inSights
the EarthScope newsletter
Winter 2013

EarthScope News

EarthScope Southeastern Regional Workshop for Interpretive Professionals

Hosted by the College of Charleston and organized by ESNO, this workshop featured presentations and collaborations by EarthScope geoscientists and interpretive professionals to better present the geologic setting and history of the southeastern region of the United States to the public, teachers, and students. Workshop participants learned about EarthScope science, the geologic evolution of the region, earthquake preparedness, scientific results from EarthScope and other sources, and developed and presented actual interpretive programs. The workshop also included a geologic field trip and a "Walk through Charleston" to view damage from the 1886 quake.

For more information check out http://earthscope.org/blog

EarthCube Presentations Are Now Online

On October 29 and 30, 2012 EarthScope hosted the EarthCube End-User Domain Workshop for 51 attendees. EarthCube is a bold, new NSF activity that aims to create a data and knowledge management system for the 21st Century.

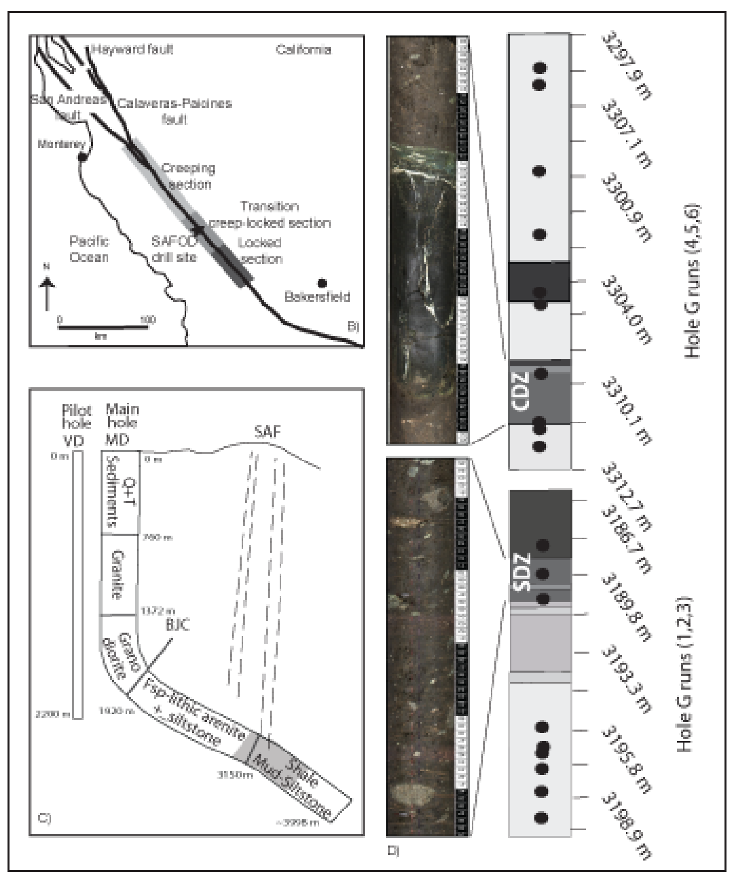
Twenty-seven talks can be found on-line at http://www.earthscope.org/earthcube.

Chlorite-smectite clay minerals and fault behavior: Evidence from the San Andreas Fault Observatory at Depth (SAFOD)

Anja M. Schleicher, Ben A. van der Pluijm, Laurence N. Warr

Drilling into an actively creeping section of the San Andreas Fault (SAF) is a fascinating milestone in earthquake science, as it provides direct information on the composition and mechanical properties of the rocks that are deformed in a fault zone (Hickman et al. 2004). The project offers an opportunity to test contrasting hypotheses on properties, behavior and strength of the SAF, which have been actively debated. The cores retrieved from the San Andreas Fault Observatory at Depth (SAFOD) drill hole in Parkfield, California show intensively sheared and foliated rocks in the two creeping sections of the fault, containing different smectitic clay minerals. This occurrence supports our hypothesis that clay phases convey fault weakness along creeping segments. While constraining the behavior at relatively shallow levels, deeper sections of the fault may also be guided by clays that are stable to greater depths than smectitic illite.

In our latest study, we focused on the stability and the formation mechanisms of specific smectite-rich clay minerals as a function of depth (Schleicher et al. 2012). Mg-rich smectite is generally unstable at temperatures > 150°C (Inoue and Utada, 1991) and is therefore expected not to occur at depths > 4km (assuming the present geothermal gradient in the San Andreas Fault of 25-35 °C/km). In that case, other interpretations are necessary to explain fault weakness at these depths, such as the presence of other weak mineral phases like talc (Moore and Rymer, 2007, Wibberley, 2007), pore fluid pressures (Fulton and Saffer 2009), or stress-induced solution precipitation creep (Holdsworth et al. 2011). We propose that mixed-layer chlorite-smectite minerals, including 50:50 varieties like corrensite, offer an alternative explanation for a weak fault behavior at greater depth, because of their likely low frictional strength and their stability across a broader range of upper-crustal conditions. Chlorite-smectite has been reported to appear at 120°C and persist to temperatures as high as 260°C with decreasing smectite content (Hillier 1993).



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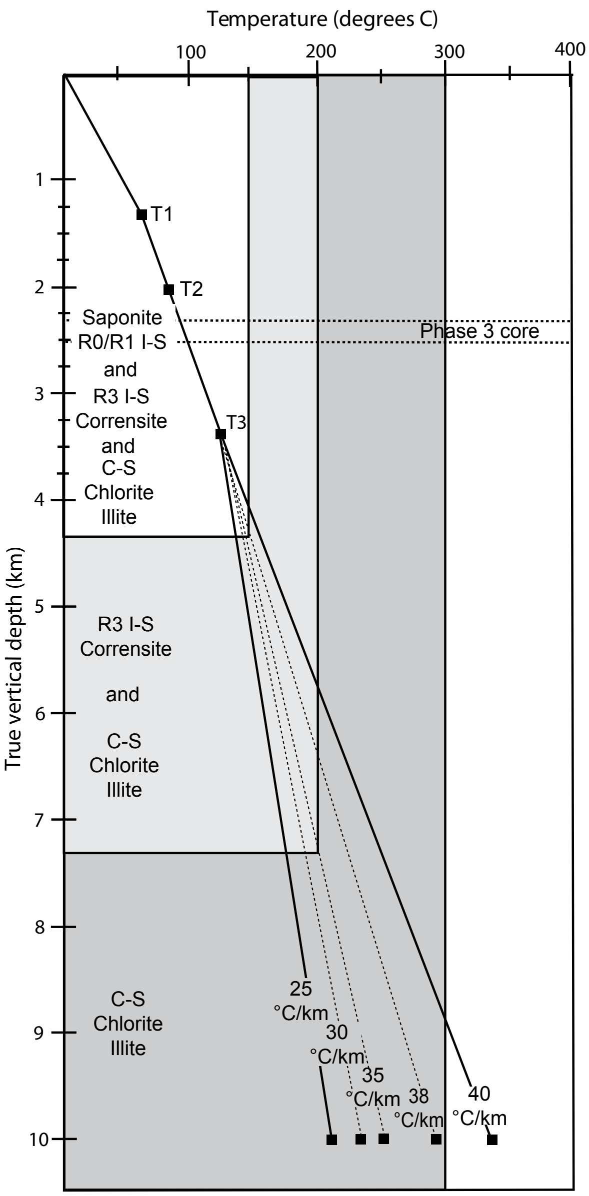

Detailed X-Ray diffraction and electron microscopy study show that the dominant phases in most cores are interlayered clay minerals. Importantly, smectite-rich clay minerals occur as ultrathin coatings on fracture surfaces (Schleicher et al. 2006, 2010), which are visible throughout the entire fault rocks as shiny faces and slickenlines. They consist of Mg-rich smectite, illite-smectite and chlorite-smectite clay phases, which are interconnected to allow slip with minimal breakage of stronger matrix clasts. Based on today's geothermal gradient and the stability of chlorite-smectite, we predict that the formation of those thin smectitic clay coatings can occur as deep as 8-10 km when the activity of Mg is appropriately high (Schleicher et al. 2012). We propose that smectite-bearing clay coatings, including chlorite-smectite minerals formed by the dissolution of mafic lithologies, govern fault behavior down to the brittle-plastic transition.

The frictional behavior of smectite-chlorite phases has not been extensively studied yet, especially at conditions where illite-smectite is not expected to be stable. Existing work on smectite-rich fault rocks shows that they are typically weak, but leaves open questions about the effective frictional strength of chlorite-smectite phases at greater depths. The stability of Mg-rich chloritic clay at higher pressure-temperature conditions offers a possible explanation for fault weakness at depth approaching the brittle-plastic transition, pointing the way forward for important experimental and analytical studies on these phases. New laboratory experiments conducted at appropriate temperatures and pressures on hydrated chlorite-smectite phases are needed to test this hypothesis, which would require artificially-produced samples rather than exhumed or drilled samples that are altered since their initial formation.

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Hot New Science

In each **inSights** we will highlight a few recent publications of EarthScope results. Please submit your latest publications to earthscope@asu.edu

De Angelis, S., Fee, D., Haney, M. M., & Schneider, D. J. (2012). Detecting hidden volcanic explosions from Mt. Cleveland Volcano, Alaska with infrasound and ground-coupled airwaves. Geophysical Research Letters, 39(October), 1–6. doi:10.1029/2012GL053635

Liu, L., & Stegman, D. R. (2012). Origin of Columbia River flood basalt controlled by propagating rupture of the Farallon slab. Nature, 482(7385), 386–9. doi:10.1038/nature10749

Yuan, L., & Chao, B. F. (2012). Analysis of tidal signals in surface displacement measured by a dense continuous GPS array. Earth and Planetary Science Letters, 355-356, 255–261. doi:10.1016/j.epsl.2012.08.035

Hedlin, M. (2012). Studies of large- and fine-scale atmospheric structure using dense seismic networks. EGU General Assembly, p.12355.

Liu, K., Levander, A., Zhai, Y., Porritt, R. W., & Allen, R. M. (2012). Asthenospheric flow and lithospheric evolution near the Mendocino triple junction. Earth and Planetary Science Letters, in press.

USArray Detects Hurricane Sandy

The USArray's Transportable Array (TA) seismometers and barometers have documented ground motion and atmospheric pressure changes due to Hurricane Sandy. The image below shows the TA sensors and the ground vibrating in the up-down direction (red dots) as the hurricane approaches (offshore concentric circles). Snapshots of ground motion are shown over a six day period at midnight. As the hurricane approaches, the stations furthest south start vibrating; as it sweeps north, the whole TA lights up with activity, and eventually returns to normal as the hurricane moves on land and loses its energy. This weak ground motion is not detectable by humans, but the sensitive TA instruments routinely record microscopic motions (or hum) of the Earth, called microseisms. This motion is generated by the ocean waves from the hurricane, which beat on the ocean shore with a dominant period of seven seconds, which these snapshots highlight. The images were taken from an animation made by Dr. Alex Hutko, at the IRIS Data Management Center. For more information, see http://www.iris.edu/dms/products/hurricanesandy.

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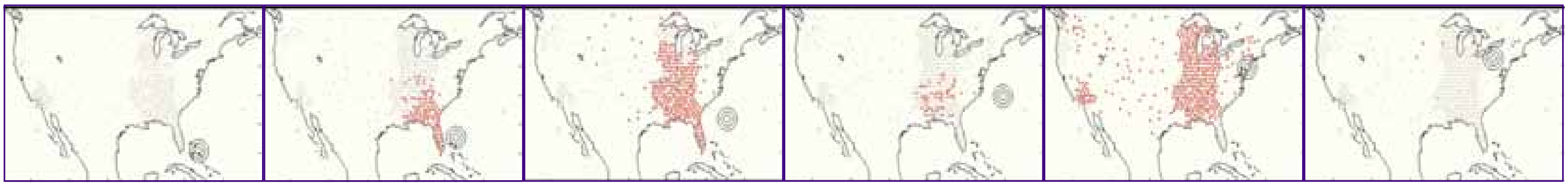

GSA and AGU Recap

EarthScope was well represented at the Geologic Society of America (GSA) and the American Geological Union (AGU) conferences in November and December, 2012. Earthscope featured 32 talks and 51 posters in a variety of topical sessions at both conferences. The session topics included but were not limited to geoscience education, public outreach, geophysics, geodynamics, hazard assessment, tectonics, seismoacoustics, data processing, and instrumentation. The EarthScope National office also hosted a Town Hall at AGU and was at the Exhibition Halls for both AGU and GSA.

InTeGrate: Interdisciplinary Teaching of Geoscience for a Sustainable Future *Cathryn A. Manduca*

InTeGrate is an NSF sponsored community effort to support the teaching of geoscience in the context of societal issues both within geoscience courses and across the undergraduate curriculum. Our goal is to develop a citizenry and workforce that can address environmental and resource issues facing our society.

Geoscience literacy and expertise play a role in all societal issues that involve the Earth. These issues range from environmental degradation and natural hazards to creating sustainable economic systems or livable cities. Yet, very few students in the United States develop a sufficient understanding of geoscience to help inform either their personal decision-making or their choice of career pathways. Those that have encountered geoscience may not develop a sufficient, practical knowledge to apply their understanding to address societal challenges.

Thus, there are two main goals of the InTeGrate project. (1) To dramatically increase geoscience literacy of all undergraduate students including those that do not major in the geosciences, those who are historically under-represented in the geosciences, and future K-12 teachers, such that they are better positioned to make sustainable decisions in their lives and as part of the broader society. (2) To increase the number of majors in the geosciences and associated fields that are able to work with other scientists, social scientists, business people, and policy makers to develop viable solutions to current and future environmental and resource challenges.

Achieving these goals requires a revolution in how geoscience education is perceived and practiced by geoscientists, as well as the roles that the geosciences play in the broader curriculum in institutions of higher education. An integrated approach combines the following elements:
1. Materials development: to develop teaching materials and evaluation of new teaching resources and instruction strategies,
2. Undergraduate program design and development: to incorporate geoscience throughout the curriculum,
3. Professional development and dissemination: to promote widespread adoption of these new approaches, and
4. Assessment and project evaluation: so that the materials and programs developed meet their stated goals, and that project activities meet overarching InTeGrate goals.

The InTeGrate project hinges on active participation from faculty across the country. In 2012, the project hosted four workshops that produced a rich set of teaching materials, essays, course descriptions, and program descriptions available on the project website. Additionally, teams of faculty developed and piloted curriculum with topics ranging from environmental justice and freshwater resources to natural hazards and energy resources. To attend a workshop or join a curriculum development team, visit: https://serc.carleton.edu/integrate/participate/index.html

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inSights is a quarterly publication showcasing exciting scientific findings, developments, and news relevant to the EarthScope program. Contact earthscope@asu.edu to be added or deleted from the hardcopy mailing list; electronic copies are available at www.earthscope.org. Editor: Devon Baumback ASU/EarthScope National Office.

EarthScope National Meeting, May 13-15, 2013

Matt Fouch, ESNO

Every two years EarthScope hosts a National Metting, and this year the conference will be held in Raleigh, North Carolina. There will be four plenary sessions: "EarthScope the Dream", "EarthScope in Full Swing", "EarthScope: Alaska", and "The Next Big Dream: Think BIG!!!" The full agenda will be announced in March.

The website for abstract submissions and meeting/hotel registration will open soon. The abstract format will be a single page PDF generated by the lead author. We will ask that all abstracts include at least one high-resolution figure representative of the research presented. The abstract deadline is April 1. We also ask that opportunities and efforts for Education and Public Outreach be highlighted in each abstract. For more information go to http://www.earthscope.org/meetings/national_meeting_2013.

The program committee is chaired by Lara Wagner (UNC-Chapel Hill). Ramón Arrowsmith and Matt Fouch are assisting from the EarthScope National Office. The committee is comprised of scientific community members from a range of disciplines.