agree with Andrews, except for a slight difference in the exact value of L_c/L for transition from sub-Rayleigh to super-Rayleigh velocity.

T 77

SEISMIC SOURCE MECHANISM OF A FLUID DRIVEN TENSILE CRACK

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The dynamics of tensile crack propagation forced by a pressure increase in fluid inside the crack are studied to understand basic problems in the interpretation of seismograms obtained during hydrofracturing experiments and natural volcanic activities associated with the magmatic ascent process. Since the cohesive stress for a tensile crack is negligibly small, we first thought that a crack once nucleated propagates rapidly, thereby radiating seismic waves. This is not the case. Although the intrinsic cohesion is negligible, a strong cohesive stress is introduced because of the fact that the fluid does not fill the crack completely, but there is always a fluid-free part of the crack behind the tip (Barenblatt, 1962). We formulate the problem of tensile crack propagation in two space-dimensions in the form of an integral equation, which is discretized and solved by using Hamano's method (1974). Unlike an in-plane shear crack, a tensile crack propagates always at sub-Rayleigh velocities. Once the pressure increase in fluid overcomes the cohesive stress, the crack starts propagating. The increase in crack length is accompanied by the increase in the fluid-free region, resulting in a sharp increase in cohesive stress. The movement of the crack-tip thus depends on how rapidly fluid follows the crack-tip. We shall present the crack-tip movement, as well as the displacements and stresses around the crack under various conditions on the ambient pressure, rate of fluid pressure increase, the size of the fluid-free region and speed of fluid motion.

T 78

MAGNETISM OF ROCKS AS A FUNCTION OF VOLUMETRIC STRAIN

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The demagnetization of rock samples was measured from zero stress to failure, under zero and 500 bar confining pressure. The rock type used was a relatively coarse grained extrusive (dacite). In some samples the NRM was measured; in others an RM was induced isothermally to enlarge the signal to noise ratio. Each sample was oriented in the press such that its magnetic moment was oriented in a plane defined by two orthogonal flux gate sensors and containing the direction of applied stress. The change of the total magnetization and of the inclination could therefore be observed throughout the experiments. The measurements under confining pressure were made in a Be-Cu pressure vessel within a magnetic shield to eliminate the influence on the probe by the magnetic field in the laboratory. The following parameters were measured as a function of stress up to failure in all runs: (1) vertical and horizontal component of the sample magnetization; (2) axial and radial strain. During the unconfined experiments the P-wave travel time perpendicular to the applied stress was also measured. Preliminary results indicate: (1) The inclination rotated away from the stress axis by a few degrees and returned to the original value during several stress cycles from zero to near failure. (2) Both the change of the total magnetization and that of the inclination are sensitive to the onset of dilatancy. Both changed less rapidly after dilatancy started. (3) At stresses near the onset of dilatancy the anomalous behavior of the demagnetization is more pronounced than changes in P-wave velocity. Near failure the opposite is true; magnetic changes are very small unless pronounced creep occurs in the sample.

T 79

STRESS MEASUREMENTS IN CENTRAL CALIFORNIA

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A system to use the hydrofrac technique for measuring in-situ stress to depths of 300 m has been developed. A small drill rig, together with all the necessary pumps, packers, and gauges, permits a flexible, low-cost operation that allows us to make repeated stress measurements in areas of potential seismic activity. Measurements have now been attempted in six holes drilled in rocks typical of the seismically active portions of central California. Although in most hydrofrac operations anomalous pressure-time histories are often attributed to equipment malfunction, after a two-year development program we can now identify several characteristics of observed pressure-time histories that are not consistent with idealized fracture theory. Multiple breakdown pressures sometimes are found when the fluid pressure is cycled on a previously fractured formation and high initial breakdown pressures are observed in sedimentary rocks near the fault where the highly fractured cores suggest very low tensile strength. Least-principal stress obtained from the shut-in pressure is the most consistent measurement in the observations. The least-principal stress gradient is usually less than or equal to one PSI per foot, but anomalous shut-in pressures also are observed. Most of the anomalous observations appear to be associated with the complex nature of fracture initiation and propagation, and it is clear that a detailed theoretical model is needed to explain the observations. However, the data indicate that we are in fact forming consistently oriented hydraulic fractures in already fractured rock, and this result demonstrates that the technique can be used for stress measurements in fractured rocks near potentially active major faults.

T 80

STRAIN RATE DETERMINATIONS NEAR HOLLISTER, CALIFORNIA: INITIAL RESULTS USING A MULTI-WAVELENGTH EDM INSTRUMENT

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Since late Sept. 1975, 11 baselines around Hollister, Cal. have been measured by a multi-wavelength EDM instrument developed at the APL, U. of Wash. The lines range from 3 to 11 km long and are measured daily whenever possible.

It soon became obvious that two of the baselines were shortening. This trend continued until mid-Nov. when, after showing about 1u strain of contraction, the two lines abruptly stabilized. Both lines are about 4 km long and extend northerly from Hollister, ending on the east side of the Calaveras Fault. The remaining 9 lines showed no significant change. Creep meter records indicate a large event on the Calaveras in July 1975. The southern terminus of that event appears to have been near the northern ends of the two baselines. Since the EDM instrument is also located on the east side of the Calaveras Fault, the contraction of the two lines is thought to be due to some form of viscous relaxation related to the July creep event. This region had been seismically quiet for many months. About 5 days after the two baselines stabilized, two earthquakes (mag. 2.8 and 3.1) occurred about 5 km north of the northern ends of the two baselines. Most models predict that displacements associated with earthquakes of that magnitude would not be detected by such an instrument, but the coincidence is intriguing.

T 81

INVESTIGATION OF THE POSSIBLE MECHANISMS OF THE TECTONICS OF SOUTHERN CALIFORNIA IN THE REGION OF THE TRANSVERSE RANGES

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(Sponsor: D. G. Harkrider)

Whereas most of the faulting in Southern California is of the right lateral strike-slip type in the region of the Transverse Ranges there is a sizable component of thrust type motion. By means of a series of three dimensional Finite Element calculations various models for the tectonics of the area were tested. In particular, the possibilities that the Transverse Ranges were caused by the geometry of the big bend in the San Andreas fault or by gross material heterogeneities in the crust and Upper Mantle were considered. After examining the stress and displacement patterns for a variety of models it was concluded that by geometry and material heterogeneities alone it is difficult to explain the existence of the San Gabriel mountains. On the other hand, models in which the San Andreas fault was assumed to be locked to a certain depth and with very weak material properties below, produced considerable amount of uplift along the region of the bend.

T 82

A NUMERICAL METHOD FOR FINITE SOURCES: APPLICATION TO FINITE DISLOCATIONS PENETRATING A LAYERED MEDIA

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A numerical method has been developed explicitly for finite sources (Finite Source Method or FSM) which allows the computation of fields from a dislocation that penetrates several layers of a layered half-space. The speed of the FSM allows the calculation of many models which are not economically possible by other means. The FSM has been used to model earthquakes in layered media and plate bottom effects due to the interaction of lithospheric plates. The following conclusions have been reached, from the static models studied: (1) The displacement fields from a dislocation embedded in a layered half-space in which all of the layers have a Poisson's ratio of 0.25 do not differ greatly from those of a dislocation in a half-space with a Poisson's ratio (ν) of 0.25. However, when ν is not 0.25 in all the layers (e.g. the soft overlying sedimentary layer), certain components of the displacements differ significantly from a half-space model with $\nu = 0.25$. This effect can play an important role in attempting to ascertain the seismic moment of small earthquakes or aseismic slip. (3) Following Brown (1975), dislocation theory has been used to model the problem of plate interaction. For both strike-slip and collisional types of faults the vertical component of motion is most strongly affected by the presence of a soft underlying half-space. In particular, the uplift near a collisional fault (one across which two plates have a collisional component of motion) can become comparable in magnitude to the horizontal component of motion across the fault if the effect of a soft underlying half-space is included. Thus, given the relative motion between two plates which are colliding across a certain region, we may infer the softness of the underlying region by the amount of vertical uplift in that region.

Plate Tectonics II

Mingl/Town/Terrace, Wednesday 1330h

JAMES YORK (Department of Geological Sciences, Cornell University, Ithaca, New York), Cochairman

T 83 POSTER PAPER

GEOMETRY OF PLATE ACCRETION

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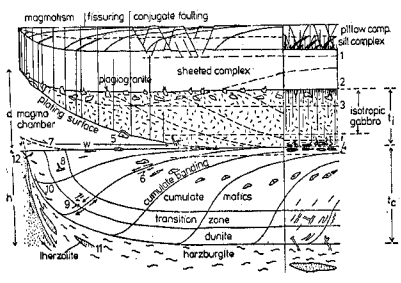
A model for plate accretion is based mainly on west Newfoundland ophiolite complexes but incorporates oceanic data and theoretical considerations and comprises three essential rheological elements; a lid thickening by the addition of basalts above and 'plated' gabbro beneath, a wedge-shaped magma chamber with a flat floor and a subsiding cumulate trough with an axial partially-melting



lherzolite welt. The geometry of instantaneous dike injection and basalt extrusion and the progressive deformation of the pillow/sheeted complexes depends upon to what extent isostatic subsidence is controlled by faulting versus accelerating through a thickening bend fold. The thickness of plated gabbro (t_t) and cumulate mafic/ultramafic rocks (t_c) are controlled by the depth/width (d/w) ratio of the magma chamber and the height (h) of the lherzolite welt, such that t_c cannot exceed w.

T 84 POSTER PAPER

TECTONIC FABRIC OF THE MID-ATLANTIC RIDGE CREST BETWEEN 36° AND 46°N

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Long range side-scan sonar (GLORIA) has been used to survey three crestal areas of the mid-Atlantic Ridge at 37°, 40.5° and 45.5°N. The resulting sonograph mosaics, totalling 61,000 sq km were linked by sonographs taken on passage tracks parallel to the ridge crest. In all surveys, linear echoes were found parallel to the spreading axis. When viewing outwards from the axis these were narrow and strong, and correlate with steep inward facing scarps interpreted as fault scarps. When viewing towards the axis the echoes were usually more diffuse, arising from the gentler outward facing slopes of the crestal mountains. Transverse fracture zones could be recognised by the infilling of sediment, producing echo-less areas, away from the axial region, and by the interruption of the axial trends. At 40.5°N, the Kurchatov Fracture Zone was found to be saw-toothed in plan but with a mean E-W trend. Between 39.5° and 46°N the principle non-axial trend directions are approximately NE-SW in contrast to those suggested on the physiographic diagrams of the North Atlantic. These trends are similar to that found in the offset of the Kurchatov Fracture Zone and may have originated in the same way.

T 85 POSTER PAPER

A GEOMETRIC ANALYSIS OF THE ORIENTATION RIDGE SEGMENTS

T. Lutz
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A simple, geometric analysis of the ocean ridge system suggests that the orientation of spreading centers, viewed as a global system, is far from random. Individual segments of the oceanic ridge network fall into one of two groups each of which is described by symmetry about a pole. Measurements of the segment end points from a generalized map of major spreading boundaries were used to calculate a great circle for each segment. The majority of these great circles pass close to one of two points on the Earth's surface. Analysis of these data using a spherical normal distribution show that ridge sections are described rather well by one of two hypothetical poles. Most of the segments, and most of the total ridge length, fall into an axial symmetry pattern about a pole in the vicinity of the Greenland-Iceland Rise; those remaining fall about a similar pole close to the Galapagos Islands. The circle of confidence ($\alpha 95$) for both poles is less than 10°. About 85% of the total length of the mid-ocean ridge system falls into the Iceland-Greenland pattern. Perhaps surprisingly, the segments which fit this pole do not lie only in the Atlantic, but include those of the Southeast Indian Ridge and the Albatross Cordillera. Two legs of each of four triple junctions fit this pattern; the other ridges describe the Galapagos pole. Such an apparent orderly orientation of the ridge system might not be expected in a complexly interacting convection regime, and the results suggest that mantle convection may be relatively simple and may be driven by some force acting on the global scale.

T 86 POSTER PAPER

MAGNETIC ANOMALIES AND A REALISTIC MODEL OF SPREADING IN ICELAND

Kees Rutten (Vening Meinesz Laboratorium, Lucas Bolwerk 7, Utrecht, Netherlands)

In eastern Iceland a wide, linear magnetic anomaly is associated with the neovolcanic zone ('Central Graben'). The wavelength of this anomaly is 80 km, its amplitude 600 γ (flight level 4.2 km). Over the center of Reykjanes Ridge a similar anomaly is present though the prevailing wavelengths are shorter. In southwest Iceland several long wavelength anomalies resemble this wide anomaly, but these are not linear, possibly through transform movement. The shorter wavelength magnetic anomalies (<60 km) in Iceland exhibit very little linearity.
The fall-off rate of power spectrum of the magnetic anomalies over Reykjanes Ridge suggests a fairly thin and shallow source layer. The spectrum of the anomalies over Iceland on the other hand suggests a thick and deep source layer. A magnetic model based on the kinematic model of steady-state crustal spreading in Iceland proposed by Pálmason (1973), but modified to include a median valley, explains that the loss of linearity of the shorter wavelength anomalies is related to the conditions of formation of the magnetic layer, and that the wide linear anomaly system is associated with the spreading at a deeper level.

T 87 POSTER PAPER

DISPLACEMENT AND STRAIN HISTORY OF FRACTURE ZONES

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Oceanic fracture zones and their transform segments are the sites of development of extremely complex geological relationships between magmatism, deformation, and sedimentation, because of two geometric constraints: (1) On the non-transform extensions, only the older side of the fracture zone will have passed through the transform domain, and thus the two sides will have experienced different strain histories. (2) Opposite sides of a fracture zone are generally of different ages and therefore subside at different rates (due to $\sqrt{t}$ dependence of depth). Thus, over virtually all of its length, including the aseismic extensions, a fracture zone has a small component of dip-slip motion. This motion may contribute to seismicity on non-transform segments of fracture zones and to troughs near ridge/transform junctions, where dip-slip will be greatest. Cumulative effects of dip-slip motion may produce a substantial fraction of the total strain history recorded within the fracture zone/transform. Depth, subsidence, dip-slip, and net-slip relationships have been calculated for several ridge geometries. From these models, it has been possible to predict an extraordinary variety of complex unconformities, diachronous and polyphase strain sequences, and facies thickness variations to be found in fracture zones. Many of the predicted relationships are recognizable in ophiolite complexes in Newfoundland, the northern Apennines, the Taurides in southern Turkey, and the Troodos Complex, Cyprus.

T 88 POSTER PAPER

CONTINENTS, OCEANS, RIDGES, TRENCHES AND THE EXCITATION OF POLAR WANDER

Donna M. Jurdy (Dept. of Geological and Geophysical Sciences, Princeton Univ., Princeton, New Jersey 08540)

A non-equilibrium distribution of mass on the surface of the earth can cause a reorientation of the rotation axis with respect to the earth, i.e. true polar wander. To cause an instability there must exist regions with vertical density contrasts such that there are different contributions per unit area to the inertia tensor of the earth, and the geometric arrangement of these regions must be such that these contributions are to the off-diagonal components of the inertia tensor, Ixz and Iyz. It has been suggested that the rearrangement of the continents and oceans has caused polar wander. The present arrangement of the continents and oceans is a non-equilibrium one and the excitation function is nearly constant back to the Early Cretaceous. However, a study of the density models leaves unresolved whether sufficient density contrasts exist to excite polar wander. The ridges and trenches have a greater potential for causing imbalances, because their density contrasts are more pronounced than that of the continents and oceans. The hot material of the ridges creates a mass deficiency and the cold dense slabs of the trenches cause a mass excess. The symmetry of the present arrangement of both the ridges and trenches is such that the associated perturbing tensors have principal axes near the pole.

T 89 POSTER PAPER

GEOLOGICAL AND GEOPHYSICAL DISCONTINUITIES IN CHILE NEAR 33° - 35° S

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R. Hey (Hawaii Institute of Geophysics, Univ. of Hawaii, Honolulu, Hi. 96822)

There are several types of geological and geophysical discontinuities at about 33°- 35° S along the western margin of South America. Between 33° and 34° S the average elevation of the Andes peaks begins to decrease from an average elevation of 6 km; within a distance of 300 km to the south, the average elevation has dropped to 3 km. The width of the Andes also decreases abruptly between 33° and 35° S. The southern Chilean volcanic belt begins near 33.5° S; to the north there is a marked gap in recent volcanoes extending to about 27.5° S. The average elevation of the coastal range peaks decreases abruptly between 33° and 35° S. Sediment fill in the Peru - Chile trench increases dramatically near 33° S. A major gravitational change occurs near 34° S. The density of known porphyry copper prospects changes abruptly near 34° S. The abruptness, magnitude, and types of these discontinuities suggest a plate tectonic origin, as opposed to a geomorphologic origin such as differential erosion.

One speculative explanation of these observations is that the subduction rate north of 33° - 35° S was different from that south of this boundary in the geologically recent past. Although highly speculative, this is a testable hypothesis.

T 90 POSTER PAPER

SEISMICITY AND QUATERNARY FAULTING IN CHINA

James York
Richard Cardwell
James Ni (all at: Dept. of Geological Sciences, Cornell University, Ithaca, NY 14853)

Both Quaternary faulting, based on an interpretation of a new mosaic of LANDSAT-1 imagery, and seismicity, based on maps of all reported earthquakes in historical records for 1177 B.C. -1903 A.D., of all instrumental data for 1904-Feb. 1975, and of all earthquakes with M≥6 for 1177 B.C.-Feb. 1975 A.D.,demonstrate a distinct difference in Quaternary tectonics between western and eastern China. East-west trending reactivated Paleozoic mountain belts and subparallel large left-lateral strike-slip faults predominate in western China. The northeasterly trending Cenozoic Shansi graben and subparallel right-lateral strike-slip faults characterize eastern China. Nearly aseismic blocks occur in both west and east, but a satisfactory model of small plates that explains all of the observed phenomena is not apparent. The tectonic activity may be controlled by stresses from nearby plate margins, with the collision of India and Eurasia predominating, or by asthenospheric processes beneath China.

Large earthquakes and surface faulting have occurred on some of the faults observed in the satellite images. Because the Chinese historic

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Cover. The 1976 AGU Spring Annual Meeting will be held April 12–15 at the Sheraton-Park Hotel in Washington, D. C. In the bicentennial spirit, AGU has planned a Thomas Jefferson Birthday Dinner at the Annual Honors Banquet on Tuesday evening. This meeting issue of E⊕S contains the preliminary program, session summary, abstracts of papers to be presented, and the author index, all beginning on page 224.

E⊕S is devoted to the publication of contributions dealing with the interface of all aspects of geophysics with society and of semitechnical reviews of currently exciting areas of geophysics. Through E⊕S, earth scientists should enjoy keeping abreast of new activity and be better prepared to face their own work with a broad perspective. This journal is an effective way to address or redress those who are involved in the study of the earth and its environment in space.

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