NORTHERN CALIFORNIA GEOLOGICAL SOCIETY

MEETING ANNOUNCEMENT

DATE: **February 24, 2010**

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

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

SPEAKER: **Dr. C. Page Chamberlain, Professor,** Dept. Environmental Earth System Science, Stanford University, CA

The Evolution of Eocene Highlands and the Climate of the Western U.S. Cordillera

In this talk I present oxygen isotope records from Cretaceous to Recent terrestrial sediments in the western North American Cordillera. The purpose of this analysis is to use these data to understand the coupled surface elevation and climate history of this region through the Cenozoic. To do this we constructed $\delta^{18}O$ maps of surface waters for critical time intervals that display the origin of topography of the western U.S. These maps are based on 3887 oxygen isotope analyses from both published (3394) and new data (493). We determined the $\delta^{18}O$ of surface waters using temperatures previously determined from floral assemblages and the appropriate isotope fractionation factors. These data suggest that in the late Cretaceous to early Eocene the Sevier hinterland formed a modestly high plateau. Around 50 Ma a topographic wave developed in British Columbia and eastern Washington that swept southward reaching northeastern Nevada at 40 to 38 Ma, and southern Nevada 23 Ma. The topographic wave caused massive reorganization of drainage patterns such that the intraforeland basins of Wyoming and Utah drainages extended deep within the Sevier hinterland as the wave swept southward. The landscape within the Sevier hinterland developed into a rugged and high mountain range with the hypsometric mean elevation of 4 km and relief of 1.5 km. This Eocene highland was bordered on the west by a high Sierra Nevada ramp and on the east by the intraforeland basins that captured water off of these growing highlands. Growth of this highland occurred rapidly with 2.5 km of surface uplift in <2 Ma. The spatial and temporal evolution of this highland roughly correlates with the timing of volcanism and extension. These observations support tectonic models that call for north to south removal of the Farallon slab or mantle delamination. By the mid-Miocene the highlands began to collapse throughout the Northern and Central Basin and Range. Impingement of the Yellowstone hot spot modified the topographic evolution of the northern Basin and Range by creating a bulge that migrated eastward with the plume head and tail. *…Continued on the back…*

NCGS 2009 – 2010 Calendar

Wednesday February 24, 2010
The Evolution of Eocene Highlands and the Climate of the Western U.S. Cordillera
Dr. C. Page Chamberlain, Professor, Geological & Environmental Sciences, Stanford, CA
7:00 pm at Orinda Masonic Lodge

Wednesday March 31, 2010
Structural Model for the Interpretation of the Central Basin and Range Province of Utah and Nevada
Dr. Mel Erskine, Consulting Geologist
7:00 pm at Orinda Masonic Lodge

Wednesday April 28, 2010
TBA
Dan Leigh, Shaw Group, Inc.
7:00 pm at Orinda Masonic Lodge

Wednesday May 26, 2010
TBA
7:00 pm at Orinda Masonic Lodge

Wednesday June 30, 2010
TBA
7:00 pm at Orinda Masonic Lodge

Our Usual Summer Break: July – August 2010

Upcoming NCGS Field Trips

April 18 or 25, 2010 ***Mammoth Rubbing Rocks? and Other Local Geology;*** E. Breck Parkman, Senior State Archaeologist, California State Parks, and Rolfe Erickson, Emeritus, Sonoma State University

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 John Christian at: **jmc62@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.

- March 9, 2010, Robin Stewart, USGS Water Resources; ***Understanding the Influence of Food Web Dynamics on Mercury and Selenium Bioaccumulation in Nature***.
- April 13, 2010, Dave Wagner, California Geological Survey, ***Recent work on the Oak Creek debris flows east of the Sierras***
- May 11, 2010, Julie C. Fosdick, Stanford, Andes research.
- June 1, 2010, Victoria Langenheim, Presidential address

Association of Engineering Geologists San Francisco Section
Upcoming meetings

Meeting locations rotate between San Francisco, the East Bay, and the South Bay. Please check the website for current details:

- March 16, 2010; 6:00pm Paul Marnios, Jahns Lecturer
- April 13, 2010; 6:00pm Student Night
- June 8, 2010, John Wakabayashi

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/

- February 25, 2010; 7:00 pm, Dale Cox, Project Manager, ***USGS Multi-Hazards Demonstration Project***

NCGS Bay Bridge Field Trip

Contributed by Jean Hetherington
Photos by Mark Detterman

On Friday, October 23, almost a week to the day after the 20th anniversary of the Loma Prieta earthquake (LPE), 25 NCGS members and guests had the pleasure of a field trip to the underbelly of the construction site of the new Bay Bridge. This trip was a bit unusual in that members only looked at rocks from afar (actually, only one exposure, perhaps 300 yards away). No standing and arm waving on outcrops. Instead, attendees were treated to a boat cruise on calm bay waters to view the 73 year old work horse next to its up and coming replacement, a graceful arc of steel and concrete rising out of the bay.

Participants arrived at 1 pm at the San Francisco-Oakland Bay Bridge Seismic Safety Project building in Oakland, where they were greeted by members of the Public Information Team. **Heather Rowe** gave an informal presentation to the group. With images of the construction project on the screen, taken primarily from the project website (baybridgeinfo.org), we were told the story of why the new bridge construction is being done, and some of the highlights of recent events for the project.

New bridge construction from Yerba Buena to the Oakland "touchdown" is being done because of the significant damage that happened to the old bridge during the LPE. Although the old bridge was designed to be useable for 150 years, its rigid design and substandard seismic elements make it inappropriate to withstand the seismic shaking that is likely to happen during a significant Bay Area earthquake. Heather confirmed that support piers for the old bridge are indeed made of timber. She also said that the bridge failed during the LPE at the place that engineers considered most vulnerable: at the tower where the causeway transitions to the trussed portion of the bridge. Here, the bridge is very rigid, and resisted the motion of the earthquake. Failure occurred as the old steel fatigued. Heather suggested that if a Bay Area earthquake of LPE magnitude occurs before the new bridge is finished, the entire section west of the causeway would likely tip over and fall into the bay. The new bridge is designed to move with earthquake shaking, not resist it. A number of cutting-edge seismic innovations will allow portions of the bridge to displace up to a meter as seismic waves roll through. While the experience would be an "E-ticket" ride for those on the bridge, the span will remain standing. For example, hinge pipe beams have moveable sleeves that will slide and absorb the seismic energy by deforming their middle "fuse" sections. The iconic single tower will have four separate steel legs, connected by shear link beams, which will allow the legs to move independently during shaking. Damaged beams and fuses can then be quickly replaced after the earthquake. Overall, the new bridge has been designed for a maximum credible earthquake with a recurrence interval of 1500 years. On the website, this translates to an event on the San Andreas Fault of Richter magnitude 8, or an event of 7.25 magnitude on the Hayward Fault.

Questions arose about whether supports for the bridge were anchored in bedrock. For the Skyway, which will replace the existing causeway, 160 steel and concrete piles are driven into Bay Mud and older sediments that rest on Franciscan bedrock. The angled orientation of these piles provides support in a fashion similar to a tripod. For the tower, which will support the suspension portion of the bridge, concrete and steel piles have been inserted into "rock sockets" drilled into Franciscan on the bottom of the bay near Yerba Buena. We later learned that one of the piles on the tower's foundation will have accelerometers affixed to provide shaking data during earthquakes.

Heather was on-site during the Labor Day closure of the Bay Bridge. To appease the media's appetite for information about progress during the closure, while insuring safety during construction, Caltrans media people took video as work progressed and supplied broadcast media with downloads, for nearly continuous updates. Heather was very proud of this unprecedented approach to providing information to the public, along with Tweets (twitter.com) that were generated, as well. Public response to both of these approaches was very favorable.

At around 2:15, the information session ended, and the group got outfitted with hard hats, safety glasses and life jackets. The group was then met by **Jordona Jackson**, who was to be the guide on the boat tour. We walked outside to find a perfect Bay Area October afternoon of warm sun, no wind, and calm, fog-free water on the bay. After boarding the boat, we motored to Yerba Buena, were we viewed the "T1 foundation" for the soon–to-be-built tower for the Self-Anchored Suspension (SAS) portion of the bridge. The boating portion of the tour was a challenge. Where is the best place to be on a small boat with 28 people? Near the railing for the best photo-ops, or near Jordona to hear her wealth of information about the project?

With the old / existing bridge in the foreground, the W2 pier can be seen in the background along with a portion of the temporary scaffolding that is used to slide the new road sections in to place. The bedrock in the foreground was conclusively determined to be our outcrop for the day.

At the first "stop", Jordona described three of the designated Environmentally Sensitive Areas (ESA's). An ESA for aquatic life is designated here to protect eel grass from being harmed by the construction. Buoys outline areas of growth. On the tip of Yerba Buena, directly under the new construction is a structural ESA, to protect a torpedo bunker dating from World War II. Further onshore is a cultural ESA, where artifacts of Ohlone Indians, including 4" long obsidian spear points and shell beads, have been recovered. From this vantage, we were able to see rusty, steel "scaffolding" which was used over Labor Day to slide sections of the old bridge out of the way, so that the "S curve" could be emplaced, diverting traffic so that construction on the new tunnel approach could be started. We also viewed the W2 pier, anchored in Franciscan bedrock on Yerba Buena. One of the unique designs of the new bridge involves the use of a single suspension cable that will be anchored within the decks of the bridge at the eastern end. This single cable will wrap around and be held by the W2 pier. A short distance away, we got an excellent view of the T1 pier and foundation, where the SAS tower will stand.

With the old / existing bridge in the foreground, the temporary scaffolding almost obscures the E2 pier.

E2 on the left, with temporary scaffolding supporting the new bridge.

The next "stop" was by the E2 pier, where both ends of the single suspension cable will be anchored. Here we learned of another unconventional aspect of the construction. With typical suspension bridges, the suspension cables are hung first, and the sections of roadbed are attached afterward. For this bridge, the steps are reversed. "Scaffolding" is being built to support sections of the roadbed as they arrive (by ship). They will be lifted into place to sit on top of the scaffolding. Next, the single cable will be hung and connected to the bed sections. Then, the scaffolding will be removed. Essentially, "two bridges are being built to get one". From this vantage, we also could see a cross section of the prefabricated sections of roadbed that have already been put in place. A large open space 30' tall will run the length of the bridge, through its interior. In addition to providing access for repair to the fuses in the hinge pipe beams, there are water and power conduits, restrooms and storage facilities for equipment….all inside the bridge. Fantastic! We were also able to view wire perches hung from the underside of the new span, for the cormorants that will be displaced from their current accommodations on the old bridge, when is torn down.

The cracked I-Bar and the temporary fix that failed the day after our trip.

Taking it all in!

The next "stop" provided an excellent view of the section of the old bridge damaged during the LPE. Piston-like elements have been attached diagonally across the upper and lower deck, to repair and strengthen the section. Steel salvaged from the repair by construction workers was artistically fashioned into a goblin, about eight inches tall. It was secretly attached to the side of the upper deck, a signature, of sorts, inscribed by the workers. From our vantage, it looked like a smudge of grease. But a photograph was passed around to show the details of the little dancing devil.

Bay Bridge Goblin

Motoring back to the project building allowed time to reflect on the complexity of this giant undertaking, the seismic aspect being only one part. The beauty of this iconic span may render this complexity unappreciated by most, but not by those who participated in the trip this day. Many thanks to **Tridib Guha** for arranging the trip for the NCGS, and to **Heather and Jordona** who guided us.

Earth Science Week

It's Coming - Is it on Your Horizon?

Exploring Energy – The 2010 Earth Science Week Theme

2010 October 10-16

www.agiweb.org

Alexandria, VA – The American Geological Institute (AGI) is pleased to announce the theme of Earth Science Week 2010: "Exploring Energy." "Exploring Energy" will engage young people and the public in learning about Earth's energy resources. It will emphasize the important role earth scientists play in expanding our understanding of the complex interactions of energy resources with earth systems — the planet's atmosphere, hydrosphere, geosphere, and biosphere.

ESW 2010 materials will highlight the many important energy resource questions earth scientists explore: Where do energy resources come from? How are they found and harnessed? How has energy use changed over time? What is the importance of renewable energy? What does science tell us about timely issues such as conservation and public safety? Where are the energy careers of the future likely to be? "Energy is a topic that always generates electricity in education," says Ann E. Benbow, Ph.D., AGI's Director of Education and Outreach. "Students and teachers are used to hearing about energy crises in the news media. We all understand the vital role that energy plays in our lives. That's why we're taking the opportunity during Earth Science Week 2010 to explore energy as a subject of scientific inquiry."

AGI leads Earth Science Week annually in cooperation with its sponsors and the geosciences community as a service to the public. Each year, community groups, educators, and interested citizens organize celebratory events. Earth Science Week offers the public opportunities to discover the earth sciences and engage in responsible stewardship of the Earth. Earth Science Week is supported by the U.S. Geological Survey, the AAPG Foundation, the US Department of Energy, NASA, the National Park Service, Exxon Mobil, and ESRI.

ESW 2010 will be celebrated October 10-16. To learn more about this week, ways to become involved; including newsletters, local events, and classroom activities, please go to the Earth Science Week website at http://www.earthsciweek.org.

The American Geological Institute is a nonprofit federation of 46 geoscientific and professional associations that represents more than 120,000 geologists, geophysicists and other earth scientists. Founded in 1948, AGI provides information services to geoscientists, serves as a voice of shared interests in the profession, plays a major role in strengthening geoscience education, and strives to increase public awareness of the vital role the geosciences play in society's use of resources, resiliency to natural hazards, and interaction with the environment.

NSF Press Release 10-011

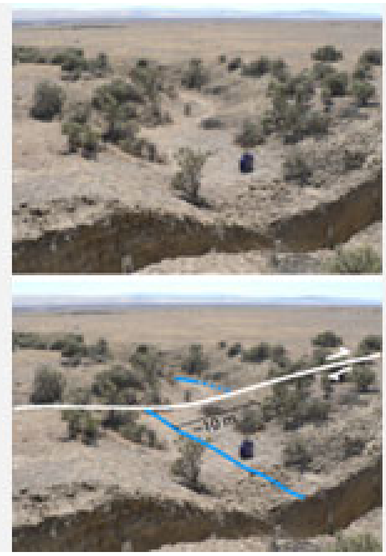
New Earthquake Information Unearthed by San Andreas Fault Studies

Stream Channel Offsets Features Linked to Large Earthquakes

January 21, 2010

Recent studies of stream channel offsets along the San Andreas Fault reveal new information about fault behavior--changing our understanding of the potential for damaging earthquakes.

The studies were conducted at the Carrizo Plain, 100 miles north of Los Angeles and site of the original "Big One"--the Fort Tejon quake of 1857--by scientists at Arizona State University (ASU) and the University of California at Irvine (UCI).



The southeast channel of the Bidart Fan/Carrizo Plain, has been offset 16 meters by 5 quakes. Credit: L. Grant Ludwig

Applying a systems science approach, the teams report results of a pair of studies in the journal *Science Express* on January 21st. The results incorporate the most comprehensive analysis of this part of the San Andreas fault system to date.

"These research results challenge the widely accepted characteristic earthquake model and could transform our understanding of fault behavior," said David Fountain, program director in the National Science Foundation (NSF)'s Division of Earth Sciences, which funded the research.

"The results show a substantially reduced estimate of time between large earthquakes on the south-central San Andreas Fault, which implies more frequent smaller earthquakes than previously believed. This in turn has significant implications for earthquake hazards in southern California."

In one of the studies, ASU geologists Ramon Arrowsmith and Olaf Zielke employed topographic measurements from LiDAR (Light Detection and Ranging), which provided a view of the Earth's surface at a resolution at least 10 times higher than previously available, enabling the scientists to "see" and measure fault movement, or offset.

To study older earthquakes, researchers turned to offset landforms such as stream channels, which cross the fault at a high angle.

The scientists' detailed overhead views of Carrizo Plain stream channels measured the offset features linked to large earthquakes in this section of the southern San Andreas Fault.

"This virtual approach is not a substitute for going out and looking at the features on the ground," says Zielke. "But it is a powerful approach that is repeatable by other scientists."

A team led by UCI's Lisa Grant Ludwig, Sinan Akciz and Gabriela Noriega determined the age of offset features in Carrizo Plain dry stream channels. They studied how much the fault had slipped during previous earthquakes. The distance a fault "slips," or moves, determines its offset.

By digging trenches across the fault, radiocarbon-dating sediment samples, and studying historic weather data for the Carrizo Plain channels, and combining them with LiDAR data, the researchers found something new.

Rather than seeing the same slip repeat in characteristic ways, they found that the slip varied from earthquake to earthquake.

"When we combine our offset measurements with estimates of the ages of these offset features, and the ages of prior earthquakes, we find that the earthquake offset from event to event in the Carrizo Plain is not constant, as is current thinking," Arrowsmith said.

"The idea of slips repeating in characteristic ways along the San Andreas Fault is very appealing, because if you can figure that out, you are on your way to forecasting earthquakes with some reasonable confidence," added Ludwig

"Our results show that we don't understand the San Andreas fault as well as we thought we did," she said. "We therefore don't know the chances of earthquakes as well as we thought."

Before these studies, the magnitude 7.8 Fort Tejon earthquake of 1857 (the most recent earthquake along the southern San Andreas Fault) was thought to have caused a nine-to-ten meter slip along the Carrizo Plain.

This montage includes an aerial view from a balloon and researchers at work at the Carrizo Plain. Credit: *L. Grant Ludwig*

But the data the teams acquired show that it was actually half as much, and that slip in some of the prior earthquakes may have been even less.

The researchers also found that none of the past five large earthquakes in the Carrizo Plain dating back 500 years produced slip anywhere near nine meters. The maximum slip seen was about five to six meters, which includes the slip caused by the Fort Tejon quake.

This result changes how we think the San Andreas Fault behaves, the researchers say. It probably is not as segmented in its release of accumulated stress as was thought.

This makes forecasting future earthquakes harder because geologists cannot rely on the assumption of constant behavior for each section.

It could mean that earthquakes are more common along the San Andreas, but that some of those events may be smaller than previously expected.

Since the 1857 quake, an approximate five meters of strain, or potential slip, has been building up on the San Andreas fault in the Carrizo Plain, ready to be released in a future earthquake.

In the last five earthquakes, the most slip that has been released was five to six meters in the big 1857 quake. This finding points to the potential of a large temblor along the southern San Andreas fault.

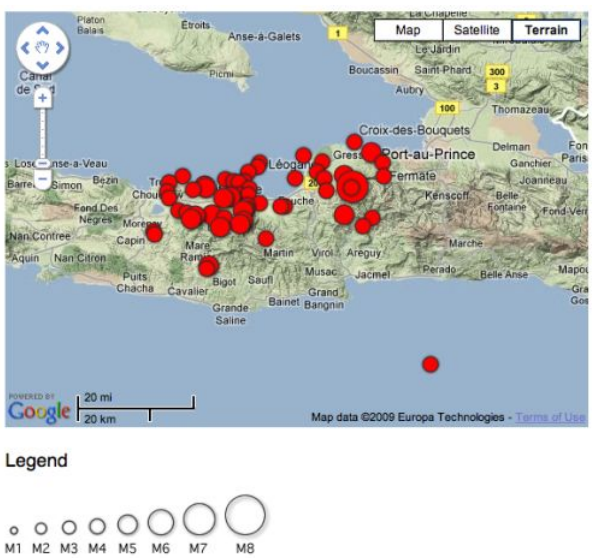
"Our collaboration has produced important information about how the San Andreas Fault works," said Arrowsmith. "I am optimistic that these results, which change how we think about how faults work, are moving us to a better understanding of the complexity of the earthquake process."

"The recent earthquake in Haiti is a reminder that a destructive earthquake can strike without warning," Ludwig said. "One thing that hasn't changed is the importance of preparedness and earthquake resistant infrastructure in seismically active areas around the globe." -NSF-

Haiti's seismic future

http://scienceblogs.com/

Chris Rowan is a geologist specializing in the dark arts of paleomagnetism, and getting people to pay him to travel to exotic destinations for fieldwork. Having drilled up New Zealand during his PhD, and South Africa in his first post-doc, he now works at the University of Edinburgh.

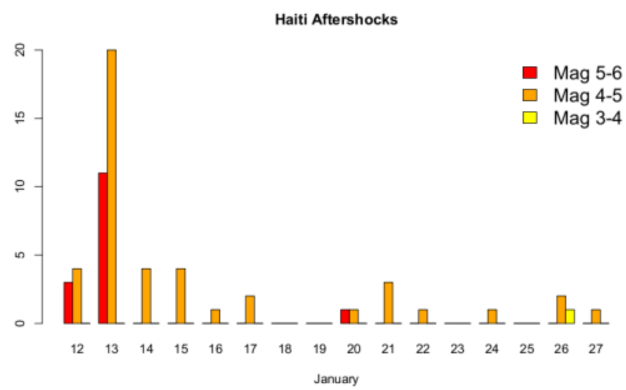


Source: USGS

It's now been just over 3 weeks since a magnitude 7.0 earthquake hit Haiti, devastating the capital Port-au-Prince and many other surrounding towns and villages. The sheer scale of the disaster - the tens, even hundreds of thousands who have lost their lives, or their homes and families - has been quite overwhelming. As the country struggles to recover and rebuild, and with aftershocks still occasionally shaking things up, one question that people want answered is, are we safe yet? When is the continued seismic activity going to stop? Will there be another devastating earthquake in the future - and if so, when? And what about the rest of the northern Caribbean?

Let's start with the aftershocks. When a fault ruptures, the surrounding crust will be deformed by the motion. The upper crust is brittle, so will accommodate this deformation by rupturing at further points of weakness like minor faults and fractures, causing aftershocks. As of February 2nd, there have been 62 significant aftershocks powerful enough to be picked up by the global seismograph network. The USGS provide a handy map (which is being updated over time; this is a static snapshot):

If we plot the frequency of aftershocks over time, we see that the vast majority occurred in the 24 to 36 hours following the main shock (which occurred quite late on the 12th January). This period also included about 15 aftershocks with a magnitude greater than 5, whilst there has only been one (a magnitude 5.9) since.



This makes sense: most of the response to the local redistribution of stress in the crust following a large earthquake will occur almost immediately, as weak points are pushed beyond their point of failure. But there will be some places where stress was increased almost to the point of failure, but not quite over it, and will finally fail a bit later. This means that although there doesn't seem to have been a significant aftershock for a week (although there were probably smaller ones that weren't properly picked up by distant seismometers), there's still the risk of a strained part of the crust finally giving, producing a sizeable aftershock, for some time yet. Which is why this USGS assessment predicted, based on statistical modelling of the aftershocks in the week or so following the mainshock, 2 or 3 aftershocks of magnitude 5 or greater would occur in the 30 day period after 21st January, with a 25% chance of a magnitude 6 or greater aftershock.

However, focussing on just the aftershocks ignores what seems to be the real concern about future seismic risk in Haiti: namely, that only an approximately 40 km long segment of the Enriquillo Fault ruptured on January 12th, and in the same way that stress redistribution around the ruptured section causes aftershocks, stress transferred onto adjacent, and as yet unruptured, sections of the Enriquillo Fault might well trigger large earthquakes on them. This worry has a precedent. In the aftermath of the magnitude 9.0 Boxing Day 2004 Sumatra earthquake, John McCloskey and his colleagues at the University of Ulster calculated that this rupture had placed more stress on the subduction megathrust further to the southeast. Less than a month after publishing a warning of the increased seismic hazard, there was a magnitude 8.7 earthquake in the area in question. It seems that a similar process may possibly be at work in Haiti; here's a map of the stress changes resulting from the January 12th earthquake, as modelled by Eric Calais (I originally found this on a brilliant collection of scientific imagery for the Haiti earthquake being collated by the Group on Earth Observations). Note that the aftershocks (circles) are clustered in the red areas indicating the largest stress increases, but also note the stress increases in the region surrounding the Enriquillo fault both to the east and the west.

Modelled stress changes for the Jan 12 earthquake: thick line marks the modelled rupture length.

As always when talking about triggering earthquakes, it is important to emphasize that this is just giving already strained bits of crust an extra nudge that might cause them to rupture a bit earlier than they otherwise would. The worry comes from the fact that these fault segments might just have enough strain stored up on them to be primed for such triggering. The historical map below shows that a large section of the Enriquillo-Plantain Garden Fault system running through southern Haiti and the neighbouring Dominican Republic last ruptured in a sequence of earthquakes concentrated in a 20 year period between 1750 and 1770, meaning that prior to January 12th, more than 250 years' worth of tectonic movement between the North American and Carribean plates (or, more precisely, the fraction of that tectonic motion that is accommodated by this fault) was being stored as elastic strain across the Enriquillo fault.

Eric Calais was co-author of a 2008 paper (pdf) that used GPS measurements to estimate the rate that strain was building up on the Enriquillo fault, extrapolated from that the total elastic strain accumulated on the Haitian part of the fault zone since the last big earthquake, and calculated that if it was all released in a single earthquake, it would have had a magnitude of approximately 7.2. Some of that strain has now been released by the magnitude 7.0 three weeks ago, but it might be less than you instinctively think: the earthquake magnitude scale is logarithmic, so a magnitude 7.2 earthquake represents about 1.6 times more energy than is released by a magnitude 7.0 earthquake. This leads to the conclusion that the unruptured parts of the Enriquillo fault, particularly the part to the east of January's rupture (which is still very close to Port-au-Prince), still represent a significant seismic hazard.

Another look at the earthquake history of Haiti and the Dominican Republic also reveals a second potential earthquake hazard. The northern Septentrional Fault System seems (from current, GPS-derived, deformation patterns), to accommodate just as much tectonic motion as the Enriquillo system. The part of the Septentrional Fault that runs through Haiti last ruptured in 1842, and has built up enough strain to potentially cause a magnitude 6.9 earthquake if it all ruptured in one go. But there are no historically recorded earthquakes on the part that runs through the Dominican Republic, and paleoseismic studies (which look for disruption of datable horizons in trenches dug along the fault) indicate it probably last ruptured almost 1000 years ago. If that's right, there's enough strain stored up on this section to cause up to a magntiude 7.5 earthquake.

To sum, up then, despite January's quake releasing a fair amount of the strain built up at the plate boundary, there's still plenty more yet to be released in this part of the Caribbean. Seismologists can't really predict if the recent earthquakes have increased the chances of this remainder being released sooner rather than later; more data is definitely required about how the crust has responded to the last month of shaking and stress changes, both through close study of comparative radar imagery (several examples are up at the Group on Earth Observations site), and getting on the ground to make more GPS measurements. However, what should not be ignored is that regardless of the details, this region is always going to be at risk from these sorts of earthquakes. The strain still being stored on the Enriquillo and Septentrional faults is going be released at some point in the decades to come, and it's just a question of when, and how (multiple ruptures, or one big one?). But even then, the danger will not disappear - the slow yet inexorable motion of the North American and Carribean plates will place strain across these faults again - including the segment that caused so much carnage three weeks ago - and eventually they will rupture again. After that, the earthquake cycle will restart once more until they rupture again, and again, and again. The tectonic rhythms of our planet are slow, and a few hundred years of inactivity on a fault is a mere eyeblink when its lifetime can be measured in hundreds of thousands, even millions, of years.

Whilst geologists can not - and may not ever - be able to predict exactly when an earthquake will hit, we are getting to the stage where we know where they are most likely to strike, and roughly how big and how frequent they are likely to be. The northern Carribean is seismically active, and will remain so until what is, for us, an unimaginably distant point in the future. Making the people who live there aware of the seismic risks is important: even after 50 years pass and last month's tragedy fades from the Haitians' memories, geologists need to press home the fact that it *will* happen again, and people should plan and build - and live - accordingly.

Fossil Bone Helps Reconstruct Life Along California's Ancient Coastline

ScienceDaily (June 10, 2009) — In the famed Sharktooth Hill Bone Bed near Bakersfield, Calif., shark teeth as big as a hand and weighing a pound each, intermixed with copious bones from extinct seals and whales, seem to tell of a 15-million-year-old killing ground.

Yet, new research by a team of paleontologists from the University of California, Berkeley, the University of British Columbia in Vancouver, Canada, and the University of Utah paints a less catastrophic picture. Instead of a sudden die-off, the researchers say that the bone bed is a 700,000-year record of normal life and death, kept free of sediment by unusual climatic conditions between 15 million and 16 million years ago.

The team's interpretation of the fossils and the geology to establish the origins of the bone bed, the richest and most extensive marine deposit of bones in the world, are presented in the June 2009 issue of the journal *Geology*.

The mix of shark bones and teeth, turtle shells three times the size of today's leatherbacks, and ancient whale, seal, dolphin and fish skeletons, comprise a unique six-to-20-inch-thick layer of fossil bones, 10 miles of it exposed, that covers nearly 50 square miles just outside and northeast of Bakersfield.

Teeth such as this from the extinct 40-foot-long shark Carcharocles megalodon are common in the Sharktooth Hill Bone Bed because, like modern sharks, these extinct sharks also shed teeth throughout their lives. (Credit: Image courtesy of University of California - Berkeley)

Since the bed's discovery in the 1850s, paleontologists have battled over an obvious question: How did the bones get there? Was this a killing ground for megalodon, a 40-foot version of today's great white shark? Was it a long-term breeding area for seals and other marine mammals, like Mexico's Scammon's lagoon is for the California gray whale? Did a widespread catastrophe, like a red tide or volcanic eruption, lead to a massive die-off?

The new and extensive study of the fossils and the geology of Sharktooth Hill tells a less dramatic story, but an important one, for understanding the origin of rich fossil accumulations, said Nicholas Pyenson, a former UC Berkeley graduate student who is now a post-doctoral fellow at the University of British Columbia.

"If you look at the geology of this fossil bed, it's not intuitive how it formed," Pyenson said. "We really put together all lines of evidence, with the fossil evidence being a big part of it, to obtain a snapshot of that period of time."

Pyenson and his colleagues, totaling five UC Berkeley Ph.D.s and UC Berkeley integrative biology professor Jere Lipps, hope that the study will draw renewed attention to the bone bed, which

Lipps said needs protection even though a small portion of it was added to the National Natural Landmark registry in 1976.

"This deposit, if properly developed, would look just like Dinosaur National Monument," said Lipps, referring to a popular park in Colorado and Utah. "(Sharktooth Hill) is actually much more extensive, and the top of the bone bed has complete, articulated skeletons of seals and other marine mammals."

One 12-foot-long fossil seal skeleton that Lipps helped excavate during the 50 years he has visited the bone bed was mounted and displayed for decades at the Natural History Museum of Los Angeles County (NHM), which houses thousands of fossils excavated from the Sharktooth Hill deposits during expeditions in the 1960s and 1980s. Other collections are in the California Academy of Sciences, San Diego Natural History Museum, Buena Vista Museum of Natural History in Bakersfield, and UC Berkeley's Museum of Paleontology (UCMP), where students over the years have made studies of the bone bed's extinct sea turtles, sharks, marine mammals and seabirds. Lipps is a faculty curator in the UCMP.

The paper's other coauthors - all of whom obtained their Ph.D.s from UC Berkeley - are Randall B. Irmis, now an assistant professor of geology and geophysics at the University of Utah, and Lawrence G. Barnes, Edward D. Mitchell Jr. and Samuel A. McLeod of NHM's Department of Vertebrate Paleontology.

When the bone bed formed between 15,900,000 and 15,200,000 years ago, the climate was warming, sea level was at a peak, California's Central Valley was an inland sea dubbed the Temblor Sea and the emerging Sierra Nevada was shoreline. By closely studying the geology of the Sharktooth Hill area, the paleontologists determined that it was part of an underwater shelf in a large embayment, directly opposite a wide opening to the sea.

Pyenson and Irmis examined some 3,000 fossilized bone and teeth specimens in the collections of many museums, including the NHM and UCMP, and they and Lipps also cut out a meter-square section of the bone bed, complete with the rock layers above and below, and transported it to UC Berkeley for study.

Below the bone bed, they found several feet of mudstone interlaced with shrimp burrows, typical of ocean floor sediment several hundred to several thousand feet below the surface. The bone bed itself averaged 200 bones per square meter, most of them larger bones, with almost no sediment. Most were disarticulated, as if the animal carcasses had decayed and their bones had been scattered by currents.

"The bones look a bit rotten," Lipps said, "as if they lay on the seafloor for a long time and were abraded by water with sand in it." Many bones had manganese nodules and growths, which form on bones that sit for long periods in sea water before being covered by sediment.

Toward the top of the bone bed, some articulated skeletons of seals and whales were found, while in the layer above the bone bed, most skeletons were articulated and encased in sediment.

The team's conclusion is that the climatic conditions were such that currents carried sediment around the bone beds for 100,000 to 700,000 years, during which time bones remained exposed on the ocean floor and accumulated in a big and shifting pile.

Given the rarity of bones marked by shark bites, plus the occurrence of terrestrial animals such as tapirs and horses that must have washed out to sea, predation by sharks like Carcharocles megalodon seems unlikely to have been the major source of the bone bed, the authors wrote. Because of few young or juvenile specimens, the team also discounted the hypothesis that this was a breeding ground for early seals such as Allodesmus. The absence of volcanic ash makes a volcanic catastrophe unlikely, while the presence of land mammal fossils makes red tide an unlikely cause.

"These animals were dying over the whole area, but no sediment deposition was going on, possibly related to rising sea levels that snuffed out silt and sand deposition or restricted it to the very near-shore environment," Pyenson said. "Once sea level started going down, then more sediment began to erode from near shore."

Pyenson noted that, while bone beds around the world occur in diverse land and marine environments, the team's analysis of the Sharktooth Hill Bone Bed could have implications for other fossil-rich marine deposits.

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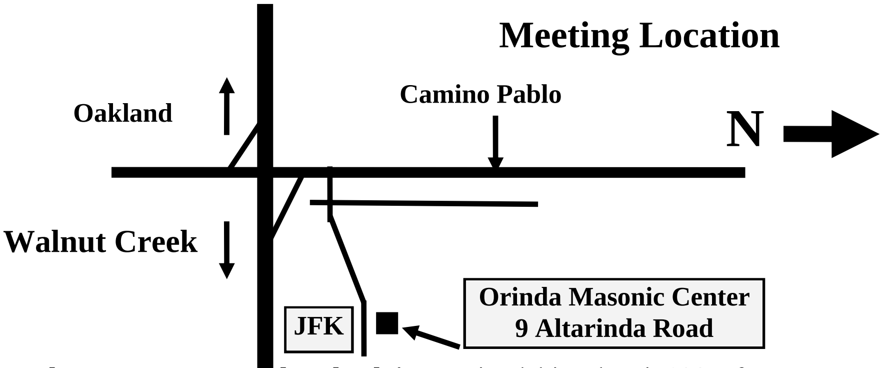
The editor again thanks John Christian for suggesting several of these articles.



Biography: Dr. C. Page Chamberlain received his PhD in1985 from Harvard University, his M.A. in 1981 from Dartmouth College, and his B.S. 1979 from Syracuse University. His research expertise is in the broad area of isotope geochemistry. Current research projects involve the use of isotopes as tracers to investigate geochemical processes in the earth interior and surface, climate change, and environmental problems. His research combines both field and laboratory components. The Stable Isotope Biogeochemistry Laboratory includes a laser-based light stable isotope laboratory for oxygen isotope analysis and a fully automated continuous flow system for carbon, oxygen, nitrogen and hydrogen of minerals and organic matter. A sampling of current research projects: **Climate and Topographic Evolution of Mountain Belts:** Understanding the topographic history of mountain belts is an important problem in Earth Sciences both because of establishing the relationship between climate change and mountain building process and because it provides fundamental information about tectonic processes. However, documenting topographic histories has been difficult because there are relatively few methods available that allow quantitative estimates of paleorelief. We have shown that oxygen and hydrogen isotopes can be used to study the topographic evolution of mountain belts. Our current research includes reconstructing the paleotopography of the Sierra Nevada of California, the Southern Alps of New Zealand, the Rocky Mountains, and the Himalaya. **Chemical Weathering and the Carbon Cycle:** We are integrating numerical models with field studies in an effort to understand weathering processes in active orogens, in an effort to understand the relationship between chemical weathering and the long- and short-term carbon cycle. Our current research focusses on the Southern Alps of New Zealand. In this area we can examine how uplift, rainfall, and weathering are related. **Climate Change:** We use stable isotope records from terrestrial setting to understand climate change. We are investigating how the western US climate responded to past levels of high carbon dioxide in an effort to understand how it might respond to increased levels of carbon dioxide in the future. For more details please go the Dr. Chamberlain's website at: http://www.stanford.edu/group/crg/chamberlain.html

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