NORTHERN CALIFORNIA GEOLOGICAL SOCIETY

MEETING ANNOUNCEMENT

DATE: **November 16, 2011** **Watch it - This is EARLY!!**

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: **Michelle Newcomer, Student Manager, NASA Ames DEVELOP Program, San Francisco State University**

A comparison of groundwater storage using GRACE data, groundwater levels, and a hydrological model in California's Central Valley

Co-Authors:

Amber Kuss, San Francisco State University
William Brandt, California State University, Monterey Bay
Joshua Randall, Arizona State University
Bridget Floyd, University of California, Berkeley
Abdelwahab Bourai, Cupertino High School
Michelle Newcomer*, San Francisco State University
Cindy Schmidt, Bay Area Environmental Research Institute
Joseph Skiles, Ph.D., NASA Ames Biospheric Sciences Branch

The Gravity Recovery and Climate Experiment (GRACE), a NASA satellite sensor, measures changes in total water storage (TWS) and may provide additional insight to the use of well-based data in California's Central Valley, an important agricultural region. Under current California law, well owners are not required to report groundwater extraction rates, making estimation of total groundwater extraction difficult. As a result, other groundwater change detection techniques must be used. GRACE was used to map changes in TWS between October 2002 and September 2009 for the three hydrological regions (the Sacramento River Basin, the San Joaquin River Basin, and the Tulare Lake Basin) encompassing the Central Valley aquifer. Net groundwater storage changes were calculated from the changes in TWS for each of the three hydrological regions and by incorporating estimates for additional components of the hydrological budget including precipitation, evapotranspiration, soil moisture, snow pack, and surface water storage. The calculated changes in groundwater storage were then compared to simulated values from the California Department of Water Resource's Central Valley Groundwater-Surface Water Simulation Model (C2VSIM) and their Water Data Library (WDL) Geographic Information System (GIS) change in storage tool. Downscaling GRACE data into… *…Continued on back page…*

NCGS 2010 – 2011 Calendar

November 16, 2011
Michelle Newcomer, SFSU, Internship projects at NASA Ames (Topic)
7:00 pm at Orinda Masonic Lodge

December 2011 – Our Usual Holiday Break

January 25, 2012
TBA
7:00 pm at Orinda Masonic Lodge

February 29, 2012
TBA
7:00 pm at Orinda Masonic Lodge

March 28, 2012
TBA
7:00 pm at Orinda Masonic Lodge

April 25, 2012
TBA
7:00 pm at Orinda Masonic Lodge

Upcoming NCGS Events

Do you have a place you've wanted to visit for the geology? Let us know. We're definitely interested in ideas. For those suggestions, or for questions regarding, field trips, please contact Tridib Guha at: **Tridibguha@sbcglobal.net**

Peninsula Geologic Society

Upcoming meetings

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.

Bay Area Science

(http://www.bayareascience.org/)

This website provides a free weekly emailed newsletter consisting of an extensive listing of local science based activities (evening lectures, classes, field trips, hikes, and etc).

Association of Engineering Geologists

San Francisco Section

Upcoming Events

Meeting locations rotate between San Francisco, the East Bay, and the South Bay. Please check the website for current details. To download meeting details and registration form go to: http://www.aegsf.org/.

USGS Evening Public Lecture Series

The USGS Evening Public Lecture Series events are free and are intended for a general public audience that may not be familiar with the science being discussed. Monthly lectures are usually scheduled for the last Thursday evening of each month during most of the year but are occasionally presented on the preceding Thursday evening to accommodate the speakers. For more information on the lectures, including a map of the lecture location (Building 3, 2nd floor; Conference Room A) go to: http://online.wr.usgs.gov/calendar/

- November 17, 2011, *Colorado River High-Flow Experiments - a story of Grand Canyon geology, water, and biology*, Presented by Jack Schmidt & David Rubin

Richard Chambers Memorial Scholarships

(Graduate Scholarships;

$1,000 Masters Level and

$2,000 PhD Level)

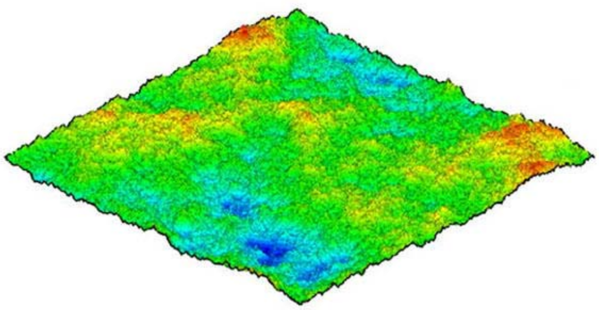
K-12 Earth Science Teacher of the Year Award (AAPG Affiliated; $750 and more!)

& Geoscience Teaching Award (Local Heroes - $500) Announcements

These announcements appeared in the **September Newsletter.** Please send them to folks you know who might have an interest in these NCGS programs, or if you need new copies go or send interested parties to the NCGS website at www.ncgeolsoc.org. The application process is not difficult.

Earthquakes Generate Big Heat in Super-Small Areas

ScienceDaily - In experiments mimicking the speed of earthquakes, geophysicists at Brown University detail a phenomenon known as flash heating. They report in a paper published in *Science* that because fault surfaces touch only at microscopic, scattered spots, these contacts are subject to intense stress and extreme heating during earthquakes, lowering their friction and thus the friction of the fault. The localized, intense heating can occur even while the temperature of the rest of the fault remains largely unaffected.



Hitting the high pointsComputer-simulated topography shows high points — asperities (in red) — on the rock surface. When in contact with asperties on the adjacent surface, these asperities may undergo intense flash heating in an earthquake.Credit: Mark Robbins and Sangil Hyun, Johns Hopkins UniversityHitting the high points Computer-simulated topography shows high points — asperities (in red) — on the rock surface. When in contact with asperties on the adjacent surface, these asperities may undergo intense flash heating in an earthquake. (Credit: Mark Robbins and Sangil Hyun, Johns Hopkins University)

Most earthquakes that are seen, heard, and felt around the world are caused by fast slip on faults. While the earthquake rupture itself can travel on a fault as fast as the speed of sound or better, the fault surfaces behind the rupture are sliding against each other at about a meter per second.

But the mechanics that underlie fast slip during earthquakes have eluded scientists, because it's difficult to replicate those conditions in the laboratory. "We still largely don't understand what is going at earthquake slip speeds," said David Goldsby, a geophysicist at Brown, "because it's difficult to do experiments at these speeds."

Now, in experiments mimicking earthquake slip rates, Goldsby and Brown geophysicist Terry Tullis show that fault surfaces in earthquake zones come into contact only at microscopic points between scattered bumps, called asperities, on the fault. These tiny contacts support all the force across the fault. The experiments show that when two fault surfaces slide against other at fast slip rates, the asperities may reach temperatures in excess of 2,700 degrees Fahrenheit, lowering their friction, the scientists write in a paper published in *Science*. The localized, intense heating can occur even while the temperature of the rest of the fault remains largely unaffected, a phenomenon known as flash heating.

"This study could explain a lot of the questions about the mechanics of the San Andreas Fault and other earthquakes," said Tullis, professor *emeritus* of geological sciences, who has studied earthquakes for more than three decades.

The experiments simulated earthquake speeds of close to half a meter per second. The rock surfaces touched only at the asperities, each with a surface area of less than 10 microns -- a tiny fraction of the total surface area. When the surfaces move against each other at high slip rates, the experiments revealed, heat is generated so quickly at the contacts that temperatures can spike enough to melt most rock types associated with earthquakes. Yet the intense heat is confined to the contact flashpoints; the temperature of the surrounding rock remained largely unaffected by these microscopic hot spots, maintaining a "room temperature" of around 77 degrees Fahrenheit, the researchers write.

"You're dumping in heat extremely quickly into the contacts at high slip rates, and there's simply no time for the heat to get away, which causes the dramatic spike in temperature and decrease in friction," Goldsby said.

"The friction stays low so long as the slip rate remains fast," said Goldsby, associate professor of geological sciences (research). "As slip slows, the friction immediately increases. It doesn't take a long time for the fault to restrengthen after you weaken it. The reason is the population of asperities is short-lived and continually being renewed, and therefore at any given slip rate, the asperities have a temperature and therefore friction appropriate for that slip rate. As the slip rate decreases, there is more time for heat to diffuse away from the asperities, and they therefore have lower temperature and higher friction."

Flash heating and other weakening processes that lead to low friction during earthquakes may explain the lack of significant measured heat flows along some active faults like the San Andreas Fault, which might be expected if friction was high on faults during earthquakes. Flash heating in particular may also explain how faults rupture as "slip pulses," wrinkle-like zones of slip on faults, which would also decrease the amount of heat generated.

If that is the case, then many earthquakes have been misunderstood as high-friction events. "It's a new view with low dynamic friction. How can it be compatible with what we know?" asked Tullis, who chairs the National Earthquake Prediction Evaluation Council, an advisory body for the U.S. Geological Survey.

"Flash heating may explain it," Goldsby replied.

The U.S. Geological Survey funded the research.

Journal Reference: D. L. Goldsby, T. E. Tullis. **Flash Heating Leads to Low Frictional Strength of Crustal Rocks at Earthquake Slip Rates**. *Science*, 2011; 334 (6053): 216

Plate Tectonics May Control Reversals in Earth's Magnetic Field

ScienceDaily - Earth's magnetic field has reversed many times at an irregular rate throughout its history. Long periods without reversal have been interspersed with eras of frequent reversals. What is the reason for these reversals and their irregularity? Researchers from CNRS and the Institut de Physique du Globe(*) have shed new light on the issue by demonstrating that, over the last 300 million years, reversal frequency has depended on the distribution of tectonic plates on the surface of the globe. This result does not imply that terrestrial plates themselves trigger the switch over of the magnetic field. Instead, it establishes that although the reversal phenomenon takes place, in fine, within Earth's liquid core, it is nevertheless sensitive to what happens outside the core and more specifically in Earth's mantle.

This work is published on 16 October 2011 in *Geophysical Research Letters.*

Earth's magnetic field is produced by the flow of liquid iron within its core, three thousand kilometers below our feet. What made researchers think of a link between plate tectonics and the magnetic field? The discovery that convective liquid iron flows play a role in magnetic reversals: experiments and modeling work carried out over the last five years have in fact shown that a reversal occurs when the movements of molten metal are no longer symmetric with respect to the equatorial plane. This "symmetry breaking" could take place progressively, starting in an area located at the core-mantle boundary (the mantle separates Earth's liquid core from its crust), before spreading to the whole core (made of molten iron).

Extending this research, the authors of the article asked themselves whether some trace of initial symmetry breakings behind the geomagnetic reversals that have marked Earth's history, could be found in the only records of large-scale geological shifts in our possession, in other words the movements of continents (or plate tectonics). Some 200 million years ago, Pangaea, the name given to the supercontinent that encompassed almost all of Earth's land masses, began to break up into a multitude of smaller pieces that have shaped Earth as we know it today. By assessing the surface area of continents situated in the Northern hemisphere and those in the Southern hemisphere, the researchers were able to calculate a degree of asymmetry (with respect to the equator) in the distribution of the continents during that period.

In conclusion, the degree of asymmetry has varied at the same rhythm as the magnetic reversal rate (number of reversals per million years). The two curves have evolved in parallel to such an extent that they can almost be superimposed. In other words, the further the centre of gravity of the continents moved away from the equator, the faster the rate of reversals (up to eight per million years for a maximum degree of asymmetry).

What does this suggest about the mechanism behind geomagnetic reversals? The scientists envisage two scenarios. In the first, terrestrial plates could be directly responsible for variations in the frequency of reversals: after plunging into Earth's crust at subduction zones, the plates could descend until they reach the core, where they could modify the flow of iron. In the second, the movements of the plates may only reflect the mixing of the material taking place in the mantle and particularly at its base. In both cases, the movements of rocks outside the core would cause flow asymmetry in the liquid core and determine reversal frequency.

* -- Laboratoire de Physique Statistique of ENS (Ecole Normale Supérieure/CNRS/UPMC/Université Paris Diderot) and the Institut de Physique du Globe de Paris (CNRS/IPGP/Université Paris Diderot)

Journal Reference: F. Pétrélis, J. Besse, J.-P. Valet. **Plate tectonics may control geomagnetic reversal frequency**. *Geophysical Research Letters*, 2011; 38 (19).

Sea Levels to Continue to Rise for 500 Years? Long-Term Climate Calculations Suggest So

ScienceDaily - Rising sea levels in the coming centuries is perhaps one of the most catastrophic consequences of rising temperatures. Massive economic costs, social consequences and forced migrations could result from global warming. But how frightening of times are we facing? Researchers from the Niels Bohr Institute are part of a team that has calculated the long-term outlook for rising sea levels in relation to the emission of greenhouse gases and pollution of the atmosphere using climate models.

The results have been published in the scientific journal *Global and Planetary Change*.

"Based on the current situation we have projected changes in sea level 500 years into the future. We are not looking at what is happening with the climate, but are focusing exclusively on sea levels," explains Aslak Grinsted, a researcher at the Centre for Ice and Climate, the Niels Bohr Institute at the University of Copenhagen.

Model based on actual measurements

He has developed a model in collaboration with researchers from England and China that is based on what happens with the emission of greenhouse gases and aerosols and the pollution of the atmosphere. Their model has been adjusted backwards to the actual measurements and was then used to predict the outlook for rising sea levels.

The research group has made calculations for four scenarios: a pessimistic one, an optimistic one, and two more realistic ones.

In the pessimistic scenario, emissions continue to increase. This will mean that sea levels will rise 1.1 meters by the year 2100 and will have risen 5.5 meters by the year 2500.

Even in the most optimistic scenario, which requires extremely dramatic climate change goals, major technological advances and strong international cooperation to stop emitting greenhouse gases and polluting the atmosphere, the sea would continue to rise. By the year 2100 it will have risen by 60 cm and by the year 2500 the rise in sea level will be 1.8 meters.

For the two more realistic scenarios, calculated based on the emissions and pollution stabilizing, the results show that there will be a sea level rise of about 75 cm by the year 2100 and that by the year 2500 the sea will have risen by 2 meters.

Rising sea levels for centuries

"In the 20th century sea has risen by an average of 2mm per year, but it is accelerating and over the last decades the rise in sea level has gone approximately 70% faster. Even if we stabilize the concentrations in the atmosphere and stop emitting greenhouse gases into the atmosphere, we can see that the rise in sea level will continue to accelerate for several centuries because of the sea and ice caps long reaction time. So it would be 2-400 years before we returned to the 20th century level of a 2 mm rise per year," says Aslak Grinsted.

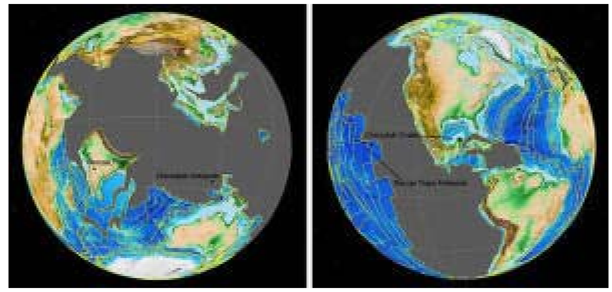
He points out that even though long-term calculations are subject to uncertainties, the sea will continue to rise in the coming centuries and it will most likely rise by 75 cm by the year 2100 and by the year 2500 the sea will have risen by 2 meters.

Journal Reference: S. Jevrejeva, J.C. Moore, A. Grinsted. **Sea level projections to AD2500 with a new generation of climate change scenarios**. *Global and Planetary Change*, 2011.

Fallout of a Giant Meteorite Strike Revealed in New Model

ScienceDaily - Seeking to better understand the level of death and destruction that would result from a large meteorite striking Earth, Princeton University researchers have developed a new model that can not only more accurately simulate the seismic fallout of such an impact, but also help reveal new information about the surface and interior of planets based on past collisions.

Princeton researchers created the first model to take into account Earth's elliptical shape, surface features and ocean depths in simulations of how seismic waves generated by a meteorite collision would spread across and within the planet. Current projections rely on models of a featureless spherical world with nothing to disrupt the meteorite's impact, the researchers report in the October issue of *Geophysical Journal International*.



The Princeton model shows (at left) that the structure of the Earth's surface at the time of the meteorite impact that caused the Chicxulub crater in Mexico would have placed the Deccan Traps in India far west of the crater's antipodal point, instead of directly opposite of the impact. Correspondingly, the model shows (at right) that the meteorite struck far east of the antipodal point for the Deccan Traps, which are remnants of large volcanoes thought to have contributed to the mass extinction event at the end of the Cretaceous period. The model also revealed that the Chicxulub impact, when the Earth's surface and shape are considered, would have likely been too small to cause the Deccan Traps. (Credit: Images by Conor Myhrvold)

The researchers -- based in the laboratory of Jeroen Tromp, the Blair Professor of Geology in Princeton's Department of Geosciences -- simulated the meteorite strike that caused the Chicxulub crater in Mexico, an impact 2 million times more powerful than a hydrogen bomb that many scientists believe triggered the mass extinction of the dinosaurs 65 million years ago. The team's rendering of the planet showed that the impact's seismic waves would be scattered and unfocused, resulting in less severe ground displacement, tsunamis, and seismic and volcanic activity than previously theorized.

The Princeton simulations also could help researchers gain insight into the unseen surface and interior details of other planets and moons, the authors reported. The simulations can pinpoint the strength of the meteorite's antipodal focus -- the area of the globe opposite of the crater where the energy from the initial collision comes together like a second, smaller impact. The researchers found this point is determined by how the features and composition of the smitten orb direct and absorb the seismic waves. Scientists could identify the planet or moon's characteristics by comparing a crater to the remnants of the antipodal point and calculating how the impact waves spread.

Lead author Matthias Meschede of the University of Munich developed the model at Princeton through the University's Visiting Student Research Collaborators program with co-authors Conor Myhrvold, who earned his bachelor's degree from Princeton in 2011, and Tromp, who also is director of Princeton's Institute for Computational Science and Engineering and a professor of applied and computational mathematics. Meschede describes the findings as follows:

"We have developed the first model to account for how Earth's surface features and shape would influence the spread of seismic activity following a meteorite impact. For the Earth, these calculations are usually made using a smooth, perfect sphere model, but we found that the surface features of a planet or a moon have a huge effect on the aftershock a large meteorite will have, so it's extremely important to take those into account.

"After a meteorite impact, seismic waves travel outward across the Earth's surface like after a stone is thrown in water. These waves travel all the way around the globe and meet in a single point on the opposite side from the impact known as the antipode. Our model shows that because the Earth is elliptical and its surface is heterogeneous those waves travel with different speeds in different areas, changing where the waves end up on the other side of the world and the waves' amplitude when they get there. These waves also are influenced by the interior. The effect on the opposite side is a result of the complete structure.

"We began by asking whether the meteorite that hit the Earth near Chicxulub could be connected to other late-Cretaceous mass-extinction theories. For example, there's a prominent theory that the meteorite triggered huge volcanic eruptions that changed the climate. These eruptions are thought to have originated in the Deccan Traps in India, approximately on the opposite side of the Earth from the Chicxulub crater at the time. Because North America was closer to Europe and India was closer to Madagascar during the Cretaceous period, however, it seemed questionable that the Deccan Traps were at the Chicxulub impact's antipode.

"Regarding the mass extinction, we saw from our measurements that a Chicxulub-sized impact alone would be too small to cause such a large volcanic eruption as what occurred at the Deccan Traps. Our model shows that the antipodal focusing of the seismic wave from such an impact was hugely overestimated in previous calculations, which used a spherical-Earth model.

"The Earth's maximum ground displacement at this point has been calculated to be 15 meters, which is extreme. The first outcome of our model was that this is reduced by a large amount to about three to five meters. On the spherical model, all the waves come together at exactly one point and, as a result, have a huge amplitude. We found the waves are disturbed by surface features and take on a more ragged structure, meaning less energy is concentrated at the antipode.

"But our results go beyond Chicxulub. We can, in principle, now estimate how large a meteorite would have to have been to cause catastrophic events. For instance, we found that if you increase the radius of the Chicxulub meteorite by a factor of five while leaving its velocity and density the same, it would have been large enough to at least fracture rocks on the opposite side of the planet. Our model can be used to estimate the magnitude and effect of other major impacts in Earth's past. A similar model could be used to study other examples of antipodal structures in the solar system, such as the strange region opposite the gigantic Caloris Basin crater on Mercury.

"Also, such a model can help examine the interior of a moon or planet by comparing the size of the crater to the amount of antipodal disruption -- you only need two pictures, basically. One could correlate a certain impact magnitude with the observed antipodal effect -- which is dependent on the object's surface features -- and better understand the heterogeneity of the surface by how the energy was distributed between those two points. That can reveal information about not only the surface structure of the body at the time of the impact, but also the interior, such as if the planet has a hard core."

This research was supported by the National Science Foundation and the German Academic Exchange Service.

Journal Reference: Matthias A. Meschede, Conor L. Myhrvold, Jeroen Tromp. **Antipodal focusing of seismic waves due to large meteorite impacts on Earth**. *Geophysical Journal International*, 2011; 187 (1): 529

Threshold Sea Surface Temperature for Hurricanes and Tropical Thunderstorms Is Rising

ScienceDaily - Scientists have long known that atmospheric convection in the form of hurricanes and tropical ocean thunderstorms tends to occur when sea surface temperature rises above a threshold. The critical question is, how do rising ocean temperatures with global warming affect this threshold? If the threshold does not rise, it could mean more frequent hurricanes.

According to a new study by researchers at the International Pacific Research Center (IPRC) of the University of Hawaii at Manoa (UHM), this threshold sea surface temperature for convection is rising under global warming at the same rate as that of the tropical oceans.

Their paper appears in the journal *Nature Geoscience*.

In order to detect the annual changes in the threshold sea surface temperature, Nat Johnson, a postdoctoral fellow at IPRC, and Shang-Ping Xie, a professor of meteorology at IPRC and UHM, analyzed satellite estimates of tropical ocean rainfall spanning 30 years. They find that changes in the threshold temperature for convection closely follow the changes in average tropical sea surface temperature, which have both been rising approximately 0.1°C per decade.

"The correspondence between the two time series is rather remarkable," says lead author Johnson. "The convective threshold and average sea surface temperatures are so closely linked because of their relation with temperatures in the atmosphere extending several miles above the surface."

The change in tropical upper atmospheric temperatures has been a controversial topic in recent years because of discrepancies between reported temperature trends from instruments and the expected trends under global warming according to global climate models. The measurements from instruments have shown less warming than expected in the upper atmosphere. The findings of Johnson and Xie, however, provide strong support that the tropical atmosphere is warming at a rate that is consistent with climate model simulations.

"This study is an exciting example of how applying our knowledge of physical processes in the tropical atmosphere can give us important information when direct measurements may have failed us," Johnson notes.

The study notes further that global climate models project that the sea surface temperature threshold for convection will continue to rise in tandem with the tropical average sea surface temperature. If true, hurricanes and other forms of tropical convection will require warmer ocean surfaces for initiation over the next century.

This work was supported by grants from NOAA, NSF, NASA, and JAMSTEC.

Journal Reference: Doug M. Smith, Rosie Eade, Nick J. Dunstone, David Fereday, James M. Murphy, Holger Pohlmann, Adam A. Scaife. **Skilful multi-year predictions of Atlantic hurricane frequency**. *Nature Geoscience*, 2010.

Noah's Flood' Kick-Started European Farming?

ScienceDaily - The flood believed to be behind the Noah's Ark myth kick-started European agriculture, according to new research by the Universities of Exeter, UK and Wollongong, Australia. New research assesses the impact of the collapse of the North American (Laurentide) Ice Sheet, 8000 years ago. The results indicate a catastrophic rise in global sea level led to the flooding of the Black Sea and drove dramatic social change across Europe.

The research team argues that, in the face of rising sea levels driven by contemporary climate change, we can learn important lessons from the past.

The collapse of the Laurentide Ice Sheet released a deluge of water that increased global sea levels by up to 1.4 metres and caused the largest North Atlantic freshwater pulse of the last 100,000 years. Before this time, a ridge across the Bosporus Strait dammed the Mediterranean and kept the Black Sea as a freshwater lake. With the rise in sea level, the Bosporus Strait was breached, flooding the Black Sea.

This event is now widely believed to be behind the various folk myths that led to the biblical Noah's Ark story. Archaeological records show that around this time there was a sudden expansion of farming and pottery production across Europe, marking the end of the Mesolithic hunter-gatherer era and the start of the Neolithic. The link between rising sea levels and such massive social change has previously been unclear.

The researchers created reconstructions of the Mediterranean and Black Sea shoreline before and after the rise in sea levels. They estimated that nearly 73,000 square km of land was lost to the sea over a period of 34 years. Based on our knowledge of historical population levels, this could have led to the displacement of 145,000 people. Archaeological evidence shows that communities in southeast Europe were already practising early farming techniques and pottery production before the Flood. With the catastrophic rise in water levels it appears they moved west, taking their culture into areas inhabited by hunter-gatherer communities.

Professor Chris Turney of the University of Exeter, lead author of the paper, said: "People living in what is now southeast Europe must have felt as though the whole world had flooded. This could well have been the origin of the Noah's Ark story. Entire coastal communities must have been displaced, forcing people to migrate in their thousands. As these agricultural communities moved west, they would have taken farming with them across Europe. It was a revolutionary time."

The rise in global sea levels 8000 years ago is in-line with current estimates for the end of the 21st century. Professor Chris Turney continued: "This research shows how rising sea levels can cause massive social change. 8,000 years on, are we any better placed to deal with rising sea levels? The latest estimates suggest that by AD 2050, millions of people will be displaced each year by rising sea levels. For those people living in coastal communities, the omen isn't good."

This research was published in the journal Quaternary Science Reviews.

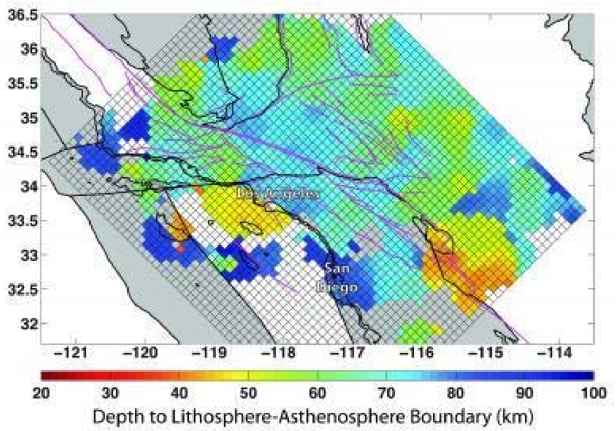
Southern California's Tectonic Plates Revealed in Detail

Rifting is one of the fundamental geological forces that have shaped our planet. Were it not for the stretching of continents and the oceans that filled those newly created basins, Earth would be a far different place. Yet because rifting involves areas deep below Earth's surface, scientists have been unable to understand fully how it occurs.

What is known is that with rifting, the center of the action lies in the lithosphere, which makes up the tectonic plates and includes the crust and part of the upper mantle. In a paper in *Science*, researchers at Brown University produce the highest-resolution picture of the bottom of the lithosphere in southern California, one of the most complex, captivating geologic regions in the world. The team found the lithosphere's thickness differs markedly throughout the region, yielding new insights into how rifting shaped the southern California terrain.

"What we're getting at is how (continental) plates break apart," said Vedran Lekic, a postdoctoral researcher at Brown University and first author on the paper. "What happens below the surface is just not known."

The team measured the boundary separating the lithosphere from the more ductile layer just below it known as the asthenosphere in a 400-by-300-mile grid, an area that includes Santa Barbara, Los Angeles, San Diego and the Salton Trough. The lithosphere's thickness varies surprisingly from less than 25 miles to nearly 60 miles, the researchers write.



The geologic forces that shape the Earth's surface do their work in the lithosphere, often out of sight and far below the surface. Researchers have now measured the lithosphere's thickness in southern California. It varies widely, from less than 25 miles to nearly 60 miles. (Credit: Fischer Lab, Brown University)

"We see these really dramatic changes in lithosphere thickness, and these occur over very small horizontal distances," said Karen Fischer, professor of geological sciences at Brown and a paper author. "That means that the deep part of the lithosphere, the mantle part, has to be strong enough to maintain relatively steep sides."

"This approach provides a new way to put observational constraints on how strong the rocks are at these depths," she added.

Specifically, the researchers found two areas of particular interest. One is the Western Transverse Range Block. The plate lies below Santa Barbara, yet some 18 million years ago, it was located some 125 miles to the south and hugged the coastline. At some point, this plate swung clockwise, rotating more than 90 degrees and journeyed northward, like a mobile, swinging door. Interestingly, the lithosphere remained intact, while the area left behind the swinging plate, called the Inner Continental Borderland and which lies off the coast of Los Angeles, was stretched, the Brown geophysicists believe. Indeed, the lithosphere is nearly 30 percent thinner in the area left behind than the range block.

"The fact that the Western Tranverse Range Block retained its lithosphere along its journey tells us the mantle-lithosphere (of the block) must be very strong," Lekic said.

Another interesting feature noted by the researchers is the Salton Trough, which encompasses the Salton Sea and the city of Palm Springs, and "is a classic example of rifting," according to Fischer. Some 6 million years ago, the continental plate at this location was stretched, but the question remains whether it simply thinned or whether it actually broke apart, creating new lithosphere in between. In the paper, the researchers confirm that the lithosphere is thin, but "we can't tell which of these scenarios happened," Fischer said. However, the thickness of the mantle part of the lithosphere and the fact that deformation at the surface runs all the way to the base of the lithosphere in roughly the same geographical location are new constraints against which modelers can test their predictions, she added.

The team made use of permanent seismic recording stations set up by the Southern California Seismic Network and other networks, as well as seismometers from the EarthScope USarray Transportable Array, a grid of National Science Foundation-funded stations that is gathering earthquake information as it moves west to east across the nation. To measure the lithosphere's depth, the authors looked at how waves generated by earthquakes -- called S waves and P waves -- convert from type S to type P across the boundary between the lithosphere and the asthenosphere.

The team will compare its results with those of another famous rift system in East Africa, from a study at the University of Bristol led by Kate Rychert, who earned her doctorate at Brown in 2007.

Scott French, who earned his baccalaureate at Brown and is now a doctoral student at Berkeley Seismological Laboratory in California, is an author on the paper. The National Science Foundation funded the study, through its Earthscope program and an Earth Sciences postdoctoral fellowship to Lekic.

Journal Reference: Vedran Lekic, Scott W. French, and Karen M. Fischer. **Lithospheric Thinning Beneath Rifted Regions of Southern California**. *Science*, 6 October 2011.

Land Animals, Ecosystems Walloped After Permian Dieoff

ScienceDaily - The cataclysmic events that marked the end of the Permian Period some 252 million years ago were a watershed moment in the history of life on Earth. As much as 90 percent of ocean organisms were extinguished, ushering in a new order of marine species, some of which we still see today. But while land dwellers certainly sustained major losses, the extent of extinction and the reshuffling afterward were less clear.

In a paper published in the journal *Proceedings of the Royal Society B*, researchers at Brown University and the University of Utah undertook an exhaustive specimen-by-specimen analysis to confirm that land-based vertebrates suffered catastrophic losses as the Permian drew to a close. From the ashes, the survivors, a handful of genera labeled "disaster taxa," were free to roam more or less unimpeded, with few competitors in their respective ecological niches. This lack of competition, the researchers write, caused vicious boom-and-bust cycles in the ecosystems, as external forces wreaked magnified havoc on the tenuous links in the food web. As a result, the scientists conclude from the fossil record that terrestrial ecosystems took up to 8 million years to rebound fully from the mass extinction through incremental evolution and speciation.

"It means the (terrestrial ecosystems) were more subject to greater risk of collapse because there were fewer links" in the food web, said Jessica Whiteside, assistant professor of geological sciences at Brown and co-author on the paper.

Survivors: Lystrosaurus, a relative to mammals, was one of a handful of "disaster taxa" to escape from the rubble of the Permian Period, along with the meter-high spore-tree Pleuromeia. Low diversity of animals delayed the full recovery of land ecosystems by millions of years. (Credit: Victor Leshyk)

The boom-and-bust cycles that marked land-based ecosystems' erratic rebound were like "mini-extinction events and recoveries," said Randall Irmis, a co-author on the paper, who is a curator of paleontology at the Natural History Museum of Utah and an assistant professor of geology and geophysics at Utah.

The hypothesis, in essence, places ecosystems' recovery post-Permian squarely on the repopulation and diversification of species, rather than on an outside event, such as a smoothing out of climate. The analysis mirrors the conclusions reached by Whiteside in a paper published last year in *Geology*, in which she and a colleague argued that it took up to 10 million years after the end-Permian mass extinction for enough species to repopulate the ocean -- restoring the food web -- for the marine ecosystem to stabilize.

"It really is the same pattern" with land-based ecosystems as marine environments, Whiteside said. The same seems to hold true for plants, she added.

Some studies have argued that continued volcanism following the end-Permian extinction kept ecosystems' recovery at bay, but Whiteside and Irmis say there's no physical evidence of such activity.

The researchers examined nearly 8,600 specimens, from near the end of the Permian to the middle Triassic, roughly 260 million to 242 million years ago. The fossils came from sites in the southern Ural Mountains of Russia and from the Karoo Basin in South Africa. The specimen count and analysis indicated that approximately 78 percent of land-based vertebrate genera perished in the end-Permian mass extinction. Out of the rubble emerged just a few species, the disaster taxa. One of these was *Lystrosaurus*, a dicynodont synapsid (related to mammals) about the size of a German shepherd. This creature barely registered during the Permian but dominated the ecosystem following the end-Permian extinction, the fossil record showed. Why *Lystrosaurus* survived the cataclysm when most others did not is a mystery, perhaps a combination of luck and not being picky about what it ate or where it lived. Similarly, a reptilian taxon, procolophonids, were mostly absent leading to the end-Permian extinction, yet exploded onto the scene afterward.

"Comparison with previous food-web modeling studies suggests this low diversity and prevalence of just a few taxa meant that links in the food web were few, causing instability in the ecosystem and making it susceptible to boom-bust cycles and further extinction," Whiteside said.

The ecosystems that emerged from the extinction had such low animal diversity that it was especially vulnerable to crashes spawned by environmental and other changes, the authors write. Only after species richness and evenness had been re-established, restoring enough population numbers and redundancy to the food web, did the terrestrial ecosystem fully recover. At that point, the carbon cycle, a broad indicator of life and death as well as the effect of outside influences, stabilized, the researchers note, using data from previous studies of carbon isotopes spanning the Permian and Triassic periods.

"These results are consistent with the idea that the fluctuating carbon cycle reflects the unstable ecosystems in the aftermath of the extinction event," Whiteside said.

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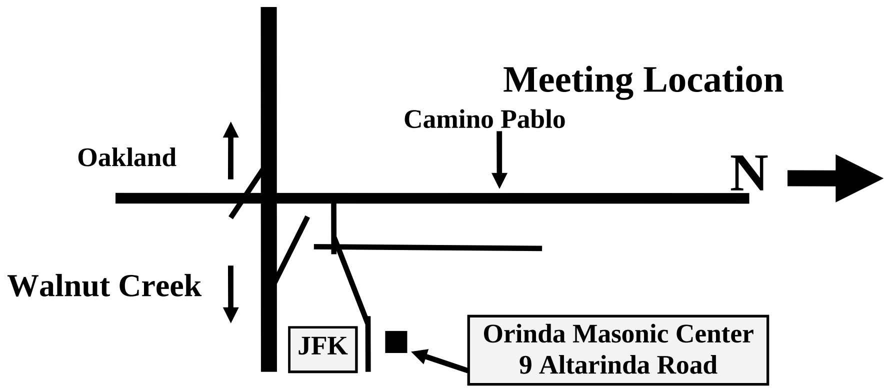

21 smaller Central Valley sub-regions included in C2VSIM was also evaluated. This work has the potential to improve California's groundwater measurements and existing hydrological models for the Central Valley.

Biography: Michelle Newcomer is the student manager of the NASA Ames DEVELOP program at NASA Ames Research Center. Michelle runs a student internship program that provides 18 internships per year to students across the country. Michelle is also currently a graduate student at San Francisco State University in the Department of Geosciences earning a Master of Science degree in Geosciences. Her academic interests range from hydrogeology, including analyzing recharge, understanding processes of water flow, and her thesis work is analyzing recharge for low-impact design rain gardens in San Francisco. Michelle is also interested in remote sensing and Geographic information systems as demonstrated by her work with NASA. Currently the team at NASA is assessing groundwater changes in California's Central Valley using the NASA GRACE satellite.

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