No precursive *strain changes* are evident in the data, either in the period leading up to this sequence, or between the two *main* events. Over the months immediately prior to the events the strain records are stable to *within* 0.02 $\mu\epsilon$, and over days to ~ 5 nϵ; there is no indication of a regional strain event around 1987 day 304, the time of reported creep events in the Imperial Valley. For the eight hours before the Superstition Hills mainshock, any strain changes were less than the instrument noise level (1% of the coseismic strain); during the last 1000 seconds before this event any precursory strains must be less than 0.5% of the coseismic amount. Postseismic strain from five minutes to two hours after the mainshock was about 10% of the coseismic strain, with a cumulative postseismic strain of nearly 15% over the next 24 hours.

T31A-06 1030

A Current Retardation in Rate of Aseismic Slip on the San Andreas Fault at San Juan Bautista, California

RO Burford and SS Schulz (both at US Geological Survey,
345 Middlefield Road, Menlo Park, CA 94025)

Aseismic slip (fault creep) has been monitored since 1968 at 10 sites along a 70-km section of the San Andreas fault *between San Juan Bautista and Pinnacles National Monument* in central California. Combined records for these sites contain at least 12 examples of slowing of creep rates in the months *before nearby moderate mainshocks* ($M_L \geq 3.9$). Onsets of such retardations were observed between 1982 and 1985 at three creepmeter sites, one near San Juan Bautista (XSJ2) and two others near Pinnacles National Monument (XFL1 and XMR1), accompanied by seismic quiescence on nearby areas of the underlying seismogenic zone. Two attempts at earthquake prediction were made in 1985 for two areas showing seismic quiescence associated with retardations in surface creep rates. One at San Juan Bautista failed and was acknowledged as a 'false alarm'. The second, 30 km southeast near Stone Canyon, was fulfilled on 31 May 1986. Despite a false–alarm status for the quiescence anomaly (as it stood in June 1986), creep retardation at San Juan Bautista persists to date with no mainshock, and thus constitutes the longest creep retardation on record (6 years as of August 11, 1988). Moderate earthquakes on the underlying source 'patch' in 1972 and 1980, both preceeded by creep retardations, suggest an approximate 8–year recurrence interval. If a transition from stable sliding to stick–slip conditions on the earthquake source patch underlying San Juan Bautista is imminent, as suggested by patterns of fault creep and moderate earthquake recurrence, a sequence of moderate earthquakes (foreshocks of $M_L \geq 3.9$, mainshock of about $M_L = 4.8$) may occur within or adjacent to the San Juan Bautista source patch by early 1989.

T31A-07 1045

Ground Deformation Accompanying Earthquake Cycles Predicted by Realistic Models of Strike-Slip Faulting

Elizabeth A. Lorenzetti (Texaco E&P Technology,
3901 Briarpark, Houston, TX 77042; 713-954-6000)
Terry E. Tullis (Dept. of Geological Sciences,
Brown University, Providence, RI 02912; 401-863-3829)

Realistic mechanical models of fault behavior during an earthquake cycle now exist that are based on laboratory-derived constitutive laws for rock friction. Such models allow calculation of the deformation changes that occur for a model fault as a *function of depth* and distance from the fault and *time in the* cycle. The behavior of models is useful for gaining insight concerning the magnitude and timing of changes that might occur prior to a real earthquake and be useful for predicting it. We have used the model of a crustal strike-slip fault of Tse and Rice (1987) to study the sensitivity to model parameters of predictions of displacement and strain fields and their time behavior.

The premonitory increases in velocity show a pattern of larger values at distances a few km away from the fault trace as a result of accelerating slip at depth. This pattern would be useful for predictive purposes if the signals were large enough to be detectable. *Unfortunately, these velocity changes are detectable with* creepmeters and two-color laser Geodimeters only for some parameter values and are undetectable by current GPS methods.

Strain changes near the fault are the most useful signals for predicting the model earthquakes, because for nearly all model parameters studied these predicted strain changes are considerably above the detectability limits of existing borehole strainmeters in the presence of earth noise. Detectable changes occur a few minutes to a month prior to the earthquake, depending on parameter values. Strain changes far from the fault sample only the total moment release and may not be detectable. In agreement with recent measurements for several earthquakes, the predicted amount of pre-seismic moment release is <<1% of the earthquake moment for most simulations, and the post-seismic moment release is a significant fraction of the earthquake moment. The modeling suggests that even though several earthquakes have not shown premonitory strain changes on sensitive strainmeters located many source dimensions from the epicenters, existing *strainmeters may* well be able to detect *premonitory strain* changes if they are located considerably closer to the earthquake.

T31A-08 1100

Mechanics of Seismic Coupling in Subduction Zones

C.H. Scholz (Lamont-Doherty Geol. Obs. & Dept. of Geol.
Sci. of Columbia Univ., Palisades, NY 10964)

The seismic coupling coefficient χ, defined as $\dot{M}_0^s/\dot{M}_0^g$, the ratio of seismic moment release rate to geologic moment release rate, is highly variable among subduction zones, ranging from $\chi=0$ (fully decoupled) to $\chi=1$ (fully coupled). Within a given subduction interface it has been found that there are different regions that exhibit three distinct coupling characteristics: Zones A:$\chi \approx 1$ (called 'Asperities') in which most large earthquakes initiate, Zones **B**: $0<\chi \leq 1$ (called 'weak zones') which rupture coseismically by triggering from rupture of adjacent A zones but slip aseismically during interseismic periods, and **C** zones: $\chi \approx 0$, which always slip aseismically. The overall value of χ for a subduction zone depends on the relative proportion of these three zones. A rough correspondence has been shown between χ and the magnitude of the normal force F_i, across the interface (Ruff and Kanamori, 1980).

Stability analysis of rate/state variable friction indicates three stability states: **U** (unstable (a-b)<0 and $K<K_c$, which is fundamentally unstable and so $\chi=1$; **CS** (conditionally stable) (a-b)<0, $K>K_c$, stable under quasi-static loading, unstable in dynamic loading, so $0 \leq \chi \leq 1$; and **S** (stable) (a-b)>0, so $\chi=0$. We can therefore identify **A=U, B=CS,** and **C=S.**

Ancient deeply eroded subduction zones indicate that the interface is lined with metamorphosed sediments. Experiments show that unconsolidated sediments have (**a-b**)>0 and hence are in the **S** field. During consolidation, (a-b) will decrease and eventually become negative, passing through the **CS** to the **U** fields. Therefore variations in consolidation in subduction zones will cause different regions to be in the different stability fields. An increase in F_i will enhance consolidation and hence increase the area of **A** and **B** zones, so increasing χ for the subduction zone overall.

T31A-09 1115

Water Level and Volumetric Strainmeter Response to Barometric Pressure Changes Near Parkfield, *California*

E. Roeloffs, E. Quilty, and S. Rojstaczer (U.S. Geological Survey, Menlo Park, CA, 94025)

Groundwater level has been monitored for several years in an 88 m deep well on Gold Hill, near Parkfield, California. As part of the Parkfield Earthquake Prediction Experiment, data are filtered by subtracting tides and the best-fitting multiple of barometric pressure from water level records to isolate changes of tectonic origin. This procedure neglects the frequency dependence of the water level response to barometric pressure. On three occasions since 1985, residual fluctuations with periods of several days have closely resembled residual fluctuations in similarly processed data from a dilatometer 150 m from the well. To rule out barometric pressure as the cause of the water level fluctuations, we are comparing the effect of barometric pressure on water level with its effect on strain.

We have estimated the response to barometric pressure of water level and strain, respectively, in the frequency range 0.03 to 5 cycles per day, using twelve months of data from 1985 and 1987. Water level response to barometric pressure falls off for frequencies above 1 cycle per day, while the strainmeter response is essentially flat in this range. Water level response has *large phase lags for periods longer than two days, increasing to a 180* degree phase lag at shorter periods. In contrast, volume strain as observed by the dilatometer is in phase with barometric pressure for periods shorter than 10 days, with an increasing phase lag at longer periods. Both strain and water level responses have largest gain near 0.3 to 0.5 cycles per day. However, both the water level and strain responses decline at longer periods, although water level does so more quickly than strain. Frequency-dependent models of the barometric response of both instruments should allow more complete removal of barometric effects from water level data, thus permitting better recogition of water level changes of tectonic origin at Gold Hill.

T31A-10 1130

Vertical Effects Evinced in Nearfield Leveling Arrays Across Faults After 1987-88 Southern California Earthquakes

A G Sylvester (Department of Geological Sciences, University of
California, Santa Barbara, CA 93106)

A subset of 45 precise leveling arrays established across faults in 1970-85 was resurveyed a few days or months after recent earthquakes to determine if earthquakes on other faults perturbed the strain field around the faults, as manifested by tilt or triggered slip. Minor offset, uplift, and tilt were observed at 3 sites at the southern end of the San Andreas fault in the days and weeks after the 24 Nov 1987 Superstition Hills earthquake (M 6.6). No anomalous preseismic tilt or strain changes, which might be interpreted as premonitory, were observed in any of the arrays.

Three NE-trending line arrays cross the San Andreas fault in Imperial Valley where triggered horizontal slip has been observed after the 1968 Borrego *Mountain (M 6.5) and 1979 Imperial (M 6.4) earthquakes, although none* was visually observed along the fault in the few days after the Superstition Hills earthquake. The 2200 m-long line over Durmid Hill (45 km N of the epicenter) shows that the hill rose, or the Salton Sea subsided, about 1 mm *between Sep and Dec 1987, and then half of the hill rose another* millimeter between Dec 1987 and Mar 1988. This pattern of vertical strain is consistent with that expected at the end of the San Andreas fault at its extrapolated intersection with the Elmore Ranch fault. An 870 m-long line *array at North Shore (65 km NNW of the epicenter) tilted SW-ward 2 μrad in* the first 2 weeks, then about 1 μrad NE-ward after 16 weeks. The Mecca Hills (90 km NNW of the epicenter) rose about 1.5 mm between Sep and Dec 1987, but returned to its Sep 1987 level by Mar 1988. Surveys in Jul *1987 and Jul 1988 show no changes in the 720 m-long line array across* the San Andreas fault at Miracle Hill (115 km NW of the epicenter).

Two N-S line arrays, 790 m and 1900 m-long across the Sierra Madre fault zone, are in the north half of the 1 Oct 1987 Whittier Narrows earthquake (M 5.9) meisoseismal area, 13 km NNE and 16 km NNW of the earthquake epicenter. Both were releveled several times since 1984 and once each 9 months after the earthquake. Neither offset at the fault nor N-S tilt across the fault were observed.

The 10 June 1988 North Garlock fault earthquake (M 5.3) caused no perceptible height changes in an 800 m-long, N-S line array across the Pleito thrust, 13 km WSW of the epicenter, or in a 450 m-long, S-shaped array across the San Andreas fault, 20 km SW of the epicenter.

Tilt at a rate of 135 μrad/yr and bedding plane thrusting accompanies uplift due to removal of rock load in a major quarry near Lompoc. A survey a few hours before the 24 June 1988 earthquake (M 2.9), compared to a second survey done 4 weeks later, showed only 2 μrad reversal of tilt.

T31A-11 1145

Presence of tilt accumulation in the Shumagin seismic gap, 1980-88.

John Beavan, Lewis E. Gilbert and John J. Taber (all at Lamont-Doherty Geological Observatory, Palisades, New York 10964)

Historical evidence indicates that the Shumagin seismic gap is seismogenic with a repeat time on the order of 70 yr, and that most of the gap last ruptured in 1917. On the other hand, the very low 1981-87 strain rates deduced from biennial USGS trilateration surveys have been used by Lisowski et al. [JGR, July 1988] to argue that the Pacific plate is currently being subducted aseismically in the Shumagin gap.

The 1980-88 tilt rates derived from annual resurveys by L-DGO of eight 1 km aperture leveling networks show a consistent pattern across the islands, with arcward tilts on the outer (nearer trench) islands, and smaller trenchward tilts on the inner and central islands. Errors in the tilt rate estimates are 2 to 5 times those in the USGS strain rate estimates, yet tilts significant at the 95% confidence level are seen in half the tilt networks. The tilt data are largely consistent with a simple 5 cm/yr plate convergence model in which the lower part (~27-50 km depth) of the main thrust zone (MTZ) is locked, and in which most of the shallow-dipping upper part of the MTZ slips aseismically. The tilt data are not consistent with an aseismic subduction model. In the region of the USGS trilateration network, the model predicts low strains that are consistent with much of the data presented by Lisowski et al Though the model is grossly simplified, it indicates that observations of large tilts and relatively small strains are consistent with plausible subduction scenarios. The inferred 5 cm/yr convergence rate is lower than the 6.8 - 7.5 cm/yr value anticipated from global plate motion models, but a lower-than-average rate towards the end of the earthquake cycle is not unexpected. The physics behind the separation of the MTZ into aseismic and locked segments is not understood, but may be related to high fluid pressures along the shallow plate interface; a similar separation has been postulated for parts of the northern Honshu arc. With this model, the M≈6 earthquakes located just trenchward of the outer islands in 1983 and 1985 may be interpreted as occurring near the upper edge of the future rupture zone. The inferred ~50 km down-dip width of the locked zone suggests that a future Shumagin earthquake of along-strike length 200-250 km would have a magnitude $M_W < 8.1 - 8.3$.

Ridge Segmentation (T31B)

CA 106 Wed AM
Presiding, R. Pockalny
Univ of Rhode Island
J. Karsten
Northwestern Univ

T31B-01 0830

Ridge Segmentation of the Central Indian Ridge South of Vema Fracture Zone.

Ph. Patriat, (Institute Physique du Globe de Paris, France)
L.M. Parson, & R.C. Searle (both at Institute of Oceanographic Sciences, Brook Road, Wormley, Surrey, U.K.)

GLORIA sidescan sonographs of the Central Indian Ridge have been combined with conventional geophysical datasets to study the nature of segmentation of 555 km of active ridge between 12°S and the Indian Ocean Triple Junction. A previously recognised first order segmentation, spaced at between 100 and 150km is defined by either single, large-offset fractures or by multiple zones comprising complexes of tightly spaced dislocations. Superimposed upon these large scale segments we recognise a second order of discontinuty marked by a wide variety of structural features, spaced at less than 50km. These include oblique offsets, overlapping spreading centres and Kurchartov type fractures. These two styles and frequencies of ridge offset are compared with previous and new studies from the Cocos-Nazca spreading centre, the Reykjanes Ridge and the Lau back-arc Basin. We critically test current predictions of segment dimension.