LaPlata Mountains, Columbus Basin. Field trip photo by Helen Mary Johnson.
See more field trip pics on page 7.

WELCOME TO THE FCGS

Peter Hennings @ FLC on October 10th, 2024

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OCTOBER 2024 MEETING

SPEAKER:	**Dr. Peter Hennings, University of Oregon**
SUBJECT:	***What Twenty Years of Injection-Induced Earthquakes in Texas and Elsewhere Tells us about Anthropogenic Fault Rupture***
DATE:	Thursday, October 10th, 2024
TIMES:	5:30-6:30 pm: Dinner and Complementary Drinks 6:30-7:30 pm: Society Business / Presentation 7:30-7:45: Raffle to raise money for students
LOCATION:	Vallecito Room, Student Union Building Fort Lewis College
COST:	$25/person. PLEASE RSVP by noon on Tuesday, October 8th. WE NEED TO KNOW HOW MANY DINNERS TO ORDER.
RESERVATIONS:	Use this link (also available on website) to reserve your place. You will be given the choice to either pay now or pay at the door. You can also choose to sponor a student. RESERVATIONS LINK STUDENTS AND FACULTY: Please RSVP to Dr. Gonzales at gonzales_d@fortlewis.edu . Most students will be sponsored. Get on the list!. All faculty will be sponsored.
ZOOM:	ZOOM LINK Passcode: **570170** Zoom starts at 6:30pm
NEXT MTG:	November 12th (*Tuesday*): Vince Matthews, retired Colorado State Geologist, on the Rotation of the Colorado Plateau.

Abstract of Talk

Over the last 20 years in the U.S. mid-continent and Permian Basin region of west Texas and southeast New Mexico, the process of disposing of approximately 60 billion barrels oilfield wastewater by injection into deep saline aquifers and, to a far lesser degree, hydraulic fracturing near sensitive faults, have caused more than 4,000 M3+ earthquakes. Several of these earthquakes have caused damage and have been felt over distances exceeding 1,000 km. Hundreds of scientific papers have been published on this topic of anthropogenic fault rupture and the Center for Injection and Seismicity Research at The University of Texas at Austin has contributed in a leading capacity to this new body of work. This grand experiment of induced fault rupture tells us much about the condition of Earth's upper crust and the physics of faulting itself and a review of these advancements forms the body of the presentation.

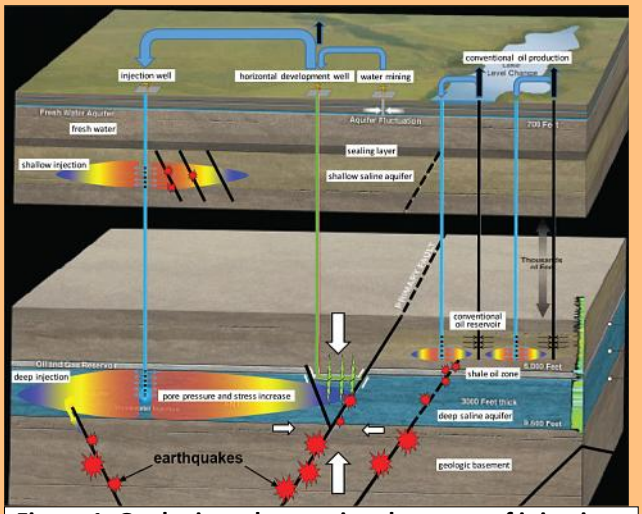


Figure 1. Geologic and operational context of injection-induced fault rupture and earthquakes.

Earth's upper crust is complexly stressed, tectonically. It is densely faulted and faults that are stressed to the point of failure lie everywhere. Almost all of the cases of induced seismogenic fault rupture have occurred in the upper reaches of the geologic basement along faults that were previously unknown and unmapped prior to recent earthquake cataloging. The degree of reservoir pore pressure change associated with induced faulting varies from as low as 10 psi to several hundred psi (0.1 to 3.0 MPa). Faulting can be induced near sites of large-scale injection or at distances of up to 50 km. Only small portions of existing faults slip at any one time which limits the magnitude of seismogenic energy release. The observed range of seismic magnitude of induced faulting in the basement is up to M6 while the magnitude of fault ruptures that are contained wholly with sedimentary rock sections is much smaller, typically ≤M3. The pore pressure history

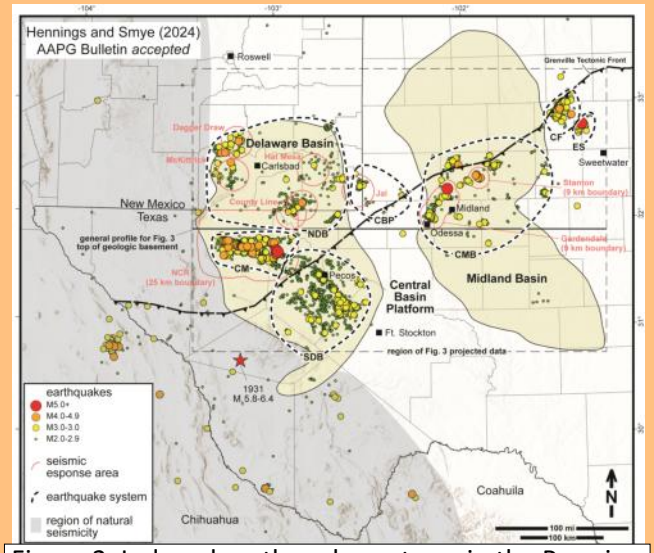


Figure 2. Induced earthquake systems in the Permian Basin region.

associated with the onset of new induced earthquake clusters ranges widely in behavior but there is typically a tight coupling of a decrease earthquake rate as injected rate is reduced. This has important hazard assessment and regulatory implications.

It is quite easy to cause earthquakes with injection. The impact of injection can spread broadly in the subsurface and impact the ground surface in surprising ways. This has important implications for the future of unconventional oil and gas development where, in the Permian Basin alone, it is estimated that the handling of future oilfield wastewater may have to deal with an additional 250 billion barrels while the subsurface capacity for injection is quickly diminishing. There are important implications for CO2 CCS sequestration as well.

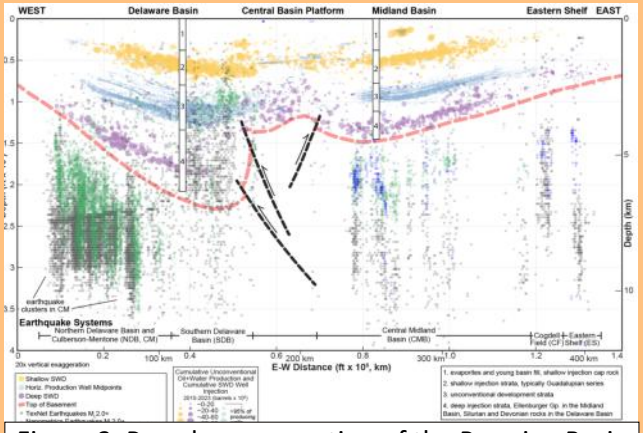
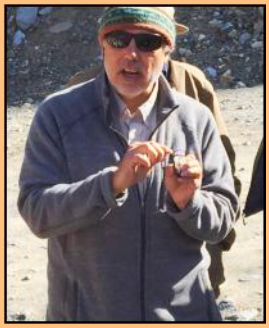


Figure 3. Psuedo-cross section of the Permian Basin showing a compilation of operational trends and earthquakes from multiple catalogs.

Speaker Biography

Dr. Peter Hennings is a Research Professor at The University of Texas Jackson School of Geosciences. Peter is the Principal Investigator for the Center for Injection and Seismicity Research at the Jackson School's Bureau of Economic Geology and he Teaches in the Department of Earth and Planetary Sciences. Prior to joining UT, Peter spent 25 years in the petroleum industry where he worked as a research scientist (Mobil Oil and Phillips Petroleum) and research manager (ConocoPhillips). Peter received B.S. and M.S. degrees from Texas A&M University and his Ph.D. from The University of Texas. Peter's research interests include induced seismicity, structural geology, seismic structural analysis, reservoir geomechanics, and geology of West Texas and the Rocky Mountains. Peter has taught over 100 classroom and field courses at the professional, university undergrad, and graduate level on seismic structural analysis, fractured reservoirs, geomechanics, petroleum systems, induced seismicity, and field methods.

Pres Sez, by Dr. David Gonzales



Tellurides!

On our recent field trip to the La Plata Mountains we stopped to search for telluride minerals and there were many questions, so I decided to provide some information. The name Telluride is applied to the town near us (and a town in Idaho), but the term tellurides refer to an important group of minerals. The name, telluride, is derived from the Latin word "tellus" which means earth.

In the world of economic minerals, sulfides (contain sulfur) and sulfosalts (contact sulfur + arsenic or antimony) are well known. Telluride minerals are less common in mineral deposits, but they have left a legacy where they occur. This is because some telluride minerals can contain gold and silver in different proportions. There are several locations in Colorado where telluride minerals are major players, two of which are Cripple Creek and the La Plata Mountains.

What distinguishes the telluride minerals is the presence of tellurium (Te) in the atomic structure rather than sulfur. Tellurium is combined with elements such as gold, silver, copper, lead, mercury, bismuth, antimony, nickel, platinum, and palladium. There are a variety of telluride minerals, but notable ones are calaverite ($AuTe_2$), krennerite (Au, Te_2), sylvanite (Au, Ag_2)Te_4, kostovite ($CuAuTe_4$), empressite (AgTe), hessite (Ag_2Te), petzite (Ag_3AuTe_2), altaite (PbTe), and coloradoite (HgTe).

Photograph of calaverite collected from the Cripple Creek & Victor Gold mine, Cripple Creek Mining District, Colorado. Photo taken from www.mindat.org

The name I find most interesting is vulcanite (CuTe) which is a rare mineral discovered in 1961 at the ghost town (and mining district) of Vulcan in Gunnison County.

Telluride minerals documented in the La Plata Mountains by Eckel (1949) include sylvanite, calaverite, krennerite, hessite, petzite, coloradoite, miargyrite, benjaminite, and cosalite. Even a savvy geologist, however, will be challenged to accurately identify these different minerals in the field since most are metallic gray in color and usually lack other distinct features unless they are perfect crystals. That is why telluride minerals are misidentified or when they are found they are just called "tellurides." We did find telluride minerals on our trip which in some cases were associated with native gold. Today, there is great interest in tellurium which is used in a variety of materials

Photograph of gray telluride minerals in quartz collected at the Bessie G mine in the La Plata Mountains. The sample is approximately 2 x 2 x 2 inches in dimension. Even though the photograph does not reveal the native gold, it is sprinkled amongst the mass of tellurides. Photo from D. Gonzales.

including solar cells and semiconductors.

The largest production of precious metals mined in the La Plata Mountains were sourced from telluride minerals and native gold in veins and replacement deposits at mines such as May Day, Bessie G, Neglected, and Jennie Lind. The production in the district, however, pales in comparison with Cripple Creek where the deposits are still mined today. The source (i.e., crust, mantle) of tellurium in these deposits, however, is still not well known and remains a challenge for geologists interested in the genesis of telluride minerals.

Foundation News, by Cindy French

It's the ***"Giving Season" Edition*** of FCGF News you can use.

This time of year means Giving Season for Non-Profits fundraising, and the FGCF is no exception. *Giving Season* occurs during the fourth quarter of the year, when tax deductions for donations to your favorite charities come to mind. Or just supporting your favorite charity with a small year-end donation.

Are some of you wondering why we say "no donation is too small?" Don't we want as many $$$$ as possible entering our foundation coffers so that our programs can maximize support for Four Corners geology students? Yes, we do, of course!

The Foundation board kicked off this new business year with a board meeting in mid-September and wouldn't you know it, a birthday party broke out! Happy Birthday to Mary Gillam, Foundation President.

However, to explain, we also have certain IRS Publicly Supported Non-Profit requirements with which we must comply, one of which is "**the sources of support factor**". This requires us to have a **representative number of persons donating to us**, and not just a few. If you are not typically a donor, you could go small with, say, a $25 donation. We would like to get multiple people to do this who aren't currently donating, that's why we say **"no donation is too small".** It will help us demonstrate that we have the support of many of our shareholders, not just a few individuals donating the larger amounts.

We very much appreciate all our past and current donors, so don't go changing! We hope to attract more donors in the future. Thanks to all of you who donated already this year, we have received 8 donations as of September 28, 2024 date for a total of $3400. No dollar amount donation is too small, so please help us continue our funding of geology students and their activities – they are our future colleagues.

AAAAND THE FINE PRINT…

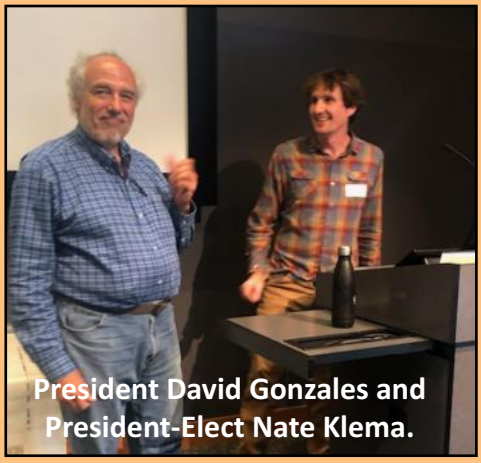
Donors, please mail checks (preferred) made out to Four Corners Geological Foundation to Treasurer Peter Mesard at 301 Hillcrest Drive, CO 81301, or, donate via PayPal link on web page (PayPal will deduct a fee). Our tax ID number is 83-4122012.

Please note that donations to the Foundation are deductible for individuals as a charitable donation, i.e. on Schedule A, because the Foundation is classified by IRS as a 501(c)(3).

Geology note: Layer cake stratigraphy with rock hammer and rock candy on top!

September Meeting Pics

September speaker Kathy Cashman with her raffle prize mug.



President David Gonzales and President-Elect Nate Klema.

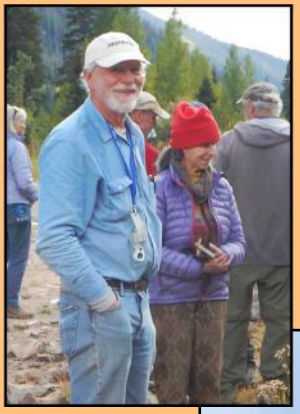
Gordon Greeve enjoying dessert!

Jim Corken and Chris Heine

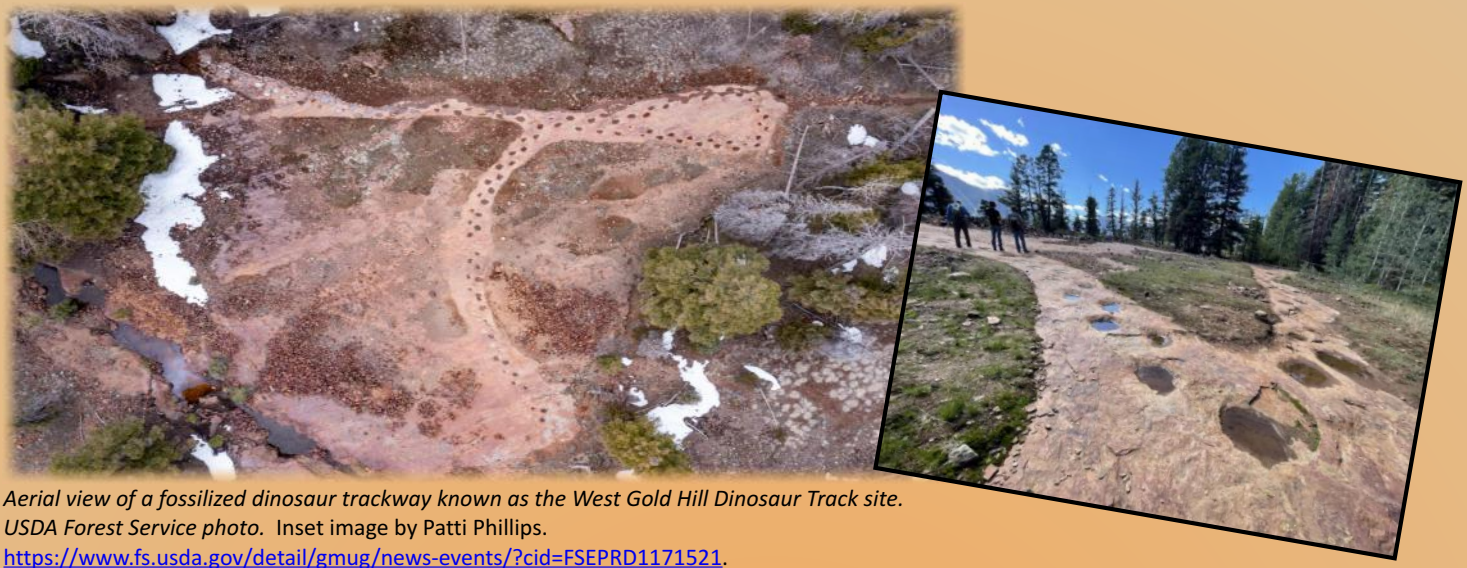
Nate Klema giving speaker Kathy Cashman her Speaker's Mug.

Sept. 22nd, Geology of LaPlata Mountains Field Trip Pictures

Thanks to Jim Corken, Helen Mary Johnson, Ron Brogdon and Laura Campbell for sharing images.



WEST GOLD HILL DINOSAUR TRACK SITE, OURAY, CO



Aerial view of a fossilized dinosaur trackway known as the West Gold Hill Dinosaur Track site. USDA Forest Service photo. Inset image by Patti Phillips.
https://www.fs.usda.gov/detail/gmug/news-events/?cid=FSEPRD1171521.

LEADERS:	**Steve Cumella and Rick Trujillo**
COORDINATOR:	**Kim Gerhardt**
DATE:	**Sunday, October 13th**
TIME:	**8:30am at the Silvershield trailhead in Ouray.**
FEE:	**$15pp. Covers FCGS field trip insurance. $13 refunded if cancel.**
LIMIT:	**10 minimum for trip to go. No maximum.** ***Registrants notified by 10th if trip cancelled.***
BRING:	**Daypack with lunch, water, rain gear and warm layers. Hiking poles <u>strongly</u> recommended for the descent back to the cars.**
REGISTRATION IS OPEN:	**REGISTRATION LINK**

LOGISTICS: Participants must arrange their own transportation to Ouray, as well as lodging if you will be staying overnight before or after the trip. A group email will be sent to participants before the trip so people can arrange carpools. In Ouray we will meet at the Silvershield trail head at 8:30am. Location information will be sent to registrants. **The dinosaur trackway is reached by a 2.1 mile, 1,600' climb uphill to 9,300' on a rough, exposed trail with unsure footing in places. Hiking poles highly recommended for descent as surface is loose in places.**

Hiking trail profile

DESCRIPTION: This is the longest recorded dinosaur trackway in the world (134 consecutive tracks, or 67 strides, extending 160 yards). The tracks were made by a single long-neck sauropod dinosaur. The animal looped in a 270-degree turn making this one of only six known sites where dinosaur tracks changed direction significantly.

The tracks are near the base of the Jurassic, Morrison Formation. Locally called the "Lower Quartzite" by miners, the sandstone has been hardened by hydrothermal alteration within the Uncompahgre Mining District.

At the top of the Lower Quartzite, researchers found two sets of symmetrical ripple marks. These are interpreted as wave ripples created by wind blowing over shallow water. Subsequently the dinosaur walked on this soft, water-saturated surface leaving deep impressions.

See the Forest Service website, the Ouray Geology Facebook page and this reference for more information: *Goodell, Z. et al., 2021, A High-Altitude Sauropod Trackway Site in the Jurassic of Colorado: The Longest Known Consecutive Footprint Sequence Reveals Evidence of Sharp Turning Behavior, in: Lucas, S.G., Hunt, A.P. and Lichtig, A.J., 2021, Fossil Record 7. New Mexico Museum of Natural History and Science Bulletin 82.*

FOUR CORNERS GEOLOGICAL FOUNDATION

Charitable Donation

Thank you for your philanthropic gift to the Four Corners Geological Foundation. The Foundation helps support geoscience education, fund research grants, and pay for scholarships in the Four Corners states.

If preferred, you may donate by Pay Pal or credit card online at:
https://fourcornersgeologicalsociety.org/foundation

Alternatively, a check or money order payable to "Four Corners Geological Foundation", along with this completed form, can be mailed to:

Four Corners Geological Foundation
115 Meadow Road East
Durango, CO 81301

Please print or type your information below:

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☐ Please do not acknowledge my donation publicly in announcements or newsletters.

Donation Notes:
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FOUR CORNERS GEOLOGICAL SOCIETY

P.O. Box 1501, Durango, CO 81302

MEMBERSHIP RENEWAL or APPLICATION: June 1, 2024 to May 31, 2025

*Name: _____

*Address: _____ City: _____ State: _____ Zip: _____

*Email: _____ Phone: _____

*Employer: _____

NEWSLETTERS SENT BY EMAIL ONLY

***Please check your interests:**

- ☐ Sedimentology & stratigraphy
- ☐ Structure & tectonics
- ☐ Mineralogy, petrology, geochemistry
- ☐ Igneous geology, volcanology
- ☐ Ore geology and hard rock mining
- ☐ Other mineral extraction
- ☐ Petroleum geology
- ☐ Geophysics
- ☐ Geological engineering
- ☐ Geomorphology
- ☐ Quaternary geology
- ☐ Hydrology & water resources
- ☐ Environmental geology
- ☐ Geography / GIS
- ☐ Other interest (see box)

Please Identify a Membership Category:

Active Member	$30	Any person engaged in the practice or teaching of geology or who holds a Bachelor's Degree in geological science from a college of acceptable academic standards. Degree requirement may be waived if applicant has adequate professional experience. **Highest Degree, Type and Year:* _____ **College / University:* _____
Associate Member	$30	Any person who is a graduate of a college of acceptable academic standards with major studies related to, or associated with, geology. Degree requirement may be waived if applicant has adequate professional experience. **Highest Degree, Type and Year:* _____ **College / University:* _____
Student Member	Free	Any undergraduate or graduate student majoring in geology at a college of acceptable academic standards. **College / University:* _____ **Year expected to graduate:* _____
Emeritus Member	Free	An Active Member of 65 years old or older who has been a member for 25 years including time spent in military service. **Year emeritus status was awarded*: _____
Honorary Member	Free	An Active Member who has contributed distinguished service to the profession of geology and to the betterment of the FCGS. Determination is made by the FCGS Executive Committee. **Year honorarium was awarded:* _____.

Other Professional Interests or Comments and Concerns.

Are you interested in Volunteering? If so, what is your area of interest?

**** Required information for new members. Current Members, please update.***

Please either print, complete and return this form with your check for dues made payable to: "Four Corners Geological Society" **and mail to the address above or go online to fourcornersgeologicalsociety.org .**