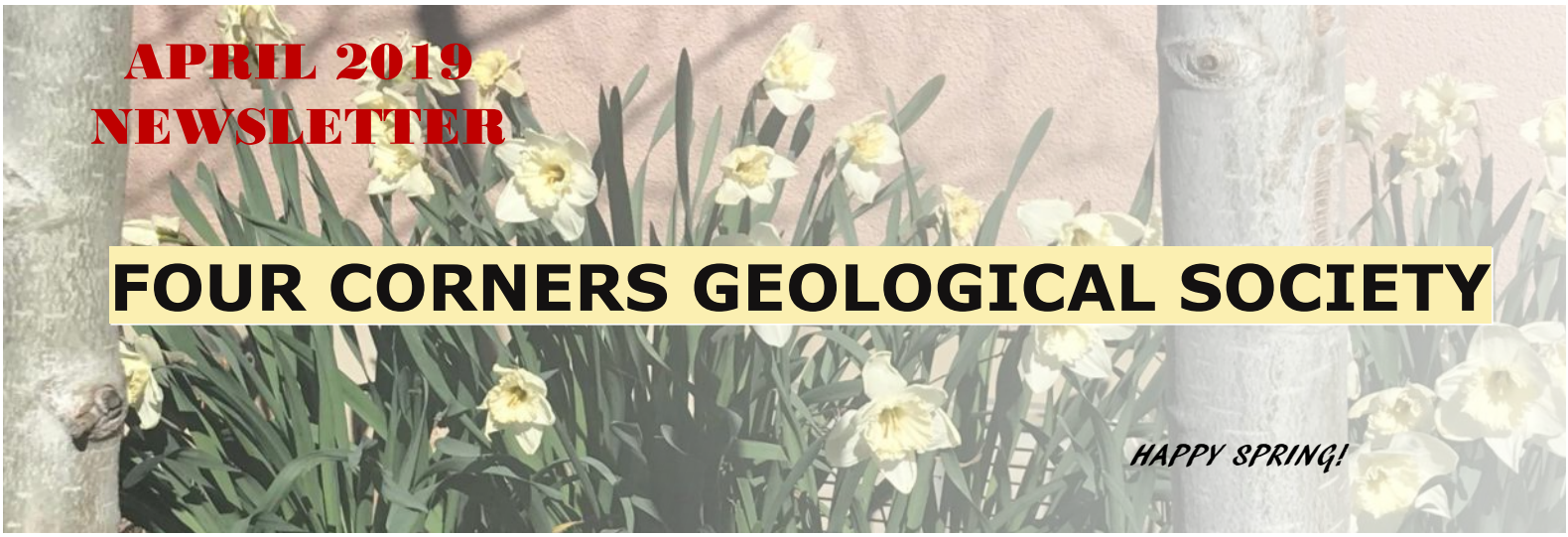


OFFICERS OF THE SOCIETY

Past President:
Jim Corken

President:
Tim Rynott

President-Elect:
Sabina Kraushaar

Treasurer:
Tom Staatz

Secretary:

Newsletter Editors:
Kim Gerhardt
Tom Ann Casey

Website:
Tim Matthews
Rachel Medina

To contact an officer click:
https://fourcornersgeologicalsociety.org/about/

APRIL DINNER MEETING

SPEAKERS: Four Lewis College Graduating Seniors

PRESENTATIONS:

Sierra Heimel, "GOING WITH THE FLOW; THE SURPRISING PREFERENTIAL KARST DEVELOPMENT IN DOLOMITES OF THE REDWALL LIMESTONE, GRAND CANYON, AZ"

Mateo Sanabria, "CONSTRAINT ON TIMING AND HISTORY OF LATE MESOZOIC TO CENOZOIC PLUTONS IN THE SAN MIGUEL MOUNTAINS, SOUTHWESTERN COLORADO"

Carson Broaddus, "THE EFFECT OF FAULT GOUGE ON FLUID FLOW, LISBON VALLEY, UT"

Connor Broaddus, "THE IMPACT OF FACIES HETEROGENEITY ON FLUID STORAGE AND TRANSPORT IN THE LOWER BURRO CANYON FORMATION, LISBON VALLEY, UTAH"

DATE: **Thursday, April 25th**

TIME: Posters (7 posters are expected) @ 4:30 pm, Social & Bar Open @ 5:00 pm, Dinner @ 6:00 pm, Bar closes @ 6:25 pm, Talks & FCGS business @ 6:30 – 8:00 pm.

LOCATION: **Fort Lewis College, Student Union, Vallecito Room**

COST: $20/person w/RSVP by deadline. $25 post deadline or at door (while food lasts). $2/person talk only, students are free for talk

RSVP and pay online at: http://www.fourcornersgeologicalsociety.org/ or

RSVP to Jim Corken at: rjcork@aol.com / 970-759-2567; Students should RSVP to Dr. Gary Gianniny at gianniny_g@fortlewis.edu Note: Student speakers are allowed one guest, but please RSVP. Students should check with Dr. Gianniny for a free dinner. A large number of our wonderful sponsors have stepped up to help.

By Tuesday, April 23rd at 5pm. Students, members who are pre-paying and members who just want to reserve a spot and pay at the door can all register at this link (use your preferred buttons):

http://www.fourcornersgeologicalsociety.org/

"PREZ SEZ" by Tim Rynott

Greetings,

Ah April - what a fine month to live in the Four Corners area, depending on your proclivity for the great outdoors. With the potential to ski (with no crowds), cross-country, snowshoe, or hike/bike all in the same day - 'ya gotta love it.

As for April, it also means winding down our FCGS calendar year. We wrap up the technical side of our dinner meetings with the annual FLC senior thesis presentations (April 25th), whilst our field trips jump into high gear. (see additional details for field trips on page 3). Jim Corken and his committee have done an outstanding job pulling together two excellent opportunities to see Mother Nature at her finest.

It is also time to consider this year's achievement's, plus offer thanks to our many volunteers.

The year started with Bylaw changes which re-structured our dues and voting procedures. During the year the Society was able to provide an important grant to FLC to help re-establish their Petroleum Geology Class. And, the year ended with reinvigorating the Four Corners Geological Foundation. As for the latter, many thanks go to **MARY GILLAM** for her tireless work on this task (please see her separate article on page 7).

Additional volunteer kudo's go to **TOM ANN CASEY** (Publications and Co-Editor), **GARY GIANINNI** (FLC liaison), **CHUCK BALTZER** (Student Sponsorships), and **RACHEL MEDINA/TIM MATHEWS** (website).

Continuing, **TOM STAATZ** has done another great job as treasurer, plus handling the front door check-ins and door prize purchaser extraordinaire. **JIM CORKEN** has been invaluable not only as the Field Trip Chairman, but also as a terrific sounding board and advisor as Past President. **KIM GERHARDT** (Newsletter Editor) continues to be the life blood for our Society, and we literally could not function without her. And last but not least, **SABINA KRAUSHAAR** has not only done a stellar job lining up outstanding monthly speakers, but has also been invaluable with technical/website issues. (Youth on our Board is VERY helpful!)

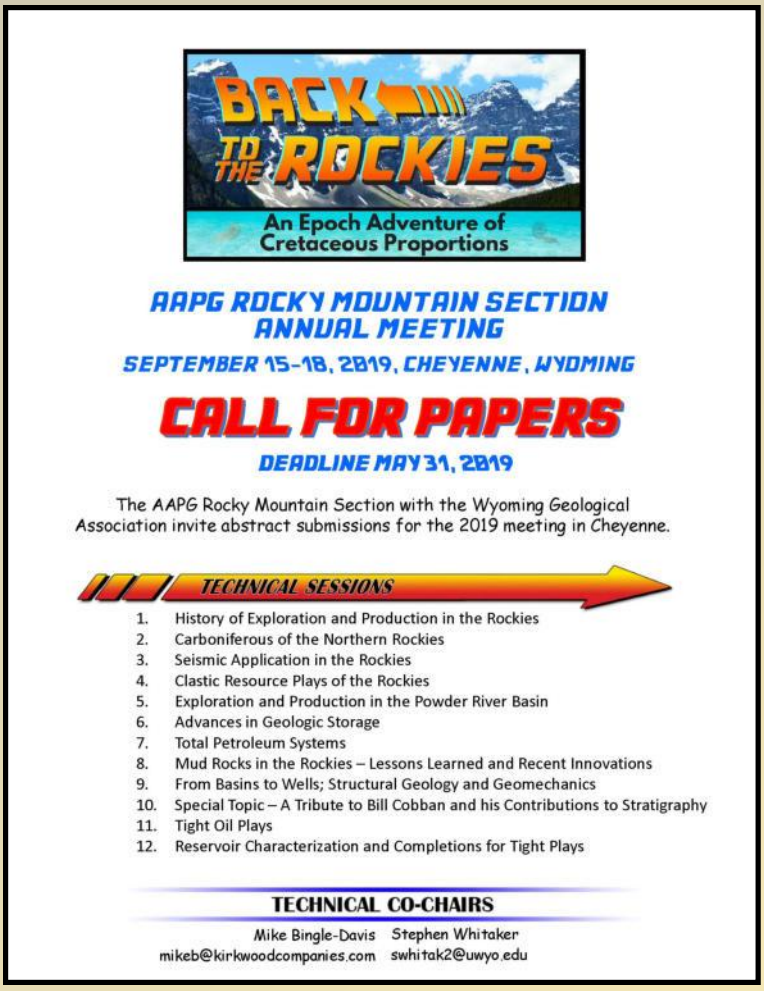
Lastly, I'm reminded of the vast number of special people who make SW Colorado an exceptional place to reside. Exemplifying this phenomena concerns a recent dining experience when a small group of us ate dinner at the re-located Yellow Carrot. We discovered via their owner that all employees must write down 3 gratitude's prior to punching the clock. Nice! The native joie de vivre seems to spout right from the faucet……for which I'm grateful.

Lastly, a heartfelt thanks goes to **Chuck Baltzer and Ron Brogdon for sponsoring the FLC students** this month. They are both relative new comers to the Four Corners area, and we're very lucky to have them as part of our geologic community.

See you on the 25th……Rock on!

TIM

PS – Be sure to mark your calendars for **May 10th**. This will mark the first FCGS May meeting in many years, and we've got some very special things planned.



Submit abstracts to: https://rmsaapg2019.com/

FIELD TRIP UPDATES

2 FiELD TRIPS COMING THIS SPRING!!

MAY 11th: FRUITLAND METHANE SEEPS AND HYDROLOGY OF THE DURANGO AREA

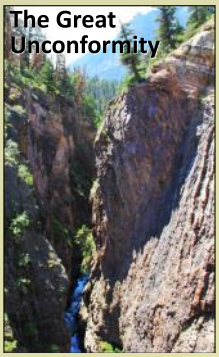
***** Space still available! *****

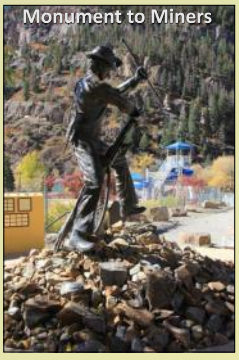
Leaders: Devin Hencman (LT Environmental) and David Schiowitz (SGM), Karen Spray (retired SUIT), Rick Ehat (Ehat Consulting, LLC) and Mike Demming (Retired USBR).
Description: Timing, in mid-May, coincides with spring high water tables that showcase bubbling methane seeps along the Fruitland coal outcrop that rims the northern San Juan Basin. Participants will learn about Fruitland Formation geology, coal bed methane production, historic methane seeps, underground coal fires and how methane seeps are now detected, monitored and mitigated. They will also learn about related hydrology issues spanning Longhollow reservoir in the west to the Pine rivers to the east including Fruitland water rights, litigation and modeling.
Itinerary: Meet 7:40am at Office Depot parking lot to board vans. Stops (from west to east) include Long Hollow Dam, the Cinder Buttes underground coal fires, Valencia gap methane gathering system, lunch at Dallabetta Park, Moving Mountain, Lake Nighthorse Dam, Palmer Ranch seeps, the reverse French drain remediation system on Texas Creek and BP's history at Pine River Ranches. We should be back in Durango by 4:30pm. After the trip relax at Ska!
Number of Participants: 28. **Space still available!** Note - minimal hiking but wear boots or sturdy shoes.
Transportation: Vans. Note - no private vehicles allowed due to SUIT stipulations.
Fee: $35pp. Includes transportation, snacks & permits. BYO lunch and refillable water bottle.
Handouts: Available in pdf format on our website. Download and print your own before the trip.
Registration: Open through the Four Corners Geological Society website. Must be a member.
Cancellation Deadline for Refund: May 1st.

Bubbling seep, S. Fork Texas Creek.

Location of Long Hollow dam abutment in Cliff House Fm. and Lewis Shale.

JUNE 1-2nd: GEOLOGY OF THE OURAY AREA – Signup opens April 19th





Leaders: David Gonzales, FLC, and Steve Cumella, Consulting geologist.
Description: This will be a 2-day trip run out of Ouray. Transportation to Ouray and lodging in Ouray are not included in the trip fee. Geologic highlights include Proterozoic basement history, the Pennsylvanian – Permian section, late Cenozoic magmatic events (San Juan volcanic field) and mineralization in the Ouray area.
Itinerary:
Pre-trip social hour May 31, 4:30-6:00pm on Ouray Brewery rooftop. Meet at 7:40am both mornings in Hot Springs parking lot at the north end of town. We will consolidate into carpools and non-drivers can leave their vehicles in the parking lot. We will provide make-your-own lunches and lunch beverages. Enjoy Saturday night dinner catered by Secret Garden. Guests welcome for dinner for additional fee! We will return each day by 5:00pm.
Please Note – moderate hiking so please wear hiking boots or sturdy shoes.
Number of Participants: 30 including trip leaders and drivers.
Transportation: Carpools
Handouts: Will be available in pdf format on our website. Download and print your own before the trip.
Lodging: Participants must find their own lodging.
Fee: $85 Includes Dinner Saturday night.
Must be an FCGS Member.
Registration: Will open April 19th through FCGS website.
Cancellation Deadline for Refund: May 1st.

Save the Date!

May 10th @ FLC: Kurt Blair, ***Expeditions into the Himalayan's.***

Spouses and guests welcome. Plus results of FCGS Officer Elections.

May 11th: Field Trip: *Hydrology and Methane Seeps in the Durango Area.*

June 1-2nd: Field Trip: *Geology of the Ouray Area.*

August 25th: @ Junction Creek Campground: *FCGS Summer Picnic.*

Hayden Clay, Kim Hannula, Tanner Morgan, and Carson Broaddus, with Lisbon Valley Mine geologist Brian Sparks

Cameron Gaco, Eric Wzientek, and Van Lancaster

GOING WITH THE FLOW; THE SURPRISING PREFERENTIAL KARST DEVELOPMENT IN DOLOMITES OF THE REDWALL LIMESTONE, GRAND CANYON, AZ

HEIMEL, Sierra M., GIANNINY, Gary L., HARVEY, Jonathan E., DOHM, Paul W. and TOBIN, Benjamin W.

The Mississippian Redwall Limestone is an important constituent of the regional karstic R-aquifer, which is the sole source of drinking water in Grand Canyon National Park and a major source of water in the region. Although faults and fractures have been recognized as focal points for localizing karst development in the aquifer (Huntoon, 1974, 1996, 2000b; Hill and Polyak, 2010; Jones et al.2017), the cause of the high concentration of caves in the Mooney Falls Member of the Redwall Limestone is not well understood. We propose an explanation for stratigraphic localization of karst networks and relate this to preferential dissolution of dolomitized facies in the Mooney Falls Member. This member has over 20 dolomite-rich dolowackestone beds with moldic and intracrystalline porosity ranging from 0-35%, with an average of 18% (Dohm et al., 2017). We posit that the localization of caves in the Mooney Falls Member of the Redwall Limestone can be attributed to the preferential dissolution of these highly porous dolomite beds. Photographic analyses of karst exposed within the canyon demonstrate that cave width and location are primarily controlled by faults and fractures, and secondarily controlled by the location of dolomite bands. These porous dolomites continue to be a pathway for groundwater, with springs of a wide range of flow discharging from dolomite bands (e.g. Vasey's Paradise Spring).

Preferential dissolution of dolomitic facies over calcite is counterintuitive because dolomite has a lower solubility product constant (Ksp) than that of calcite. Our data suggests that this is controlled by increased porosity and permeability of the dolowackestone facies, allowing for increased fluid flow, saturated water mobilization, and hence, dissolution. Permeability analyses are needed to further evaluate this hypothesis. These findings are significant for understanding both the characteristics and behavior of the R-aquifer, and more broadly, the interaction of dolomitization and karst genesis.

SANABRIA, Mateo and GONZALES, David A. "CONSTRAINT ON TIMING AND HISTORY OF LATE MESOZOIC TO CENOZOIC PLUTONS IN THE SAN MIGUEL MOUNTAINS, SOUTHWESTERN COLORADO"

The geology and landscape of the western San Juan Mountains was influenced by episodes of magmatism and mountain building in the last 80 million years. The San Miguel Mountains on the western edge of the San Juan Mountains expose numerous intermediate to felsic plutons. Previous mapping revealed the spatial distribution and relative intrusive relationships of different masses, but their ages were not constrained. New U-Pb zircon ages combined with existing age constraints reveal that the San Miguel complex is composed mostly of ~25 Ma intrusive rocks along with lesser intermediate to mafic dikes and sills emplaced at ~68 Ma and ~7 Ma. Some of the ~68 Ma dikes were emplaced along northwest-trending faults, but there is no evidence for structural control on intrusion of the younger plutons.

The ~25 Ma plutons in the San Miguel Mountains are similar in age and composition to a swarm of 26-25 Ma plutonic rocks that extend westward from Silverton to Ophir on the margins of the 29-27 Ma San Juan-Silverton caldera complex. These post-caldera intrusive rocks are spatially related to epithermal precious- and base-metal

deposits. Fluids and heat from the magmas were a main driving force for the hydrothermal systems that were established in the area. The timing of mineralization and pluton emplacement in the region, however, are not constrained.

South of the San Miguel Mountains, in the Rico Mountains, there are ~68 Ma and ~4 Ma intermediate to felsic intrusive rocks, but a noticeable lack of ~25 Ma plutons. This argues for some sort of difference in crustal-scale control on magma production over a relatively short distance.

Emplacement of the San Miguel intrusive complex at ~25 Ma caused localized uplift of over several thousand feet in a span of less than one million years. This rapid uplift created a mountainous landscape that influenced the formation of ice caps during glacial events in the past 200,000 years. Glacial erosion shaped the 14,000-foot summits in the San Miguel Mountains, and created the headwaters for the Dolores River, West Dolores River, and San Miguel River.


Carson Broaddus

BROADDUS, Carson, HANNULA, Kimberly A. and KRANTZ Robert W. "THE EFFECT OF FAULT GOUGE ON FLUID FLOW, LISBON VALLEY, UT"

The existence of authigenic and reworked clays in fault zones is well understood to control the hydrologic and mechanical properties of faults. The net effect these clays have on fluid conductivity, reservoir quality, and fluid derived mineralization is dependent on the origin of the gouge. To address this topic, we collected samples along four high-angle normal faults exposed within a copper mine in Lisbon Valley of Southeast Utah. The GTO, Lisbon Valley, Keystone, and Centennial faults were all sampled in gouge zones ranging from ~0.1 to ~5.5 meters across. Fault displacement ranged from 5 meters to 400 meters. Complementing field work was XRD analysis of all suitable samples to determine the quantity and type of clay in each gouge. We related the hydrologic properties affected by fault gouge with shale gouge ratio (SGR) modeling using T7 computer software. SGR quantitatively estimates clay amounts in fault gouge that allow fault zone permeability estimates to be derived.

Field interpretations suggest gouge zones are dominated by either maroon or green clays with most sites having lenses of the non-dominate component. Sampled gouge zones exhibited grain sizes from clay to fine sand and poorly to moderately lithified. Color of gouge samples does not seem to correlate with offset of faults, however, there is a correlation between juxtaposed stratigraphy and color. Preliminary XRD data shows high concentrations of illite in nearly all samples, chlorite is present in samples with green/yellow hues, and halloysite existing in samples with maroon hues. Along with clays, copper minerals such as Pseudomalachite were identified in some samples, suggesting copper mineralization occurred before major fault displacement.

Understanding the effect on hydrologic dynamics will ultimately assist the team of geologists at the Lisbon Valley Mine further understand and predict copper mineralization along fault zones in the area along with constraints on fault-seal capacity when considering in-situ recovery.

BROADDUS Connor, HANNULA, Kimberly A., GIANNINY, Gary L. and KRANTZ, Robert W. "THE IMPACT OF FACIES HETEROGENEITY ON FLUID STORAGE AND TRANSPORT IN THE LOWER BURRO CANYON FORMATION, LISBON VALLEY, UTAH"

The resource potential of fluvial deposits depends on their fluid storage and transport capacity, which depends on petrophysical heterogeneities caused by stratigraphic and lateral variations. In Lisbon Valley, Utah, Early Cretaceous braided stream deposits of the Lower Burro Canyon Formation (LBCF) form the primary host beds for high-grade copper ore bodies that are potential targets for in-situ leach mining. Variations in the lithology, facies associations, and depositional architecture of the LBCF represent major controls on the porosity and permeability of these ore bodies, and are the focus of this study.

Detailed logging efforts along two perpendicular transects of drill-core reveal the presence of 8 major lithofacies within the LBCF. Lithofacies include green mudstone, siltstone, mud draped siltstone-sandstone, massive to ripple laminated sandstone, planar laminated to cross-bedded sandstone, cross-bedded sandstone with chert pebbles, trough cross-bedded sandstone / pebble conglomerate with rip-up clasts, and crudely bedded gravel with rip-up clasts. Fluid storage and transport capacity were quantified for each lithofacies using


Connor Broaddus

mercury injection porosimetry data provided by the mine. Values range from 2-26% for porosity and from 10-350 Md for permeability.

Amalgamation ratio was calculated for each core based on the scheme designed by Zhang et al. (2017); preliminary results suggest that vertical connectivity of sandstone bodies is highest in the middle to upper portions of the LBCF, with overall amalgamation ratios ranging from 0.52 to 0.63.


Hayden Clay and Connor Broaddus

Measurement of two nearby stratigraphic sections accompanied core-based efforts, and revealed the presence of three different architectural element types within the LBCF. These are, in order of decreasing porosity, permeability, and overall sand body connectivity: amalgamated channel-fill deposits, isolated channel-fill deposits, and floodplain fines.

Modern recovery efforts require more detailed characterizations of the lithologic, stratigraphic, and lateral variability within sedimentary-hosted ore deposits. This study helps to constrain the multiple scales of heterogeneity observed within the Lower Burro Canyon Formation and provides a critical input into the assessment and design of the Lisbon Valley mine expansion.

FCGS BUSINESS

A Brief Update from the Four Corners Geological Foundation

The Foundation, established in 1996 with a grant from FCGS, has served numerous undergraduate and graduate students through research grants, support for the 2019 petroleum geology course at Fort Lewis College, and other benefits. During the last six months, the Foundation was reinvigorated through a collaborative process with FCGS and several members. It's a separate nonprofit corporation with 505(c)3 tax-exempt status. The current directors are **MARY GILLAM** (president), **JIM CORKEN** (secretary), **JOE HEWITT** treasurer), **JEFF CARY** and **JIM FASSETT.** Nominees for regularly elected terms will appear on the May FCGS ballot.

Applications for the Foundation's 2019 MS thesis grant program are being accepted until April 30 (information is posted on the FCGS website). If you know an MS candidate who's working in our region, please encourage him or her to apply.

Finally, the Foundation needs your help to maintain and increase its support for geoscience education and research. **Please consider making a tax-deductible donation today!** Checks payable to 'Four Corners Geological Foundation' can be mailed to FCGS at PO Box 1501, Durango CO 81302, or given to any director. We look forward to sharing more about our progress in the future.

Respectively, Mary Gillam, President

FCGS 2019-2020 Elections:
Society Officers & Foundation Directors

Nominations will be taken at the March FCGS meeting for officers to serve on the Society Board during the 2019-2020 year. Please let Tim Rynott know if you are interested in standing for election for President-Elect, Secretary, Treasurer or Editor. Descriptions of duties from our Constitution & Bylaws below.

Please let Mary Gillam know if you are interested in serving on the Foundation Board for a term of 1, 2 or 3 years.

Candidates will be announced in April and elections held in May. The new boards will be announced at the May meeting.

Descriptions of the Duties of FCGS Officers

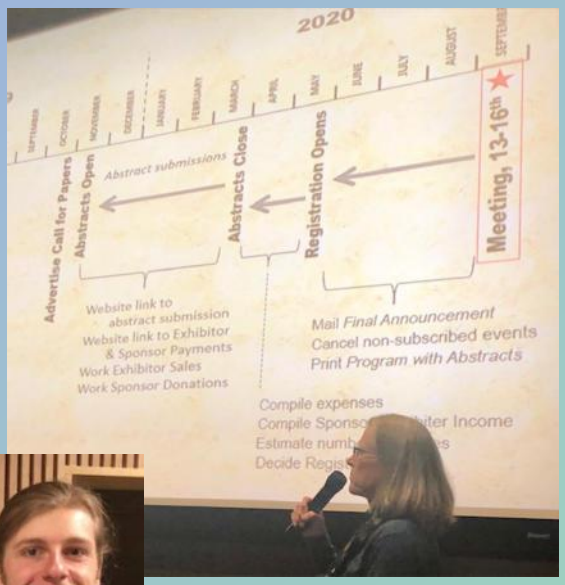
Article IV, Officers. SECTION 3. *President Elect*
The President Elect shall perform the duties of the President in the absence or inability of the President to serve. The President Elect shall assume the office of President in case of a vacancy for any cause in that office. He/she shall serve as Program and Entertainment Chairman and perform such other duties as may be assigned by the President.

SECTION 5. *Secretary*
The Secretary shall be responsible for maintaining the records of the Society, including current copies of the Articles of Incorporation, Constitution, and Bylaws. He/she shall maintain a current list of members and perform other functions related to maintaining membership. The Secretary shall be responsible for recording the actions of the Executive Committee. He/she shall work closely with all officers of the Society in handling incoming and outgoing correspondence and perform other duties as may be directed by the Executive Committee.

SECTION 6. *Treasurer*
The Treasurer shall supervise the receipt of all funds and, under the direction of the Executive Committee, be responsible for all disbursements of funds of the Society. He/she shall recommend for Executive Committee approval a plan of investment for those funds in the Society's treasury generally in excess of those necessary for normal operating expenses, and shall oversee the execution of such an approved plan. The Treasurer shall recommend for Executive Committee approval an accounting and audit procedure for Society funds with necessary professional accounting help. He/she shall advise the Executive Committee with respect to the current financial status of the Society for any major expenditure for planned projects and programs. He/she shall make an annual report as Treasurer, arrange for preparation of the Society's income tax filings, supervise book sales and the maintenance of inventory records, and perform such other duties as directed by the Executive Committee. Finally, the Treasurer shall ensure that the Society gives bond, the amount of which shall be determined by the Executive Committee.

SECTION 7. *Editor*
The Editor shall have general supervision and final authority in soliciting, accepting and rejecting all material for publication in the Newsletter and other regular publications of the Society. He/she shall ensure that the Newsletter is published in a timely manner and that it includes all required elements, such as notice of meetings, ballots for electing officers, and notices concerning proposed Society projects. The Editor shall supervise the maintenance of the Society's Website. With the approval of the Executive Committee, the Editor shall appoint, replace and reappoint such other editors and associate editors from among the membership of the Society as may be required to accomplish these activities.

FCGS BUSINESS

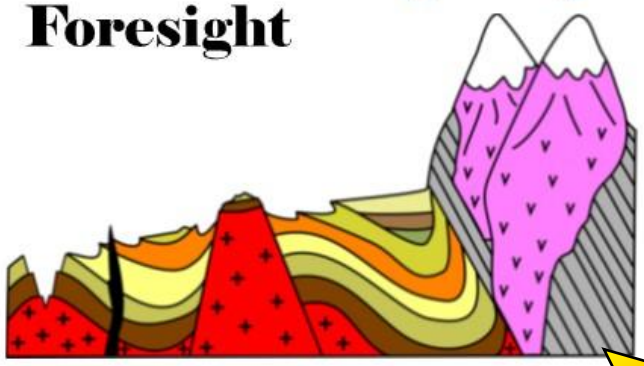


20/20 VISION

Turn Hindsight to Foresight

SPONSORS NEEDED!

Great Field Trips!
Awesome Location!
Amazing Geology!!
Great time of Year!!
Technical papers &
Short Courses to die for!



Co-Hosted by:
The Grand Junction Geological Society and
The Four Corners Geological Society

A WESTERN SLOPE COLLABORATION

THEME UNDER CONSTRUCTION

Need volunteers for the following tasks:

(Contact Kim Gerhardt, kim@mydurango.net)

- **SPONSORSHIP**: Solicit sponsors (using lists from past RMS meetings).
- **EXHIBITORS**: Solicit exhibitors & vendors (using lists from past RMS meetings & GEMs list).
- **FINANCE**: Budget & finance committee.
- **FIELDTRIPS**: Propose fieldtrips, find leaders, plan logistics, determine participant price.
- **TECHNICAL SESSIONS**: Propose technical sessions, find chairs, find subcontractor to process abstracts (AAPG contact)
- **SHORT COURSES**: Solicit short course instructors. Determine participant pricing.
- **SPEAKERS**: Recruit luncheon speakers (All Convention Luncheon, DPA).
- **AWARDS & JUDGING:**
  - Buy awards to give to last year's winners.
  - Recruit judges via registration form for this year, collect completed forms and determine winners. They will get awards at 2021 meeting.
- **WEBSITE**: Set up meeting website including links to registration & abstract submission.
- **PUBLICITY:** Publicity - use templates from other RMS meetings to make following. (Some help from GEM):

The Missionary Ridge rockfall complex roars back to life

Jon Harvey - Apr 10, 2019

A deep snowpack is generally an exciting thing for residents of the Four Corners. After a long and rewarding ski season, rivers are swelling with snowmelt runoff, bringing water and life to the drier parts of the southwest. However, all that water can be problematic. Take, for example, the Missionary Ridge rockfall/landslide complex (let's call it the MRRF for now) located a few miles north of Durango, CO. As this year's legendary snowpack melts out, the MRRF has become quite the menace to local residents and emergency managers.

Let's start by quickly recapping the history of the MRRF. In July 1998, a thick slab of Dakota sandstone broke loose from the cliffs capping Missionary Ridge, (**Figure 1**). It broke up as it crashed onto the vegetated slopes of the Morrison Formation below, yielding a debris pile full of pulverized sandstone with up to house-sized boulders. Thus, the MRRF was born. However, that was only the beginning of its story.

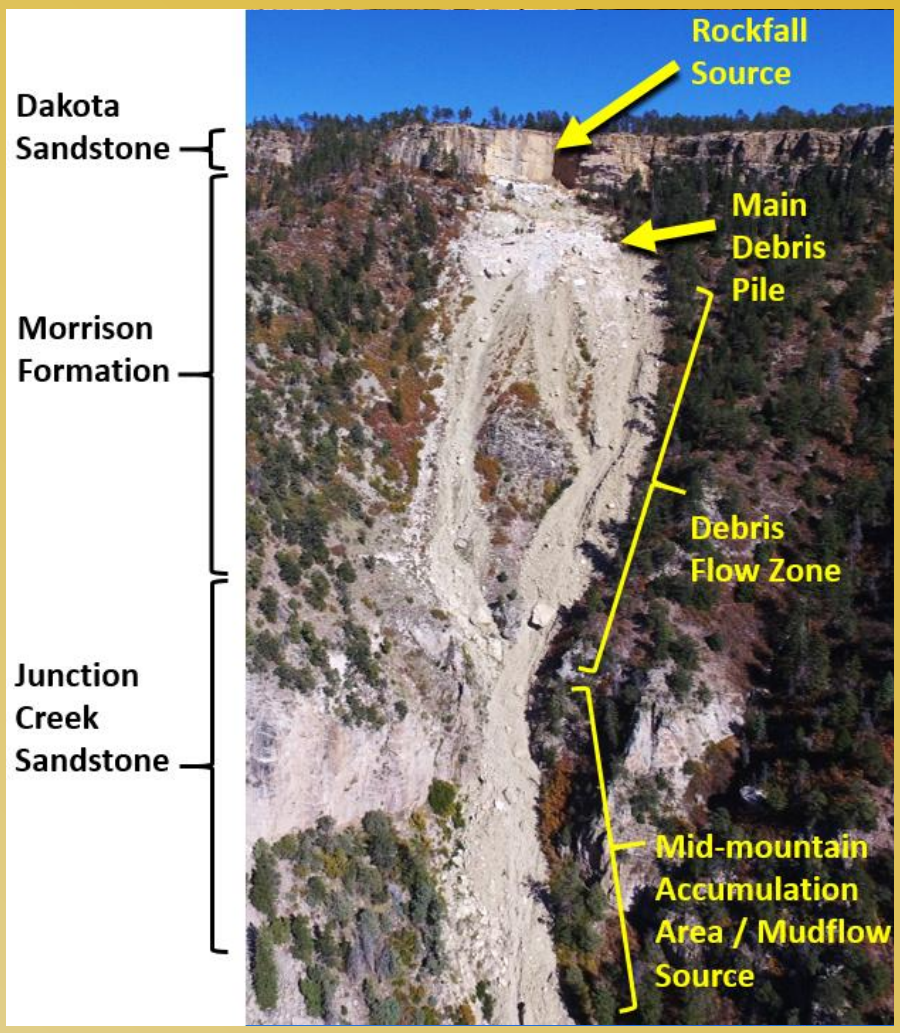


Figure 1. Photo of the Missionary Ridge Rockslide/landslide complex (MRRF) in 2017 showing the stratigraphy of the hillslope (black) and major features of the MRRF (yellow)

I've only known the MRRF since I got here in 2015, but long-time locals report that the MRRF has continued to grow and evolve since the initial failure. A 2008 report from Trautner Geotech discusses the anatomy and history of the MRRF, including the ~2001 appearance of a landslide headscarp below the source cliffs, suggesting that the Morrison Formation underlying the rockfall had slumped, perhaps under the weight of the new debris pile. The first debris flows did not make it to CR 250 until 2008.

When I started at FLC, I decided to make the MRRF the target of student research projects so that we could track its evolution through time and better understand how it operates, so that we may better understand the threat it poses to downhill residents and infrastructure. This effort was well-timed with my growing obsession with using Unmanned Aerial Vehicles (UAVs) to create detailed 3D models of landscapes. This method, commonly referred to as structure-from-motion (SfM), promises high-resolution, high-accuracy 3D models derived solely from hundreds of photos of an object or landscape. The key is that the photos must be collected from a range of perspectives, with high amount of overlap between photos. The SfM workflow includes identifying matching features in adjacent photos and performing calculations that produce the best-fit 3D model (structure) that explains the apparent distortion in position of objects as the camera moves (motion).

To visualize how SfM works, hold your finger about 6 inches in front of your face and look at it with one eye open. Notice what is behind the finger in the background. Now look at it with your other eye, and notice what is behind it now. You should have observed a change in the apparent position of your finger relative to background objects. That apparent change in position of an object based on two different perspectives is called **parallax**. Now try again with your figure an arm's length in front of you. You should notice much less distortion in the position of your finger (smaller parallax). Therein lies the power of SfM – the parallax of objects is greater the closer they are to the observer. From the perspective of a downward-looking UAV flying at a steady altitude, objects that are closer are at higher elevations.

New SfM software programs allow us to take advantage of this principle to derive 3D models of the landscape by collecting hundreds of photos of a study area with a consumer-grade UAV with an integrated camera and GPS (**Figure 2**). Flying at heights of 50 – 100 m above the surface, we produce point clouds with millions of points, which yield digital elevation models with precision on the order of <10 cm. The latter are useful for quantitative analysis and mapping in GIS.

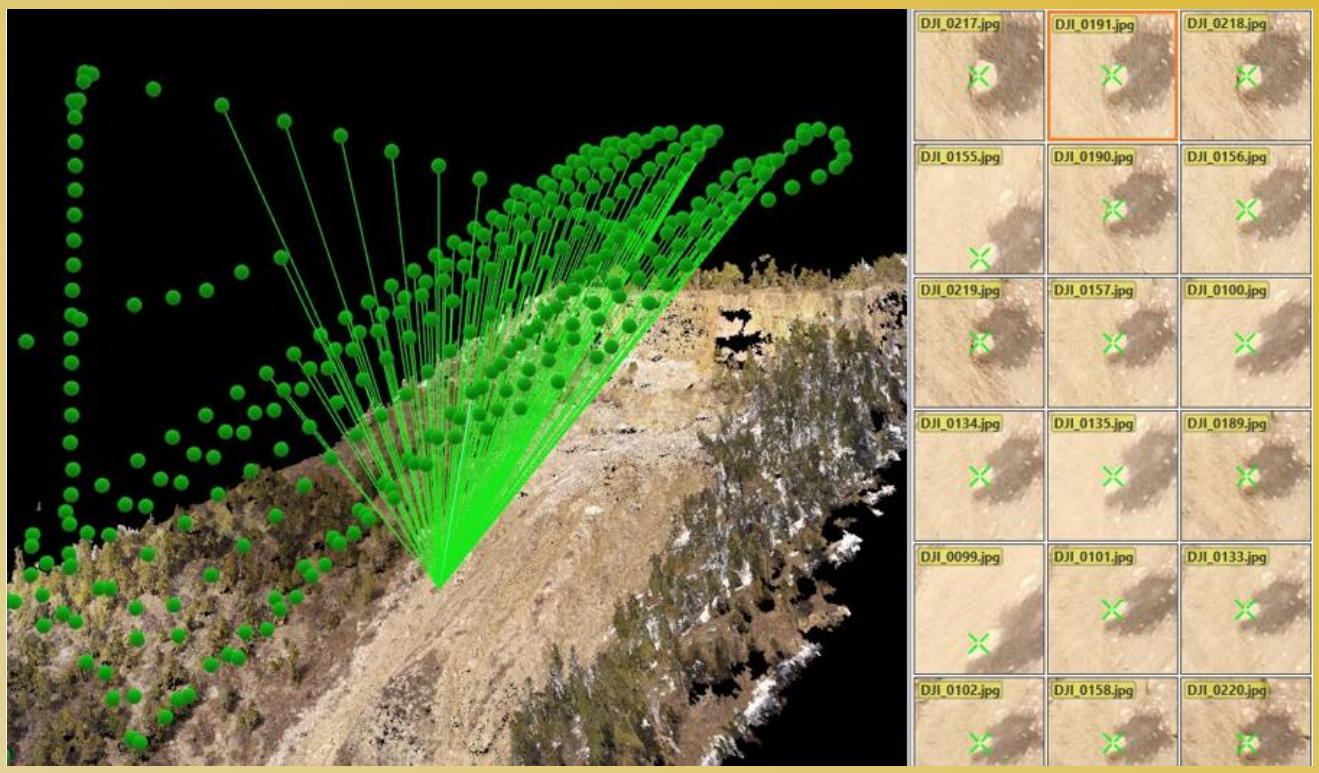


Figure 2. A) Camera locations (green spheres) above point cloud of MRRF from April 2019 survey. Green lines show all the camera locations that captured the particular boulder at their origin. B) boulder from (A) as seen in 18 photos.

Starting October 2016, my students and I have used SfM to survey the MRRF nearly every 6 months and generate *change* maps, which depict the change in elevation of the MRRF surface between surveys. As I launched the project, I expected it could be years before any measurable/interesting movement occurred on the MRRF. However, in late March 2017, I noticed from my home across the valley that the MRRF looked different. It seemed wider, and there was a giant block of sandstone now wedged between outcrops of the Junction Creek sandstone. Sure enough, a large slab of rockfall debris and underlying Morrison Formation had failed, sliding/flowing to a lower-gradient section mid-slope. Hyperconcentrated flows made their way to CR 250 below, causing headaches for CR 250 commuters but only minimal property damage. The failure and mid-slope debris accumulation zone showed up clearly in our first change maps (**Figure 3A**).

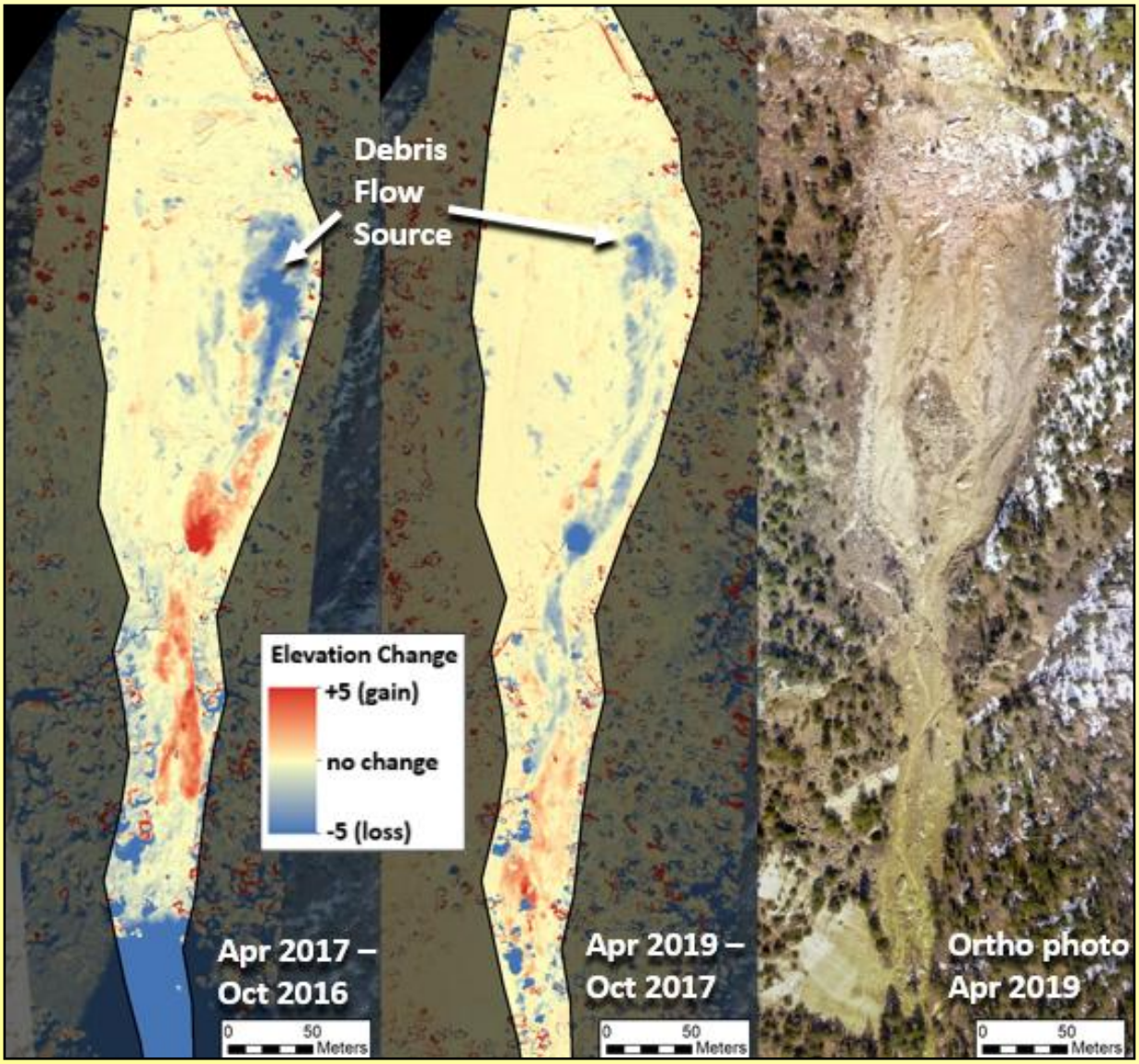


Figure 3. A) Change in elevation from Oct 2016 to Apr 2017 (positive/red values = elevation gain). B) Change in elevation from Oct 2017 to Apr 2019. C) Orthophoto generated from 2019 survey.

We surveyed again in Oct 2017, and saw only minimal change in the ensuing monsoon season, which suggested that the slow, saturating effect of snowmelt yields more movement than the short-duration, high-intensity precipitation that occurs during monsoon thunderstorms. Then came winter 2018 (the winter without a winter). Minimal snowpack, dry soils, and a moderate monsoon again yielded almost no change the MRRF between Oct 2017 and Oct 2018.

That brings us to 2019. Snowpack in the San Juans has reached levels that are anywhere from 125 to 200% of normal. Most of the low-elevation (<9000 ft) snowpack melted out in March and early April, and, as expected, the MRRF roared back to life. As temperatures started warming in mid-March, I noticed that once again, the MRRF had a different look to it. The house-sized boulder from 2017 was gone, and a new bus-sized boulder sat in the middle of the slide (**Figure 4**). The mid-slope accumulation zone was also resurfaced, and at least one big conifer was gone. I checked the Durango Herald and sure enough, the road had been closed because at least one enormous debris flow had buried it in 10+ feet of mud, boulders, and logs. Since then, additional photos have revealed multiple new failures from the steep 'failure zone' on the SW margin of the debris pile, and news reports tell me the mud continued to flow across CR 250 long after the Mar 23 failures. My students and I again surveyed the slide on April 11, 2019. The new change map shows a very similar pattern: failure at the

front of the debris pile, and accumulation of debris in the mid-mountain accumulation zone (**Figure 3B, 3C**). The change maps also confirmed a pattern that we thought we saw in 2017 - that the main debris pile itself is creeping toward a the debris flow initiation zone where slopes exceed 30 degrees (**Figure 5**). It is not yet clear whether that creeping behavior represents movement of the whole 2001 slump block or simply translational movement down the topographic surface.

At this point, our work has yielded several interesting insights into the behavior of the MRRF:

- Activity on the MRRF is enhanced by spring snowmelt far more than by monsoon storms
- The main debris pile is creeping towards a steep failure zone, where debris flows send material down to the mid-mountain accumulation zone
- When debris flows occur, they expose abundant fine-grained material, which can be transported by snowmelt as hyperconcentrated flows long after the initial debris flow event has passed (these continue to plague the ongoing cleanup effort on CR 250).

We will continue to survey the MRRF as it evolves and share our results with the county. Our research group is interested to hear about any mass wasting features you FCGS members know about / would like to get surveyed with SfM! If that's you, shoot me an email at jeharvey@fortlewis.edu.

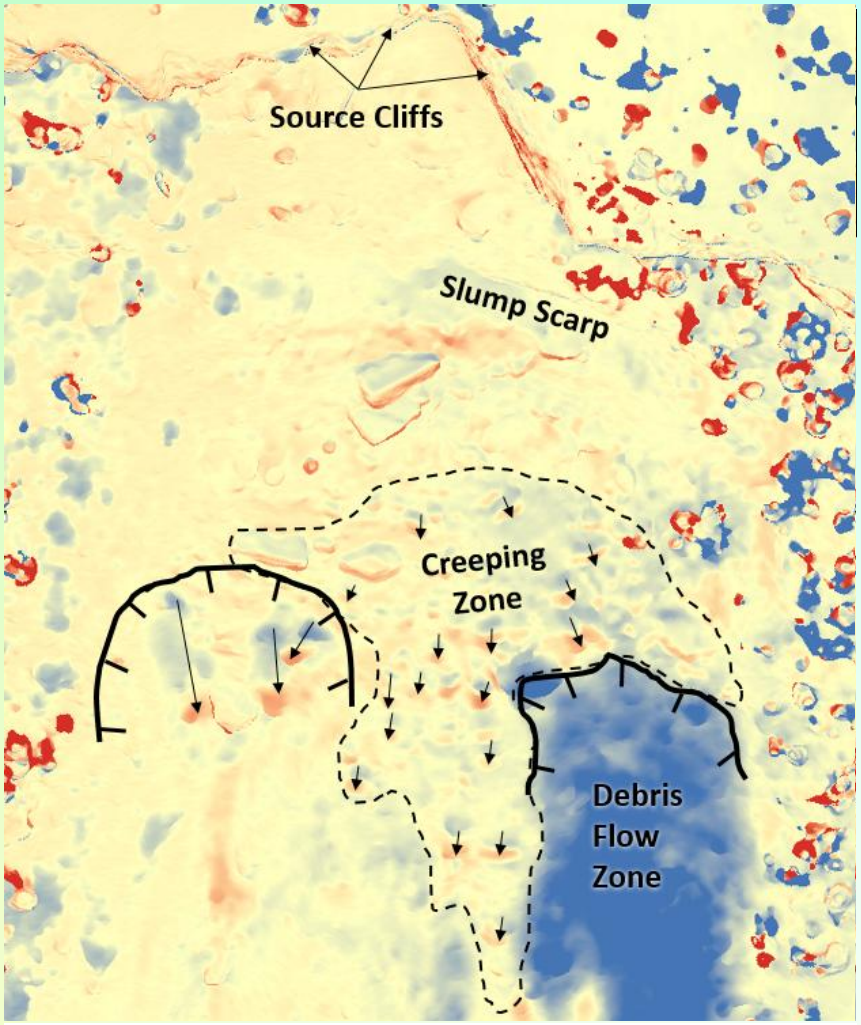


Figure 5. Zoom in of change map showing anatomy of the MRRF. Creeping zone is revealed by westward shift in marker boulders, visible as a couplet of red/blue colors

COMING NEXT MONTH:

2019: AN EPIC YEAR FOR AVALANCHES

by Andy Gleason

yikes!

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