NORTHERN CALIFORNIA GEOLOGICAL SOCIETY

MEETING ANNOUNCEMENT

DATE: **Wednesday, March 29, 2023**

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

Note: Zoom meeting attendees should see Page 2 for "Zoom Meeting Instructions"

TIME: **7:15 pm to 8:30 pm (Social time 6:30 to 7:15 pm)**

SPEAKER: ***John Karachewski, PhD***

TOPIC: ***"California Hydroscapes"***

Abstract:

Since 2009, John has written quarterly photo essays for the Groundwater Resources Association of CA (GRA) Hydrovisions newsletter. This geologic travelogue will highlight California's diverse hydroscapes, including groundwater, water resources, and environmental issues as well as tips for photographing our beautiful landscapes and parks. Examples include groundwater springs in northern CA, joint controlled waterfalls in Yosemite Valley, marine carbonate vent structures in Santa Cruz, palm oases at Joshua Tree, and tidal wetlands in southern San Diego. The images also illustrate seasonal and historical changes in California's environments.

Biography:

John has conducted geology and environmental projects throughout the western US from Colorado to Alaska to Midway Island and throughout California. John also taught evening geology and GIS classes at Diablo Valley College. He has led numerous non-technical field trips for the public throughout the Bay Area for the Field Institute at Point Reyes National Seashore Association and other organizations. Doris Sloan and John collaborated on a popular book about the "Geology of the San Francisco Bay Region," published by the University of California Press. John has volunteered for many positions in NCGS, most notably as program chairman. In 2022 he received the NCGS Honorary Member award for his contributions to the society.

NCGS 2022 – 2023 Calendar

April 26, 2023 7:00 pm
Dr. Larry Toy
The James Webb Space Telescope - A new look at the Universe

May 31, 2023 – Dinner Meeting – 6:00 pm
Rob Gailey, Consulting Hydrogeologist
Next Steps in Managing Groundwater Resources in CA

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

NEW 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 the following link: https://us02web.zoom.us/meeting/register/tZItduigqj0pGdweJFomOp2rBiwfkosqwHtG 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 6:45 PM and 7:00 PM with the meeting itself scheduled to start at 7:15 PM. The program will start no later than 7:30 PM and 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.

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 February Presentation

We held another fine meeting in February, live and via Zoom. We hope that all who wanted to see the talk by Dr.

Mathieu Lapotre, Stanford University, Earth & Planetary Sciences on ***The Power of Comparative Planetology to Decipher the Mechanics of Surface Processes and Their Records*** 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/9biDPEUODxkQaPbm0VuvbPcpo7UqanRo22OguNOltLYbznY-OkeipiNlSZTNrrNx.MAIXtUREb6n5afP8

Passcode: kVtcx#e4

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

The Northern California Geological Society's

RICHARD CHAMBERS MEMORIAL SCHOLARSHIPS

2022-2023 AWARDS

The NCGS is pleased to announce that it has awarded two $1,500 scholarships to graduate students pursuing research in northern California. The availability of the Richard Chambers Memorial Scholarship is announced to all Colleges and Universities having graduate programs in northern California. These scholarships are funded from the Richard Chambers Memorial Scholarship fund and donations made by NCGS members and others for scholarships. These two students were chosen from a collection of well-prepared applications made to the NCGS during the fall of 2022. Serving on the NCGS Scholarship Committee were Phillip Garbutt (chair), Andrew Alden, Greg Croft, Paul Henshaw, Don Lewis, Don Medwedeff and Stephen Self. The recipients are:

Regina Khoury, Cal Poly Humboldt, for a master's research proposal titled ***"Petrologic Constraints on the Pre-Eruptive Storage Conditions of Magmas Erupted During the ~12ka Flare Up of Medicine Lake Volcano, CA."*** Her advisor is Dr. Brandon L. Browne.

Sarah Leidinger, Cal Poly Humboldt, for a master's degree research proposal titled: ***"Bathymetry and carbon accumulation rate of a rare Northern California coastal peatland."*** Her advisor is Dr. Laura Levy.

SLAC Job Posting!

Position overview:

Stanford National Accelerator Laboratory (SLAC) is seeking a highly motivated Environmental Geologist with experience in environmental investigation, monitoring, remediation, hydrogeology and geologic interpretation to join our Environmental Protection Department. Reporting to SLAC's Environmental Protection Department's Environmental Restoration Group Leader, this position will support onsite soil and groundwater site investigations and monitoring, ongoing remediation, and possible future remediation projects. This position will also serve as a Subject Matter Expert for onsite hydrogeological and geological studies supported by the EP Department. This position may also provide general support to the EP Department's compliance team as needed to ensure on-going compliance with local, California state, and federal environmental laws, regulations, and DOE requirements. Compliance program support may include but not be limited to the following: stormwater, wastewater, and air quality, the National Environmental Policy Act (NEPA), and Spills Prevention Control and Countermeasure program. General work tasks may include but not be limited to preparing studies, collecting environmental samples and coordinating with analytical laboratories, performing data analysis, managing consultants, preparing timely and accurate reports and regulatory deliverables, presenting information, and interfacing with others at SLAC. Work also includes support of environmental and construction projects through interpreting subsurface geological, hydrological, geochemical and geophysical data.

For more details, go to the following link: https://erp-hprdext.erp.slac.stanford.edu/psc/hprdext/EMPLOYEE/HRMS/c/HRS_HRAM_FL.HRS_CG_SEARCH_FL.GBL?Page=HRS_APP_JBPST_FL&Action=U&FOCUS=Applicant&SiteId=1&JobOpeningId=5300&PostingSeq=1&PortalActualURL=https%3a%2f%2ferp-hprdext.erp.slac.stanford.edu%2fpsc%2fhprdext%2fEMPLOYEE%2fHRMS%2fc%2fHRS_HRAM_FL.HRS_CG_SEARCH_FL.GBL%3fPage%3dHRS_APP_JBPST_FL%26Action%3dU%26FOCUS%3dApplicant%26SiteId%3d1%26JobOpeningId%3d5300%26PostingSeq%3d1&PortalRegistryName=EMPLOYEE&PortalServletURI=https%3a%2f%2ferp-hprdext.erp.slac.stanford.edu%2fpsp%2fhprdext%2f&PortalURI=https%3a%2f%2ferp-hprdext.erp.slac.stanford.edu%2fpsc%2fhprdext%2f&PortalHostNode=HRMS&NoCrumbs=yes&PortalKeyStruct=yes&

Mystery Rock!

Mary Rose Cassa offers these comments and questions about the specimen below:

I came across this rock recently in a box that was stored away. The rock came from my great uncle's collection in New Jersey. He traveled widely and even took geology at

Yale about 1930. I suspect he purchased the specimen while traveling.

I tested it with strong vinegar (I don't have any HCl) and it doesn't fizz. The "crystals" look to be dodecahedral. The specimen has sort of a 3-sided cross-section. One side has the larger "crystals; the other two sides have much smaller "crystals." A broken cross-section of a "crystal" appears to "radiate" from a central point.

I suspect the original rock was a carbonate or evaporite or garnet that has been replaced; i.e., a pseudomorph. But from what TO what?

I'm thinking it's an iconic type of rock that shows up in many collections. Any suggestions?

Local-themed Geo-Website

Steven Edwards, Ph.D. and **Director Emeritus** of the Regional Parks Botanic Garden in Berkeley, has developed a website centered on California geology and plants. Steve has gathered some beautiful photographs of, among other things, wildflowers and petrographic thin sections – he secured some expert help from John Wakabayashi and Howard Day in interpreting thin sections. There are also essays on botany and conservation, poetry, and lithic replicas, landscapes, and animals.

You can find the site at http://californiageology.net, or it can be googled at californiawildflowers.net (which leads to the same site).

NCGS Outreach Opportunities

Watch this space and watch for any emailed messages from the secretary.

UC Berkeley Earth & Planetary Science Weekly Seminar Series

There are at least two intriguing seminars coming up: On Thursday, March 23, 2023, Claire Doody of UC Berkeley will speak on the topic ***Exploring the Earth Beneath Our Feet: Seismic Modeling of California***. Then on Thursday, April 13, 2023, David Gold of UC Davis will speak on the topic ***Combining genomes and geochemistry to reveal the origins of complex life***. Both seminars will be held at 3:45 pm at 141 McCone Hall. 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 March 30 at 6:00 PM, Ilsa Kuffner, Research Marine Biologist at USGS St. Petersburg Coastal & Marine Science Center, will speak on ***Coral Reefs in Crisis – Science to Guide Reef Restoration for Ecosystem Recovery.*** 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, May 13 (9 am)**, location to be determined.

Note from the Newsletter Editor: Bill Motzer is an accomplished geochemist and longtime NCGS member

The Irony of Iron
Part 1: Introduction

by

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

In a series of articles published in the Northern California Section of the American Chemical Society's newsletter The VORTEX, I discussed the element gold including the California Gold Rush and its environmental impacts that persist to this day (Motzer, 2021). In the next series (Motzer, 2022), I discussed the chemical element iron (Fe, Atomic No. or Z= 26) and its impact to human society. We normally don't think of iron in the same context as gold because there was no "iron rush" with mass migrations of peoples, no adornment as jewelry, and no accumulation of iron in personal portfolios, banks, and storage facilities such as Fort Knox. But iron has done more for the advancement of human civilization than gold. There was, and to a certain extent still is, an "iron age" (Motzer, 2019). In the Eastern Hemisphere, it began in the Ancient Near East and in South Asia at about 1,200 years before the common era (BCE), and lastly in Europe (Germany) at about 400 CE; however, an iron age did not occur with Western Hemisphere civilizations.

Here are some items that I'll discuss in future articles (but not necessarily in the following order):

- Iron is the only element from hydrogen through chromium that does not undergo further stellar fusion. Once a certain star type fuses its hydrogen and helium to higher elements (via nucleosynthesis) and ultimately iron, fusion ceases and for some stars a supernova event (SNE) occurs. These SNEs also create elements above iron and disperse them with iron throughout the Universe.
- Of all the planets in our Solar System, Earth has the highest overall density (5.51 g/cm^3). The reason for this may be in its rather large iron-nickel (Fe-Ni) core. How Earth acquired such a large Fe-Ni core is the focus of some rather interesting recent research. A recently discovered exoplanet (GJ 367b) by NASA's Transiting Exoplanet Survey Satellite (TESS), orbits a small red dwarf star 31 light-years from Earth. TESS's measurements indicated that this exoplanet is about 9,000 km in diameter with about 50 percent of Earth's mass, as measured the European Southern Observatory's High Accuracy Radial Velocity Planet Searcher (HARPS). Both measurements indicate a planetary density of about 8 g/cm^3, which is very close to that of pure iron (7.87 g/cm^3). Such planetary core formation has given us insights to our own planet's formation.
- Although iron is abundant in Earth's core and overall is Earth's second most abundant element, it's only the fourth most abundant element in Earth's crust. This may be an important geochemical construct because lower iron crustal concentrations resulted in less binding of water in iron minerals allowing the retention of Earth's surface water as oceans. Additionally, Earth's seawater now contained iron in bioavailable forms accessible to life. This didn't occur on Mars, which has a higher iron crustal concentration resulting in iron binding to water. The detection of goethite [FeO(OH)] by the Mössbauer spectrometer may confirm this hypothesis. Therefore, on a geochemical basis, Mars did not retain its oceans.
- Early Earth's oceans had dissolved iron in the form of ferrous iron or Fe(II). When the great oxygenation event (GOE) occurred at approximately 2.5 to perhaps 2.0 billion years ago, iron began to precipitate, as ferric iron or Fe(III) minerals, resulting in large iron ore deposits known as banded iron formations (BIF). In the U.S., BIF deposits occur in northern Wisconsin, northern Michigan, and Minnesota comprising much of the U.S. iron ore deposits.
- To exist, cellular life and particularly complex cellular life (i.e., chordates) requires water because their cells need it for normal metabolic chemistry. However, iron is also essential for such life, particularly in cellular reproduction to duplicate DNA, for proteins and enzymes, and for hemoglobin in our blood to transport oxygen throughout the body. Although some invertebrates don't need iron in their "blood" (they use copper or vanadium), and some fish also don't use iron, most complex living things do.

• The primary preferred analytical method to determine iron concentrations in geologic materials (rocks, sediments, and soil) has been by inductively coupled plasma atomic absorption emission spectroscopy (ICP-AES). Detection limits for routine rock samples are about 100 mg/kg or parts per million (ppm). A secondary method is by atomic absorption spectroscopy (AAS) and x-ray fluorescence spectroscopy (XRF) Other newer methods now exist for individual mineral analysis.

1-1 References:

Lam, K.W.F., et. Al. 2021, GJ 367b: A Dense, Ultrashort-Period Sub-Earth Planet Transiting a Nearby Red Dwarf Star: Science, v. 374, n. 6572, pp. 1271-1275.

Motzer, W.E., 2019, It's Elementary – Part 2: The VORTEX, v. LXXXI, n. 8 (October)., pp. 5-6: www.calacs.org

Motzer, W.E., 2021, All That Glitters…? – Parts 1-8: The VORTEX, v. LXXXIII, nos. 1-10 (March-December 2021): www.calacs.org.

The Irony of Iron – Part 2: Some Fundamental Properties

Iron:
Anvil, axe, nail, plow,
engine, railway, factory.
Servant, friend, partner.

Haiku by Mary Soon Lee

Iron may have contributed more than gold to the advancement of human civilization, and this is succinctly stated in Lee's Haiku (Lee, 2017). But before we discuss other aspects of iron as outlined in Part 1, let's list and examine some fundamentals.

Parameters:

Atomic Number (Z): 26
Periodic Table: Symbol: Fe
  Group: 8, Period: 4, Block d
  Classification: Transition metal
Solid at 20 ºC
Melting point: 1538 ºC
Boiling Point: 2861 ºC
Density: 7.874 g/cm$^{3:}$
Relative atomic mass: 55.845
Atomic radius: 2.04 Å
Electron configuration: [Ar]$3d^6 4s^2$
Shell structure: 2 8 14 2
Isotopes: 28 (4 stable, 24 radioactive)
Common oxidation States: -II, 0, II, III, VI
CAS No.: 7439-89-6

History: Iron is one of the nine elements known to ancient humans and civilizations. Iron objects (e.g., beads and knives) discovered in Egypt, dating from about 5,500 years ago, contain approximately 7.5% nickel (Ni; Z=28), indicating that they were probably of meteoric origin. The ancient Hittites of Asia Minor (currently, the nation of Turkey) first smelted iron from its ores about 3,500 years ago essentially launching the iron age. The Hittites' iron use in tools and weapons is believed to have given them an economic and political advantage against other ancient civilizations. Some iron ores mined at this time also contained vanadium (V; Z=23), which significantly hardened smelted iron to produce Damascene steel used in swords (Motzer, 2019; RSC, 2021).

Etymology: The name iron may be from the Anglo-Saxon (Old and Middle English) term: *iren* and *yron* from an earlier name for "holy metal" from swords used during the Crusades: later form of *isern*, *isærn*. Another source suggests that iron is from a Proto-Germanic term *isarnan*, derived the Old High German *isarn* and German term *eisen* meaning "strong."

The symbol for iron: Fe is derived from the Latin *ferrum* meaning firmness. The word could have entered Latin through the Etruscan language after an earlier term *ferzom* (Boudreaux, 2007; RSC, 2021, Harper, 2022; WebElements, 2023)

Isotopes: Iron has four naturally occurring stable isotopes: iron-54 (^{54}Fe) comprising 5.845% of the isotopes [however, it's possibly radioactive with a half-life (t ½) greater than (>) 4.4×1020 years to 3.1 x 1022 years, depending on the researcher], ^{56}Fe at 91.754%, ^{57}Fe at 2.119%, and ^{58}Fe at 0.286%. There are 24 known radioactive isotopes with varying t ½. Of these, the most stable are ^{60}Fe with a t ½ of 2.6 x 106 years and ^{55}Fe with a t ½ = 2.7 years) (WebElements, 2023).

Abundances: Iron is the sixth most abundant element in the visible Universe (Table 1-2) with hydrogen (H; Z=1) and helium (He; Z=2) the most common, originating from the Big Bang at 750,000,000 parts per billion (ppb) or 75% and 230,000,000 ppb (23%) by mass fraction, respectively. Lithium (Li; Z=3), beryllium (Be; Z=4), and boron (B; Z=5) are rare (underabundance) because they were poorly synthesized in the Big Bang and also in stars. Therefore, the third, fourth, and fifth most abundant elements are oxygen (O; Z=8), carbon (C; Z=6), and neon (Ne; Z=10) at 10,000,000 ppb (1.0%); 5,000,000 (0.5%); and 1,300,000 ppb (0.013%), respectively (WebElements, 2023).

Solar system abundances are mostly defined by the Sun, which has 99.86% of the system's entire mass. Note in Figure 1-2, that H and He are the most abundant with heavier elements comprising less than 2%. These include O at 0.80%, C at 0.36%, and Fe (~0.16%) as the fifth most common solar element. The Sun is still not hot enough to produce Fe through stellar nucleosynthesis, currently is fusing hydrogen in its core at 15 x 106 K. However, it's a "metal-rich" star and has incorporated metals from the original solar nebula (Motzer, 2020).

Table 1-2: Selected Iron Concentrations from Different Sources

Source	Parts per billion (ppb)* by mass**	Percent by mass**	Amount in grams (g)
Universe	1,100,000	0.11	–
Sun (Sol)	1,000,000 to 2,000,000	0.1 to 0.2 (~av.: 0.16)	–
Carbonaceous meteorite	22,000,000	2.2	–
Earth's Crustal rocks	41,000,000 to 63,000,000	4.1 to 6.3	–
Earth's mantle	5,800,000	5.8	–
Earth's core	800,000,000 to 850,000,000	80 to 85***	–
Sea (Ocean) water	3 to 3.4	3 to 3.4 x 10^{-7}	–
Stream (Fresh) water	670	6.7 x 10^{-5}	–
Human body	60,000 (av.)	0.006	4.0 to 8.0

Notes:
av = average
Universe and Sun (Sol) determined by spectrographic analyses.
* ppb = µg/kg for solids and µg/L for liquids. Values from many sources given in ppb.
** Range variation from different sources and research papers.
*** Alloyed with 2 to 3% Ni.
Sources: LBL (2000), Boudreaux (2007), WebElements (2023).

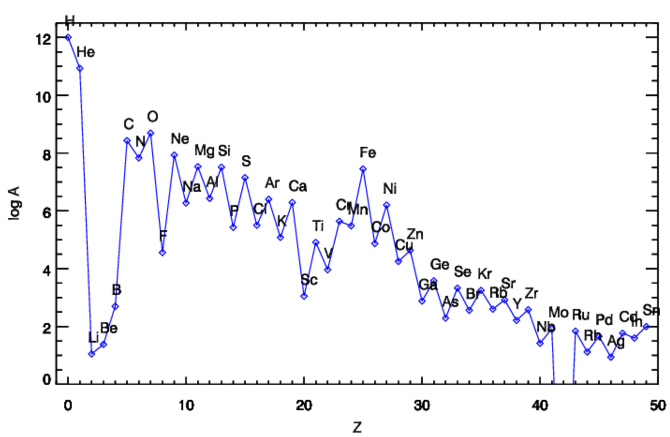


Figure 1-2: Present day element solar abundance (by mass) as a function of atomic number (Z).
Source: Bergemann and Sereneli (2014).

References 1-2:

Bergemann, M and Sereneli, A., 2014, *Solar Abundance Problem*: ResearchGate, 17 p., https://www.researchgate.net/publication/260799885

Boudreaux, K.A. 2007, *The Periodic Table of the Elements*: San Angelo State University: https://www.angelo.edu/faculty/kboudrea/periodic/physical_abundances.htm and https://www.angelo.edu/faculty/kboudrea/periodic/periodic_0.htm.

Harper, D., 2022, iron (n.): Online Etymology Dictionary: https://www.etymonline.com/word/iron

LBL (Lawrence Berkeley Laboratory), 2000, Origin of the Elements:

https://www2.lbl.gov/abc/wallchart/chapters/10/0.html

Lee, M.S., 2017, Elemental haiku: American Association for the Advancement of Science (AAAS): https://vis.sciencemag.org/chemhaiku/

Motzer, W.E., 2019, It's Elementary – Part 1: The VORTEX, v. LXXXI, n. 7 (September), pp 5-6: www.calacs.org.

Motzer, 2020, Digital Dentistry Revisited – Part 3, The VORTEX, v. LXXXII, n. 10 (December), pp. 6-7: www.calacs.org.

NCBI (National Center for Biotechnology Information), 2023, PubChem Element Summary for Atomic Number 26: https://pubchem.ncbi.nlm.nih.gov/element/Iron.

WebElements, 2023, THE periodic table on the www: www.webelements.com
RSC (Royal Society of Chemistry), 2021, Periodic Table app, version 1.5: www.rsc.org.

Mineral particles and their role in oxygenating the Earth's atmosphere

ScienceDaily: March 6, 2023
Source: University of Leeds

Mineral particles played a key role in raising oxygen levels in the Earth's atmosphere billions of years ago, with major implications for the way intelligent life later evolved, according to new research.

Up to now, scientists have argued that oxygen levels rose as the result of photosynthesis by algae and plants in the sea, where oxygen was produced as a by-product and released into the atmosphere. But a research team at the University of Leeds say the photosynthesis theory does not fully explain the increase in oxygen levels.

In a paper published March 6 in the journal *Nature Geoscience*, the researchers argue that when the algae and plants died, they would have been consumed by microbes, a process that takes oxygen from the atmosphere. The amount of atmospheric oxygen was a balance between production through photosynthesis and loss as a result of decomposition of the dead plant and algae.

To enable the atmospheric oxygen levels to get higher, the scientists say the process of decay must have been slowed or halted. This happened through what is known as mineral-organic carbon preservation, where minerals in the oceans, particularly iron particles, bind onto the dead algae and plants and inhibit their decay and decomposition. The overall result is that oxygen levels were able to increase unhindered.

Caroline Peacock, Professor of Biogeochemistry in the School of Earth and Environment at Leeds who led the research, said: "Scientists have known for many years that mineral particles can bind with dead algae and plants, making them less susceptible to attack by microbes and shielding them from the decay process, but whether mineral particles helped fuel the rise of atmospheric oxygen had never been tested."

The researchers set about testing their theory against known geological events when levels of mineral particles were likely to have been higher, for example, when the continents formed, resulting in a greater landmass from which minerals -- including particles of iron -- would have blown or been washed into the oceans.

For example, the Great Oxidation Event 2.4 billion years ago saw a spike in oxygen levels in the atmosphere. This coincided with the gradual formation of the continents, which would have caused a greater quantity of mineral particles to flow into the oceans.

Although there is large uncertainty in the estimation of the evolution of land area with time, most models show a substantial increase in land masses during 3.0–2.3 billion years ago (Ga), and between the Archaean and Paleoproterozoic the strontium isotope record shows a drift towards higher values, consistent with increased continentally sourced Sr (Fig. 3). Continental elevation and strontium isotope records are also consistent with further increases in material delivery during 1000–500 million years ago (Ma) (Fig. 3). Between 3.0 and 2.3 Ga, the emergence of land masses probably brought substantial terrigenous material to seawater and hence substantial amounts of Fe, which is also consistent with the occurrence of major Fe formations after 2.75 Ga (Fig. 3). This Fe influx corresponds with the Great Oxygenation Event (~2.4-2.2 Ga) and multiple independent lines of evidence for 'whiffs' of O_2 before it. Between 1000 and 500 Ma, the further increases in continental elevation and terrigenous inputs correspond with the Neoproterozoic Oxygenation Event (~800-550 Ma). We therefore suggest that an increase in terrigenous inputs into the ocean and an associated increase in the terrigenous Fe flux may have resulted in substantial OC burial, contributing to the oxygenation of the ocean and atmospheric system. While we focus on iron in this Article, the evidence here also supports the potential for a wider link between terrigenous material delivery and Earth's oxygenation, which may also include other minerals and processes.

It is difficult to track the global burial rate of Fe (oxyhydr)oxides directly. This is because sedimentary concentrations can reflect Fe transport in the ocean as well as redox-dependent conversion of Fe oxides to authigenic minerals such as pyrite. A compiled dataset (see Supplementary Information for the description of the compilation) for the content of Fe (oxyhydr)oxides in shales shows a particularly substantial increase during the Neoproterozoic Oxygenation Event (Fig. 3). The mean content of Fe (oxyhydr)oxides of post-Tonian age (<830 Ma) is more than twice that of the pre-Cryogenian (>830 Ma)—0.43 ± 0.12 wt% versus 0.19 ± 0.06 wt% (2 s.d.). The unpaired Student's t test shows that the difference between these two mean values is significant ($P < 0.001$, $\alpha = 0.01$), and the increase in mean contents of Fe (oxyhydr)oxides remains robust during bootstrap resampling (Fig. 3). This increase in the abundance of Fe (oxyhydr)oxides may have been driven by the progressive oxygenation of the ocean interior during the late Precambrian. If so, then this may constitute a positive-feedback regime where more OC is mineral preserved, which drives further oxygenation.

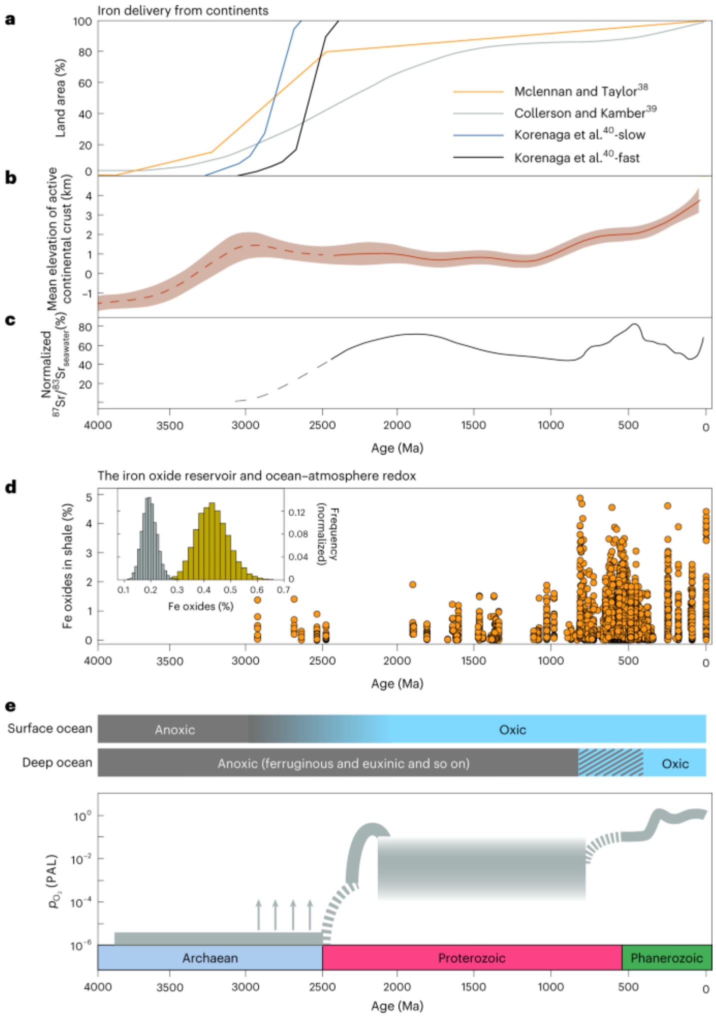


Fig. 3: The evolution of Fe fluxes, oceanic redox and atmospheric pO2.

We conclude that mineral protection of OC, driven by supply of Fe from the continents, probably has been an independent driver of increased marine O_2 and SO_4 concentrations and has led to a system that is more resilient to deoxygenation by restriction of P supply to the oceans. This adds weight to the hypothesis that the ultimate driver of Earth's oxygenation is the emergence and/or uplift of continental land masses, a process that in our model would raise atmospheric pO_2 and marine O_2 and SO_4 levels and buffer the system against collapses in biological productivity. We suggest that the direct effect of Fe minerals on OC preservation and burial should be included in subsequent analyses of the long-term oxygenation of Earth.

Dr Mingyu Zhao, formerly at Leeds but now at the Chinese Academy of Sciences in Beijing, performed the study. He said: "The increase in mineral particles in the oceans would have reduced the rate at which algae was being decomposed. This had a major impact on oxygen levels, allowing them to rise."

The increase in atmospheric oxygen had major ramifications for the development of life. It resulted in the evolution of increasingly complex organisms, which moved from inhabiting water to living on land.

For Professor Peacock, the study not only brings greater understanding to the way the Earth's atmosphere became oxygenated, it also gives a glimpse of the conditions that are necessary for complex life to develop on other planets. She said: "Our investigation is providing a new understanding of how the Earth's atmosphere became oxygen rich, which eventually enabled complex life forms to evolve.

"That is giving us an important insight into the conditions that need to exist on other planets for intelligent life to develop.

"The existence of water on a planet is only part of the story. There needs to be dry land to provide a source of mineral particles that will eventually end up in the oceans."

Journal Reference: Mingyu Zhao, Benjamin J. W. Mills, William B. Homoky, Caroline L. Peacock. Oxygenation of the Earth aided by mineral–organic carbon preservation. *Nature Geoscience*, v. 16, pages 262–267 (2023); DOI: 10.1038/s41561-023-01133-2.

New study could help pinpoint hidden helium gas fields -- and avert a global supply crisis

ScienceDaily: March 1, 2023
Source: University of Oxford

Research led by the University of Oxford could help overturn the current supply crisis of helium, a vital societal resource. The study proposes a new model to account for the existence of previously unexplained helium-rich reservoirs. The findings, published March 1 in *Nature*, could help locate untapped reservoirs of accessible helium.

Dr Anran Cheng (Department of Earth Sciences, University of Oxford), lead author of the study, said: 'Our model shows the importance of factoring in the high diffusivity of helium and the long timescales needed to accumulate significant gas quantities, and the fact that the entire geological system acts dynamically to affect the process. This model provides a new perspective to help identify the environments that slow helium gases down enough to accumulate in commercial amounts.'

Where rare helium-rich underground gas fields have been found, they always occur alongside high concentrations of nitrogen gas. Until now, there has been no explanation for this. For the first time, this new study, which also involved the University of Toronto and Durham University, provides an answer.

The research team built a model to account for these helium-rich deposits by (for the first time) factoring in the presence of nitrogen, which is also released from the deep crust along with helium. The authors identified the geological conditions where the concentration of nitrogen becomes high enough to create gas bubbles in the rock pore space.

Such a process can take hundreds of millions of years, but when it happens the associated helium escapes from the water into the gas bubbles. These bubbles rise, because of buoyancy, towards the surface until they hit a rock type that doesn't allow the bubbles through. According to the model, the helium-rich gas bubbles then collect beneath the seal and form a substantial gas field. The nitrogen and helium-rich gases contain no methane or carbon dioxide so tapping them does not release carbon emissions.

When the researchers applied the model to an example system (Williston Basin, North America) using expected nitrogen concentration values, the model predicted the observed nitrogen/helium proportions in real life. The model could help identify areas likely to contain similar helium-rich deposits.

Helium is a $6 billion (£5.3 billion) market, with the gas being essential for the operation of MRI scanners, computer chips and fiber optic manufacture, and nuclear and cryogenic applications. A current global shortage has pushed supplies almost to a crisis point, with prices skyrocketing in recent years. The situation has been escalated by the Ukraine war, since this ruled out helium being supplied from the new Russian Amur plant, planned to supply 35% of the global helium demand.

In addition, almost all helium today is a by-product of methane or carbon dioxide natural gas production. This carries a significant carbon footprint and hinders ambitions to achieve net-zero carbon emissions by 2050.

Together, these reasons mean that identifying alternative, carbon-free sources of natural helium has become critically important.

The model also suggests regions where large amounts of hydrogen gas may accumulate underground, since the radioactivity that generates helium also splits water to form hydrogen. With a global market of $135 billion, hydrogen is used to create fertilizer and to produce many compounds essential for the food, petrochemical, and pharmaceutical industries. Virtually all hydrogen gas is currently produced from coal and natural gas (methane), and this alone accounts for 2.3% of global CO_2 emissions. Hydrogen-rich underground deposits could provide an alternative carbon-free source.

Prof Chris Ballentine (Department of Earth Sciences, University of Oxford), co-author for the study, notes: "The amount of hydrogen generated by the continental crust over the last 1 billion years could power society's energy needs for over 100,000 years."

Prof Barbara Sherwood Lollar (Department of Earth Sciences, University of Toronto), co-author, adds: "Much of this hydrogen has escaped, been chemically reacted or used up by subsurface microbes -- but we know from studying the gas in deep locations in the subsurface around the world that some of this hydrogen is indeed stored underground in significant quantities."

Prof Jon Gluyas: (Earth Sciences, Durham University), co-author, states "This new understanding of helium accumulation provides us with the critical start of a recipe to identify where significant amounts of geological hydrogen, as well as helium, might still be found."

Journal Reference: Anran Cheng, Barbara Sherwood Lollar, Jon G. Gluyas, Chris J. Ballentine. Primary N2–He gas field formation in intracratonic sedimentary basins. Nature, 2023; 615 (7950): 94 DOI: 10.1038/s41586-022-05659-0.

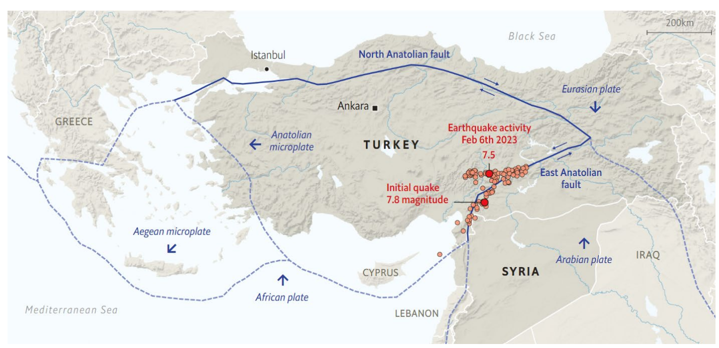
Graphic detail | Stuck in the middle

Turkey sits at the crossroads of tectonic plates as well as civilizations

The recent quake was the first magnitude-seven event on the East Anatolian fault in modern times

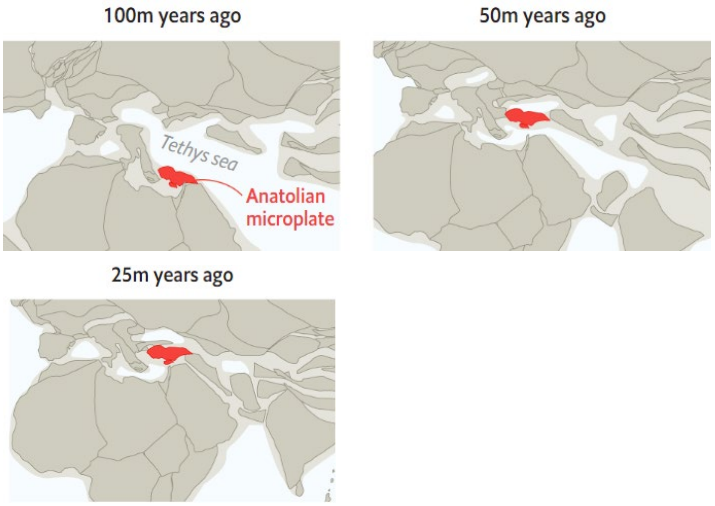
from *The Economist*, Feb 9th 2023

The earthquakes that ripped across southern Turkey and northern Syria in the small hours of February 6th were among the most devastating of this century. Within three



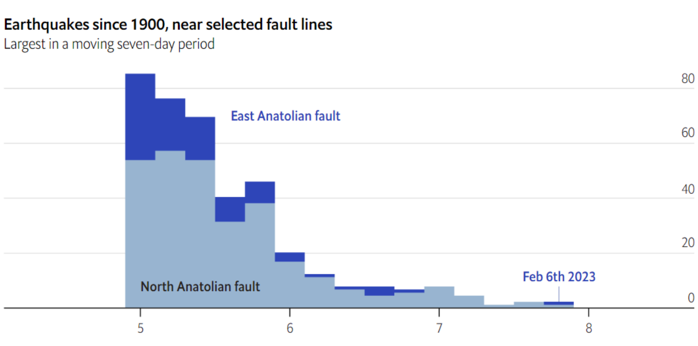
days of the disaster, the reported death toll surpassed 10,000. This horrifying impact stems largely from shoddy construction practices and from the timing of the quake, which occurred while people were sleeping. But any seismic event this powerful—the biggest quakes were of magnitude 7.8 and 7.5—would inflict grave damage. Worldwide, only around 15 earthquakes of magnitude seven or greater happen each year.

Although Turkey is far from the Pacific "ring of fire" that generates most of the world's strongest earthquakes, its neighborhood is unusually seismically active. Quakes tend to occur along the boundaries between tectonic plates, the segments of Earth’s crust that get moved around by convection currents in the hot mantle below. Along the fault lines that separate plates, crustal rocks move slowly past each other, often sticking and jamming. This causes strain to accumulate until the fault slips, causing an earthquake.



The eastern Mediterranean has a particularly complex tectonic structure involving several “microplates”, including the Anatolian plate, on which most of Turkey sits. A mere 100m years ago, this plate comprised part of the southern shore of a sea called Tethys, which separated Africa from Eurasia. As this body of water closed up, leaving the Aral, Black, Caspian and Mediterranean seas as its only remnants, the Anatolian plate drifted north. It then got squeezed between four others, including the Arabian plate to the south-east (which is migrating north) and the Eurasian plate to the north (which is moving south). Both of these plates are still pushing into their small Anatolian neighbor today.

In the wake of a catastrophic earthquake near Istanbul in 1999, Turkish leaders vowed to improve seismic preparedness. That tremor originated in the North Anatolian fault, the Anatolian plate’s boundary with the Eurasian plate, which has been the source of most of Turkey’s large quakes. In contrast, the East Anatolian fault, where it rubs up against the Arabian plate, had not seen a quake of at least magnitude seven since modern monitoring systems began in the late 19th century.



Many other active fault systems, such as the Cascadia subduction zone in the north-western United States and south-western Canada, have gone centuries without an earthquake. Such relative quiet does not necessarily indicate low seismic risk. Strain along the East Anatolian fault had been building up year after year, making the fault ripe for a cataclysm. ■

Chart sources: USGS; Christopher Scotese, Paleomap Project, 2016; “An updated digital model of plate boundaries”, Peter Bird, 2003; The Economist

This article appeared in the Graphic detail section of the print edition under the headline "Stuck in the Middle."

Science & technology | Archaeology

Antarctic rocks can help sort stone tools from natural look-alikes

That will help archaeologists who study the Paleolithic

From *The Economist*, March 1, 2023

Antarctica is somewhere archaeologists might be thought to have little business. After all, human beings did not reach it until 1821. Yet a study published in *Antiquity* by Metin Eren of Kent State University, in Ohio, argues it is worth their attention for precisely that reason.

A challenge faced by those archaeologists who study the Stone Age, particularly the Paleolithic (which is the bulk of hominid history, including species such as *Homo neanderthalensis* and *Homo heidelbergensis*), is discerning whether things which might be stone tools, are, indeed, such. There are many cases when a rock identified as having been worked deliberately by hominid hand has subsequently been reclassified as a naturally produced object.

Dr Eren and his colleagues thought it might thus be useful to assemble a library of tool-like rocks from a place where there was no chance that they could have been chipped at by humans or their ancestors. They turned to Antarctica because, not only was it reached only 200 years ago, but it also supports a variety of processes, including glacial erosion, frost cleaving and river transport, which might batter rocks into tool-like shapes.

Rather than visit the continent itself, they knocked on the doors of the Polar Rock Repository in Columbus, Ohio's capital, where thousands of Antarctic rock samples are stored. They used the repository's database to find specimens made of stuff—especially basalt, chert (of which the most familiar type is flint) and obsidian—that hominids had a penchant for working into tools before the development of bronze and iron. They then studied these in detail and identified 14 which they thought could easily have duped archaeologists into believing they had been made deliberately.

They argue in their paper that these specimens should form the core of a reference collection, with which doubtful discoveries could be compared. They also hope to add to this collection by similarly plundering the trove belonging to the British Antarctic Survey, in Cambridge. That would certainly help professional archaeologists. For amateurs who might be curious as to whether the "tool" pictured at the top of this article is natural or artificial, the answer is printed at the bottom of the page. ■

This article appeared in the Science & Technology section of the print edition under the headline "Give us the tools"

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* It is a real tool, from Spain, made 350,000 years ago by Homo heilbergensis.

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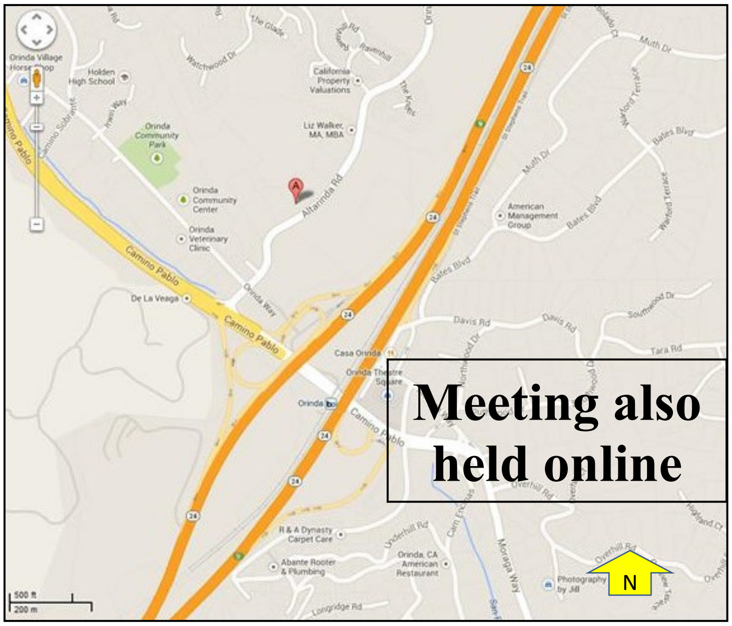

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