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AUGUST 2009 LITHOSPHERE HIGHLIGHTS

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SHARE

Boulder, CO, USA - The fourth issue of LITHOSPHERE is now available online and in print. Articles ask and answer four main questions: "What's going on beneath the Juan de Fuca slab?"; "What's down the SAFOD borehole?"; "What did the long-term borehole strain records of the Parkfield Earthquake Prediction Experiment record?"; and "What are the mechanisms responsible for map-view curvature over a range of scales for most active and ancient mountain belts?"

Highlights are provided below, and abstracts for the issue are available for review at http://lithosphere.gsapubs.org/content/1/4. Representatives of the media may obtain complementary copies of articles by contacting Christa Stratton at cstratton@geosociety.org . Please discuss articles of interest with the authors before publishing stories on their work, and please make reference to LITHOSPHERE in articles published. Contact Christa Stratton for additional information or assistance.

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Subducted oceanic asthenosphere and upper mantle flow beneath the Juan de Fuca slab

Raymond M. Russo, University of Florida, Geological Sciences, P.O. Box 112120, 241 Williamson Hall, Gainesville, Florida 32611, USA. Pages 195-205.

Oceanic plates are underlain by a weak layer -- the asthenosphere -- characterized by slow seismic velocities from ~100-250 km depth, but what happens to this asthenosphere when the oceanic plate above it subducts? Seismic waves from earthquakes in the Juan de Fuca plate, now subducting beneath North America just offshore of Washington and Oregon states, show that the asthenosphere beneath the Juan de Fuca slab develops two distinct layers: one with mantle flow trends parallel to the subduction trench, and a second, deeper layer with flow fabrics parallel to the motion of the Juan de Fuca plate. The upper mantle flow layer parallel to the Juan de Fuca subduction trench must develop when the lithosphere subducts, probably due to compression of the weak asthenosphere as it is overridden by North America.

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Arkosic rocks from the San Andreas Fault Observatory at Depth (SAFOD) borehole, central California: Implications for the structure and tectonics of the San Andreas fault zone

Sarah Draper Springer et al., 4505 Old Main Hill, Logan, Utah 84322-4505, USA. Pages 206-226.

Springer et al. marshal a wide range of data collected in the San Andreas Fault Observatory at Depth (SAFOD) project, part of the National Science Foundation's Earthscope program, to determine the nature and source of a sequence of rocks encountered in the borehole. The SAFOD borehole is a vertical hole for 2.2 km, and it then bends to the northeast and intersects the San Andreas fault at a depth of 3.2 km. Along the inclined part of the hole there is a nearly 1-km-wide section of sandstones and conglomerates, the presence of which was not predicted in the geologic models of the area. Springer et al. use geologic studies of the rock cuttings, evidence from geophysical tools in the hole, and a dating method to suggest that these rocks are part of a sequence of 65-55-million-year-old sedimentary rocks that were deposited across much of western California while the area was the coastal margin. These rocks were subsequently offset as the granitic rocks west of the San Andreas fault rotated into place and by slip along the San Andreas fault and related faults.

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Parkfield revisited: I. Data retrieval

Cinna Lomnitz, Universidad Nacional Autonoma de Mexico, Instituto de Geofisica, Ciudad Universitaria, Mexico, D.F. 04510, Mexico; and Chao-jun Zhang. Pages 227-234.

The Parkfield Earthquake Prediction Experiment (1985-2004) was designed to monitor stress accumulation in the lithosphere related to an impending earthquake on the San Andreas fault. However, no precursory signals were detected prior to the 2004 Parkfield earthquake (M6.0). In this paper, Lomnitz and Zhang reexamine the long-term borehole strain records at Parkfield. They find that they are consistent with a stationary tectonic stress field on the order of 55 MPa in the direction of the fault. This is the first measurement of far-field tectonic stresses from borehole strainmeter records. It suggests that logarithmic creep strains from boreholes can be used to interpret the state of stress in the lithosphere surrounding the San Andreas fault.

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Anisotropy of magnetic susceptibility in weakly deformed red beds from the Wyoming salient, Sevier thrust belt: Relations to layer-parallel shortening and orogenic curvature

Arlo B. Weil, Bryn Mawr College, Dept. of Geology, 101 North Merion Ave., Bryn Mawr, Pennsylvania 19010, USA; and Adolph Yonkee. Pages 235-256.

Most active and ancient mountain belts display map-view curvature over a range of scales, yet mechanisms responsible for developing such curvature remain incompletely understood. Determining the origins of curved mountain belts is critical for understanding the tectonic and paleogeographic evolution of continents. At the root of this problem is when and how mountains acquire curvature during complex and protracted deformation histories. By integrating anisotropy of magnetic susceptibility (AMS), structural, and paleomagnetic studies in the Wyoming salient of the Sevier mountain belt Weil and Yonkee have been able to constrain its 3-D kinematic evolution and interpret processes responsible for producing the belt's present-day architecture. The Wyoming salient began with minor primary curvature, which then underwent progressive secondary rotation penecontemporaneous with mountain building. Rotation was related to curvature of fault slip directions, differential shortening, and wrenching. Processes that gave rise to this kinematic evolution include (1) variations in initial thickness and strength of foreland basin-fill stratigraphy, (2) feedback with basins that were formed in front of, and eventually incorporated into, the growing mountain belt, and (3) interaction with foreland uplifts along the salient ends. Weil and Yonkee's approach of integrating AMS, regional structural, and paleomagnetic studies can be applied to other mountain belts to better understand the processes that produce curved orogens.

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Selected Abstracts

Abstract 1

RESEARCH:
R.M. Russo

Subducted oceanic asthenosphere and upper mantle flow beneath the Juan de Fuca slab

Lithosphere August 2009, v. 1, p. 195-205, doi:10.1130/L41.1

Abstract Full Text Full Text (PDF) Figures Only

Abstract 2

RESEARCH:
Sarah Draper Springer, James P. Evans, John I. Garver, David Kirschner, and Susanne U. Janecke

Arkosic rocks from the San Andreas Fault Observatory at Depth (SAFOD) borehole, central California: Implications for the structure and tectonics of the San Andreas fault zone

Lithosphere August 2009, v. 1, p. 206-226, doi:10.1130/L13.1

Abstract Full Text Full Text (PDF) Figures Only

Abstract 3

RESEARCH:
Cinna Lomnitz and Chao-jun Zhang

Parkfield revisited: I. Data retrieval

Lithosphere August 2009, v. 1, p. 227-234, doi:10.1130/L14.1

Abstract Full Text Full Text (PDF) Figures Only

Abstract 4

RESEARCH:
Arlo Brandon Weil and Adolph Yonkee

Anisotropy of magnetic susceptibility in weakly deformed red beds from the Wyoming salient, Sevier thrust belt: Relations to layer-parallel shortening and orogenic curvature

Lithosphere August 2009, v. 1, p. 235-256, doi:10.1130/L42.1

Abstract Full Text Full Text (PDF) Figures Only

Abstract 1 of 4

RESEARCH

Subducted oceanic asthenosphere and upper mantle flow beneath the Juan de Fuca slab

Many studies have shown that typical oceanic lithosphere is underlain by a well -developed asthenosphere characterized by slow seismic velocities from ~100 to 250 km depth. However, the fate of the oceanic asthenosphere at subduction zones is poorly understood. I show here using shear-wave splitting of *S* waves emanating from earthquakes in the Juan de Fuca slab that upper mantle asthenospheric anisotropy beneath the slab is consistent with the presence of two distinct subducted asthenospheric layers, one with fast shear trends parallel to the subduction trench, and a second, deeper layer with fast upper mantle fabrics parallel to the motion of the Juan de Fuca plate with respect to the deeper mantle. The consistent orientation of unsubducted Pacific asthenospheric anisotropy in the direction of current plate motion implies that the trench-parallel, subslab anisotropy develops when the lithosphere subducts.

Full Text

Abstract 2 of 4

RESEARCH

Arkosic rocks from the San Andreas Fault Observatory at Depth (SAFOD) borehole, central California: Implications for the structure and tectonics of the San Andreas fault zone

The San Andreas Fault Observatory at Depth (SAFOD) drill hole encountered indurated, high-seismic-velocity arkosic sedimentary rocks west of the active trace of the San Andreas fault in central California. The arkosic rocks are juxtaposed against granitic rocks of the Salinian block to the southwest and against fine-grained Great Valley Group and Jurassic Franciscan rocks to the northeast. We identify three distinct lithologic units using cuttings, core petrography, electrical resistivity image logs, zircon fission-track analyses, and borehole-based geophysical logs. The upper arkose occurs from 1920 to 2530 m measured depth (mmd) in the borehole and is composed of five structural blocks defined by bedding orientations, wireline log character, physical properties, and lithologic characteristics. A clay-rich zone between 2530 and 2680 mmd is characterized by low V_p and an enlarged borehole. The lower arkose lies between 2680 and 3150 mmd. Fission-track detrital zircon cooling ages are between 64 and 70 Ma, appear to belong to a single population, and indicate a latest Cretaceous to Paleogene maximum depositional age. We interpret these Paleocene-Eocene strata to have been deposited in a proximal submarine fan setting shed from a Salinian source block, and they correlate with units to the southeast, along the western and southern edge of the San Joaquin Basin, and with arkosic conglomerates to the northwest. The arkosic section constitutes a deformed fault-bounded block between the modern strand of the San Andreas fault to the northeast and the Buzzard Canyon fault to the southwest. Significant amounts of slip appear to have been accommodated on both strands of the fault at this latitude.

Full Text

Abstract 3 of 4

RESEARCH

Parkfield revisited: I. Data retrieval

The Parkfield earthquake prediction experiment (1985-2004) was designed to monitor stress accumulation in the lithosphere related to an impending earthquake on the San Andreas fault. However, no precursory signals were detected prior to the 2004 Parkfield earthquake (M6.0). In this paper we re-examine the long-term borehole strain records at Parkfield (Langbein et al., 2006). We find that they are consistent with a stationary tectonic stress field on the order of 55 MPa in the direction of the fault. This is the first measurement of far-field tectonic stresses from borehole strainmeter records. It suggests that logarithmic creep strains from boreholes can be used to interpret the state of stress in the lithosphere surrounding the San Andreas fault.

Symmetry of the experimental setup suggests conformal mapping is a useful transformation to interpret the state of stress around a cavity in a prestressed halfspace. The borehole inverts the sign of the displacement, so that compressional tectonic stresses generate extensional strains at the borehole boundary. The stress energy field is conserved under conformal transformation (Noether's theorem). This transformation facilitates recovery of the state of stress in the lithosphere from long-term Parkfield strain records. Ergodicity constrains the form of the creep function in long-term experiments as follows:

Graphic, where the decay function is

Graphic. In conclusion, available experimental evidence suggests that the Parkfield borehole strainmeter data preceding the 2004 earthquake are consistent with a tectonic stress estimate on the order of 55 MPa in agreement with the tectonics of the area. No evidence of long-term stress accumulation has been found.

Full Text

Abstract 4 of 4

RESEARCH

Anisotropy of magnetic susceptibility in weakly deformed red beds from the Wyoming salient, Sevier thrust belt: Relations to layer-parallel shortening and orogenic curvature

Anisotropy of magnetic susceptibility (AMS) and structural studies of red beds in the Wyoming salient were completed to evaluate relations of magnetic fabrics to layer-parallel shortening and vertical-axis rotation in curved fold-thrust systems. The red beds display cleavage, fractures, veins, minor folds,

and minor faults that accommodated widespread early layer-parallel shortening and minor strike-parallel extension. Magnetic susceptibility is carried mostly by paramagnetic phyllosilicates and ferromagnetic hematite that have composite fabrics related to sedimentary deposition, diagenesis, and tectonic processes. Anisotropy of magnetic susceptibility fabrics range from distinctly oblate ellipsoids parallel to bedding that reflect dominant sedimentary fabrics (type 1), to moderately oblate ellipsoids with weak magnetic lineations roughly parallel to the intersection of weak layer-parallel shortening fabrics and bedding (type 2), to triaxial and prolate ellipsoids with distinct magnetic lineations parallel to the intersection of moderate layer-parallel shortening fabrics and bedding (type 3). Type 1 sites occur mostly in the central, frontal part of the salient where layer-parallel shortening is <5%, whereas type 3 sites are found mostly in more interior thrust systems and toward the salient ends where layer-parallel shortening is >15%. Magnetic lineations are subparallel to structural trend and exhibit a tangential pattern around curved fold-thrust systems. Regional patterns of anisotropy of magnetic susceptibility are broadly similar to patterns of finite strain estimated from reduction spots. Combined with paleomagnetic data, anisotropy of magnetic susceptibility data indicate that early layer-parallel shortening fabrics started with minor primary curvature and then underwent significant vertical-axis rotation during large-scale thrusting. Correlations with finite strain, structural, and paleomagnetic data sets indicate that analysis of anisotropy of magnetic susceptibility in weakly deformed red beds is useful for evaluating kinematic evolution of thrust systems.

Full Text