sept. 20, Colorado Scientific Society September meeting: Poster Session + Short Talks; a selection of invited poster + short oral presentations by CSS members and by graduate students. Arbor House, Maple Grove Park, 14600 W. 32nd Ave., Golden CO. All are invited; complimentary refreshments (including beer!). For more information see http://coloscisoc.org .

Sat., Sept. 22, 2:30 p.m., **Scientific Spelling Stomp**, sponsored by the Friends of Dinosaur Ridge. "An all-ages team spelling bee." American Mountaineering Center, Golden CO. Entry fee, $40/adult, students (under 18) $25; spectator tickets $20. Includes hot/cold appetizers and non-alcoholic drinks.

Sun., Sept. 23, Florissant Scientific Society field trip, "**Glaciation on Pikes Peak**"; led by geologist, Alex Paul. "Meet at 10 a.m. at the entrance to the Pikes Peak Highway toll gate for parking and car-pooling." Stops will include the Crystal Lake visitor center, distribution and character of glaciers on Pikes Peak, comparing types of moraines, Glen Cove and its moraine, two glacial valleys at the N. French Creek/E. Beaver Creek divide, the

“Crater”, and more. Open to anyone interested! No charge other than the toll road fee. If you want to come, please contact Beth Simmons, cloverknoll@comcast.net.

Wed., Sept. 26, 4:00 p.m., CU Geological Sciences Colloquium, David Boutt, University of Massachusetts, GSA Birdsall-Dreiss Distinguished Lecturer in Hydrogeology, **Water and Lithium - The nexus of hydrogeosciences and green energy in the transition from fossil fuels.** Benson Earth Sciences Building, Room 180; refreshments follow meeting; all welcome.
Abstract: “The Earth is warming at an unprecedented pace due to the release of carbon dioxide from the burning of fossil fuels. Our society is now in the great transition to a green and more sustainable energy supply. The development of portable and powerful energy storage mechanisms is essential to replace our dependence on the high-energy density fossil fuels. Lithium-ion batteries have emerged as one important technology for this purpose. The element lithium is abundant and plentiful on the planet but is rarely found at high concentrations to be of economical use. Economic deposits of lithium are found in pegmatites and closed-basin continental brines. The origin of the lithium brines and their distribution worldwide is fundamentally tied to the hydrology and hydrogeology of the host basins. This talk focuses on the multifaceted role of (ground) water in transporting, accumulating, and extracting lithium in continental brines and this discipline represents an important interface between hydrogeology, economic geology, and our green energy supplies. Field examples from Northern Chile and the Great Basin of the United States highlight the inter-disciplinary nature of the origin and evolution of continental lithium brine deposits. Many aspects of geosciences including volcanology, sedimentology, geomorphology, geochemistry, geophysics, paleoclimate, structural geology and tectonics combine with hydrogeosciences make this a particularly exciting example of the importance of earth sciences to future energy supplies. The environmental impacts of lithium brine pumping is explored and discussed in the context of balancing the sustainability of lithium-ion batteries.”

Sat., Oct. 13, 9 a.m. – 3 p.m., **Dinosaur Discovery Day** at Dinosaur Ridge, featuring “**Girl Scout Day**”. Public tour day at Dinosaur Ridge, 16831 W. Alameda Parkway, Morrison. Walk up and down the Ridge to see interpretive guides explain the various fossil and geology stations, or ride a guided shuttle up and/or back for $4. There will be special activities and earth science badges to complete for Girl Scouts, who may register in advance [$6 for Scouts to register]. See www.dinoridge.org for more info.

Thurs., Oct. 18, 7:00 p.m., Colorado Scientific Society October meeting, **“Structural Geology of Colorado”** by Ned Sterne, plus “**Electric log cross sections of Colorado”** by Steve Cumella. Shepherd of the Hills Church, 11500 W. 20th Ave., Lakewood; all are welcome.

Thurs. Nov. 15, 7:00 p.m., Colorado Scientific Society November meeting, **“Geothermal Energy**”, by Jeff Winick, DOE, plus a possible 2nd speaker. Shepherd of the Hills Church, Lakewood.

For more lecture series during the year see:
Colorado Beer Talks (2nd Tuesday, 6-8 p.m.), Windy Saddle Café, 1110 Washington Avenue, Golden, “Golden’s grassroots version of TED talks, Expand your mind with a beer in your hand”, http://goldenbeertalks.org/
Colorado Café Scientifique in Denver, monthly lectures on science topics held either at Blake Street Station or Brooklyn’s, Denver; open to the public, no charge other than refreshments you may choose to purchase; see http://cafescicolorado.org/ .
Colorado Scientific Society (3rd Thursday, 7 p.m.), see http://coloscisoc.org/ . Meets at Shepherd of the Hills Church, 11500 W. 20th Ave., Lakewood CO, except when otherwise noted.
CU Geological Science Colloquium (Wednesdays, 4 p.m.) see http://www.colorado.edu/geologicalsciences/colloquium
CSU Dept. of Geoscience Seminars (Fridays, 4 p.m.), see https://warnercnr.colostate.edu/geosciences/geosciences-seminar-series/

Van Tuyl Lecture Series, Colorado School of Mines, (Thursdays, 4 p.m.): https://geology.mines.edu/events-calendar/lectures/
Denver Mining Club (Mondays, 11:30), see http://www.denverminingclub.org/ **.**
Denver Museum of Nature and Science, Earth Science Colloquium Series: *to be announced*
Denver Region Exploration Geologists Society (DREGS; 1st Monday, 7 p.m.), http://www.dregs.org/index.html
Florissant Scientific Society (FSS); meets monthly in various Front Range locations for a lecture or field trip; meeting locations vary, normally on Sundays at noon; all interested persons are welcome to attend the meetings and trips; see http://www.fss-co.org/ for details and schedules.
Nerd Night Denver is a theater-style evening featuring usually 3 short (20-minute) TED-style talks on science or related topics; held more-or-less monthly at the Oriental Theater, 4335 W. 44th Ave., Denver; drinks are available; for ages 18+. Admission is $6 online in advance, $10 at the door. See https://www.nerdnitedenver.com/ .
Rocky Mountain Map Society (RMMS; Denver Public Library, Gates Room, 3rd Tuesday, 5:30 p.m.), http://rmmaps.org/
U.S. Geological Survey Rocky Mountain Science Seminars: 10:30-11:30 a.m. Tuesday mornings, biweekly, Jan.-May, Building 25 auditorium, Denver Federal Center, Lakewood; 2019 schedule to be announced.
Western Interior Paleontology Society (WIPS; Denver Museum of Nature & Science, 2nd Monday, 7 p.m.), http://westernpaleo.org/ . Meetings are held either in the Ricketson Auditorium or the Planetarium at the Denver Museum of Nature & Science, unless otherwise noted

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CSS Officers for 2018

President…………………… Bob Raynolds, bob.raynolds@dmns.org
President Elect……………… Tom Casadevall, tcasadev@gmail.com
Past President……………… Marith Reheis, 303-277-1843, marith16@gmail.com
Secretary…………………… Lisa Fisher, 303-215-0480, lisa.fisher@alumni.mines.edu
Treasurer…………………… Don Sweetkind, 303-236-1828, dsweetkind@usgs.gov

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2016-2018: Melissa Foster, melissa.ann.foster@gmail.com, 707-498-2484
2017-2019: Jim Reed, jim@rockware.com
2017-2019: Chris Morrison, chris-morrison@comcast.net
2018-2020: Pete Modreski, pmodreski@aol.com, 720-205-2553
2018-2020: Matt Rhoades, rhoadesgeo1@gmail.com

Committee Chairpersons

Database Manager: Paul Morgan, 303-384-2648, morgan@mines.edu
Field Trip Chair: Cal Ruleman, 303-236-7804, cruleman@usgs.gov
GSA Meeting Co-chairs, Lisa Fisher & Libby Prueher
History Chair: Beth Simmons, cloverknoll@comcast.net
Hospitality Chair: Mary-Margaret Coates, geotechedit@gmail.com
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Colorado Scientific Society, September 20, 2018
Short Talks and Poster Session Evening

Arbor House, Maple Grove Park, 14600 W. 32nd Ave., Golden CO
5:30 p.m., social time, refreshments, and poster viewing
7:00 p.m., 15-minute oral presentations

ABSTRACTS

Posters

Evidence of rapid incision within tributary box canyons during historical times, South Platte River corridor, northeastern Colorado

Margaret E. Berry, U.S. Geological Survey

Geologic mapping of surficial deposits in areas surrounding the South Platte River corridor in eastern Colorado documents a period during historical times of rapid incision within ephemeral, headward-eroding box canyons north of the town of Fort Morgan. The box canyons reflect a long geologic history, with older paleovalleys incised into Pierre Shale bedrock and filled with at least 4 m of middle Pleistocene sediment. The deposits consist of interstratified sand, pebbly sand, silt, and poorly sorted sandy pebble gravel, overlain by mostly finer grained, weakly stratified sandy silt with lenses and stringers of sand and fine pebbles, and massive silty very fine sand. The sediments are interpreted as stream deposits overlain by loess or eolian sand deposits that were largely reworked by sheetwash processes. A middle Pleistocene age for this section is indicated by the presence of an eroded pedogenic carbonate horizon with stage III morphology at the contact between it and the sediment that overlies it. The overlying deposits, about 1.5 m thick, consist of weakly stratified silt with scattered, poorly sorted sand stringers, and minimal soil development. This uppermost section is interpreted as latest Holocene sheetwash deposits derived primarily from the reworking of late Pleistocene and Holocene loess that blankets the low drainage divides. A bison tooth, collected (along with bison bones) at a depth of about 92 cm from young sheetwash deposits in one of the box canyons, has a ^{14}C age estimate that calibrates to the early 1820's. Based on this age estimate, the box canyon floors aggraded about a meter and then were entrenched by as much as 5–6 meters to create steep-walled gullies exposing the paleovalley sediment fill, all within the last approximately 190 years.

The importance of mineralogy for deciphering the evolution of alkali-basaltic magmas: a case study of Dotsero volcanics (Eagle County, central Colorado)

Anton Chakhmouradian, Geological Sciences, University of Manitoba, and Peter Modreski, U.S. Geological Survey

The Dotsero scoria cone and lava flow, located along the Colorado River east of Glenwood Canyon, are the youngest volcanic occurrence in Colorado, dated from charcoal as 4150 years BP. These volcanics were emplaced through Proterozoic basement and Phanerozoic sedimentary rocks and contain abundant xenoliths of shale, sandstone, gypsum and transparent quartz xenocrysts known as “Dotsero Diamonds”. Texturally, the rocks range from massive flow-banded types to highly vesicular scoria, but these different types are remarkably similar in composition. All of the examined samples correspond to potassic hyalo-trachybasalt (Na/K = 1.0-1.1) enriched in large-ion lithophile elements (particularly, Ba and Pb) and relatively

depleted in Ti. Texturally, the rocks consist of (micro)phenocrysts of olivine (Ol), augite (Aug), plagioclase (Pl) and magnetite (Mgt) set in a glassy matrix containing smaller crystals of the same four minerals. The Ol phenocrysts are zoned from a kite-shaped Mg-rich core (75-81 mol.% Fo, < 0.3 wt.% MnO, < 0.2 wt.% CaO) to a skeletal rim enriched in Fe, Mn and Ca (67-75 mol.% Fo, 0.4-0.9 wt.% MnO, 0.2-0.5 wt.% CaO). Groundmass Ol is compositionally identical to the phenocryst rims. One exception is oxidized varieties of scoria, where phenocrysts are rimmed by Mg-rich Ol (80-84 mol.% Fo) plus hematite. Aug shows oscillatory zoning superposed over hourglass zoning involving significant variations in the sum proportion of Tschermak components (12-28 mol.%) and diopside (48-64 mol.%) between the sectors. Pl phenocrysts are zoned toward Na-rich compositions (80-65 mol.% An); the K and Fe contents increase concomitantly with Na. Groundmass Pl is similar to the phenocryst rims. Mgt microphenocrysts are enriched in Mg, Al, Ti, V (+/-Cr), and exhibit diverse exsolution textures reflecting different cooling histories of their host rocks. The whole-rock and mineral-chemistry data were used to model potential evolutionary paths of trachybasaltic magma. Fractionation of Ol, Pl, Mgt and Aug will drive the chemistry of residual melt to shoshonitic and then potassic phonotephritic compositions. This calculated trend is in general agreement with the presence of nepheline-normative phonotephritic and tephriphonolitic glass in some samples. However, the alkali content of the glass is higher than the predicted content, indicating that the Dotsero magmas were modified by assimilation of crustal material. Further evidence of assimilation includes the presence of rhyolitic glass and Aug corona around quartz xenocrysts.
M&M6, Sixth International Conference, Mineralogy and Museums, Colorado School of Mines, Golden, CO, Sept. 7-9, 2008, Program & Abstracts, p. 47.

Evolution of an interbasin mountain-block extensional accommodation zone within the central Colorado Rio Grande rift, USA

Scott A. Minor, Jonathan Saul Caine, Chris J. Fridrich, Mark R. Hudson, and Cal Ruleman, U.S. Geological Survey

Understanding of extensional strain transfer and accommodation in continental rifts has grown considerably, but few studied transfer zones exhibit high internal topographic and structural relief. In the Rio Grande rift of Colorado the WNW-trending northern tip of the Sangre de Cristo Range separates the opposite-tilted Upper Arkansas River (UAR) and San Luis half grabens. We investigated the development of faults flanking this “Poncha” intrarift mountain block and their role in transferring extension between rift basins and contributing to mountain block surface uplift and landscape evolution. The elevated high-relief core of the Poncha block consists of Proterozoic metamorphic and plutonic rocks overlain on its west and southwest flanks by 34.6-33-Ma volcanic rocks and Mio-Pliocene, locally derived, basin-fill deposits of the Dry Union Formation. Similar Dry Union sediments underlie a moderately elevated, strongly dissected older piedmont along the northern mountain flank. All the flanking units are tilted 10-35º to the W and SW. A broad WNW-trending, right-stepping fault system ~33 km in length separates the piedmont Dry Union sediments and UAR basin from the steep northern Poncha mountain front underlain by Proterozoic rocks. The fault system continues west to the N-striking Sawatch range-front fault. Slip measurements along the Poncha frontal fault system within Dry Union and overlying deposits as young as ~200 ka indicate mainly dextral-normal oblique movement on WNW-striking fault segments and sinistral-normal movement on faults striking ~NNW. The southern continuation of the Sawatch range-front fault forms the western terminus

of the Poncha block. Gently tilted proximal diamicton and alluvial deposits on the downthrown blocks of both range-front faults record Plio-Pleistocene mountain-block uplift. Preliminary paleomagnetic data from the volcanic rocks and Dry Union sediments suggest modest (25±11°) clockwise vertical-axis rotations accompanied oblique-slip faulting on the Poncha flanks. Tentatively, we view the Poncha frontal fault system as a broad normal-oblique relay zone that developed in the late Neogene to transfer extensional strain across the left step between the Sawatch and Sangre de Cristo rift-bounding faults, coevally accommodating surface uplift of the Poncha mountain block.

Geology of the upper Arkansas River valley, Colorado - a field mapper's perspective

Colorado Scientific Society, Field Trip, Sept 15-16, 2018

Trip leaders: Karl Kellogg (USGS emeritus), Cal Ruleman (USGS), and Scott Minor (USGS)

This two-day trip will examine a number of geologic features of the upper Arkansas River valley that resulted from recent USGS mapping in the region. The valley comprises a northern portion of the Rio Grande rift, a north-trending zone of crustal extension that extends from Mexico northward into northern Colorado. The initiation of rifting at about 30 Ma (Oligocene) is closely associated with a change from calc-alkaline (mostly andesitic to dacitic) volcanics to bi-modal rhyolite-basalt assemblages, including the rhyolite flows of the Nathrop volcanics. The region has experience multiple phases of volcanism and plutonism from Cretaceous to Oligocene and we'll visit various examples of these igneous rocks. The Colorado mineral belt, a product of multiple generations of igneous activity, traverses the northern part of the valley, and contains the world-class ore deposits of the Leadville mining district (mostly bearing Pb, Zn, Ag, and some Au and Cu). We will examine potentially active normal faulting associated with crustal extension, and discuss geomorphic, paleoseismic, and geodetic relationships related to Pleistocene basin evolution and regional tectonic and geomorphic development. The glacial history has been recently enhanced by abundant cosmogenic dating of multiple generations of glacial till and associated outwash deposits, revealing the rapidity of the Last Glacial Maximum demise as well as the overall timing of the Pleistocene glacial record. We will visit large glacial outburst flood deposits associated with the Last Glacial Maximum (Pinedale) damming of the Upper Arkansas Valley by the Clear Creek glacial system, a late Pleistocene ~22 ka glacial complex that repeatedly dammed the Arkansas River creating monstrous, catastrophic breakout floods, carrying truck-sized boulders downstream. We will examine terraces containing these boulders and the chronologic constraints on basin-wide terrace development. We will also visit a location where the Lava Creek B ash (~640 ka) from the Yellowstone caldera was captured within basin stratigraphy, providing a constraint for the onset of Pleistocene glaciations and its associated effects on the landscape. We have worked out the detailed terrace stratigraphy of the valley, which extends as far back as the early Pleistocene and possibly Pliocene and directly relates to the formation of the Royal Gorge. Extensive basin-fill deposits of the lower Pliocene and Miocene Dry Union Formation will be visited, as will some of the extensive pre-rift (33-39 Ma) volcanic rocks which include several major ignimbrites and several minor ones. As time allows, we will visit other interesting localities – there are lots of them!

U-Th Geochronology using hydrogenic and biogenic materials

James B. Paces, USGS, Elizabeth M. Niespolo, Dept. Earth & Planetary Science, Univ. of California, Berkeley, and Warren D. Sharp, Berkeley Geochronology Center, Berkeley, CA

The U-Th dating method is applicable to a diverse range of hydrogenic and biogenic materials formed during the last 500 ka and has been widely used in geomorphic, tectonic, paleoclimate, paleohydrologic, and archaeologic studies. Calcite, aragonite, and dolomite from speleothems, corals, soil carbonate, tufa, travertine, and fault-related veins are most commonly used. However, opal, sulfates, phosphates, and hydroxides (including ice) can also be dated, as can fossil bones, teeth, and ratite eggshells when enriched with secondary U. Dating of hydrogenic material relies on the large fractionation between U and Th in most near-surface water: U is relatively soluble while Th is not. Consequently, materials precipitated under these conditions typically incorporate U (notably 238U and 234U) but little or no 230Th (the alpha-decay progeny of 234U), thus starting the U-Th "clock". Amenable material can yield precise Quaternary dates (better than ±1%), and because ages depend only on intrinsic sample properties, both newly collected and archival materials can be dated. Simple assumptions inherent to radioactive decay allow levels of accuracy to approach precision, and the system includes inherent checks on the reliability of resulting dates. A key assumption is that samples remain closed to U and Th after formation, or in the case of bones, teeth and eggshells, since U uptake. This assumption is likely valid if U-Th ages preserve micro-or macro-stratigraphic order, and if samples of coeval material produce concordant dates. Visual criteria applied during subsampling increase the likelihood of success. A second assumption is that initial 230Th is absent or can be quantitatively subtracted using common Th corrections or isochron techniques. Contributions of 230Th from detrital sources can be reduced by careful selection of small (0.130 mg), "clean" subsamples. The veracity of U-Th dates can be further assessed by evaluating age versus initial 234U/238U results for a suite of related samples. In situ methods using laser ablation or ion probe analyses are capable of high spatial resolution (10-100 µm) and can provide increased accuracy for ages of materials with slow growth rates, albeit at reduced precision. We will present examples of dated materials and approaches for obtaining U-Th ages on a variety of materials.

Mineralogy and petrogenesis of the California Blue mine aquamarine- and topaz-bearing pegmatite deposit, San Bernardino County, California

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Exploration for granitic pegmatites is important for the mining of critical metals used in the production of industrial glasses, ceramics, metal alloys, high-technology and green industries, and for prospecting gemstones. Such exploration relies upon an understanding of how and where mineralization of these metals develops in pegmatites. Further, these pegmatites yield information about the transition of magmatic to hydrothermal processes occurring in the Earth's crust. The California Blue Mine is a recently discovered, unclassified aquamarine- and topaz-bearing granitic pegmatite in San Bernardino County, California. Research into pegmatite evolution has traditionally focused on igneous processes, but the presence of hydrothermal alteration and miarolitic pockets suggests that the California Blue Mine is an ideal place to study the extent to which hydrothermal processes influence mineralization of economically significant phases. Petrographic observations using hand samples, optical microscopy, and scanning electron microscopy (SEM) will be used to provide a mineralogical description and petrogenetic classification of the California Blue Mine pegmatite. Electron microprobe analysis (EMPA) and laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) will both be used to analyze the major and trace element composition of selected beryl crystals from the pegmatite and the miarolitic pockets. This study will provide a reference description of a newly discovered pegmatite and enrich geological understanding of hydrothermal influences in granitic pegmatite genesis.

Pleistocene lakes and paleohydrologic environments of the Tecopa Basin: Constraints on the drainage integration of the Amargosa River

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The Tecopa basin served as the terminus of the Amargosa River, southern Nevada and California, during most of the Quaternary. Its stratigraphy, sedimentology, chronology, and diagenesis have long been studied. We use shoreline deposits and strandlines to reconstruct lake level and ostracodes preserved in lake and groundwater-discharge deposits to interpret depositional and hydrochemical environments. These two lines of evidence shed light on the integration of the Amargosa River into Death Valley.

We can document only 8 lakes that had enough fetch to construct distinct shorelines; nearshore deposits of the three oldest of these lakes lack beach gravel and were likely quite shallow. The oldest lake (L1) coincided with deposition of the 2.01-Ma Huckleberry Ridge tephra and overlying lower Glass Mountain tephra. The second lake (L2) rose just prior to deposition of a 1.25-Ma tephra (previously mis-correlated with the older Huckleberry Ridge). Ostracodes in these two deposits are mostly incompatible with alkaline water; the lakes were probably sustained by spring discharge sourced mainly from the regional carbonate aquifer. A third shallow lake (L3) may have formed around 1 Ma. The fourth lake (L4) has limited deposits of beach gravel and just predates the 0.76-Ma Bishop ash. This lake records the first incursion of the Amargosa River; ostracodes in this and all younger lakes tolerate its alkaline water. The next lake (L5) is bracketed by the Bishop and Lava Creek tephra. The first apparently long-lived lake (L6, the "Lava Creek Lake") preceded and coincided with deposition of the 0.63-Ma Lava Creek tephra. A later lake (L7), which we term the "High Lake", is recorded by thick deposits of beach gravel and deltaic deposits that lie ~12-15 m stratigraphically higher than the Lava Creek tephra. This lake may have an age of ~600-500 ka based on deposition rates and U-series analysis.

We infer a long hiatus between High Lake and a much younger "Terminal Lake" (L8), inferred to be early OIS 6 in age based on geomorphic relations in the area of Greenwater fan. Beach sand and gravel of this lake overlie many meters of faulted, deformed, distal-fan and groundwater-discharge deposits, in turn overlying Lava Creek Lake and High Lake deposits. The Terminal Lake led to incision of the Sperry Hills threshold, creating the Amargosa River canyon and river flow into Lake Manly by early OIS-6 time (supported by the appearance of an alkaline-tolerant ostracode in the Death Valley core). A lower and somewhat younger lake (L9?) likely resided in the Tecopa basin during a stillstand at the level of resistant Proterozoic bedrock in the upper Amargosa Canyon.

Gravels and strandlines representing the Lava Creek Lake and High Lake are present from the north end of the basin to the south end. Differences in elevation of these gravels indicate as much as 23 m [510-487 m) of displacement up to the north for deposits of the Lava Creek Lake and 18 m [526-508 m) for those of the High Lake, nearly all due to displacement along a NE-trending monoclinal fold in the northern part of the basin.

Understanding geomorphic response to floods: the role of scale and gradients

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Morphodynamic response of channels and floodplains to flooding reflects interactions of erosive and resisting forces with sediment transport capacity and supply at multiple scales. Monotonic relationships between reach-scale channel response to floods with independent variables such as flood stream power and channel confinement can be confounded by longitudinal variations (i.e., gradients) in these variables. In these cases, channel response depends on both local and upstream drivers. Using high resolution pre- and post-flood digital elevation models, we calculate reach-scale (0.5 to 1 km) and segment scale (10 km) longitudinal variations in channel widening and sediment balance as a response to the 2013 Colorado Front Range flood. We found that the channel widening response is more closely linked with reach scale gradients in unit stream power: abrupt widening typically occurred within reaches where a large drop in unit stream power occurred relative to upstream. Sediment balance exhibited a net degradational trend within the foothills that transitioned to a net aggradational trend within the transition to the plains and was less sensitive to reach-scale fluctuations in unit stream power and confinement. These findings indicate that unit stream power gradients mediate channel response at reach to segment scales. Predictive modeling of stream response to floods and fluvial hazards assessments that only consider absolute values of reach-scale stream power may under-estimate fluvial hazards in some settings by ignoring unit stream power gradients.

Indigenizing water resources on the Navajo Nation: A water policy analysis and critique

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The Navajo Nation is the largest American Indian Reservation in the United States, located at the Four Corners of Utah, Arizona, New Mexico, and Colorado with territory within all four states, is home to 156,823 Navajo living in an area the size of West Virginia with a median family income of $22,392. The Navajo Nation was formed in 1868, and those familiar with the prior appropriation system of water rights allocation in the Western United States will recognize this as one of the most senior water rights able to be claimed. However, American Indian water rights are in constant contention in Federal courthouses across the country and a common alternative to litigation are negotiated settlements, often for far less water than could be otherwise claimed. However, unfair dealings with various state governments and Federal agencies have left many American Indian nations wary of relying on these same groups for assistance in creating the infrastructure necessary to physically move water to its destination. Reducing the reliance on Federal assistance, both technical and financial, is essential to the retention of Navajo culture and self-determination. As such, having a water supply system that effectively moves water along more cost-effective routes and methods, may depart from the traditional American methods of building water supply systems. This analysis will focus on critiquing current policy direction, outlining a new methodology for a water supply system, and proposing methods for merging the current infrastructure too far in development with the newly proposed policy. This report does not focus on the myriad of American Indian water rights law,

instead it focuses on the resources available and making the most of them. Make no mistake, these are people who have had many challenges thrust upon them, and the Navajo have risen to each one. Their ability to respond to the challenge of providing water to their people will determine their ability to remain relevant in the 21st century.

The basement tapes: Mapping the Precambrian beneath the Colorado Plateau

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As part of the USGS National Cooperative Geologic Mapping Program's strategy to expedite geologic mapping of the nation, the USGS has begun work on an integrated digital geologic map and 3-D geologic framework for the Intermountain West. Mapping will be conducted at a nominal scale of 1:250,00 along a regional transect that straddles the 37th parallel in CO, NM, UT, AZ, and NV. The map transect crosses the Basin and Range, Colorado Plateau, and Rocky Mountains physiographic provinces; the map extent forces reconciliation of state and quadrangle border problems and requires resolution of regional stratigraphic correlations.

In conjunction with the surface geologic mapping, subsurface datasets are being compiled and developed in anticipation of building regional-scale 3D framework models that will support the mapping and USGS minerals and water-resource assessments in the region. 3-D surfaces will be constructed from scattered XYZ point data developed using surface outcrop, well, cross section, and structure contour data. Data will be gridded using mapped or inferred faults for each surface.

As a start on a top-of-Precambrian surface, previously published structure contour maps were compiled. The maps were assessed and digitized using a series of rules that evaluated contours based on the density of associated wells data, the presence of contouring artifacts, and consistency with adjacent or overlapping contour maps. Future work will involve resolution of differences between adjacent contour maps, addition of point data from surface outcrops, wells, and cross sections, and creation of the final surface. Initial compilation of maps of the top-of-Precambrian surface suggests that prospects are good for creating a new regional-scale contour map that integrates data from multiple sources, has a consistent tectonic and contouring style, and is digital and well-documented.

A paleoseismic investigation of the Northern Teton fault at the Steamboat Mountain trench site, Grand Teton National Park, Wyoming.

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The Teton fault is the major range bounding normal fault along the eastern flank of the Teton Range in western Wyoming and a significant contributor to regional seismic hazard. The ~70 km-long fault has an estimated vertical slip rate of ~1-2 mm/yr; however, the history of large earthquakes on the fault remains uncertain because paleoseismic data are restricted to the central and southern parts of the fault near Leigh Lake, Granite Canyon, and Teton Village. Although the northern section has remained understudied, possible paleoliquefaction features along Jackson Lake suggest strong ground motion from earthquakes with inferred ages of ~4 and ~1.6 ka. The ages differ from paleoseismic results from Granite Creek, but cannot be directly attributed to the Teton fault due to a lack of paleoseismic data for its northernmost section.

To address the uncertainty in the paleoseismology of the northernmost Teton fault, we excavated two paleoseismic trenches at the Steamboat Mountain site, within 5-km of the northern fault termination. The trenches crossed a ~1-3 m-high down-to-the-east, uphill-facing scarp that traverses a west-facing Pleistocene glacial and alluvial-fan surface. The trench exposed fine grained, well-stratified hanging wall deposits with intervals of charcoal and paleosols. These sediments interfinger with scarp-derived colluvial wedges that unconformably overlie coarse-grained, glacially derived footwall deposits. We infer two late Quaternary surface-faulting earthquakes at the site on the basis of two scarp-derived colluvial wedges exposed in each trench. Radiocarbon and luminescence samples (ages pending) will constrain the timing of earthquakes. Comparison of our results with existing and pending paleoseismic records for sites to the south and to the inferred paleoliquefaction ages will help to refine the timing and rupture length of Teton fault earthquakes.
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Session: The Next Big Earthquake: The Usual and the Unusual Suspects

Oral Presentations

The effects of geological structure and clay on landslides in the Teklanika Formation in Denali National Park and Preserve, Alaska

Michael Frothingham, PhD student, CU Boulder, and Denny M. Capps

The dramatic landscape of Denali National Park and Preserve is sculpted by extreme geological forces of uplift and erosion along a major plate boundary. Visitors to the park have the unique opportunity to witness these forces as they occur while scientists, engineers, and staff are tasked with understanding and mitigating the geological hazards associated with them. In response to the many landslides present along the park road corridor, this project identifies, characterizes, and maps the clay and geological structures that are associated with landslides between miles 31 to 53 along the park road.

Clay occurs within the Paleocene Teklanika Formation as an alteration product in moderately continuous stratigraphic horizons of tuff, perlite, and rhyolite that are traceable across structural geometries. Landslides also contain this clay, which is mixed in with debris.
Major landslides often occur where the following conditions unique to the Teklanika Formation are met: (1) erosion occurs along a weak horizon of clay, (2) topography above clay horizon is steepened, (3) large colluvium piles are accumulated near the clay horizon, and (4) detrital clay is mixed in with colluvium. Following these conditions, landslides are triggered when the critical shear stress of clay-rich debris is achieved by hydration and weakening of clays, degradation of permafrost or seasonal frost, overloading, or debuttressing.

Newly-identified geological controls suggest increased landslide probability where the basal tuff and clay horizon marks the contact of Teklanika and Cantwell formations, and where steeply-dipping perlite and clay horizons intersect faults or sharp topographic relief. Using the geologic map of clay occurrence, stratigraphy, and structure with reference to landslide conditions listed above, this project illuminates the cause of past and present landslides, and can be used to predict and mitigate future geological hazards.

Insight into incipient motion of blocks on a river bed from Computation Fluid Dynamics modeling

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Erosion of bedrock river channels is an important driver of landscape evolution, as it governs the baselevel lowering rate of adjacent hillslopes in mountainous landscapes. In many settings, the upstream migration of bedrock steps or small knickpoints accomplishes most of the vertical erosion in bedrock channels. However, as most models of channel evolution focus on abrasion without accounting for the entrainment of blocks at the downstream edges of bed steps, the magnitude of channel erosion and the detailed geometry of bedrock channels are not well captured. In order to quantitatively capture the role of channel erosion by block entrainment, or plucking, in future models, we first require insight into the physics of incipient motion of blocks on a bedrock channel bed. To date, all of the theory and experiments that inform plucking models are based upon force balances on individual blocks (i.e., Dubinski and Wohl, 2013; Lamb, 2015) with limited application to larger scale models of landscape evolution (i.e., Shobe et al., 2017; Larsen et al., 2016). A significant hurdle in predicting block entrainment by plucking is the lack of sufficient data to defend the choice of a drag coefficient that informs block entrainment thresholds in these force balances. We currently lack consistent predictions of the proper drag coefficient necessary to estimate the drag force, and lack constraints on the magnitudes of pressures to which the vertical edges of a block are subjected in a given flow. We hypothesize that short temporal scale fluctuations in the water pressure in the recirculation zone downstream of a block in open channel turbulent flow greatly influences the magnitude of the drag force acting on the block, and thus values of drag coefficients and pressure differences that should be used in calculation of the force balances. These recirculation zone lengths reflect a combination of block and upstream step geometries and turbulent fluctuations in the flow. We use Computation Fluid Dynamics **(**CFD) experiments to test the effects of block and step geometries on drag coefficients in order to estimate the range of drag coefficients to be expected for given block aspect ratios and protrusion heights that are found in natural streams. We then use these constraints to develop a relationship between drag, channel geometry, and block geometry that will place future channel evolution models on firm physics-based ground.

Seasonality of a Sub-Alpine Lake: Understanding evolving physical and biogeochemical controls on aquatic ecosystem structure under ice cover. Rocky Mountain National Park, Colorado USA

Garrett Rue, PhD Candidate, CU Boulder, and Diane McKnight

In mountainous regions such as Colorado's Front Range, changes in hydroclimatology and enhanced exogenous input of nitrogen from atmospheric deposition, are driving changes in lake ecosystems. While summer is an important period when primary production dominates lake ecosystem structure and function, less is known about how these trophodynamics change during the longer period of winter ice-cover. Ongoing research of Bear Lake, located in the sub-alpine of Rocky Mountain National Park, Colorado, USA has shown that depth profiles of dissolved oxygen change in the lake due to variation of snow cover on the ice. Preferential deposition of snow on the east side of the lake driven by wind creates a shallower depth to the oxycline by limiting light penetration through the snow and ice to support photoautotrophs compared to the snow-free west side of the lake. However, concentrations of dissolved organic carbon (DOC) appear consistent across these surface cover conditions and predictably increase by depth. Under the competing role of snow cover influencing primary production near the surface in producing oxygen against heterotrophic processes consuming it at increasing depths, we hypothesize that the developing strata create a redox gradient where dissolved organic matter (DOM) accumulates in a reduced state below the oxycline to essentially act as a battery to store chemical energy. Favoring heterotrophic activity, this further promotes the assimilation of nitrogen into the DOM pool and an evolving reservoir of labile carbon primed to jumpstart the aquatic ecosystem during lake turnover in the spring. We present data collected from Bear Lake throughout the winter of 2018, to better elucidate these shifts in aquatic ecosystem function against physical and chemical conditions. This both advances our understanding of oligotrophic, mountain lake sensitivity to change and predicting response to future pressure, also identifying key biogeochemical processes that may seasonally control microbial and planktonic foodweb structure.

The role of flashing in the formation of high-grade, low-sulfidation epithermal deposits: a case study from the Omu Camp in Hokkaido, Japan

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The Miocene low-sulfidation epithermal Hokuryu and Omui deposits of the Omu camp in northeastern Hokkaido, Japan, are small past-producers of high-grade Au and Ag ores. The quartz textures of high-grade ore samples and the distribution of ore minerals within crustiform banded and brecciated quartz veins were studied to identify the processes that resulted in the bonanza-grade precious metal enrichment in these deposits. Correlative microscopy involving optical microscopy, cathodoluminescence microscopy, and scanning electron microscopy was employed in the study of quartz textures and the ore minerals. The research shows that quartz occurring in the quartz veins exhibits a wide range of textures that represent primary growth patterns. In addition, textures indicative of recrystallization of silica precursor phases and replacement of other vein minerals were recognized. In the high-grade vein samples, which are crustiform or brecciated in hand specimen, ore minerals almost exclusively occur within distinct dark gray to black quartz bands. These bands alternate with barren, white to light gray quartz suggesting that ore deposition was episodic during the formation of the low-sulfidation epithermal veins. The dark gray to black quartz bands hosting the ore minerals are colloform and are composed of mosaic quartz. High-magnification microscopy reveals the presence of densely packed relic microspheres providing evidence that the mosaic quartz hosting the ore minerals formed through recrystallization of a non-crystalline silica precursor phase. The ore minerals occur interstitially to the densely packed microspheres or form dendrites within a framework of microspheres indicating that ore deposition was contemporaneous to the agglomeration of the microspheres. These colloform bands with relic microsphere textures are interpreted to have formed through rapid silica and ore mineral deposition within the veins at high temperatures, presumably involving temporary flashing of the hydrothermal system. Limited fluid inclusion data suggest that silica deposition occurred at a temperature of over 245-250°C implying that flashing occurred to a depth of over 400 m below the paleosurface. The ore-hosting colloform bands composed of agglomerated microspheres are texturally distinct from barren, colloform bands containing fibrous chalcedonic quartz bands formed at lower temperatures. The findings of this study are consistent with models linking the high-grade precious metal enrichment in low-sulfidation epithermal veins to episodic flashing of the hydrothermal system in the near-surface environment and have significant implications to the design of exploration strategies for bonanza-grade low sulfidation epithermal vein deposits.