A plane stress hybrid distinct element, boundary element code is developed in which the far field is modelled as an elastic continuum with stresses applied at infinity. The near field is considered as a non-linear inclusion inserted into the elastic continuum with its boundary modelled by boundary elements. The near field may have any arrangement of faults and joints which themselves define the boundaries of distinct elements. The distinct elements are fully elastic and the joints have elastic-plastic behavior. The faults have Mohr-Coulomb behavior with their ends or various points along them given unduly high values of cohesion or friction angle so that slip does not occur at those points. Quasi-static situations are modelled where the fault is given constitutive behavior which combines the Dieterich-Ruina law for step changes in velocity with that reported at this meeting by Hobbs and Brady for step changes in normal stress. A range of geologically realistic situations is examined and the inhomogeneous stress-field and the stability of sliding investigated for both single fault and multiple fault configurations. In particular, the triggering of failure on a fault associated with the build up or relaxation of stress on another fault is examined. Phase plane trajectories and Poincare maps allow the stability fields for sliding on a single fault to be investigated using the fully coupled normal stress-shear stress-velocity constitutive law and the ability of these diagrams to provide predictive tools for instabilities in fault motion is discussed.

T52B-08 1530H

An Approach to Modeling Present Day Deformation in Southern California*

JOHN B. RUNDLE (Geophysics Division 1541, Sandia National Laboratories, Albuquerque, NM 87185)

An approach to modeling the complete, time-dependent deformation in southern California is presented. We make use of a variety of techniques to include the far field plate motion, stress relaxation in the asthenosphere, aseismic fault slip within the elastic lithosphere, and the complex, three dimensional nature of the faults within the southern California region. Based upon the modeling presented here, we conclude that: 1) the lithosphere is probably thin in southern California; 2) the most sensitive determinant for lithospheric thickness and viscosity of the asthenosphere is the rotation rate of the motion vectors toward or away from major faults; 3) the shallow crustal, shallow dipping thrust fault proposed by Rundle (1978) and subsequently by others probably exists; and 4) that this modeling approach offers a good method for eventually constructing a complete, realistic model for understanding tectonic processes in southern California.

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T52B-09 1545H

Creep and Slip Rate on the North Anatolian Fault

M.N. TOKSOZ and G.E. KEOUGH
(Earth Resources Laboratory, Department of Earth, Atmospheric, and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, MA 02139)
H. SAV
(MTA Institute, Ankara, Turkey)

The North Anatolian fault in Turkey is a major right-handed strike-slip fault. The fault was ruptured by a series of major earthquakes ($M_s > 7.0$) between 1939 and 1967. The earthquakes show well-defined space-time migration patterns. The slip rate across the fault is an important parameter for understanding the westward motion of the Anatolian plate, the strain accumulation, and earthquake potential on the fault. The geologic estimates of the relative motion vary considerably, ranging between 1 cm/year to 5 cm/year.

Recently, data from creepmeters installed and geodetic networks have become available. At one location (Ismetpasa), the creep rate in the past two years was 1.1 and 0.9 cm/year respectively. A small trilateration network at the same site gives a 10 cm slip over a ten year period. This value is also in agreement with the average creep in the past twenty years.

During the 1944 earthquake, the Ismetpasa site had a fault displacement of 140 cm, about 100 cm less than the average displacement. Given the mean occurrence time of earthquakes, based on historic data, and creep and fault displacement values, the relative motion across the North Anatolian fault is about 2.0 cm/yr.

T52B-10 1600H

Salton Sea Level Data - Active Transpression on the Southern San Andreas Fault

HUDNUT, K.[1]
BEAVAN, J.
BILHAM R. (All at: Lamont-Doherty Geol. Obs. of Columbia Univ., Palisades, NY 10964; [1] Also at: Dept. of Geol. Sci. Columbia Univ.)

Three sets of water level data from the Salton Sea have been analysed for the period 1951-1983. Tectonic deformation reported by an earlier study (Wilson and Wood, 1980) is confirmed with tilting 0.15 μrad a^{-1} down to the southeast ceasing in 1972. Tilt up to the east at 0.4 μrad a^{-1} occurred between 1978 and 1982 resulting in 2 cm of uplift at North Shore. This uplift may be related to the 1.5 cm uplift of the north-east shore of the Salton Sea revealed by NGS leveling lines between Mecca and Niland in the period 1974-1978, and is partly confirmed by the observation that a high rate of tilt up to the east was measured on a short fault-crossing level line near North Shore in the period 1981-1982 (Sharp, 1983).

Oblique slip of the southern 15 km long, N48°W segment of the San Andreas fault that follows the north-east shore of the Salton Sea has resulted in transpressive folding of sedimentary rocks, forming Durmid Hill. The observed data are consistent with active aseismic deformation of the Durmid anticlinorium for the period 1974-1983, indicating possible increased loading of the fault zone. This loading is presumably discontinuous in time because the observed uplift rate is inconsistent with the present elevation of ancient Lake Cahuilla shoreline. A possible conclusion is that the data may represent accelerated uplift during a late stage in the earthquake cycle that may be relieved by seismic rupture.

T52B-11 1615H

Theoretical Line Length Changes Before Great Earthquakes in Southern California

WILLIAM D. STUART (U.S. Geological Survey, 525 S. Wilson Avenue, Pasadena, CA 91106)

Theoretical changes of trilateration line lengths have been computed for times preceding great earthquakes on the San Andreas fault in southern California. The length changes are obtained from an earthquake instability model which simulates both pre-seismic and co-seismic faulting. The model represents the San Andreas, Imperial, Cerro Prieto, and San Jacinto faults by numerous vertical rectangular dislocation surfaces. The fault plane between positions corresponding to Parkfield and the Salton Sea, and between 0 and 12 km depth, is assumed to obey a brittle, slip-softening constitutive law. The part of the fault plane just outside the brittle area is stress free, approximating ductile deformation. Forcing is by an imposed fault slip rate far from the brittle area on the San Andreas fault and on the entire Imperial, Cerro Prieto, and San Jacinto faults. The strength variation of the brittle fault along strike is adjusted by trial until the times, lengths, and amounts of unstable slip predicted by the model are in overall agreement with actual fault offsets since 1080 AD reported by Sieh and others.

Prior to instabilities, computed lengthening rates of certain 20 km long trilateration lines spanning the fault show rate changes of the order of 1 cm/yr starting several years to several decades before instability. For individual lines, the timing and magnitude of rate changes depend on the location and size of the impending instability. The rate changes are due to failure of the bottom (and sometimes ends) of long sections of the slip softening portion of the fault.

T52B-12 1630H

Postseismic Viscoelastic Relaxation Following the 1959 M = 7.5 Hebgen Lake, Montana Earthquake

ROBERT REILINGER (Air Force Geophysics Lab, Hanscom Air Force Base, MA 01731)

A 1983 releveling survey conducted by the National Geodetic Survey provides evidence for ongoing vertical deformation of a broad region (diameter ~ 150 km) surrounding the site of the 1959 Hebgen Lake earthquake. Deformation consists of relative uplift centered roughly on the coseismic fault and a smaller amplitude zone of relative subsidence south of the fault. Maximum observed elevation change during the postseismic period (1960 to 1983) exceeds 30cm. The rate of vertical deformation appears to be decreasing exponentially with a characteristic decay time of about 10 years. The spatial pattern and time behavior of the observed movements are consistent with simple models of post-seismic deformation following normal faulting in an elastic layer (thickness ~ 30-40km) overlying a visco-elastic half-space (viscosity ~ 10^{20} poise). This model may also account for the anomalously large horizontal strain around the Hebgen Lake region measured by repeated trilateration surveys during the period 1973 to 1984. The 1983 M=7.3 Borah Peak, Idaho earthquake occured in a similar tectonic setting as the Hebgen Lake event (Northern Basin and Range) and the geometry of the coseismic faults are quite similar. If the amplitude of postseismic viscoelastic deformation is linearly related to fault slip as suggested by the model used for the Hebgen Lake event, then a minimum of 6 cm of relative elevation change over a distance of about 50 km should occur during the 10 yr period following the Borah Peak earthquake. This should be easily detected with modern geodetic techniques. The releveling and trilateration measurements in the Hebgen Lake region appear to provide the first observations of viscoelastic relaxation in the asthenosphere following an intraplate earthquake in the U.S.

T52B-13 1645H

Deformation of the Pacific Plate

W. H. PRESCOTT, N. E. KING, M. LISOWSKI, J. C. SAVAGE, (U.S. Geological Survey, Menlo Park, CA 94025)

Observations of the distance from three geodetic stations on the edge of North America to the Farallon Islands off the coast of San Francisco, California, are yielding some new evidence about the distribution of relative motion along this section of the Pacific-North American plate boundary. During the 7 year period spanned by the observations, there has been very little ongoing deformation of the crust on the Pacific side of the San Andreas fault. This absence of deformation is in sharp contrast to the North American side of the fault, where the deformation extends to at least 50 km northeast of the San Andreas fault. The observed distribution of displacement is not readily explained by any models of the plate boundary which have all of the slip occurring on the San Andreas fault. The observations suggest that in North Central California, the difference between the slip observed along the San Andreas fault (30 ± mm/yr) and the inferred plate motion rate (55 mm/yr) cannot be explained by slip west of the San Andreas fault. While the observations do not constrain San Gregorio fault slip very well (+/- 8 mm/yr), they are consistent with no slip at depth on this fault. The data are best fit by a model with 15 +/- 2 mm/yr of right lateral slip below 8 km depth on the San Andreas fault. The Farallon observations combined with other geodetic observations indicate that in addition to the 15 mm/yr slip on the San Andreas fault, an additional 20 mm/yr of relative motion is distributed in the coast range province northeast of the San Andreas fault.

T52B-14 1700H

Seismotectonics of the Cajon Pass Region of the southern San Andreas Fault

LUCILE M. JONES (U.S. Geological Survey, 525 S. Wilson Avenue, Pasadena, CA 91106)

Three of the largest faults in southern California, the San Andreas, San Jacinto and Transverse Ranges Frontal faults, intersect at Cajon Pass. This complex region is the southern terminus of the 1857 rupture and one of the most persistently seismically active areas of southern California. Re-analysis of the earthquakes in the region from 1978 to 1984 has shown that while two strands of the San Jacinto fault are very active, both the Transverse Ranges and San Andreas faults are quiescent. Almost all of the earthquakes are confined to the western side of the San Andreas fault. Focal mechanisms were determined from P-wave first motions for all $M \geq 3.0$ earthquakes since 1978. All of these earthquake mechanisms had one plane striking subparallel to the San Andreas fault and dipping slightly to the northeast. Two thirds of these mechanisms showed almost pure right-lateral, strike-slip motion along the northwest trending plane, while the rest had a significant component of reverse motion (rake of 120° to 150°). The reverse mechanisms are more common north of the Transverse Ranges Frontal fault and close to the San Andreas fault. Inversion of these data for stress state using the methods of Angelier shows the maximum principal stress is horizontal along a north-south direction. The minimum stress is also horizontal and strikes east-west.

T52B-15 1715H

Space Geodetic Observations and the Tectonics of California

G. A. LYZENGA, (Jet Propulsion Laboratory, California Institute of Technology, Pasadena, Ca. 91109)

Recently reported results of very long baseline interferometrty (VLBI) and satellite laser ranging (SLR) in the Western U.S. have begun to give us a clearer picture of relative plate motions and deformations in this region. Early results suggest a spatial inhomogeneity of strain which may reflect plate driving forces such as asthenospheric drag. This work presents a group of finite element strain models which seek to explain observed deformation patterns.

Additionally, these models are examined with the intent of determining useful configurations of GPS observing sites, in order to resolve ambiguous interpretations. It is found that currently available space geodetic data are successfully explained by a modification to the simple strike-slip boundary, through the introduction of active convective flow tractions spatially coincident with the location of the Transverse Ranges. GPS measurements which cover regions southeast and northwest of the Transverse Ranges will help to either strengthen or eliminate this hypothesis.

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