NORTHERN CALIFORNIA GEOLOGICAL SOCIETY

MEETING ANNOUNCEMENT

DATE: **January 27, 2016**

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. Samuel Johnson, USGS Pacific Coastal & Marine Science Center**

Topic: Exploring California's Amazing Seafloor - the Visionary California Seafloor Mapping Program

The California Seafloor Mapping Program (CSMP) is a collaborative effort to develop comprehensive bathymetric, geologic, and habitat maps for all of California's State Waters. CSMP began in 2007 when the California Ocean Protection Council (OPC) allocated funding for high-resolution bathymetric mapping, largely to support the California Marine Life Protection Act. Subsequent support from the OPC, NOAA, USGS, and other partners has lead to development of one of the world's largest seafloor-mapping datasets. CSMP data stimulates and enables research, raises public education and awareness, and is essential for coastal and marine spatial planning. Specific applications include:

- *Documenting coastal geologic framework*
- *Hazard assessments – earthquakes and tsunamis*
- *Sea-level rise impacts, coastal erosion*
- *Regional sediment management*
- *Forecasting coastal flooding – storm inundation*
- *Baselines for long-term monitoring, climate change*
- *Designation of marine protected areas*
- *Defining habitat, ecosystem-based management*
- *Siting infrastructure (e.g., renewable ocean energy)*
- *Safer navigation and commerce*

(continued on back page)

NCGS 2015 – 2016 Calendar

February 24, 2016 7:00 pm
Robert Davies, Merced College
Living Above the Fossil Zoo: 23 Million Years of Geologic History Under the Central Valley

March 30, 2016 7:00 pm
Dr Jeff Unruh, Lettis Consultants International Inc.
Tectonics of Mount Diablo and Vicinity

April 27, 2016 7:00 pm
Dr. Ronald Olowin, Department of Physics and Astronomy, Saint Mary's College
Title to be determined.

May 25, 2016 7:00 pm (dinner meeting)
Dr. Charles K. Paull, Monterey Bay Aquarium Research Institute
Sediment movement through Monterey and other submarine canyons along the California coast

June 22, 2016. 7:00 pm
Jerome V. De Graff, CSU Fresno, Richard H. Jahns Lecturer for 2016 by the Association of Environmental & Engineering Geologists and the Geological Society of America, "Fire, Earth & Rain"

A Reminder: *It's Renewal Time!* Our Year Runs From September to September. Please Use the Renewal Form Included as Page 11 of the Newsletter.

NCGS Field Trips

Saturday February 6th, 2016
***Promontory Klippe of the Franciscan Complex – Examining the Geology, Geography, Vineyard, and Wine,* Oakville-Yountville area of the Napa Valley, California. Dr. David Howell,** retired USGS geologist and wine enthusiast.

We are sorry, but this trip is already filled!
Please DO NOT send in a reservation form.

Other 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

On Thursday, Jan. 21 at 4 pm at 141 McCone, Erik Sperling will speak on the topic "**The ecological physiology of the Cambrian radiation and Earth's second oxygen revolution"**

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

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. NCSE provides information and advice on keeping evolution and climate change in the science classroom.

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

Scientists peg Anthropocene to first farmers

Study shows 300-million-year natural pattern ended 6,000 years ago because of human activity

Ox team farming (stock image). When did human domination of the planet start, asks a new study that now reports a dramatic shift in one of the rules of nature about 6,000 years ago—connected to growing human populations and the rise of farming. Credit: © Pworadilok / Fotolia

A new analysis of the fossil record shows that a deep pattern in nature remained the same for 300 million years. Then, 6,000 years ago, the pattern was disrupted -- at about the same time that agriculture spread across North America.

"When early humans started farming and became dominant in the terrestrial landscape, we see this dramatic restructuring of plant and animal communities," said University of Vermont biologist Nicholas Gotelli, an expert on statistics and the senior author on the new study.

In the hunt for the beginning of the much-debated "Anthropocene" -- a supposed new geologic era defined by human influence of the planet -- the new research suggests a need to look back farther in time than the arrival of human-caused climate change, atomic weapons, urbanization or the industrial revolution.

"This tells us that humans have been having a massive effect on the environment for a very long time," said S. Kathleen Lyons, a paleobiologist at the Smithsonian's National Museum of Natural History who led the new research. The study was published Dec. 16 in the journal *Nature*.

Species split

Gotelli and Lyons were part of a team of 29 scientists, supported by the National Science Foundation, who studied plant and animal datasets from both modern ecosystems and the fossil record stretching back to the Carboniferous Period, well before the emergence of the dinosaurs.

Examining thousands of pairs of species, the scientists looked to see how often a particular pair of plant or animal species was found within the same community. Analyses of modern communities of plants and animals have shown that, for most pairs of species, the presence of one species within a community does not influence whether the other is present or absent. "We don't expect much interaction between, say, a woodpecker and an earthworm," Gotelli explains.

But some pairs of species appear to be "aggregated," meaning they tend to appear together in nature more often than one would expect by chance -- like cheetahs and giraffes who both depend on savannah habitats. Other species are "segregated," meaning that when one is found, it's unlikely to find the other there too -- "say two species of woodpecker that compete for insect prey," Gotelli says -- being driven apart by, perhaps, different habitat needs or fierce competition, so that they occur together less often than would be expected by chance.

For modern communities of plants and animals, recent studies show that segregated species pairs are more common than aggregated ones. But when the team investigated the composition of ancient communities using data from fossils, they were surprised to find the opposite pattern: from 307 million years ago to about 6,000 years ago, there was a higher frequency of aggregated species pairs. Then, from 6,000 years ago to the present, the pattern shifted to a predominance of segregated species pairs. An ancient rule had changed.

Humans were here

"We don't have direct evidence to show that this pattern change was caused by humans," Gotelli cautions, but the indirect evidence is compelling. The team's statistical analyses considered nearly 358,896 pairs of organisms in 80 plant or mammal communities on different continents, with data sets that collectively covered the last 300 million years of earth history -- including data sets that spanned the huge Permian-Triassic extinction (the "Great Dying" 252 million years ago), the Cretaceous-Paleogene extinction of the dinosaurs (66 million years ago), and a period of rapid global climate change around 56 million years ago.

The pattern of aggregated species occurrences remained the same across these massive disturbances and time spans, but then a dramatically new pattern started emerging about 6,000 years ago, during the great Neolithic revolution when humans developed agriculture and their populations grew and spread globally. From this time until the present, plant and animal communities exhibit less co-occurrence and a greater frequency of segregated species pairs.

The scientists explored -- and eliminated -- many possible reasons for why this new pattern appeared, including several kinds of statistical and sampling artifacts that might explain the shift they saw in the data. For example, Earth's climate became much more variable during modern times, and the team wondered whether this might explain the shift. But when they tracked climactic trends that occurred during the periods represented by their fossils, using data obtained from ancient ice and deep-sea cores, they found no evidence that ancient climate variability was responsible for the change in co-occurrence patterns.

"So we're left with human impacts," Lyons said. "We think it's something that humans do that causes barriers to dispersal for both plant and animal species." That idea is supported by data from modern island communities of plants and animals, which show even fewer co-occurring pairs than modern mainland communities. Island data sets, the authors note, are an extreme example of this phenomenon.

"If human activity has caused the terrestrial landscape to become more island-like, more fragmented," Gotelli said, "that would be consistent with this pattern of more segregated species pairs."

Difficult dispersal

Around the time these patterns changed, humans were becoming increasingly dependent on agriculture -- a cultural shift that physically altered the environment and would have introduced new barriers to dispersal of plants and animals. Even during the initial development of agriculture and expansion of human populations, the scientists could detect a shift in the structure of species co-occurrence, perhaps suggesting that species were not able to migrate as easily as they did for the previous 300 million years.

"The pattern of co-occurring species remained stable through the evolution of land organisms from the earliest tetrapods through dinosaurs, flowering plants and mammals," said Anna K. Behrensmeyer, a paleobiologist with the Smithsonian's Museum of Natural History and a co-author of the study. "This pattern didn't change because of previous mass extinctions or ancient climate variability, but instead, early human activities 6,000 years ago suddenly began resetting a basic property of natural communities."

Climate considerations

And this change in an ancient natural pattern may have implications for modern conservation. "Isolating species has consequences -- it can catalyze evolutionary change over hundreds of thousands to millions of years," Behrensmeyer said, "but it also makes species more vulnerable to extinction."

"We humans have influenced the landscape, but perhaps for a lot longer than we had previously recognized," says Gotelli, a professor in UVM's biology department. "When we look at landscapes and say, 'this is pristine or unaltered,' that's not necessarily true. We may have changed the rules over a much larger scale than we appreciate."

Modern human-driven forces, like climate change and pollution, are "orders of magnitude more destructive than what early humans were doing," Lyons said, but even at the dawn of human civilizations, people were certainly having major -- and unprecedented -- ecological impacts, she said. "If we are thinking about how we're going to restore ecosystems, or how they're going to respond to climate change," UVM's Gotelli said, "we need to understand how they were organized before humans ever came on the scene."

Story Source: The above post is reprinted from materials provided by University of Vermont. The original item was written by Joshua E. Brown.

Journal Reference: S. Kathleen Lyons, Kathryn L. Amatangelo, Anna K. Behrensmeyer, Antoine Bercovici, Jessica L. Blois, Matt Davis, William A. DiMichele, Andrew Du, Jussi T. Eronen, J. Tyler Faith, Gary R. Graves, Nathan Jud, Conrad Labandeira, Cindy V. Looy, Brian McGill, Joshua H. Miller, David Patterson, Silvia Pineda-Munoz, Richard Potts, Brett Riddle, Rebecca Terry, Anikó Tóth, Werner Ulrich, Amelia Villaseñor, Scott Wing, Heidi Anderson, John Anderson, Donald Waller, Nicholas J. Gotelli. **Holocene shifts in the assembly of plant and animal communities implicate human impacts**. *Nature*, 2015; DOI: 10.1038/nature16447.

'Fourth strand' of European ancestry originated with hunter-gatherers isolated by Ice Age

DNA was extracted from the molar teeth of this skeleton, dating from almost 10,000 years ago and found in the Kotias Klde rockshelter in Western Georgia. Credit: Eppie Jones

The first sequencing of ancient genomes extracted from human remains that date back to the Late Upper Palaeolithic period over 13,000 years ago has revealed a previously unknown "fourth strand" of ancient European ancestry.

This new lineage stems from populations of hunter-gatherers that split from western hunter-gatherers shortly after the 'out of Africa' expansion some 45,000 years ago and went on to settle in the Caucasus region, where southern Russia meets Georgia today.

Here these hunter-gatherers largely remained for millennia, becoming increasingly isolated as the Ice Age culminated in the last 'Glacial Maximum' some 25,000 years ago, which they weathered in the relative shelter of the Caucasus mountains until eventual thawing allowed movement and brought them into contact with other populations, likely from further east.

This led to a genetic mixture that resulted in the Yamnaya culture: horse-borne Steppe herders that swept into Western Europe around 5,000 years ago, arguably heralding the start of the Bronze Age and bringing with them metallurgy and animal herding skills, along with the Caucasus hunter-gatherer strand of ancestral DNA -- now present in almost all populations from the European continent.

The research was conducted by an international team led by scientists from Cambridge University, Trinity College Dublin and University College Dublin. The findings are published today in the journal *Nature Communications*.

"The question of where the Yamnaya come from has been something of a mystery up to now," said one of the lead senior authors Dr Andrea Manica, from Cambridge's Department of Zoology.

"We can now answer that as we've found that their genetic make-up is a mix of Eastern European hunter-gatherers and a population from this pocket of Caucasus hunter-gatherers who weathered much of the last Ice Age in apparent isolation. This Caucasus pocket is the fourth major strand of ancient European ancestry, one that we were unaware of until now," he said

Professor Daniel Bradley, leader of the Trinity team, said: "This is a major new piece in the human ancestry jigsaw, the influence of which is now present within almost all populations from the European continent and many beyond."

Previously, ancient Eurasian genomes had revealed three ancestral populations that contributed to contemporary Europeans in varying degrees, says Manica.

Following the 'out of Africa' expansion, some hunter-gatherer populations migrated north-west, eventually colonising much of Europe from Spain to Hungary, while other populations settled around the eastern Mediterranean and Levant, where they would develop agriculture around 10,000 years ago. These early farmers then expanded into and colonised Europe.

Finally, at the start of the Bronze Age around 5,000 years ago, there was a wave of migration from central Eurasia into Western Europe -- the Yamnaya.

However, the sequencing of ancient DNA recovered from two separate burials in Western Georgia -- one over 13,000 years old, the other almost 10,000 years old -- has enabled scientists to reveal that the Yamnaya owed half their ancestry to previously unknown and genetically distinct hunter-gatherer sources: the fourth strand.

By reading the DNA, the researchers were able to show that the lineage of this fourth Caucasus hunter-gatherer strand diverged from the western hunter-gatherers just after the expansion of anatomically modern humans into Europe from Africa.

The Caucasus hunter-gatherer genome showed a continued mixture with the ancestors of the early farmers in the Levant area, which Manica says makes sense given the relative proximity. This ends, however, around 25,000 years ago -- just before the time of the last glacial maximum, or peak Ice Age.

At this point, Caucasus hunter-gatherer populations shrink as the genes homogenise, a sign of breeding between those with increasingly similar DNA. This doesn't change for thousands of years as these populations remain in apparent isolation in the shelter of the mountains -- possibly cut off from other major ancestral populations for as long as 15,000 years -- until migrations began again as the Glacial Maximum recedes, and the Yamnaya culture ultimately emerges.

"We knew that the Yamnaya had this big genetic component that we couldn't place, and we can now see it was this ancient lineage hiding in the Caucasus during the last Ice Age," said Manica.

While the Caucasus hunter-gatherer ancestry would eventually be carried west by the Yamnaya, the researchers found it also had a significant influence further east. A similar population must have migrated into South Asia at some point, says Eppie Jones, a PhD student from Trinity College who is the first author of the paper.

"India is a complete mix of Asian and European genetic components. The Caucasus hunter-gatherer ancestry is the best match we've found for the European genetic component found right across modern Indian populations," Jones said. Researchers say this strand of ancestry may have flowed into the region with the bringers of Indo-Aryan languages.

The widespread nature of the Caucasus hunter-gatherer ancestry following its long isolation makes sense

geographically, says Professor Ron Pinhasi, a lead senior author from University College Dublin. "The Caucasus region sits almost at a crossroads of the Eurasian landmass, with arguably the most sensible migration routes both west and east in the vicinity."

He added: "The sequencing of genomes from this key region will have a major impact on the fields of palaeogeneomics and human evolution in Eurasia, as it bridges a major geographic gap in our knowledge."

David Lordkipanidze, Director of the Georgian National Museum and co-author of the paper, said: "This is the first sequence from Georgia -- I am sure soon we will get more palaeogenetic information from our rich collections of fossils."

Story Source: The above post is reprinted form materials provided by University of Cambridge.

Journal Reference: Eppie R. Jones, Gloria Gonzalez-Fortes, Sarah Connell, Veronika Siska, Anders Eriksson, Rui Martiniano, Russell L. McLaughlin, Marcos Gallego Llorente, Lara M. Cassidy, Cristina Gamba, Tengiz Meshveliani, Ofer Bar-Yosef, Werner Müller, Anna Belfer-Cohen, Zinovi Matskevich, Nino Jakeli, Thomas F. G. Higham, Mathias Currat, David Lordkipanidze, Michael Hofreiter, Andrea Manica, Ron Pinhasi, Daniel G. Bradley. **Upper Palaeolithic genomes reveal deep roots of modern Eurasians**. *Nature Communications*, 2015; 6: 8912 DOI: 10.1038/ncomms9912

New kind of hydrothermal vent system found in Caribbean

A high resolution 3D bathymetry of the Von Damm vent field. Credit: NOCS

Researchers from the University of Southampton have identified hydrothermal vents in the deep sea of the Caribbean which are unlike any found before. Collaborating with colleagues at the National Oceanography Centre, the team has revealed active vents in the Von Damm Vent Field (VDVF) that are unusual in their structure, formed largely of talc, rather than the more usual sulphide minerals.

Lead researcher Matthew Hodgkinson and colleagues analysed samples from the VDVF -- a vent field south of the Cayman Islands discovered by scientists and crew on board the RRS James Cook in 2010. Results of the analysis are now published in the journal *Nature Communications*.

Matthew comments: "This vent site is home to a community of fauna similar to those found at the Mid-Atlantic Ridge in the Atlantic Ocean, but the minerals and chemistry at the Von Damm site are very different to any other known vents."

Hydrothermal vents form in areas where Earth's tectonic plates are spreading. At these sites, circulating seawater is heated by magma below the seafloor and becomes more acidic -- leaching metals from the surrounding rocks and redepositing them as the hot water spews out of vents or 'chimneys' at the seabed and hits the cold seawater.

The scientists have also found the VDVF system has a very energetic heat flux (the amount of energy it emits into the surrounding ocean) of around 500 megawatts. This is much more than would be expected since the VDVF, on the slopes of an underwater mountain and away from a large magma supply, is on the edge of a spreading area and not in between two separating tectonic plates. The unusual positioning of this new vent field suggests that other similar ones elsewhere in the world may have been overlooked.

Matthew Hodgkinson adds: "If more of these unusual sites exist they could be important contributors in the exchange of chemicals and heat between Earth's interior and the oceans, and may be missing from current global assessments of hydrothermal impact on the oceans."

Story Source: The above post is reprinted from materials provided by University of Southampton.

Journal Reference: Matthew R. S. Hodgkinson, Alexander P. Webber, Stephen Roberts, Rachel A. Mills, Douglas P. Connelly, Bramley J. Murton. **Talc-dominated seafloor deposits reveal a new class of hydrothermal system**. *Nature Communications*, 2015; 6: 10150.

Dissecting paleoclimate change

Global climate change isn't new -- the phenomenon has been around for millions of years. But now, a core from

the ocean floor in the Santa Barbara Basin provides a remarkable ultra-high-resolution record of Earth's paleoclimate history during a brief, dynamic time hundreds of thousands of years ago.

New research from UC Santa Barbara geologist James Kennett and colleagues examines a shift from a glacial to an interglacial climate that began about 630,000 years ago. Their research demonstrates that, although this transition developed over seven centuries, the initial shift required only 50 years. Called a deglacial episode because of its association with the melting of large Northern Hemisphere ice sheets, this interval illustrates the extreme sensitivity to change of Earth's climate system. The findings appear in the journal *Paleoceanography*.

"One of the most astonishing things about our results is the abruptness of the warming in sea surface temperatures," explained co-author Kennett, a professor emeritus in UCSB's Department of Earth Science. "Of the 45 degree Fahrenheit total, a shift of about 40 degrees occurred almost immediately right at the beginning."

For more than a million years, Earth's climate has oscillated from glacial (ice age) to interglacial (warm) -- the latter representing modern conditions. According to Kennett, the Santa Barbara Basin holds the most pristine marine record of these fluctuations, thanks in large part to the area's unique location along the California margin. The basin is the confluence of the cool California current from the subpolar region and the warm countercurrent from the tropics.

"The record is incredibly high fidelity, because unlike other places where the amount of sedimentation varies as a function of climate change, here it is remarkably constant," said co-author Craig Nicholson, a research geophysicist at UCSB's Marine Science Institute and an adjunct professor of earth science. "That's because it's largely controlled by tectonics, the uplift of the mountains to the north and the islands to the south, rather than by climate change."

Finding Climatic 'Windows'

Because the scientists were unable to drill deeper than 200 meters into the ocean floor, they turned to tectonics to piece together a semi-continuous record of paleoclimate history. They were able to use the active tectonics to find climatic "windows" going back 700,000 years.

"With this particular core, we hit it rich," Kennett said. "We opened a really clear window to view one of these glacial-to-interglacial transitions, providing a unique opportunity to determine just how fast the climate operated. We discovered that the changes were much faster than we ever thought possible, especially for these large shifts between a full ice age and a full interglacial. These are big events."

Of additional interest was the discovery of a volcanic ash layer in the core. "Volcanic eruptions can produce widely distributed ash layers, each with a distinct geochemical fingerprint," Kennett said. "Our tests showed that this particular ash was ejected from the Yellowstone volcanic caldera in Wyoming, which has exactly the same fingerprint. This huge caldera formed about 630,000 years ago, with most of the enormous volume of ash blown to the east. However, this eruption was so explosive that the ash reached the Santa Barbara Basin, forming a layer one to two inches thick. The discovery of this ash helped with dating the core."

Kennett noted that this remarkable record of paleoclimate changes also raises an important question: What process can possibly push Earth's climate so fast from a glacial to an interglacial state? The researchers may have discovered the answer based on the core's geochemical record: The warming associated with the major climatic shift was accompanied by simultaneous releases of methane -- a potent greenhouse gas.

"This particular episode of climate change is closely associated with instability that caused the release of methane from gas hydrates at the ocean floor," Kennett said. "These frozen forms of methane melt when temperatures rise or pressure decreases. Changes in sea level affect the stability of gas hydrates and water temperature even more so.

"The clear synchronism of this rapid warming and the onset of the destabilization of gas hydrates is important," Kennett concluded. "It suggests that methane hydrate instability and the warming are somehow linked, which is an interesting and potentially important observation. The beauty of these paleoclimate records from the Santa Barbara Basin is that you can actually determine these relationships at high fidelity."

Modern Global Warming Worries

Kennett said that one of the current worries about modern global warming is that the increase in ocean temperatures will destabilize methane hydrates located at relatively shallow depths on the ocean margin, in turn causing positive feedbacks that reinforce the global warming. In fact, this appears already to be occurring in the ocean.

Recent research by others indicates that methane hydrates off the coast of Washington, Oregon and British Columbia are destabilizing in response to a small increase in bottom water temperatures (only 0.3 degrees Celsius) during the past 44 years. This is producing methane gas plumes that billow upward from the ocean floor. Additional ocean margin areas are exhibiting similar responses to warming, which are documented in other scientific work.

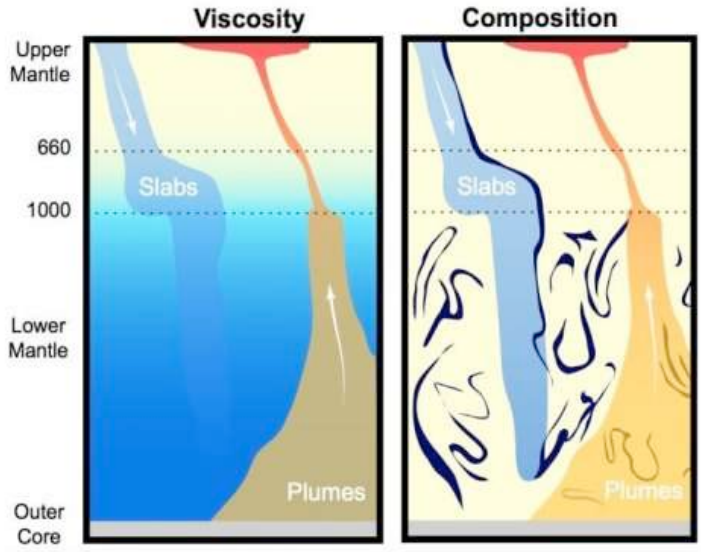
Kennett concluded that such investigations of past climate changes not only inform the world about how climate may change in the future but also illuminate the processes involved.

Story Source: The above post is reprinted from materials provided by University of California, Santa Barbara. The original item was written by Julie Cohen.

Journal Reference: Walter E. Dean, James P. Kennett, Richard J. Behl, Craig Nicholson, Christopher C. Sorlien. **Abrupt termination of Marine Isotope Stage 16 (Termination VII) at 631.5 ka in Santa Barbara Basin, California**. *Paleoceanography*, 2015; 30 (10): 1373 DOI: 10.1002/2014PA002756.

First explanations for boundary within Earth's mantle

Observed physical transition hundreds of miles below Earth's surface



Sinking slabs of ocean crust and rising plumes of hot rock in Earth's mantle are observed to behave differently below one megameter (1,000 kilometers) depth. Two explanations for this behavior were published on Dec. 11, 2015. At left, Rudolph et al. (Science, 2015) propose a viscosity increase (dark blue) below the megameter boundary. At right, Ballmer et al. (Science Advances, 2015) propose a density increase due to accumulated ocean crust (dark squiggles) below the boundary. Credit: Nicholas Schmerr/Vedran Lekic/UMD

Earth's mantle, the large zone of slow-flowing rock that lies between the crust and the planet's core, powers every earthquake and volcanic eruption on the planet's surface. Evidence suggests that the mantle behaves differently below 1 megameter (1,000 kilometers, or 621 miles) in depth, but so far seismologists have not been able to explain why this boundary exists.

Two new studies co-authored by University of Maryland geologists provide different, though not necessarily incompatible, explanations. One study suggests that the mantle below 1 megameter is more viscous--meaning it flows more slowly--than the section above the boundary. The other study proposes that the section below the boundary is denser--meaning its molecules are more tightly packed--than the section above it, due to a shift in rock composition.

Taken together, the studies provide the first detailed look at why large-scale geologic features within the mantle behave differently on either side of the megameter divide. The papers were published on December 11, 2015, in the journals *Science* and *Science Advances*.

"The existence of the megameter boundary has been suspected and inferred for a while," said Vedran Lekic, an assistant professor of geology at UMD and co-author of the *Science* paper that addresses mantle viscosity. "These papers are the first published attempts at a detailed explanation and it's possible that both explanations are correct."

Although the mantle is mostly solid, it flows very slowly in the context of geologic time. Two main sources of evidence suggest the existence of the megameter boundary and thus inspired the current studies.

First, many huge slabs of ocean crust that have been dragged down, or subducted, into the mantle can still be seen in the deep Earth. These slabs slowly sink downward toward the bottom of the mantle. A large number of these slabs have stalled out and appear to float just above the megameter boundary, indicating a notable change in physical properties below the boundary.

Second, large plumes of hot rock rise from the deepest reaches of the mantle, and the outlines of these structures can be seen in the deep Earth as well. As the rock in these mantle plumes flows upward, many of the plumes are deflected sideways as they pass the megameter boundary. This, too, indicates a fundamental difference in physical properties on either side of the boundary.

"Learning about the anatomy of the mantle tells us more about how the deep interior of Earth works and what mechanisms are behind mantle convection," said Nicholas Schmerr, an assistant professor of geology at UMD and co-author of the *Science Advances* paper that addresses mantle density and composition. "Mantle convection is the heat engine that drives plate tectonics at the surface and ultimately leads to things like volcanoes and earthquakes that affect people living on the surface."

The physics of the deep Earth are complicated, so establishing the mantle's basic physical properties, such as density and viscosity, is an important step. Density refers to the packing of molecules within any substance (gas, liquid or solid), while viscosity is commonly described as the thickness of a fluid or semi-solid. Sometimes density and viscosity correlate with each

other, while sometimes they are at odds. For example, honey is both more viscous and dense than water. Oil, on the other hand, is more viscous than water but less dense.

In their study, Schmerr, lead author Maxim Ballmer (Tokyo Institute of Technology and the University of Hawaii at Manoa) and two colleagues used a computer model of a simplified Earth. Each run of the model began with a slightly different chemical composition--and thus a different range of densities--in the mantle at various depths. The researchers then used the model to investigate how slabs of ocean crust would behave as they travel down toward the lower mantle.

In the real world, slabs are observed to behave in one of three ways: The slabs either stall at around 600 kilometers, stall out at the megameter boundary, or continue sinking all the way to the lower mantle. Of the many scenarios for mantle chemical composition the researchers tested, one most closely resembled the real world and included the possibility that slabs can stall at the megameter boundary. This scenario included an increased amount of dense, silicon-rich basalt rock in the lower mantle, below the megameter boundary.

Lekic, lead author Max Rudolph (Portland State University) and another colleague took a different approach, starting instead with whole-Earth satellite measurements. The team then subtracted surface features--such as mountain ranges and valleys--to better see slight differences in Earth's basic shape caused by local differences in gravity. (Imagine a slightly misshapen basketball with its outer cover removed.)

The team mapped these slight differences in Earth's idealized shape onto known shapes and locations of mantle plumes and integrated the data into a model that helped them relate the idealized shape to differences in viscosity between the layers of the mantle. Their results pointed to less viscous, more free-flowing mantle rock above the megameter boundary, transitioning to highly viscous rock below the boundary. Their results help to explain why mantle plumes are frequently deflected sideways as they extend upward beyond the megameter boundary.

"While explaining one mystery--the behavior of rising plumes and sinking slabs--our results lead to a new conundrum," Lekic said. "What causes the rocks below the megameter boundary to become more resistant to flow? There are no obvious candidates for what is causing this change, so there is a potential for learning something fundamentally new about the materials that make up Earth."

Lekic and Schmerr plan to collaborate to see if the results of both studies are consistent with one another--in effect, whether the lower mantle is both dense and viscous, like honey, when compared with the mantle above the megameter boundary.

"This work can tell us a lot about where Earth has been and where it is going, in terms of heat and tectonics," Schmerr said. "When we look around our solar system, we see lots of planets at various stages of evolution. But Earth is unique, so learning what is going on deep inside its mantle is very important."

Story Source: The above post is reprinted from materials provided by University of Maryland.

Journal References:

1. Maxwell Rudolph, Vedran Lekic and Carolina Lithgow-Bertelloni. **Viscosity jump in Earth's mid-mantle**. *Science*, December 11, 2015 DOI: 10.1126/science.aad1929
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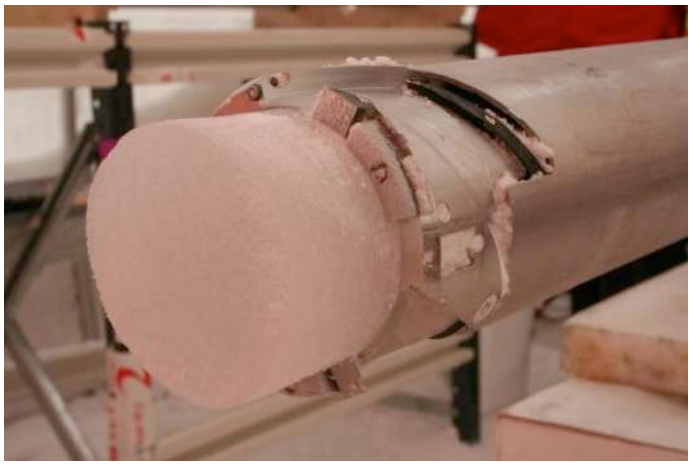
The past shows how abrupt climate shifts affect Earth



The study uses data from ice cores, here from Law Dome, coastal East Antarctica.
Credit: Credit: Joel Pedro

New research shows how past abrupt climatic changes in the North Atlantic propagated globally. The study, led by researchers from Centre for Ice and Climate at the University of Copenhagen's Niels Bohr Institute, shows how interaction between heat transport in the ocean and the atmosphere caused the climatic changes to be expressed in different ways across the Southern Hemisphere. The results show how forcing the climate system into a different state can trigger climate variations that spread globally and have very different impacts in different regions of Earth. This is important now, where rising atmospheric CO_2 levels lead to global warming and may trigger abrupt climatic changes. The results have been published in the scientific journal *Nature Geoscience*.

The history of climate on Earth is stored in tiny variations in kilometer-thick ice cores, sediments from lakes and oceans, and other natural archives that are layered down over thousands of years and works as archives of past temperatures. By recovering and deciphering these archives, researchers can reveal how and why the climate changed in the past, and in this way learn how the climate system may react in the future as the planet warms and the ice sheets melt.

As Earth warmed out of the last ice age, the climate of the northern hemisphere high-latitudes became extremely unstable. Ice cores from the Greenland Ice Sheet document temperature jumps of 10°C in the space of a few decades. To understand how the climate can change so rapidly and whether similar events could be lurking in the future is a major focus of climate research.

The North-South climate seesaw

Paleoclimate scientists have long held that changes in the amount of heat carried northward by Atlantic Ocean currents during the most recent ice age period were responsible for past abrupt climate changes. But most previous research into abrupt climate change has focused on climate records from the Northern Hemisphere.

"In this study, we take a different approach; examining in detail how the climate of the Southern Hemisphere behaved during a period of abrupt warming in Greenland and the North Atlantic. We find that changes in ocean heat transport are only half the picture and that fast adjustments in atmospheric heat transport are also crucial to explaining abrupt climate change," says Dr. Joel Pedro, lead author and postdoc at Centre for Ice and Climate at the Niels Bohr Institute, University of Copenhagen in Denmark.

The research was conducted by a team of scientists from Denmark, Australia, New Zealand, the United States, and France. The team compiled information from a wide array of climate records (84 in total), spanning Antarctic ice cores to northern Australian cave records and Patagonia glaciers to southern African rodent middens.

By comparing the climate records with climate model results, the researchers were able to confirm previous ideas that increasing northward heat transport in the Atlantic warms the North Atlantic and Greenland at the expense of abrupt cooling in the South Atlantic -- a concept known as the 'bipolar ocean seesaw'.

The importance of the atmosphere in climate change

Their crucial new result is to show that the atmospheric circulation adjusts in an effort to compensate for the change in ocean heat transport: as the ocean transports more heat northward the atmosphere responds by transporting more heat southward. However, the compensation is imperfect.

Climate changes in different locations throughout the Southern Hemisphere reflect the battle between the heat transport in the ocean and atmosphere. At low latitudes, the atmosphere wins out, driving abrupt drying and warming. In the South Atlantic and Southern Ocean, New Zealand and Patagonia, the ocean wins out, driving cooling that is amplified around Antarctica by expanding sea ice.

"Our research underlines the intimate coupling between the ocean and atmosphere and helps to explain why past abrupt climate change unfolded so differently in different regions on Earth. The study further underlines a warning that climate scientists have been issuing for many years: forcing the climate system into a different state, as occurred during the warming out of the last ice age, can trigger climate instability with impacts that spread globally," Joel Pedro adds.

Story Source: The above post is reprinted from material provided by University of Copenhagen – Niels Bohr Institute.

Journal Reference: Joel B. Pedro, Helen C. Bostock, Cecilia M. Bitz, Feng He, Marcus J. Vandergoes, Eric J. Steig, Brian M. Chase, Claire E. Krause, Sune O. Rasmussen, Bradley R. Markle, Giuseppe Cortese. **The spatial extent and dynamics of the Antarctic Cold Reversal**. *Nature Geoscience*, 2015; DOI: 10.1038/ngeo2580

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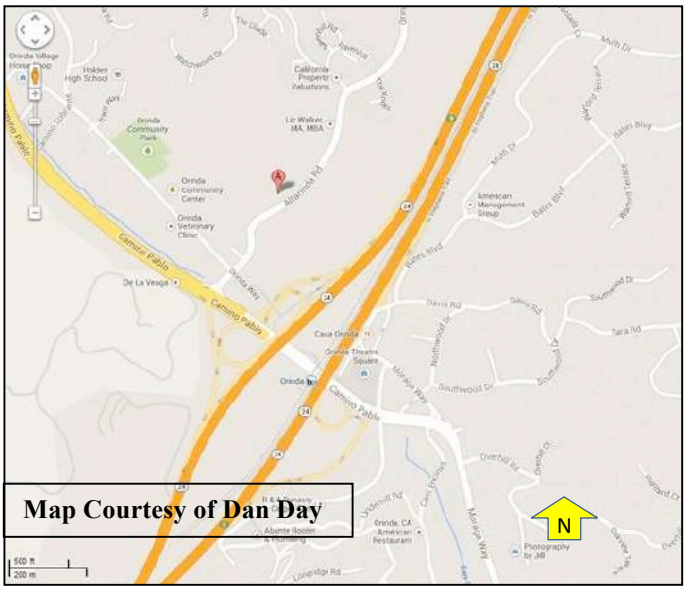

Biography: Dr. Samuel Johnson is a Research Geologist in the U.S. Geological Survey Pacific Coastal and Marine Science Center in Santa Cruz. He currently designs, coordinates, and conducts research projects that focus on seafloor mapping, coastal and marine geomorphology and geologic framework, coastal evolution, and coastal earthquake and tsunami hazards. He is the USGS lead for the California Seafloor Mapping Program, an ambitious cooperative program to create a comprehensive coastal/marine bathymetric, geologic and habitat base map series for all of California's State waters.

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