NORTHERN CALIFORNIA GEOLOGICAL SOCIETY

MEETING ANNOUNCEMENT

DATE: **September 30, 2015**

LOCATION: Orinda Masonic Center, 9 Altarinda Rd., Orinda

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

SPEAKER: Dr. Gregory Beroza, Stanford University, Berkeley Seismological Laboratory - Lawson Lecture

Induced Earthquakes in the 21st Century

Earthquakes triggered by human activities have been documented for over half a century, but the past decade has seen a resurgence of induced earthquakes associated with energy resources. In 2006, an M 3.4 earthquake occurred during geothermal energy development in Basel, Switzerland, causing the project to be abandoned. In 2009, concerns about triggered earthquakes in the Geysers, California contributed to the early termination of an experimental exploitation effort. New technologies allow hydrocarbons to be recovered from low permeability rocks; however, injection of water produced from that process has the potential to trigger earthquakes. Plans to reduce greenhouse gas in the atmosphere by deep CO_2 injection would require such massive injection volumes that it may set off earthquakes. In all of these ways, induced seismicity is a problem that impacts future energy options, so it is important to understand it. The phenomenon of induced earthquakes also raises interesting questions. How can we tell induced earthquakes from naturally occurring, tectonic earthquakes? How can we predict where they are likely to occur? How can we mitigate the risk associated with induced earthquakes? How should induced earthquakes be treated in existing policy – from quantifying seismic hazard to mitigating the consequences of earthquakes? In this talk I will review recent instances of induced seismicity, and summarize the state of the science seeking to answer these questions.

Biography. Greg Beroza is the Wayne Loel Professor of Earth, Energy, and Environmental Sciences at Stanford University, where he has been on the faculty since 1990. He holds a BS degree from UC Santa Cruz and a Ph.D. degree from MIT. He has been Co-Director, in charge of science planning, for the Southern California Earthquake Center since 2007, and Co-Director of the Stanford Center for Induced and Triggered Seismicity since 2013. His research focus is on earthquake seismology. Of particular relevance to induced and triggered earthquakes are his work on earthquake detection, high precision earthquake location, and earthquake ground

Continued on back…

NCGS 2015 – 2016 Calendar

October 28, 2015 **(may be postponed to Spring 2016)** **7:00 pm**
Dr. Robert I. Davies, Merced College
Living Above the Fossil Zoo: 23 Million Years of Geologic History Under the Central Valley

November 18, 2015 (1 Week Early) 7:00 pm
Dr. Andrea Foster, U.S. Geological Survey
The Environmental Legacy of California's Gold Rush: Arsenic and Mercury Contamination from Historic Mining

NCGS Field Trips

Fall 2015
Anatomy and provenance of a deep-water boulder conglomeratic submarine canyon in the Upper Cretaceous Panoche Formation (Cenomanian), Great Valley Group, San Luis Reservoir, central California-
Dr. Todd J. Greene, Department of Geological and Environmental Science, California State University, Chico

Additional Trips in 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.

Early Career Scientists Sought to Speak in K-12 classrooms

The following is an email from The National Center for Science Education received by the Kathleen Burnham; it may be of interest to some of our members.

Dear Kathleen,

The National Center for Science Education is piloting a new program this fall to get early career scientists into K-12 classrooms to talk about climate change and evolution!

We are looking for all types of early career scientists, from graduate students all the way up to folks in their first years of their academic positions. The time commitment for the program is low, just one in-class visit and regular monthly social media interactions throughout the semester, but the impact will be enormous. This is a great opportunity for scientists looking to share their work with a broader audience and inspire a new generation of scientists and science-loving citizens.

Interested? Intrigued? Know of a great fit for such a new and innovative program? Perfect! Sign up yourself, share with colleagues or departments who might be interested, and send some early career scientists our way!

To find out more about the program and sign up, visit our website or contact Minda Berbeco at berbeco@ncse.com.

Sincerely,

Minda Berbeco
Programs and Policy Director
National Center for Science Education
420 40th Street Suite 2
Oakland, CA 94702
p. 510-601-7203 e. berbeco@ncse.com

Obituary

Barry Arthur Reik (1953-2015)

Barry Arthur Reik passed away on Sunday, March 15, after a long illness. He would have been 61 on March 20.

Barry worked his way through the University of Wisconsin and then went to Florida State University where he worked on carbonates and received a Master's degree. Having worked at the Wehr Steel Company while an undergraduate, he found more comfortable employment at the Florida Bureau of Geology as a Geological Assistant. In January of 1981, Barry left Florida for Louisiana, where he joined Chevron in New Orleans on January 20, 1981. He worked in various jobs for Chevron in New Orleans and then transferred to Lafayette, Louisiana in 1986. In 1992, Barry moved to Chevron's research lab in La Habra, California and then to Chevron Overseas Petroleum COPI in San Ramon in late 1993.

In San Ramon, Barry worked on Formation Evaluation, mostly for Angola where he pioneered the use of mineral-based log analysis to identify pay in mixed carbonate-clastic reservoirs. He transferred into the Chevron Research Company (Chevron Petroleum Technology Company) after it moved to San Ramon. Barry became more involved in training and, together with Tom Wild and Bruce Bilodeau, coordinated and taught all the basic and intermediate formation evaluation classes for Chevron. Barry travelled literally around the world, teaching formation evaluation in nearly all Chevron's upstream North America offices, as well as the U.K, Indonesia, China, Australia, Angola, Nigeria, Libya, and others. He also spent some time in Argentina helping to develop formation evaluation expertise in the Chevron operations there. The last major project Barry worked on was the "Petrophysical Organizational Capability" training project. Groups of about 20 early- and mid-career Chevron geoscientists and engineers spent about two years in an intense, focussed program where they learned about all aspects of formation evaluation and petrophysics. Barry was responsible for developing and coordinating the training curriculum, organizing each class, teaching some of the material, recruiting "Subject "Matter Experts" to teach the more advanced sections of the class, and generally keeping the whole enterprise running. He was dedicated to ensuring that trainees learned the fundamentals of petrophysics as well as the workings of each measurement technology. His expertise using mineral-based log analysis was unsurpassed and he took every opportunity to mentor new users.

Barry was the secretary of Chevron's Intercompany Technical Group on Formation Evaluation, which encouraged the sharing of information and expertise across the entire Chevron community. Barry organized yearly meetings that brought together technical experts from around the world. He tried to keep all the disparate parts of the Corporation in communication and made sure that new methods and techniques were shared as widely as possible.

Barry made many contributions to Formation Evaluation at Chevron. Through the many students he taught and colleagues he worked with, his legacy will live for a long time.

Submitted by Bill Corea, San Ramon, California

2014-2015 Richard Chambers Memorial Scholarships

The NCGS awarded Richard Chambers Memorial Scholarships to three students in early February 2015. Two $ 1,000 scholarships were to students pursuing Masters Degrees and one $ 2,000 to a student pursuing a Doctorate Degree.

A **Richard Chambers Memorial Scholarship** at the Masters Degree level was awarded to Nathan Dickey, a student at California State University, Northridge. His advisor is Dr. Richard V. Heermance.

Mr. Dickey's research project is titled "**Investigation of Late Pleistocene glaciations in the Trinity Alps of northern California using ^{10}Be cosmogenic dating and numerical modeling".** He plans on careful geomorphic and field mapping of glacial moraines in the Trinity Alps to develop a relative timing of moraine deposition and correlations with glaciations in the Sierra Nevada and Cascades. After sample collection in the Trinity Alps he will determine absolute ages of LGM (Last Glacial Maximum) via ^{10}Be concentration in samples from top of boulders in these moraines. He plans on extracting the ^{10}Be and preparing samples adding ^{9}Be in a clean lab at CSUN. The ratio of ^{9}Be to ^{10}Be will be determined using the accelerator mass spectrometer at Lawrence Livermore National Laboratory. This will provide what the original amount ^{10}Be is in the original samples. Then using a numerical model will determine the paleoclimate required to sustain glaciations of the extents indicated by field evidence. Comparison of new data with older data from the Sierra Nevada and Cascades provides an opportunity to understand responses to abrupt climate changes occurring before, during and after the LGM.

The other **Richard Chambers Memorial Scholarship** at the Masters Degree level was awarded to Jan Weninger, a student at the University of California, Davis. Ms. Weninger's advisor is Dr. Charles E. Lesher in the Earth & Planetary Sciences.

Ms. Weninger's research is titled "**The Plutonic Rocks of the Smartville Complex**". Ms. Weninger is studying the 160 Ma Smartville Complex, which has been interpreted to represent an exhumed volcanic island-arc that has a complex history. The gabbro-diorite plutons are described as reversely zoned. In her recent geologic mapping she has observed that magmas with high compositional and presumably high temperature contrasts comingled in proximity to gabbroic and tonalite plutons.

She states in her proposal that commingling of magmas with high compositional and temperature contrast is increasingly recognized as an important process relating to magmatic evolution and pluton formation. However, commingling of two contrasted magmas has not yet been considered to result in the perceived "reverse-zoning" of gabbro-diorite plutons. Jan plans on mapping (1:4000) of the "*Oregon Hill Gabbroic Intrusion - characterization of the intrusion and the surrounding intrusive environment*" and also the "*Colgate Power Station-Defining the relationship between the biotite hornblende tonalite pluton, the mafic magma injections (flow sheets), the olivine gabbro/gabbro-diorite units, and the metamorphosed tonalite?, basement rock? unit that has been injected with an abundance of mafic dikes*." She will then perform petrographic and geochemical analysis to corroborate field observations. This will include electron microprobe analysis of mineral compositions, XRF whole rock major elements and ICP-MS for trace element and multi-collector ICP-MS for Sr, Nd and Hf. This will all further our understanding of the Smartville Complex magmatic history.

A Richard Chambers Memorial Scholarship at the Doctorate level was awarded to Kristen Fauria, a student at the University of California, Berkeley. Her advisor is Dr. William E. Dietrich, Department of Earth and Planetary Science.

Ms. Fauria research is titled "**Decoding the effects of lithology on topography in a soil-mantled landscape**".

From her proposal her" Hypotheses 1) Stream incision varies as a function of lithology; valleys form where stream incision is greatest in "weak" lithologies. 2) Lithologies influences the depth-dependent production, rate, grain size, cohesion, and permeability of soil. These in turn, affect the magnitude and pathways of surface runoff as well as the biota that disturb and transport soil."

Ms. Fauria has built a numerical model with collaborator Mong-Han Huang. Her field area is in the Wilbur Springs Quadrangle (USGS). This is an area in the Northern Coast Range within "Great Valley Sequence" (150 – 65 Ma) of interbedded turbidities and conglomerates. Clear topographic features related to lithology include ridges parallel to strike of the bedding and a well-defined first-order valley spacing, and aspect dependent differences in vegetation and soil depth. She will be using LiDAR in her field study and also cosmogenic nuclides to measure erosion rates and other parameters.

2015-2016 Chambers Scholarships

The 2015-2016 RCMS application deadline is December 18, 2015. Applicants should go to the NCGS website for the application process. Phil Garbutt will bring copies of the application procedures to the NCGS general meetings between now and December.

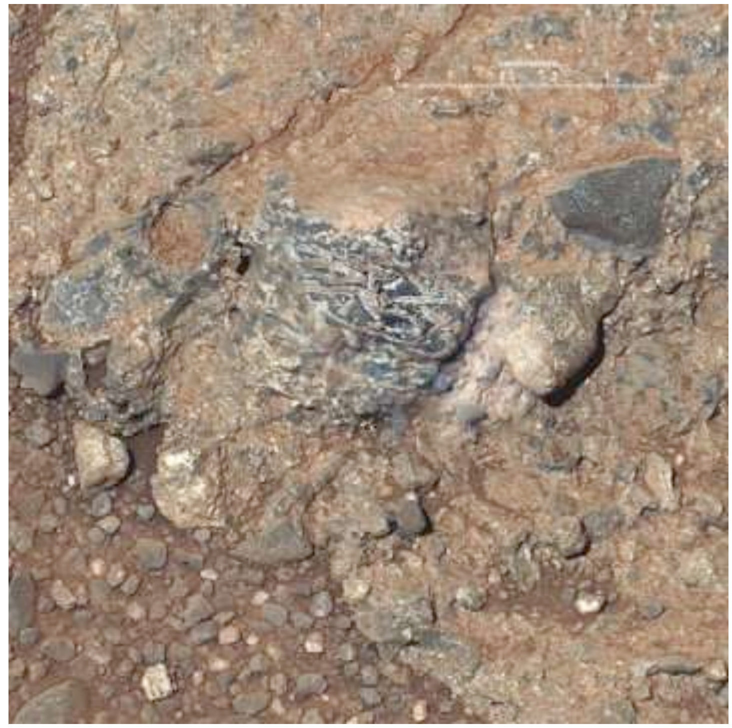
Curiosity rover finds evidence of Mars' primitive continental crust

ChemCam instrument shows ancient rock much like Earth's

The ChemCam laser instrument on NASA's Curiosity rover has turned its beam onto some unusually light-colored rocks on Mars, and the results are surprisingly similar to Earth's granitic continental crust rocks. This is the first discovery of a potential "continental crust" on Mars.

"Along the rover's path we have seen some beautiful rocks with large, bright crystals, quite unexpected on Mars" said Roger Wiens of Los Alamos National Laboratory, lead scientist on the ChemCam instrument. "As a general rule, light-colored crystals are lower density, and these are abundant in igneous rocks that make up the Earth's continents."

Mars has been viewed as an almost entirely basaltic planet, with igneous rocks that are dark and relatively dense, similar to those forming the Earth's oceanic crust, Wiens noted. However, Gale crater, where the Curiosity rover landed, contains fragments of very ancient igneous rocks (around 4 billion years old) that are distinctly light in color, which were analyzed by the ChemCam instrument.



Igneous clast named Harrison embedded in a conglomerate rock in Gale crater, Mars, shows elongated light-toned feldspar crystals. The mosaic merges an image from Mastcam with higher-resolution images from ChemCam's Remote Micro-Imager. Credit: NASA/JPL-Caltech/LANL/IRAP/U. Nantes/IAS/MSSS.

French and US scientists observed images and chemical results of 22 of these rock fragments. They determined that these pale rocks are rich in feldspar, possibly with some quartz, and they are unexpectedly similar to Earth's granitic continental crust. According to the paper's first author, Violaine Sautter, these primitive Martian crustal components bear a strong resemblance to a terrestrial rock type known to geologists as TTG (Tonalite-Trondhjemite-Granodiorite), rocks that predominated in the terrestrial continental crust in the Archean era (more than 2.5 billion years ago).

The results were published this week in *Nature Geoscience*, "*In situ* evidence for continental crust on early Mars."

Gale crater, excavated about 3.6 billion years ago into rocks of greater age, provided a window into the Red Planet's primitive crust. The crater walls provided a natural geological cut-away view 1-2 miles down into the crust. Access to some of these rocks, strewn along the rover's path, provided critical information that could not be observed by other means, such as by orbiting satellites.

Story Source: The above post is reprinted from materials provided by DOE/Los Alamos National Laboratory and Science Daily July 14, 2015.

Journal Reference: V. Sautter, M. J. Toplis, R. C. Wiens, A. Cousin, C. Fabre, O. Gasnault, S. Maurice, O. Forni, J. Lasue, A. Ollila, J. C. Bridges, N. Mangold, S. Le Mouélic, M. Fisk, P.-Y. Meslin, P. Beck, P. Pinet, L. Le Deit, W. Rapin, E. M. Stolper, H. Newsom, D. Dyar,

N. Lanza, D. Vaniman, S. Clegg, J. J. Wray. **In situ evidence for continental crust on early Mars**. *Nature Geoscience*, 2015; DOI: 10.1038/ngeo2474

Spectacular Moroccan fossils redefine evolutionary timelines

A marrellomorph arthropod, probably belonging to the genus Furca. Credit: Peter Van Roy

Some of the oldest marine animals on the planet, including armoured worm-like forms and giant, lobster like sea creatures, survived millions of years longer than previously thought, according to a spectacularly preserved fossil formation from southeastern Morocco.

The Lower Fezouata formation has been revealing exciting discoveries about life in the Ordovician -- around 485 -- 444 million years ago -- since its discovery just five years ago.

'The Fezouata is extraordinarily significant' says Professor Derek Briggs of Yale University, co-author of a study published today in the *Journal of the Geological Society*. 'Animals typical of the Cambrian are still present in rocks 20 million years younger, which means there must be a cryptic record in between, which is not preserved.'

Over 160 genera have already been documented from the Fezouata, with much more expected to be found. They include animals which would have looked perfectly at home during the Cambrian: armoured lobopodians -- worm like creatures with spines on their backs and short, stubby legs, and anomalocaridids -- huge segmented animals with remarkable feeding limbs, which are some of the largest marine creatures of the time.

As well as demonstrating the longevity of fauna thought to have been extinct millions of years previously, the Fezouata proves that other creatures evolved far earlier than previously thought.

'Horseshoe crabs, for example, turn out to be at least 20 million years older than we thought. The formation demonstrates how important exceptionally preserved fossils are to our understanding of major evolutionary events in deep time' says Peter Van Roy, also of Yale, who first recognised the scientific importance of the Fezouata fauna and is lead author of the study, part of a project funded by the National Science Foundation.

The spectacular preservation, which includes detailed soft parts and organisms over 2 metres in length, is thanks to the fine grained, muddy sediments in which the organisms were preserved.

'These are special rocks' says Professor Briggs. 'Some of the organisms are enormous -- several metres in length. With such exceptional preservation, in a fully marine exposure, we can develop a reasonably full picture of what marine life looked like in the Ordovician.'

The discoveries suggest the 'Great Ordovician Biodiversification Event' -- an explosion in diversity throughout the earlier part of the Ordovician period -- may have been a continuation of the Cambrian explosion.

'There is much more to learn from the Fezouata' says Professor Briggs. 'Why do we not see more assemblages like this in the Ordovician? What ecological changes happened at the Cambro-Ordovician interval? Are the Cambrian Explosion and the Great Ordovician Biodiversification Event separate, or phases of the same event?'

The paper, published online today, marks the start of a themed series of 'Review focus' articles for the Journal of the Geological Society, centring on sites of exceptional fossil preservation spanning Earth's history. All papers in the series will be available for free download, and further 'Review focus' themes are planned.

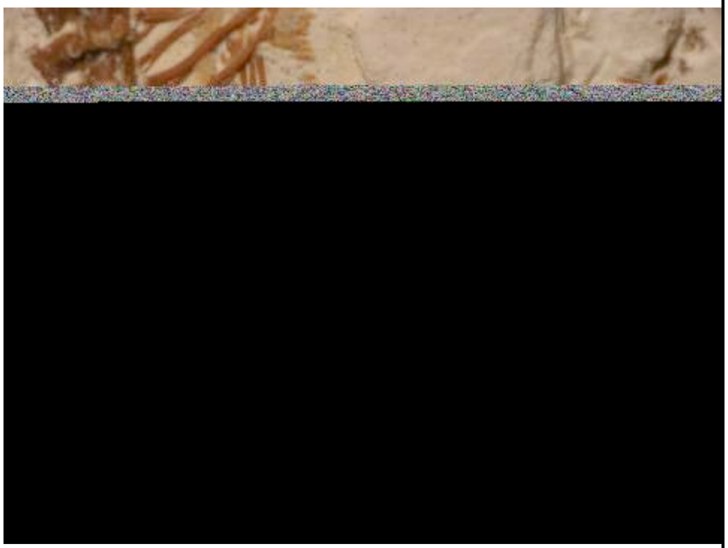
'The purpose of these articles is to present a distilled, forward looking review of a topic', says the series editor Professor Philip Donoghue. 'We decided to start with a thematic series on fossil Lagerstätten since these deposits are fundamental archives of evolutionary history.'

'By making the papers freely available, it is hoped they will interest a wide range of readers, from undergraduates, to specialists in the field, to members of the public.'

Story Source: The above post is reprinted from materials provided by **Geological Society of London** and ScienceDaily July 7, 2015.

Journal Reference: Van Roy, P., Briggs, D.E.G. & Gaines R.R. **The Fezouata fossils of Morocco; an extraordinary record of marine life in the Early Ordovician**. *Journal of the Geological Society*, July 8, 2015 DOI: 10.1144/jgs2015-017

Four-legged snake fossil found



The snake has small 'hands' that are approx 1cm long. Credit: Image courtesy of University of Portsmouth

An "absolutely exquisite" fossil of a snake that had four legs has been discovered by a team of scientists and may help show how snakes made the transition from lizards to serpents.

It is the first known fossil of a four-legged snake, and the team -- led by Dr Dave Martill from the University of Portsmouth -- say that this discovery could help scientists to understand how snakes lost their legs.

The findings were published in the journal *Science.*

Dr Martill said: "It is generally accepted that snakes evolved from lizards at some point in the distant past. What scientists don't know yet is when they evolved, why they evolved, and what type of lizard they evolved from. This fossil answers some very important questions, for example it now seems clear to us that snakes evolved from burrowing lizards, not from marine lizards."

The fossil, from Brazil, dates from the Cretaceous period and is 110 million years old, making it the oldest definitive snake.

Dr Martill discovered the fossil as part of a routine field trip with students to Museum Solnhofen, Germany, a museum that is well-known for its prestige with regard to fossils.

Dr Martill said: "The fossil was part of a larger exhibition of fossils from the Cretaceous period. It was clear that no-one had appreciated its importance, but when I saw it I knew it was an incredibly significant specimen."

Dr Martill worked with expert German palaeontologist Helmut Tischlinger, who prepared and photographed the specimen, and Dr Nick Longrich from the University of Bath's Milner Centre for Evolution, who studied the evolutionary relationships of the snake.

Dr Longrich, who had previously worked on snake origins, became intrigued when Martill told him the story over a pint at the local pub in Bath.

He said: "A four-legged snake seemed fantastic and as an evolutionary biologist, just too good to be true, it was especially interesting that it was put on display in a museum where anyone could see it."

He said he was initially sceptical, but when Dr Martill showed him Tischlinger's photographs, he knew immediately that it was a fossil snake.

The snake, named Tetrapodophis amplectus by the team, is a juvenile and very small, measuring just 20cm from head to toe, although it may have grown much larger. The head is the size of an adult fingernail, and the smallest tail bone is only a quarter of a millimetre long. But the most remarkable thing about it is the presence of two sets of legs, or a pair of hands and a pair of feet.

The front legs are very small, about 1cm long, but have little elbows and wrists and hands that are just 5mm in length. The back legs are slightly longer and the feet are larger than the hands and could have been used to grasp its prey.

Dr Longrich said: "It is a perfect little snake, except it has these little arms and legs, and they have these strange long fingers and toes.

"The hands and feet are very specialised for grasping. So when snakes stopped walking and started slithering, the legs didn't just become useless little vestiges -- they started using them for something else. We're not entirely sure what that would be, but they may have been used for grasping prey, or perhaps mates."

Interestingly, the fossilised snake also has the remains of its last meal in its guts, including some fragments of bone. The prey was probably a salamander, showing that snakes were carnivorous much earlier in evolutionary history than previously believed.

Helmut Tischlinger said: "The preservation of the little snake is absolutely exquisite. The skeleton is fully articulated. Details of the bones are clearly visible and impressions of soft tissues such as scales and the trachea are preserved."

Tetraphodophis has been categorised as a snake, rather than a lizard, by the team due to a number of features:

· The skeleton has a lengthened body, not a long tail.

· The tooth implantation, the direction of the teeth, and the pattern of the teeth and the bones of the lower jaw are all snake-like.

· The fossil displays hints of a single row of belly scales, a sure fire way to differentiate a snake from a lizard.

Tetrapodophis would have lived on the bank of a salt lake, in an arid scrub environment, surrounded by succulent plants. It would probably have lived on a diet of small amphibians and lizards, trying to avoid the dinosaurs and pterosaurs that lived there.

At the time, South America was united with Africa as part of a supercontinent known as Gondwana. The presence of the oldest definitive snake fossil in Gondwana suggests that snakes may originally have evolved on the ancient supercontinent, and only became widespread much more recently.

Story Source: The above post is reprinted from material provided by University of Portsmouth and ScienceDaily July 23, 2015

Journal Reference: Dave Martill et al. **A four-legged snake from the Early Cretaceous of Gondwana**. *Science*, July 2015 DOI: 10.1126/science.aac5672

Mammoths killed by abrupt climate change

New research has revealed abrupt warming, that closely resembles the rapid human-made warming occurring today, has repeatedly played a key role in mass extinction events of large animals, the megafauna, in Earth's past.

Using advances in analysing ancient DNA, radiocarbon dating and other geologic records an international team led by researchers from the University of Adelaide and the University of New South Wales (Australia) have revealed that short, rapid warming events, known as interstadials, recorded during the last ice age or Pleistocene (60,000-12,000 years ago) coincided with major extinction events even before the appearance of man.

Published today in *Science*, the researchers say by contrast, extreme cold periods, such as the last glacial maximum, do not appear to correspond with these extinctions.

"This abrupt warming had a profound impact on climate that caused marked shifts in global rainfall and vegetation patterns," said University of Adelaide lead author and Director of the Australian Centre for Ancient DNA, Professor Alan Cooper.

"Even without the presence of humans we saw mass extinctions. When you add the modern addition of human pressures and fragmenting of the environment to the rapid changes brought by global warming, it raises serious concerns about the future of our environment."

Mammoth vertebrae in ice, Yukon Territory, Canada. Credit: Kieren Mitchell, University of Adelaide

suggesting the rapid disappearance of large species. At first the researchers thought these were related to intense cold snaps.

However, as more fossil-DNA became available from museum specimen collections and through improvements in carbon dating and temperature records that showed better resolution through time, they were surprised to find the opposite. It became increasingly clear that rapid warming, not sudden cold snaps, was the cause of the extinctions during the last glacial maximum.

The research helps explain further the sudden disappearance of mammoths and giant sloths that became extinct around 11,000 years ago at the end of the last ice age.

"It is important to recognize that man still played an important role in the disappearance of the major mega fauna species," said fellow author Professor Chris Turney from the University of New South Wales.

"The abrupt warming of the climate caused massive changes to the environment that set the extinction events in motion, but the rise of humans applied the coup de grace to a population that was already under stress."

In addition to the finding, the new statistical methods used to interrogate the datasets (led by Adelaide co-author Professor Corey Bradshaw) and the new data itself has created an extraordinarily precise record of climate change and species movement over the Pleistocene.

This new dataset will allow future researchers a better understanding of this important period than has ever been possible before.

Story Source: The above post is reprinted from materials provided by University of Adelaide and ScienceDaily July 23, 2015.

Journal Reference: Alan Cooper, Chris Turney, Konrad A. Hughen, Barry W. Brook, H. Gregory McDonald, and

Corey J. A. Bradshaw. **Abrupt warming events drove Late Pleistocene Holarctic megafaunal turnover**. *Science*, 23 July 2015 DOI: 10.1126/science.aac4315

Exit dinosaurs, enter fishes

Mass extinction event that killed the dinosaurs gave rise to modern 'age of fishes'

An assortment of Early Cenozoic ichthyoliths.
Credit: Elizabeth Sibert with Yale University

A pair of paleobiologists from Scripps Institution of Oceanography, UC San Diego have determined that the world's most numerous and diverse vertebrates ¬- ray-finned fishes -- began their ecological dominance of the oceans 66 million years ago, aided by the mass extinction event that killed off dinosaurs.

Scripps graduate student Elizabeth Sibert and Professor Richard Norris analyzed the microscopic teeth of fishes found in sediment cores around the world and found that the abundance of ray-finned fish teeth began to explode in the aftermath of the mass die-off of species, which was triggered by an asteroid strike in the Yucatan Peninsula. Scientists refer to this episode as the Cretaceous-Paleogene (K/Pg) extinction event.

Ninety-nine percent of all fish species in the world -- from goldfish to tuna and salmon -- are classified as ray-finned fishes. They are defined as species with bony skeletal structures and have teeth that are well preserved in deep ocean mud. Sharks, in contrast, have cartilaginous skeletons and are represented by both teeth and mineralized scales, also known as denticles, in marine sediments.

"We find that the extinction event marked an ecological turning point for the pelagic marine vertebrates," write the authors in the study. "The K/Pg extinction appears to have been a major driver in the rise of ray-finned fishes and the reason that they are dominant in the open oceans today."

The breakthrough for the researchers in reaching their conclusion came through their focus on fossilized teeth and shark scales. In cores from numerous ocean basins, they found that while the numbers of sharks remained steady before and after the extinction event, the ratio of ray-finned fish teeth to shark teeth and scales gradually rose, first doubling then becoming eight times more abundant 24 million years after the extinction event. Now there are 30,000 ray-finned fish species in the ocean, making this class the most numerically diverse and ecologically dominant among all vertebrates on land or in the ocean.

Scientists had known that the main diversification of ray-finned fishes had happened generally between 100 million and 50 million years ago.

"The diversification of fish had never been tied to any particular event. What we found is that the mass extinction is actually where fish really took off in abundance and variety," said Sibert, who is the recipient of an NSF Graduate Research Fellowship. "What's neat about what we found is that when the asteroid hit, it completely flipped how the oceans worked. The extinction changed who the major players were."

Sibert and Norris believe that some key changes in the oceans might have helped ray-finned fishes along. Large marine reptiles disappeared during the mass extinction, as did the ammonites, an ancient cephalopod group similar to the chambered nautilus. Those species, the researchers believe, had been either predators of ray-finned fishes or competitors with them for resources.

"What's amazing," said Norris, "is how quickly fish double, then triple in relative abundance to sharks after the extinction, suggesting that fish were released from predation or competition by the extinction of other groups of marine life."

Sibert noted that before the extinction event, ray-finned fishes existed in a state of relative ecological insignificance, just like mammals on land.

"Mammals evolved 250 million years ago but didn't become really important until after the mass extinction. Ray-finned fishes have the same kind of story," said Sibert. "The lineage has been around for hundreds of millions of years, but without the mass extinction event 66 million years ago, it is very likely that the oceans wouldn't be dominated by the fish we see today."

Story Source: The above post is reprinted from materials provided by University of California, San Diego. The original item was written by Robert Monroe. *Note: Materials may be edited for content and length.*

Journal Reference: Elizabeth C. Sibert, Richard D. Norris. **New Age of Fishes initiated by the**

Cretaceous−Paleogene mass extinction. *Proceedings of the National Academy of Sciences*, 2015; 201504985 DOI: 10.1073/pnas.1504985112

As carbon emissions climb, so too has Earth's capacity to remove CO2 from atmosphere

A new paper, co-authored by Woods Hole Research Center Senior Scientist Richard A. Houghton, entitled, "Audit of the global carbon budget: estimate errors and their impact on uptake uncertainty," was published in the journal *Biogeosciences*. The paper confirms that as carbon emissions continue to climb, so too has Earth's capacity to absorb carbon dioxide from the atmosphere. About half of the emissions of CO_2 each year remain in the atmosphere; the other half is taken up by the ecosystems on land and the oceans.

For Dr. Houghton, "There is no question that land and oceans have, for at least the last five and half decades, been taking up about half of the carbon emitted each year. The outstanding question is, Why? Most of the processes responsible for that uptake would be expected to slow down as Earth warms, but we haven't seen it yet. Since the emissions today are three times higher than they were in the 1960s, this increased uptake by land and ocean is not only surprising; it's good news. Without it, the concentration of CO_2 in the atmosphere would be twice what it is, and climate change would be much farther along. But, there's no guarantee that it will continue."

For at least the last five and half decades, land and oceans have been taking up about half of the carbon emitted each year. The outstanding question is, Why?
Credit: © James Thew / Fotolia

Since 1956, when the monitoring of atmospheric CO_2 concentrations began at Mauna Loa Observatory (MLO), many more stations have been added to measure the amount of carbon in the atmosphere and how it varies seasonally and geographically. The measurements provide the ability to detect changes in the behavior of the global carbon cycle. This paper outlines a new framework for assessing errors and their impact on the uncertainties associated with calculating carbon sinks on land and in oceans. Dr. Houghton and colleagues conclude that the greater certainty in atmospheric carbon measurements has led to an increased certainty in the calculated rate of carbon uptake by land and oceans. The scientists are confident that the rates have so far increased in proportion to emissions. Monitoring that uptake year by year is critical for understanding the carbon cycle and for knowing how to deal with it.

Story Source: The above story is based on materials provided by Woods Hole Research Center and ScienceDaily May 14, 2015

Journal Reference: A. P. Ballantyne, R. Andres, R. Houghton, B. D. Stocker, R. Wanninkhof, W. Anderegg, L. A. Cooper, M. DeGrandpre, P. P. Tans, J. B. Miller, C. Alden, J. W. C. White. **Audit of the global carbon budget: estimate errors and their impact on uptake uncertainty**. *Biogeosciences*, 2015; 12 (8): 2565 DOI: 10.5194/bg-12-2565-2015

Why Have Volcanoes in the Cascades Been So Quiet Lately?

This week marks the 100th anniversary of the eruption of California's Lassen Peak. As the anniversary slides past, it leaves Mount St. Helens the only Cascade Range volcano that has erupted over the last century. This means that although we have thirteen major composite volcanoes plus a multitude of smaller cinder cones and lava domes running from California into Canada, only one has experienced an eruption in the past 100 years. Does that mean we don't have to worry about the Cascades as a volcanic hazard anymore? That answer is decidedly "no" … but why?

Why do the Cascade volcanoes exist, anyway?

It is all thanks to subduction, the process of recycling that sends old oceanic crust back into the mantle. For the Cascades, this is subduction of three very small tectonic plates: the Juan de Fuca, Explorer and Gorda Plates. These are all remnants of a much larger plate (the Farallon) that broke apart and has mostly been subducted (and helped form the Sierra Nevada). Today, these microplates are sliding underneath North America at a rate of ~3.5 centimeters per year. As the oceanic plates slide under the continental plate of North America, they start to dip sharply (at ~55º from horizontal for the Cascades). This means that by the time the plate is ~70-100 kilometers from the trench (see above), it reaches a depth of ~100 kilometers … and as the plate goes deeper in the Earth, it gets hotter.

This is the root cause of all the volcanism in the Cascades (and all volcanic arcs). However, it might not be what you think. The downgoing plate (as the oceanic plate is called) heats up but it doesn't melt to form the magma that eventually erupts in the Cascades. Instead, a pile of different mineral reactions occur to release water trapped in the structure of certain minerals.

These are dehydration reactions that they send water and other fluids upwards into the mantle that trapped between the downgoing plate (see above) and the overriding plate (in this case, North America). This water does to the mantle what salt does to ice: lowers the melting point. So, what was solid mantle begins to melt a little bit and it is this melting of the mantle that creates the magma that may eventually erupt.

So, without that tectonic action of these microplates sliding to their doom under North America, we would have no Cascade Range. The Cascades aren't the only place on Earth with volcanoes caused by subduction. The western coasts of South America, Japan, the Kamchatka Peninsula of Russia, New Zealand, Indonesia and many more places have active subduction and with it, lots of active volcanoes. The Cascades are merely one piece of the puzzle for how the Earth's crust keeps its balance, destroying crust as it creates new crust at the mid-ocean ridges.

Volcanic Activity in the Cascades

The USGS watches over the Cascade volcanoes, from Washington's Baker in the north to Lassen Peak in the south, through the Cascades Volcano Observatory and California Volcano Observatory. Most of the volcanoes show signs that they are still active volcanoes, whether it be small earthquake swarms from time to time, hot and cold springs, fumaroles or the occasional bouts of deformation. However, only St. Helens has erupted since the 1915 activity at Lassen Peak. Twice St. Helens roared back, first in the 1980's, including the cataclysm eruption for which it is most famous and then again in the 2000's, when domes of lava started to refill the scar left from the 1980 explosion and collapse. For an entire volcanic arc, that seems quiet to many onlookers. Right now, the USGS status for the Cascades has it "green" across the board. This means that none of the volcanoes it monitors are showing any sign of activity. Compare that to some other similar subduction-related locations and the Cascades seem awfully still. In Kamchatka, there are sometimes four or more volcanoes erupting at the same time and if you glance at the USGS/Smithsonian Weekly Volcanic Activity Report, you'd see that most volcanic arcs have at least a volcano or two making trouble.

So why do the Cascades seem to be so different?

Before we can answer this question, we should probably look at the past activity in the Cascades. The USGS has a great graphic that shows the eruptions in the Cascades for the last few thousand years (see above). From this perspective, the Cascades don't look as quiet and for geologic processes, thinking in terms of hundreds to thousands of years is probably a better frame of reference than any human lifespan.

A few volcanoes really dominate the activity (St. Helens, Rainier, Medicine Lake, and Shasta) so are they skewing our views of Cascade activity? I compiled the last confirmed eruption from each Cascade volcano (and some other volcanic areas in the range) to get a sense how odd this current quiet might be. If you take a look at the plot, you can notice a few things.

First, it has been quiet over the last hundred years. However, if you back up to about 1700 AD, then the numbers climb rapidly. Over the last 3 centuries or so, Hood, Rainier, Shasta, Glacier Peak and Baker join St. Helens and Lassen Peak

in the Eruption Club. Go back a little further, and we can add Cinder Cone (a small eruption at the edges of the Lassen Volcanic Center). After that, we have to jump back to around 900-1100 AD for other volcanoes' last eruptions. This bunch includes Jefferson, Adams, Medicine Lake (Glass Mountain) and the eruption of the Chaos Crags domes at the Lassen Volcanic Center. The Big Obsidian Flow at Newberry Caldera erupted about 1330 years ago while some of the big lava flow fields in central Oregon formed about 1500 years ago.

Really, the only volcanoes that haven't joined in over the last 2,000 years are Crater Lake and the Three Sisters (not including Collier Cone, which might not be related directly to North Sister). However, both of those did produce some spectacular eruptions in the geologically-recent past, including the Devils's Hills on South Sister and the collapse of Mt. Mazama to form Crater Lake at ~5,700 BCE, the largest eruption recorded in the Cascades.

So, from a deep(er) time perspective, the Cascades aren't all that quiet … but still, they definitely aren't as active as a lot of volcanic arcs.

Is there a tectonic reason?

If the Cascades are quieter than most arcs, you have to think it has something to do with the tectonic processes that form the magma that erupts. So, can we identify anything about the Cascade subduction zone that might make it different than other, more active, subduction zones?

[Speculation Alert!]

When we look at arcs, the age of the oceanic crust that is being pulled downward, the angle that it is heading and the rate that the plate is going down are thought to play an important role in how magma might be produced. If we want to compare our Cascades with a very active volcanic arc, let's say on the Kamchatka Peninsula in Russia, we might get a sense of the different between a very active and less active subduction zone.

The oceanic plates going down under North America are younger, dipping steeper and moving slower than their counterparts on the opposite side of the Pacific Ocean. Why might that make a difference? One reason might be the age of the crust that being shoved under North America.

Old, cold oceanic crust (some of the oldest on Earth), like what is going down under Kamchatka, has had a lot of time to have the mineral reactions that create water-bearing minerals, converting the oceanic crust into a "sponge" of water, ready to be heated and "squeezed" out as it plunges under the Eurasian plate. Off of North America, the oceanic plates are young and hot (almost 10 times younger than the Pacific Plate going down under Kamchatka), so they haven't experienced as much alteration so they might not have as much of those water-bearing minerals really needed to get a lot of magma to form.

The slab dip might be important too. For the Cascades, the plate plunges down at ~55º, both near the trench and under the volcanic arc. For Kamchatka, the slab is steep as it goes down and then gets shallower under the arc. This might allow for more dehydration of the slab under Kamchatka than the Cascades. Even the rate of subduction might play a role, where the faster subduction under Kamchatka allows for more "wet" oceanic slab to move through, releasing more fluids and forming more magma.

It appears that there are a few tectonic factors that might suppress the generation of magma under the Cascades, so the overall lower output might make sense. Although geologists are confident about what are the processes going on under a subduction zone are to form volcanoes, the balance of these factors—that is, which ones are most important for generating magma—is still being actively studied. So, right now all we can say is that differences exists between the Cascades and Kamchatka and they might be the root cause of the different levels of activity … but exactly why is beyond our knowledge right now. However, this ought to operate over geologic timescales of thousands or more years … what about the last hundred?

So, what is it?

There are a few things we can say about the Cascades after looking at all these data. First, the Cascades, although quiet now, aren't always so quiet. Second, compared to other arcs, the Cascades are less active. I tend to think that the quiet over the last 100 years is a product of statistics. The eruptions are mostly randomly distributed through time, so our 100 year time slice is just an anomaly in that distribution. We're just in a lucky/unlucky period where many of the big Cascade volcanoes aren't in eruptive cycles. However, looking at the distribution of eruptions for the last few thousand years, we can expect that this might not last.

The Cascades have the added bonus of likely being a volcanic arc that is near its end. The San Andreas fault system is slowly working its way up the North American coast as the small plates get completely consumed by subduction. This means that eventually, as the Mendocino Triple Junction moves north, the Cascade volcanoes will likely "shut off" when the source of their magma stops operating. This won't be for millions of years, but the clock is ticking.

The greater question of the overall lower volcanic activity in the long term for the Cascades is fascinating question for which we don't have the answer. In any case, we can't be lulled into a sense of complacency about the "quiet Cascades". Almost any of these volcanoes could erupt in our lifetimes (and I almost expect that one other than St. Helens will), so we need to be ready for that next Cascade eruption.

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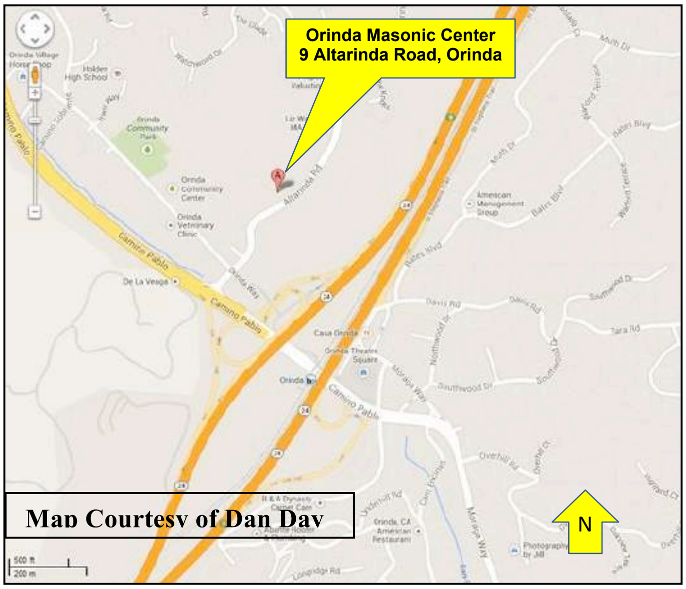

Biography: Greg Beroza is the Wayne Loel Professor of Earth, Energy, and Environmental Sciences at Stanford University, where he has been on the faculty since 1990. He holds a BS degree from UC Santa Cruz and a Ph.D. degree from MIT. He has been Co-Director, in charge of science planning, for the Southern California Earthquake Center since 2007, and Co-Director of the Stanford Center for Induced and Triggered Seismicity since 2013. His research focus is on earthquake seismology. Of particular relevance to induced and triggered earthquakes are his work on earthquake detection, high precision earthquake location, and earthquake ground motion prediction. He is an AGU Fellow, President of the Seismology Section of the AGU, and the 2014 Gutenberg Medalist of the EGU for outstanding contributions to seismology.

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