NORTHERN CALIFORNIA GEOLOGICAL SOCIETY

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MEETING ANNOUNCEMENT

DATE: **Wednesday, May 31, 2023**

LOCATION: **Orinda Masonic Hall - and - Online using Zoom**

Notes: Send in your registration form and check – see Page 12. Zoom meeting attendees should see Page 2 for "Zoom Meeting Instructions"

TIME: **Social time: 6 to 6:45 pm; Dinner: 6:45 to 8 pm; Presentation: 8 to 9 pm**

SPEAKER: ***Robert M. Gailey, PG, CHG, R. M. – Gailey Consulting Hydrogeologist PC***

TOPIC: ***"Groundwater Management in California: Big Picture Issues, Recent Regulatory Requirements and Scientific-Economic Approaches"***

Abstract:

Sustainable management of California's groundwater resources is vital to the interests of residents, local industries and those elsewhere that rely on agricultural products from the state. The management challenge is significant in scope, multi-faceted and complex. Both physical and economic processes must be considered when developing viable management approaches. Focusing on the Central Valley as an example, this presentation will 1) provide a historical perspective on groundwater use and evolving conditions, 2) highlight some impacts from overuse of the resource, 3) discuss recent management requirements by the State and 4) provide information on groundwater recharge efforts. Details related to groundwater resources in other parts of the state may be addressed during discussion following the presentation.

Biography:

Rob Gailey has been a practicing hydrogeologist since 1985 contributing to both environmental and water supply projects. His work ranges from performing field investigations and quantitative analysis to regulatory negotiation and expert witness engagements. Rob particularly enjoys envisioning and scoping new projects. Licensed as a Professional Geologist and Certified Hydrogeologist in California, he also holds degrees in geology (ScB, Brown University), hydrogeology (MS, Stanford University), civil and environmental engineering (PhD, University of California at Davis), as well as business (MBA, University of California at Berkeley). Rob welcomes spirited discussion of the material that he presents.

NCGS 2022 – 2023 Calendar

June 28, 2023 7:00 pm
Andrew Alden
Deep Oakland: How Geology Shaped a City

Zoom Meeting Instructions – Advance Registration Required

Now that Contra Costa County Health Department has cleared us to meet in person, we are holding hybrid monthly meetings – in person and via ZOOM. The Zoom option is available for those not wishing to come to our Orinda Masonic Hall meeting place.

We have switched to a registration system for those who would like to join the NCGS meetings by Zoom. Please click on or enter the following link into your browser:

https://us06web.zoom.us/meeting/register/tZEucOisqjwuGtIf3R1dgx79xILSLO4HTPkw

in order to self-register. A zoom link for the meeting will be automatically sent to you for your use on the night of the meeting. The meeting room will be opened by the host between 7:45 PM and 8:00 PM with the presentation scheduled to start at 8:00 PM. The program will end by 9:00 PM. As in the past, the meeting will be recorded and kept on the Cloud for member viewing over the following month. A link for that recording will be made available to members the day after the event.

K-12 news for ways to support Earth Science in our communities & schools

NCGS and other Earth Science organizations are seeking to revitalize K-12 and Teacher of the Year (TOTY) awards. Our Society continues to lead in speaker programs and field trips. Let's see if we can do more with our other programs as well!

K-12 Science/Geology Outreach ALERT

Science is back in Fashion!! With the slam from COVID issues and confusing election information, support for schools is moving up in priority. Many professional societies (AGU, AAPG, PSAAPG and SPE included) are making an effort to get us to work with our communities and schools. Are you willing to HELP?

For K-12 Science programs, West Coast societies plus AAPG want to increase our efforts in working with K-12 Schools to provide support and reward teachers for stimulating programs in the Earth Sciences. NCGS has been working with Math Science Nucleus, BAESI, Science Fairs, individual schools and some Scout groups for many years. However, as we age, we have been losing our volunteer NCGS members as well as some schoolteachers and community organizations that have provided leadership and support for decades.

We currently have six community organizations/schools seeking our support: needing volunteers for field trips or trade shows/classroom lectures/exercise-experiments; as well as books, rock samples, docents, etc. Do you have teachers that should be considered for Teacher of the Year?

NCGS, PSAAPG, SCGS, AAPG, and SPE will be coordinating our efforts for 2023. I will keep you posted every month through the NCGS Newsletter. I'm currently talking with 5 organizations as well as several schools and teachers to determine their needs and line up our support capabilities. I thank our Executive Committee and all of you that have been busy the last few months communicating with K-12 teachers and community groups.

It is time to commit to K-12 Activities for 2023.

Below is a list of opportunities to help our communities – we ask you to please help. If you are interested in joining our effort through volunteering or donations, please contact Paul Henshaw, at drphenshaw@comcast.net.

K-12 Science Education Opportunities:

1) Develop AAPG-PSAAPG-NCGS Co-ordination
   Work with Coordination Committee
2) Math Science Nucleus: https://msnucleus.org
   Positions: Docents & 1 paid position
3) CCC Science Fair - Bay Area LEEDS (Linking Education & Economic Development Strategies): Judging positions
4) Cub Scouts Interest in K-12 Program
   Earth Science support as needed
5) Eden Area Regional Occupation Program in Hayward:
   Position – Work-Based Learning Specialist
6) School in Hayward that might need some lecturers

As new opportunities arise, we will update this list. If you wish to have NCGS consider additional organizations, please contact us at drphenshaw@comcast.net.

View the April Presentation

We held another fine meeting in March, live and via Zoom. We hope that all who wanted to see the talk by Dr. Larry Toy, PhD, on ***The James Webb Space Telescope,*** were able to, without significant interruption or other issues. If you missed it or would just like to see it again, please use the following link and password:

https://us02web.zoom.us/rec/share/x504PjujmYAWYw7_dGFoUkxzOMruS8rVcBV-WG6jTyb3rhDv6TPTkHUDo3lg3-YK.WqYW8jFmiTcBEjmm

Passcode: nY2W.zk9

(**Note**: As usual, we suggest that you type in the password, rather than cutting and pasting it in.)

New publication on Oakland's Geologic Story

"In Deep Oakland: How Geology Shaped a City, published in May by Heyday Books, longtime NCGS member Andrew Alden takes an attentive and affectionate look at Oakland "from the ground down." Deep Oakland weaves together three different histories of this Bay Area city: the Quaternary history of tectonics and glacial cycles that constructed and maintains Oakland's landscape, the late Phanerozoic history of California recorded in Oakland's surprisingly diverse rocks, and the Holocene history of human interactions with this geological setting. Three different civilizations -- Indigenous, Spanish and Anglo-American -- have managed and exploited Oakland's geological resources, and adjusted to the site's constraints, in distinctive ways. Andrew seeks not only to awaken East Bay citizens to the secrets in their home landscape, but also to tempt local geologists with textbook features waiting in their own back yard. The latter topic will be his focus in his presentation at our June meeting.

Deep Oakland is available at many local bookstores as well as the usual online sources. Use the discount code "OAKLAND" for a discount from the Heyday Books website (https://www.heydaybooks.com/catalog/deep-oakland/)."

That catalog page features this blurb by Doris Sloan, among others: "In this vivid account of Oakland's exceptionally rich geology, Andrew Alden weaves together historical and geological tales in elegant non-technical language that will tempt you to explore Oakland's beautiful landscape from the Bay margins to the crest of the hills."

Come to June's NCGS meeting when Andrew will offer us a more in-depth discussion of local geology on the other side of the hill!

Field Trip Photos Sought!

Ray Sullivan had a great idea several months ago when he shared several photos with us all. Now I would like to put out a request to the membership. Do you have any photos of memorable field trips that you might share with the society? If so, please send them to me at msorensen64 @ earthlink.net. Response has been good, but I can use a few more!

NCGS Photo of the Month

Here's a photo of a well-attended field trip to the Vasco Hills in 1988 that was led by Ron Crane. Photo courtesy of Ray Sullivan.

NCGS Outreach Opportunities

Watch this space and watch for any emailed messages from the secretary. Also see the K-12 news on Page 2!

NCGS Member Notes

We regret to inform the society that NCGS members Danielle Forester and Rolfe Erickson recently passed away. Rolfe was a professor at California State Sonoma, and led at least one field trip for the society in the mid-2000s.

Lost members: Does anyone know the whereabouts of Tommy Bartas? The editor has received two recent newsletters returned by the Post Office as undeliverable.

UC Berkeley Earth & Planetary Science Weekly Seminar Series

Seminars are on vacation for the summer. Watch this space for information about fall offerings. Send an email to eps_frontoffice@berkeley.edu to join the department's email list. For updated listings of upcoming seminars, go to https://eps.berkeley.edu/seminars-courses/eps-seminars.

USGS Evening Public Lecture Series

The USGS evening public lecture series events are free and are intended for a general public audience that may not be familiar with the science being discussed. Pre-Covid, talks were held at USGS; the talks are now online. Talks are scheduled through August. On May 25 at 6:00 PM, Shawna Gregory and Matt Rhoads, USGS Water Resources, will speak on ***Harnessing Our Greatest Life Force – Swim with Us Through Water Data for the Nation.*** Check the website to join the live stream, at: www.usgs.gov/pls/. To be added to the email notification list for future USGS Public Lecture Series events, please email: wmcesic@usgs.gov.

Have You Renewed Your Membership?

Please see page 13 of the April newsletter for a blank registration form, fill it out with your check and send to our Treasurer, Don Medwedeff. Note: Please do not pay for more than 3 years in advance, as it introduces bookkeeping issues.

WE'RE ON FACEBOOK!

CHECK OUT THE MOST RECENT POST: @NCGEOLSOC

ALSO, VISIT TWITTER @NORCALGEOSOC

Check out our NCGS Website at:

http://ncgeolsoc.org/

We have posted many older field trip guidebooks for free downloading, and we describe the process for purchasing newer guidebooks. The website includes a list of upcoming meetings, information on our scholarship program, a list of useful web links, and list of NCGS officers.

NCGS Board Meetings

Board meetings (online for now) are open to all NCGS members. If you'd like to attend, please contact President Noelle Schoellkopf at NoellePrince @ sbcglobal.net. Board meetings generally are on Saturday mornings in Jan., Apr./May, and Aug./Sep. Upcoming meeting: **Saturday, August 26, 2023 at 9 a.m., by Zoom**.

A Great Website to Check Out

Dr. Ray Sullivan has recently completed an excellent website – see http://raysullivangeologist.com/. As many of you know, Ray was a longtime professor of geology at San Francisco State University as well as serving in multiple positions with other societies and organizations, and with NCGS as president, program chair, field trip leader and counselor, and co-editor of the Mount Diablo volume recently published with the Geological Society of America. The website has a biography, list of journal and book publications, and a list of projects on which he's worked, with some great photos and stories. Check it out!

Note from the Newsletter Editor: These are Parts 5 and 6 in a series that began in the March issue, contributed by Bill Motzer, an accomplished geochemist and longtime NCGS member

The Irony of Iron

Part 5 – Terrestrial Planet Compositions and Iron

by

William E. (Bill) Motzer, PhD, PG, CHG

In Part 4, I discussed the relatively large iron-rich cores of the Solar System's inner rocky (terrestrial) planets: Mercury, Venus, Earth, and Mars. Only Earth and Mars have mantles and crusts that seem to be enriched in soluble or ferrous iron [Fe(II)]. How this came about is an interesting question and many answers are still hypothetical and theoretical. The following descriptions are from several sources including: Solomon (2011), Tanaka (2014), and NASA (2022a,b,c,d).

Mercury: data returned from NASA's Messenger space probe survey (2011-2015) determined, via X-ray fluorescence spectroscopy, that Mercury's surface (i.e., crust) is thin but quite dense with a high ratio of magnesium (Mg) to silicon (Si) (Mg/Si) and low ratios of aluminum (Al) and calcium (Ca) to Si (Al/Si, Ca/Si). The crust also contains sulfur (S) at concentrations more than 20 times that of Earth but very low amounts of titanium (Ti) and Fe. Mercury does not have a significantly thick mantle (500 km to 700 km thick); however, its huge liquid Fe core forms 85% of the planet's mean radius (2,440 km) and 75% of its mass. It's also believed that Mercury's original crust and perhaps parts of its original mantle were removed by a large ancient asteroid impact. Therefore, its current crust may represent resurfacing derived from its present mantle.

Venus' surface composition is somewhat known from the Soviet Union's Venera probes (1960s-1980s) and Vega missions (1975) which landed on Venus' surface. X-ray fluorescence and gamma-ray spectrometers on Veneras 8, 9, and 10 and Vega 1 (1985) and 2 (1987) measured elemental and radioactive crustal compositions. Venera 15 and 16 (1983) orbited the planet mapping Venus' northern quarter's surface with side-looking radar. The U.S. Mariner 2 (1962), 5 (1967), and 10 (1974) probes analyzed Venus' atmosphere on the way to Mercury. The Magellan spacecraft (1990-1994) in a near-polar orbit produced surface radar images with 100 m resolution, thereby mapping almost the entire planet.

Results of these and other subsequent space probes indicated that Venus' surface consists of "young" impact craters on a volcanic terrain composed of basalt largely erupted as lava plains, domes, and shield volcanoes. Planetary scientists believe that its entire surface underwent resurfacing from about 750 to 350 million years ago (Ma) and perhaps as recently as 150 Ma. Gravity data suggests a fairly uniform crust ranging in thickness from 20 to 50 km. Below the crust is a semi-solid rocky mantle overlying a Fe-Ni-S rich core which may be 7,000 km in diameter. However, because Venus lacks a dynamo-magnetic field like Earth's, it's not known if it has a liquid or solid core. Therefore, it's also not known how elemental iron gets from the core to the mantle and crust. In such a reducing environment soluble Fe(II) oxides probably don't occur. However, iron in the basalts may exist as pyrite and/or marcasite (FeS_2).

Mars is known as the "Red Planet" because of the iron-rich (oxide) minerals in its surface regolith, including goethite [FeO(OH)], hematite (Fe_2O_3), and jarosite [$KFe_3(SO_4)_2(OH)_6$]. Over the past 50-plus years, NASA has launched various space probes to Mars, including Mariner 4 (1965), Mariner 6 and 7 (1967), Mariner 9 (1971), and Vikings 1 and 2 (1976-78 and 1976-1980, respectively), both landing in 1976. Surface robots such as Sojourner (1997-1998) – the first wheeled rover, which analyzed rocks over a period of 95 Earth days. In 2001, NASA launched the Odyssey orbiter which mapped water ice below the Martian surface. The Spirit (2004-2011), Opportunity (2004-2018), and Phoenix (2008) probes were robotic geologists analyzing atmosphere and soil. The Insight lander (2018) contains a seismometer, until recently measuring Martian earthquakes. The ongoing Perseverance (2021) rover's mission is to drill, return soil and rock cores, and determine if life existed or currently exists on Mars.

Mars' surface is a heavily asteroid- and meteor-impact-cratered, largely volcanic (basalt and andesite) terrain with sedimentary deposits (mudstones, sandstones, clays, and sands) derived from flowing water when Noachian Mars had shallow oceans, perhaps 4.1 to 3.7-3.5 billion years ago (Ga). Mars has a dense Fe-, Ni-, and S-rich solid core between 3,580 and 3,740 km diameter that's surrounded by less dense silicate-, Fe-, Mg-rich (rocky) mantle about 1,240 km to 1,880 km thick. If Mars had a magnetic field, it probably shut down about 500 million years after its formation. The mantle is overlain by a 10 km to 50 km thick crust composed of Fe, Al, Ca, K, and Si. Iron mobilized from the core to mantle to crust is illustrated in **Figure 1-5**. Note that for both cases abundant surface water occurs. It's in such oceans that life can begin and evolve and I'll discuss such possibilities in the next part.

Part 5 References

Ballmer, M.D. and Noack, L., 2021, *The Diversity of Exoplanets: From Interior Dynamics to Surface Expressions*: Elements magazine, v. 17, n. 4, pp. 245-250.

NASA (National Aeronautics and Space Administration), 2022a, *Mercury*: https://solarsystem.nasa.gov/planets/mercury/overview/

NASA (National Aeronautics and Space Administration), 2022b, *Venus*: https://solarsystem.nasa.gov/planets/venus/overview/

NASA (National Aeronautics and Space Administration), 2022c, *Mars*: https://solarsystem.nasa.gov/planets/mars/overview/

NASA (National Aeronautics and Space Administration), 2022d, https://nssdc.gsfc.nasa.gov/planetary/factsheet/planet_table_ratio.html

Solomon, S.C., 2011, *A New Look at the Planet Mercury*: Physics Today, January issue, pp. 50-55.

Tanaka, K.L., et al., 2014, *Geologic Map of Mars* (text): U.S. Geological Survey (USGS) Scientific Investigations Map 3292, USGS, Washington DC, 48 p.

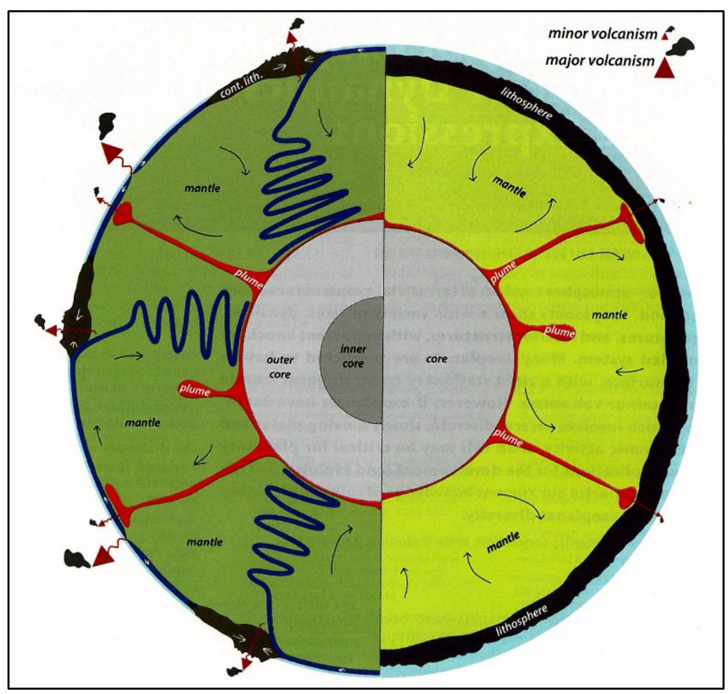


Figure 1-5: Schematic cross sections (not to scale) of a plate tectonic planet (left): e.g.. Earth versus a plume/static-lid planet (right): e.g., Mars. Solid inner core

(dark gray) surrounded by a liquid outer core (light gray) overlain by a mantle (green). Lithospheres (crusts) are in dark brown; upwelling plumes in orange. On Earth, Fe0 is transported by plumes from the core-mantle boundary through the mantle to the crust. Fe0 is oxidized in a hydrous (oceanic) crust and via subduction enriches the mantle. On Mars, plumes from the core to the crust bring Fe0 through the mantle where it may undergo oxidation eventually forming soluble Fe(II) oxides. Mars's mantle is probably not enriched with Fe oxides because liquid water and subduction does not occur. White arrows show plate movement; oceans in light blue. Source: Ballmer and Noack (2021).

The Irony of Iron: Part 6 – Banded Iron Formation Geochemistry

In Part 5, I noted that two terrestrial planets (Mars and Earth) have crusts that contain soluble hydrous ferrous [Fe(II)] oxides mobilized from their metallic iron-nickel cores through their respective mantles. This largely occurred via mantle plumes but also from subducting oceanic plates that recycle weathered Fe(II) crust back into the mantle (**Figure 1-6**). However, the latter process only occurs on Earth because there's no evidence for plate tectonics having ever occurred on Mars. A stationary Martian mantle plume most likely resulted in the largest shield volcano in the Solar System: Olympus Mons (elevation: 21.9 km above the Martian base level). Additionally, Mars once had oceans but because it lacked a dynamo magnetic field, it's believed that most of its early atmosphere and water leaked into space. Therefore, Fe(II) precipitated out in and on Martian surface rocks and regolith, never to be recycled. Earth's thicker atmosphere and protective magnetic field allowed atmospheric and oceanic retention. As a result, Earth's crust, and subsequently its oceans, were enriched in Fe(II) oxides, the sources of which were from plumes erupting as volcanoes, oceanic hydrothermal vents, and some crustal rock weathering. Over time, Earth's oceans became saturated with Fe(II) oxides, which eventually precipitated either chemically, biologically, or a combination of both. And it's this and subsequent Fe(II) precipitation events that helped in stabilizing and forming an environment conducive to complex life.

In the geological record this is apparent in the worldwide occurrence of banded iron formations (BIFs) (**Figure 2-6**), of which deposition is believed to have occurred from Fe(II) oxidation in seawater either from oxygenic photosynthesis or iron-dependent anoxygenic photosynthesis (aka photoferrotrophy). As an analog, modern aerobic Fe(II) oxidation occurs from acidophilic oxidizing bacteria using O_2 as an oxidant as a terminal electron acceptor:

$$2Fe^{2+} + 0.5O_2 + 2H^+ \rightarrow 2Fe^{3+} + H_2O$$

Most BIFs were deposited in Precambrian [early Archean to late Paleoproterozoic ~3.8 to 1.8 billion or giga years ago (Ga)] oceans. However, BIF deposition remains somewhat controversial because possible photosynthetic biomasses produced during iron oxidation are absent. Additionally, early Earth's surface environment (atmosphere and oceans) is believed to have been largely anaerobic or anoxic, as was early bacterial (microbial) life – perhaps appearing as early as 3.3 Ga – that used hydrogen, nitrogen, and perhaps even sulfur as electron acceptors, e.g.:

$$10Fe^{2+} + 2NO_3^- + 24H_2O \rightarrow 10Fe(OH)_3 + N_2 + 18H^+$$

Archean sedimentary rocks and fossils also indicate the presence of liquid water on the Earth's surface. The dominant atmospheric Archean gases were most likely carbon dioxide (CO_2) and nitrogen (N_2) with perhaps traces of methane (CH_4). Additionally, the rock record suggests an absence of atmospheric oxygen (O_2) (**Figure 3-6**), although O_2 may have started increasing in shallow seas as early as 3.5 Ga, produced by cyanobacteria in stromatolites. However, it's the greenhouse gases that probably allowed above-freezing surface and oceanic temperatures even though the warming mechanism effectiveness during the Archean is still not well understood.

BIF deposition by photoferrotrophs may have also contributed to CH_4 atmospheric fluxes, thereby aiding in stabilizing Earth's climate under a dim early Sun (Solar luminosity is estimated to have been 77% to 79% of its present value at 3.2 Ga to 3.5 Ga) (**Figure 4-6**). The absence of significant O_2 in the Archean atmosphere is also indicated by unoxidized detrital sulfides (e.g., pyrite or FeS_2) and uraninite (UO_2) contained in Archean fluvial sediments and by sulfur isotopes in sedimentary rocks that were fractionated independent of mass by ultraviolet photolysis of SO_2 in an anoxic atmosphere.

But not all mantle plumes are created equal and there's at least one that may have been responsible for wiping out nearly 95% of land and ocean species. And we'll discuss this in my next article.

Part 6 References

Chen, J. and Esdaille, S.S., 2022*, Is the Earth's Core Rusting?*: EOS, v. *103*, https://doi.org/10.1029/2022EO220201. Published on 25 April 2022.

Hayes, J.M. and Rafferty, J.P. (editors), 2020, *Evolution of the Atmosphere*: Encyclopedia of Britannica: https://www.britannica.com/topic/evolution-of-the-atmosphere-1703862.

Spencer, J., 2019, *The Faint Young Sun Revisited*: GSA Today, v. 29, pp. 4-10.

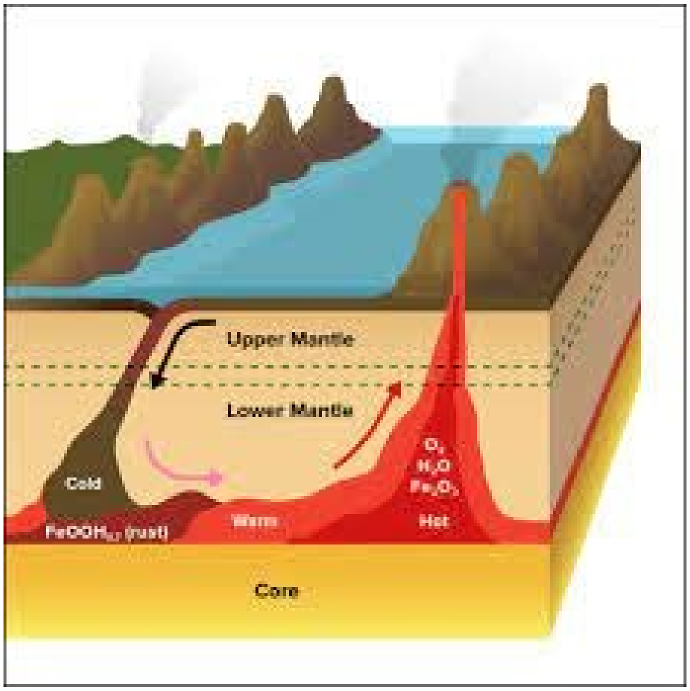
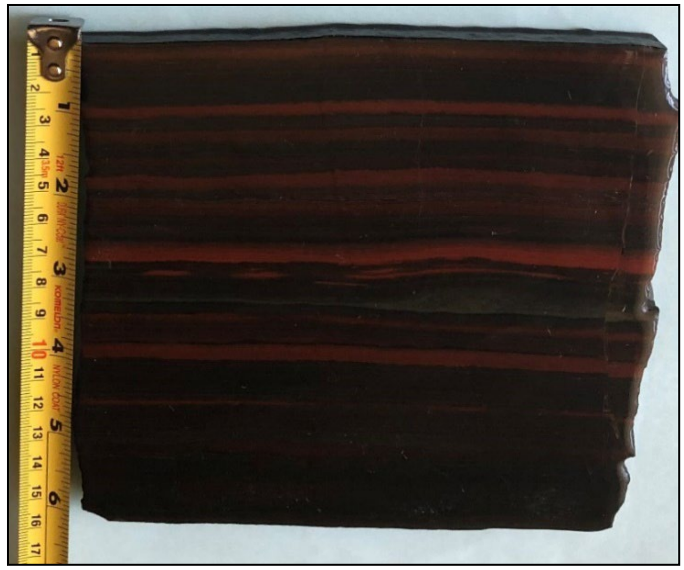


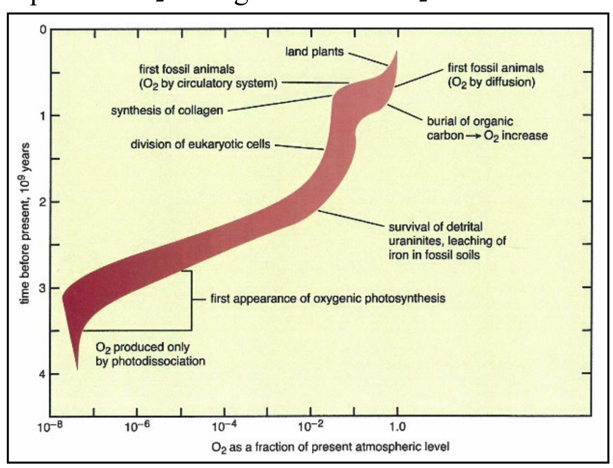
Figure 1-6: Schematic/cartoon model suggesting that core "rust" (as FeOOH0.7) could form when a relatively cold subducting slab carrying hydrous minerals meets the outer core. Driven by mantle convection, core rust deposits from this cold region could then migrate along the core-mantle boundary to a hotter region at the root of a mantle plume, where it could become unstable and decompose into hematite (Fe_2O_3), water (H_2O), and oxygen (O_2). Source: Chen and Esdaille (2022) with credit to Mary Heinrichs/American Geophysical Union.

Figure 2-6 (below): Polished specimen of a banded iron formation (BIF) with repeated thin layers of iron oxides and chert. Scale on left in both inches (large numbers) and cm (small numbers). Sample location typical of the Mitten Mine, northern Michigan. A typical BIF consists of these repeated, thin layers (a few mm to a few cm in thickness) of light gray/silver hematite (Fe_2O_3), and black magnetite (Fe_3O_4) alternating with bands of red iron-poor chert. BIFs may range in thickness from tens to several hundred meters extending laterally for several hundred km. BIF deposits are responsible for much of the mined iron ore; they occur in Russia, Australia, Brazil, Russia, Canada, and the U.S. (northern Michigan, Minnesota, and



Wisconsin). Sample shown is from author's collection.

Figure 3-6: An estimated reconstruction of Earth's atmosphere of O_2 through time. The O_2 abundance axis is



logarithmic (Source: Hayes and Rafferty (2020).

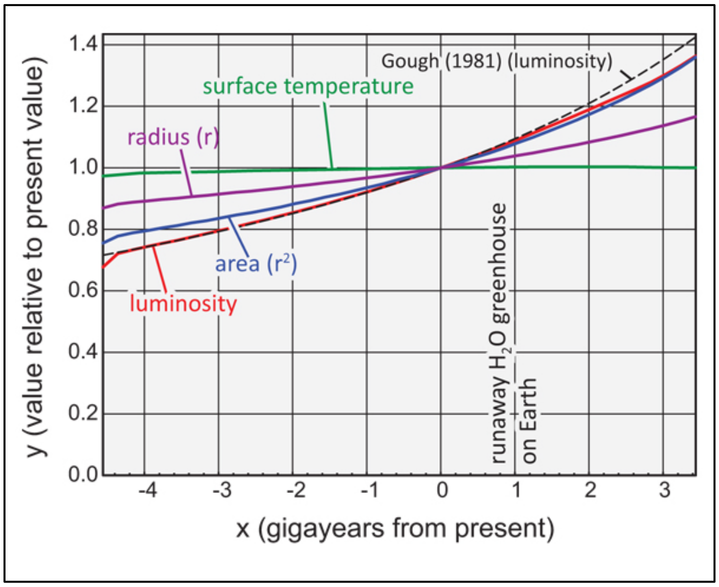


Figure 4-6: Evolution of solar properties. A simple approximation of solar-luminosity evolution is shown as the solid red line paralleling equation 1 of Gough (1981) is also shown. See Spencer (2019) for reference.

Warm liquid spewing from Oregon seafloor comes from Cascadia fault, could offer clues to earthquake hazards

ScienceDaily, April 11, 2023
Source: University of Washington

The field of plate tectonics is not that old, and scientists continue to learn the details of earthquake-producing geologic faults. The Cascadia Subduction Zone -- the eerily quiet offshore fault that threatens to unleash a magnitude-9 earthquake in the Pacific Northwest -- still holds many mysteries.

A study led by the University of Washington discovered seeps of warm, chemically distinct liquid shooting up from the seafloor about 50 miles off Newport, Oregon. The paper, published Jan. 25 in *Science Advances*, describes the unique underwater spring the researchers named Pythia's Oasis. Observations suggest the spring is sourced from water 2.5 miles beneath the seafloor at the plate boundary, regulating stress on the offshore fault.

The team made the discovery during a weather-related delay for a cruise aboard the RV Thomas G. Thompson. The ship's sonar showed unexpected plumes of bubbles about three-quarters of a mile beneath the ocean's surface. Further exploration using an underwater robot revealed the bubbles were just a minor component of warm, chemically distinct fluid gushing from the seafloor sediment.

"They explored in that direction and what they saw was not just methane bubbles, but water coming out of the seafloor like a firehose. That's something that I've never seen, and to my knowledge has not been observed before," said co-author Evan Solomon, a UW associate professor of oceanography who studies seafloor geology.

The feature was discovered by first author Brendan Philip, who did the work as a UW graduate student and now works as a White House policy advisor.

Observations from later cruises show the fluid leaving the seafloor is 9 degrees Celsius (16 degrees Fahrenheit) warmer than the surrounding seawater. Calculations suggest the fluid is coming straight from the Cascadia megathrust, where temperatures are an estimated 150 to 250 degrees Celsius (300 to 500 degrees Fahrenheit).

The new seeps aren't related to geologic activity at the nearby seafloor observatory that the cruise was heading toward, Solomon said. Instead, they occur near vertical faults that crosshatch the massive Cascadia Subduction Zone. These strike-slip faults, where sections of ocean crust and sediment slide past each other, exist because the ocean plate hits the continental plate at an angle, placing stress on the overlying continental plate.

Loss of fluid from the offshore megathrust interface through these strike-slip faults is important because it lowers the fluid pressure between the sediment particles and hence increases the friction between the oceanic and continental plates.

"The megathrust fault zone is like an air hockey table," Solomon said. "If the fluid pressure is high, it's like the air is turned on, meaning there's less friction and the two plates can slip. If the fluid pressure is lower, the two plates will lock -- that's when stress can build up."

Fluid released from the fault zone is like leaking lubricant, Solomon said. That's bad news for earthquake hazards: Less lubricant means stress can build to create a damaging quake.

This is the first known site of its kind, Solomon said. Similar fluid seep sites may exist nearby, he added, though they are hard to detect from the ocean's surface. A significant fluid leak off central Oregon could explain why the northern portion of the Cascadia Subduction Zone, off the coast of Washington, is believed to be more strongly locked, or coupled, than the southern section off the coast of Oregon.

"Pythias Oasis provides a rare window into processes acting deep in the seafloor, and its chemistry suggests this fluid comes from near the plate boundary," said co-author Deborah Kelley, a UW professor of oceanography. "This suggests that the nearby faults regulate fluid pressure and megathrust slip behavior along the central Cascadia Subduction Zone."

Solomon just returned from an expedition to monitor sub-seafloor fluids off the northeast coast of New Zealand. The Hikurangi Subduction Zone is similar to the Cascadia

Subduction Zone but generates more frequent, smaller earthquakes that make it easier to study. But it has a different sub-seafloor structure meaning it's unlikely to have fluid seeps like those discovered in the new study, Solomon said.

The research off Oregon was funded by the National Science Foundation. Other co-authors are Theresa Whorley, who did the work as a UW doctoral student and now works as an environmental consultant in Seattle; Emily Roland, a former UW faculty member now at Western Washington University; Masako Tominaga at Woods Hole Oceanographic Institution; and Anne Tréhu and Robert Collier at Oregon State University.

Journal Reference: Brendan T. Philip, Evan A. Solomon, Deborah S. Kelley, Anne M. Tréhu, Theresa L. Whorley, Emily Roland, Masako Tominaga, Robert W. Collier. **Fluid sources and overpressures within the central Cascadia Subduction Zone revealed by a warm, high-flux seafloor seep**. *Science Advances*, 2023; 9 (4) DOI: 10.1126/sciadv.add6688.

Why 536 was 'the worst year to be alive'

Glacier cores reveal Icelandic volcano that plunged Europe into darkness

Source: Science, November 15, 2018

by Ann Gibbons

Ask medieval historian Michael McCormick what year was the worst to be alive, and he's got an answer: "536." Not 1349, when the Black Death wiped out half of Europe. Not 1918, when the flu killed 50 million to 100 million people, mostly young adults. But 536. In Europe, "It was the beginning of one of the worst periods to be alive, if not the worst year," says McCormick, a historian and archaeologist who chairs the Harvard University Initiative for the Science of the Human Past.

A mysterious fog plunged Europe, the Middle East, and parts of Asia into darkness, day and night—for 18 months. "For the sun gave forth its light without brightness, like the moon, during the whole year," wrote Byzantine historian Procopius. Temperatures in the summer of 536 fell 1.5°C to 2.5°C, initiating the coldest decade in the past 2300 years. Snow fell that summer in China; crops failed; people starved. The Irish chronicles record "a failure of bread from the years 536–539." Then, in 541, bubonic plague struck the Roman port of Pelusium, in Egypt. What came to be called the Plague of Justinian spread rapidly, wiping out one-third to one-half of the population of the eastern Roman Empire and hastening its collapse, McCormick says.

Historians have long known that the middle of the sixth century was a dark hour in what used to be called the Dark Ages, but the source of the mysterious clouds has long been a puzzle. Now, an ultraprecise analysis of ice from a Swiss glacier by a team led by McCormick and glaciologist Paul Mayewski at the Climate Change Institute of The University of Maine (UM) in Orono has fingered a culprit. At a workshop at Harvard this week, the team reported that a cataclysmic volcanic eruption in Iceland spewed ash across the Northern Hemisphere early in 536. Two other massive eruptions followed, in 540 and 547. The repeated blows, followed by plague, plunged Europe into economic stagnation that lasted until 640, when another signal in the ice—a spike in airborne lead—marks a resurgence of silver mining, as the team reports in Antiquity this week.

To Kyle Harper, provost and a medieval and Roman historian at The University of Oklahoma in Norman, the detailed log of natural disasters and human pollution frozen into the ice "give us a new kind of record for understanding the concatenation of human and natural causes that led to the fall of the Roman Empire—and the earliest stirrings of this new medieval economy."

Ever since tree ring studies in the 1990s suggested the summers around the year 540 were unusually cold, researchers have hunted for the cause. Three years ago polar ice cores from Greenland and Antarctica yielded a clue. When a volcano erupts, it spews sulfur, bismuth, and other substances high into the atmosphere, where they form an aerosol veil that reflects the sun's light back into space, cooling the planet. By matching the ice record of these chemical traces with tree ring records of climate, a team led by Michael Sigl, now of the University of Bern, found that nearly every unusually cold summer over the past 2500 years was preceded by a volcanic eruption. A massive eruption—perhaps in North America, the team suggested—stood out in late 535 or early 536; another followed in 540. Sigl's team concluded that the double blow explained the prolonged dark and cold.

Mayewski and his interdisciplinary team decided to look for the same eruptions in an ice core drilled in 2013 in the Colle Gnifetti Glacier in the Swiss Alps. The 72-meter-long core entombs more than 2000 years of fallout from volcanoes, Saharan dust storms, and human activities smack in the center of Europe. The team deciphered this record using a new ultra–high-resolution method, in which a laser carves 120-micron slivers of ice, representing just a few days or weeks of snowfall, along the length of the core. Each of the samples—some 50,000 from each meter of the core—is analyzed for about a dozen elements. The approach enabled the team to pinpoint storms, volcanic eruptions, and lead pollution down to the month or even less, going back 2000 years, says UM volcanologist Andrei Kurbatov.

In ice from the spring of 536, UM graduate student Laura Hartman found two microscopic particles of volcanic glass. By bombarding the shards with x-rays to determine their chemical fingerprint, she and Kurbatov found that they closely matched glass particles found earlier in lakes and peat bogs in Europe and in a Greenland ice core. Those particles in turn resembled volcanic rocks from Iceland. The chemical similarities convince geoscientist David Lowe of The University of Waikato in Hamilton, New Zealand, who says the particles in the Swiss ice core likely came from the same Icelandic volcano. But Sigl says more evidence is needed to convince him that the eruption was in Iceland rather than North America.

Either way, the winds and weather systems in 536 must have been just right to guide the eruption plume southeast across Europe and, later, into Asia, casting a chilly pall as the volcanic fog "rolled through," Kurbatov says. The next step is to try to find more particles from this volcano in lakes in Europe and Iceland, in order to confirm its location in Iceland and tease out why it was so devastating.

A century later, after several more eruptions, the ice record signals better news: the lead spike in 640. Silver was smelted from lead ore, so the lead is a sign that the precious metal was in demand in an economy rebounding from the blow a century before, says archaeologist Christopher Loveluck of the University of Nottingham in the United Kingdom. A second lead peak, in 660, marks a major infusion of silver into the emergent medieval economy. It suggests gold had become scarce as trade increased, forcing a shift to silver as the monetary standard, Loveluck and his colleagues write in Antiquity. "It shows the rise of the merchant class for the first time," he says.

Still later, the ice is a window into another dark period. Lead vanished from the air during the Black Death from 1349 to 1353, revealing an economy that had again ground to a halt. "We've entered a new era with this ability to integrate ultra–high-resolution environmental records with similarly high-resolution historical records," Loveluck says. "It's a real game changer."

Source link: doi: 10.1126/science.aaw0632

Pressurized natural caves could offer a home from home on the Moon

It would make building bases a lot cheaper and easier

from *The Economist*, March 15, 2023

Imagine a habitable colony on Mars or the Moon and the kinds of structures that come to mind are probably gleaming domes or shiny metallic tubes snaking over the surface. But with no Earth-like atmosphere or magnetic field to repel solar radiation and micrometeorites, space colonists would probably need to pile meters-thick rocks and geological rubble onto the roofs of such off-world settlements. More like a hobbit hole than Moonbase Alpha.

There could be another solution, however, that would offer future colonists safer and far more expansive living space than any cramped base built on the surface. Writing in *Acta Astronautica*, Raymond Martin, an engineer at Blue Origin, a rocket company, and Haym Benaroya, an aerospace engineer at Rutgers University, explore the benefits of setting up a Moon base inside giant geological tunnels that lie just below the lunar surface.

First discovered during the Apollo program, these lunar lava tubes are a legacy of when Earth's nearest celestial neighbor was geologically hyperactive, with streams of boiling basaltic magma bursting from the interior to flow across the Moon's surface as lava. Found on Earth (see picture), and identified on Mars, lava tubes form when the sluggish top layer of a lava stream slows and cools, forming a thick and rocky lid that is left behind when the rest of the lava underneath eventually drains away.

Lava tubes on Earth are usually up to 15 meters wide and can run for several kilometers. But the reduced gravity on the Moon makes them hundreds of times bigger, creating colossal cave systems that are up to a kilometer across and hundreds of kilometers long.

Space scientists have long identified these lava caves as a likely site for human habitation on the Moon, because the thick walls and ceiling offer protection from the harsh radiation striking the Moon's surface. But Mr Martin and Dr Benaroya went a step further. Rather than simply situating a Moon base inside a lava tube—domes and shiny buildings and all—they suggested that a section of such a tube could be pressurized with breathable air. Residents could live, work and sleep inside the pressurized tubes with no need for space suits and with plenty of spare real estate for some low-gravity recreation. And although the costs and details need more planning, it could end up cheaper than having to send from Earth everything needed to survive on the lunar surface.

In their latest study, the two scientists crunched some numbers on what might be possible. "One of the first big hurdles there is proving that they [the lava tubes] are structurally sound," says Mr Martin. To find out, he and Dr Benaroya built a computer model to simulate the integrity of a relatively small lava tube in the Moon's Oceanus Procellarum (Ocean of Storms), which was photographed by the Indian Chandrayaan-1 lunar probe 15 years ago.

After checking several combinations of internal pressure and roof thickness, and whether the resulting structure was stable, the study suggested a lava tube with a roof thickness of ten meters could be safely pressurized to almost the same conditions found at sea level on Earth. The scientists also showed that the overall pressure (and so the risk of roof failure) could be reduced by increasing the proportion of oxygen in the artificial air used to fill the caverns. And given the awkwardness of moving around in a space suit, the study looked at how astronauts could get themselves and their equipment safely in and out of the tubes. The best option, it concluded, would be to build the entrance where a wall of the lava tube had naturally collapsed open.

Knowing that the roof will not fall in should give engineers the confidence to work on other aspects of the idea, such as how to use inflatable structures to cap the ends of a pressurized section of the tube. Such membranes are already used for flood prevention in tunnels on Earth, where they can be quickly deployed to block incoming floodwater. Another issue is whether the lava tube's ceiling would be fully airtight, and if not, how to seal it to prevent leaks. And, of course, how to prepare humanity for a return to life in caves. ■

This article appeared in the Science & Technology section of the print edition under the headline "Lunar living"

NCGS ANNUAL DINNER MEETING

Wednesday, May 31st, 2023 at 6:00 pm
Orinda Masonic Center, 9 Altarinda Road, Orinda, CA

Next Steps in Managing Groundwater Resources in CA

Dr. Rob Gailey
Consulting Hydrogeologist

Reservations are required by May 22, 2023; Limit 80 persons.
We are sorry, but we will not be able to accommodate "walk-ins"

TIME: Social 6:00 – 6:45 pm Dinner 6:45 – 8:00 pm Presentation 8:00 – 9:00 pm COST: $40/person; $20/student. Submit REGISTRATION FORM (below) by May 22nd.

The **NCGS** is pleased to host our Annual May Dinner Meeting with **Dr. Gailey.** The dinner, catered by *Back Forty Texas BBQ*, will include Pork Ribs and BBQ Chicken, a variety of Side Dishes, and Ranch Rolls; a Vegetarian Burger is available upon request. NCGS will provide a selection of wine, beer, and non-alcoholic beverages. Contributed desserts will be happily accepted!

The speaker's bio and details of his presentation will be included in our May newsletter.

**************************** **COVID-19 Logistics** ***************************

In keeping with county guidelines, we no longer require special COVID protocols. **However, if you are unwell, please stay home!**

✂ ******************* **May 2023 Dinner Registration** ***********************

Name(s):____

e-mail(s):____________________________________Phone:_________________

Number of People attending______@ $40 each = Amount Enclosed: $___________

Number of Students attending____@ $20 each = Amount Enclosed: $___________

Indicate # of people for: Regular BBQ Dinner_______or Vegetarian Burger _______

Please clip and mail this registration form, with a check made out to **NCGS,** to:
Noelle Schoellkopf, NCGS President, 416 La Gonda Way, Danville, CA 94526.
Questions? NoellePrince@sbcglobal.net

NORTHERN CALIFORNIA GEOLOGICAL SOCIETY

NCGS FIELD TRIP
Saturday May 27, 2023

Clastic Deposition and Accretion, Franciscan Complex At Point Richmond and Point Molate, California

Leader: Dr. Thomas MacKinnon, Retired Geologist and NCGS Past President
With assistance from Dr William Schweller

The Franciscan Complex is one of the best-known ancient subduction complexes in the world and is extensively exposed throughout the northern San Francisco Bay area. Some of the best outcrops are at Point Richmond and Point Molate where rocks known as the Novato Quarry terrane are well-exposed and easily accessible. Most of the outcrops are thin-bedded turbidites, some with beautifully preserved sedimentary structures. Very thick-bedded sandy turbidites are present as well. Small-scale structural deformation features are ubiquitous, however, most outcrops are stratigraphically intact. Exceptions include volumetrically minor, but well-exposed outcrops of mélange and dismembered formation. New mapping suggests that the rocks at Point Richmond were mainly accreted as coherent "slices", up to several hundred meters thick. We will discuss the mechanics of the accretionary process and the difficulties in reconstructing Bay Area Franciscan geology due to post-accretionary deformation.

The field trip will begin and end at the parking lot at the southwest corner of Miller Knox regional shoreline.
We will circulate an attendees list for carpooling to the field trip locations.

Field Trip Reminders: We will be walking mainly on a paved trail and service road. However, at one stop we will be scrambling over rocky beach outcrops. These outcrops can be slippery so boots are recommended. We are planning to eat lunch (bring your own lunch!) at our Beach outcrop where there are no facilities. Restrooms and drinking water are available at our meeting place and we will also make a restroom stop after lunch.

THIS FIELD TRIP WILL BE LIMITED TO 25 PEOPLE.

** **Field Trip Logistics** ***
Time: Saturday, May 27, 2023. The trip will begin at 9:30 am and will last about 4 to 5 hours.
Meeting Location: Meet at the parking lot at the southwest corner of Miller Knox Regional Shoreline. On Google maps, this is also the western terminus of Brickyard Cove Road. The easiest way to get there is through the tunnel from downtown Point Richmond.

Cost: $30/person, which includes the field trip guide. **Lunches will NOT be provided, so remember to bring your own!**

*****************************REGISTRATION FORM (Devil's Slide Field Trip) *******************************

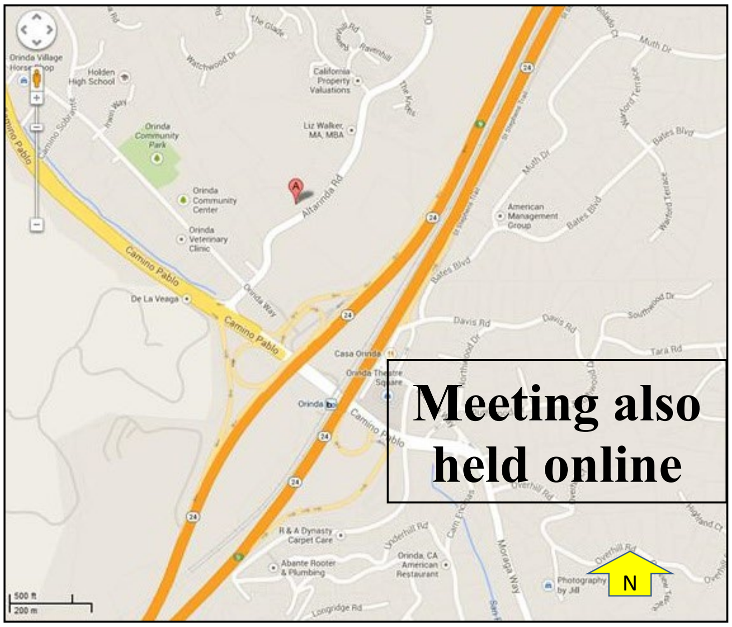
Name:__________________________________ E-mail:__________________________________

Carpool origin: ____________________ Phone: _______________ Phone (alternate):____________

Check no./amount _________________________

Lunches will NOT be provided for this field trip. Please bring your own lunch!

Please mail registration with a check payable to NCGS: **Will Schweller, 820 Appaloosa Drive, Walnut Creek, CA 94596**
Questions e-mail: willschweller@yahoo.com Phone 925-768-3530



Northern California Geological Society
c/o Mark Sorensen
734 14th Street, #2
San Francisco, CA 94114

To NCGS members receiving the newsletter <u>by U.S. Mail only</u>: *Would you like to instead receive the NCGS newsletter by e-mail?* If you are not already doing so, and would like to, please contact Tom Barry at **tomasbarry@aol.com**.