NORTHERN CALIFORNIA GEOLOGICAL SOCIETY

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MEETING ANNOUNCEMENT

DATE: **Wednesday, January 25, 2023**

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: ***Dr. Erik Sperling, Stanford University***

TOPIC: ***"The Environmental Context of Early Animal Evolution"***

Abstract:

Animals originated and evolved during one of the most unique times in Earth history—the Neoproterozoic Era—and early animal evolution has long been causally linked to environmental change during this interval. However, geochemical patterns of change are often noisy, and no stratigraphic section covers the entirety of Earth history; global database studies are required. Here, data from the Sedimentary Geochemistry and Paleoenvironments Project (SGP) will be used to demonstrate how machine learning methods and an increased emphasis on accounting for sampling bias can yield a more resolved pattern of environmental change in deep time. The talk will also discuss the prospects and pitfalls of 'team science' approaches in the geological sciences. The results suggest that early animals evolved in a Neoproterozoic world that had lower oxygen levels and lower primary productivity than the Paleozoic, although the magnitude of oxygen change at the dawn of the Phanerozoic was likely less than commonly hypothesized. Finally, ecosystems along modern natural gradients of oxygen and primary productivity will be used to conceptualize Neoproterozoic ecosystems and deduce the possible role of environmental change in the Cambrian 'explosion' of animal life.

Biography: I graduated with an undergrad and Master's from Stanford University, and after my doctorate and postdoc on the East Coast I feel very lucky to be back in the Bay Area teaching at Stanford again. My research interests are Earth history and the evolution of life, and the interactions between the biosphere and the geosphere. As such, this research can generally be considered paleontology, insofar as paleontology encompasses all aspects of the history of life. My research incorporates multiple lines of evidence, and multiple tools, to investigate questions in the history of life. These lines of evidence include fossil data, molecular phylogenetics, sedimentary geochemistry, and ecological and physiological data from modern organisms. Ultimately, the goal is to link environmental change with organismal and ecological response through the lens of physiology.

NCGS 2022 – 2023 Calendar

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 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, January 22, 2023. Zoom **invitations will be emailed** Monday, January 23, **by 7 PM,** via a calendar invitation that you simply accept (YES) to place it 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 (included in the invitation) may be required as well. 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. 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.

K-12 news this month 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 November Presentation

We held another excellent meeting in November – both live and via Zoom – and we hope that all who wanted to see the talk 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/p10Pxw1as-b9N1yc7fzpug4Zp7q0QyF9v99QcMmlOObuT8tnMETu0xcmm_E_YkPB.h-L-ctPtfXc6XyAL.

Passcode: jvV7&uaG

(**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

Rock Identification Quiz!

Tom MacKinnon presents this query: Anyone know what this is? It's heavy, consists of carbonate mud, is fully indurated but soft when scratched. Layers, laminations, or platelets; feels heavy. No context, but it was found in an illegally dumped pile. He thinks it's local, from freshwater or a marsh. Will S. suggested some sort of spring deposit.

If you have an idea, please contact Tom at tom.mackinnon @ comcast.net. The second photo is a cut slice.

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. On Thursday, February 2, 2022, Helen Fitzmaurice of UC Berkeley will speak on the topic ***Using Local Data to Bring Climate Change into OUSD Classrooms (exit seminar)***, 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 April. On January 26 at 6:00 PM, Charles Mandeville, USGS Volcano Hazards Program Coordinator, will speak on "***Building a National Volcano Early Warning System (NVEWS) for the Future.***" 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

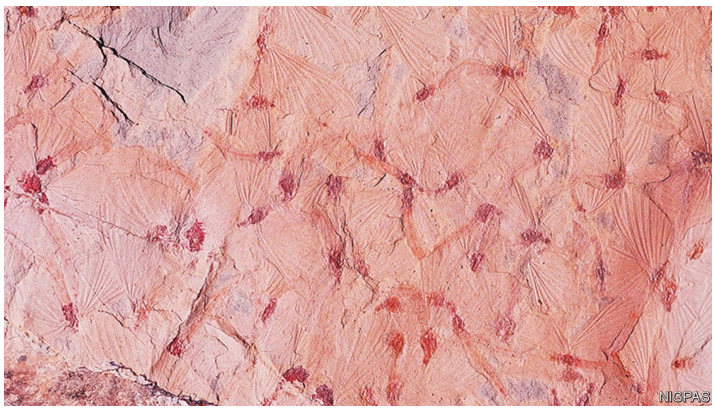
Board meetings (online for now) are open to all NCGS members. If you'd like to attend, please contact President Noelle Schoellkopf at NoellePrince @ sbcglobal.net. Board meetings generally are on Saturday mornings in Jan., Apr./May, and Aug./Sep. Upcoming meeting: **Saturday, May 13 (9 am)**, location to be determined.

The oldest mayfly swarm

A feast for Jurassic insectivores

From the December 7, 2022 issue of ***The Economist***

Below is part of the oldest known mayfly swarm. It was collected, by a team led by Zhang Qianqi of the Nanjing Institute of Geology and Palaeontology, from a site near Hezhou, in southern China, and is reported in the latest edition of *Geology*. Some 180 million years ago, during the early part of the Jurassic period, this site was a lake where mayflies lived and swarmed to mate, as they do today, providing, as a side-effect, a feast for local insectivores. These probably included small pterosaurs, but not birds, which had not yet evolved. Insects rarely fossilize well in rock (though they do in amber), but in this case exquisite anatomical details of the creatures are visible in the mudstone that has solidified from the lake's sediments.



Evolution of tree roots may have driven mass extinctions

Geologists find parallels between ancient, global-scale extinction events and modern threats to Earth's oceans

ScienceDaily, November 9, 2022
Source: Indiana University

The evolution of tree roots may have triggered a series of mass extinctions that rocked the Earth's oceans during the Devonian Period over 300 million years ago, according to a study led by scientists at IUPUI, along with colleagues in the United Kingdom.

Evidence for this new view of a remarkably volatile period in Earth's pre-history is reported in the *Geological Society of America Bulletin*. The study was led by Gabriel Filippelli, Chancellor's Professor of Earth Sciences in the School of Science at IUPUI, and Matthew Smart, a Ph.D. student in his lab at the time of the study.

"Our analysis shows that the evolution of tree roots likely flooded past oceans with excess nutrients, causing massive algae growth," Filippelli said. "These rapid and destructive algae blooms would have depleted most of the oceans' oxygen, triggering catastrophic mass extinction events."

The Devonian Period, which occurred 419 million to 358 million years ago, prior to the evolution of [extensive] life on land, is known for mass extinction events, during which it's estimated nearly 70 percent of all life on Earth perished.

The process outlined in the study -- known scientifically as eutrophication -- is remarkably similar to modern, albeit smaller-scale, phenomenon currently fueling broad "dead zones" in the Great Lakes and the Gulf of Mexico, as excess nutrients from fertilizers and other agricultural

runoff trigger massive algae blooms that consume all of the water's oxygen.

The difference is that these past events were likely fueled by tree roots, which pulled nutrients from the land during times of growth, then abruptly dumped them into the Earth's water during times of decay.

The theory is based upon a combination of new and existing evidence, Filippelli said. Based upon a chemical analysis of stone deposits from ancient lake beds -- whose remnants persist across the globe, including the samples used in the study from sites in Greenland and off the northeast coast of Scotland -- the researchers were able to confirm previously identified cycles of higher and lower levels of phosphorus, a chemical element found in all life on Earth.

They were also able to identify wet and dry cycles based upon signs of "weathering" -- or soil formation -- caused by root growth, with greater weathering indicating wet cycles with more roots and less weathering indicating dry cycles with fewer roots.

Most significantly, the team found the dry cycles coincided with higher levels of phosphorus, suggesting dying roots released their nutrients into the planet's water during these times.

"It's not easy to peer over 370 million years into the past," said Smart. "But rocks have long memories, and there are still places on Earth where you can use chemistry as a microscope to unlock the mysteries of the ancient world."

In light of the phosphorus cycles occurring at the same time as the evolution of the first tree roots -- a feature of Archaeopteris, also the first plant to grow leaves and reach heights of 30 feet -- the researchers were able to pinpoint the decay of tree roots as the prime suspect behind the Devonian Periods extinction events.

Fortunately, Filippelli said, modern trees don't wreak similar destruction since nature has since evolved systems to balance out the impact of rotting wood. The depth of modern soil also retains more nutrients compared to the thin layer of dirt that covered the ancient Earth.

But the dynamics revealed in the study shed light on other newer threats to life in Earth's oceans. The study's authors note that others have made the argument that pollution from fertilizers, manure and other organic wastes, such as sewage, have placed the Earth's oceans on the "edge of anoxia," or a complete lack of oxygen.

"These new insights into the catastrophic results of natural events in the ancient world may serve as a warning about the consequences of similar conditions arising from human activity today," Fillipelli said.

Additional authors on the paper are William P. Gilhooly III of IUPUI and John Marshall and Jessica Whiteside of the University of Southampton, United Kingdom. Smart is currently an assistant professor of oceanography at the U.S. Naval Academy. This study was supported in part by the National Science Foundation.

Journal Reference: Matthew S. Smart, Gabriel Filippelli, William P. Gilhooly III, John E.A. Marshall, Jessica H. Whiteside. **Enhanced terrestrial nutrient release during the Devonian emergence and expansion of forests: Evidence from lacustrine phosphorus and geochemical records**. *GSA Bulletin*, 2022; DOI: 10.1130/B36384.1.

Giant mantle plume reveals Mars is more active than previously thought

ScienceDaily: December 5, 2022
Source: University of Arizona

On Earth, shifting tectonic plates reshuffle the planet's surface and make for a dynamic interior, so the absence of such processes on Mars led many to think of it as a dead planet, where not much happened in the past 3 billion years.

In the current issue of *Nature Astronomy*, scientists from the University of Arizona challenge current views of Martian geodynamic evolution with a report on the discovery of an active mantle plume pushing the surface upward and causing earthquakes and volcanic eruptions. The finding suggests that the planet's deceptively quiet surface may hide a more tumultuous interior than previously thought.

"Our study presents multiple lines of evidence that reveal the presence of a giant active mantle plume on present-day Mars," said Adrien Broquet, a postdoctoral research associate in the UArizona Lunar and Planetary Laboratory and co-author of the study with Jeff Andrews-Hanna, an associate professor of planetary science at the LPL.

Mantle plumes are large blobs of warm and buoyant rock that rise from deep inside a planet and push through its intermediate layer -- the mantle -- to reach the base of its crust, causing earthquakes, faulting, and volcanic eruptions. The island chain of Hawaii, for example, formed as the Pacific plate slowly drifted over a mantle plume.

"We have strong evidence for mantle plumes being active on Earth and Venus, but this isn't expected on a small and supposedly cold world like Mars," Andrews-Hanna said. "Mars was most active 3 to 4 billion years ago, and the prevailing view is that the planet is essentially dead today."

"A tremendous amount of volcanic activity early in the planet's history built the tallest volcanoes in the solar system and blanketed most of the northern hemisphere in

volcanic deposits," Broquet said. "What little activity has occurred in recent history is typically attributed to passive processes on a cooling planet."

The researchers were drawn to a surprising amount of activity in an otherwise nondescript region of Mars called Elysium Planitia, a plain within Mars' northern lowlands close to the equator. Unlike other volcanic regions on Mars, which haven't seen major activity for billions of years, Elysium Planitia experienced large eruptions over the past 200 million years.

"Previous work by our group found evidence in Elysium Planitia for the youngest volcanic eruption known on Mars," Andrews-Hanna said. "It created a small explosion of volcanic ash around 53,000 years ago, which in geologic time is essentially yesterday."

Volcanism at Elysium Planitia originates from the Cerberus Fossae, a set of young fissures that stretch for more than 800 miles across the Martian surface. Recently, NASA's InSight team found that nearly all Martian quakes, or marsquakes, emanate from this one region. Although this young volcanic and tectonic activity had been documented, the underlying cause remained unknown.

On Earth, volcanism and earthquakes tend to be associated with either mantle plumes or plate tectonics, the global cycle of drifting continents that continually recycles the crust.

"We know that Mars does not have plate tectonics, so we investigated whether the activity we see in the Cerberus Fossae region could be the result of a mantle plume," Broquet said.

Mantle plumes, which can be viewed as analogous to hot blobs of wax rising in lava lamps. give away their presence on Earth through a classical sequence of events. Warm plume material pushes against the surface, uplifting and stretching the crust. Molten rock from the plume then erupts as flood basalts that create vast volcanic plains.

When the team studied the features of Elysium Planitia, they found evidence of the same sequence of events on Mars. The surface has been uplifted by more than a mile, making it one of the highest regions in Mars' vast northern lowlands. Analyses of subtle variations in the gravity field indicated that this uplift is supported from deep within the planet, consistent with the presence of a mantle plume.

Other measurements showed that the floor of impact craters is tilted in the direction of the plume, further supporting the idea that something pushed the surface up after the craters formed. Finally, when researchers applied a tectonic model to the area, they found that the presence of a giant plume, 2,500 miles wide, was the only way to explain the extension responsible for forming the Cerberus Fossae.

"In terms of what you expect to see with an active mantle plume, Elysium Planitia is checking all the right boxes," Broquet said, adding that the finding poses a challenge for models used by planetary scientists to study the thermal evolution of planets. "This mantle plume has affected an area of Mars roughly equivalent to that of the continental United States. Future studies will have to find a way to account for a very large mantle plume that wasn't expected to be there.

"We used to think that InSight landed in one of the most geologically boring regions on Mars -- a nice flat surface that should be roughly representative of the planet's lowlands," Broquet added. "Instead, our study demonstrates that InSight landed right on top of an active plume head."

The presence of an active plume will affect interpretations of the seismic data recorded by InSight, which must now take into account the fact that this region is far from normal for Mars.

"Having an active mantle plume on Mars today is a paradigm shift for our understanding of the planet's geologic evolution," Broquet said, "similar to when analyses of seismic measurements recorded during the Apollo era demonstrated the moon's core to be molten."

Their findings could also have implications for life on Mars, the authors say. The studied region experienced floods of liquid water in its recent geologic past, though the cause has remained a mystery. The same heat from the plume that is fueling ongoing volcanic and seismic activity could also melt ice to make the floods -- and drive chemical reactions that could sustain life deep underground.

"Microbes on Earth flourish in environments like this, and that could be true on Mars, as well," Andrews-Hanna said, adding that the discovery goes beyond explaining the enigmatic seismic activity and resurgence in volcanic activity. "Knowing that there is an active giant mantle plume underneath the Martian surface raises important questions regarding how the planet has evolved over time. "We're convinced that the future has more surprises in store."

Journal Reference: A. Broquet, J. C. Andrews-Hanna. **Geophysical evidence for an active mantle plume underneath Elysium Planitia on Mars**. *Nature Astronomy*, 2022; DOI: 10.1038/s41550-022-01836-3.

Science & technology | Paleonotology

A new explanation for ankylosaurs' clubbed tails

They were for fighting other ankylosaurs, rather than fending off predators

From the December 7, 2022 issue of ***The Economist***

Few dinosaurs evoke images of dramatic battle better than *Ankylosaurus*. This seven-meter-long late-Cretaceous herbivore, shielded by thick bony plates and armed with a club at the end of its tail, has been depicted for decades using its weapon to batter the likes of *Tyrannosaurus*. No doubt it did, if need arose. But a paper in Biology Letters by Victoria Arbour of the Royal British Columbia Museum, in Victoria, Canada, suggests this was not a club's main purpose. That, she and her colleagues reckon, was to bash other ankylosaurs.

Ankylosaurs came in many species. *Anklyosaurus* itself was merely the first to be discovered. In 2017 Dr Arbour and her team found yet another. They called it Zuul crurivastator. Zuul was a demon in "Ghostbusters", a film from the 1980s. This demon's head, they thought, resembled that of their find. "Crurivastator" means "destroyer of shins"—for back then, Dr Arbour accepted conventional wisdom that tail-clubs were for bashing the legs of predators.

But a closer look raised doubts. The fossil is spectacularly preserved, which let the team study its armored plates in detail. Many of those on its flanks show signs of injury. Plates on most of the rest of the body do not. Nor was this flank-damage from the piercing teeth or slashing claws of predators. Rather, it was the result of being hit by something hard and heavy. On top of this, the damaged plates had healed to different degrees, indicating not only that the bashing had not been lethal, but also that it had happened numerous times.

All this suggests ankylosaurs used their clubs to hit one another, did so frequently, and that (because of the local nature of the damage) such fights had a ritual quality to them—like contests between modern-day bison, rams and red deer. Those fights are over mates, which is what Dr Arbour suggests was also going on with ankylosaurs.

There is a wrinkle. Sexually selected weapons are generally restricted to males, and it is impossible to tell a dinosaur's sex from its fossilized remains. To add to the confusion, many of the 20-25 seriously large ankylosaur tail-clubs that have been found were discovered detached from the rest of the animal. When the assumption was that clubs were for defense, it was logical to assume also that both sexes were thus armed. Now, the question is open.

In modern animals, if females are armed like males, it is usually to protect resources rather than garner mates. This is why, among deer, only reindeer sport antlers regardless of sex. Females' antlers are smaller than males', and, unlike males', are retained over winter. Their purpose is to aid defense of patches of ground their wearers have cleared of snow to reach the lichen beneath, at a time when they are pregnant and in need of good nutrition. Female cattle are likewise armed with horns which, though not as big as a bull's, are sufficient to defend their feeding territories.

Whether something similar pertained to ankylosaurs is difficult to determine from the existing evidence. But, either way, the image of the sturdy ankylosaur defending itself fiercely against the unwanted attention of predators is probably the exception. Rather, males were beating up other males—and, possibly, females other females. Not quite such a heroic picture.

A Cathedral Tried to Approach Heaven, but the Earth Held a Deep Secret

Flows of spring water cut the planned height of St. John the Divine in half and prompted studies to illuminate the church's watery past and future

From ***The New York Times***, Dec. 23, 2022
By William J. Broad; photographs by George Etheredge
Published Dec. 23, 2022; Updated Dec. 26, 2022

The Cathedral Church of St. John the Divine, set on a cliff, could have dominated Manhattan's emerging skyline. It could have soared to dazzling heights, its central tower 445 feet high, dwarfing all else, including the Statue of Liberty.

"It was to be the end-all be-all," said Janet Adams Strong, an architectural historian who wrote her doctoral thesis on the Episcopal cathedral. "They didn't anticipate problems. And why should they? It was an era of great optimism."

But nature demurred. The cathedral's chosen ground turned out to be honeycombed with springs and decomposing rock. The surprise led planners to delay the

church's foundation and eventually to scrap the looming tower, beginning what in time became known as St. John the Unfinished. Though it is now a defining New York City institution, it remains half-built after some 130 years, its front towers little more than stubs.

Manhattan — a land of steel towers and countless triumphs over nature — turns out to possess a lost history in which the subterranean remnants of springs and streams have destabilized many buildings, perhaps hundreds in all.

Early on, the hidden waters roiled St. John's. Lingering trickles can still be found in a lair deep beneath the cathedral, deeper than even the crypt, which holds the tombs of deceased bishops and runs the length of the gigantic church.

The upwellings in the subbasement are largely unknown to the public and can evoke more fancy than fact among church staffers. One said the vault held a river; another, a creek. Such descriptions may reflect old impressions but today appear to be unfounded. Officials say the worst of the flooding has subsided in recent years. The keepers of the crypt have a theory as to what caused the flow's reduction, but they have yet to pin down the water's origin.

The uncertainties have prompted church officials to study old photos, books and records to better understand how the springs arose, begot the church's early construction woes and got elevated at one point into the waters of baptism. Eager for clues, staff members are discussing an experiment that would inject dye into the residual flows as a way to track their wanderings across the church's 11-acre property.

The Very Rev. Patrick Malloy, St. John's lead cleric, called the water "a great blessing," despite the havoc it wrought. "It's primal and real," he said. "It connotes life." God, he emphasized, "is revealed in natural things."

Tales From Beneath the Crypt

My wife and I live near St. John the Divine. When we toured the cathedral this year, my ears perked up when a guide mentioned deep waters in the subbasement. After months of research and questions, talks and interviews, I finally got a chance to take a look.

The scouting party was led by Lisa A. Schubert, head of public affairs for the cathedral, and Keith C. Hinkson, head of cathedral security. We descended a long staircase into the church's crypt. Surprisingly, the area was well lit, its ceiling high. A vast storage area, the crypt held not only tombs and piles of equipment but elegant light fixtures from the long-demolished Pennsylvania Station.

As we moved through the crypt toward the subbasement's entrance, I saw dark footprints ahead of us, their dampness making them stand out against the concrete floor. "This is where it's always wet," Mr. Hinkson said.

We approached an area where the floor was covered with about a half-inch of watery sludge. At the bottom, we stopped. The reconnaissance over, we retraced our steps. Our brief look was a reasonable start. But understanding what was really going on beneath the cathedral was going to take more digging.

A Metropolis Set on Stone

Manhattan's bedrock is primarily schist — a hard metamorphic rock strong enough to support miles of skyscrapers. Typically, schist is also poor at letting water seep through its pores because its mineral grains are so tightly packed.

However, Manhattan schist is riddled with fissures through which water can flow. "We're talking about relatively thin openings — not something a person could splash through," said William H. Menke, a geologist at Columbia University.

But water running through schist can decompose it. Dr. Menke said the hard rock's mineral components can turn into sand and clay. Over geologic time, the clay can turn into shale, a soft sedimentary rock that easily splits into fragile slabs.

In the last ice age, Manhattan was covered with an immense sheet of frozen water, perhaps one-third of a mile thick. Starting 18,000 years ago, the ice pack began to melt.

What emerged from the watery chaos was a heavily forested isle full of ponds, brooks, springs, rivers, swamps, marshes and tidal inlets. Eric W. Sanderson, author of a natural history of Manhattan, said hundreds of freshwater springs attracted the island's first Indigenous settlers, then European colonists eager to avoid the Hudson's brackish waters.

Early maps of Manhattan — dated 1782 and 1865 — depict a number of rivers and bodies of water on the plateau that became Morningside Heights, the neighborhood where St. John the Divine was eventually built.

Egbert L. Viele, a graduate of the Military Academy and Civil War veteran who made the 1865 map, became a public voice of caution on the dangers of building atop the old springs and riverbeds. In 1892, the year St. John's cornerstone was laid, The New York Times quoted him as warning that subterranean water "is constantly bubbling out of the rocks on which the city is built."

Morningside Heights was rural into the late 1800s. St. John's was among the first large institutions to arrive, followed by St. Luke's Hospital (now Mount Sinai Morningside), Columbia University and many other scholarly and religious bodies. The developers of Morningside Heights found lots of Manhattan schist. They

also discovered that the quality of the rock varied drastically from site to site.

A Site of 'Commanding Dignity'

The foremost proponent of the cathedral was Henry C. Potter, a wealthy man who eventually married an heir to the Singer Sewing Machine fortune. The company's tower in Lower Manhattan was briefly the world's tallest. In 1887, when the Right Reverend Potter became the Episcopal bishop of New York, he had the connections and, it appeared, the financial backing to erect in Upper Manhattan what he saw as America's pre-eminent church.

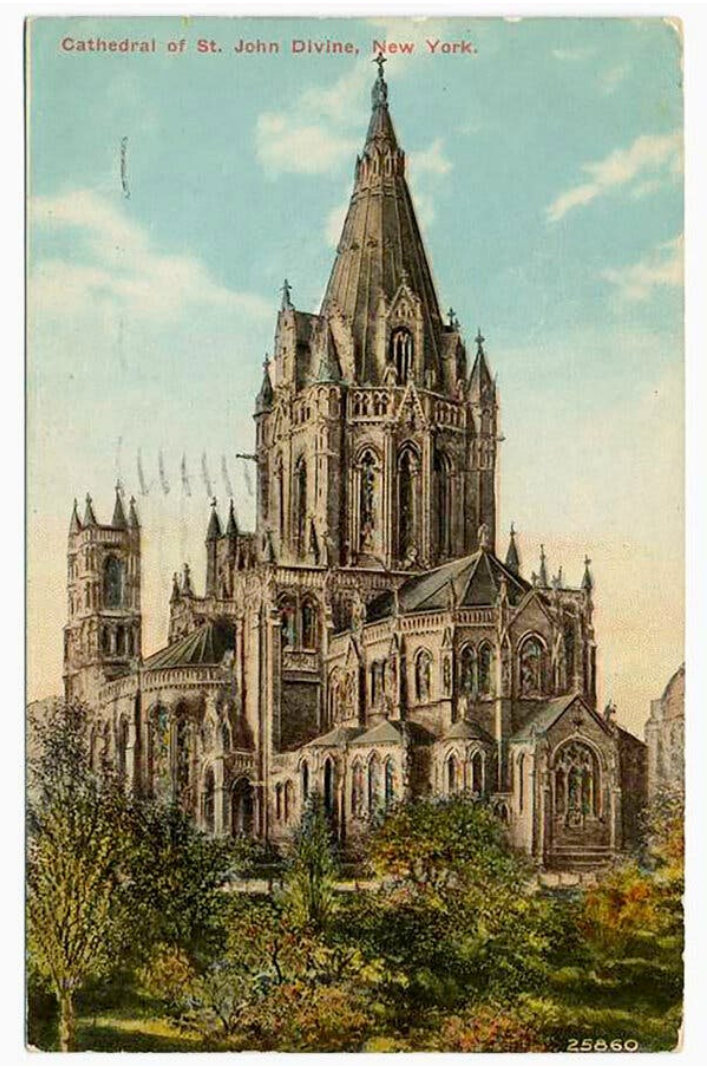
He and his advisers chose a parcel of sloping land that ran along a cliff extending from West 113 Street to West 110 Street, which became known as Cathedral Parkway. Set on the second highest point in Manhattan, the site offered a sweeping view of the rising metropolis.

"No cathedral in any great city in the world has today a site which, for commanding dignity, will approach that which we have secured," Bishop Potter declared.

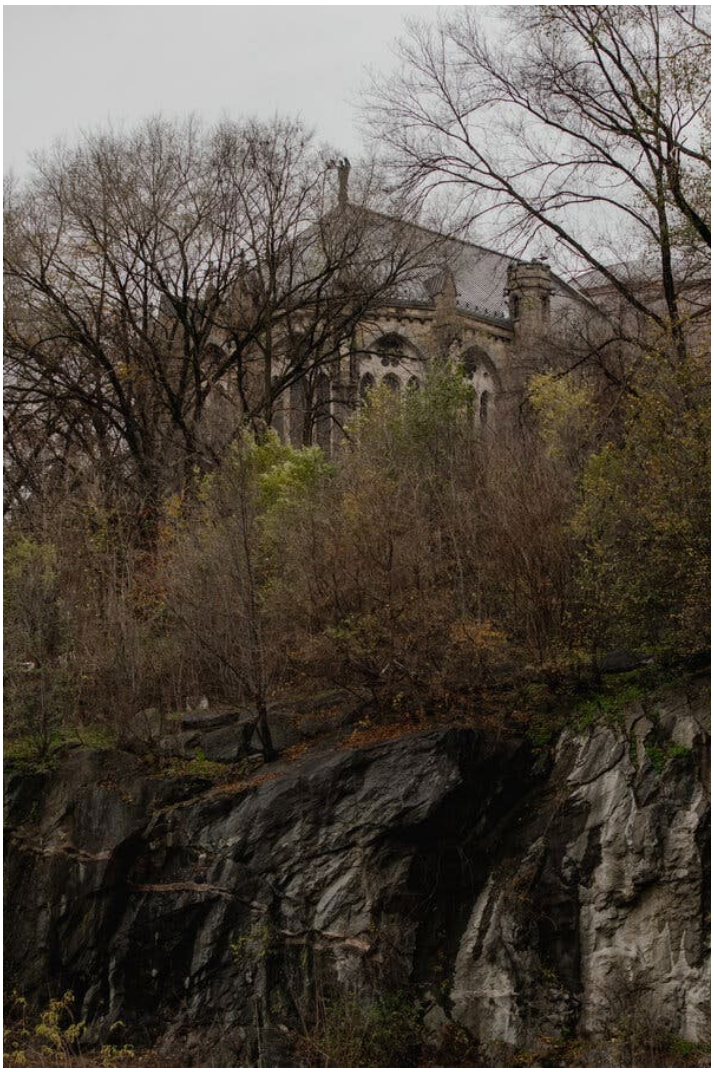
On a winter day in 1892, the prelate — aided by a silver trowel from Tiffany & Company, a harp, an organ, a 70-person choir, an orchestra, the secretary of the Navy, the chief justice of the U.S. Supreme Court and hundreds of other dignitaries — laid its cornerstone.

During the spring thaw of 1893, workmen began to dig. They found not solid rock but springs, decomposing schist, sand, clay, loose boulders, and shale.

"Fruitless Digging," the New York World declared in a Sept. 9 headline. The article said the crews excavated a pit 40 feet deep but found no bedrock. The gargantuan hole, it added, "filled with water."



A postcard, circa 1910, showed the cathedral based on its designs, including its giant tower, which was never completed.
Credit via New York Public Library



The chosen site for the cathedral ran from West 113 Street to West 110 Street, the second highest point in Manhattan.

Things got worse. The softest ground, it turned out, lay precisely under the spot where the colossal spire was to rise. “In one terrible instant,” Dr. Strong noted in her dissertation, “the cathedral’s glory, its great central tower, was transformed into its nemesis.”

After two more years of digging, the crews finally hit bedrock. In places, it lay 72 feet down, about halfway through the Morningside plateau.

In August 1895, The Times reported that St. John’s would build a supplemental foundation for the cathedral made of concrete. The newspaper said the dense mass had to be “flawless” because the central tower would weigh 136 million pounds — more than twice the weight, it noted, of the world’s tallest office building.

The cathedral’s tower, the newspaper added, “will easily be the most prominent object on Manhattan Island.”

J. Pierpont Morgan, founder of the nation’s largest bank, gave the cathedral $500,000 — or more than $17 million in today’s dollars. His objective, he told Bishop Potter, was to “get us out of a hole.” The Astors, the Vanderbilts and the Belmonts also donated.

But years of digging and pouring concrete were no help. The tower’s envisioned size was slowly reduced over decades. In the end, what was to have been the church’s main feature vanished.

“Why would you ever suspect there was water there?” Dr. Strong asked. “Who would ever imagine the ground would be so soft?”

Saved by a Sacred Rite

The nightmare, in time, became an ecclesiastical asset.

For baptisms, early Christians are said to have preferred the “living” waters of springs and streams. In fact, many early churches and cathedrals were built near or over springs. It follows that the founders of St. John the Divine may have been eager to make use of the church’s natural waters, even if they had been uncovered by accident.

The church’s ornate room for baptisms was modeled on the great baptisteries of Pisa and Florence. Its font is made of French marble. The descendants of Peter Stuyvesant, the last Dutch governor of New Amsterdam, paid for the baptistery’s construction.

Evidence that St. John’s used its waters for baptismal rites begins with the photographer James Reuel Smith, who toured Upper Manhattan on a bicycle from 1897 to 1901 to document its vanishing world of springs, wells and other pastoral features. Mr. Smith put his findings into a book that the New-York Historical Society published.

In appraising St. John the Divine, Mr. Smith noted that the land’s previous owner had a well, “just about” where the cathedral had planned to construct its baptismal font. Pure waters for the sacred rite, he declared, might arise “from the well!”

Stephen A. Facey, a senior St. John’s official in the 1990s and 2000s, said water from the spring was indeed “piped up to the Baptistery and fed the baptismal font.”

But at some point, many decades ago, Mr. Facey said, city water replaced the spring water. Why? Its acidity was seen as damaging to the font’s marble basin, just as acid rain can eat away marble tombstones and statuary.

A Hunt for Hidden Waterways

The church property slopes to the south. In 1897, downhill, near the intersection of Cathedral Parkway and Morningside Drive, the intrepid Mr. Smith photographed a spring that evoked the secret world of subterranean water.

He said the spring originated near the base of the cliff. His photograph shows a rivulet surrounded by a detached boulder, small rocks and weedlike plants.

“Recently the city had a sign placed at this spring cautioning people not to drink from it,” Mr. Smith wrote in 1897, “but the sign soon disappeared.”

So did the spring. Years later, when Mr. Smith revisited the site, construction workers were erecting a giant stone retaining wall along Cathedral Parkway that he described as three feet thick and 30 feet high. “It is today just covered,” he said of the spring.

For the cathedral’s sleuths, the photo is Exhibit A. The spring’s disappearance also evokes the challenges they face in tracking the subterranean flows.

Wayne Kempton, the archivist for the Episcopal Diocese of New York, found two photographs made in 1907 during a large excavation on the cathedral’s south flank. The dig site was filled with water — from one of the springs, Mr. Kempton suspects.

He also found evidence that the underground flow kept running downhill from the cathedral and carved out a new exit or exits. A 1916 photograph shows a continuation of the retaining wall along Cathedral Parkway that Mr. Smith saw in construction, its bottom edge revealing what appears to be large rectangular drain openings.

Some 90 years later, around 2006, the same continuation of the wall buckled and collapsed, according to Mr. Kempton. He suspected the spring was the cause.

Connecting the dots, Mr. Kempton envisions a hidden watercourse that flows across nearly three blocks of the cathedral’s property — starting at the church’s north side near West 113th Street and running southward across the 11-acre property to Cathedral Parkway.

“The question is, ‘Where has it gone?’” he said of the southern flow. Mr. Kempton sees using a dye test that traces where the water flows as providing a possible answer.

What’s clear already is that the cathedral site is geologically uncommon. A recent book found that the deepest cut went down nearly twice the early reports. Rather than 72 feet, it plunged 135 feet — roughly the overall thickness of the Morningside plateau. The unusually deep bedrock was needed to support the church’s eight giant pillars around its main altar. Each weighed 130 tons, making them the biggest ever cut from an American quarry.

“Very unusual,” Dr. Menke, the Columbia geologist, said of the property. “Rivers often follow pre-existing geological features such as faults and fractures. So there’s a chicken-and-egg issue here. The present-day water may not so much reflect the former rivers, but rather the old river channels reflect some deeper geological feature.”

Today, Mr. Patterson, the cathedral’s head of facilities, said that the sub-crypt flooding is much reduced. Why? His theory centers on the rise of Enclave — a 430-unit rental complex that runs the length of West 113th Street between Amsterdam Avenue and Morningside Drive. The dwelling, built from 2014 to 2016, set off protests from opponents who said the 15-story complex obscured street views of the cathedral.

With a slightly bemused expression, Mr. Patterson argued that Enclave’s foundation went down far enough to act as a subterranean barrier that diverted most of the underground flow away from the cathedral. “They solved our problem.”

We left his office to take another look at the deep vault. Crucially, Mr. Patterson knew exactly where electricians had recently installed new light switches, so we had no need for cellphone lights.

The cathedral’s cavernous subbasement consisted of big rooms, its ceiling perhaps 25 or 30 feet high. It was all poured concrete, and, unlike the crypt above, it was empty, its floor bare. That and its cavern-like size helped to explain the echoes we heard. With the lights on, the sump pumps looked less spooky, especially when Mr. Patterson started them up manually and the pit water gurgled upward.

We moved into the bigger room. The large pit was about eight or nine feet wide, and Mr. Patterson said it served as a gathering point that fed water into the pumps. The surrounding floor, like the steps, was full of watery muck. Our shoes made splish-splashy noises.

During our tour, Mr. Patterson kept pointing out features of the sub-crypt area that were either old and unused or mysterious in purpose. There were pipes, stairs and a giant shaft that went nowhere — relics from 130 years of building and rebuilding.

Now, in passing, he mentioned another relic.

At the bottom of the large gathering pool, Mr. Patterson said, was a feeder pipe, its source unknown. “It’s another pipe from nowhere,” he said, his voice reverberating. “But it was put there intentionally to get water into that pit.”

Mr. Patterson, who seemed to know more about St. John’s riddles and hidden waters than anybody else, offered a final twist.

Truth be told, he said as we roamed the muddy vault, “we really don’t know where all this water is coming from.”

William J. Broad is a science journalist and senior writer. He joined The Times in 1983, and has shared two Pulitzer Prizes with his colleagues, as well as an Emmy Award and a DuPont Award.

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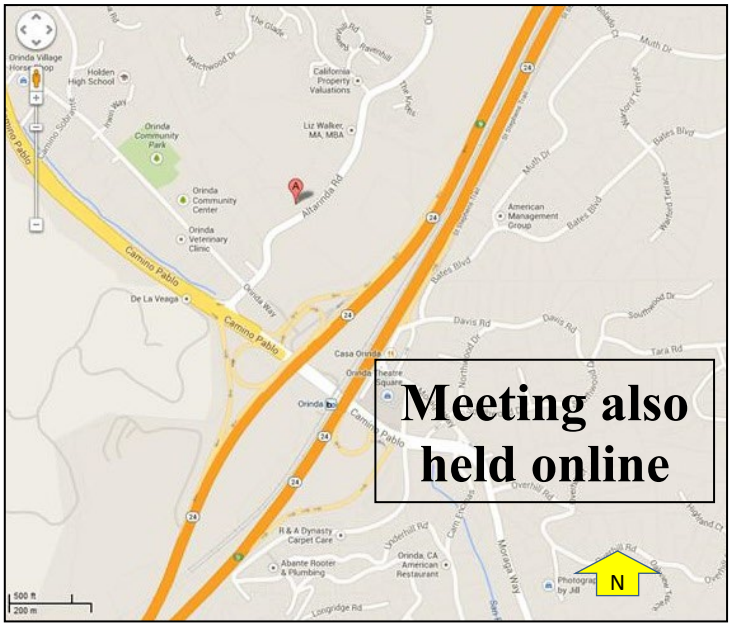

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