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LETTERS TO THE EDITOR

POSSIBLE FAULT SLIP ON THE BRAWLEY FAULT, IMPERIAL VALLEY, CALIFORNIA

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The relative motion of two triangulation stations, Obsidian and Alamo, located on the volcanic domes Obsidian Butte and Red Hill, respectively, at the southeast end of the Salton Sea, has been determined from geodetic surveys in 1934, 1941, 1954, 1967, and 1972. Alamo has apparently moved south-southeast at a uniform rate of about 5 mm/yr relative to Obsidian, a motion which would be roughly consistent with fault slip on the Brawley Fault, which passes between the two domes (Figure 1).

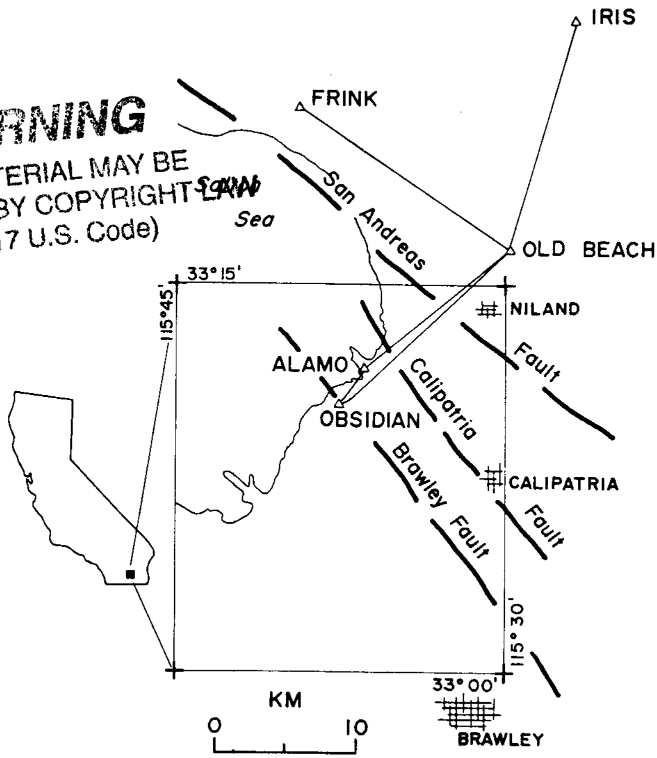

FIG. 1. Location of geodetic stations Obsidian and Alamo relative to the inferred faults in the area. Geodetic stations Frink, Iris, and Old Beach are also shown. Fault locations are taken from Elders *et al.* (1972).

The triangulation surveys of the U.S. Coast and Geodetic Survey measured the angles in the narrow triangle Obsidian-Alamo-Old Beach (Figure 1) in 1934, 1941, 1954, and 1967 (Miller *et al.* 1970). Because Alamo, Obsidian, and Old Beach lie almost on the same line and Alamo is so close to Obsidian, the change in the angles at Alamo and at Obsidian provides a sensitive measure of their component of relative motion perpendicular to the line joining Obsidian and Old Beach. That component of motion is almost parallel to the Brawley Fault, so that the relative motion determined by parallax should be a sensitive measure of the strike-slip displacement across the fault. Because of the distance between the stations, the measurement is not adequate, of course, to prove that the relative motion occurs as slip on the fault; it could equally well represent strain accumulation parallel to the fault.

Figure 2 shows the rate at which the angles measured at Alamo and Obsidian changed. Linear least-squares fits to the measurement indicate that the angle at Alamo increased at the rate of 0.25±0.02 sec/yr and the angle at Obsidian decreased 0.24±0.03 sec/yr. The fact that the measurements fit the linear trends so well and the two measurements are consistent suggests that we have a reliable measure of the apparent parallax of Alamo relative to Old Beach as seen from Obsidian. The motion of Alamo relative to Obsidian, as indicated by the observed parallax, is about 4.5 mm/yr to the SE. The total angle changes and relative motion are about 8 sec and 15 cm in the 33-year period. An additional contribution to the motion would be involved if the line Obsidian to Old Beach were rotating. However, comparison of angles measured at Old Beach from Obsidian to other

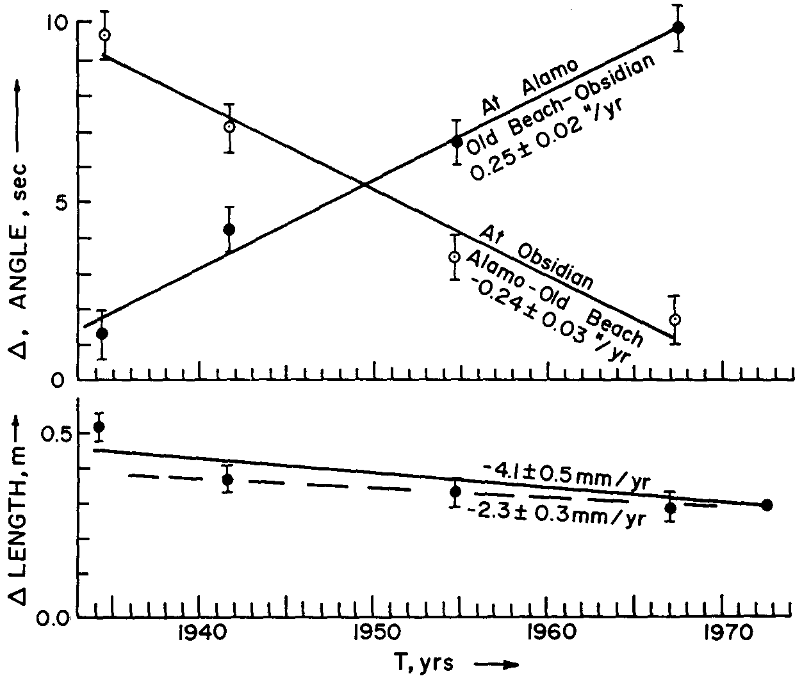

FIG. 2. Rate of change of geodetic observations with time. The top graph shows the changes in the angles in the triangle Obsidian-Alamo-Old Beach as measured at the former two stations, and the bottom graph shows the changes in distance between Alamo and Obsidian. The error bars represent one standard deviation on either side of the plotted points. All data were taken from Miller *et al.* (1970) except the final distance measurement, which is an unpublished U.S. Geological Survey measurement.

stations indicates that the azimuth of that line changes slowly, if at all (e.g., similar least-squares fits to the angles Obsidian to Frink and Obsidian to Iris (see Figure 1 for locations) indicate changes of −0.06±0.05 sec/yr and −0.01±0.01 sec/yr, respectively). Simple regional shear would rotate the Obsidian-Alamo and Obsidian-Old Beach lines almost equally, so the change of angle at Obsidian indicates uneven shear or fault slip.

It is possible to estimate the component of relative motion between Obsidian and Alamo along the line joining them by using the distances between the stations calculated from triangulation. Because, in triangulation, angles are measured locally but distances calculated from remote bases, cumulative errors are introduced into the distance calculations. Thus, changes in distance are not nearly as reliable as changes in angles. Nevertheless, because the distance between Alamo and Obsidian is so short (3.7 km), the uncertainties in distance measurement are likely to be small (e.g., 10 ppm or about 40 mm), so that an estimate of the SW component of relative motion is possible. A plot of the triangulated distances (Miller *et al.* 1970) as a function of time supplemented by one U.S. Geological Survey direct geodimeter measurement of distance in 1972 is shown in Figure 2. A linear least-squares fit to the measurement indicates a rate of shortening of 4.1 ± 0.5 mm/yr. Although that fit is generally satisfactory in view of the possible errors involved, the 1934 observation does appear discordant with the remarkably good trend defined by the other data points. In the following we will prefer to use the trend defined by omitting the 1934 observation; the slope for that trend (indicated by a dashed line in Figure 2) is 2.3 ± 0.3 mm/yr shortening. It is possible that the 1934 measurement is exceptional because of a change in the base line induced by the 1940 Imperial Valley earthquake (magnitude 7.1). This, of course, would induce a change in scale of the whole network. The expected change in scale is in the right direction to account for the discrepancy in distance shown in Figure 2, but it requires an overall change in scale (3×10^{-5}) somewhat larger than might be expected. Although we are not sure of the origin of the anomaly in the 1934 length determination, we do feel justified in neglecting that measurement and adopting the lower (2.3 ± 0.3 mm/yr) rate of shortening. In any case, the determination of the southwest component of relative motion can be combined with the parallax determination to give the complete relative motion: 6 mm/yr S6°E for all of the data or 5 mm/yr S21°E if the 1934 distance measurement is omitted. The Brawley Fault is thought to pass just east of Obsidian with a strike of about S35°E (see Figure 2 of Elders *et al.* 1972), but its exact location and orientation are quite uncertain. Preliminary data from the U.S. Geological Survey microearthquake network in Imperial Valley (D. P. Hill, oral communication, 1973) indicate a well-defined line of epicenters extending parallel to, but just east of, the line joining Brawley and Obsidian (see Figure 1 for locations), a trend which presumably coincides with the Brawley Fault. The strike of this trend is near S25°E, quite close to the direction of motion of Alamo relative to Obsidian. This coincidence of fault trend and relative motion vector suggests that right-lateral fault slip on the Brawley Fault could be an explanation of the observed motion.

It is, of course, possible that the observed deformation is not due to fault slip. The fact that both Obsidian and Alamo lie near the center of the Buttes geothermal area (Elders *et al.* 1972) might suggest that anomalous deformation should be expected. Furthermore, the possibility that the relative displacement may include an appreciable component normal to the Brawley Fault (2 mm/yr if the 4 mm/yr rate in Figure 2 were taken for the line-length shortening) makes the hypothesis of fault slip less attractive. Even if the parallelism of relative motion and fault strike is accepted, the motion could be a consequence of a high rate of right-lateral shear accumulation across the Brawley Fault. However, the large discrepancy between the rate of rotation of the line Obsidian to Alamo and the line Obsidian to Old Beach suggests that strain accumulation, if that is indeed the explanation, is strongly concentrated close to the Brawley Fault. Thus, the evidence suggests that if the observations do not in fact require fault slip, at least they require a narrow shear zone lying along the Brawley Fault.

References

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