NORTHERN CALIFORNIA GEOLOGICAL SOCIETY

Website: www.ncgeolsoc.org

NCGS OFFICERS

President:
Mark Sorrensen,
msorensen@itsi.com
Innovative Technical Solutions, Inc.

***President-Elect*:**
Open

Field Trip Coordinator:
John Christian,
jmc62@sbcglobal.net
Patent Legal Assistant

Treasurer:
Phil Reed, philecreed@yahoo.com
Consultant

Program Chair:
Tom Barry,
Tom.Barry@shawgrp.com
Shaw Group, Inc.

Scholarship:
Phil Garbutt,
plgarbutt@comcast.net
Retired, Cal State East Bay

K-12 Programs:
Paul Henshaw,
candphenshaw@comcast.net
Retired, K-12 education

Membership:
Rob Nelson,
rlngeology@sbcglobal.net
Clearwater Group, Inc.

NCGS Newsletter & Website Editor:
Mark Detterman
mdetter1@gmail.com
Alameda County Environ. Health

Secretary:
Dan Day: danday94@pacbell.net
***NCGS Voice Mail:* 925-424-3669**
VA Engineering, Inc.

COUNSELORS

Mel Erskine,
mcerskine@comcast.net
Consultant

Tridib Guha,
Tridibguha@sbcglobal.net
Advanced Assessment Services, Inc.

Don Lewis, donlewis@comcast.net
Consultant

Ray Sullivan,
sullivan@lucasvalley.net
Emeritus, San Francisco State University

MEETING ANNOUNCEMENT

DATE: **June 30, 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. Jacob Covault, Chevron Clastic Stratigraphy R&D, San Ramon

Natural "laboratories" of southern California: Integrated methodologies to predict coarse-grained sediment flux to the deep sea

Members of the Chevron Clastic Stratigraphy R&D team are conducting research in modern, that is, earth surface and shallow subsurface, natural "laboratories" of southern California to test and develop predictive models of the timing and processes of sediment transport from source to sink. Such research provides predictive guidelines for basinal sediment composition, caliber, distribution, and supply. Southern California sediment-routing systems were chosen as pilots because of their data availability and small sizes, which allow for manageable analyses of different routing segments and their interactions. Here we focus on results from two studies of a sediment-routing system comprising the terrestrial Peninsular Ranges, shelfal Oceanside littoral cell, and La Jolla Canyon and deep-sea fan.

1) Our initial study was an integrated radiocarbon and seismic-stratigraphic analysis of the timing and volume of sediment supplied to the deep sea during thousands of years of sea-level fluctuations. We show that the amount of sediment transported to deep-sea basins is approximately constant regardless of sea level, but the pathways of transport are different. These results highlight caveats to generally successful sequence-stratigraphic predictive models.

2) Our subsequent study was a sediment budget for on- to offshore sediment transfer using cosmogenic radionuclide-derived Peninsular Ranges erosion rates and La Jolla deep-sea fan deposition rates measured during the latest Pleistocene to Holocene marine transgression. We found that there is remarkable similarity between rates of terrestrial erosion and deep-sea deposition, indicating that the redistribution of sediment from land to sea is approximately steady over thousand-year time scales. This insight has direct implications for basinal sediment characteristics in spatially restricted systems- sediment is predicted to be texturally immature and deposition is focused at the terminus of the routing system, with little sediment sequestered en route.

…Continued on the back…

NCGS 2009 – 2010 Calendar

Wednesday June 30, 2010
Dr. Jacob Covault; Chevron Clastic Stratigraphy R&D, San Ramon, CA
Natural "Laboratories" of Southern California: Integrated Methodologies to Predict Coarse-Grained Sediment Flux to the Deep Sea
7:00 pm at Orinda Masonic Lodge

Our Usual Summer Break: July – August 2010

Wednesday September 29, 2010
TBA
7:00 pm at Orinda Masonic Lodge

Wednesday October 27, 2010
Dr. Geoffrey W. Marcy; Professor of Astronomy, University of California, Berkeley (Tentative)
TBA
7:00 pm at Orinda Masonic Lodge

Wednesday November 17, 2010 (Early Date!)
TBA
7:00 pm at Orinda Masonic Lodge

Upcoming NCGS Field Trips

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.

- No further meetings scheduled until the new academic year.

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:

- July 13, 2010, Jordana Jackson, Bay Bridge Seismic Retrofit Project
- September 20 – 25; 2010 Annual Meeting; Charleston, SC

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/

- June 24, 2010; 7:00 pm, **Monterey Canyon - Superhighway to the Deep-Sea,** USGS-MBARI Cooperative Oceanographic Research; Charles Paull, Senior Scientist Monterey Bay Aquarium Research Institute Moss Landing, CA

Modest Update on the BGG

You will recall that Tom Berry (NCGS Programs Chair and former Board of Geology and Geophysicists (BGG) Examination Committee Member) reported last month that at the Board of Professional Engineers and Land Surveyors (BPELS) meeting in Sacramento on May 5th, the Board voted to establish a Geologists and Geophysicists Technical Advisory Committee (G&G TAC). Five geologists including Tom were appointed on an interim basis to the G&G TAC, which as of this date has not met. Tom has requested that a meeting be convened. Tom also reports that until that time several geologists have volunteered to be Subject Matter Experts (SME).

Errata

The editor appears to have been sleep deprived last month as a number of typos managed to get through the review process. Most were obvious, but one article lacked an attribution that should be acknowledged. The article *Geologists: 'We May Be Slowly Running Out Of Rocks'* should be attributed to the online publication the "The Onion News."

Notice of Discussion - Two Potential New NCGS Payment Policies

At a recent Board meeting the NCGS Board considered adopting two new policies that may be effective in the new society year (academic year; September 2010 to June 2011). We wanted to get your comments before these changes are implemented.

For members who prefer to simplify their lives, the NCGS may adopt a **3-Year Membership Option**. This may be an easier option than trying to recall if you actually did pay your membership for the year! But please note this option will require receipt of the newsletter by email.

For members who receive our newsletter by regular mail, the Board may reluctantly adopt a second policy. Mailing each newsletter generally costs the Society $2.20 to $2.75, depending on the number of pages (and thus weight). With nine newsletters a year, total newsletter costs/mail member (alone) range between $19.80 and $24.75; clearly a money losing proposition. Regrettably, budget demands may require the Board to cover those costs. A **$5 to 10 Snail Mail Surcharge** may be placed on all mailed newsletter membership fees. To save yourself some funds in these trying times, please consider converting to electronic delivery; it really prints just the same! And please note, with very rare exceptions with other societies, NCGS does not share email addresses. Pleas contact President **Mark Sorensen** to make your opinion known. Thanks.

Millions of Years

(Or What Doris Does in her Spare Time! – editor)

Peter DaSilva for The New York Times

Doris Sloan said this view showed, in a short distance, the history of the hills.

Bay Area Report

This article is part of our expanded Bay Area coverage.

By KATHARINE MIESZKOWSKI

Published: January 16, 2010

When Doris Sloan, 79, is stuck in traffic on Highway 24 east of the Caldecott Tunnel, she takes the long view — the really long view. An adjunct professor of earth and planetary science at the University of California, Berkeley, Ms. Sloan, who lives in North Berkeley, wrote the field guide "Geology of the San Francisco Bay Region." (Her words have been edited and condensed.)

DISCOVERING ROCKS I came to the Bay Area in the 50s from St. Louis after a brief stopover in Southern California. I raised a family up in Sonoma County; I have four kids. I didn't come to Cal and geology until the 70s. I took this wonderful geology course — a week in the high Sierra — and I was hooked. I hiked out 18 miles, which is farther than I had ever walked in my life, and almost expired on the trail. I was 41 when I went back to school.

TEXT OF TIME This place is special to me because so much dynamic movement from millions of years to the present day can be read from the rock exposed here.

STREAMBEDS AND LAVA The gray and slightly reddish rocks are sedimentary. About 11 million years ago, sand and pebbles were deposited by streams. When the Hayward fault started coming up through this area, the fracture allowed molten material to ooze up.

BIG SQUEEZE These rocks are tilted up. They're almost vertical. The Pacific Plate is moving past the North American Plate a couple of inches a year, on the way to Alaska. It's slightly angled into the North American Plate. That squeezes the Bay Area. It's that ongoing movement that is creating our landscape, folding up the East Bay Hills.

INSIDE THE TUNNEL You're driving under 16-million-year-old marine rocks. Fossils of microscopic single-celled plants and animals tell us they were deposited in the ocean.

A WINDOW There are few places where such a variety of geologic processes are all illustrated in such a short distance — especially a place accessible to so many who don't even have to leave their cars.

CR_Evolution_2 Workshop
May 25 to 27, 2010
Flagstaff, Arizona

(Editor's Note: Although somewhat distal to Northern California there is considerable interest in the Colorado Plateau in the Society. The majority of this newsletter consists of selected extracts from the results of this workshop; first background information, then a participant's blog comments during the conference, and finally an extended abstract on a proposed evolution of the Grand Canyon through approximately 60 M.Y. Links to pertinent references are provided.)

An informal Colorado River workshop, was held at the USGS Science Center in Flagstaff, Arizona on these dates, and was intended to provide a forum for summarizing ongoing research and future goals relating to our understanding of the Cenozoic evolution of the Colorado Plateau-Rocky Mountain landscape, including the upper and lower Colorado River system, uplift of the plateau, and carving of Grand Canyon. The workshop was planned as a "decade-after" update of the symposium held at Grand Canyon in 2000 (link at - *Colorado River, Origin and Evolution*, edited by Young and Spammer, 2001). The results of the workshop were identified as: 1) a summary paper that summarizes the last 10 years of progress and continued challenges to be submitted as the "Introduction" to a Geosphere theme issue, and 2) Individual research papers from the community to be solicited for the Geosphere issue for 12 months after the workshop.

A full set of abstracts can be accessed here.

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The following comments are from Mr. Wayne Ranney's Blog "Earthly Musings". Mr. Ranney was a participant in the workshop. Of himself, he says: "My lifelong relationship with the Grand Canyon and the Colorado Plateau has engendered in me a reverence and awe for the wonder of geologic thought. My goal as a geologist and educator is to share these insights with a larger audience, many of whom have not had the good fortune of living as I have "among the rocks". I am a published author, accomplished trail guide, and a professional geologist who teaches college classes and leads field trips in northern Arizona, the American West, and around the world."

Tuesday, May 25, 2010

The first day of the Colorado River Workshop has now ended and things are as I suspected they might be for me - exhaustive! I got home at 7:30 last night and couldn't decide if I was wide awake ready for more, or just merely ready for bed. It didn't matter - I woke up at some unruly hour in the middle of the night and couldn't get the river or the canyon out of my head. I missed my morning walk but am using the extra time to write a few words about some of my impressions. I'll be back at the 2nd day of the proceedings at 8 AM today and am listed as a co-author on two of the talks.

Overall, everyone was pretty good natured about presenting their ideas, although the two sets of black boxing gloves visible on one of the entry tables wasn't entirely a joke. At least no one screamed but there was a few hearty discussions concerning the lower river (downstream from Hoover Dam). The format of the Workshop is like this: An agenda has been made and you can read it here. Each speaker gets five minutes to present their findings or ideas and then five minutes of discussion after that. That's not a typo. It's five minutes. And fortunately it's policed pretty stringently. It's enough time to show three or four slides although others push that to ten (and then end up being surprised that the five minutes went by so quickly). A cell phone type ringer goes off when each five minutes are up. It's a pretty good system and keeps things moving without having to endure long-winded talks.

There was at least one earth-shattering idea presented in the morning. Brian Wernicke of Cal Tech proposes that a river carved the entire Grand Canyon to within a few hundred meters of its present depth between 80 and 70 million years ago! Not only that, but this river was going in the opposite direction towards Colorado and Wyoming. For those of you who have read ***"Carving Grand Canyon"*** this may not seem like such a new idea, since Don Elston and Andre Potochnik have also proposed such a vision. But Wurnicke uses a technique called thermochronology, which essentially measures when the now removed; overlying rocks were stripped off the ones we can see in the canyon today. (The two previous ideas spoke to surface evidence only). Wernicke has been a giant in the study of the Basin and Range for the last 20 years and this is his first entry into the Grand Canyon debate.

He calls his river the California River (get it - the modern Colorado River flows into California but the ancient California River flowed into Colorado). You can read his abstract here (although it's unfortunate he did not include a map shown in his talk that depicts the California River going from the Sierra's through the Grand Canyon exactly in the alignment familiar to us today and on into northern Colorado. (Remember the Sierra's were much closer to Grand Canyon before Nevada was stretched into the Basin and Range only after 20 Ma. The Sierra's in this depiction were in the approximate position of Las Vegas). I hope to obtain a copy of this map when I see him today.

On the other end of the time spectrum, Kyle House and colleagues provide outstanding evidence from the lower Colorado River between Hoover Dam and Blythe for the catastrophic filling of basins that overflowed sequentially downstream. These basins were separated by bedrock sills and essentially mirror the dammed basins today (Lake Mojave, Lake Havasu, etc.) All of this occurred in the 5 Ma time frame. You can read their abstract here. This seems to argue for a very young river, at least for its lower reach. Amazing the two frames between Wernicke and House.

Wednesday, May 26, 2010

The 2nd day of this workshop proved to be even more exciting than the first since the topics covered the area of the Grand Canyon specifically and the upper Colorado River in Colorado. Much of the discussion again focused on the evidence gleaned from studying the thermochronology of the rocks (basically studying when they were uncovered by erosion). At this workshop, everyone gets their five minutes but then there are hour-long or even 90 minute discussions where everyone in the room can return to ideas that were presented in a talk. In this way, important concepts are revisited and discussed by all in the room.

I have been impressed at how focused these discussions have been. I think everyone who is attending probably felt that this might be an impossible outcome from this workshop since there are so many divergent views. But the discussions have been as enlightening as the individual talks. Sue Beard discussed the evidence for the Kingman Arch, a pre-Basin and Range high that sat southwest of the Grand Canyon. She showed an image that depicted some Laramide (70 to 40 Ma) paleovalleys that were cut into Tonto Group rocks on the southern Grand Wash Cliffs. (I had just flown over Music Mountain a week before and had seen these remnant valleys from the air). These paleovalleys came off of the Kingman Arch and flowed northeast towards the Grand Canyon (but perhaps, before the canyon was here). See the image below from their talk.

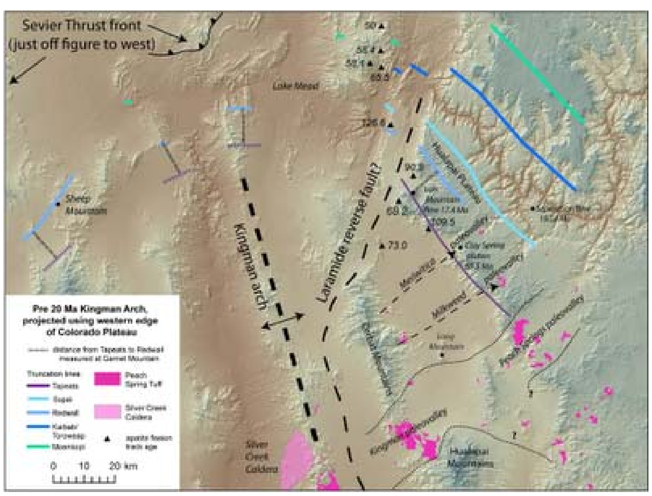


Image from Sue Beard and Jim Faulds workshop abstract showing the area of the Kingman Arch (heavy dashed line, left); three paleovalleys with their names trending onto the Colorado Plateau (small dashed lines); outcrops of the 18.5 Ma Peach Springs Tuff (dark pink) and its suspected source caldera (light pink); and the western end of the Grand Canyon (upper right). The parallel colored lines are the southwestern limit of various Grand Canyon strata.

Ivo Lucchitta showed similar space images from near the Echo Cliffs where, northeast of The Gap, there is a sinuous high-standing ridge of gravel that trends northeast for about 35 miles. Ivo thinks that this may be an ancient main-stem river channel (the San Juan?) that flowed toward the lower end of the Little Colorado River. Some of the clasts in the deposit are identified as coming from the San Juan Mts. in Colorado. Rich Hereford who studied this same deposit 30 year ago thinks it may just be coming from Black Mesa with the clasts being reworked into this.

Composite Landsat and DEM image of Crooked Ridge from Lucchitta and Holm workshop abstract. Note the Echo Cliffs and The Gap (lower left) and Black Mesa (upper right). Crooked Ridge is a sinuous line of gravel between the two. Ive believes this river ran down the monocline of the Echo Cliffs and then turned west into the Little Colorado River.

My name was on two abstracts at this workshop but both of my co-authors gave the talks. (I've been busy transcribing notes). Ron Blakey showed evidence for the age of the Mogollon Rim (> 27 Ma) and we suggested that this feature could have trended all the way to the western end of the Grand Canyon. Carol Hill summarized our work concerning the Laramide to present paleogeography of the Grand Canyon, which includes northeast-directed rivers in some portions of the canyon, and a karst connection between the Marble Canyon section and the rest of Grand Canyon. This karst connection is a tough sell to a group specializes in surface processes but Carol is on to something that may be overlooked in this story.

Having said that, one of the big surprises to me at this workshop is the amount of evidence being presented for the Colorado River going across the Kaibab Arch well before it was integrated with the lower river. This idea means that the ancestral river would have had to leave its present track in the vicinity of Kanab Creek (destination unknown). The time-frame for this is between 20 and 6 Ma. This gets around the problem of how did the river cross the upwarp but still leaves its exit as a problem.

What else? Gosh there was so much. It looks like the Colorado River "instantly appeared" into its delta area around 5.3 Ma. Lots of great evidence for this. And Charles Ferguson really came up with an outrageous idea (not wrong, just outrageous). He thinks that a main-stem river was headed from the basin of Lake Bidahochi (Winslow area) to the Pacific Northwest through the Green and Snake rivers! Not only that, but he believes that this system was intact until integration of the river through Grand Canyon at about 5.3 Ma! That might be tough sell but Charles thinks he has the evidence based on fossil fish assemblages and the gravels. I'll be reporting once more for the 3rd and final day of this workshop.

Thursday, May 27, 2010

The third and final day of the workshop was reserved for participants to discuss some of the progress made since the Grand Canyon Symposium in 2000 and to identify those areas that need more work and clarification. It is difficult at this time to say where progress has been made. Certainly the techniques used to glean information out of the sparse deposits have improved. Remember, in 2000 everyone gave their presentations with slides on Kodak carousels (and at the 1964 symposium plate tectonics did not yet exist). But advances have been made.

Andres Aslan and Rex Cole presented information on the evolution of the upper Colorado River. It was in place and flowing towards the Colorado Plateau by about 11 Ma and the evidence comes from Colorado River gravels preserved beneath the lava flows capping Grand Mesa. This is a big move forward to understand the upper river. The question becomes, where did that river go? Was there a lake somewhere on the central Plateau? Or did the river continue south towards Grand Canyon and Hopi Lake? Or as others have suggested, did that river turn north and go into an ancestral Green River. Seems that the answer to one question yields additional unanswerable questions. Still, we now have solid evidence for the existence of an ancestral upper Colorado River flowing onto the Colorado Plateau before 11 Ma.

Regarding the lower river, Kyle House and colleagues presented perhaps the most solid story presented here, concerning the river's history in the reach between Las Vegas and Blythe. They have deposits that show the presence of isolated basins that were sequentially filled with lake water, and then breached at bedrock divides producing distinctive outburst flood deposits. They are preserved around the Laughlin/Bullhead City area and cluster in age around 5.5 to 5.0 Ma. Irrefutable evidence (we don't get to use that term too often in this story) for the creation and existence of the higher parts of the lower river. Other work from the area around Anza Borrego shows that reworked fossils from the Colorado Plateau arrived in a delta to the Colorado River by 5.3 Ma. So the picture of the lower river is becoming better known as well.

We are still left however, with the mystery of the Grand Canyon. As reported earlier in this blog, evidence was presented for a Grand Canyon cut to near its present depth by 70 Ma, a truly mind-boggling idea. This flies in the face of other lines of evidence for a much younger canyon but it seems that the old canyon idea will not go away, even with the passing 3 years ago of Don Elston. Some at this workshop questioned how a landform could just sit there for all of that time and not appreciably get bigger (or at least develop a soil or something). Other thermochronologic evidence from John Lee suggested that only a paleovalley (and not a canyon) was developed about 18 Ma over eastern Grand Canyon. These discrepancies will have to be worked out.

Concerning the persistent "Muddy Creek Problem" (no Colorado River sediment is found in the deposit, so there could be no Grand Canyon as recently as 6 Ma), yours truly asked the whole group, "If you were looked towards the Grand Wash Cliffs 6 Ma, what would it look like?" Ivo Lucchitta replied, "A wall of rock across the cliff face". Meaning that there was nothing at all of the canyon at that time. But we now know that the river arrived at its delta only 700,000 years later (5.3 Ma). Is it reasonable to assume that we could go from no river to the one we have today in such a short time? Only if spillover is right I guess. If we could answer this one question, (and if you attended the workshop and want to give me your best guess) we might be on our way to understanding if headward erosion, spillover, or sapping is what caused the outburst floods downstream from here.

Another new focus this year was the presentation that rather recent mantle-driven uplift may have affected the southwestern edge of the Plateau in just the last 5 Ma. Presented by Karl Karlstrom, this work suggests that movement on the Toroweap and Hurricane faults in western Grand Canyon may be the result of uplift to the east where removal of the Farallon slab has allowed the hot mantle to heat the overlying crust. The uplift could be what is driving the incision of the Grand Canyon according to this view.

Many came here to bury the idea of spillover from a presumed Hopi Lake (Lake Bidahochi if you prefer).

But John Douglass gave a rousing defense of its possibility, even showing the group that in every geology textbook surveyed, not one mention of spillover was included, while stream piracy, antecedence, and superposition are all mentioned. He argued that we as a science are not trained to appreciate the role that spillover can have on the landscape. And given the evidence from the lower Colorado River where spillover seems to be verified, one does have to wonder.

Speaking of unknowns, karst processes were also presented as possible players in the formation of the Grand Canyon. Carol Hill and Laura Crossey did not collaborate on such an idea, yet their results seemed to dovetail toward the roll that groundwater might have played in creating the canyon. In spite of their endorsements for this process, the community remains largely in favor of the surface evidence only, seeming to make John Douglass's point about inherent biases in our training.

At the end of the third day, it was decided that this group should meet more often to share data and ideas. Sue Beard motioned that since 2014 will be the 50th anniversary of the first symposium in 1964, that we meet then. It was seconded and passed by those in attendance! So the topic will not soon go away.

I was impressed with the respectful manner that most everyone brought to this workshop. Although very observant ones may have seen a few brief moments of impatience towards those who hold certain disfavored ideas, these were very minor and did not disrupt the general tenor of the community. Everyone here obviously loves their work and would not be involved with it were it not so satisfying. The future looks promising for more cooperation and coordination in this effort to understand the Grand Canyon of the Colorado River.

PROPOSED EVOLUTION OF GRAND CANYON FROM THE LARAMIDE TO THE PRESENT

Carol Hill, Wayne Ranney, and Bob Buecher

(Editor's note: The following is but one of the abstracts that can be down loaded at the listed link (see page 3 of NCGS newsletter).

In the Poster Session at the Grand Canyon Workshop Meeting, Flagstaff, Arizona, May 24-26, 2010, we will present eight posters that trace the evolution of Grand Canyon for the time periods of 60 Ma, 50 Ma, 40 Ma, 30 Ma, 17-11 Ma, 11-6 Ma, 6-5 Ma, and 5-0 Ma. Because of space limitations, only one of these poster diagrams is shown in this extended abstract (Fig. 1). All paleotopographic base maps used for these eight posters were taken from Blakey and Ranney (2008), and the authors thank Ron Blakey for his permission to use them. Input from the participants of this Workshop are both needed and welcomed so that modifications can be made to these diagrams.

Paleocene Paleotopography (~60 Ma)

In the Paleocene, drainage off the Mogollon Highlands to the south and Kingman arch to the west flowed north down the regional dip and into Lake Claron along the west side of the Kaibab arch. Flow of the ancestral Little Colorado River was also down the regional dip and north into Lake Claron, but along the east side of the Kaibab arch. This regional drainage on both the west and east sides of the Kaibab arch represent the Laramide "proto-Grand Canyon" of Hill and Ranney (2008). The route that the Colorado River still takes today through the central Grand Canyon – but which was then at a much higher (Mesozoic) stratigraphic level – was set up way back in the Paleocene, with later sections of canyon integrating with this original paleocanyon. Rim gravels, such as the Robbers Roost Conglomerate (~70-50 Ma), were transported from the Prescott area and filled paleovalleys on the Hualapai and Coconino Plateaus (Young, 1999).

Early Eocene Paleotopography (~50 Ma)

As in the Paleocene, drainage off the Mogollon Highlands to the south and Kingman arch to the west continued to flow north down the regional dip and into Lake Claron along the west side of the Kaibab arch, and drainage of the ancestral Little Colorado River flowed north into Lake Claron along the east side of the Kaibab arch. According to Flowers et al. (2008), Upper Granite Gorge had incised down to Triassic-Jurassic level by ~50-30 Ma, and thus a "proto-Grand Canyon" existed in the area of the central Grand Canyon – as was independently proposed by Hill and Ranney (2008) based on their study of the distribution of Canaan Peak-type gravels north of the canyon.

In the Eocene the inferred position of the Shivwits scarp was just north of the Hindu Canyon rim-gravel channel, and the base of Milkweed-Hindu Canyon was incised down as far as the Tapeats Sandstone (Young, 1985). Streams flowing from the Mogollon Highlands and Kingman arch brought arkosic rim gravels onto the Hualapai and Coconino Plateaus; i.e., the Music Mountain Formation (~55-45 Ma), which can be traced all the way from the Grand Wash Cliffs to the vicinity of Long Point.

Late Eocene Paleotopography (~40 Ma)

As the Rocky Mountains rose and basins subsided, giant inland lakes formed over the Colorado Plateau. The Green River Lake covered parts of three states; Lake Claron could have occupied the southern part of a combined Lake Flagstaff/Green River Lake (Hintze, 1988). As in the Early Eocene, drainage off the Mogollon Highlands to the south and Kingman arch to the west flowed north down the regional dip and into Lake Claron along the west side of the Kaibab arch. Hill and Ranney (2008) proposed that a "proto-Kanab Creek" had flowed north high along the west side of the Kaibab arch and into Lake Claron at this time. Flow of the ancestral Little Colorado River was still down the regional dip and north into Lake Claron along the east side of the Kaibab arch. By the late Eocene, Upper Granite Gorge and the "proto-Grand Canyon" would have incised even deeper than it had in the Early Eocene. Rivers in the Mogollon Highlands and Kingman arch incised headward. The main drainage channel incising the Hualapai Plateau was along the northeast trending Hurricane monocline, through Truxton Valley, and then north down Peach Springs Canyon (Young and Brennan, 1974). The Chino-Aubrey Valley also carried rim gravels onto the Hualapai Plateau. Lake Westwater (Westwater Limestone, ~45-40 Ma) was deposited in topographic lows along the Hurricane monocline. Lake Long Point may, or may not, have been present on the Coconino Plateau. In the late Eocene a paleoerosion surface formed on the Hualapai Plateau (Young, 1999). This erosion surface may be contemporaneous with the low-relief Tsaile erosion surface identified by Cather et al. (2008) along the flanks of the Chuska Mountains to the east of the Grand Canyon area.

Oligocene Paleotopography (~30 Ma)

The Oligocene was generally a time of non-deposition, and therefore reconstructions are hard to make. The main sedimentary feature on the Colorado Plateau was the Chuska erg that occupied much of northeast Arizona and northwest New Mexico, and which overlies the Tsaile physiographic erosion surface (Cather et al., 2008). The Buck and Doe Conglomerate formed at this time as a reworked rim-gravel deposit that spread across the Hualapai Plateau over the late Eocene erosion surface (Young, 1999).

The Oligocene was also a time of pronounced volcanism on and surrounding the Colorado Plateau. The Navajo Mountain laccolith probably dates to about 32-23 Ma (Nelson et al., 1992). Uplift of the southern Utah volcanic area caused a reversal of drainage from north to south and the disappearance of the great Eocene lakes in Utah. Lake Claron drained except for in the Cedar Breaks area, where it still existed in the Oligocene (Taylor, 1993). Uplift and volcanism also caused the ancestral Little Colorado River to shift its position eastward and to begin flowing into the Oligocene lake of Hunt (1956). The ancestral Colorado and San Juan Rivers may have also begun flowing into this lake at this time. Early reversed drainage southward from the Bryce Canyon area was along the west side of the Kaibab arch, as is documented by Canaan Peak-type gravels at ~7500 ft (Scarborough et al., 2007). This ~7500 ft level may have been part of the ~7500-7600 ft Valencia physiographic surface of Cooley et al. (1969). Where this southward drainage flowed to is not known, but Hill and Ranney (2008) speculated that it may have been into Lake Long Point. The Kingman arch/uplift was still in existence to the west and southwest of the Grand Canyon area until at least 30 Ma to 17 Ma, and therefore these highlands would have directed flow to the east or northeast and would have prevented drainage from flowing west during this time. Water flowing eastward from the Kingman arch along the Paleocene-Eocene proto-Grand Canyon and westward from the Kaibab arch along Upper Granite Gorge may have joined with water flowing south along the west side of the Kaibab arch to discharge into Lake Long Point.

Middle Miocene Paleotopography (17-11 Ma)

17-16 Ma marks the beginning of Basin and Range west-down faulting along the Grand Wash fault (Faulds et al., 2001). Headward incision eastward began along the Shivwits scarp, which separated the Hualapai and Shivwits Plateaus (Young, 2001). Water thus began to flow west towards the Basin and Range where before 17 Ma it had flowed east. This westward flowing water pooled in a shallow, evaporative lake(s) at the base of the Grand Wash Cliffs and at the mouth of the Shivwits-scarp canyon. Rapid down-dropping along the Grand Wash fault caused alluvial fans of the 16-13 Ma fanglomerate facies of the Muddy Creek Formation to form along the base of the Grand Wash Cliffs. As headward incision caused more water to flow into the Grand Wash Trough, the lake became more extensive and the 13-11 Ma siltstone-sandstone-gypsum facies of the Muddy Creek Formation was deposited (Fig. 2). This facies was supplied by clastic/evaporite rocks being cut by this early westward drainage (Faulds et al., 1997). The Red Lake halite probably also precipitated ~13-11 Ma in a flanking basin south of the main evaporative lake where gypsum was precipitating (Faulds et al., 2001). Headward incision eastward along the Shivwits scarp canyon had not yet reached the old proto-Grand Canyon channel of Hill and Ranney (2008), so a stream flowing westward from the Kaibab arch could not yet make it all the way to the Basin and Range. Rather, this stream water may have pooled in a temporary lake in the Peach Spring-Lower Granite Gorge area. At 16 Ma the lower member of the Bidahochi Formation began depositing from "Lake" Bidahochi. According to Dallegge et al. (2001), "Lake" Bidahochi was probably never one large continuous lake but instead consisted of a series of ephemeral lakes. At 16 Ma the ancestral Little Colorado River flowed north, the ancestral San Juan River flowed west, and the ancestral Colorado River flowed south into the Miocene "Glen Lake" of Hill et al. (2008). The ancestral Green River could have connected with the Snake River in Wyoming, thus accounting for fossil fish of Snake River affinity found in the Bidahochi Formation (Spencer et al., 2008); i.e., the fish could have swam up the Snake to the Green before ~16 Ma when these two rivers became disconnected, then down the Green to the ancestral Colorado River and into Glen Lake, then up the ancestral Little Colorado River and into "Lake" Bidahochi. Basin and Range west-down faulting along the Muav fault caused Kanab Creek to shift from its high (~7500 ft) position along the west side of the Kaibab arch to a lower course, leaving behind Canaan Peak-type gravels from Johnson Creek to Cedar Knoll-Little Cedar Knoll to the Goosenecks (Hill and Ranney, 2008). Then even later in time, with westdown faulting along the Gunsight-Kanab fault, the position of Kanab Creek shifted even further to the west to where it exists today. Thus none of the tributaries to Kanab Creek are barbed, since drainage never reversed along its present-day position – it only reversed from north to south along its highest, ~7500 ft, position along the west side of the Kaibab arch.

Late Miocene Paleotopography (11-6 Ma)

11 Ma was the time when the 16-6 Ma "western Grand Canyon" of Young (2008) and Polyak et al. (2008) became integrated from the west side of the Kaibab arch all the way to the Grand Wash Cliffs. This western Grand Canyon followed the route of the Laramide proto-Grand Canyon in the area of the central Grand Canyon and was occupied by a small river or stream. Headward incision along a proto-Grand Canyon solves the "Headward Erosion Problem" posed by Spencer and Pearthree (2001): how could headward erosion have incised eastward to the Kaibab arch and then across it in only 6 Ma? Incision had to have been along a former canyon for such erosion to have occurred. At 11 Ma headward incision eastward along the Shivwits scarp connected with the Laramide proto-Grand Canyon

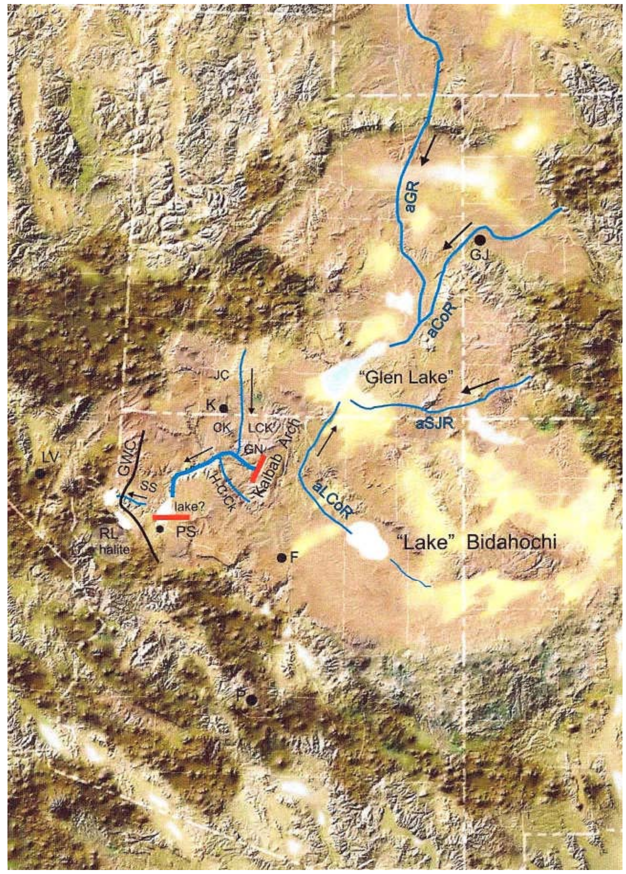


Figure 1: Proposed drainage on the Colorado Plateau with respect to the Grand Canyon area in the time frame of 17-11 Ma. F=Flagstaff, PS=Peach Springs, LV= Las Vegas, K=Kanab, GJ=Grand Junction, GWC=Grand Wash Cliffs, aGR=ancestral Green River, aCoR=ancestral Colorado River, aSJR=ancestral San Juan River, aLCoR=ancestral Little Colorado River, JC=Johnson Creek, C=Cedar Knoll, LCK=Little Cedar Knoll, GN=Goosenecks, RL halite=Red Lake halite, SS=Shivwits scarp. Between the red lines mark the route that the Colorado River still takes today. Base map from Blakey and Ranney (2008).

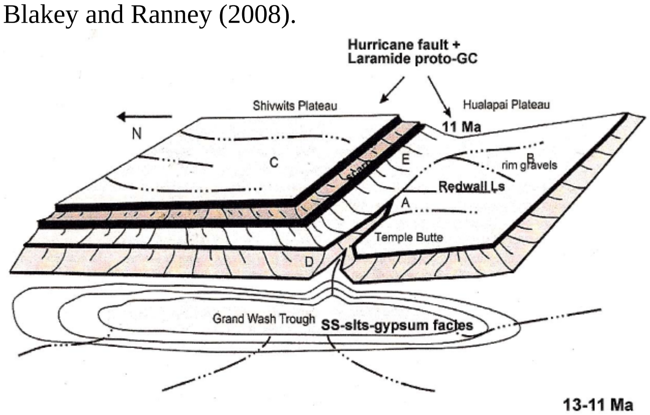


Figure 2: Young's (2008) schematic of initial canyon incision at base of retreating Shivwits scarp; water drains to Grand Wash Trough. Tributary drainage on the Hualapai Plateau was parallel to regional dip and provided runoff for headward incision eastward. Rocks from Temple Butte to Redwall age were beveled across the northeast dipping structural slope on the Hualapai Plateau. The 13-11 Ma sandstone-siltstone-gypsum facies was supplied by Supai, Coconino, and Toroweap clastics

and evaporites long a retreating Shivwits scarp. Once incision reached the Hurricane fault/proto-Grand Canyon at 11 Ma, then water could have flowed from the west side of the Kaibab arch all the way to Lake Hualapai.

(Fig. 2), thus allowing water to flow all the way from the west side of the Kaibab arch to Lake Hualapai. Water that filled Lake Hualapai was carbonate-rich, high 87Sr/86Sr, karst water derived from the breaching and dewatering of the Redwall-Muav aquifer by headward incision as it progressed eastward; i.e., Flowers et al. (2008) projected incision of Upper Granite Gorge down to about Mississippian Redwall level by 16 Ma. Karst water solves the "Hualapai Limestone Problem" posed by Hunt (1974): What was the source of so much carbonate-rich water for the Hualapai Limestone? The reason why the Hualapai Limestone has no clastic delta and is clastic-poor is because the Toroweap, Coconino, and Supai Formations along the proto-Grand Canyon route, along which the later western Grand Canyon followed, had *already* been incised during the Laramide. This solves the "Muddy Creek Problem" that has troubled geologists for decades.

The 16-6 Ma western Grand Canyon headward-incised into the west side of the Kaibab arch until it reached Redwall Limestone level along the synclinal axis of the Grandview monocline. When this happened, a karst-water connection of the eastern and western sections of Grand Canyon occurred *under* the Kaibab arch at ~6 Ma (Hill et al., 2008). "Lake" Bidahochi increasingly broke up into separate ephemeral lakes and playas. The fossil fish of Snake River affinity are found in rocks of ~7 Ma (Spencer et al., 2008). By ~6 Ma the fluivial-eolian lower member of the Bidahochi Formation had been incised by the modern Little Colorado River (Holm, 2001) – perhaps due to the karst connection of the eastern and western sections of Grand Canyon at this time. There never was a "lake overflow" of Lake Bidahochi, as modeled by Meek and Douglas (2001), because no large, high-elevation lake existed at ~6 Ma.

Late Miocene-Early Pliocene Paleotopography, (~6.0-5.0 Ma)

After a karst connection at ~6 Ma, headward incision proceeded up Little Colorado River Canyon and the Little Colorado River incised into the Bidahochi Formation. Headward incision also proceeded up Marble Canyon until a "final connection" was made with "Glen Lake" at ~5.5 Ma in the area between Navajo Mountain and Fifty-Mile Mountain. This final connection caused the draining of Glen Lake, a reversal of drainage in Marble Canyon, and the final integration of the Colorado River through Grand Canyon from Colorado to the Gulf of California. With the incision of a <6 Ma Grand Canyon, the karst connection section under the Kaibab arch collapsed, deepened, and widened into a canyon that became continuous with the rest of Grand Canyon. The tectonic opening of the Gulf of California happened at ~6.5-6.3 Ma (Oskin and Stock, 2003). The lacustrine Bouse Formation was deposited 5.5-5.3 Ma in two paleo-lakes: Lake Mohave and Lake Blythe where these lakes were impounded by paleodams (Spencer and Pearthree, 2005). The southernmost part of the Bouse Formation in the Blythe basin may represent an estuarine environment. Lake Mohave has normal 87Sr/86Sr values because this lake was being supplied by Colorado River water in contrast to the Hualapai Limestone whose source was predominantly high 87Sr/86Sr karst water derived from the Redwall-Muav aquifer at a time *before* the integration of the river through the canyon.

Pliocene Paleotopography to Present Topography (~5-0 Ma)

The integration of the Colorado River through Grand Canyon set off an intense erosion cycle, not only within the canyon itself, but also in the Upper Colorado River Corridor. Over the last 6-5 My, headward incision (knickpoint propagation) has proceeded up the Little Colorado River, the Colorado River in Glen Canyon (and above Glen Canyon), the San Juan River, and the Green River, thus creating the deep, narrow, "young" canyons that are seen today along these rivers. The meandering patterns of these river sections were inherited from a pre-6 Ma earlier erosion cycle. Large tributaries to the Colorado River within the canyon (Havasu-Cataract, Kanab, and Little Colorado River) were already forming before the Colorado River erosion cycle and thus appear older than other tributaries incised during the present Colorado River erosion cycle. Over the last 5 Ma or so the paleolakes along the Lower Colorado River Corridor became drained as the Colorado River established its final integrated course to the Gulf of California. While most of the erosion of Grand Canyon by the Colorado River has occurred over the last ~5-0 Ma, this does not diminish the role that the two earlier episodes – the Laramide proto-Grand Canyon and 16-6 Ma western Grand Canyon – played in establishing the route that the Colorado River now takes through the canyon. It is proposed that the route of the central Grand Canyon was established way back in the Laramide; then, starting at about 11 Ma, the 16-6 Ma western Grand Canyon along the Shivwits scarp became integrated with this Laramide proto-Grand Canyon; at 6 Ma, the eastern Grand Canyon became connected to the 16-6 Ma western Grand Canyon via a karst connection; and at ~5.5 Ma the "final connection" was made with "Glen Lake," thus allowing Colorado River gravels to travel through Grand Canyon and first appear at the mouth of the canyon/Grand Wash Cliffs around 5.5 Ma.

REFERENCES: There is an extensive set of references for this abstract that you can access here.

Did First Feathers Prevent Early Flight?

Science Now

by Michael Balter on May 13, 2010 1:50 PM

No frequent flier. *The feathers of Confuciusornis, a 100–million-year-old prehistoric bird, could probably not sustain vigorous flapping flight.*

Credit: Carnegie Museum of Natural History, Pittsburgh, PA

If, as the old proverb goes, a bird in the hand is worth two in the bush, it's because most of today's birds can swiftly fly away before you can catch them. But that hasn't always been true: The first birds were not impressive flyers, according to a new study of fossil bird feathers. Some researchers, though, say it's too soon to clip the wings of our earliest feathered friends.

Most scientists agree that birds evolved from small dinosaurs at least 150 million years ago and the earliest known birds have wings and feathers that look much like those of modern birds. Yet researchers have long debated whether these first birds, such as 140-million-year-old *Archaeopteryx,* were capable of the kind of vigorous wing flapping necessary for sustained flight, or whether they merely glided or parachuted between treetops and the ground.

Biologist Robert Nudds of the University of Manchester in the United Kingdom and paleontologist Gareth Dyke of University College Dublin in Ireland focused on *Confuciusornis*, a bird dated to about 100 million years ago. They wanted to know whether its feathers were strong enough to provide both lift and rapid flapping without buckling from the effort. To figure that out, they turned to an approach called Euler-Bernoulli beam theory, which has long been used by engineers to calculate the load-bearing strength of structural beams. (Early successes of this method were the Eiffel Tower in Paris and the invention of the Ferris wheel, both in the late 19th century.)

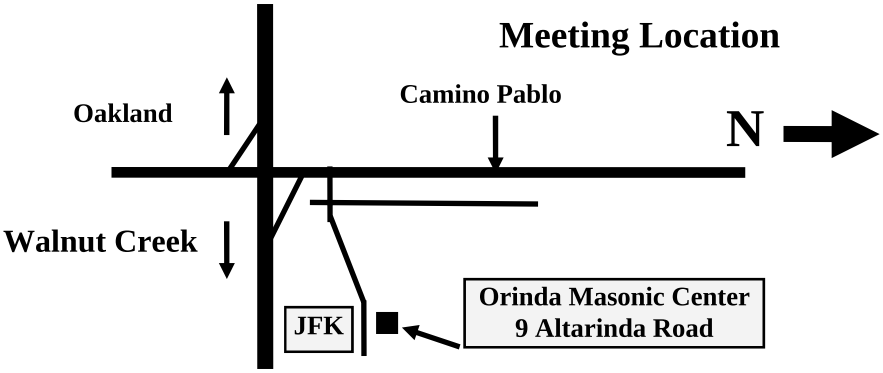
Nudds and Dyke concentrated their analysis on the so-called primary feathers on the outer edge of the wing, which bear most of the load. Using five specimens of *Confuciusornis* from two museums in Germany, the researchers measured the lengths of the primary feathers and the diameters of the rachis, the long, thin shafts that make up the backbones of the feathers and which are analogous to structural beams. These measurements, along with estimates of *Confuciusornis'* body weight, were plugged into Euler-Bernoulli equations to calculate how well its primary feathers would withstand the forces generated by lift and flapping. When the number crunching was done, it didn't look good for early flight: The wings would have buckled under the stress, Nudds and Dyke report in tomorrow's issue of *Science*.

And when the same analysis was applied to a specimen of the older *Archaeopteryx*, it too failed to make the grade. Yet whereas the feathers of both prehistoric birds had only about half the strength necessary to prevent buckling, Nudds and Dyke calculated that modern birds—such as pigeons, gulls, and vultures—have feather strengths up to 13 times greater than necessary to engage in flapping flying, an impressive margin of error. The authors conclude that unless the feather structures of *Confuciusornis* and *Archaeopteryx* were greatly different from those of modern birds—for example if their rachis were solid rather than hollow like those of modern birds, a possibility they consider unlikely—then flapping flying must have been a later development.

But some researchers are not ready to close the book on early flight. "I agree that *Confuciusornis* and *Archaeopteryx* were poor fliers," says Luis Chiappe, a paleontologist at the Natural History Museum of Los Angeles County in California. "I don't agree, however, that these birds were unable to fly by flapping their wings." That's because, he says, the fossilized shafts of the feathers of early birds are often not well defined, making them difficult to measure accurately.

Philip Currie, a paleontologist at the University of Alberta in Canada, says that although the paper provides the "most convincing evidence yet" that these birds did not do well in the air, he also questions the authors' conclusions that they were capable of only gliding or parachuting. The birds' fossils have been found both in marine and lake sediments, Currie says. "If they were only dropping out of trees, how did they end up so far from shore?"

Again as usual of late, the editor sincerely thanks John Christian for suggesting more than several of these articles for the newsletter! Please thank him for spotting some of these gems!



As a preliminary test of insights from this small southern California sediment-routing system, we employed a global database of highly temporally resolved (i.e., k.y.'s) continental-margin deep-sea deposition rates, activities of canyon-channel systems, and episodes of fan growth since 35 ka to assess the timing of terrigenous sediment delivery to the deep sea. Results show that deposition rates are relatively large during periods of marine transgression and lowstand of sea level; however, deposition of coarse-grained sediment in the deep sea can occur at any sea-level state as a result of the tectono-morphologic character of the margin (e.g., narrow shelves) and climatic extremes (e.g., sporadic subglacial meltwater and monsoonal pulses). Therefore, rather than a one-size-fits-all approach to sedimentologic and stratigraphic models, a more holistic understanding of the tectonic and climatic forcings inherent to a continental margin is essential to accurately predict timing, magnitude, and character of deep-sea deposition and place it in the context of sequence stratigraphy.

Biography: **Dr. Jacob Covault** attended Stanford University for his undergraduate degree on a football scholarship, during which he was on 2000 Rose Bowl and 2001 Seattle Bowl teams and received Pac-10 Athletic Conference honors (2003 preseason All-Pac10, second team middle linebacker). Jake stuck around Stanford for his PhD working with Steve Graham and Bill Normark (USGS). Jake has authored >20 peer-reviewed journal articles (three of which currently in review) and nearly 40 conference abstracts. Jake received the 2005 and 2009 AAPG Pacific Section A.I. Levorsen awards (first author and co-author, respectively) and was a co-author on the 2009 AAPG Pacific Section H. Victor Church Memorial Award for best poster at the annual convention. Jake also received the 2008-2009 Stanford-USGS Fellowship. Jake currently is a research scientist at Chevron Energy Technology Company in San Ramon, CA.

Northern California Geological Society
c/o Mark Detterman
3197 Cromwell Place
Hayward, CA 94542-1209

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