NORTHERN CALIFORNIA GEOLOGICAL SOCIETY

MEETING ANNOUNCEMENT

DATE: **March 30, 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: **Jeff Unruh, Senior Principal Geologist, Lettis Consultants International, Inc. (LCI)**

Topic: Geologic History of Mt. Diablo

Mt. Diablo is a large, actively growing anticline that has formed in a restraining stepover between two major dextral strike-slip faults of the San Andreas system. Uplift of Mt. Diablo anticline during the past 3-5 million years has produced unique 3-D exposures of normal faults that were active in the ancestral Great Valley forearc basin during late Cretaceous-early Tertiary time, coeval with plate convergence and subduction beneath western California. Stepwise restoration of Mt. Diablo anticline reveals that the Mesozoic-early Tertiary normal faults are related to low-angle structures that attenuate the ophiolitic basement and juxtapose metamorphosed blueschist-facies rocks of the Franciscan complex with relatively unmetamorphosed marine forearc sediments. Apatite fission-track analyses indicate that the Franciscan rocks were uplifted and cooled from depths of 20+ km in the subduction zone while normal faulting and extension were occurring in the overlying forearc crust. The unique stratigraphic and structural relations at Mt. Diablo support models for exhumation of Franciscan blueschists through syn-subduction extension and attenuation of the overlying forearc crust, rather than uplift and erosion of the accretionary prism.

Biography: Jeff Unruh is Senior Principal Geologist with Lettis Consultants International, Inc. (LCI), a consulting firm headquartered in Walnut Creek that specializes in geologic and seismic hazard analysis. Unruh got his B.S. (1985) and Ph.D. (1990) degrees at UC Davis, and has been with LCI since it was founded in 2011. Previously he worked with Fugro Consultants and William Lettis & Associates, Inc. Unruh's primary areas of expertise are structural geology, neotectonics and seismic hazard

(Continued on last page)

NCGS 2015 – 2016 Calendar

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 6:00 pm (dinner meeting; submit flyer on Page 11 to reserve your seats!)
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

NCGS Field Trips

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 weekly at EPS throughout the academic year. An upcoming seminar of possible interest will be held Thursday, April 7 at 4 pm at 141 McCone, when Mark Torres of Caltech will speak on the topic **"The Policeman Revisited: Uplift, Weathering, and Atmospheric CO_2"**

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

Report on the Napa Earthquake, California (M6, 2014-08-24)

Open the following link for a report by the French agency IRSN on the 2014-08-24 Napa County earthquake:

http://paleoseismicity.org/irsn-report-on-the-napa-earthquake-california-m6-24-08-2014/

Recent Article on De-Licensing of Geologists in Arizona

The posting "Coming down to the wire on bill to de-license geologists in Arizona" appears in the Thursday, March 17, 2016 blog posting on Arizona Geology. See the article at the above date at the link: http://arizonageology.blogspot.com

Extracting rare-earth elements from coal could soon be economical in US

The U.S. could soon decrease its dependence on importing valuable rare-earth elements that are widely used in many industries, according to a team of Penn State and U.S. Department of Energy researchers who found a cost-effective and environmentally friendly way to extract these metals from coal byproducts.

Rare-earth elements are a set of seventeen metals—such as scandium, yttrium, lanthanum and cerium—necessary to produce high-tech equipment used in health care, transportation, electronics and numerous other industries. They support more than $329 billion of economic output in North America, according to the American Chemistry Council, and the United States Geological Survey expects worldwide demand for REEs to grow more than 5 percent annually through 2020. China produces more than 85 percent of the world's rare-earth elements, and the U.S. produces the second most at just over 6 percent, according to the USGS.

"We have known for many decades that rare-earth elements are found in coal seams and near other mineral veins," said Sarma Pisupati, professor of energy and mineral engineering, Penn State. "However, it was costly to extract the materials and there was relatively low demand until recently. Today, we rely on rare-earth elements for the production of many necessary and also luxury items, including computers, smart phones, rechargeable batteries, electric vehicles, magnets and chemical catalysts. We wanted to take a fresh look at the feasibility of extracting REEs from coal because it is so abundant in the U.S."

Using byproducts of coal production from the Northern Appalachian region of the U.S., the team investigated whether a chemical process called ion exchange could extract REEs in a safer manner than other extraction methods. For example, past research has examined "roasting," a process that is energy intensive and requires exposure to concentrated acids. In contrast, ion exchange is more environmentally friendly and requires less energy. Ion exchange involves rinsing the coal with a solution that releases the REEs that are bound to the coal.

"Essentially, REEs are sticking to the surface of molecules found in coal, and we use a special solution to pluck them out," said Pisupati. "We experimented with many solvents to find one that is both inexpensive and environmentally friendly."

The team reported in their findings, published in the current issue of Metallurgical and Materials Transactions E, that ammonium sulfate was both environmentally friendly and able to extract the highest amount of REEs. Extracting 2 percent of the available REEs would provide an economic boon to companies, the team said.

"We were able to very easily extract 0.5 percent of REEs in this preliminary study using a basic ion exchange method in the lab," said Pisupati. We are confident that we can increase that to 2 percent through advanced ion exchange methods."

The researchers used coal byproducts in their study, some of which were discarded or marked as refuse during mining operations due to poor quality. Finding more uses for discarded coal could provide yet another economic benefit to companies.

In their study, the team also identified the locations within the coal seam that contained the highest amounts of REEs. Often the highest concentration is found in the poorest quality coal, said Pisupati.

"You find some REEs in the coal itself, but the highest concentration is in what we call the coal shale, or the top layer of a coal seam. Knowing this, we can further target our operations to be more efficient," he said.

The team is now collaborating with several Pennsylvania coal-mining companies to explore the viability of a commercial REE-extraction operation.

From materials provided by: Pennsylvania State University. Read more at http://www.geologyin.com/2016/02/extracting-rare-earth-elements-from.html#bqccGoqvQzkCiq13.99

The Irvingtonian Type Locality (Alameda Co. California) – A Historical Perspective

Virginia Friedman, Philip E. Gordon and Joyce R. Blueford, Children's Natural History Museum, 4074 Eggers Drive, Fremont, California 94536.

(Editor's Note: Here is an abstract given by former NCGS Member Virginia Friedman on the Irvington type area that contained fossil animals that defined the Irvington mammal age, at the start of the Pleistocene in the US.)

ABSTRACT

The Pleistocene epoch was a time of extensive glacial ice deposition commonly known as the Ice Age. Although the San Francisco Bay area was not itself glaciated, it felt the effects of the Ice Age indirectly and, as a consequence, its landscape was altered. Floods of glacially eroded sediments were carried down from the Sierra Nevada by meltwater streams and much of these sands and gavels reached the Bay area. It is generally accepted that the fossil-bearing Irvingtonian sediments were deposited by southern streams feeding into the evolving bay. The Calaveras fault had already been uplifted but the Hayward Fault had not created the East Bay Hills yet. In the 1940s and 1950s, a school teacher named Wes Gordon and his "Boy Paleontologists of Hayward "were nationally recognized throughout the United States. They were a group of boys ranging in age from 7 to 13 who unearthed one of the best preserved fossil sites in North America at that time. Fossils from the Irvington District created such international interest that a section of time was honored as the Irvingtonian Stage (1.8 – 0.24 Mya). The Irvingtonian mammal age was originally defined by Donald E. Savage in 1951 as the beginning of the Pleistocene in North America based on the fauna recovered from gravel and sand pits southeast of Irvington, Alameda County, California. The locality has yielded at least 20,000 specimens, belonging to 56 genera. The sediments adjacent to the locality are reversely magnetized are were dated as 700, 000 to 1.3 Mya based on paleomagnetic data analysis carried out back in 1975. The collection of the Irvingtonian Type locality is currently housed in five institutions: University of California Museum of Paleontology at Berkeley, Children's Natural History Museum, Ohlone College, The Museum of Local History in Fremont, California and in the collection of the family of one of the six surviving Boy Paleontologists, Philip E. Gordon. Nowadays, the type locality is mostly under Interstate 680 but the City of Fremont has created Sabercat Historical Park which is adjacent to the locality and open to the public. Future plans include signage and tours. In summary, efforts are being made to resurrect what is left of this important paleontological locality for future generations.

Evolutionary leap from fins to legs was surprisingly simple

New research reveals that the limbs of the earliest four-legged vertebrates, dating back more than 360 million years ago, were no more structurally diverse than the fins of their aquatic ancestors.

Axolotl / Ambystoma mexicanum, an amphibian. New findings challenge some long-standing assumptions about evolution. Credit: © mgkuijpers / Fotolia

The new finding overturns long-held views that the origin of vertebrates with legs (known as tetrapods) triggered an increase in the anatomical diversity of their skeletons.

The research was carried out by Dr Marcello Ruta from the School of Life Sciences at the University of Lincoln and Professor Matthew Wills from the Milner Centre for Evolution at the University of Bath in the UK. The authors found that fish and early tetrapods developed similar levels of anatomical diversity within their fins and limbs, despite the fact that their skeletons were constructed in very different ways.

Published in the leading scientific journal *Palaeontology*, the findings challenge some long-standing assumptions about evolution. It is generally expected that when organisms evolve new features -- or 'key innovations' -- that enable them to exploit new environments, the rate of evolution and diversification will speed up. This is believed to have happened with the evolution of birds from dinosaurs and, most iconically of all, in the transition from finned aquatic fish to limbed tetrapods.

The evolution of limbs was thought to have opened up a whole new realm of possibilities for tetrapods, so the scientists set out to examine just how substantial the evolutionary transition from fish to tetrapods really was by analysing a variety of different fin and limb skeletons from the fossil record.

Dr Marcello Ruta said: "Our work investigated how quickly the first legged vertebrates blossomed out to explore new skeletal constructions, with surprising results. We might expect that early tetrapods evolved limbs that were more complex and diverse than the fins of their aquatic predecessors. However, although radically different from limbs, the fins of the distant fish-like forerunners of tetrapods display a remarkable array of subtly varying traits.

"This variation may point to a previously unsuspected range of biomechanical functions in their fins, despite the fact that those ancestors lived exclusively in water."

Professor Matthew Wills explained: "It has usually been assumed that when organisms evolve novel attributes that enable them to colonize fundamentally new environments -- as in the move from water to land -- this should trigger rapid evolutionary diversification and be accompanied by an increase in structural variety. Our work challenges this received wisdom, and shows that, at least in the case of the evolution of early tetrapods, key innovations did not quickly lead to greater anatomical variety.

"For the first time, legs had evolved to fulfill new functions. Not only must they be able to support the weight of the body on land, but they also needed to enable the animal to walk. Perhaps these dual requirements limited the number of ways in which these first legs could function and evolve, thereby constraining their range of variability."

Dr Ruta concluded: "This study has profound implications for the analyses of biological systems, past and present, especially when we deal with major diversification events. Perhaps early tetrapods did something different from other organisms, and this makes this finding even more fascinating and challenging. Or perhaps we are forced to recast our notions of evolutionary success and concede that, in some cases, key innovations enable changes that have nonetheless taken many millions of years to play out."

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

Journal Reference: Marcello Ruta, Matthew A. Wills. **Comparable disparity in the appendicular skeleton across the fish-tetrapod transition, and the morphological gap between fish and tetrapod postcrania**. *Palaeontology*, 2016; 59 (2): 249 DOI: 10.1111/pala.12227

Photosynthesis more ancient than thought, and most living things could do it

Photosynthesis is the process by which plants, algae and cyanobacteria use the energy from the Sun to make sugar from water and carbon dioxide, releasing oxygen as a waste product. But a few groups of bacteria carry out a simpler form of photosynthesis that does not produce oxygen, which evolved first.

Primitive bacteria at Morning Glory Pool. Yellowstone National Park, Wyoming, USA

Credit: © Irina K. / Fotolia

A new study by an Imperial College (London) researcher suggests that this more primitive form of photosynthesis evolved in much more ancient bacteria than scientists had imagined, more than 3.5 billion years ago.

Photosynthesis sustains life on Earth today by releasing oxygen into the atmosphere and providing energy for food chains. The rise of oxygen-producing photosynthesis allowed the evolution of complex life forms like animals and land plants around 2.4 billion years ago.

However, the first type of photosynthesis that evolved did not produce oxygen. It was known to have first evolved around 3.5-3.8 billion years ago, but until now, scientists thought that one of the groups of bacteria alive today that still uses this more primate photosynthesis was the first to evolve the ability.

But the new research reveals that a more ancient bacteria, that probably no longer exists today, was actually the first to evolve the simpler form of photosynthesis, and that this bacteria was an ancestor to most bacteria alive today.

"The picture that is starting to emerge is that during the first half of Earth's history the majority of life forms were probably capable of photosynthesis," said study author Dr Tanai Cardona, from the Department of Life Sciences at Imperial College London.

The more primitive form of photosynthesis is known as anoxygenic photosynthesis, which uses molecules such as hydrogen, hydrogen sulfide, or iron as fuel -- instead of water.

Traditionally, scientists had assumed that one of the groups of bacteria that still use anoxygenic photosynthesis today evolved the ability and then passed it on to other bacteria using horizontal gene transfer -- the process of donating an entire set of genes, in this case those required for photosynthesis, to unrelated organisms.

However, Dr Cardona created an evolutionary tree for the bacteria by analyzing the history of a protein essential for anoxygenic photosynthesis. Through this, he was able to uncover a much more ancient origin for photosynthesis.

Instead of one group of bacteria evolving the ability and transferring it to others, Dr Cardona's analysis reveals that anoxygenic photosynthesis evolved before most of the groups of bacteria alive today branched off and diversified. The results are published in the journal *PLOS ONE*.

"Pretty much every group of photosynthetic bacteria we know of has been suggested, at some point or another, to be the first innovators of photosynthesis," said Dr Cardona. "But this means that all these groups of bacteria would have to have branched off from each other before anoxygenic photosynthesis evolved, around 3.5 billion years ago.

"My analysis has instead shown that anoxygenic photosynthesis predates the diversification of bacteria into modern groups, so that they all should have been able to do it. In fact, the evolution of oxygneic photosynthesis probably led to the extinction of many groups of bacteria capable of anoxygenic photosynthesis, triggering the diversification of modern groups."

To find the origin of anoxygenic photosynthesis, Dr Cardona traced the evolution of BchF, a protein that is key in the biosynthesis of bacteriochlorophyll a, the main pigment employed in anoxygenic photosynthesis. The special characteristic of this protein is that it is exclusively found in anoxygenic photosynthetic bacteria and without it bacteriochlorophyll a cannot be made.

By comparing sequences of proteins and reconstructing an evolutionary tree for BchF, he discovered that it originated before most described groups of bacteria alive today.

Story Source: The above post is reprinted from materials provided by Imperial College London. The original item was written by Hayley Dunning.

Journal Reference: Tanai Cardona. **Origin of Bacteriochlorophyll a and the Early Diversification of Photosynthesis**. *PLOS ONE*, 2016; 11 (3): e0151250 DOI: 10.1371/journal.pone.0151250

Climate variations analyzed five million years back in time

Peter Ditlevsen's calculations show that you can view the climate as fractals, that is, patterns or structures that repeat in smaller and smaller versions indefinitely. The formula is: Fq(s)~sHq.
Credit: Maria Lemming

When we talk about climate change today, we have to look at what the climate was previously like in order to recognise the natural variations and to be able to distinguish them from the human-induced changes. Researchers from the Niels Bohr Institute have analysed the natural climate variations over the last 12,000 years, during which we have had a warm interglacial period and they have looked back 5 million years to see the major features of the Earth's climate. The research shows that not only is the weather chaotic, but the Earth's climate is chaotic and can be difficult to predict. The results are published in the scientific journal, Nature Communications.

The Earth's climate system is characterized by complex interactions between the atmosphere, oceans, ice sheets, landmasses and the biosphere (parts of the world with plant and animal life). Astronomical factors also play a role in relation to the great changes like the shift between ice ages, which typically lasts about 100,000 years and interglacial periods, which typically last about 10-12,000 years.

Climate repeats as fractals

"You can look at the climate as fractals, that is, patterns or structures that repeat in smaller and smaller versions indefinitely. If you are talking about 100-year storms, are there then 100 years between them? -- Or do you suddenly find that there are three such storms over a short timespan? If you are talking about very hot summers, do they happen every tenth year or every fifth year? How large are the normal variations? -- We have now investigated this," explains Peter Ditlevsen, Associate Professor of Climate Physics at the Niels Bohr Institute at the University of Copenhagen. The research was done in collaboration with Zhi-Gang Shao from South China University, Guangzhou in Kina.

The researchers studied temperature measurements over the last 150 years, ice core data from Greenland from the interglacial period 12,000 years ago, for the ice age 120,000 years ago, ice core data from Antarctica, which goes back 800,000 years, as well as data from ocean sediment cores going back 5 million years.

"We only have about 150 years of direct measurements of temperature, so if, for example, we want to estimate how great of variations that can be expected over 100 years, we look at the temperature record for that period, but it cannot tell us what we can expect for the temperature record over 1000 years. But if we can determine the relationship between the variations in a given period, then we can make an estimate. These kinds of estimates are of great importance for safety assessments for structures and buildings that need to hold up well for a very long time, or for structures where severe weather could pose a security risk, such as drilling platforms or nuclear power plants. We have now studied this by analyzing both direct and indirect measurements back in time," explains Peter Ditlevsen.

The research shows that the natural variations over a given period of time depends on the length of this period in the very particular way that is characteristic for fractals. This knowledge tells us something about how big we should expect the 1000-year storm to be in relation to the 100-year storm and how big the 100-year storm is expected to be in relation to the 10-year storm. They have further discovered that there is a difference in the fractal behavior in the ice age climate and in the current warm interglacial climate.

Abrupt climate fluctuations during the ice age

"We can see that the climate during an ice age has much greater fluctuations than the climate during an interglacial period. There has been speculation that the reason could be astronomical variations, but we can now rule this out as the large fluctuation during the ice age behave in the same 'fractal' way as the other natural fluctuations across the globe," Ditlevsen says..

The astronomical factors that affect the Earth's climate are that the other planets in the solar system pull on the Earth because of their gravity. This affects the Earth's orbit around the sun, which varies from being almost circular to being more elliptical and this affects solar radiation on Earth. The gravity of the other planets also affects the Earth's rotation on its axis. The Earth's axis fluctuates between having a tilt of 22 degrees and 24 degrees and when the tilt is 24 degrees, there is a larger difference between summer and winter and this has an influence on the violent shifts in climate between ice ages and interglacial periods.

The abrupt climate changes during the ice age could be triggered by several mechanisms that have affected the powerful ocean current, the Gulf Stream, which transports warm water from the equator north to the Atlantic, where it is cooled and sinks down into the cold ocean water under the ice to the bottom and is pushed back to the south. This water pump can be put out of action or weakened by changes in the freshwater pressure, the ice sheet breaking up or shifting sea ice and this results in the increasing climatic variability.

Natural and human-induced climate changes

The climate during the warm interglacial periods is more stable than the climate of ice age climate.

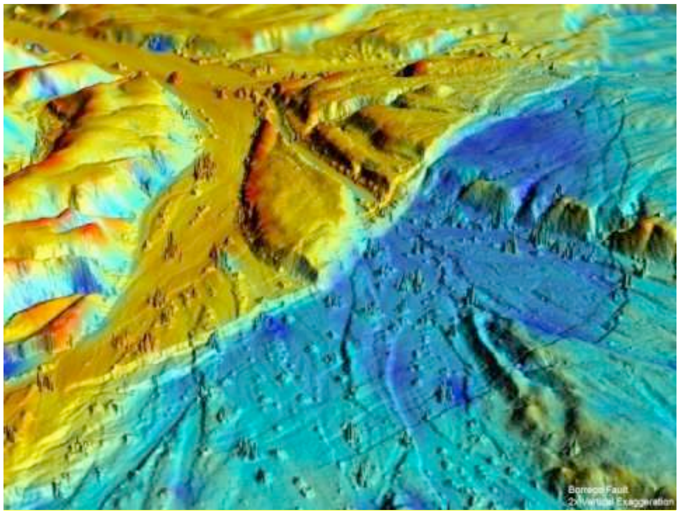
"In fact, we see that the ice age climate is what we call 'multifractal', which is a characteristic that you see in very chaotic systems, while the interglacial climate is 'monofractal'. This means that the ratio between the extremes in the climate over different time periods behaves like the ratio between the more normal ratios of different timescales," explains Ditlevsen.

This new characteristic of the climate will make it easier for climate researchers to differentiate between natural and human-induced climate changes, because it can be expected that the human-induced climate changes will not behave in the same way as the natural fluctuations.
"The differences we find between the two climate states also suggest that if we shift the system too much, we could enter a different system, which could lead to greater fluctuations. We have to go very far back into the geological history of the Earth to find a climate that is as warm as what we are heading towards. Even though we do not know the climate variations in detail so far back, we know that there were abrupt climate shifts in the warm climate back then," points out Peter Ditlevsen.

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

Journal Reference: Zhi-Gang Shao, Peter D. Ditlevsen. **Contrasting scaling properties of interglacial and glacial climates**. *Nature Communications*, 2016; 7: 10951 DOI: 10.1038/ncomms10951

Breaking the strongest link triggered Big Baja Earthquake



This 3-D LiDAR imaging of the Borrego Fault, ruptured during the 2010 El Mayor-Cucapah earthquake in Baja California, Mexico shows numerous small faults. The various colors represent elevation changes during the earthquake.

Credit: UC Davis

A spate of major earthquakes on small faults could overturn traditional views about how earthquakes start, according to a study from researchers at the Centro de Investigación Científica y de Educación Superior in Ensenada, Mexico, and the University of California, Davis.

The study, published Feb. 15 in the journal *Nature Geoscience*, highlights the role of smaller faults in forecasting California's risk of large earthquakes.

In the past 25 years, many of California's biggest earthquakes struck on small faults, away from the San Andreas Fault plate boundary. These events include the Landers, Hector Mine and Napa earthquakes. Several of the quakes were unexpected, rattling areas thought seismically quiet.

A closer look at one of the surprise events, the magnitude-7.2 El Mayor-Cucapah earthquake, showed that small faults may often link together along a "keystone" fault. A keystone is the central stone that holds a masonry structure together. During the El Mayor-Cucapah earthquake, the keystone fault broke first, unlocking seven smaller faults, the study found.

However, the research team discovered that of all the faults unzipped during the El Mayor-Cucapah earthquake, the keystone fault was not the one closest to breaking.

"One of the important outcomes of this study is you can have a whole network of faults activated together by one underpinning fault, and that's an important concern," said study co-author Michael Oskin, a UC Davis professor of geology. "An earthquake involving a system of small faults can be more damaging than a single event because it increases the amount of seismic energy released."

House of Cards

The April 4, 2010, El Mayor-Cucapah earthquake leapfrogged across seven faults and jumped a 5-mile wide gap. The researchers used a wealth of recorded seismic data and detailed mapping of surface changes to reconstruct the complex earthquake sequence.

The study reveals the underlying reason for this unusual pattern: a hidden fault buried at a shallow angle to the surface. Each of the seven faults steeply dips toward this hidden fault, linking up deep underground.

Lead author John Fletcher, a professor at CICESE, likened the system to a house of cards -- remove one key piece and the entire structure tumbles.

"The trick here is the cards can bend, but it isn't until one particular fault goes that the whole set ruptures," Fletcher said.

Earthquake risk

The El Mayor-Cucapah earthquake occurred in a transition zone, between faults spreading open to form the Gulf of California and faults where the Pacific and North America tectonic plates slip sideways past one another. The earthquake was centered about 30 miles south-southeast of Mexicali in northern Baja California, Mexico.

The results suggest similar processes are at work in other areas where the Earth's crust accommodates major changes in shape.

"This gives us insight into how those messy things between the main faults work," Oskin said. "This might be pretty common."

In past events, the signal of a low-angle fault could have been masked because it activated a lot of high-angle faults in the same earthquake, the researchers said.

The idea could also explain a longstanding mystery: why the central San Andreas fault is almost perpendicular to its stress field. Oskin said the central San Andreas fault may also behave like a keystone fault.

The El Mayor-Cucapah earthquake caused extensive damage to the city of Mexicali, displacing more than 35,000 people and causing two deaths. The shaking demolished roads and irrigation channels in surrounding agricultural areas. Reports documented widespread liquefaction, road ruptures, cracked infrastructure, tilting power line towers and partial or total collapse of many buildings. Damage topped $440 million in the Mexicali Valley and $90 million in California's Imperial Valley.

Orlando Teran, a recent Ph.D. graduate with CICESE also co-authored the report.

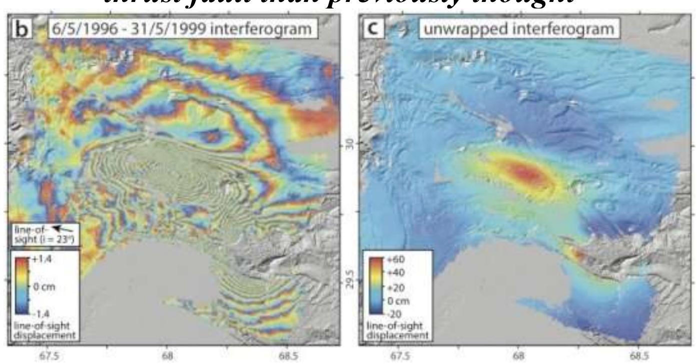
The study was funded by the National Council of Science and Technology (CONACYT), National Science Foundation and the Southern California Earthquake Center.

Story Source: The above post is reprinted form materials provided by University of California, Davis. The original item was written by Becky Oskin.

Journal Reference: John M. Fletcher, Michael E. Oskin, Orlando J. Teran. **The role of a keystone fault in triggering the complex El Mayor–Cucapah earthquake rupture**. *Nature Geoscience*, 2016; DOI: 10.1038/ngeo2660

Long jumping earthquakes: Double dose of bad earthquake news

Researchers find that earthquakes on thrust faults can spread 10 times farther to a second nearby thrust fault than previously thought



These are interferogram images of the earthquakes in Pakistan.

Credit: UC Riverside

The scientists found that an earthquake that initiates on one thrust fault can spread 10 times farther than previously thought to a second nearby thrust fault, vastly expanding the possible range of "earthquake doublets," or double earthquakes.

That could mean in areas such as Los Angeles, where there are multiple thrust faults close to each other, an earthquake from one thrust fault could spread to another fault, creating twice as much devastation.

One potential bad scenario involves a single earthquake spreading between the Puente Hills thrust fault, which runs under downtown Los Angeles, and the Sierra Madre thrust fault, located close to Pasadena, said Gareth Funning, an associate professor of earth sciences at UC Riverside, and a co-author of a paper published online today (Feb. 8, 2016) about the research in the journal *Nature Geoscience*.

Other susceptible areas where there are multiple thrust faults are in close proximity include the Ventura, Calif. area, the Middle East, particularly Tehran, Iran, and the front of the Himalayas, in countries such as Afghanistan, Pakistan, India and Nepal.

The researchers studied a 1997 earthquake in Pakistan, originally reported as a magnitude 7.1 event, showing that it was in fact composed of two 'subevents' -- a magnitude 7.0 earthquake, that was followed 19 seconds later by a magnitude 6.8 event, located 50 kilometers (30 miles) to the southeast.

Funning considers the two earthquakes as subevents of one 'mainshock,' as opposed to the second earthquake being an aftershock, because they happened so close together in time and were so similar in size. There were many aftershocks in the following minutes and hours, but most of them were much smaller.

The scientists used satellite radar images, precise earthquake locations, modeling and back projection of seismic radiation to prove the seismic waves from the first subevent caused the second to initiate, effectively 'jumping' the 50 kilometer distance between the two. Scientists previously thought an earthquake could only leap up to five kilometers.

The finding has implications for seismic hazard forecasts developed by the United States Geological Survey. The current forecast model does not include the possibility of a similar double earthquake on the thrust faults in the Los Angeles area.

"This is another thing to worry about," Funning said. "The probability of this happening in Los Angeles is probably pretty low, but it doesn't mean it can't happen."

Funning started work on the paper about 12 years ago as a graduate student at the University of Oxford. He was the first to find the satellite data for the earthquakes in Pakistan, which occurred in a largely unpopulated area, and notice they occurred close together in space and time.

After dropping the work for several years, he, along with lead author Ed Nissen of the Colorado School of Mines, picked it up about three to four years ago, in part because of the possible implications for the Los Angeles area, which has a similar plate boundary, with similar faults, similar distances apart as the region in Pakistan where the 1997 earthquake doublet occurred.

Thrust faults happen when one layer of rock is pushed up over another, often older, layer of rock by compressional forces. Thrust faults came to the attention of Californians after the 1994 Northridge earthquake, about 20 miles northwest of Los Angeles, which occurred on a thrust fault.

Thrust faults are not as well understood by scientists as strike-slip faults, such as the San Andreas, in part because they are not as visible in the landscape, and do not preserve evidence for past earthquakes as well.

Story Source: The above post is reprinted from materials provided by University of California, Riverside.

Journal Reference: E. Nissen, J. R. Elliott, R. A. Sloan, T. J. Craig, G. J. Funning, A. Hutko, B. E. Parsons, T. J. Wright. **Limitations of rupture forecasting exposed by instantaneously triggered earthquake doublet**. *Nature Geoscience*, 2016; DOI: 10.1038/ngeo2653

Faults control the amount of water flowing into the Earth during continental breakup

New light has been shed on the processes by which ocean water enters the solid Earth during continental breakup.

Research led by geoscientists at the University of Southampton, and published in *Nature Geoscience* this week, is the first to show a direct link on geological timescales between fault activity and the amount of water entering the Earth's mantle along faults.

When water and carbon is transferred from the ocean to the mantle it reacts with a dry rock called peridotite, which makes up most of the mantle beneath the crust, to form serpentinite.

Dr Gaye Bayrakci, Research Fellow in Geophysics, and Professor Tim Minshull, from Ocean and Earth Science, with colleagues at the University of Southampton and six other institutions, measured the amount of water that had entered the Earth by using sound waves to map the distribution of serpentinite.

The sound waves travel through the crust and mantle and can be detected by sensitive instruments placed on the ocean floor. The time taken for the signals to travel from an acoustic seismic source to the seafloor instruments reveals how fast sound travels in the rocks, and the amount of serpentinite present can be determined from this speed.

The four-month experiment, which involved two research ships (the R/V Marcus Langseth and the F/S Poseidon), mapped an 80 by 20 km area of seafloor west of Spain called the Deep Galicia Margin where the fault structures were formed when North America broke away from Europe about 120 million years ago.

The results showed that the amount of serpentinite formed at the bottom of each fault was directly proportional to the displacement on that fault, which in turn is closely related to the duration of fault activity.

Dr Bayracki said: "One of the aims of our survey was to explore the relationship between the faults, which we knew already were there, and the presence of serpentinite, which we also knew was there but knew little about its distribution. The link between fault activity and formation of serpentinite was something we might have hoped for but did not really expect to see so clearly.

"This implies that seawater reaches the mantle only when the faults are active and that brittle processes in the crust may ultimately control the global amount of seawater entering the solid Earth."

In other tectonic settings where serpentinite is present such as mid ocean ridges and subduction zones, the focused flow of seawater along faults provides a setting for diverse hydrothermal ecosystems where life-forms live off the chemicals stripped out of the rocks by the water as it flows into and then out of the Earth's mantle.

The researchers were able to estimate the average rate at which seawater entered the mantle through the faults at the Deep Galicia Margin and discovered that rate was comparable to those estimated for water circulation in hot rock at mid-ocean ridges, where such life-forms are more common. These results suggest that in continental rifting environment there may have been hydrothermal systems, which are known to support diverse ecosystems.

Co-Author and Professor of Geology at the University of Birmingham Tim Reston commented: "Understanding the transport of water during deformation has broad implications, ranging from hydrothermal systems to earthquake mechanics. The new results suggest a more direct link between faulting and water movements than we previously suspected."

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

Journal Reference: G. Bayrakci, T. A. Minshull, D. S. Sawyer, T. J. Reston, D. Klaeschen, C. Papenberg, C. Ranero, J. M. Bull, R. G. Davy, D. J. Shillington, M. Perez-Gussinye, J. K. Morgan. **Fault-controlled hydration of the upper mantle during continental rifting**. *Nature Geoscience*, 2016; DOI: 10.1038/ngeo2671

NORTHERN CALIFORNIA GEOLOGICAL SOCIETY

NCGS DINNER MEETING Wednesday May 25, 2016
Orinda Masonic Center, 9 Altarinda Road, Orinda, CA

Monterey Canyon: Superhighway to the Deep-Sea

Dr. Charlie Paull
Senior Scientist at the Monterey Bay Aquarium Research Institute (MBARI)

(Reservations are required by May 20, 2015, Limit 100 persons)
We are sorry but we will not be able to accommodate "walk-ins"

The **NCGS** is pleased to host this *special dinner meeting* with **Dr. Paull**. This annual event will be catered by *Back Forty Texas BBQ and consist of Pork Ribs and BBQ Chicken, Tossed Green Salad, BBQ Beans, and Fresh Corn Cobettes. A deluxe veggie burger is available upon request (see below). Desert will include assorted cookies and brownies. Wine will also be served.*

Dr. Charlie Paull will describe the on-going efforts to understand the geologic processes occurring within Monterey Submarine Canyon, offshore of central California. For perspective, Monterey Canyon is equivalent in size to the Grand Canyon. Submarine canyons in general are conduits in which sediment-laden flows (including the wide range of gravity flows from slumps to turbidity currents) swiftly transport massive amounts of sediment from the shallow ocean to the deep sea. While such flows are among the most important processes by which sediments are carried across the Earth's surface and are credited for forming the canyons, very few direct measurements have ever been made of what actually happens during the sediment flow events. The lack of empirical data on sediment flows is a consequence of the difficulty in accessing canyon floors, the inability to predict when flows will happen, and the reality that energetic flows put monitoring equipment at risk. To understand submarine canyons and to further deep-sea technology development, the Monterey Bay Aquarium Research Institute (MBARI) has taken on the challenge of monitoring sediment flows and making direct measurements within these events. To achieve this goal, state of the art robotic vehicles have been utilized and several novel new instruments have been developed. With these technologies, Charlie's group at MBARI and neighboring institutions, have demonstrated that sediment-laden flows occur on a sub-annual basis in Monterey Canyon and produced startling surprises as to what happens during these energetic submarine events. These efforts have changed the focus of marine geologic research on submarine flows from a forensic science to making real time measurements of the evolving system.

**********************************Dinner Logistics**
Social Hour: 6:00 – 6:45 pm; **Dinner**: 6:45 – 8:00 pm; **Presentation**: 8:00 – 9:00 pm
Cost: **$25/person**

******************* ✂ *************Registration **

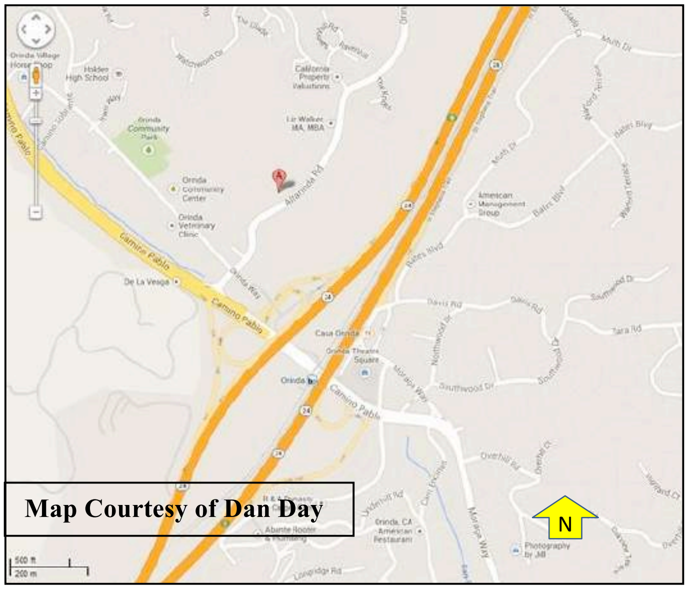
Name(s):____

E-mail:____

Phone (day):_________________________ Phone (cell)_________________________

Check one per person: Regular Dinner: ____ Vegetarian: ___ # Attending_____________Check Amount: ___________

Please clip and mail this registration form with a check made out to **NCGS** to:
Barbara Matz, 803 Orion #2, Hercules CA 94547
Questions: e-mail barbara.matz@cbifederalservices.com ; Phone: (415) 713-8482



Map Courtesy of Dan Day

Biography (continued): assessment. Recent projects include seismotectonic analysis of the southern San Joaquin Valley, and evolution of the Miocene Pismo Basin during late Cenozoic uplift of the central California Coast Ranges. Unruh held a courtesy appointment as a Research Geologist at UC Davis from 1994-2015, and is currently President of LCI.

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

Would you like to receive the NCGS newsletter by e-mail? If you are not already doing so, and would like to, please contact Tom Barry at **tomasbarry@aol.com** to sign up for this free service.