Strain Accumulation Rates in the Western United States Between 1970 and 1978

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The rate of dilatation and the rate and direction of shear have been determined from trilateration data for 23 Geodolite networks in the western United States. Sixteen nets are located along the San Andreas fault system between Point Reyes, California, and the United States–Mexico border. Other locations are across the Garlock fault in California; across Puget Sound near Seattle, Washington; near Hanford in eastern Washington; near Hebgen Lake in Montana; across the Wasatch fault at Ogden, Utah; across the Rio Grande rift at Socorro, New Mexico; and Dixie Valley in Nevada; and at the northern end of Owens Valley on the California-Nevada border. Implicit in the treatment are the assumptions that the strain was accumulating at a constant rate over the time period (within the interval 1970–1978) and over the local area (usually about 50-km diameter) covered by the surveys. Of the nets located away from the San Andreas fault, only Ogden and Hebgen show significant strain accumulation. At Ogden the deformation is principally an east-west compression of 0.23 ± 0.05 μstrain/yr and at Hebgen Lake a northeast-southwest extension of 0.17 ± 0.03 μstrain/yr. Along the San Andreas fault system the rate of shear is 0.2 to 0.4 μstrain/yr. The direction of shear agrees very well with the surface strike of nearby faults. This agreement is maintained even in regions like the 'big bend,' where both the fault strike and the observed shear direction are more westerly than they are elsewhere. Shear strain in northern California appears to be concentrated more closely on the faults, whereas in southern California the strain is a broader, smoother feature. In the San Francisco Bay area the strain data indicate slip at depth on both the San Andreas and the Calaveras faults. In addition to the observed shear the nets in California indicate a negative dilatation (areal decrease) of about 0.2 μstrain/yr. This dilatation is unexplained, but the following sources appear unlikely: (1) systematic survey error, (2) an association with the southern California uplift, (3) an association with the big bend in the San Andreas fault in Southern California, or (4) the result of the superposition of a uniaxial strain on the Pacific–North American plate boundary shear.

INTRODUCTION

As part of the earthquake studies program of the U.S. Geological Survey a large number of distances have been measured very precisely several times during the interval 1970–1978. These measurements, which are concentrated in regions of appreciable seismic risk, constitute a measure of deformation that presumably is related to the earthquake process. In this paper we present a summary of the data by reporting average rates of strain accumulation in the various seismic regions. A typical rate of strain accumulation is found to be of the order of 0.1 μstrain/yr tensor strain.

To detect such low rates of deformation with present distance-measuring instruments requires averaging a number of observations and/or looking at time periods over which strain changes are large in relation to the noise level. In this study, about 3000 observations of distance, spanning the period from 1970 to early 1978, were included. The data naturally divide into 23 geographic sections henceforth referred to as Geodolite networks or nets. Fifteen networks are along the San Andreas fault system; other nets are located across the Garlock fault in California; across Puget Sound near Seattle, Washington; near Hanford in eastern Washington; near Hebgen Lake in Montana; across the Wasatch fault at Ogden, Utah; across the Rio Grande rift at Socorro, New Mexico; along Dixie Valley in Nevada; and at the northern end of Owens Valley on the California-Nevada border. Each survey of a net is generally carried out within the span of a few weeks. Each net covers an area of radius between 10 and 50 km, includes between 10 and 60 individual lines, and has been surveyed between 2 and 8 times. To extract strain rates from the noise, we have made two assumptions about the nature of the strain accumulation. First, we have assumed that spatially, the strain accumulates uniformly over each network. This is probably a simplification of the actual mode of strain accumulation. Each net spans a considerable area, and the strain might vary appreciably within that area. The strains we obtain are averages over the area involved. In some cases the average is not very meaningful, and we have tried to exclude such cases. For example, between San Juan Bautista and Cholame in central California, deformation occurs principally as slip on the fault. Consequently, strain is not uniform over any area that crosses the fault. We have therefore excluded data from this area except for some lines near the northern end of the creeping section, lines that do not cross known creeping faults. In other areas, deviations from spatial uniformity are probably within the uncertainties in the observations. The second assumption is that the rate of strain accumulation is constant. That is, for each network we assume that in any given time period, say, between January 1970 and January 1973, the change in strain is the same as during any other time period of the same length. Since all of the observations span only an 8-year period and in some nets much less, this is a reasonable first approximation. Data from the U.S. Atomic Energy Commission's Nevada Test Site [*Savage et al.*, 1974], where strain is largely imposed by nuclear explosions, clearly violate this assumption and are not considered here.

Because all of the different nets span different time periods, it is convenient to discuss strain rates rather than strains that require specifying a time period and are difficult to compare. All strains given in this paper will be in annual rates, as indicated by a dot over the strain symbol. Strain rates were extracted from the observations by the method of least

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