NORTHERN CALIFORNIA GEOLOGICAL SOCIETY

Website: www.ncgeolsoc.org

MEETING ANNOUNCEMENT

DATE: **February 22, 2017**

LOCATION: **Orinda Masonic Center, 9 Altarinda Rd., Orinda** **(see map on back page)**

TIME: **6:30 p.m. social; 7:00 pm talk (no dinner) Cost: $5 per regular member; $1 per student or K – 12 teachers**

SPEAKER: **Tom Williams, Williams GeoAdventures**

Topic: The Geology and Landscapes of Iceland

Iceland has been called ‘the ultimate nature experience’ and is one of the world’s geologically most fascinating places, where you can experience tectonic, volcanic, hydrologic, glacial, and erosional processes firsthand. The scenery created by these geologic processes is extraordinarily beautiful. There are waterfalls everywhere!

Iceland is geologically unique in a number of ways. It has been created by volcanism from a combination of the Mid-Atlantic Ridge and a hot spot. It is the only place on Earth where you can observe a rift valley on dry land. Iceland has the largest glacier in Europe. The volcanic and glacial landforms are spectacular! Come explore the geology and landscapes of Iceland.

Biography: Thomas R. Williams, M.S., P.G., has more than 40 years of working and teaching experience and is a retired Engineering Geologist with the North Coast Regional Water Board. He has taught earth sciences at eight Bay Area colleges and is currently a geology lecturer at Sonoma State University, this semester teaching Hydrology and Environmental Geology. He has led 31 Western U.S. and international geology field trips since 1997 through his teaching and his adventure travel business, Williams GeoAdventures.

NCGS 2016 – 2017 Calendar

March 29, 2017 7:00 pm
Dr. Kim Blisniuk, San Jose State University
Tectonic Geomorphology of San Andreas Fault in Southern CA

April 26, 2017 7:00 pm
Dr. Mark Richards, UC Berkeley
Topic to be determined

May 31, 2017 6:00 pm
Dr. Greg Stock, National Park Service
The Rise and Fall of Sierra Nevada Glaciers

June 28, 2017 7:00 pm
Dr. Matthew J. James, Sonoma State University
Collecting Evolution:
The Galapagos Expedition that Vindicated Darwin

NCGS Field Trips

Ray Sullivan, Professor Emeritus at San Francisco State University, will lead a great field trip, back by popular demand, to explore subsidence features in the fill south of Market St., the old S.F. Bay shoreline, earthquake and fire history, and engineering issues for large downtown buildings in San Francisco:

"A Walk Along The Old Bay Margin In Downtown San Francisco – Tracing The Events Of The 1906 Earthquake & Fire"

Sunday, February 26, 2017

The trip is filled, but it may still be possible to sign on the waiting list. See the announcement and sign-up flyer on Page 13 of the January newsletter.

Field trips in a preliminary planning stage:

- Geology of Devil's Slide
- Pt. Sal Ophiolite in Santa Barbara Co,
- Convergent Margin Tectonics across Central California Coast Ranges - Pacheco Pass
- Tuscan Formation volcanic mudflow deposits, Cascade foothills

Peninsula Geologic Society

For an updated list of meetings, abstracts, and field trips go to http://www.diggles.com/pgs/. The PGS has also posted guidebooks for downloading, as well as photographs from recent field trips at this web address. Please check the website for current details.

UC Berkeley Earth & Planetary Science Weekly Seminar Series

Interesting seminars are presented in many weeks at EPS throughout the academic year, generally from late August through early May. Seminars are held on **selected** Thursdays at 4 pm at 141 McCone. Fall speakers are listed through May 4, but titles are not currently available.

For an updated list of seminars, go to http://eps.berkeley.edu/events/seminars.

A gentle reminder: *It's still Renewal Time!* Our year runs from September to September. If you haven't already renewed, please use the Renewal Form on page 13 of the November newsletter, or see the Treasurer at the next meeting, at registration time.

NCGS members are invited to attend any of our **NCGS Board meetings** held quarterly throughout the year (except for summer), generally in September, January, and May, at the CB&I (formerly Shaw E&I) offices at 4005 Port Chicago Hwy, Concord, CA 94520. The next board meeting has been scheduled for 8:30 to 11 am on Saturday, May 13. If you arrive much after 8:30, call Barbara Matz (415) 713-8482 or Mark Sorensen (925) 260-6942 to open the door.

Update on Millenium Tower

See the following link for an update on the tilting Millenium Tower at 301 Mission Street, at 58 stories the largest residential building in downtown SF. The city inspection of December 2 and January 11 resulted in conclusions that the building is safe to live in, despite some stress on supporting electrical conduits:

http://www.sfgate.com/bayarea/article/Sinking-Millennium-Tower-safe-to-live-in-city-10890276.php

Hyoliths: Mysterious Cambrian Animals Classified as Lophophorates

Paleontologists have finally determined what hyoliths — a group of extinct marine creatures — actually are.

Reconstruction of the hyolith Haplophrentis on the Cambrian sea floor. Image credit: D. Dufault / Royal Ontario Museum.

Hyoliths evolved over 530 million years ago during the Cambrian period and are among the first animals known to have produced mineralized external skeletons.

Long believed to belong to the same family as snails, squid and other mollusks, a new study shows that hyoliths are instead more closely related to brachiopods — a group of animals which has a rich fossil record, although few living species remain today.

Brachiopods have a soft body enclosed between upper and lower shells (valves), unlike the left and right arrangement of valves in bivalve mollusks. Brachiopods open their valves at the front when feeding, but otherwise keep them closed to protect their feeding apparatus and other body parts.

Although the skeletal remains of hyoliths are abundant in the fossil record, key diagnostic aspects of their soft-anatomy remained critically absent until now. "Hyoliths are abundant and globally distributed 'shelly' fossils that appear early in the Cambrian period and can be found throughout the 280 million year span of Paleozoic strata," the study's authors said.

"The ecological and evolutionary importance of this group has remained unresolved, largely because of their poorly constrained soft anatomy and idiosyncratic scleritome."

Joseph Moysiuk, an undergraduate student at the University of Toronto and corresponding co-author on the study," said: "our most important and surprising discovery is the hyolith feeding structure, which is a row of flexible tentacles extending away from the mouth, contained within the cavity between the lower conical shell and upper cap-like shell."

"Only one group of living animals – the brachiopods – has a comparable feeding structure enclosed by a pair of valves. This finding demonstrates that brachiopods, and not mollusks, are the closest surviving relatives of hyoliths. It suggests that these hyoliths fed on organic material suspended in water as living brachiopods do today, sweeping food into their mouths with their tentacles."

All hyoliths had an elongated, bilaterally symmetrical cone-shaped shell and a smaller cap-like shell that covered the opening of the conical shell (known as an operculum). Some species also bore a pair of rigid, curved spines (known as helens) that protruded from between the conical shell and operculum — structures with no equivalents in any other group of animals.

Examination of the orientation of the helens in multiple hyolith specimens from the renowned Cambrian Burgess Shale suggests that these spines may have been used like stilts to lift the body of the animal above the sediment, elevating the feeding apparatus to enhance feeding.

"We examined over 1,500 specimens of the mid-Cambrian hyolith Haplophrentis from the Burgess Shale and Spence Shale Lagerstätten," they said. "We reconstructed Haplophrentis as a semi-sessile, epibenthic suspension feeder that could use its helens to elevate its tubular body above the sea floor."

"Exceptionally preserved soft tissues include an extendable, gullwing-shaped, tentacle-bearing organ surrounding a central mouth, which we interpret as a lophophore, and a U-shaped digestive tract ending in a dorsolateral anus."

"Together with opposing bilateral sclerites and a deep ventral visceral cavity, these features indicate an affinity with the lophophorates (brachiopods, phoronids and tommotiids), substantially increasing the morphological disparity of this prominent group."

The Burgess Shale is one of the most important fossil deposits for studying the origin and early evolution of animals that took place during the Cambrian period, starting about 542 million years ago.

Hyoliths are just one of the profusion of animal groups that characterize the fauna of the 'Cambrian explosion.' They became a diverse component of marine ecosystems around the globe for more than 280 million years, only to go extinct 252 million years ago, prior to the evolution of the first dinosaurs.

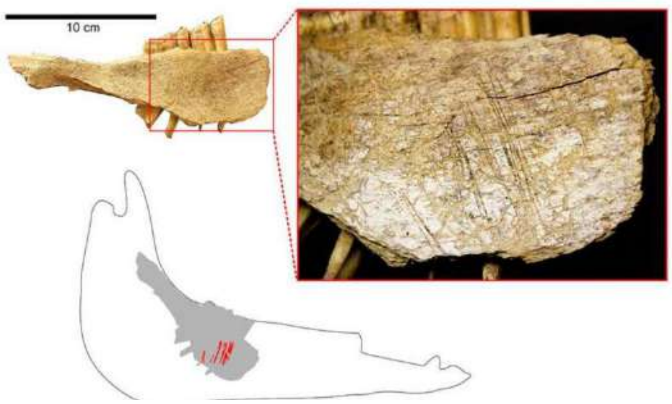
"Resolving the debate over the hyoliths adds to our understanding of the Cambrian explosion, the period of rapid evolutionary development when most major animal groups emerge in the fossil record," said co-author Dr. Martin Smith of Durham University, UK.

Our study reiterates the importance of soft tissue preservation from Burgess Shale-type deposits in illuminating the evolutionary history of creatures about which we still know very little.”

Story Source: The article summary was published online in the Jan. 12, 2017 issue of **Science News** (http://www.sci-news.com).

Journal Reference: Joseph Moysiuk et al. Hyoliths are Palaeozoic lophophorates. **Nature**, published online January 11, 2017; doi: 10.1038/nature20804.

First humans arrived in North America 10,000 years earlier than believed



This horse mandible from Cave 2 shows a number of cut marks on the lingual surface. They show the animal’s tongue was cut out with a stone tool.

Credit: University of Montreal

The timing of the first entry of humans into North America across the Bering Strait has now been set back 10,000 years.

This has been demonstrated beyond a shadow of a doubt by Ariane Burke, a professor in Université de Montréal's Department of Anthropology, and her doctoral student Lauriane Bourgeon, with the contribution of Dr. Thomas Higham, Deputy Director of Oxford University's Radiocarbon Accelerator Unit.

The earliest settlement date of North America, until now estimated at 14,000 years Before Present (BP) according to the earliest dated archaeological sites, is now estimated at 24,000 BP, at the height of the last ice age or Last Glacial Maximum.

The researchers made their discovery using artifacts from the Bluefish Caves, located on the banks of the Bluefish River in northern Yukon near the Alaska border. The site was excavated by archaeologist Jacques Cinq-Mars between 1977 and 1987. Based on radiocarbon dating of animal bones, the researcher made the bold hypothesis that human settlement in the region dated as far back as 30,000 BP.

In the absence of other sites of similar age, Cinq-Mars' hypothesis remained highly controversial in the scientific community. Moreover, there was no evidence that the presence of horse, mammoth, bison and caribou bones in the Bluefish Caves was due to human activity.

To set the record straight, Bourgeon examined the approximate 36,000 bone fragments culled from the site and preserved at the Canadian Museum of History in Gatineau—an enormous undertaking that took her two years to complete. Comprehensive analysis of certain pieces at UdeM's Ecomorphology and Paleoanthropology Laboratory revealed undeniable traces of human activity in 15 bones. Around 20 other fragments also showed probable traces of the same type of activity.

"Series of straight, V-shaped lines on the surface of the bones were made by stone tools used to skin animals," said Burke. "These are indisputable cut-marks created by humans."

Bourgeon submitted the bones to further radiocarbon dating. The oldest fragment, a horse mandible showing the marks of a stone tool apparently used to remove the tongue, was radiocarbon-dated at 19,650 years, which is equivalent to between 23,000 and 24,000 cal BP (calibrated years Before Present).

"Our discovery confirms previous analyses and demonstrates that this is the earliest known site of human settlement in Canada," said Burke. It shows that Eastern Beringia was inhabited during the last ice age."

Beringia is a vast region stretching from the Mackenzie River in the Northwest Territories to the Lena River in Russia. According to Burke, studies in population genetics have shown that a group of a few thousand individuals lived in isolation from the rest of the world in Beringia 15,000 to 24,000 years ago.

"Our discovery confirms the 'Beringian standstill [or genetic isolation] hypothesis,'" she said, "Genetic isolation would have corresponded to geographical isolation. During the Last Glacial Maximum, Beringia was isolated from the rest of North America by glaciers and steppes too inhospitable for human occupation to the West. It was potentially a place of refuge."

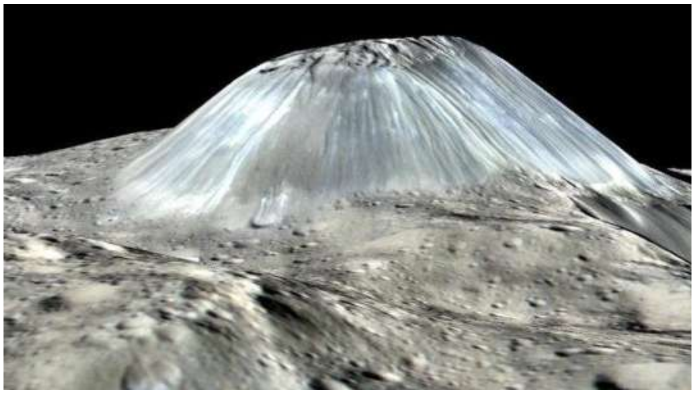
The Beringians of Bluefish Caves were therefore among the ancestors of people who, at the end of the last ice age, colonized the entire continent along the coast to South America.

Story Source: The article summary was published online in a Jan. 16, 2017 web post on PhysOrg (https://phys.org/news/).

Reference: Lauriane Bourgeon, Ariane Burke, and Thomas Higham. Earliest Human Presence in North

America Dated to the Last Glacial Maximum: New Radiocarbon Dates from Bluefish Caves, Canada, *PLOS ONE* (2017). DOI: 10.1371/journal.pone.0169486.

Dwarf planet Ceres may have vanishing ice volcanoes



This is Ahuna Mons seen in a simulated perspective view. The elevation has been exaggerated by a factor of two. The view was made using enhanced-color images from NASA's Dawn mission. Credit: NASA

A recently discovered solitary ice volcano on the dwarf planet Ceres may have some hidden older siblings, say scientists who have tested a likely way such mountains of icy rock -- called cryovolcanoes -- might disappear over millions of years.

NASA's Dawn spacecraft discovered Ceres's 4-kilometer (2.5-mile) tall Ahuna Mons cryovolcano in 2015. Other icy worlds in our solar system, like Pluto, Europa, Triton, Charon and Titan, may also have cryovolcanoes, but Ahuna Mons is conspicuously alone on Ceres. The dwarf planet, with an orbit between Mars and Jupiter, also lies far closer to the sun than other planetary bodies where cryovolcanoes have been found.

Now, scientists show there may have been cryovolcanoes other than Ahuna Mons on Ceres millions or billions of years ago, but these cryovolcanoes may have flattened out over time and become indistinguishable from the planet's surface. They report their findings in a new paper accepted for publication in *Geophysical Research Letters*, a journal of the American Geophysical Union.

"We think we have a very good case that there have been lots of cryovolcanoes on Ceres but they have deformed," said Michael Sori of the Lunar and Planetary Laboratory at the University of Arizona in Tucson, and lead author of the new paper.

Ahuna Mons is a prominent feature on Ceres, rising to about half the height of Mount Everest. Its solitary existence has puzzled scientists since they spied it. "Imagine if there was just one volcano on all of Earth," Sori said. "That would be puzzling."

Adding to the puzzle are the steep sides and well-defined features of Ahuna Mons -- usually signs of geologic youth, Sori said. That leads to two possibilities: Ahuna Mons is just as it appears, inexplicably alone after forming relatively recently on an otherwise inactive world. Or, the cryovolcano is not alone or unusual, and there is some process on Ceres that has destroyed its predecessors and left the young Ahuna Mons as the solitary cryovolcano on the dwarf planet, according to Sori.

Ceres has no atmosphere, so the processes that wear down volcanoes on Earth -- wind, rain and ice -- aren't possible on the dwarf planet. Sori and his colleagues hypothesized that another process, called viscous relaxation, could be at work.

Viscous relaxation is the idea that just about any solid will flow, given enough time. For example, a cold block of honey appears to be solid. But if given enough time, the block will flatten out until there is no sign left of the original block structure.

On Earth, viscous relaxation is what makes glaciers flow, Sori explained. The process doesn't affect volcanoes on Earth because they are made of rock, but Ceres's volcanoes contain ice -- making viscous relaxation possible. On Ceres, viscous relaxation could be causing older cryovolcanoes to flatten out over millions of years so they are hard to discern. Ceres's location close to the sun could make the process more pronounced, Sori said.

To test the idea that viscous relaxation had caused cryovolcanoes to flatten out on Ceres, Sori and his colleagues created a model using the actual dimensions of Ahuna Mons to predict how fast the mountain might be flowing. They ran the model assuming different water contents of the material that makes up the mountain -- ranging from 100 percent water ice to 40 percent water ice, Sori explained.

Ahuna Mons would need to be composed of more than 40 percent water ice to be affected by viscous relaxation, they found. At this composition, Sori estimates that Ahuna Mons should be flattening out at a rate of 10 to 50 meters (30 to 160 feet) per million years. That is enough to render cryovolcanoes unrecognizable in hundreds of millions to billions of years, suggesting there could have been other cryovolcanoes on Ceres, according to the new study.

"Ahuna Mons is at most 200 million years old. It just hasn't had time to deform," Sori said.

The next step for Sori and his team will be to try and identify the flattened remnants of older cryovolcanoes on Ceres. The findings could help scientists better decipher the history of how the dwarf planet formed, he added.

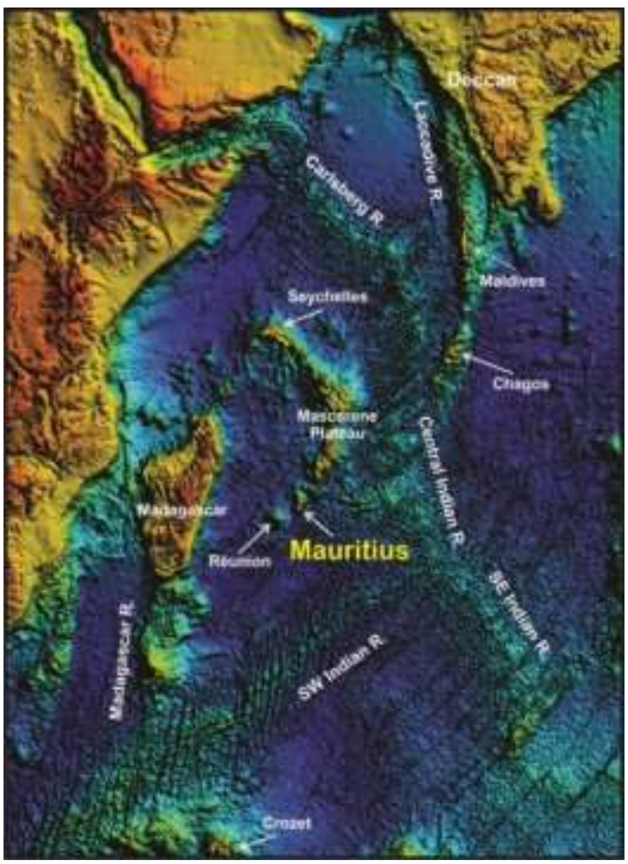
The new study helps scientists expand their knowledge of what might be possible on planetary bodies in our solar system, said Kelsi Singer, a postdoctoral researcher who studies icy worlds at Southwest Research Institute in Boulder, Colorado, and was not involved with the new research.

"It would be fun to check some of the other features that are potentially older domes on Ceres to see if they fit in with the theory of how the shapes should viscously evolve over time," she said. "Because all of the putative cryovolcanic features on other worlds are different, I think this helps to expand our inventory of what is possible."

Story Source: Materials provided by American Geophysical Union.

Journal Reference: Michael M. Sori, Shane Byrne, Michael T. Bland, Ali M. Bramson, Anton I. Ermakov, Christopher W. Hamilton, Katharina A. Otto, Ottaviano Ruesch, Christopher T. Russell. **The vanishing cryovolcanoes of Ceres**. *Geophysical Research Letters*, 2017; DOI: 10.1002/2016GL072319.

Researchers confirm the existence of a 'lost continent' under Mauritius



This is Indian Ocean topography showing the location of Mauritius as part of a chain of progressively older volcanoes extending from the presently active hot-spot of Réunion toward the 65-million-year-old Deccan traps of northwest India. *Credit: Wits University*

Scientists have confirmed the existence of a "lost continent" under the Indian Ocean island of Mauritius that was left-over by the break-up of the supercontinent, Gondwana, which started about 200 million years ago. The piece of crust, which was subsequently covered by young lava during volcanic eruptions on the island, seems to be a tiny piece of ancient continent, which broke off from the island of Madagascar, when Africa, India, Australia and Antarctica split up and formed the Indian Ocean. "We are studying the break-up process of the continents, in order to understand the geological history of the planet," says Wits geologist, Professor Lewis Ashwal, lead author on the paper "Archaean zircons in Miocene oceanic hotspot rocks establish ancient continental crust beneath Mauritius," published in the journal *Nature Communications*.

By studying the mineral, zircon, found in rocks spewed up by lava during volcanic eruptions, Ashwal and his colleagues Michael Wiedenbeck from the German Research Centre for Geosciences (GFZ) and Trond Torsvik from the University of Oslo, guest scientist at GFZ, have found that remnants of this mineral were far too old to belong on the island of Mauritius.

"Earth is made up of two parts -- continents, which are old, and oceans, which are "young." On the continents you find rocks that are over four billion years old, but you find nothing like that in the oceans, as this is where new rocks are formed," explains Ashwal. "Mauritius is an island, and there is no rock older than 9 million years old on the island. However, by studying the rocks on the island, we have found zircons that are as old as 3 billion years."

Zircons are minerals that occur mainly in granites from the continents. They contain trace amounts of uranium, thorium and lead, and due to the fact that they survive geological process very well, they contain a rich record of geological processes and can be dated extremely accurately.

"The fact that we have found zircons of this age proves that there are much older crustal materials under Mauritius that could only have originated from a continent," says Ashwal.

This is not the first time that zircons that are billions of years old have been found on the island. A study done in 2013 has found traces of the mineral in beach sand. However, this study received some criticism, including that the mineral could have been either blown in by the wind, or carried in on vehicle tyres or scientists' shoes.

"The fact that we found the ancient zircons in rock (6-million-year-old trachyte), corroborates the previous study and refutes any suggestion of wind-blown, wave-transported or pumice-rafted zircons for explaining the earlier results," says Ashwal.

Ashwal suggests that there are many pieces of various sizes of "undiscovered continent," collectively called "Mauritia," spread over the Indian Ocean, left over by the breakup of Gondwanaland.

"According to the new results, this break-up did not involve a simple splitting of the ancient super-continent of Gondwana, but rather, a complex splintering took place with fragments of continental crust of variable sizes left adrift within the evolving Indian Ocean basin."

Story Source: Material provided by University of the Witwatersrand.

Journal Reference: Lewis D. Ashwal, Michael Wiedenbeck, Trond H. Torsvik. Archaean zircons in Miocene oceanic hotspot rocks establish ancient continental crust beneath Mauritius. *Nature Communications*, 2017; 8: 14086 DOI: 10.1038/ncomms14086.

Bag-like sea creature was humans' oldest known ancestor

Artist's reconstruction of Saccorhytus coronarius, based on the original fossil finds. The actual creature was probably no more than a millimeter in size.
Credit: S Conway Morris / Jian Han

Researchers have identified traces of what they believe is the earliest known prehistoric ancestor of humans -- a microscopic, bag-like sea creature, which lived about 540 million years ago.

Named *Saccorhytus*, after the sack-like features created by its elliptical body and large mouth, the species is new to science and was identified from microfossils found in China. It is thought to be the most primitive example of a so-called "deuterostome" -- a broad biological category that encompasses a number of sub-groups, including the vertebrates.

If the conclusions of the study, published in the journal *Nature*, are correct, then *Saccorhytus* was the common ancestor of a huge range of species, and the earliest step yet discovered on the evolutionary path that eventually led to humans, hundreds of millions of years later.

Modern humans are, however, unlikely to perceive much by way of a family resemblance. *Saccorhytus* was about a millimetre in size, and probably lived between grains of sand on the seabed. Its features were spectacularly preserved in the fossil record -- and intriguingly, the researchers were unable to find any evidence that the animal had an anus.

The study was carried out by an international team of academics, including researchers from the University of Cambridge in the UK and Northwest University in Xi'an China, with support from other colleagues at institutions in China and Germany.

Simon Conway Morris, Professor of Evolutionary Palaeobiology and a Fellow of St John's College, University of Cambridge, said: "We think that as an early deuterostome this may represent the primitive beginnings of a very diverse range of species, including ourselves. To the naked eye, the fossils we studied look like tiny black grains, but under the microscope the level of detail is jaw-dropping. All deuterostomes had a common ancestor, and we think that is what we are looking at here."

Most other early deuterostome groups are from about 510 to 520 million years ago, when they had already begun to diversify into not just the vertebrates, but the sea squirts, echinoderms (animals such as starfish and sea urchins) and hemichordates (a group including things like acorn worms). This level of diversity has made it extremely difficult to work out what an earlier, common ancestor might have looked like.

The *Saccorhytus* microfossils were found in Shaanxi Province, in central China, and pre-date all other known deuterostomes. By isolating the fossils from the surrounding rock, and then studying them both under an electron microscope and using a CT scan, the team were able to build up a picture of how *Saccorhytus* might have looked and lived. This revealed features and characteristics consistent with current assumptions about primitive deuterostomes.

Dr Jian Han, of Northwest University, said: "We had to process enormous volumes of limestone -- about three tonnes -- to get to the fossils, but a steady stream of new finds allowed us to tackle some key questions: was this a very early echinoderm, or something even more primitive? The latter now seems to be the correct answer."

In the early Cambrian period, the region would have been a shallow sea. The study suggests that its body was bilaterally symmetrical -- a characteristic inherited by many of its descendants, including humans -- and was covered with a thin, relatively flexible skin. This in turn suggests that it had some sort of musculature, leading the researchers to conclude that it could have made contractile movements, and got around by wriggling.

Perhaps its most striking feature, however, was its rather primitive means of eating food and then dispensing with the resulting waste. *Saccorhytus* had a large mouth, relative to the rest of its body, and probably ate by engulfing food particles, or even other creatures.

A crucial observation are small conical structures on its body. These may have allowed the water that it swallowed to escape and so were perhaps the evolutionary precursor of the gills we now see in fish. But the researchers were unable to find any evidence that the creature had an anus. "If that was the case, then any waste material would simply have been taken out back through the mouth, which from our perspective sounds rather unappealing," Conway Morris said.

The findings also provide evidence in support of a theory explaining the long-standing mismatch between fossil evidence of prehistoric life, and the record provided by biomolecular data, known as the "molecular clock."

Technically, it is possible to estimate roughly when species diverged by looking at differences in their genetic information. In principle, the longer two groups have evolved separately, the greater the biomolecular difference between them should be, and there are reasons to think this process is more or less clock-like.

Unfortunately, before a point corresponding roughly to the time at which *Saccorhytus* was wriggling in the mud, there are scarcely any fossils available to match the molecular clock's predictions. Some researchers have theorised that this is because before a certain point, many of the creatures they are searching for were simply too small to leave much of a fossil record. The microscopic scale of *Saccorhytus*, combined with the fact that it is probably the most primitive deuterostome yet discovered, appears to back this up.

Story Source: Materials provided by St. John's College, University of Cambridge. The original story is licensed under a creative common license.

Journal Reference: Jian Han, Simon Conway Morris, Qiang Ou, Degan Shu, Hai Huang. **Meiofaunal deuterostomes from the basal Cambrian of Shaanxi (China)**. *Nature*, 2017; DOI: 10.1038/nature21072.

Release of water shakes Pacific plate at depth

The green mineral in this specimen from Washington University's teaching collection is serpentine. (Rocks that consist mostly of serpentine are called serpentinite.) The smooth surface on the sample is called a "slickenside." *Credit: Image courtesy of Jill Pasteris*

Tonga is a seismologists' paradise, and not just because of the white-sand beaches. The subduction zone off the east coast of the archipelago racks up more intermediate-depth and deep earthquakes than any other subduction zone, where one plate of Earth's lithosphere dives under another, on the planet.

"Tonga is such an extreme place, and that makes it very revealing," said S. Shawn Wei, a seismologist who earned his doctorate at Washington University in St. Louis and now is a postdoctoral fellow at the Scripps Institution of Oceanography in San Diego.

That swarm of earthquakes is catnip for seismologists because they still don't understand what causes earthquakes to pop off at such great depths.

Below about 40 miles, the enormous heat and pressure in Earth's interior should keep rock soft and pliable, more inclined to ooze than to snap. So triggering an earthquake at depth should be like getting molasses to shatter.

In the Jan. 11 issue of *Science Advances*, a team of seismologists from Washington University, Scripps Institution of Oceanography and Carnegie Institution for Science analyze the data from 671 earthquakes that occurred between 30 and 280 miles beneath Earth's surface in the Pacific Plate as it descended into the Tonga Trench.

Analyzing data from several seismic surveys with both ocean bottom seismometers and island-based seismic stations, they were surprised to find a zone of intense earthquake activity in the downgoing slab, which they call a seismic belt. The pattern of the activity along the slab provided strong evidence that the earthquakes are sparked by the release of water at depth.

"It looks like the seismic belt is produced by the sudden flushing of water when the slab warms up enough that the hydrated minerals can decompose and give off their water," said Doug Wiens, the Robert S. Brookings Distinguished Professor of earth and planetary sciences in Arts & Sciences at Washington University.

A champion subduction zone

The Tonga Trench holds a place of honor in the annals of seismology because this is where American scientists, invited to investigate the grumbling earth by the King of Tonga, got their first clear glimpse of a subduction zone in action.

The classic paper that scientists Bryan Isacks, Jack Oliver and Lynn Sykes published in 1968 led to the acceptance of the then speculative theory of plate tectonics.

In 1985, the Japanese seismologist Hitoshi Kawakatsu discovered something else interesting in Tonga: the descending slab has a double seismic zone. "There are two zones of earthquakes in the slab," Wiens said. "One is in the top part of the slab and the other is toward the middle of the slab."

Wiens, who has been studying the Tonga subduction zone since the early 1990s, says it is a great natural laboratory because its characteristics are so extreme. The ocean floor taking the dive there is older and colder than most other subducting slabs. It is also moving very fast.

"In the northern part of the Tonga Trench, the slab is moving 9 inches a year," said Wiens. "The San Andreas Fault, by comparison, moves 2 inches a year."

And the subducting slab has another useful quirk. It isn't descending into the trench at uniform speed but instead going down much faster at the northern end of the trench than at the southern end.

This means that the slab warms up at different rates along its length. "It's like pushing a cold bar of chocolate into a bubbling pan of pudding," said Wiens. "If you push slowly, the chocolate has a chance to warm up and melt, but if you push fast, the chocolate stays cold longer." This is a perfect setup for studying temperature-dependent phenomenon.

The surprise

When Wei analyzed the data from Tonga, he saw the double seismic zone the Japanese scientist had discovered. "We're pretty much to follow up on that 1985 paper," he said.

"Where the double seismic zone started to break down in Tonga, however, we saw this really active area of earthquakes that we named the seismic belt," Wiens said. "That was a surprise; we weren't expecting it."

Why the sudden burst of earthquakes as the slab descended? The telling clue was that the burst angled upward from north to south along the slab. The faster the slab was moving, the deeper the earthquakes, and the slower the slab, the shallower the earthquakes.

The angled seismic belt told the scientists that the mechanism triggering earthquakes was temperature sensitive. "We think the earthquakes occur when the mantle in the downgoing slab gets hot enough to release its water," Wiens said.

"People have proposed this mechanism before, but this is the smoking gun," Wiens continued. "The seismicity is changing depth in a way that's correlated with the subduction rate and the slab temperature."

The deep water cycle

But where does the water come from, and why is it released suddenly?

The interior of the Pacific plate is exposed to seawater as the plate is pulled under the Tonga Plate and faults open on its upper surface, Wei said. Seawater reacts with the rock to form hydrous minerals (minerals that include water in their crystal structure) in the serpentine family. The most abundant of these serpentine minerals is a green stone called antigorite.

But as the slab descends and the temperature and pressure increases, these hydrous minerals become unstable and break down through dehydration reactions, Wei said.

This sudden release of large amounts of water is what triggers the earthquakes. "The temperature we predict in the earthquake locations strongly suggests that minerals dehydrate very deep in the Tonga subduction zone, said Peter van Keken, a staff scientist at the Carnegie Institution for Science and a co-author on the paper.

The "phase diagrams" for antigorite dehydration reactions overlap neatly with the pressure and temperature of the slab at the seismic belt.

But the phase diagrams aren't that reliable at these extreme temperatures and depths. So Wei, for one, would like to see more laboratory data on the behavior of antigorite and other hydrous minerals at high temperature and pressure to nail down the mechanism.

For him, the most exciting part of the research is the evidence of water 180 miles beneath the surface. " We currently don't know how much water gets to the deep Earth or how deep the water can finally reach," Wei said. "In other words, we don't know how much water is stored in the mantle, which is a key factor for Earth's water budget."

The water down there may be as important to us as the water up here. It is beginning to look like water is the lubricant that oils the machine that recycles Earth's crust.

"The Tonga dataset is such a great treasure chest that we'll be exploiting for many years to come," said Wei.

Story Source: Materials provided by Washington University in St. Louis.

Journal Reference: S. Shawn Wei et al. **Slab temperature controls on the Tonga double seismic zone and slab mantle dehydration**. *Science Advances*, January 2017 DOI: 10.1126/sciadv.1601755.

New theory may explain mystery of Fairy Circles of Namibia

The fairy circles of the Namib Desert.
Credit: Photo by Tyler Coverdale, Princeton University; and Jen Guyton, Princeton University.

One of nature's greatest mysteries -- the 'Fairy Circles' of Namibia -- may have been unraveled by researchers at the University of Strathclyde and Princeton University.

The cause of the circular patches of earth surrounded by grass, which are arranged in honeycomb-like patterns in huge areas of the Namib desert, has been the source of scientific debate for decades. The new research, published in scientific journal *Nature*, suggests that the interaction between termite engineering and the self-organization of vegetation could be jointly responsible for the phenomenon.

Regular vegetation patterns form spectacular landscapes across the globe, with the Fairy Circles in Namibia holding special interest for scientists since the 1970s. Some have argued that termites alone create these patterns by destroying vegetation to reduce competition for water, while others have suggested the circles follow patterns of rainfall and are solely caused by competition between plants.

The newly-published findings show that Fairy Circles may actually result from the close interaction between both termites and vegetation, which facilitates their mutual survival.

Dr. Juan Bonachela from the University of Strathclyde's Department of Mathematics and Statistics, said: "There have long been two theories on how these regular patterns, and especially Fairy Circles, are formed, and both theories are normally presented as mutually exclusive.

"Our findings harmonize both theories and find a possible explanation for regular vegetation patterns observed around the globe. In the case of Fairy Circles, termites remove vegetation on their mounds to increase moisture, which is essential for the insects' survival in dry environments, thus creating the bare disk. Vegetation around the mound takes advantage of this water accumulation to grow, and this taller vegetation forms the circle. Regular repetition of the pattern results from different termite colonies competing next to one another.

"This behavior affects the whole ecosystem, allowing it to survive harsher conditions and recover from droughts much more quickly than if there were no termites. The Fairy Circles remind us of the delicate balance of interactions necessary to sustain ecosystems."

The findings come as a result of an international collaboration between academics at Princeton and Strathclyde, which allowed researchers to use their different expertise to develop and test the theory.

Their multidisciplinary approach included field data from four different continents and computer simulations. Thanks to the latter, the authors were able to explore their theory on a variety of scales, testing different environmental scenarios, which would have been almost impossible to achieve on ground due to cost and time issues.

Story Source: Materials provided by University of Strathclyde.

Journal Reference: Corina E. Tarnita, Juan A. Bonachela, Efrat Sheffer, Jennifer A. Guyton, Tyler C. Coverdale, Ryan A. Long, Robert M. Pringle. **A theoretical foundation for multi-scale regular vegetation patterns**. *Nature*, 2017; 541 (7637): 398 DOI: 10.1038/nature20801.

Exceptionally preserved Jurassic sea life found in new fossil site

A fossilized mantle of a vampyropod, a relative to the modern vampire squid (pictured on bottom right). The ink sack is the raised structure in the center, and muscles have a striated appearance. *Credit: Rowan Martindale/The University of Texas at Austin Jackson School of Geosciences and the Monterey Bay Aquarium Research Institute.*

A trove of exceptionally preserved Jurassic marine fossils discovered in Canada, rare for recording soft-bodied species that normally don't fossilize, is expanding scientists' view of the rich marine life of the period.

The preservation of the fossils -- which include soft body parts as well as shells and bones -- ranks the site among the highest quality sources of Jurassic (183 million year old) marine fossils in the world, and the only such site in North America. A paper describing the site and fossils recovered from it was published online in the journal *Geology* in January.

The presence of fossilized soft tissue is especially significant because it offers a more complete view of life in ancient ecosystems and can help fill the gaps in knowledge connecting extinct organisms to those living today, said Rowan Martindale, a professor at The University of Texas at Austin's Jackson School of Geosciences who led research on the fossils.

"In a normal fossil deposit, you only preserve a fraction of the organisms that were alive in the past. When you get an extraordinary fossil deposit with soft tissues preserved, you see significantly more of the community that would have been alive," said Martindale, a paleontologist in the Department of Geological Sciences. "Normally, we wouldn't find many of the animals because they lack a skeleton or have a very soft skeleton."

Collaborators include researchers from Harvard University, Virginia Tech and Florida State University.

The new site was found on the Parks Canada Ya Ha Tinda Ranch near Banff National Park in southwest Alberta. Co-author Benjamin Gill, a professor at Virginia Tech, spotted the first exceptional fossil when he noticed his Ph.D. student and co-author, Theodore Them, standing right on top of a lobster.

"The lighting was just right to make out the outline of the lobster," Gill said. "Then we looked around and noticed fossils all around us."

The lobster was the first sign the site could be special because lobsters' flexible exoskeletons usually aren't preserved as fossils. Other unusual fossils recovered from the site include delicate shrimp, complete fish skeletons with scales and gills, large dolphin-like marine reptiles called ichthyosaurs, as well as "vampyropods" (related to modern vampire squid and octopus) with their delicate ink sacks still intact.

The presence of many well-preserved, soft-bodied animals marks the new site as a "Konservat-Lagerstätte," a term for fossil beds that preserve an array of organisms with soft tissues as well as hard ones. These sites are rare. There are only three other sites, all located in Europe, that are known to contain fossils from the Early Jurassic like the Ya Ha Tinda site. Another famous example of a Canadian Lagerstätte is the Burgess Shale, which preserves a community of soft tissue organisms from the Cambrian Explosion (540 million years ago), named for the burst of animal diversity that appears in the fossil record from this time.

The new site is about 183 million years old, meaning the fossilized life was alive during the Early Jurassic. At this time, Ya Ha Tinda and the similarly aged European sites were on opposite sides of an ancient continent that became modern-day North America and parts of Europe. Having an array of well-preserved fossils from marine ecosystems on opposite sides of the continent will help scientists understand the distribution of sea life millions of years ago.

"This is the first time we have a site like this outside of Europe, so the Ya Ha Tinda fossilized community will give us a unique snapshot of life in the Early Jurassic Panthalassa Ocean," Martindale said.

The researchers have been visiting the site every summer since 2013 and have recovered dozens of fossils, including some that are probably newly discovered species. Notable specimens include a lobster with bulky arms capped with diminutive, scissor-like claws, and 16 new vampyropod specimens, a number that Gill estimates increases known diversity of specimens from North America by threefold.

"Every time we've gone, we've found something new," Gill said. "It's a really abundant place."

The next step of the research is to investigate how so many diverse organisms were fossilized together.

Researchers think that the high-quality preservation is related to a widespread extinction of marine life caused by a period of extremely low levels of oxygen in parts of the Jurassic oceans. Free of most scavengers, these low oxygen areas could have been an ideal place for a carcass to lay undisturbed and become beautifully fossilized.

"If a carcass sinks into anoxic water, you're more likely to get the conditions that will favor the preservation of soft tissues, feathers and articulated skeletons," Martindale said. "These 'fossil jackpots' are really special."

Story Source: Materials provided by University of Texas at Austin.

Journal Reference: Rowan C. Martindale, Theodore R. Them, Benjamin C. Gill, Selva M. Marroquín, Andrew H. Knoll. **A new Early Jurassic (ca. 183 Ma) fossil Lagerstätte from Ya Ha Tinda, Alberta, Canada**. *Geology*, 2017; G38808.1 DOI: 10.1130/G38808.1.

Celebrating Concrete, Part 1

(Editor's Note: We thank Bill Motzer for contributing this article. Bill is an NCGS member and Ph.D. geochemist, and writes a column for the Vortex newsletter of the local branch of the American Chemical Society. Like this one, some of his articles hold special interest for NCGS members, and will appear periodically.)

By Bill Motzer (bmotzer@toddengineers.com)

We walk on it, ride on it, work and live within it. The Romans built their aquaducts and the Coliseum from it. It is *concrete* and modern civilization could not be possible without it. As a geologist, I was trained to look upon and examine concrete as an artificial rock. As a geochemist, my view is completely different because I have to examine concrete from a chemical framework and as a forensic geochemist, I get to work on some interesting projects, one of which was an investigation on concrete degradation.

Concrete consists of (1) cement, which acts as a binder and (2) aggregate, which gives it strength and durability. Most cements are Portland cement, named after the Portland limestone on the English Isle of Portland.

Cement consists of five major compounds. Cement chemists use abbreviations[1] to describe these compounds (see **Table 1**) and when water is added these compounds undergo hydration. Only the calcium silicates (C_2S and C_3S) contribute to strength. When water is added, tricalcium silicate reacts to release calcium ions, hydroxide ions, and a large amount of heat. The pH quickly increases to 12 because of the release of hydroxide (OH^-) ions. Once concrete sets and is in place it begins to degrade; the causes for this are described below.

[1] The abbreviations used by cement chemists are not preferred because of the possible confusion with chemical elements in the formula (e.g., C_2S could be read as a carbon-sulfur compound).

Possible Causes of Cement/Concrete Degradation

The physical causes are relatively straight forward: (1) too many pores develop, (2) shrinkage results in microcracks from improper curing, (3) cracks from stress and freeze/thaw, and (4) aggregate separation

Chemical causes are by far more complicated and interesting and there are several types of cement/concrete corrosion or attack:

(1) Carbonation corrosion (pH loss) generally occurs when atmospheric CO_2 enters concrete pores to form carbonic acid. This occurs because normal concrete pores contain water and free lime (calcium hydroxide). Carbonic acid neutralizes the free lime forming a neutral pH solid calcium carbonate. The reactions are:

$$CO_2 + H_2O \rightarrow H_2CO_3$$

$$Ca(OH)_2 + H_2CO_3 \rightarrow CaCO_3 + 2H_2O$$

Concrete affected by carbonation undergoes significant pH reductions. If the concrete contains steel rebar, as the pH decreases to <9.5, steel corrosion begins creating rust. Volume expansion from this rust will cause cracking and spalling.

(2) Chloride corrosion occurs when salt water or deicing salt comes in contact with cement easily penetrates cracks and joints. It may also occur when calcium chloride was deliberately added to the concrete mix during construction as an accelerating admixture, and/or a result of impurities in the aggregate or mixing water.

(3) Sulfate attack or corrosion occurs when sulfate (as sodium sulfate, magnesium sulfate, etc.) dissolved in water (e.g., groundwater) reacts with calcium hydroxide in the hardened cement paste. Such sulfate-rich groundwater may be found in zones containing abundant clay. The products of the reaction are:

If sodium sulfate is the reactant, then:

$$Ca(OH)_2 + Na_2SO_4\bullet 10H_2O \rightarrow CaSO_4\bullet 2H_2O + 2NaOH + H_2O$$

Where flowing water occurs, calcium hydroxide may be completely leached away.

The reaction of sodium sulfate with calcium aluminate hydrate in the concrete is:

$$2(3CaO\bullet Al_2O_3\bullet 12H_2O) + 3(Na_2SO_4\bullet 10H_2O) \rightarrow$$

$$3CaO\bullet Al_2O_3\bullet 3CaSO_4\bullet 31H_2O + 2Al(OH)_3 + 6NaOH + 17H_2O.$$

The reaction produces calcium sulfoaluminate, which is the mineral ettringite. The growth of needle-like crystal ettringite results in a considerably greater volume than the reactants, particularly in restricted pore spaces; this causes a bursting pressure on the concrete, resulting in concrete cracking and disruption.

If magnesium sulfate is the reactant, then calcium silicate hydrates, calcium hydroxide, and calcium aluminate hydrate will be attacked; for calcium silicate hydrate the reaction will be:

$$3CaO{\bullet}SiO_2\ (aq.) + 3(MgSO_4{\bullet}7H_2O) \rightarrow 3(CaSO_4{\bullet}2H_2O) + 3Mg(OH)_2 + 2SiO_2{\bullet}12H_2O(aq)$$

Because magnesium hydroxide has a very low solubility, the reaction proceeds to completion so that under certain conditions the reaction of magnesium sulfate with concrete can be more severe than from other sulfates.

The rate of attack on concrete is greatest when concrete is exposed to the pressure of sulfate-bearing water on one side of the concrete (such as a retaining wall). Alternating saturation and drying leads to rapid concrete deterioration. Sulfate attack on concrete has a characteristic whitish appearance (from the minerals ettringite and thaumasite). Damage begins at the edges and/or corners followed by progressive cracking and spalling which reduces the concrete to a friable or soft state.

(4) Aggregate attack: concrete is about 75% by volume aggregate. Generally clean hard, and durable sand is used. However, excessive amounts of silt, clay, coal, lignite, and sulfide minerals, such as pyrite (FeS_2), pyrrhotite (FeS_x), or cinnabar (HgS), can stain and/or weaken concrete.

(5) Other acid attack: Portland cement is not acid resistant and acid attack can come from several sources:

(a) SO_2 and CO_2 produced from industrial emissions and internal combustion engines can attack chimneys and railway tunnels constructed from concrete because SO_2 produces sulfurous acid (H_2SO_3) and CO_2 produces weak carbonic acid (H_2CO_3).

(b) Organic-rich soil-generate natural organic acids such as humic and fulvic acids.

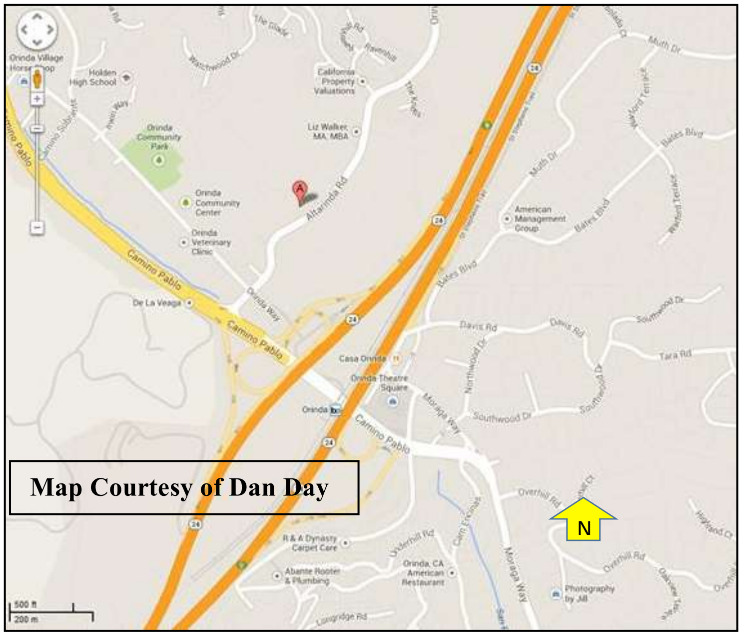
(c) Sewage effluent: animal manure, high temperature sewage results in the generation of anaerobic bacteria producing hydrogen sulfide (H_2S) which is then oxidized producing H_2SO_3 and sulfuric (H_2SO_4) acid. Acid attack on cement will occur above the level of sewage flow.

(d) Solvent attack: solvents generally do not degrade concrete but will penetrate and weaken concrete because many solvents, such as the chlorinated hydrocarbons, have high density-viscosity ratios, easily penetrating through cement's microfractures.

In part 2, I'll describe some of the forensic techniques used in concrete degradation investigations.

TABLE 1
Composition of a Typical Portland Cement

Name	Abbreviation	Formula	Mass Percentage
Dicalcium silicate	C_2S	$(CaO)_2SiO_2$ or Ca_2SiO_4	25
Tricalcium silicate	C_3S	Ca_3SiO_5 or $(CaO)_3SiO_2$	50
Tricalcium aluminate	C_3A	$Ca_3Al_2O_6$	10
Tetracalcium aluminum ferrite	C_4AF	$Ca_4Al_2Fe_2O_{10}$ or $CaO_4Al_2O_3Fe_2O_3$	10
Gypsum	-	$CaSO_4{\cdot}2H_2O$	5
Monocalcium aluminate	CA	$CaOAl_2O_3$	–



Map Courtesy of Dan Day

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

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