NORTHERN CALIFORNIA GEOLOGICAL SOCIETY

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MEETING ANNOUNCEMENT

DATE: **Wednesday, November 16, 2022**

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

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

TIME: **7 pm to 8:30 pm (Social half-hour at 6:30 pm)**

SPEAKER: ***Marty Grove, Stanford University***

TOPIC: ***"Nature and Timing of Deformation and Heat Flow related to Laramide Shallow Subduction beneath the Southern California Margin"***

Abstract:

Comparatively low heat flow is observed along convergent margins as a result of subduction refrigeration of the forearc while higher heat flow in the adjacent arc reflects magmatism. This normally sharp contrast in heat flow regimes is eliminated when oceanic crust is rapidly subducted at shallow depths beneath a continental margin. Subnormal geotherms are established within the arc as magmatism shifts into the continental interior. Such was the case during Late Cretaceous – Early Cenozoic (ca. 85-40 Ma) shallow subduction episode that occurred beneath southern California during the Laramide Orogeny and produced the Rocky Mountains in the continental interior. This talk focuses upon the imprint of the Laramide Orogeny at the leading edge of the margin in the southern Sierra Nevada and western Mojave desert region of southern California. There, field observations and thermochronology from upper plate arc crust and accreted trench sediment (Pelona-Orocopia-Rand schist) as well as from sediment shed from the arc provide a precise chronology into the timing of the onset of shallow subduction as well as insights into deformation related to this process.

(Continued on last page)

NCGS 2022 – 2023 Calendar

December – No meeting; our usual Holiday Break

January 25, 2023 7:00 pm
Dr. Erik Sperling, Stanford University
Paleo-oceanography using mud-rock chemistry

February 22, 2023 7:00 pm
Mathieu LaPotre, Stanford University
Eolian dunes and landscapes on Mars – 10 years into the mission of Curiosity Rover

March 29, 2023 7:00 pm
Dr. Don Lowe, Stanford University
Early Precambrian environments

April 26, 2023 7:00 pm
Speaker and program to be announced

May 31, 2023 – Dinner Meeting – 6:00 pm
Speaker and program to be announced

June 28, 2023 7:00 pm
Speaker and program to be announced

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 the in-person meeting at our Orinda Masonic Hall meeting place. Jim O'Brient, our Program Manager, will host the Zoom meeting. Register by emailing Jim at j.obrient@comcast.net.

Members only can reserve a slot. Register by Sunday, November 13, 2022. Zoom **invitations will be emailed** on Monday, November 14, **by 7 PM.** The invitations will come via a calendar invite that you simply accept (YES) in order to place this on your calendar. Jim's default calendar is Google. He will also copy the link to you in email, but if that is used, a password may be required as well (that will be included in the invitation). DO NOT FORWARD THIS LINK TO ANYONE ELSE.

The meeting will use a "waiting room" for security purposes. The host will open the meeting about 6:45 PM. You will be admitted by host after matching names to the registration list. To save the host work, please try to join the meeting no later than 6:50 PM as it will take longer to gain admittance after the meeting starts. You will need to turn on your own video and audio once you have entered the meeting. Once the meeting starts, the host will mute everyone and ask that your video be turned off to minimize bandwidth constraints for a big group except when requested by the host for specific meeting roles.

A Note from the President

Look to Paul Henshaw's news this month and next, for ways to support Earth Science in our schools. NCGS and other geology organizations are seeking to revitalize K-12 and Teacher of the Year (TOTY) award. 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!

Thank you to Phil Garbutt for continuing to man the "pay what you wish" book sales; all proceeds support NCGS scholarships.

Although I realize that most of our members live in the East Bay or San Francisco, a Cub Scout leader in Marin is seeking a geologist to lead 4th graders in an "Earth Rocks!" program involving geology, rock identification, testing minerals using the Mohs scale and teaching about local geological features. If willing to help, please contact Laura Elze at Lelze06@yahoo.com.

Remember that our monthly meeting is a week early this month, due to Thanksgiving. I wish all of you a happy reunion with family and friends!

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 school teachers 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. If you are interested in joining our effort, please contact me, Paul Henshaw, at drphenshaw@comcast.net. In December, we will publish the list of opportunities to help our communities – we ask you to please help.

MISSING OCTOBER'S NEWSLETTER?

We have been made aware that some members did not receive the Oct.16th email message conveying the Oct. Newsletter. The number affected is possibly less than 10, but we are unsure if that is the case. If you have not previously been in communication with the secretary (Steve S.) and did not get that Oct. 16th message, with newsletter attached, please let him know by message to steve.self1815@gmail.com.

We hope that this was a one-time glitch! Thanks.

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View the October Presentation

We held another excellent meeting in October – both live and via Zoom – and we hope that all who wanted to see it 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/PK6WWqaNKPUsN_7s_QHxXH8Qr_2m3WaL0WbxJTw_iVPSGgAG8UJJecIvP0B8BtpY.Ej63b05-tsKApv2b.

Passcode: .&pw3SHD

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

Missing NCGS Field Trip Guidebooks

Do you have any of the guidebooks on the list below?

NCGS is working to track down older missing field trip guidebooks so we can post them on our website for free download. We already have over 70 historic guidebooks available in PDF format at http://www.ncgeolsoc.org/.

If you have a copy of any of the guidebooks below, please contact Greg Bartow at gbartow @ gmail.com or 925-818-8525.

Guidebook Title	Year	Author
Northern Mt. Diablo Area	1950	Al Solari
Eastside Salinas Valley	1966	
Field trip to the Geysers, Sonoma County, California	1968	J.B. Koenig
Mt. Diablo and Livermore Valley	1969	E.H. Pampeyan/ H.E. Wollenberg
San Andreas Fault and Point Reyes Peninsula	1970	A.J. Galloway/ R.D. Brown
Hayward-Hollister Field Trip	1971	R.D. Nason/ T.H. Rogers
Environmental geology of northeastern flank of the Santa Cruz Mountains	1972	T. Rogers
Mother Lode Country	1973	O. Bowen
San Francisco Bay Model	1974	L. Crebassa
Ophiolites in the Mesozoic subduction zone of central California	1974	R.G. Coleman
Raised Pleistocene terraces and upper Tertiary sedimentary rocks of Santa Cruz	1974	R.E. Garrison/ L.F. Laporte/ G. Weber
A look at the Franciscan rocks of the Napa Valley	1977	NCGS
Geology and engineering in the Livermore-Hayward region, California	1979	L.H. Moir
Upper Cretaceous and Paleocene turbidites, central Cal Coast	1981	V. Frizzell (editor)

The Franciscan Complex and the San Andreas Fault from the Golden Gate to Point Reyes, CA	1981	J.R. Kleist (editor)
Turbidites along the coast south of San Francisco	1985	T. Nilsen
Submarine Canyons - Meganos Canyon and sand, north flank, Mt. Diablo	1986	V. Chevron/ P. Fischer
Shallow marine and coastal depositional facies, Mussel Rock, Pacifica to Fort Funston, San Francisco	1987	E. Clifton
Bay Model	1987	U.S. Army Corps of Engineers
Field trip guide to the geology of western Solano County	1991	S.H. Figuers
Tertiary and Quaternary tectonics of the boundary between the central Diablo range and the San Joaquin Valley	1992	M. Erskine
Wine and geology guide for fieldtrip of the Napa Valley	1995	D. Howell
When did Point Reyes Move North from Monterey?	1996	Joseph C. Clark/ Earl E. Brabb
Geology of the Keller Canyon Landfill and the Concord Naval Weapon Station	1996	Ray Sullivan/ Tim Bray/ Greg Bartow
Monterey Bay Aquarium and Research Institute and Moss Landing Marine Labs	1997	G. Greene/ Stakes
Geology of the Sutter Buttes	1998	Dr. Brian P. Hausback
Vallecitos syncline and Coalinga fossil hunt	1999	M. Erskine/ D. Howell
Caldecott Tunnel Tour	2001	R. Maihot/ M. Hart
Geology of the Monterey Bay region	2002	G. Greene
The Winemaker's Dance: Exploring Terroir in the Napa Valley, California	2004	David Howell
The Sutter Buttes	2007	M. Steinpress/ B. Hausback
Devil's Slide	2007	G. Wilcox
Coso Geothermal System	2008	Andrew Sabin
Key sites of uplift and glacial constraints, central Sierra Nevada	2008	J. Schaffer
Lassen Volcanic Park - a wonderland of volcanoes and thermal features	2013	P. Muffler

AAPG Delegate Opportunity

NCGS is entitled to have one member who is an AAPG member to serve as delegate to the House of Delegates, AAPG's legislative body. Don Lewis has been a delegate for many years but would be happy to pass the torch to someone who might be interested in AAPG's governance. The term is three years and the duties are few. There are one or a few Zoom meetings per year, but they are not burdensome. For more information, please contact Don at donlewis2 @ comcast.net.

Interesting 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

UC Berkeley's seminar series has returned for the academic year. Among a couple other talks currently listed, on Thursday, December 1, 2022, Lung Chan of the University of Hong Kong will speak on the topic ***Morphology and structures of hydrothermal breccias: Implications for subsurface hydrodynamics and thermodynamics***, 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 http://eps.berkeley.edu/events/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. There are talks scheduled through next April (except for December). On November 17 at 6:00 PM, John Mola, Associate Professor at Colorado State University and former USGS Research Ecologist, will speak on "***Endangered Bumble Bees: Science on the Threats and 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.

It's Membership Renewal Time!

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 HAVE A FACEBOOK GROUP! FIND US ON FACEBOOK @NCGEOLSOC AND TWITTER @NORCALGEOSOC

Check out our updated 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

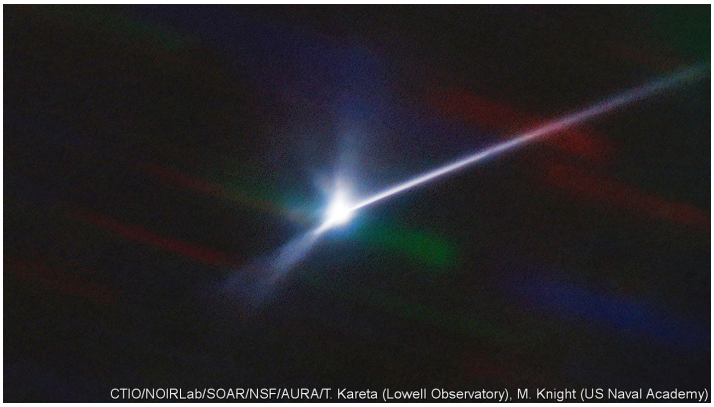
Board meetings (online for now) are open to all NCGS members. If you'd like to attend, please contact president Noelle Schoellkopf at NoellePrince @ sbcglobal.net. Board meetings generally are on Saturday mornings in Jan., Apr./May, and Aug./Sep. Upcoming meeting: **Saturday, January 7 (9 am)**, location to be determined.

Science & technology | The Double Asteroid Redirection Test

The DART planetary defense test worked 25 times better than hoped

A step has been taken towards protecting Earth from space rocks

From the October 15, 2022 issue of ***The Economist***



It worked! The Double Asteroid Redirection Test (DART) exceeded its minimum specification twenty-five-fold. This picture, taken by the Southern Astrophysical Research telescope, in Chile, shows the plume of debris ejected when that probe, which weighed 600 kg, hit Dimorphos, the asteroidal moonlet of a somewhat larger asteroid, Didymos, on September 26th. The hope was to change the time it took for Dimorphos to orbit, to demonstrate how something similar might be done to the trajectory of a space rock threatening Earth. The mission would have been deemed successful if the moonlet's orbit had changed by as little as 73 seconds. In fact, observations by telescopes on Earth, announced on October 11th, show that it changed by just over half an hour, from 11 hours 55 minutes to 11 hours 23 minutes, probably assisted by Dimorphos's recoil from the plume's release. The idea that an actual threat from space might thus be pushed away, is vindicated.

Impact that killed the dinosaurs triggered 'mega-earthquake' that lasted weeks to months

ScienceDaily: October 6, 2022
Source: Geological Society of America

Some 66 million years ago, a 10-kilometer asteroid hit Earth, triggering the extinction of the dinosaurs. New evidence suggests that the Chicxulub impact also triggered an earthquake so massive that it shook the planet for weeks to months after the collision. The amount of energy released in this "mega-earthquake" is estimated at 10^{23} joules, which is about 50,000 times more energy than was released in the magnitude 9.1 Sumatra earthquake in 2004.

Hermann Bermúdez presented evidence of this "mega-earthquake" on October 9 at the GSA Connects meeting in Denver. Earlier this year, with support from a GSA Graduate Student Research Grant, Bermúdez visited outcrops of the infamous Cretaceous-Paleogene (K-Pg) mass extinction event boundary in Texas, Alabama, and Mississippi to collect data, supplementing his previous

work in Colombia and Mexico documenting evidence of the catastrophic impact.

In 2014, while doing fieldwork on Colombia's Gorgonilla Island, Bermúdez found spherule deposits -- layers of sediment filled with small glass beads (as large as 1.1 mm) and shards known as 'tektites' and 'microtektites' that were ejected into the atmosphere during an asteroid impact. These glass beads formed when the heat and pressure of the impact melted and scattered the crust of the Earth, ejecting small, melted blobs up into the atmosphere, to then fall back to the surface as glass under the influence of gravity.

The rocks exposed on the coast of Gorgonilla Island tell a story from the bottom of the ocean -- roughly 2 km down. There, about 3,000-km southwest from the site of the impact, sand, mud, and small ocean creatures were accumulating on the ocean floor when the asteroid hit. Layers of mud and sandstone as far as 10-15 meters below the sea floor experienced soft-sediment deformation that is preserved in the outcrops today, which Bermúdez attributes to the shaking from the impact. Faults and deformation due to shaking continue up through the spherule-rich layer that was deposited post-impact, indicating that the shaking must have continued for the weeks and months it took for these finer-grained deposits to reach the ocean floor. Just above those spherule deposits, preserved fern spores signal the first recovery of plant-life after the impact.

Bermúdez explains, "The section I discovered on Gorgonilla Island is a fantastic place to study the K-Pg boundary, because it is one of the best-preserved and it was located deep in the ocean, so it was not affected by tsunamis."

Evidence of deformation from the mega-earthquake is also preserved in Mexico and the United States. At the El Papalote exposure in Mexico, Bermúdez observed evidence of liquefaction -- when strong shaking causes water-saturated sediments to flow like a liquid. In Mississippi, Alabama, and Texas, Bermúdez documented faults and cracks likely associated with the mega-quake. He also documents tsunami deposits at several outcrops, left by an enormous wave that was part of the cascading catastrophes resulting from the asteroid collision.

Bermúdez also presented a poster about his observations of tsunami deposits and earthquake-related deformation at the Denver conference on Monday, 10 October, which is available in English, Spanish, Italian, French, and Chinese. In discussing his research, he emphasized the important role collaboration has played in visiting and studying so many outcrops that tell the story of this extreme event in Earth's history. Bermudez is a PhD student in the Environmental Science and Management program at Montclair State University (New Jersey), and received a GSA research grant to support his field work.

Proceedings Reference:
https://gsa.confex.com/gsa/2022AM/meetingapp.cgi/Paper/377578.

Science & technology | Venus's LIPs

Unlucky LIPs may explain Venus's hostile environment

Huge volcanoes may have wrecked the Venusian climate—and may yet do the same to Earth's

From the October 15, 2022 issue of ***The Economist***

Venus and Earth are of almost equal size and grew from the same mixture of raw materials, yet while Earth has been wet and temperate for most of the 4.5 bn years it has existed, Venus is a bone-dry 450 °C pressure cooker.

This has only a little to do with Venus being closer to the Sun. Though it receives about twice as much sunshine as Earth, its slow rotation (from sunrise to sunrise its days last for 117 terrestrial ones) means that if Venus magically got as wet as Earth, those long, hot days would let thick cloud cover form. This would shield its surface, making it not much warmer than Earth is. Its oceans would not boil away.

Yet the evidence suggests they have. There are, for example, traces of erosion by water on some of the planet's older features. And the Venusian atmosphere is ridiculously rich in deuterium, a heavy isotope of hydrogen. This is thought to have come from a vanished ocean tens or hundreds of meters deep, the water of which evaporated. Molecules of the resulting vapor were then broken up by sunlight and the normal hydrogen in them escaped into space, leaving its heavier cousin behind.

Based on this idea, Michael Way of NASA calculated in 2016 that Venus could once have had a stable, temperate climate. Something bad must have happened to bring it to its present sorry state. And if Richard Ernst, of Carleton

University in Ottawa, Canada, is correct, that bad thing might one day happen to Earth, as well.

Dr Ernst outlined his theory of what occurred—which he developed jointly with Dr Way and Jeffrey Scargle, also of NASA—at a recent meeting in Denver of the Geological Society of America. It depends on the fact that, from time to time, Earth experiences huge volcanic eruptions which form basalt-covered areas called large igneous provinces (LIPs). These eruptions also burp vast amounts of CO_2 into the atmosphere.

One of the biggest of them, 252m years ago, caused the greatest mass extinction of animal life on Earth. Another, 66m years ago, probably helped do for most of the dinosaurs (though Earth's collision at this time with a large space rock is reckoned to have delivered the coup de grâce). But smaller LIP-forming eruptions also upset Earth's equilibrium. The greenhouse effect caused by the CO_2 released can increase the planet's temperature by 10-15 °C.

In the long term, that is a blip. But Drs Ernst, Way and Scargle wondered what would happen if two or more LIP-forming events occurred simultaneously.

By itself, a double LIP would serve only to make things hotter than a single one, before they then returned to normal. A triple LIP, however, or even a double one that occurred during a period with an already-hot climate, would raise the temperature past a tipping point. All surface water would evaporate—and water vapor is, itself, a greenhouse gas, so this would raise the temperature even further.

With no rain, no rivers and no oceans, there would be no erosion of rocks—a process that allows them to react with and sequester atmospheric CO_2. Plate tectonics would also grind to a halt, for it depends on the rocks of the ocean floor being waterlogged, and therefore heavy enough to sink into the underlying mantle. This buries carbon fixed in those rocks for eons. If that no longer happened Earth, like Venus, would remain hot and dry indefinitely.

But could such a coincidence realistically occur? The trio think so. The hundreds of LIPs found on Earth formed over a period of about 2.8 bn years. Those numbers are large enough for them to have carried out a statistical analysis.

First, they established that LIP-formation occurs at random. There is thus no reason why two or more events should not happen simultaneously. Given their average frequency—once every 15m years—the chances that, were history rerun, multiple simultaneous LIPs would have wrecked Earth's climate look to be about one in five.

Earth, then, has been lucky—and Venus perhaps unlucky. There are features on Venus which look like LIPs, but extensive volcanism about 700m years ago has made the planet's earlier history hard to read. That volcanism may, on the other hand, be a sign of the multiple LIPs that the trio reckon should be there.

For proof of their theory, Dr Ernst pins his hope on three probes which should visit Venus in the 2030s—*EnVision*, to be launched by the European Space Agency, and NASA's *Da Vinci* and *Veritas*. These will look in detail at both surface features and the composition of the atmosphere.

There might also, Dr Way reckons, be another way to add confidence to their idea. If the search for extraterrestrial planets turned up two like Earth and Venus that were in the same system, but with the one nearer to its star having oceans and the one farther away being in a runaway-greenhouse state, it would suggest that, one day, Earth's luck could run out as well.

Earth's newest secret: How volcanoes really work

Recent findings from Iceland's Fagradalsfjall eruptions change what we know about how volcanoes work

ScienceDaily: September 15, 2022
Source: University of California - Santa Barbara

It isn't every day that we learn something that fundamentally changes how we understand our world. But for UC Santa Barbara Earth scientist Matthew Jackson and the thousands of volcanologists across the globe, such a revelation has occurred.

While sampling magma from the Fagradalsfjall volcano in Iceland, Jackson and his collaborators uncovered a process far more dynamic than anyone had assumed in the two centuries scientists have been studying volcanoes.

"Just when I think we've gotten close to figuring out how these volcanoes work, we get a big surprise," he said. The geologists' findings are published in the journal *Nature*.

10,000 Years in a Month

It took a sabbatical, a pandemic and 780 years of melting subterranean rock to put Jackson in the right place and time to witness the birth of Fagradalsfjall, a fissure in the lowlands of southwest Iceland that split and exploded with magma in March 2021. By that time, he said, everyone on the Reykjanes Peninsula was ready for some kind of eruption.

"The earthquake swarm was intense," he said of the 50,000 or so temblors -- some magnitude 4 and higher -- that shook the earth for weeks and kept most of Iceland's population on edge. Scientists and visitors alike flocked to the area to see the newest section of the Earth's crust

form. They were able to get close enough to sample the lava continuously from the start, thanks to winds that blew the noxious gases away, and the lava's slow flow.

What the geologists, led by Sæmundur Halldórsson at the University of Iceland, were trying to find out was "how deep in the mantle the magma originated, how far beneath the surface it was stored before the eruption and what was happening in the reservoir both before and during the eruption."

[The next six paragraphs are from the *Nature* article:]

The 2021 eruption in the Fagradalsfjall complex was preceded by tectonic unrest from January 2020 and episodically during 2020, with the latest unrest cycle initiated by a magnitude 5.7 earthquake on 24 February 2021. After three weeks of intense seismicity, surface deformation indicated rifting accompanying a dike injection along normal faults in the vicinity of Fagradalsfjall. The intrusion reached the surface on 19 March 2021. The first several weeks of the eruption were characterized by a low to modest magma effusion rate of 1–8 $m^3\ s^{-1}$ from multiple vents, associated with formation of spatter cones and low-viscosity lava flows. The eruption style changed after April 27th with an increased discharge rate (9–13 $m^3\ s^{-1}$) from a single vent and high (more than 450 m) lava fountaining.

The Fagradalsfjall lavas are olivine tholeiite basalts with petrographic features (Extended Data Fig. 1) and major element compositions similar to Reykjanes Peninsula lavas erupted historically (that is, since settlement, circa AD 870). Whole-rock MgO and TiO_2 contents range from 8.8 to 10.0 wt% and from 0.95 to 1.12 wt%, respectively, for which the high-MgO content suggests the magmas were less processed in shallow magmatic plumbing systems, and here these are referred to as ‘primitive’.

The primitive character of the Fagradalsfjall lava is further indicated by its primitive crystal cargo, which is typical of magmas that have experienced limited low-pressure magmatic evolution. For example, macrocrysts have highly primitive cores: Cr-rich spinel with Cr# up to 50.2, Fo_{90} olivine, An_{91} plagioclase and green clinopyroxene with Mg# up to 88.8 and Cr_2O_3 up to 1.48 wt%.

In contrast to the RP lavas, the Fagradalsfjall lava displays an exceptionally wide range in ratios of incompatible minor elements K_2O and TiO_2 (0.124–0.263; Fig. 2a). K_2O/TiO_2 and other incompatible trace element ratios (ITERs) are insensitive to variations in modal crystal proportions and thus fractional crystallization. Although interactions between the magma and some magmatic phases (for example, titano-magnetite and amphibole) can fractionate K_2O/TiO_2, such phases are unlikely to be present in substantial proportions in the magma storage region. Moreover, in contrast with single-eruptive basaltic units (MgO > 6.5 wt%) from different parts of the Icelandic rift system, for which large datasets are available, the Fagradalsfjall lava has an uncommonly wide range in K_2O/TiO_2 values. Notably, it has been suggested that high-MgO units best preserve signatures associated with the Icelandic mantle (for example, Borgarhraun, North Iceland).

The large range in K_2O/TiO_2 became apparent in both whole-rock and glass samples as the eruption progressed. In only the first three weeks of the eruption, the Fagradalsfjall lava underwent a remarkable compositional shift in K_2O/TiO_2 and La/Yb—which are geochemical proxies that signify different mantle compositions and/or melting conditions—with both increasing by a factor of around 2. The Fagradalsfjall lava also records a simultaneous shift towards more radiogenic Sr and Pb, and less radiogenic Nd isotope ratios, confirming that the deeply derived, lower-degree melts from later in the eruption sample a higher proportion of an enriched mantle source with higher incompatible trace element concentrations, and radiogenic isotope signatures indicative of long-term incompatible trace element enrichment.

The frequent sampling of lavas during the eruption allows evaluation of the rate of geochemical change. In comparison to other eruptions for which high-resolution temporal data are available the Fagradalsfjall eruption has significantly greater rates of change in terms of mantle source indicators. For example, in comparison with Kīlauea’s Pu‘u ‘Ō‘ō 1983–2018 eruption, the Fagradalsfjall eruption shows larger geochemical source change over a shorter period of time. To show this, we quantify the rate of compositional shift for the Pu‘u ‘Ō‘ō eruption as dR/dt, where R represents the ratio of two incompatible elements or isotopes and t is time. Using the highest and lowest K_2O/TiO_2 values (0.19 in January 1983 and 0.17 in January 2015) as an example we calculate a dR/dt (0.02/32 yr) for Pu‘u ‘Ō‘ō of $6.3 \times 10^{-4}\ yr^{-1}$. In comparison, the rate of the source signature shifts at Fagradalsfjall (dR/dt = 0.1/0.12 yr) is some four orders of magnitude faster, or $0.81\ yr^{-1}$. For Pb isotopes ($^{206}Pb/^{204}Pb$), the comparison is similar: $6.3 \times 10^{-4}\ yr^{-1}$ for Pu‘u ‘Ō‘ō and $1\ yr^{-1}$ for Fagradalsfjall.

"The assumption was that a magma chamber fills up slowly over time, and the magma becomes well mixed," Jackson explained. "And then it drains over the course of the eruption." As a result of this well-defined two-step process, he added, those studying volcanic eruptions do not expect to see significant changes in the chemical composition of the magma as it flows out of the earth.

"This is what we see at Mount Kilauea, in Hawaii," he said. "You'll have eruptions that go on for years, and there will be minor changes over time.

"But in Iceland, there was more than a factor of 1,000 higher rates of change for key chemical indicators," Jackson continued. "In a month, the Fagradalsfjall eruption showed more compositional variability than the Kilauea eruptions showed in decades. The total range of chemical compositions that were sampled at this eruption over the course of the first month span the entire range that has ever erupted in southwest Iceland in the last 10,000 years."

According to the scientists, this variability is a result of subsequent batches of magma flowing into the chamber from deeper in the mantle.

"Picture a lava lamp in your mind," Jackson said. "You have a hot lightbulb at the bottom, it heats up a blob and the blob rises, cools and then sinks. We can think of the Earth's mantle -- from the top of the core to under the tectonic plates -- operating much like a lava lamp." As the heat causes regions of the mantle to rise and plumes form and move buoyantly upward toward the surface, he explained, molten rock from these plumes accumulates in chambers and crystallizes, gases escape through the crust and the pressure builds until the magma finds a way to escape.

For the first few weeks, as described in the paper, what erupted was the expected "depleted" magma type that had been accumulating in the reservoir, located about 10 miles (16 km) below the surface. But by April, evidence showed that the chamber was being recharged by deeper, "enriched" type melts with a different composition that were sourced from a different region of the upwelling mantle plume beneath Iceland. This new magma had a less modified chemical composition, with a higher magnesium content and a higher proportion of carbon dioxide gas, indicating that fewer gases from this deeper magma had escaped. By May, the magma that dominated the flow was the deeper, enriched type. These rapid, extreme changes in magma composition at a plume-fed hotspot, they say, "have never before been observed in near real-time."

These changes in composition may not be so rare, Jackson said; it's just that opportunities to sample eruptions at such an early stage are not common. For example, prior to the 2021 Fagradalsfjall eruption, the most recent eruptions on Iceland's Reykjanes peninsula occurred eight centuries ago. He suspects that this new activity signal the start of a new, possibly centuries-long volcanic cycle in southwest Iceland.

"We often don't have a record of the first stages of most eruptions because these get buried by lava flows from the later stages," he said. This project, according to the researchers, allowed them to see for the first time a phenomenon that was thought to be possible but had never been witnessed directly.

For the scientists, this result presents a "key constraint" in how models of volcanoes around the world will be built, though it is not yet clear how representative this phenomenon is of other volcanoes, or what role it plays in triggering an eruption. For Jackson, it's a reminder that the Earth still has secrets to yield.

"So when I go out to sample an old lava flow, or when I read or write papers in the future," he said, "it'll always be on my mind: This might not be the complete story of the eruption."

Journal Reference: Sæmundur A. Halldórsson, Edward W. Marshall, Alberto Caracciolo, Simon Matthews, Enikő Bali, Maja B. Rasmussen, Eemu Ranta, Jóhann Gunnarsson Robin, Guðmundur H. Guðfinnsson, Olgeir Sigmarsson, John Maclennan, Matthew G. Jackson, Martin J. Whitehouse, Heejin Jeon, Quinten H. A. van der Meer, Geoffrey K. Mibei, Maarit H. Kalliokoski, Maria M. Repczynska, Rebekka Hlín Rúnarsdóttir, Gylfi Sigurðsson, Melissa Anne Pfeffer, Samuel W. Scott, Ríkey Kjartansdóttir, Barbara I. Kleine, Clive Oppenheimer, Alessandro Aiuppa, Evgenia Ilyinskaya, Marcello Bitetto, Gaetano Giudice, Andri Stefánsson. **Rapid shifting of a deep magmatic source at Fagradalsfjall volcano, Iceland**. *Nature*, 2022; 609 (7927): 529 DOI: 10.1038/s41586-022-04981-x.

Laying geological groundwork for life on Earth

Study offers new, sharper proof of early plate tectonics, flipping of geomagnetic poles

ScienceDaily, October 24, 2022
Source: Harvard University

New research analyzing pieces of the most ancient rocks on the planet adds some of the sharpest evidence yet that Earth's crust was pushing and pulling in a manner similar to modern plate tectonics at least 3.25 billion years ago. The study also provides the earliest proof of when the planet's magnetic north and south poles swapped places.

The two results offer clues into how such geological changes may have resulted in an environment more conducive to the development of life on the planet.

The work, described in PNAS and led by Harvard geologists Alec Brenner and Roger Fu, focused on a portion of the Pilbara Craton in western Australia, one of the oldest and most stable pieces of the Earth's crust. Using novel techniques and equipment, the researchers show that some of the Earth's earliest surface was moving at a rate of 6.1 centimeters per year and 0.55 degrees every million years.

That speed more than doubles the rate the ancient crust was shown to be moving in a previous study by the same researchers. Both the speed and direction of this latitudinal drift leaves plate tectonics as the most logical and strongest explanations for it.

"There's a lot of work that seems to suggest that early in Earth's history plate tectonics wasn't actually the dominant way in which the planet's internal heat gets released as it is today through the shifting of plates," said Brenner, a Ph.D. candidate in the Graduate School of Arts and Sciences and member of Harvard's Paleomagnetics Lab. "This evidence lets us much more confidently rule out explanations that don't involve plate tectonics."

For example, the researchers can now argue against phenomena called "true polar wander" and "stagnant lid tectonics," which can both cause the Earth's surface to shift but aren't part of modern-style plate tectonics. The results lean more toward plate tectonic motion because the newly discovered higher rate of speed is inconsistent with aspects of the other two processes.

In the paper, the scientists also describe what's believed to be the oldest evidence of when Earth reversed its geomagnetic fields, meaning the magnetic North and South Pole flipped locations. This type of flip-flop is a common occurrence in Earth's geologic history with the pole's reversing 183 times in the last 83 million years and perhaps several hundred times in the past 160 million years, according to NASA.

The reversal tells a great deal about the planet's magnetic field 3.2 billion years ago. Key among these implications is that the magnetic field was likely stable and strong enough to keep solar winds from eroding the atmosphere. This insight, combined with the results on plate tectonics, offers clues to the conditions under which the earliest forms of life developed.

"It paints this picture of an early earth that was already really geodynamically mature," Brenner said. "It had a lot of the same sorts of dynamic processes that result in an Earth that has essentially more stable environmental and surface conditions, making it more feasible for life to evolve and develop."

Today, the Earth's outer shell consists of about 15 shifting blocks of crust, or plates, which hold the planet's continents and oceans. Over eons the plates drifted into each other and apart, forming new continents and mountains and exposing new rocks to the atmosphere, which led to chemical reactions that stabilized Earth's surface temperature over billions of years.

Evidence of when plate tectonics started is hard to come by because the oldest pieces of crust are thrust into the interior mantle, never to resurface. Only 5 percent of all rocks on Earth are older than 2.5 billion years old, and no rock is older than about 4 billion years.

Overall, the study adds to growing research that tectonic movement occurred relatively early in Earth's 4.5-billion-year history and that early forms of life came about in a more moderate environment. Members of the project revisited the Pilbara Craton in 2018, which stretches about 300 miles across. They drilled into the primordial and thick slab of crust there to collect samples that, back in Cambridge, were analyzed for their magnetic history.

Using magnetometers, demagnetizing equipment, and the Quantum Diamond Microscope -- which images the magnetic fields of a sample and precisely identifies the nature of the magnetized particles -- the researchers created a suite of new techniques for determining the age and way the samples became magnetized. This allows the researchers to determine how, when, and which direction the crust shifted as well as the magnetic influence coming from Earth's geomagnetic poles.

The Quantum Diamond Microscope was developed in a collaboration between Harvard researchers in the Departments of Earth and Planetary Sciences (EPS) and of Physics.

For future studies, Fu and Brenner plan keep their focus on the Pilbara Craton while also looking beyond it to other ancient crusts around the world. They hope to find older evidence of modern-like plate motion and when the Earth's magnetic poles flipped.

"Finally being able to reliably read these very ancient rocks opens up so many possibilities for observing a time period that often is known more through theory than solid data," said Fu, professor of EPS in the Faculty of Arts and Sciences. "Ultimately, we have a good shot at reconstructing not just when tectonic plates started moving, but also how their motions -- and therefore the deep-seated Earth interior processes that drive them -- have changed through time."

Journal Reference: Alec R. Brenner, Roger R. Fu, Andrew R. C. Kylander-Clark, George J. Hudak, Bradford J. Foley. **Plate motion and a dipolar geomagnetic field at 3.25 Ga.** *Proceedings of the National Academy of Sciences*, 2022; 119 (44) DOI: 10.1073/pnas.2210258119.

500-million-year-old fossils reveal answer to evolutionary riddle

ScienceDaily: November 2, 2022
Source: University of Oxford

An exceptionally well-preserved collection of fossils discovered in eastern Yunnan Province, China, has enabled scientists to solve a centuries-old riddle in the evolution of life on earth, revealing what the first animals

to make skeletons looked like. The results have been published in *Proceedings of the Royal Society B*.

The first animals to build hard and robust skeletons appear suddenly in the fossil record in a geological blink of an eye around 550-520 million years ago during an event called the Cambrian Explosion. Many of these early fossils are simple hollow tubes ranging from a few millimeters to many centimeters in length. However, what sort of animals made these skeletons was almost completely unknown, because they lack preservation of the soft parts needed to identify them as belonging to major groups of animals that are still alive today.

The new collection of 514-million-year-old fossils includes four specimens of *Gangtoucunia* aspera with soft tissues still intact, including the gut and mouthparts. These reveal that this species had a mouth fringed with a ring of smooth, unbranched tentacles about 5 mm long. It's likely that these were used to sting and capture prey, such as small arthropods. The fossils also show that *Gangtoucunia* had a blind-ended gut (open only at one end), partitioned into internal cavities, that filled the length of the tube.

These are features found today only in modern jellyfish, anemones and their close relatives (known as cnidarians), organisms whose soft parts are extremely rare in the fossil record. The study shows that these simple animals was among the first to build the hard skeletons that make up much of the known fossil record.

According to the researchers, *Gangtoucunia* would have looked similar to modern scyphozoan jellyfish polyps, with a hard tubular structure anchored to the underlying substrate. The tentacle mouth would have extended outside the tube, but could have been retracted inside the tube to avoid predators. Unlike living jellyfish polyps however, the tube of *Gangtoucunia* was made of calcium phosphate, a hard mineral that makes up our own teeth and bones. Use of this material to build skeletons has become more rare among animals over time.

Corresponding author Dr Luke Parry, Department of Earth Sciences, University of Oxford, said: “This really is a one-in-million discovery. These mysterious tubes are often found in groups of hundreds of individuals, but until now they have been regarded as ‘problematic’ fossils, because we had no way of classifying them. Thanks to these extraordinary new specimens, a key piece of the evolutionary puzzle has been put firmly in place.”

The new specimens clearly demonstrate that *Gangtoucunia* was not related to annelid worms (earthworms, polychaetes and their relatives) as had been previously suggested for similar fossils. It is now clear that *Gangtoucunia's* body had a smooth exterior and a gut partitioned longitudinally, whereas annelids have segmented bodies with transverse partitioning of the body. The fossil was found at a site in the Gaoloufang section in Kunming, eastern Yunnan Province, China. Here, anaerobic (oxygen-poor) conditions limit the presence of bacteria that normally degrade soft tissues in fossils.

PhD student Guangxu Zhang, who collected and discovered the specimens, said: “The first time I discovered the pink soft tissue on top of a *Gangtoucunia* tube, I was surprised and confused about what they were. In the following month, I found three more specimens with soft tissue preservation, which was very exciting and made me rethink the affinity of *Gangtoucunia*. The soft tissue of *Gangtoucunia*, particularly the tentacles, reveals that it is certainly not a priapulid-like worm as previous studies suggested, but more like a coral, and then I realized that it is a cnidarian.”

Although the fossil clearly shows that *Gangtoucunia* was a primitive jellyfish, this doesn't rule out the possibility that other early tube-fossil species looked very different. From Cambrian rocks in Yunnan province, the research team have previously found well-preserved tube fossils that could be identified as priapulids (marine worms), lobopodians (worms with paired legs, closely related to arthropods today) and annelids.

Co-corresponding author Xiaoya Ma (Yunnan University and University of Exeter) said: “A tubicolous mode of life seems to have become increasingly common in the Cambrian, which might be an adaptive response to increasing predation pressure in the early Cambrian. This study demonstrates that exceptional soft-tissue preservation is crucial for us to understand these ancient animals.”

Related Multimedia: Fossil specimen and diagram of *Gangtoucunia* aspera preserving soft tissues, including the gut and tentacle

Journal Reference: Guangxu Zhang, Luke A. Parry, Jakob Vinther, Xiaoya Ma. **Exceptional soft tissue preservation reveals a cnidarian affinity for a Cambrian phosphatic tubicolous enigma.** *Proceedings of the Royal Society B: Biological Sciences*, 2022; 289 (1986) DOI: 10.1098/rspb.2022.1623.

Land plants changed Earth's composition

ScienceDaily: August 30, 2022
Source: University of Southampton

Scientists at the University of Southampton have discovered that the evolution of land plants caused a sudden shift in the composition of Earth's continents.

The Southampton researchers, led by Dr Tom Gernon, working with Queen's University Canada, led by Dr

Christopher Spencer, and colleagues at the University of Cambridge, the University of Aberdeen, and the China University of Geosciences, Wuhan, studied the effects of land plant evolution on Earth's chemical composition over the past 700 million years.

The researchers' findings are published in the journal *Nature Geoscience*.

The evolution of land plants took place about 430 million years ago during the Silurian Period, when North America and Europe were conjoined in a landmass called Pangaea.

The proliferation of plants completely transformed Earth's biosphere -- those parts of the planet's surface where life thrives -- paving the way for the advent of dinosaurs about 200 million years later.

"Plants caused fundamental changes to river systems, bringing about more meandering rivers and muddy floodplains, as well as thicker soils," says Dr Christopher Spencer, Assistant Professor at Queen's University in Kingston, Ontario, lead author of the study. "This shift was tied to the development of plant rooting systems that helped produce colossal amounts of mud (by breaking down rocks) and stabilized river channels, which locked up this mud for long periods."

The team recognized that Earth's surface and deep interior are linked by plate tectonics -- rivers flush mud into the oceans, and this mud then gets dragged into the Earth's molten interior (or mantle) at subduction zones where it gets melted to form new rocks.

"When these rocks crystallize, they trap in vestiges of their past history," says Dr Tom Gernon, Associate Professor of Earth Science at the University of Southampton and co-author of the study. "So, we hypothesized that the evolution of plants should dramatically slow down the delivery of mud to the oceans, and that this feature should be preserved in the rock record -- it's that simple."

To test this idea, the team studied a database of over five thousand zircon crystals formed in magmas at subduction zones -- essentially 'time capsules' that preserve vital information on the chemical conditions that prevailed on Earth when they crystallized.

The team uncovered compelling evidence for a dramatic shift in the composition of rocks making up Earth's continents, which coincides almost precisely with the onset of land plants.

Notably, the scientists also found that the chemical characteristics of zircon crystals generated at this time indicate a significant slowing down of sediment transfer to the oceans, just as they had hypothesized.

The researchers show that vegetation changed not only the surface of the Earth, but also the dynamics of melting in Earth's mantle. "It is amazing to think that the greening of the continents was felt in the deep Earth," concludes Dr Spencer.

"Hopefully this previously unrecognized link between the Earth's interior and surface environment stimulates further study."

Journal Reference: Christopher J. Spencer, Neil S. Davies, Thomas M. Gernon, Xi Wang, William J. McMahon, Taylor Rae I. Morrell, Thea Hincks, Peir K. Pufahl, Alexander Brasier, Marina Seraine, Gui-Mei Lu. **Composition of continental crust altered by the emergence of land plants.** *Nature Geoscience*, 2022; DOI: 10.1038/s41561-022-00995-2.

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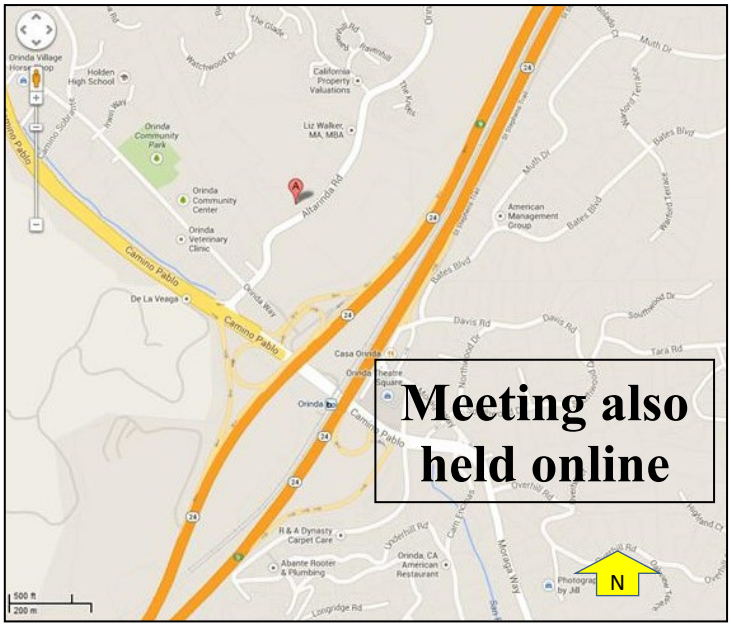

(Continued from Page 1)

Biography:

Marty Grove is a native southern Californian with a PhD in Geology from UCLA (1993) who has been a professor in the Geological Sciences department (School of Earth, Energy, and Environmental Sciences) at Stanford University since 2008. Grove meshes field studies, petrology, structure, tectonics, geochemistry, and geo/thermochronology to elucidate the nature and rates of lithospheric deformation processes.

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