

NORTHERN CALIFORNIA GEOLOGICAL SOCIETY



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MEETING ANNOUNCEMENT

DATE: Wednesday, June 28, 2023

LOCATION: Orinda Masonic Hall - and - Online using Zoom

Notes: Online participants see Page 2 for "Zoom Meeting Instructions"

TIME: Social: 6:30 to 7:15 pm; Program: 7:15 to 8:30 pm

SPEAKER: *Andrew Alden, Geoscience Writer*

TOPIC: *"Oakland Geology: Answers and Questions"*

Abstract:

I researched and wrote Deep Oakland: How Geology Shaped a City to explore the relationship between the city's geology and its sequence of human inhabitants. Along the way I learned this: Oakland's landscape represents the combined effects of Quaternary orbital cyclicity and tectonic action on the diffuse North America-Pacific plate boundary. Its bedrock represents the accretionary wedge, ophiolitic complex and foreland basin of a westward-stepping Mesozoic subduction regime and succeeding Tertiary foreland sediments on a foundered slab wedge, dissected by ongoing transcurrent wrench faulting with eastward dextral transpression. I will show how I turned that into everyday language and then present some outstanding problems in Oakland's geology that perhaps we can brainstorm.

Biography:

Andrew Alden earned a BA in Earth Science from the University of New Hampshire in 1974, then began serving as a scientific copyeditor and occasional field hand at the U.S. Geological Survey in Menlo Park. He left the Survey in 1984 to work as a free-lance editor and, other than a ten-year stint at technical firms, pursued this career until retiring in 2023. He has been writing and speaking on geological topics for global and local audiences since 1997. He began his ongoing "Oakland Geology" blog (deepoakland.com) in 2007. Deep Oakland: How Geology Shaped a City (Heyday, 2023) is his first book.

Editor's note: Andrew was interviewed on KQED/Forum! Here's the link:

<https://www.kqed.org/forum/2010101893356/the-history-of-oakland-told-through-its-geology>

NCGS 2022 – 2023 Calendar

September 27, 2023 7:00 pm
Speaker and topic to be determined later

For Zoom Meeting Participants Only – Registration Instructions

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://us02web.zoom.us/meeting/register/tZYscOGupj0pE9UYMoMxT9X8nVhvcS3tgSmt#/registration](https://us02web.zoom.us/join/https://us02web.zoom.us/meeting/register/tZYscOGupj0pE9UYMoMxT9X8nVhvcS3tgSmt#/registration)

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 7:00 pm and 7:15 pm with the presentation scheduled to start at 7:15 pm. The program will end by 8:30 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.

NCGS Slate of Officers for the 2023-2024 Term

Here is the proposed Slate of Officers for the upcoming **2023-2024** term. As stated in our Constitution and Bylaws, this Slate of Officers will need to be confirmed by vote at the monthly meeting in June.

Officers (Elected):

- President, **Jim O'Brien**
- President-Elect, **Phil Reed**
- Recording Secretary, **Stephen Self**
- Treasurer, **Don Medwedeff**
- Field Trip Coordinator, **Will Schweller**
- Program Director, for the first time we will have a three-person team, consisting of **Greg Bartow, John Karachewski, and Paul Henshaw.**
- Membership Chair, **Tom Barry**
- Newsletter Editor, **Mark Sorensen**
- Website and Social Media Manager, **Andrew Alden**

Committee Chairs (Appointed):

- **Phil Garbutt** will continue to chair the Scholarship Committee.
- The K-12 Program / Teacher of the Year (TOTY)

position, formerly held by Paul Henshaw, is now **open**.
• The Outreach position also remains **open**.

Counselors (Appointed):

- Bill Motzer
- Greg Bartow
- Wayne Narr

Please contact Noelle Schoellkopf or Jim O'Brien if you have any interest in serving in any of the Officer or Committee roles. All these officers can always use extra help, and this is a good way to learn the ropes. We would also like to acknowledge Chris McGuffin, who continues to help us with the audio-visual set-ups for our meetings.

New Honorary NCGS Members

The Board unanimously approved **Don Lewis** and **Phil Reed** for Honorary Membership to NCGS. We felt it was important to honor them at the same time, as two respected and very hard-working members of our Society, who have contributed substantially to the health and well-being of NCGS over many years.

Don Lewis has been our unofficial NCGS Historian, with knowledge of the Society throughout its early years, and continues to document our history and participates actively in our Society activities. He has served NCGS in many capacities, as Program Director, President-Elect and President, and advised us as Counselor for a record 21 years! Over the years, Don also has been our active link to AAPG, keeping NCGS apprised of activities in that association, through his participation in the Pacific Section AAPG Advisory Council and his many years as Delegate to AAPG. It is worth noting that Don also has been recipient of several honors from AAPG for his service, including Distinguished Member and Honorary Member.

Phil Reed has served a record 13 terms as NCGS Treasurer, two terms as President-Elect, and one term as President. He also served eight years as Counselor and continues to provide valuable advice to the Society. Over the years, Phil has regularly volunteered and tirelessly represented NCGS at numerous community events and outreach activities.

It was our great pleasure to award these Honorary Memberships to Don and Phil at our May Dinner Meeting.

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.

Dinner Meeting Special Guests

It was a special treat to have all four co-editors of the GSA Volume on Mount Diablo at the dinner meeting (top row Jeff Unruh and David Schwartz; bottom row Ray Sullivan and Doris Sloan). The GSA Volume, titled "Regional Geology of Mount Diablo, California: Its Tectonic Evolution on the North American Plate Boundary" is available from GSA at <https://rock.geosociety.org/Store/detail.aspx?id=MWR217>.



View the May Presentation

We held another fine meeting in May, live and via Zoom. We hope that all who wanted to see the talk by Dr. Rob Gailey, PG, CHG, on *Groundwater Management in California: Big Picture Issues, Recent Regulatory Requirements and Scientific-Economic Approaches*, 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 (password not needed this time!):

<https://www.dropbox.com/s/ag2vuzxdzt9uf7r/May%2031%20Meeting.mp4?dl=0>

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 (our June speaker) 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."

NCGS Photo of the Month

Here's a photo of our field trip to the Kennedy Mine in 2009. Photo courtesy of Ray Sullivan.



For the Rockhounds

For links to upcoming rock and mineral shows, go to www.cfmsinc.org/shows.

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 June 29 at 6:00 PM, Ariel Doumbouya, USGS National Geospatial Program, will speak on *Next Generation Topographic Mapping – Map What You Want, Where You Want, When You Want with topoBuilder!* 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 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 7 and 8 in a series that began in the March issue, contributed by Bill Motzer, an accomplished geochemist and longtime NCGS member

The Irony of Iron

by

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

Part 7 – Extinction Plumes and Iron

In Parts 5 and 6 of this series (Motzer, 2023), I discussed how mantle plumes brought iron (Fe) from planetary cores to planetary crusts (see also Motzer, 2022). Dissolved iron in Earth's oceans gave rise to complex life allowing organisms to develop blood hemoglobin. At about 385 million years ago (Ma) some oceanic vertebrates (e.g., fish) evolved to become land dwelling by exchanging gills for lungs. Therefore, because of more efficient circulatory systems using iron, complex organisms expanded their domain landward.

However, not all plumes are so “benevolent” and at least one is theorized to have nearly eliminated most complex life. The geologic record suggests that there have been at least five significant extinctions to life on Earth. The most well-known is the dinosaur extinction event that occurred about 65 Ma from an asteroid impact that wiped out perhaps 75% of planetary species (Motzer, 2010). Less known is the most severe extinction event that occurred at the end of the Permian Period (about 252 Ma) in which perhaps 70% of all land vertebrates, particularly the amphibians, and 90% of all marine life died out. This extinction event allowed for the rise of the dinosaurs in the

subsequent Triassic Period (about 252 Ma to about 201 Ma) (Benton, 2005; Benton 2018; Payne, 2022).

So what caused this massive extinction event? The prevailing theory is that a massive volcanic eruption in present-day Siberia from either a stationary or slow-moving mantle plume (hot spot) pumped enormous quantities of carbon dioxide (CO₂) and sulfur dioxide (SO₂) into the atmosphere, resulting in major effects to the terrestrial and oceanic biosphere. These eruptions occurred over a rather brief geologic time period of about one million years. The Siberian eruptions (aka Siberian traps, Siberian Large Igneous Province or LIP) cover an area of about 7 million km² with a volume of approximately 4 million km³. The rocks are largely basaltic in composition (**Figures 1-7 and 2-7**).

Also, underlying the traps is a large sedimentary basin (aka the Tungas Sedimentary Basin), containing both early to mid-Paleozoic (~525 Ma to ~375 Ma) thick carbonate and evaporite deposits and Carboniferous-Permian (~350 Ma to ~275 Ma) aged coal-bearing clastic rocks. The heating of such rocks may also have contributed additional emissions of large amounts of CO₂, SO₂, and methane (CH₄).

The geologic record indicates that Earth's biosphere was significantly perturbed for at least 5 to 8 million years before recovery began in the early Triassic Period (about 237 Ma to 234 Ma). World-wide anoxia (anaerobia) – particularly in Earth's oceans followed (**Figure 3-7**). An indicator of such anoxia is the presence of framboidal pyrite (FeS₂) in end-Permian and early Triassic sediments. Framboids are a micromorphological feature common to certain sedimentary minerals, particularly pyrite. The term is derived from the French “la framboise” meaning “raspberry” reflecting structural appearances under magnification (**Figure 4-7**). Such structures form spherical aggregates averaging from 5 µm to 20 µm in diameter.

What occurred is that, in addition to significant declines of dissolved oceanic oxygen, dissolved iron was reduced to pyrite, which was subsequently deposited and/or accumulated in sediments. Oceanic areas with complete oxygen removal are considered as anoxic. Where only partial oxygen removal occurs, the term euxinic is used (see Table 1 in Bond and Wignall, 2010). Also, the type (morphology) and size of the framboids may indicate the degree of anoxia, thereby showing biosphere recovery as oxygen and iron concentrations improved to pre-extinction levels.

References:

- Benton, M.J., 2005, *When Life Nearly Died: The Greatest Mass Extinction of all Time*. London: Thames & Hudson Ltd., UK Publishers, 336 p.
- Benton, M.J., 2018, *Hyperthermal-Driven Mass Extinctions: Killing Models During the Permian–Triassic*

Mass Extinction:

<https://royalsocietypublishing.org/doi/10.1098/rsta.2017.0076>

Bond, D.P.G. and Wignall, P.B., 2010, *Pyrite Framboid Study of Marine Permian-Triassic Boundary Sections: A Complex Anoxic Event and its Relationship to Contemporaneous Mass Extinction*: Geological Society of America Bulletin., v.122, n. 7/8, pp. 1265-1279.

Motzer, W.E., 2010, *The Impacts of Impacts – Aspects of Climate and Ecological Changes by Asteroid Impacts – Parts 1 and 2: The VORTEX*, v. LXXI, n. 3 (pp. 10 and 16) and n. 4 (pp. 8-12). www.calacs.org

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Payne, J., 2022, *Connecting end-Permian Paleontological and Geochemical Records Using Physiology and Earth System Models*: October 26 Presentation Notes, Northern California Geological Society (NCGS) October Newsletter, 14 p., www.ncgeolsoc.org.

Scotese, C.R., and Moore, T.L., 2014, *Atlas of Phanerozoic Oceanic Anoxia (Mollweide Projection)*, v. 1-6, PALEOMAP Project for ArcGIS, PALEOMAP Project, Evanston, IL, Map 49.

Stanley, G. 2022, *Mass Extinctions in Geologic Time and What We Learn from Them*: June 29, Presentation Notes, Northern California Geological Society (NCGS) June Newsletter, 14 p. www.ncgeolsoc.org.



Figure 1-7: Present location of Siberian traps – a geologic/geomorphic term derived from the Swedish word for stairs ("trappa"): referring to the step-like hills forming the regional landscape. Map source: <http://www.athenapub.com/arial/PAL/siberia1.html>.

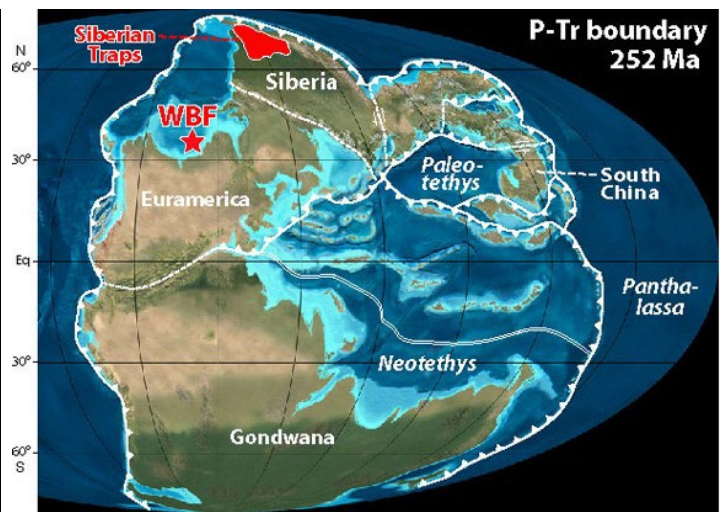


Figure 2-7: Location map of Siberian traps during the end Permian extinction event at 252 Ma. Source: map by T. Algeo (2012), <https://spaceref.com/press-release/global-extinction-gradual-doom-as-bad-as-abrupt/>.

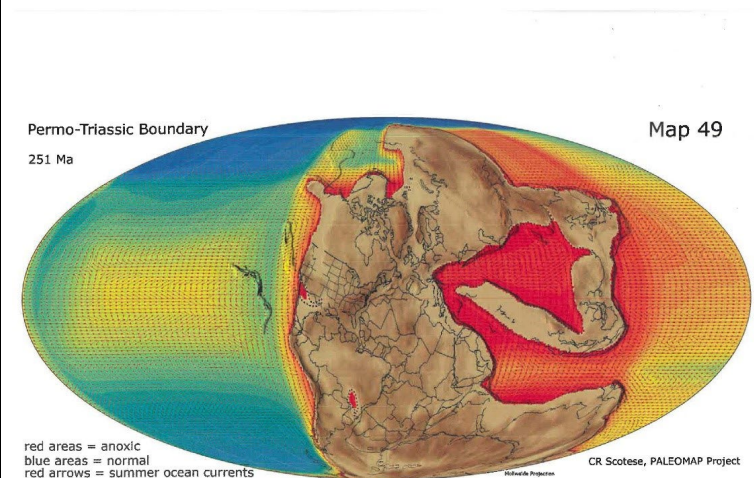


Figure 3-7: Anoxia occurrences in Earth's oceans during the end Permian (252 Ma) event. Red areas indicate anoxic environments, yellow suggest euxinic environments and blue indicates normal environments. Source: Scotese and Moore (2014).

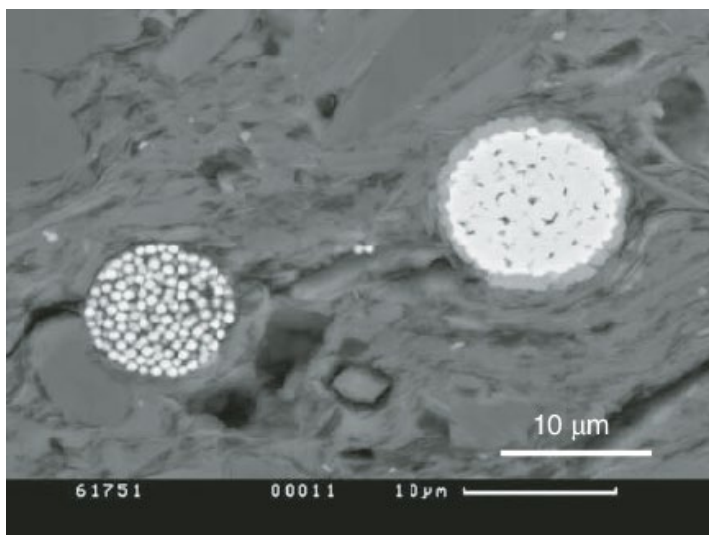


Figure 4-7: Scanning electron microscope (SEM) image of pyrite (FeS_2) framboids in end-Permian sedimentary rocks. Source: Bond and Wignall (2010).

Part 8 - Hemoglobin Chemistry/Geochemistry

Introduction: In Part 7, I discussed how a mantle (volcanic) plume probably caused one of the Earth's greatest extinction and how iron (Fe) in the mineral pyrite (iron sulfide or FeS_2) was an indicator of almost worldwide anoxia with the depletion of oceanic soluble hydrous ferrous $[\text{Fe(II)}]$ oxides. However, oceanic iron concentrations soon returned to normal as the Earth biosystems recovered and complex life (principally vertebrates and some invertebrates) continued using iron in the form of blood hemoglobin (Hb). But when did complex life develop and begin using it as an oxygen (O_2) transporter? More about that later, but first let's discuss Hb.

Some Hb Fundamentals: Hb is the iron-containing O_2 -transport metalloprotein contained in red blood cells (erythrocytes) of almost all vertebrates (except for the *Channichthyidae* fish family) and some invertebrate tissues. Hb in blood transports oxygen from the respiratory organs (i.e., lungs or gills) to the rest of the body's tissues, where it releases oxygen permitting aerobic respiration providing the energy for an organism's metabolism.

In most mammals, chromoprotein comprises approximately (~) 96% of red blood cells' dry content (by mass), and ~35% of total when water is included. Hb's oxygen-binding capacity is 1.34 mL O_2/g , increasing total blood capacity about 70 times when compared to dissolved oxygen in blood. Mammalian Hb molecules can bind up to four O_2 molecules. In humans, Hb ranges from 12 to 20 g of Hb for every 100 mL of blood.

Hb also transports other gases, including ~20% to 25% of the body's respiratory carbon dioxide (CO_2) as carbaminohemoglobin (CO_2Hb), where carbon dioxide is

bound to the [heme protein](#). Twenty-three percent of blood carbon dioxide is carried in this form with 70% converted into bicarbonate (HCO_3^-) by [carbonic anhydrase](#), a metalloenzyme group that catalyzes conversion between carbon dioxide and water and dissociated ions of carbonic acid [i.e., HCO_3^- and hydrogen (H^+) ions]. This enzyme also maintains acid-base balance and aids in carbon dioxide transport in plasma. The remaining 7% of blood carbon dioxide is dissolved as free carbon dioxide in plasma. CO_2Hb also carries and transports the important controlling [nitric oxide](#) (NO) molecule that's bound to a [thiol](#) group in the globin protein, releasing it at the same time as oxygen.

Hb Structure and Activity: Hb has a quaternary-type structure, occurring in many multi-subunit globular proteins. Most Hb amino acids form alpha helices connected by short non-helical sections with hydrogen bonds stabilizing the protein's interior helical sections. This produces intermolecular attractions, causing folding of each polypeptide chain into a specific shape. Hb's quaternary structure occurs from its four subunits in a rough tetrahedral assembly (**Figure 1-8**).

In most vertebrates, the Hb molecule is built from four globular protein subunits each composed of a protein chain associated with a non-protein [prosthetic](#) (the structural non-amino acid component of hetero- or conjugated proteins linked to the apoprotein or apoenzyme required for the protein's biological activity) [heme](#) group. Each protein chain assembles as a set of alpha-helix structural segments connected together in a globin fold arrangement, which is the same folding pattern employed by other heme/globin proteins (i.e., myoglobin). This folding pattern contains a pocket strongly binding the heme group.

A heme group consists of an iron ion in a heterocyclic ring (aka porphyrin ring) with four pyrrole molecules, cyclically bound by methine (CH^-) bridges. These are center bound with the iron ion, the site of oxygen binding, coordinating with the four nitrogen (N) atoms in the ring's center, all arranged in one plane. Heme is strongly covalently bound to the globular protein via the nitrogen atoms of the imidazole ($\text{C}_3\text{N}_2\text{H}_4$) ring of a histidine ($\text{C}_6\text{H}_9\text{N}_3\text{O}_2$) F8 amino acid residue (aka proximal histidine) below the porphyrin ring. A sixth position can reversibly bind oxygen by a coordinate covalent bond, completing the octahedral group of six ligands. This reversible bonding with oxygen is why Hb is so useful for transporting oxygen throughout the body. Oxygen binds in an "end-on bent" (where generally the central atom has two lone electron pairs associated with two bond pairs) arrangement, where one oxygen atom binds to iron and the other projects at an angle. When oxygen is not bound, a

very weakly bonded water molecule fills the site, forming a distorted octahedron. Although carbon is carried by Hb, it doesn't compete with oxygen for iron-binding positions because it's bound to the protein chain's amine groups that are attached to the heme groups.

Oxidation Chemistry: In Hb, the iron ion may occur in ferrous [Fe(II)] or ferric [Fe(III)] oxidation states. However, methemoglobin [aka ferrihemoglobin or ferriHb because iron occurs as Fe(III)] cannot bind oxygen. In binding, oxygen temporarily and reversibly oxidizes ferrous iron to ferric iron with oxygen temporarily turning into a superoxide (O_2^-) ion. Therefore, iron must exist as Fe(II) to bind oxygen. If the O_2^- associated to Fe(III) is protonated, Hb iron will remain oxidized and incapable of binding oxygen. In such cases, the enzyme ferriHb reductase will be able to eventually reactivate ferriHb by reducing the Fe center.

Hb Origins are lost in antiquity. Did oceanic chlorophyll-containing cyanobacteria, that are believed to have produced Earth's first free oxygen, at some point evolve into iron fixing bacteria? And did these chlorophyll producing organisms, which have structures similar to Hb, evolve into Hb producing organisms? Cyanobacteria have extensive fossil records with the oldest known forms from 3.5-billion-year-old (Ga) Precambrian (Archaean Eon) rocks of western Australia. They are some of most recognizable microfossils with group morphologies remaining unchanged for billions of years, and also leaving chemical fossil traces as pigment breakdown products. Microfossil cyanobacteria have been extracted from Precambrian rock, and studied through scanning (SEM) and transmission electron (TEM) microscopy (Hardison, 1996).

Modern analogs of these ancient bacteria occur in present-day oceanic prokaryotic microbes. These have an important role in oceanic iron cycling, because they accumulate most offshore water's biogenic iron. In North Pacific subarctic surface populations, heterotrophic microbes assimilate more than 50% of dissolved iron, thereby directly competing with phytoplankton for this limited resource. In oligotrophic tropical and subtropical waters, photosynthetic bacteria become more important in iron cycling with increasing unicellular cyanobacteria populations. For example, nitrogen-fixing filamentous cyanobacteria genus *Trichodesmium* (aka sea sawdust) contain the most abundant biogenic iron in the mixed marine layer. Similar to their terrestrial counterparts, heterotrophic and phototrophic marine bacteria produce iron-binding siderophores that chelate and acquire Fe. Research has demonstrated that these bacteria may modify iron marine chemistry through the production of these

ligands, thereby playing a significant role in regulating production of eukaryotic phytoplankton. Paleogeneticists have used such bacterial DNA to model Hb evolution (Figure 2-8).

Fossilized blood and animal circulatory systems are extremely rare because soft animal body parts invariably decay after death; therefore, most fossil remains are those containing only hard parts (i.e., shells, bones, and teeth). One of the earliest, a recently discovered fossil containing soft body parts, is a shrimp-like animal (arthropod) that lived during the early Cambrian Period ~520 million years ago (Ma). This fossil has remarkably well-preserved brain, tubular heart, and blood vessels leading to eyes, antennae, a brain, and legs (**Figure 3-8**). Its digestive, nervous and vascular system are similar to modern day shrimp-like crustaceans. Researchers have suggested that animals with cardiovascular systems probably lived earlier than this creature, but evidence is still lacking in the fossil record.

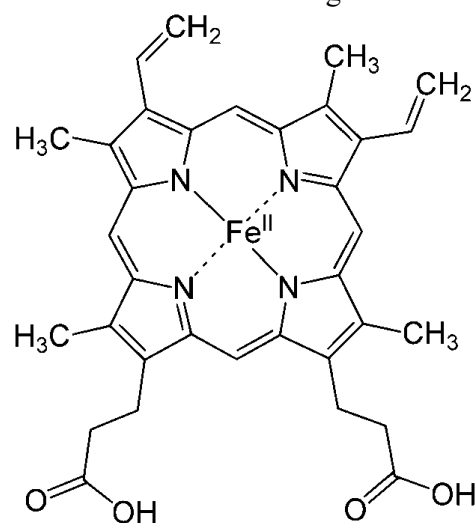


Figure 1-8: Part of hemoglobin (Hb) structure showing a porphyrin ring, which contains a central iron (Fe) group, linked to four nitrogen (N) atoms of all pyrrole rings of porphyrin. See text for complete description. Source: Memon, et al., (2018).

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- Hardison, R. C., 1996, *A brief history of Hemoglobins: Plant, Animal, Protist, and Bacteria*: Proceedings of the National Academy of Sciences, v. 93, n. 12, pp. 5675–5679.
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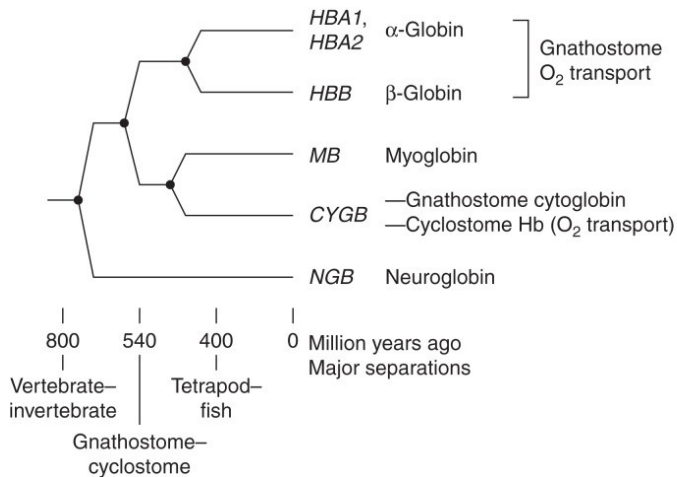


Figure 2-8: Evolutionary model or “tree” of vertebrate globin genes. Horizontal axis shows possible duplication and divergence times in millions of years ago. Contemporary human globin genes are shown as HBA1 and HBA2. Major duplication events in globin gene evolution are noted along the tree, and time of origin of some major animal groups is also indicated along the horizontal axis. Source: Hardison (2012).

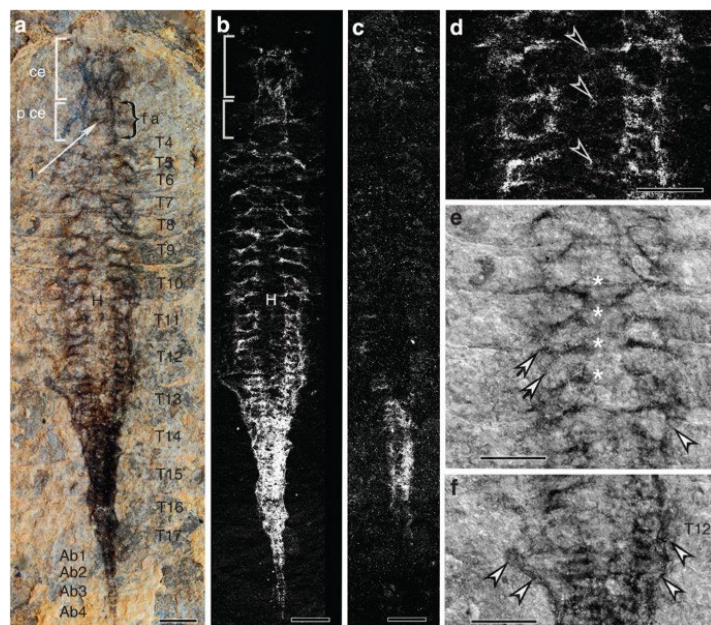


Figure 3-8: Preserved cardiovascular system (CVS) of fossil arthropod *F. protensa*. (a) image of entire cardiovascular system showing a broad heart (H) at

arrow’s end; (b) energy-dispersive X-ray spectroscopy (EDX) showing CVS represented by a carbon film. See Ma, et al. (2014) for complete description. Scale bar is 2 mm long.

HIDDEN PLANET

Researchers find why San Andreas fault hasn’t caused a big earthquake in L.A. — yet

Over the past 1,000 years, earthquakes at the southern San Andreas fault occurred when water levels of a large nearby lake were high

Source: *The Washington Post*, by Kasha Patel

Updated June 7, 2023 at 12:20 p.m. EDT | Published June 7, 2023 at 11:00 a.m. EDT

The southern San Andreas fault in California is in a seismic drought, going more than 300 years without a major earthquake. New research shows the lack of seismic activity may be due to the drying of the nearby Salton Sea and provides clues on future potential earthquake triggers, including projects aimed to refill the body of water.

Want to know how your actions can help make a difference for our planet? Sign up for the Climate Coach newsletter, in your inbox every Tuesday and Thursday.

One of the largest faults in the world, the 800-mile-long San Andreas marks the meeting of the North American and Pacific plates in western California. The fault has three sections, but the southern section from the Salton Sea to Parkfield, Calif., has been historically the quietest — and that’s not a positive. The pent-up energy, when released, could be catastrophic to nearby populated cities.

“This fault poses the largest seismic hazard in all of California,” said Ryley Hill, lead author and PhD candidate at San Diego State University. “The southern San Andreas fault is a locked section, and when this fault ruptures ... it would cause significant damage to the Los Angeles metropolitan area.”

Earthquakes generally form when two tectonic plates are essentially stuck at their edges because of friction, building stress. When the stress becomes greater than the frictional forces, the two blocks can suddenly slip past one another and release the energy in waves and cause shaking.

The U.S. Geological Survey estimates at least a 60 percent chance that an earthquake at a magnitude of 6.7 or greater could occur in the next 30 years in the Los Angeles area.

The new study, published Wednesday in *Nature*, investigated earthquake activity along the southern San Andreas fault over the last 1,000 years. Collecting field data from rocks near the fault, Hill and his colleagues

found earthquakes occurred about every 180 years, give or take 40 years, and coincided with high water levels of the nearby ancient Lake Cahuilla.

“If previous earthquakes on it occurred every 180 years, plus or minus 40 years, why is it that we sit on 300 years without an earthquake?” asked Hill. “This made a lot of scientists scratch their heads for many years. Understanding the history of this fault and what may have caused ruptures in the past helps us inform our understanding of what might happen in the future.”

The team created a computer model that simulated how a full lake affected the fault. They found high water levels in Lake Cahuilla prompted activity along the fault in two aspects. First, the weight of the lake water caused the crust beneath it to bend, unlocking the plates so they don’t touch as much. The lake water also seeped into the cracks and pores in Earth’s crust beneath it, increasing the fluid pressure inside the fault and further unclasping the plates.

Think of the scenario like playing a game of air hockey, said Hill. Without air, the puck does not slide easily across the table, much like when frictional forces hold two stuck tectonic plates together. When air (or water from the lake) is added, it helps relieve tension and makes it easier for the two to slip past one another.

“The correlation between the stressing rate from lake loading ... and the observed earthquake likelihood is astounding,” wrote Götz Bokelmann, a geophysicist at the University of Vienna who was not involved in the study, in an email. “If this holds up, then this will be quite important.”

Bokelmann said that there will probably be some debate following this study because earlier studies in the region have come to different conclusions, but he finds this mechanism “quite plausible.” The new study counters previous research that found the effects from Lake Cahuilla weren’t as significant as found here and that looked at secondary faults within the Salton Sea as additional stress contributors.

“Our study shows that the lake by itself was sufficient enough to trigger events on the southern San Andreas fault — and large events,” said Hill. “This is pretty applicable to pretty much anywhere where hydrologic loading, either natural or anthropogenic, exists.”

Hill points out other areas where added stress from water played a part in triggering an earthquake. China’s Wenchuan earthquake in 2008, 7.9-magnitude, was linked to the impoundment of the Zipingpu Dam. Water level

changes have also been associated with historical earthquakes at the Dead Sea.

But could changes to the present-day Salton Sea help trigger an earthquake? Maybe.

The good news, Hill said, is that the odds of Salton Sea refilling back to the size of ancient Lake Cahuilla “is effectively impossible, thankfully.” Lake Cahuilla was about 32 times as big as the present-day Salton Sea and was also fed from the Colorado River. Today, because of drought and overallocation, the Colorado River is unable to deliver as much water to the Salton Sea, he said.

The bad news, however, is that Hill and his colleagues found that it’s not necessarily the volume that could add stress, but the rate at which the lake could be filled. This is problematic because of plans to restore and potentially refill the Salton Sea, which has increasingly been affected by climate change and an area of toxic dust.

“If you suddenly rapidly increase the filling of the lake, that might actually stimulate seismicity,” said Hill. “That would be really bad for this area, because we already know that so much stress has accumulated on this fault.”

At long last, ocean drillers exhume a bounty of rocks from Earth’s mantle

Rocks fulfill 60-year-old quest and could yield science bonanza

Source: Science, May 25, 2023

by Paul Voosen

In 1961, geologists off the Pacific coast of Mexico embarked on a daring journey to a foreign land—the planet’s interior. From a ship, they aimed to drill through the thin veneer of Earth’s crust and grab a sample of the mantle, the 2900-kilometer-thick layer of dense rock that fuels volcanic eruptions and makes up most of the planet’s mass. The drill only got a couple hundred meters below the seabed before the project foundered under spiraling costs. But the quest—one of geology’s holy grails—remained.

This month, researchers onboard the JOIDES Resolution, the flagship of the International Ocean Discovery Program (IODP), say they have finally succeeded. Drilling below the seabed in the mid-Atlantic Ocean, they have collected a core of rock more than 1 kilometer long, consisting largely of peridotite, a kind of upper mantle rock. Although it’s not clear how pristine and unaltered the samples are, it is certain the cylinders of gray-green rock present an unparalleled new record, says Susan Lang, a biogeochemist at the Woods Hole Oceanographic Institution and a co-lead of the cruise. “These are the types of rock we’ve been hoping to recover for a long time.”

Researchers on land are eagerly following the ship's daily scientific logs as it continues to drill, says Jessica Warren, a mantle geochemist at the University of Delaware. "Getting down to this really fresh stuff has been a dream for decades and decades," she says. "We're finally going to see the Wizard of Oz."

The samples can help answer a host of questions, says Johan Lissenberg, an igneous petrologist from Cardiff University onboard the ship. They can provide direct evidence for how oceanic crust differs in composition from the upper mantle and better estimates of elemental abundances in the planet's primary reservoir of rock. The samples of mantle will also help researchers understand how magma melts out of the mantle and rises through the crust to drive volcanism, Lissenberg says. "This could be a whole step forward for understanding magmatism—and the global composition of the bulk Earth."

The 1961 project, called Project Mohole, was the first of a handful of unsuccessful attempts to reach the mantle. It was named after the Mohorovičić discontinuity, or "Moho," a geophysical boundary defined by a sudden spike in the speed of seismic waves where the crust, a mélange of rocks crystallized out of mantle melt and altered by water, gives way to the more homogeneous mantle. The Moho lies some 35 kilometers below thick continental crust. But it is only about 7 kilometers below ocean crust. And it is shallower still at drilling site of the JOIDES Resolution at the Mid-Atlantic Ridge, where the North American and Eurasian tectonic plates are being stretched apart, forcing the mantle upward.

Recovering a long mantle core was not the primary goal of the cruise, which is probing the Atlantis Massif, an underwater mountain, for clues to the origin of life. The massif rocks contain lots of olivine, a mineral that reacts with water in a process called serpentinization. The reactions generate hydrogen, which serves as an energy source for microbial life at the "Lost City," a nearby complex of ocean-bottom mineral chimneys deposited by gushers of superheated water.

It's long been theorized that life could have originated in such settings, which are rich in organic molecules. The cruise aimed to deepen a previously drilled 1.4-kilometer-deep hole, pushing to a depth too hot for life, where organic compounds that might have provided the raw material for the earliest life might lurk. But progress was slow.

So the ship returned to another site near Lost City, where shallow cores drilled in 2015 had found what appeared to be mantle rocks highly altered by seawater. After punching through a horizontal fault near the seabed, "the drilling just went so magically well," says Andrew McCaig, a geologist at the University of Leeds and the cruise's other chief scientist. The only hiccup came when

the recovered peridotite rocks contained veins of asbestos, prompting increased safety protocols.

There's still some room for debate about whether the rocks are a true sample of the mantle, says Donna Blackman, a geophysicist at the University of California, Santa Cruz. The seismic speedup at the Moho is thought to reflect the lack of water or calcium and aluminum minerals in mantle rocks. Because the samples still show some influence of seawater, Blackman says she might classify them as deep crust. "But the petrology is interesting and special regardless," she says. And as the team continues drilling into deeper rocks, Lissenberg says, "They're getting fresher."

Indeed, it appears the team is already sampling mantle rock that has never melted into magma, which then cools and crystallizes into different kinds of crustal rocks, says Vincent Salters, a geochemist at Florida State University. By capturing the rock at this point, he says, researchers should be able to learn how magma melts, flows, and separates—clues to the workings of volcanoes worldwide.

The rocks could also answer other basic questions, such as how much the lavas collected at midocean ridges—which are often taken as a stand-in for the mantle—differ from the mantle itself, says James Day, a geochemist at the Scripps Institution of Oceanography. The abundance of radioactive elements in the rocks could improve estimates of how much heat the mantle produces as a whole, driving the deep convective motions that are the engine of plate tectonics. And their physical strength can inform studies of how earthquakes fracture and propagate in the upper mantle. The cores could also help clarify how well the mantle is mixed, reincorporating ingredients from the continental crust that is drawn back into Earth's interior at deep ocean trenches. "There's so much more to this than understanding a little piece of ocean floor," Day says.

Research on the rocks has already begun in labs onboard the JOIDES Resolution, and eventually the cores will be available at IODP repositories for all. But all the excitement over the rock samples also comes with some bittersweetness: The expedition may be one of the last for the ship. In March, the National Science Foundation (NSF) announced that, because of cost increases and a lack of a deal with its international collaborators, it will end its operating contract for the ship in September 2024.

The ship is in great condition and could continue until 2028, says Anthony Koppers, an associate vice president at Oregon State University and a leader in the IODP community. There's still a slim possibility that the U.S. Congress will fund an extension, he says. But NSF has no plan yet to develop a successor ship. And the other two big contributors to IODP, Europe and Japan, are moving on. This month, they announced the creation of IODP³, a new global drilling program that will make heavy use of

Japan's drill ship, the D/V Chikyū, which in the past has operated mostly in waters near Japan.

This was Lang's first cruise on the JOIDES Resolution, and she was astonished at how well outfitted its labs were and how knowledgeable its technical staff is. The success they're having testifies to their decades of experience probing beneath the ocean floor, she says. "It's so unfortunate that something like this is going to be lost."

Source link: doi: 10.1126/science.adi9181

Key building block for life found at Saturn's moon Enceladus

SwRI helped find evidence for phosphorus in the liquid water ocean beneath the moon's icy surface

ScienceDaily, June 14, 2023

Source: Southwest Research Institute

The search for extraterrestrial life in our solar system just got more exciting. A team of scientists including Southwest Research Institute's Dr. Christopher Glein has discovered new evidence that the subsurface ocean of Saturn's moon Enceladus contains a key building block for life. The team directly detected phosphorus in the form of phosphates originating from the moon's ice-covered global ocean using data from NASA's Cassini mission. Cassini explored Saturn and its system of rings and moons for over 13 years.

"In 2020 (published in 2022), we used geochemical modeling to predict that phosphorus should be abundant in Enceladus' ocean," said Glein, a leading expert in extraterrestrial oceanography. He is a co-author of a paper in the journal *Nature* describing this research. "Now, we have found abundant phosphorus in plume ice samples spraying out of the subsurface ocean."

The Cassini spacecraft discovered Enceladus' subsurface liquid water and analyzed samples in a plume of ice grains and gases erupting into space from cracks in the moon's icy surface. Analysis of a class of salt-rich ice grains by Cassini's Cosmic Dust Analyzer showed the presence of sodium phosphates. The team's observational results, together with laboratory analogue experiments, suggest that phosphorus is readily available in Enceladus' ocean as phosphates.

Phosphorus in the form of phosphates is vital for all life on Earth. It is essential for the creation of DNA and RNA, energy-carrying molecules, cell membranes, bones and teeth in people and animals, and even the sea's microbiome of plankton. Life as we know it is simply not possible without phosphates.

"We found phosphate concentrations at least 100 times higher in the moon's plume-forming ocean waters than in

Earth's oceans," Glein said. "Using a model to predict the presence of phosphate is one thing, but actually finding the evidence for phosphate is incredibly exciting. This is a stunning result for astrobiology and a major step forward in the search for life beyond Earth."

One of the most profound discoveries in planetary science over the past 25 years is that worlds with oceans beneath a surface layer of ice are common in our solar system. Such worlds include the icy satellites of the giant planets, such as Europa, Titan and Enceladus, as well as more distant bodies like Pluto. Worlds like Earth with surface oceans must reside within a narrow range of distances from their host stars to maintain the temperatures that support surface liquid water. Interior ocean worlds, however, can occur over a much wider range of distances, greatly expanding the number of habitable worlds likely to exist across the galaxy.

"Geochemical experiments and modeling demonstrate that such high phosphate concentrations result from enhanced phosphate mineral solubility, in Enceladus and possibly other icy ocean worlds in the solar system beyond Jupiter," Glein said. "With this finding, the ocean of Enceladus is now known to satisfy what is generally considered to be the strictest requirement for life. The next step is clear -- we need to go back to Enceladus to see if the habitable ocean is actually inhabited."

Journal Reference: Frank Postberg, Yasuhito Sekine, Fabian Klenner, Christopher R. Glein, Zenghui Zou, Bernd Abel, Kento Furuya, Jon K. Hillier, Nozair Khawaja, Sascha Kempf, Lenz Noelle, Takuya Saito, Juergen Schmidt, Takazo Shibuya, Ralf Srama, Shuya Tan. Detection of phosphates originating from Enceladus's ocean. *Nature*, 2023; 618 (7965): 489 DOI: 10.1038/s41586-023-05987-9.

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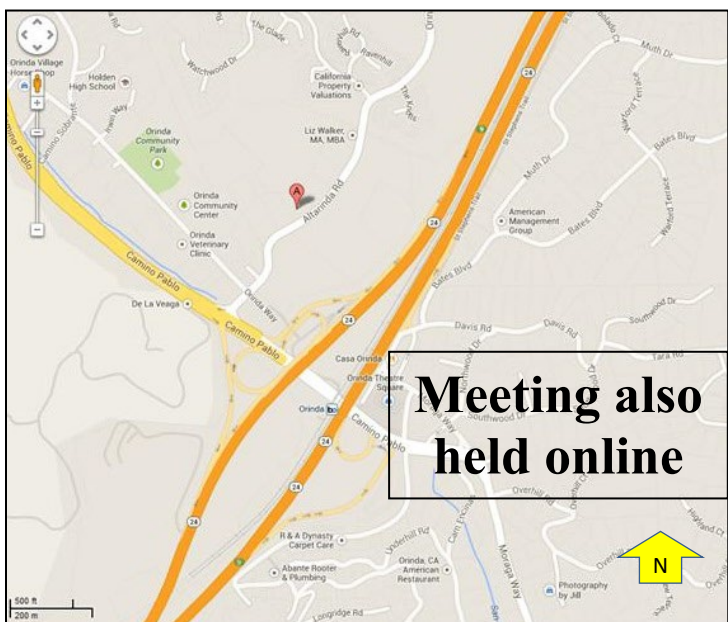
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