ing samples also depends on sample size. At the Quaternary Isotope Laboratory the ^{14}C activity of ocean water samples is being measured (*14*) with an accuracy of ±4 per mil. To obtain such accuracy the CO_2 has to be stripped from 200-liter seawater samples. Large Gerard barrels are used to collect the samples, and only a few large samples can be collected on each cast. If the accuracy of ion counting could be improved to ±4 per mil, much smaller samples could be used. Large numbers of 1-liter samples could be collected in a single cast and shipboard time would be reduced.

Many problems that elude beta counting can be studied with ion counting. Amino acid racemization dating can be internally checked by determining the ^{14}C age of single amino acids. Carbon-14 studies of the CO cycle (oceanic versus anthropogenic CO) are within reach. Fraudulent oil paintings can be detected more easily because it is not necessary to combust appreciable portions of the painting. Cave paintings in which organic materials such as blood were used can be dated directly with ion counting. It is no longer necessary to use huge ice samples, up to 5 tons for dating; sample amounts can be reduced to 100 kg. Thus, although beta counting will still be used in the future, ion counting will tremendously enlarge the range of applications of ^{14}C analyses.

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Strain in Southern California: Measured Uniaxial North-South Regional Contraction

Abstract. *The plate tectonics model of the Pacific moving northwest relative to North America implies that the regional strain in California should be simple shear across a vertical plane striking N45°W or equivalently equal parts of north-south contraction and east-west extension. Measurements of the strain accumulation at seven separate sites in southern California in the interval 1972 through 1978 indicate a remarkably consistent uniaxial north-south contraction of about 0.3 part per million per year; the expected east-west extension is absent. It is not clear whether the period from 1972 through 1978 is anomalous or whether the secular strain in southern California is indeed a uniaxial north-south contraction.*

As part of the earthquake studies program of the U.S. Geological Survey, seven trilateration networks along the major faults in southern California (Fig. 1) have been surveyed several times during the period from 1972 through 1978. In each survey the distances between geodetic monuments within the network are determined. The distances are measured with a Geodolite, a precise electrooptical distance-measuring instrument, and the refractivity corrections are calculated from temperature and humidity profiles determined from aircraft-mounted sensors flown along the line of sight at the time of ranging (*1*). The errors in distance determination are described by a normal distribution with a standard deviation ranging from about 3 mm at a few kilometers to about 7 mm at 30 km (*1*).

To calculate the average strain rate tensor for each network, it is assumed that the strain rate is uniform in space over the breadth of the network and in time over the interval from 1972 through 1978. The changes of length of the individual lines then yield a large number of strain rates at various orientations from which the three components of the surface strain rate tensor ($\dot{\epsilon}_{11}$, $\dot{\epsilon}_{12}$, and $\dot{\epsilon}_{22}$ in a coordinate system with the 1 axis directed east and the 2 axis directed north) can easily be computed. Because a large number of lines (about 30 for each network) are used to calculate just three strain rate components, reliable estimates of both the strain rate components and their standard deviations may be made. The standard deviations reflect not only the observational uncertainties but also the departures from the assumed uniformity of strain accumulation in both space and time.

The tensor strain rates with standard deviations for the seven networks are shown in Table 1, and the principal strain rates are shown in Fig. 1. Each of the networks may be described adequately

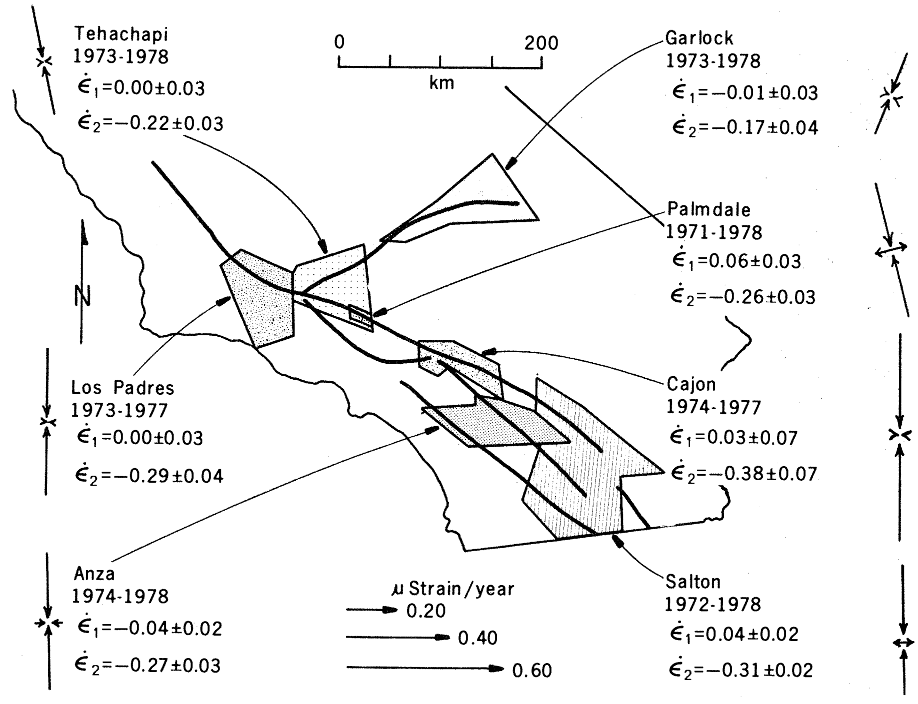

Fig. 1. Map of southern California showing the locations of the seven trilateration networks and the principal strains (in μstrain/year) measured at each. The heavy sinuous lines represent the major faults.

by a uniaxial north-south contraction of about 0.2 to 0.3 μstrain/year (1 μstrain/year = 10^{-6} per year). The mean value of the north-south strain rate $\dot{\epsilon}_{22}$ is -0.27 μstrain/year, and only the Garlock network differs significantly from that mean. The average values of $\dot{\epsilon}_{12}$ and $\dot{\epsilon}_{11}$ are virtually 0.00 μstrain/year. The predominance of north-south contraction is unmistakable.

The assumed uniformity of strain accumulation over a network can be tested. The Palmdale network consists of 31 short lines wholly within the area covered by the 26 long lines of the Tehachapi network. The strain rates for the two networks (Table 1) are quite comparable although no lines are common to the two networks. Similarly, large networks (Salton and Anza) have been divided into four or more subsections that were independently analyzed for strain accumulation. Reasonable consistency among the strain rates for the subsections was found, and in each subsection the strain rate was essentially a uniaxial north-south contraction.

Uniformity in time for strain accumulation can also be demonstrated for most networks. Changes in line length relative to the initial survey can be calculated for each survey, and the uniform strain field that best fits the changes in line length for a particular survey can be assigned to that survey. A plot of those strains as a function of the time at which the survey was carried out shows how uniformly strain accumulated. Such a plot of the three strain components for the Salton network is shown in Fig. 2. The strain appears to accumulate quite uniformly with time. All networks except Palmdale and Anza showed similar uniform rates of accumulation. For Palmdale, the interval from 1971 through 1973 exhibited a uniaxial east-west extension, possibly an aftereffect of the 1971 San Fernando earthquake (magnitude, 6.4; epicentral distance, about 25 km). It was not until after 1974 that the uniaxial north-south contraction became dominant near Palmdale (*2*). No significant accumulation of any strain component in the Anza network was observed between the 1974 and 1976 surveys; the north-south contraction occurred between the 1976 and 1978 surveys. Thus, for the Palmdale and Anza networks the rate of strain accumulation was apparently not uniform, and the strain rates in Table 1 represent averages over the time intervals.

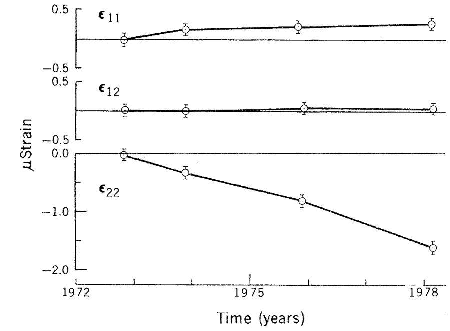

Fig. 2. Strain accumulation as a function of time in the Salton network. The strain components are referred to a coordinate system with the 1 axis directed east and the 2 axis directed north. The error bars represent 1 standard deviation on either side of the plotted point.

It is possible, although unlikely, that this demonstration of uniaxial north-south contraction is due in part to some unidentified systematic error. In measurements of distance, a systematic error will manifest itself as an apparent isotropic dilatation. Because in two dimensions a pure shear differs from a uniaxial strain only by a pure dilatation, it is possible that the measured north-south contraction is actually a pure shear strain contaminated by a systematic survey error. Such a systematic error must arise from a drift in the calibration of either the Geodolite or the meteorological probes.

For several reasons we believe that no drift in calibration has occurred. (i) The Geodolite frequency standard is checked against an independent quartz oscillator in the field at the time of each line measurement. The two frequency standards are calibrated annually by different establishments (the Geodolite by Spectra-Physics and the quartz oscillator by Hewlett-Packard). No significant drift has accumulated in either frequency standard. (ii) The refractivity measurements are made from two independent probes (one on each wing of the aircraft). These probes are standardized commercial units, and in practice they are replaced frequently so that small random changes are possible but systematic drifts are very unlikely. In addition, the temperature probes are independently calibrated in the laboratory every several months to ensure that there is no intermediate-term drift in calibration. (iii) Survey procedures have been uniform over the period from 1972 through 1978 except for one minor change in the Palmdale network. (iv) A long-term systematic bias is not evident in similar networks surveyed elsewhere. For example, networks along the San Andreas fault in central California (*3*) tend to show shear rather than pure uniaxial contraction. (v) The consistency of the uniaxial north-south contraction in Table 1, despite the variability in the amount of contraction, suggests that the effect is real. Moreover, it would be remarkable if the instrumental drift were of just the right amount to convert the actual strain accumulation into a uniaxial field.

Data are not available to enable us to determine whether the strain rates reported here are typical of southern Cali-

Table 1. Strain rates with standard deviations in a coordinate system with the 1 axis directed east and the 2 axis directed north for the trilateration networks in Fig. 1.

Network	Interval	$\dot{\epsilon}_{11}$ (μstrain/year)	$\dot{\epsilon}_{12}$ (μstrain/year)	$\dot{\epsilon}_{22}$ (μstrain/year)
Anza	1974–1978	-0.04 ± 0.02	0.01 ± 0.02	-0.27 ± 0.03
Cajon	1974–1977	-0.03 ± 0.07	-0.01 ± 0.07	-0.37 ± 0.07
Garlock	1973–1978	-0.03 ± 0.02	-0.05 ± 0.02	-0.15 ± 0.04
Los Padres	1973–1977	-0.01 ± 0.03	-0.02 ± 0.03	-0.29 ± 0.04
Palmdale	1971–1978	$+0.07 \pm 0.03$	0.07 ± 0.02	-0.24 ± 0.03
Salton	1972–1978	0.04 ± 0.01	0.01 ± 0.01	-0.31 ± 0.02
Tehachapi	1973–1978	-0.00 ± 0.03	0.04 ± 0.02	-0.21 ± 0.03

Table 2. Comparison of shear rate components calculated from triangulation and trilateration for different epochs. Quoted uncertainties are standard deviations.

Network	Epoch	$\dot{\gamma}_1 = \dot{\epsilon}_{11} - \dot{\epsilon}_{22}$ (μstrain/year)	$\dot{\gamma}_2 = 2\dot{\epsilon}_{12}$ (μstrain/year)	Azimuth of principal contraction axis (degrees clockwise from north)
Imperial *	1941–1954	0.78 ± 0.09	-0.07 ± 0.11	3
Salton	1972–1978	0.35 ± 0.02	0.02 ± 0.02	−2
Taft-Mojave*	1959–1967	0.40 ± 0.18	0.19 ± 0.18	−13
Tehachapi	1973–1977	0.21 ± 0.04	0.08 ± 0.04	−11
Palmdale	1932–1963	0.15 ± 0.08	0.33 ± 0.07	−32
Palmdale	1971–1978	0.31 ± 0.04	0.14 ± 0.04	−12

* Data from Thatcher (*5*).

fornia in the past or simply represent a temporary aberration, perhaps associated with the southern California uplift. The older Geodimeter surveys along the San Andreas fault (which extend back to 1959) are apparently contaminated by systematic errors (*4*) due to changes in survey procedures that make strain calculations suspect. With the other source of data, triangulation surveys, it is possible to determine the shear components accurately, but the dilatational component is very uncertain (*5*). For this reason pure right-lateral shear across a vertical plane striking N45°W may not be distinguished from uniaxial north-south contraction or uniaxial east-west extension. Nevertheless, comparisons of the current strain rates with shear components determined from triangulation in earlier epochs furnish some information on the variability of strain accumulation. The Palmdale network (Fig. 1) was surveyed several times by triangulation in the interval from 1932 through 1963 (*6*), and triangulation surveys of the Imperial and Taft-Mojave networks (*5*) overlap the trilateration surveys of the Salton and Tehachapi networks, respectively. A comparison of the shear rate components $\dot{\gamma}_1 = \dot{\epsilon}_{11} - \dot{\epsilon}_{22}$ and $\dot{\gamma}_2 = 2\dot{\epsilon}_{12}$ for different epochs for these triangulation-trilateration pairs is given in Table 2. Of the six comparisons, four agree to within 2 standard deviations; the values of $\dot{\gamma}_1$ for the Salton and Imperial networks and the two values of $\dot{\gamma}_2$ for the Palmdale network differ significantly. The limited number of comparisons available in Table 2 suggests some variability in strain rate accumulation. A much more extensive analysis of strain accumulation in southern California (*5*) demonstrates appreciable variability in the strain rate in both space and time.

The observations of uniaxial north-south contraction in Fig. 1 are within the region generally under the influence of both the "big bend" in the San Andreas fault system (between the Cajon and Los Padres networks in Fig. 1) and the Transverse Ranges geologic province. The "big bend" of the San Andreas fault (strike about N70°W) deviates significantly from the direction of relative plate motion (N45°W) and presumably introduces an appreciable component of north-south convergence into the plate interaction. The Transverse Ranges themselves are apparently the product of a predominantly north-south compression. Thus, there is both reason for and evidence of north-south contraction, but there is no apparent reason why the stress system should be a uniaxial north-south contraction.

The uniaxial north-south compression could be formed by the superposition of two stress systems, the north-south compression plus east-west extension associated with the Pacific–North American plate boundary plus an east-west compression of the Pacific coastal region caught between the Pacific block on the west and the spreading Basin and Range province on the east. Alternatively, the east-west contraction could be attributed to the preearthquake closure of dilatancy cracks as in the "dry-dilatancy" models (*7*). In the interplate shear field the dilatancy cracks would open predominantly in the east-west direction, and so closure of those cracks would provide the necessary contraction. In either case it is remarkable that the east-west compression just cancels the east-west extension associated with the drift of the Pacific plate to the northwest.

Possibly the uniaxial north-south contraction is associated with the southern California uplift (*8*). Indeed, Thatcher (*9*) has suggested than an episode of significant horizontal straining may have accompanied the main episode of uplift (1961 through 1963). However, Thatcher found that the orientation of that anomalous strain field was highly variable in contrast to the homogeneity of the uniaxial north-south contraction discussed here. If the strain rates in Table 1 represent elastic processes, the condition that the normal stress must vanish at the free surface requires that at the surface

$$\frac{\partial \dot{w}}{\partial z} = \frac{-\lambda(\dot{\epsilon}_{11} + \dot{\epsilon}_{22})}{\lambda + 2\mu}$$

where $\dot{w}$ is the vertical component of velocity, z is the vertical coordinate, and λ and μ are the usual elastic constants. For the strain rates in Table 1, $\partial\dot{w}/\partial z$ is about 10^{-7} per year. If this gradient were maintained to a sufficient depth within the lithosphere, it could result in an appreciable rate of uplift (for example, 8 mm/year if an 80-km-thick lithosphere were involved). However, the major uplift preceded the period from 1972 through 1978, and, in fact, present evidence indicates that this period was dominated by subsidence (*8*), at least in the central part of the uplifted zone. In any case, an association with the uplift in no way explains the origin of the north-south contraction; it merely associates the contraction with another unexplained phenomenon.

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Stone Tools from Mid-Pleistocene Sediments in Java

Abstract. *Two stone tools (a chopper and a retouched flake) were found in mid-Pleistocene channel fills at Sambungmachan (Java), which earlier yielded a hominid skull cap with characteristics of Solo man and a Trinil-like fauna. The artifacts are the first discovered in place in deposits on Java that are assigned to the mid-Pleistocene on faunal grounds.*

On 20 June 1975, in the course of a week-long tour of hominid localities, museums, and research institutions in Java, F. Clark Howell, F.H.B., L.G.F., and T.J. and staff members of the Gadjah Mada Department of Physical Anthropology visited the site of Sambungmachan, on the banks of the Solo River near Sragen in Central Java. While examining alluvial channel fills that had yielded a mid-Pleistocene fauna and a hominid calotte in 1973, we found two stone artifacts partially exposed in the section but still embedded in the top of a fossiliferous gravel bed. The potential importance of the finds was immediately recognized; the face of the adjacent section was carefully cleaned to rule out the possibility that the tools might be incorporated in slumped material of more recent age than the gravel bed, and the artifacts were then excavated from their matrix. All present at the discovery are agreed that the association of the stone artifacts with the gravel layer is unquestionable (Fig. 1). Therefore, the age of the artifacts must be at least as great as the gravel layer containing them. The artifacts are not at all abraded, suggesting that if they were derived from earlier lev-

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