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MEETING ANNOUNCEMENT

DATE: **May 27, 2015** **DINNER MEETING!**

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

TIME: **6:00 p.m. Social; 7:00 p.m. Dinner; 8:00 p.m. Talk**

SPEAKER: **Dr. Lynn Ingram, Professor, University of California, Berkeley**

The West Without Water

(Reservations are required by May 22, 2015, Limit 100 persons)
We are sorry but we will not be able to accommodate "walk-ins"

The West without Water documents the tumultuous climate of the American West over twenty millennia, with tales of past droughts and deluges and predictions about the impacts of future climate change on water resources. Looking at the regions current water crisis from the perspective of its climate history, the authors ask the central question of what is "normal" climate for the West, and whether the relatively benign climate of the past century will continue into the future.

Biography: Dr. Lynn Ingram received her B.S. and her M.S. in geology from UCLA, and her Ph.D in Geology from Stanford University.

Her current research focusses on stratigraphy with strontium isotopes and paleoclimatic and paleo-environmental reconstruction in aquatic environments (estuarine, lacustrine, riverine, and marine) using sedimentological, paleontological, and geochemical data (primarily stable isotopes).

She has assessed changes in climate in California over the past several thousand years using geochemical analyses of sediment cores from San Francisco Bay and surrounding marshes, as well as stratified shellmounds from San Francisco Bay and Santa Barbara Basin. She has also studied lake sediments from California and the Gulf of California.

Her expertise includes sedimentary geochemistry, specifically using environmentally-sensitive isotopic tracers (87Sr/86Sr, 18O/16O,13C/12C, and 14C/12C) to document changes in salinity, streamflow, temperature, ocean circulation, and coastal upwelling.

Please Use Attached Signup Form!!

NCGS 2014 – 2015 Calendar

June 24, 2015 **7:00 pm**
Dr. Will Schweller, NCGS President and Consultant
Injected Sands – Mother Nature's Giant Frac Job?

September 30, 2015 **7:00 pm**
TBD

October 28, 2015 **7:00 pm**
TBD

November 18, 2015 **(1 Week Early)** **7:00 pm**
TBD

NCGS Field Trips

July 25, 2015
The Geysers - Geothermal Energy

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

Additional Trips in Preliminary Planning Stage -

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

Peninsula Geologic Society

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

NASA and industry partner to impact asteroid into Arizona to mine for rare earths

NASA and a consortium of mining companies announced plans today to capture a metal-rich asteroid as it passes by Earth, with the intent of sending it to Arizona, where it will be mined for rare earth elements. Rare earth minerals are in increasing demand for technology applications including hybrid cars and cell phones, but China dominates the world market raising concerns about supply disruptions.

NASA proposes sending a small rocket to asteroid Heise-2014 discovered by an amateur astronomer last year who is the world's wealthiest breeder of thoroughbred seahorses, that would nudge it out of orbit and towards lands controlled by the McCrory Asteroid Mineral Alliance (MAMA) west of Phoenix, Arizona. A company spokesperson downplayed the chances that the asteroid would be significantly off target when it lands (or "impacts" as the news media says). Company president Art McCrory, issued a statement from at an undisclosed location on the Canadian shield, saying, "A gazillion tons of rock and metal hurled towards Arizona at 25,000 miles per hour, what could go wrong?" He closed by wishing us luck and asking that we let him know how it works out before retreating to his underground bunker with the former Miss Rhenium of 2006.

NASA noted that Meteor Crater, Arizona was formed by an impacting body without damaging property 50,000 years ago, so there should be no worries this time around either. In fact, NASA and MAMA may sell tickets to view the landing from ringside seats. Dark glasses will be provided to spectators.

That's the news from April 1, 2015. [Happy April Fool's Day!] We must thank John Christian for this little tidbit!

Chicxulub and the deccan eruptions: Just a coincidence?

In a new paper published online by *GSA Bulletin* on 30 April, researchers Mark Richards and colleagues address the "uncomfortably close" occurrence of the Chicxulub impact in the Yucatán and the most voluminous phase of the Deccan Traps flood basalt eruptions in India. Specifically, the researchers argue that the impact likely triggered most of the immense eruptions of lava in India -- that indeed, this was not a coincidence, but a cause-and-effect relationship.

Knowledge and study of the Deccan Traps eruptions have consistently cast a shadow of doubt on the theory that the Chicxulub impact was the sole cause of the end-Cretaceous mass extinction, most infamous for killing off Earth's dinosaurs. But Richards and colleagues write that historical evidence for the triggering of volcanoes

by large earthquakes, coupled with a wide range of data, show that the massive outpouring of Deccan lavas are likely to have been triggered by the Chicxulub impact -- and thus following on as a secondary disaster.

This photo shows a spectacular sigmoidal jointing within a very thick lava flow from the Ambenali formation in the Western Ghats area of India. See related open-access article by M.A. Richards et al.
Credit: M.A. Richards and colleagues, and GSA Bulletin

"The chances of that occurring at random are minuscule," says Richards. "It's not a very credible coincidence."

Several of the authors visited India in April 2014 to obtain lava samples for dating, and noticed that there are pronounced weathering surfaces, or terraces, marking the onset of the huge Wai subgroup flows. This geological evidence likely indicates a period of quiescence in Deccan volcanism prior to the Chicxulub impact, which, says Richards, "gave this thing a shake," thus mobilizing a huge amount of magma over a short period of time.

Richards and colleagues write that while the Deccan eruptions probably spewed massive amounts of carbon dioxide and other noxious, climate-modifying gases into the atmosphere, "It's still unclear if this contributed to the demise of most of life on Earth at the end of the Age of Dinosaurs."

This article is open access online. Co-authors of the paper are Paul Renne, Michael Manga, Stephen Self, and Courtney Sprain, all from UC-Berkeley; Walter Alvarez, a UC-Berkeley professor emeritus and the co-originator of the dinosaur-killing asteroid theory; Leif Karlstrom of the University of Oregon; Jan Smit of Vrije Universeit in Amsterdam; Loÿc Vanderkluysen of Drexel University in Philadelphia; and Sally A. Gibson of the University of Cambridge, UK. Learn more about this team's research via the UC-Berkeley newsroom.

Story Source: The above story is based on materials provided by **Geological Society of America**.

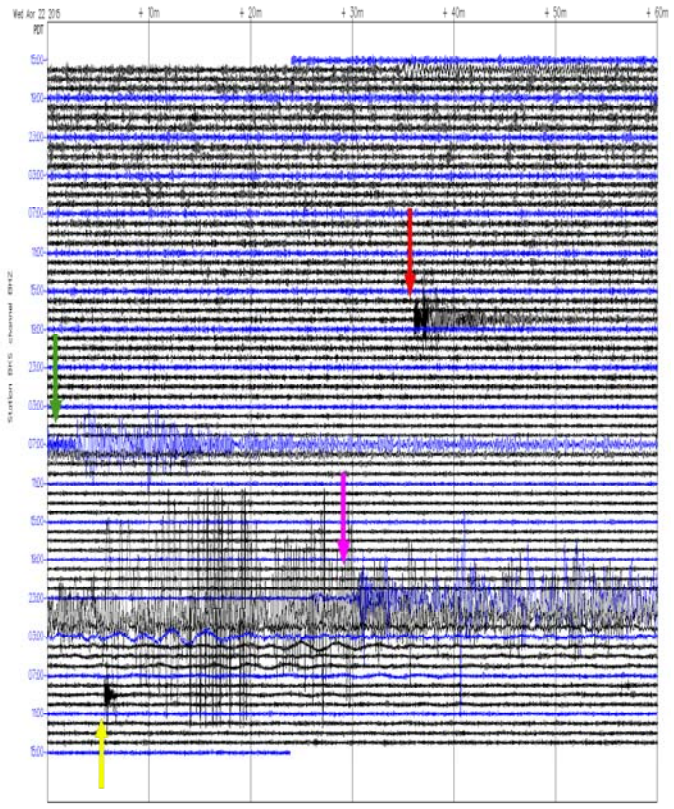
Journal Reference: M. A. Richards, W. Alvarez, S. Self, L. Karlstrom, P. R. Renne, M. Manga, C. J. Sprain, J. Smit, L. Vanderkluysen, S. A. Gibson. **Triggering of the largest Deccan eruptions by the Chicxulub impact**. *Geological Society of America Bulletin*, 2015; DOI: 10.1130/B31167.1

How to Read a Seismogram - Part III

UC Berkeley Seismological Laboratory Seismo Blog

This entry was posted on April 29th, 2015 at 04:52:00 pm and is filed under Earthquake special reports.

The seismic waves generated by the earthquake in Nepal were recorded by seismometers all over the globe, including the ones in the network operated by the Berkeley Seismological Laboratory in Northern California and Southern Oregon. However, looking at the seismogram from our station BKS shown here reveals much more than just the seismic waves originating from the hypocenter in the Himalayas.



A seismogram from 4/22-4/25 at station BKS in Berkeley, CA.

BKS is located in a short tunnel leading into the Berkeley Hills at Strawberry Canyon near the UC Berkeley Botanical Gardens. The tunnel - or adit - was dug in the late 50's of the last century. Its three letter code BKS is unique to this station and clearly identifies it - just like SFO or LAX are codes used by airlines and pilots to uniquely describe the international airports in San Francisco and Los Angeles. The data collected by

the various seismometers in the tunnel are sent to the Seismolab via the internet and stored on various secured data server computers. The computers, located off site, are protected against fire, flood and earthquakes, so that these valuable data don't get lost. Some of these computers are programmed to display the data, and this is how the picture in this blog was generated.

What looks confusing at first can easily be deciphered when you think of reading it line by line, like a page in a book. Each line, read from left to right, shows the motion of the ground caught by the seismometer over exactly one hour, indicated by the 10 minute marks along the top of the picture. The vertical markings depict the actual time in Pacific Daylight time in the 24 hour format. Using these markers one sees that the seismogram begins last Wednesday, April 22, at 3:22pm, as indicated by the blue top line. It ends 72 hours later with the last line on Saturday, April 25, on 3:22 pm. In order to make reading the lines a little bit easier, every fourth line is colored blue, the three lines in between are black.

Looked at through the eyes of a seismologist, this seismogram is actually very unique, because it contains four different kinds of earthquakes, all of them pictured here in a textbook manner. Let's start with the last one (yellow arrow) first: What looks like a black smudge is actually a magnitude 3.3 quake which occurred on Saturday around 9:05 am near the small town of Cobb in The Geysers areas of Lake County. Its epicenter lies about 70 miles north northwest of BKS and it took the first seismic wave about 20 seconds to reach the seismometer. Because of the short distance such a quake is called a local earthquake. These quakes can be spotted on seismogram because they are short, lasting just about a minute.

Now let's look at the quake indicated by the red arrow: It shook the seismometer for more than 12 minutes, starting again with a black smudge, but then after about 2 minutes follow clear wave motions motion. This is the recording of a magnitude 5.5 earthquake, which happened last Thursday at 6:35 pm about 150 miles off the coast of Cape Mendocino. Because this quake's epicenter lies about 350 miles away from BKS, it took the first wave about 2 minutes to reach Berkeley. The greater distance also causes the waves of this quake to be more spread out in time as the local event. Such a quake is commonly called a regional event.

The third set of seismic waves (green arrow) woke up the seismometer last Friday shortly after 7am. They originated from an M6.2 earthquake just south of the Island of Haida Gwaii (formerly known as Queen Charlotte Islands) off the coast of the Canadian Province of British-Columbia. The distance between the epicenter and Berkeley is more than 1050 miles. As a consequence the shaking under BKS lasted more than an hour. You can see the whole blue line wiggle.

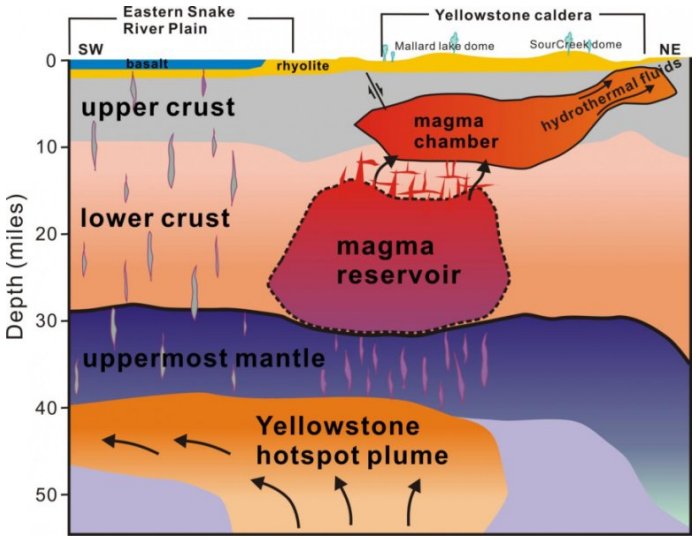
The dominant feature in the seismogram is - of course - the Nepal earthquake. The arrival of its first seismic wave is indicated by the pink arrow. It lasts several hours and the waves were strong enough to cause the largest amplitude of ground motion in this seismogram. Our seismometers at BKS are also sensitive enough to record the Nepali seismic waves traveling around the world several times. Both the quake off Canada as well as the quake in Nepal fall under the category of teleseismic events. (hra103).

For more information on how to read seismograms, see our previous two blogs on how to read seismograms (Part I and Part II).

Scientists see deeper Yellowstone magma

The hot rock in the newly discovered, deeper magma reservoir would fill the 1,000-cubic-mile Grand Canyon 11.2 times, while the previously known magma chamber would fill the Grand Canyon 2.5 times, says postdoctoral researcher Jamie Farrell, a co-author of the study published online today in the journal *Science*.

"For the first time, we have imaged the continuous volcanic plumbing system under Yellowstone," says first author Hsin-Hua Huang, also a postdoctoral researcher in geology and geophysics. "That includes the upper crustal magma chamber we have seen previously plus a lower crustal magma reservoir that has never been imaged before and that connects the upper chamber to the Yellowstone hotspot plume below."



A new University of Utah study in the journal Science provides the first complete view of the plumbing system that supplies hot and partly molten rock from the Yellowstone hotspot to the Yellowstone supervolcano. The study revealed a gigantic magma reservoir beneath the previously known magma chamber. This cross-section illustration cutting southwest-northeast under Yelowstone depicts the view revealed by seismic imaging. Seismologists say new techniques have provided a better view of Yellowstone's plumbing system, and that it hasn't grown larger or closer to

erupting. They estimate the annual chance of a Yellowstone supervolcano eruption is 1 in 700,000.
Credit: Hsin-Hua Huang, University of Utah

Contrary to popular perception, the magma chamber and magma reservoir are not full of molten rock. Instead, the rock is hot, mostly solid and spongelike, with pockets of molten rock within it. Huang says the new study indicates the upper magma chamber averages about 9 percent molten rock -- consistent with earlier estimates of 5 percent to 15 percent melt -- and the lower magma reservoir is about 2 percent melt.

So there is about one-quarter of a Grand Canyon worth of molten rock within the much larger volumes of either the magma chamber or the magma reservoir, Farrell says.

No increase in the danger

The researchers emphasize that Yellowstone's plumbing system is no larger -- nor closer to erupting -- than before, only that they now have used advanced techniques to make a complete image of the system that carries hot and partly molten rock upward from the top of the Yellowstone hotspot plume -- about 40 miles beneath the surface -- to the magma reservoir and the magma chamber above it.

"The magma chamber and reservoir are not getting any bigger than they have been, it's just that we can see them better now using new techniques," Farrell says.

Study co-author Fan-Chi Lin, an assistant professor of geology and geophysics, says: "It gives us a better understanding the Yellowstone magmatic system. We can now use these new models to better estimate the potential seismic and volcanic hazards."

The researchers point out that the previously known upper magma chamber was the immediate source of three cataclysmic eruptions of the Yellowstone caldera 2 million, 1.2 million and 640,000 years ago, and that isn't changed by discovery of the underlying magma reservoir that supplies the magma chamber.

"The actual hazard is the same, but now we have a much better understanding of the complete crustal magma system," says study co-author Robert B. Smith, a research and emeritus professor of geology and geophysics at the University of Utah.

The three supervolcano eruptions at Yellowstone -- on the Wyoming-Idaho-Montana border -- covered much of North America in volcanic ash. A supervolcano eruption today would be cataclysmic, but Smith says the annual chance is 1 in 700,000.

Before the new discovery, researchers had envisioned partly molten rock moving upward from the Yellowstone hotspot plume via a series of vertical and horizontal cracks, known as dikes and sills, or as blobs. They still believe such cracks move hot rock from the plume head to the magma reservoir and from there to the shallow magma chamber.

Anatomy of a supervolcano

The study in *Science* is titled, "The Yellowstone magmatic system from the mantle plume to the upper crust." Huang, Lin, Farrell and Smith conducted the research with Brandon Schmandt at the University of New Mexico and Victor Tsai at the California Institute of Technology. Funding came from the University of Utah, National Science Foundation, Brinson Foundation and William Carrico.

Yellowstone is among the world's largest supervolcanoes, with frequent earthquakes and Earth's most vigorous continental geothermal system.

The three ancient Yellowstone supervolcano eruptions were only the latest in a series of more than 140 as the North American plate of Earth's crust and upper mantle moved southwest over the Yellowstone hotspot, starting 17 million years ago at the Oregon-Idaho-Nevada border. The hotspot eruptions progressed northeast before reaching Yellowstone 2 million years ago.

Here is how the new study depicts the Yellowstone system, from bottom to top:

-- Previous research has shown the Yellowstone hotspot plume rises from a depth of at least 440 miles in Earth's mantle. Some researchers suspect it originates 1,800 miles deep at Earth's core. The plume rises from the depths northwest of Yellowstone. The plume conduit is roughly 50 miles wide as it rises through Earth's mantle and then spreads out like a pancake as it hits the uppermost mantle about 40 miles deep. Earlier Utah studies indicated the plume head was 300 miles wide. The new study suggests it may be smaller, but the data aren't good enough to know for sure.

-- Hot and partly molten rock rises in dikes from the top of the plume at 40 miles depth up to the bottom of the 11,200-cubic mile magma reservoir, about 28 miles deep. The top of this newly discovered blob-shaped magma reservoir is about 12 miles deep, Huang says. The reservoir measures 30 miles northwest to southeast and 44 miles southwest to northeast. "Having this lower magma body resolved the missing link of how the plume connects to the magma chamber in the upper crust," Lin says.

-- The 2,500-cubic mile upper magma chamber sits beneath Yellowstone's 40-by-25-mile caldera, or giant crater. Farrell says it is shaped like a gigantic frying pan about 3 to 9 miles beneath the surface, with a "handle" rising to the northeast. The chamber is about 19 miles from northwest to southeast and 55 miles southwest to northeast. The handle is the shallowest, long part of the chamber that extends 10 miles northeast of the caldera.

Scientists once thought the shallow magma chamber was 1,000 cubic miles. But at science meetings and in a

published paper this past year, Farrell and Smith showed the chamber was 2.5 times bigger than once thought. That has not changed in the new study.

Discovery of the magma reservoir below the magma chamber solves a longstanding mystery: Why Yellowstone's soil and geothermal features emit more carbon dioxide than can be explained by gases from the magma chamber, Huang says. Farrell says a deeper magma reservoir had been hypothesized because of the excess carbon dioxide, which comes from molten and partly molten rock.

A better, deeper look at Yellowstone

As with past studies that made images of Yellowstone's volcanic plumbing, the new study used seismic imaging, which is somewhat like a medical CT scan but uses earthquake waves instead of X-rays to distinguish rock of various densities. Quake waves go faster through cold rock, and slower through hot and molten rock.

For the new study, Huang developed a technique to combine two kinds of seismic information: Data from local quakes detected in Utah, Idaho, the Teton Range and Yellowstone by the University of Utah Seismograph Stations and data from more distant quakes detected by the National Science Foundation-funded EarthScope array of seismometers, which was used to map the underground structure of the lower 48 states.

The Utah seismic network has closely spaced seismometers that are better at making images of the shallower crust beneath Yellowstone, while EarthScope's seismometers are better at making images of deeper structures.

"It's a technique combining local and distant earthquake data better to look at this lower crustal magma reservoir," Huang says.

Story Source: The above story is based on materials provided by University of Utah.

Journal Reference: Hsin-Hua Huang, Fan-Chi Lin, Brandon Schmandt, Jamie Farrell, Robert B. Smith, Victor C. Tsai. **The Yellowstone magmatic system from the mantle plume to the upper crust**. *Science*, 2015 DOI: 10.1126/science.aaa5648

At last, a theory about why Denver is a mile above sea level

By DAN ELLIOTT, Associated Press

DENVER (AP) — Geologists may finally be able to explain why Denver, the Mile High City, is a mile high: water.

A new theory suggests that chemical reactions, triggered by water far below the Earth's surface, could have made part of the North American plate less dense many millions of years ago, when the continents we know today were still forming.

Because plates float on the Earth's mantle, the parts of the Western United States might have risen, like an empty boat next to one with a heavy cargo, pushing the vast High Plains far above sea level, according the theory formulated by geologists Craig Jones and Kevin Mahan at the University of Colorado-Boulder.

© AP Photo/Rocky Mountain News, Marc Piscotty, file FILE - In this April 14, 2003 file photo, the downtown Denver skyline is pictured, with the foothills, and the Rocky Mountains in the background. Geologists say they might finally know why the Mile High City is a mile high.

Their work appeared last week on the website of the journal Geology, and is a big deal for Denver, where the 5,280-foot elevation is a point of pride and a big part of the city's identity. At Coors Field, where the Colorado Rockies play baseball, a single row of purple seats interrupts about 50,000 green ones, marking the mile-high line in the grandstand.

Geologists have long been puzzled by how the High Plains could be so big, so high and so smooth. The plains descend gently from roughly 6,000 feet to 2,000 feet above sea level as they stretch for thousands of square miles, from the Texas Panhandle to southern Montana, and from western Kansas to the foothills of the Rocky Mountains in Colorado.

It's well established that much of the West was still at sea level 70 million years ago, and that tectonic shifts don't fully explain the High Plains' altitude. The lifting began long after the ancient Farallon oceanic plate was shoved deep under a vast part of western North America and then settled into the planet's molten center over millions of years.

Why? "Crustal hydration," they theorize.

Jones and Mahan suggest that water that had been locked in minerals in the Farallon plate was released because of pressure from the overlying rock and heat emanating from the Earth's core. The water then rose into the continental plate, setting off chemical reactions that turned garnet and other dense rock into mica and other less heavy rock, making vast areas of the crust lighter.

Jones said the Earth's crust under the High Plains "floats higher" over magma, much like a plank of buoyant balsa

wood rises higher in the water than a plank of dense pine.

The reason crustal hydration happened where and when it did has to do with how steeply the oceanic plate descended, Jones said. At some point, the angle at which the plate was descending became shallower, enabling the released water to rise for reasons that remain unclear, he said.

Few geological formations appear so uniform on such a vast scale as the High Plains — the only other known location in the world that's similar is in southern Africa, Jones said. The prevailing theory there is different, involving heat rising from below that may be causing the surface to expand and become more buoyant, Mahan said.

The composition of rocks found in the High Plains is strong evidence in favor of the hypothesis, he said, but it needs more testing, and that was one reason for publishing it.

"Do we think this is 'the' answer? No. Could it be 'an' answer? I suppose it's possible," said Jones, who is also a fellow at the Cooperative Institute for Research in Environmental Sciences, a partnership of CU and the National Oceanic and Atmospheric Administration.

The theory has merit, according to Ken Dueker, a professor of geology and geophysics at the University of Wyoming.

"It's a plausible hypothesis that has some data to support it," said Dueker, who was not part of the team that devised it. One unanswered question, which Jones and Mahan raised in the journal Geography, is what channeled the water up into the North American plate, Dueker said.

The Farallon plate also helped form the Rocky Mountains just west of Denver, which soar as high as 14,433 feet. As it moved under the continent, friction caused the North American plate above to compress horizontally, like a rug that bunches up if a foot is dragged across it, geologists say.

Cracks opened from that horizontal pressure, and one side was shoved higher than the other, creating the Rockies.

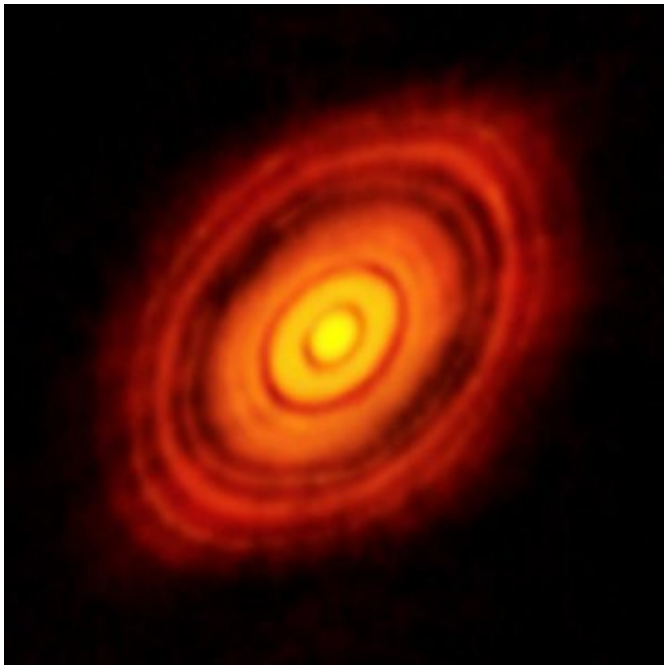
Not knowing why Denver is a mile high is a little awkward for Colorado geologists. Jones recalls having to tell a British TV producer a few years ago that he couldn't explain it.

"We probably need to figure this one out, guys, because it's kind of embarrassing," Jones said.

Astrophysicists offer proof that famous image shows forming planets

A recent and famous image from deep space marks the first time we've seen a forming planetary system, according to a study by U of T astrophysicists.

The team, led by Daniel Tamayo from the Centre for Planetary Science at U of T Scarborough and the Canadian Institute for Theoretical Astrophysics, found that circular gaps in a disk of dust and gas swirling around the young star HL Tau are in fact made by forming planets.



This image sparked scientific debate when it was released last year, with researchers arguing over whether newly forming planets were responsible for gaps in the dust and gas swirling around the young star. Credit: Atacama Large Millimeter/submillimeter Array (ALMA)

"HL Tau likely represents the first image taken of the initial locations of planets during their formation," says Tamayo. "This could be an enormous step forward in our ability to understand how planets form."

The image of HL Tau, taken in October 2014 by the state-of-the-art Atacama Large Millimeter/submillimeter Array (ALMA) located in Chile's Atacama Desert, sparked a flurry of scientific debate.

While those who observed the original image claimed that planets were most likely responsible for carving the gaps, some remained skeptical. It had been suggested that the gaps, especially the outer three, could not represent forming planets because they are so close together. It was argued that planets massive enough to carve such gaps should be scattered violently by the force of gravity and ejected from the system early on in its development.

But Tamayo's study is the first to suggest the gaps are evidence of planetary formation because the gaps are separated by amounts consistent with what's called a

special resonant configuration. In other words, these planets avoid violent collisions with each other by having specific orbital periods where they miss each other, similar to how Pluto has avoided Neptune for billions of years despite the two orbits crossing one another.

Tamayo created two videos to show how HL Tau would appear in both resonant and non-resonant configurations.

The system can be much more stable in a resonant configuration and it's a natural state for planets in the HL Tau system to migrate to says Tamayo.

The HL Tau system is less than a million years old, about 17.9 billion kilometres in radius and resides 450 light years from Earth in the constellation Taurus.

Since young systems like HL Tau are shrouded by a thick cloud of gas and dust, they can't be observed using visible light. ALMA resolves that issue by using a series -- or an array -- of telescopes located 15 kilometres apart that use much longer wavelengths. The result is unprecedented access to high resolution images that Tamayo says will continue to revolutionize the study of planetary formation.

"We've discovered thousands of planets around other stars and a big surprise is that many of the orbits are much more elliptical than those found in our solar system" said Tamayo.

This and future ALMA discoveries may be the key to connecting these discovered planets to their original birth locations.

While the HL Tau system remains stable in its relatively young age, Tamayo says over billions of years it will act as a "ticking time bomb." Eventually the planets will scatter, ejecting some and leaving the remaining bodies on elliptical orbits like the ones found around older stars.

Our solar system does not seem to have undergone such a dramatic scattering event, notes Tamayo. Future observations could also go a long way in determining whether our solar system is typical or an oddity ideally suited for life.

"If further observations show these to be the typical starting conditions around other stars, it would reveal our solar system to be a remarkably special place," says Tamayo.

The findings are available online and will be published in the upcoming edition of *Astrophysical Journal*.

Story Source: The above story is based on materials provided by University of Toronto.

Journal Reference: Daniel Tamayo, Amaury H. M. J. Triaud, Kristen Menou, Hanno Rein. **Dynamical Stability of Imaged Planetary Systems in Formation: Application to HL Tau**.

Dating the moon-forming impact event with meteorites

Through a combination of data analysis and numerical modeling work, researchers have found a record of the ancient Moon-forming giant impact observable in stony meteorites. Their work will appear in the April 2015 issue of the Journal *Science*. The work was done by NASA Solar System Exploration Research Virtual Institute (SSERVI) researchers led by Principal Investigator Bill Bottke of the Institute for the Science of Exploration Targets (ISET) team at the Southwest Research Institute and included Tim Swindle, director of the University of Arizona's Lunar and Planetary Laboratory.

This image shows a meteorite fragment found after a 17-20 meter asteroid disrupted in the atmosphere near Chelyabinsk, Russia on Feb. 15, 2013. The blast wave produced by this event not only caused damage over a wide area but also created a strewn field of stony meteorites like this one. The meteorite is an ordinary chondrite (type LL5). It shows a beautiful contact between impact melt (dark material at top of image) and chondritic host (light material at bottom of image). Chondrules (circular features) are visible in the chondritic host at the bottom and right-hand side of the image. Portions of the chondrite were broken or otherwise separated and have migrated into the impact melt. The impact melt is estimated to be 4452±21 (Popova et al. 2013) and 4456±18 million years old (Lapen et al. 2014). These ages match the ~4470 million year old age of the Moon predicted by our model. We argue these impact melts were likely created when high velocity debris from the Moon-forming impact hit the parent asteroid of the Chelyabinsk bolide and heated near-surface material. Credit: Vishnu Reddy, Planetary Science Institute

The inner Solar System's biggest known collision was the Moon-forming giant impact between a large protoplanet and the proto-Earth. The timing of this giant impact, however, is uncertain, with the ages of the most ancient lunar samples returned by the Apollo astronauts still being debated. Numerical simulations of the giant

impact indicate this event not only created a disk of debris near Earth that formed the Moon, but it also ejected huge amounts of debris completely out of the Earth-Moon system. The fate of this material, comprising as much as several percent of an Earth mass, has not been closely examined until recently. However, it is likely some of it blasted main belt asteroids, with a record plausibly left behind in their near-surface rocks. Collisions on these asteroids in more recent times delivered these shocked remnants to Earth, which scientists have now used to date the age of the Moon.

The research indicates numerous kilometer-sized fragments from the giant impact struck main belt asteroids at much higher velocities than typical main belt collisions, heating the surface and leaving behind a permanent record of the impact event. Evidence that the giant impact produced a large number of kilometer-sized fragments can be inferred from laboratory and numerical impact experiments, the ancient lunar impact record itself, and the numbers and sizes of fragments produced by major main belt asteroid collisions.

Once the team concluded that pieces of the Moon-forming impact hit main belt asteroids and left a record of shock heating events in some meteorites, they set out to deduce both the timing and the relative magnitude of the bombardment. By modeling the evolution of giant impact debris over time and fitting the results to ancient impact heat signatures in stony meteorites, the team was able to infer the Moon formed about 4.47 billion years ago, in agreement with many previous estimates. The most ancient Solar System materials found in meteorites are about one hundred million years older than this age.

Insights into the last stages of planet formation in the inner solar system can be gleaned from these impact signatures. For example, the team is exploring how they can be used to place new constraints on how many asteroid-like bodies still existed in the inner Solar System in the aftermath of planet formation. They can also help researchers deduce the earliest bombardment history of ancient bodies like Vesta, one of the targets of NASA's Dawn mission and a main belt asteroid whose fragments were delivered to Earth in the form of meteorites. It is even possible that tiny remnants of the Moon-forming impactor or proto-Earth might still be found within meteorites that show signs of shock heating by giant impact debris. This would allow scientists to explore for the first time the unknown primordial nature of our homeworld.

Co-author Swindle, who specializes in finding the times when meteorites or lunar samples were involved in large collisions, said: "Bill Bottke had the idea of looking at the asteroid belt to see what effect a Moon-forming giant impact would have, and realized that you would expect a lot of collisions in the period shortly after that.

"Here at LPL, we had been determining ages of impact events that affected meteorites, and when we got together, we found that our data matched his predictions," he added. "It's a great example of taking advantage of groups that work in two different specialties -- orbital dynamics and chronology -- and combining their expertise."

Intriguingly, some debris may have also returned to hit the Earth and Moon after remaining in solar orbit over timescales ranging from tens of thousands of years to 400 million years.

"The importance of giant impact ejecta returning to strike the Moon could also play an intriguing role in the earliest phase of lunar bombardment," said Bottke, who is an alumnus of the University of Arizona's Lunar and Planetary Laboratory. "This research is helping to refine our time scales for 'what happened when' on other worlds in the Solar System."

Yvonne Pendleton, Director of the NASA SSERVI Institute, notes: "This is an excellent example of the power of multidisciplinary science. By linking studies of the Moon, of main belt asteroids, and of meteorites that fall to Earth, we gain a better understanding of the earliest history of our Solar System."

Story Source: The above story is based on materials provided by University of Arizona.

Journal Reference: W. F. Bottke, D. Vokrouhlický, S. Marchi, T. Swindle, E. R. D. Scott, J. R. Weirich, H. Levison. **Dating the Moon-forming impact event with asteroidal meteorites**. *Science*, 2015 DOI: 10.1126/science.aaa0602

Repeated marine predator evolution tracks changes in ancient and Anthropocene oceans

Modern dolphins (pictured) and extinct marine reptiles called ichthyosaurs descended from distinct terrestrial species, but independently converged on an extremely similar fish-like body plan although they were separated in time by more than 50 million years. In April 2015, a team of Smithsonian scientists synthesized decades of scientific discoveries to illuminate the common and unique patterns driving the extraordinary transitions that whales, dolphins, seals and other species underwent as they moved from land to sea, offering a comprehensive look at how life in the ocean has responded to environmental change from the Triassic to the Anthropocene. Credit: Courtesy of NOAA

For more than 250 million years, four-limbed land animals known as tetrapods have repeatedly conquered the Earth's oceans. These creatures--such as plesiosaurs, penguins and sea turtles--descended from separate groups of terrestrial vertebrates that convergently evolved to thrive in aquatic environments.

In a new scientific review, a team of Smithsonian scientists synthesized decades of scientific discoveries to illuminate the common and unique patterns driving the extraordinary transitions that whales, dolphins, seals and other species underwent as they moved from land to sea. Drawing on recent breakthroughs in diverse fields such as paleontology, molecular biology and conservation ecology, their findings offer a comprehensive look at how life in the ocean has responded to environmental change over time. The paper also highlights how evolutionary history informs an understanding of the impact of human activities on marine species today. More information is available in the April 17 issue of *Science*.

Marine tetrapods represent a diverse group of living and extinct species of mammals, reptiles, amphibians and birds that all play--or played--a critical role as large ocean predators in marine ecosystems. The repeated transitions between land and sea have driven innovation, convergence and diversification against a backdrop of changing marine ecosystems and mass extinctions dating back to the Triassic period. In this way, they provide ideal models for testing hypotheses about the evolution of species over long periods of time. Modern species of marine tetrapods now face a suite of human-driven impacts to their environment, including climate change, habitat degradation, ship collisions and underwater noise.

"We know from the fossil record that previous times of profound change in the oceans were important turning points in the evolutionary history of marine species," said Neil Kelley, a Peter Buck post-doctoral researcher in the National Museum of Natural History's department of paleobiology and lead author in the study. "Today's oceans continue to change, largely from human activities. This paper provides the evolutionary context for understanding how living species of marine predators will evolve and adapt to life in the Anthropocene."

Recent investigations in the fossil record have provided new insight into the evolution of traits that allowed marine tetrapods to thrive in the sea. In some cases, similar anatomy evolved among lineages that adapted to marine lifestyles. For example, modern dolphins and extinct marine reptiles called ichthyosaurs descended from distinct terrestrial species, but independently converged on an extremely similar fish-like body plan although they were separated in time by more than 50 million years. The repeated transformation of legs adapted for walking on land into fins is another classic example of convergent evolution. Species ranging from seals to mosasaurs independently developed streamlined forelimbs as they transitioned from living on land to the ocean, allowing them to move quickly and efficiently in the water. This transformation may have been achieved by parallel changes at the genome level.

"Land to sea transitions have happened dozens of times among reptiles, mammals and birds, across major mass extinctions," said Nicholas Pyenson, the museum's curator of fossil marine mammals. "You often get similar looking results but convergence is more than skin deep. It can be seen on a broad range of scales, from molecules to food webs, over hundreds of millions of years."

In the case of deep divers such as beaked whales and seals, these species have independently evolved to have positively charged oxygen-binding proteins called myoglobin in their muscles, allowing them to survive underwater for long periods of time. Scientists also have found identical genetic sequences in different marine species, such as whales, seals and sea cows. Whether these invisible molecular similarities account for larger-scale visible patterns of convergent evolution, or whether convergent anatomy follows different genetic pathways in different groups, remains an important open question to be tackled as genomic sequences become available for more species.

Not all adaptations observed in marine tetrapods can be attributed to convergent evolution. For instance, as baleen whales evolved to live underwater, they developed a unique filter-feeding system that depends on hair-like plates instead of teeth. In contrast, toothed whales evolved to catch and feed on prey by emitting calls and using echolocation, a kind of sonar, to process the echoes from these noises and detect objects in the sea.

Kelley and Pyenson synthesized research from existing studies and referenced the Smithsonian's paleobiology collections during the course of their research. They intend that this comprehensive review will encourage future collaboration between researchers across scientific fields and lead to new insights about evolutionary biology, paleontology and marine conservation.

Story Source: The above story is based on materials provided by **Smithsonian**.

Journal Reference: Neil P. Kelley, Nicholas D. Pyenson. **Evolutionary innovation and ecology in marine tetrapods from the Triassic to the Anthropocene**. *Science*, 2015 DOI: 10.1126/science.aaa3716

NORTHERN CALIFORNIA GEOLOGICAL SOCIETY

NCGS DINNER MEETING Wednesday May 27, 2015

6:00 PM at Orinda Masonic Center

"THE WEST WITHOUT WATER"

Speaker: Dr. B. Lynn Ingram, Professor of Geology, University of California, Berkeley

(Reservations are required by May 22, 2015, Limit 100 persons)
We are sorry but we will not be able to accommodate "walk-ins"

Stepping out of our normal routine, the **Northern California Geological Society** is pleased to announce this *special dinner and evening* with **Dr. Ingram**. For this unique event, planned for our normal monthly meeting date, but starting one-half hour early, we are planning in typical NCGS style, a **Back Forty Texas BBQ dinner consisting of Pork Ribs and BBQ Chicken, Tossed Green Salad, BBQ Beans, Fresh Corn Cobettes. For vegetarian dinners a deluxe veggie burger will be served in place of BBQ. Desert will include assorted cookies and brownies. We may be again serving wines from California specials (90 pts +).** Please also note that a vegetarian option is available if notified ahead (please see the registration form below).

Abstract:

The West without Water documents the tumultuous climate of the American West over twenty millennia, with tales of past droughts and deluges and predictions about the impacts of future climate change on water resources. Looking at the regions current water crisis from the perspective of its climate history, the authors ask the central question of what is "normal" climate for the West, and whether the relatively benign climate of the past century will continue into the future.

******************************Dinner Logistics***

Meeting Details: Social Hour: 6:00 – 7:00 pm; Dinner: 7:00 – 8:00 pm; **Presentation**: 8:00 – open

Time: May 27, 2015, 6:00 pm, Orinda Masonic Center 9 Altarinda Road, Orinda, CA.

Cost: **$25/person**

******************************REGISTRATION FORM (Dr. Ingram's Dinner)**************************

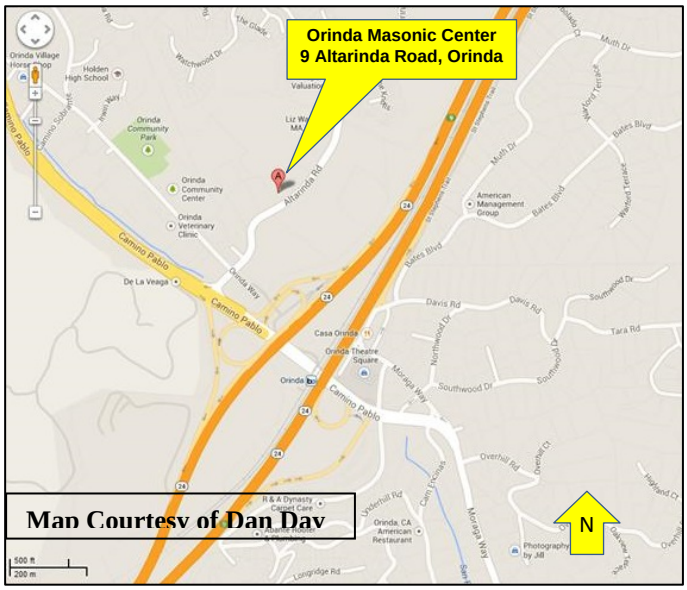
Name:_____

E-mail:_____

Phone (day):_____ Phone (cell) _____

Dinner: Regular: _____ Vegetarian: _____ (Please check one) Check Amount: _____

Please mail a check made out to **NCGS** to:
Tridib Guha, 5016 Gloucester Lane, Martinez, CA 94553
Questions: e-mail: tridibguha@yahoo.com
Phone: (925) 451-1999



GET TO THE DINNER MEETING!

But Remember - Reservations are required by May 22, 2015,
Limit 100 persons
We are sorry but we will not be able to accommodate "walk-ins"

Northern California Geological Society
c/o Mark Detterman
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Hayward, CA 94542-1209

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