SEISMICITY AND SOURCE PARAMETERS FROM
THE DIGITAL ARRAY AT ANZA, CA

Jon Fletcher (I) Frank Vernon (II)
Linda Haar (I) Jon Berger (III)
Thomas C. Hanks (I) James Brune (IV)
Presenting Author: Jon Fletcher

SUMMARY

An array of 10 three-component short-period seismometers has been installed in and around the Anza seismic gap on the San Jacinto fault to obtain a set of precise source parameters for all earthquakes above $M \sim 2$. The digital array is supplemented by 20 or more strong motion SMA-1 film accelerographs depending on distance for recording the largest events on-scale. The digital instrumentation is specifically designed for broadband recording with high-dynamic range. To this end on-site digitization at 250 s/s per channel with a 16 bit analog-to-digital converter provides the basic digital data stream. Both local VHF and microwave digital telemetry transmit the data from the Anza region to San Diego for computer data logging. The array has been operating since October 1982. During this period source parameters, such as moment and stress drop, have been compiled for about 200 events. These data are applied to problems such as the estimation of near-source ground motion for $2 < M < 5$ earthquakes, the interaction of rupture zones and fault segments with one another, and the characterization of a seismic gap in space and time.

INTRODUCTION

Over the last several years we have investigated aftershock sequences of several earthquakes including the Oroville earthquake (1 Aug. 1975, $M_L = 5.7$), the sequence at Monticello, South Carolina (starting at about Feb. 1978, max $M = 3$)), the New Brunswick, Canada earthquake (9 Jan. 1982, $M = 5.7$), and the sequence at Enola, Arkansas (starting at about Jan. 1982, max. $M = 4.7$)) recording both strong and weak ground motion with film and digital recorders. These investigations have yielded a wealth of of high-quality ground motion time histories that have been used in understanding seismological determinations of stress drop and stress in the upper crust, scaling of earthquake source parameters, and differences between eastern and western US earthquakes. Recording aftershocks has inherent limitations for several aspects of ground motion and source mechanism studies. For instance, since the mainshock is generally missed or poorly recorded, the ground motion parameters for the upper limit of the available magnitude range is absent. Yet it is the data needed most because the greatest damage is usually associated with the largest magnitude

(I) Geophysicist, U.S. Geological Survey, Menlo Park, CA 94025
(II) Graduate Student, Scripps Inst. of Oceanography, La Jolla, CA 92093
(III) Rsch. Associate, Scripps Inst. of Oceanography, La Jolla, CA 92093
(IV) Prof. Geophysics, Scripps Inst. of Oceanography, La Jolla, CA 92093

shock. Perhaps more importantly, however, is that long-term studies for understanding fault zone interactions are not possible. The Anza array was conceived to provide data without these limitations and thus could be applied to a wide variety of seismological problems.

The essential purpose of the Anza array will be to provide a precise set of source parameters; e.g., seismic moment, source radius, stress drop and focal mechanism, to be used in the analysis of strong ground motion. The rock environment at Anza is similar to many eastern US sites: ground motion parameters normalized by moment can be directly compared for Anza and the eastern US without complications arising from different attenuation effects. We are also interested in how the occurrence of one earthquake conditions the source zone of another earthquake. We intend to study this process by analyzing the moment-release rate and stress drops compiled over whole source zones. Other interests include high-frequency excitation, coda characteristics, and the physical mechanism that governs f_{max} (Ref. 1).

We chose this particular region for investigation because of several scientific (both seismological and geological) and logistical reasons. This section of the San Jacinto fault has been identified as a seismic gap from the distribution of large events since about the turn of the century (Ref. 2). This gap represents a deficit in moment release and is bordered on the north by 3 events ($M \sim 6$) that occurred in 1890, 1899, and 1918. The rupture zone for these events ends coincidently with the southern terminus of the Hot Springs fault (Fig. 1). The southern boundary is defined by the northern end of the rupture zone of the 1968 Borrego Mountain earthquake. The intervening region is a gap about 30 km long. This gap, however, is not uniformly quiescent: the southern half, south of the trifurcation of the San Jacinto fault, has been quite active with seven $M < 4.0$ events since 1970. Consequently we expect continued seismic activity at the $M = 4.5$ to 5.5 level with the possibility of a $M \sim 6.5$. Recordings near Anza should result in a set of source parameters that extends over an unusually large range in magnitude.

The San Jacinto fault is bordered on both sides by competent rock such as granites. The propagation path for seismic waves transmits nearly all of the high frequency energy emitted by the source: seismograms recorded on the surface of the earth should be representative of the source excitation. As a consequence of the similarity of the rock type on both sides of the fault earthquakes are located with an excellent relative accuracy. This is a necessity if we are to associate slip and stress drops with particular sections of the fault. Furthermore, no creep (aseismic slip) has been detected in this area so that the entire slip budget of the fault can be computed from summing the moments of the earthquakes that occur on the faults: an important consideration for studying the dynamics of fault zone interactions.

The logistical reasons for being at Anza center on the proximity of Anza to the geophysical observatory at Pinyon Flat operated by the University of California, San Diego. Earth strain, tilt and gravity are routinely measured there. In addition geodetic networks for determining broad-scale strain are maintained at Anza. Thus a remarkable set of geophysical data are available to be integrated with the seismological data.

SEISMICITY

It is widely believed that asperities or barriers control the extent of rupture and may be the nucleation point for initiation of rupture in large events. It seems possible that these asperities may be identifiable during times of normal activity based on concentrations of seismic activity or relatively large stress drop which may indicate fault segments with higher strength.

Figure 1 shows the seismicity for the ten months since Oct. 1982. There are three centers of seismic activity. The northern zone lies at the southern end of the Hot Springs fault. It is moderately diffuse and extends to depths of at least 18 km. These are some of the deepest events reported in California. The second zone extends from the west towards the San Jacinto fault in a cross-cutting trend, but appears to stop at the San Jacinto fault. The depths are shallowest at the western end and deepen towards the fault in a Benioff zone-like fashion (Fig. 2). The concentration of activity at the western end is the Cahuilla zone and has had seismic activity precursory to at least two of the historical shocks. Just south of the cross-cutting trend the fault trifurcates. A hot spot of seismicity is located at the northern extension of the Coyote Creek fault segment which appears to be continuously active (Ref. 3). Scattered activity is also present in the general vicinity of the Buck Ridge fault.

Moment, source radius, and stress drop (from the Brune model) (Ref. 4) and from the a_{rms} model of Hanks and McGuire (Ref. 5), have been calculated for most of the events by averaging individual estimates from all useable components of the array. Values of moment range from about 10^{17} to 10^{21} dyne-cm. Eight events with moments greater than 4×10^{20} dyne-cm (M = 3.1, the cut-off chosen arbitrarily) are classed as large: their source parameters are given in Table 1. At least one large event has occurred in each center of activity with two in the northern zone. Three large events are located near the Buck Ridge fault. Stress drops range from less than one bar to about 250 bars. Small stress drop events seem to occur at all locales. Six of the eight large events have stress drops of at least 100 bars and are among the largest obtained so far. The largest stress drop, 250 bars, is for the event east of the Buck Ridge fault.

The pattern of seismicity suggests that the San Jacinto fault is a zone with a width of about 7 km and not a single planar feature. Concentrations of seismicity are apparent and suggest that the fault has large variations in strength possibly related to changes in its geometry. Stress drop values of 100 bars suggest that this is a minimum estimate for the shear stress on the fault: in fact a 500 bar value is obtained for a M_L = 5.5 shock that occurred on Feb. 25, 1980. These stress drops are greater than generally found in central California (a creeping section of the fault). The high level of stress is supported by heat flow measurements where Lee (Ref. 6) has found a 0.8 HFU anomaly on the San Jacinto fault compared to no anomaly in central California (Ref. 7).

REFERENCES

1. Hanks, T. C. (1982), f_{max}, Bull. Seismol. Soc. Am. 72, 1867-1880.

2. Thatcher, W., J. Hileman, and T. Hanks (1975), Seismic slip distribution along the San Jacinto fault zone, southern California, and its implications, Geol. Soc. Am. Bull. 86, 1140-1146.

3. Arabasz, W. J., J. N. Brune, and G. R. Engen (1970), Locations of small earthquakes near the trifurcation of the San Jacinto fault southeast of Anza, California, Bull. Seismol. Soc. Am. 60, 617-627.

4. Brune, J. N. (1970), Tectonic stress and the spectra of seismic shear waves from earthquakes, J. Geophys. Res. 75, 4977-5009.

5. Hanks, T. C. and R. K. McGuire (1981), The character of high frequency strong ground motion, Bull. Seismol. Soc. Am. 71, 2071-2096.

6. Lee, T.-C. (1983), Heat flow anomaly over the San Jacinto fault, southern California, preprint.

7. Lachenbruch, A. H. and J. H. Sass (1980), Heat flow and energetics of the San Andreas fault, J. Geophys. Res. 85, 6185-6222.

TABLE 1
SOURCE PARAMETERS FOR EIGHT LARGEST EVENTS
OCT. 1982 TO AUG. 1983

Nos.[1]	Event[2]	Depth[3]	Moment[4]	Stress Drop[5] Brune	Stress Drop[5] A_{rms}
1).	83/01/19 07.34	8.6	$4.2x10^{20}$	126	30
2.)	83/05/26 16.30	14.1	$5.3x10^{20}$	121	17
3.)	83/05/27 11.25	11.25	$3.6x10^{20}$	119	24
4.)	83/05/27 11.27	13.2	$3.6x10^{20}$	116	24
5.)	83/07/04 07.03	11.0	$5.6x10^{20}$	110	10
6.)	83/08/02 22.21	12.0	$1.4x10^{20}$	244	11
7.)	82/10/28 07.34	17.3	$1.4x10^{20}$	19	16
8.)	82/11/23 07.38	11.0	$4.1x10^{20}$	24	22

Notes:

1.) Number is given for event identification in Figure 1.
2.) Time is given as year 19__/month/day hour.minute.
3.) Depth is in units of kilometers.
4.) Moment is in units of dyne-cm.
5.) Stress drop is units of bars.

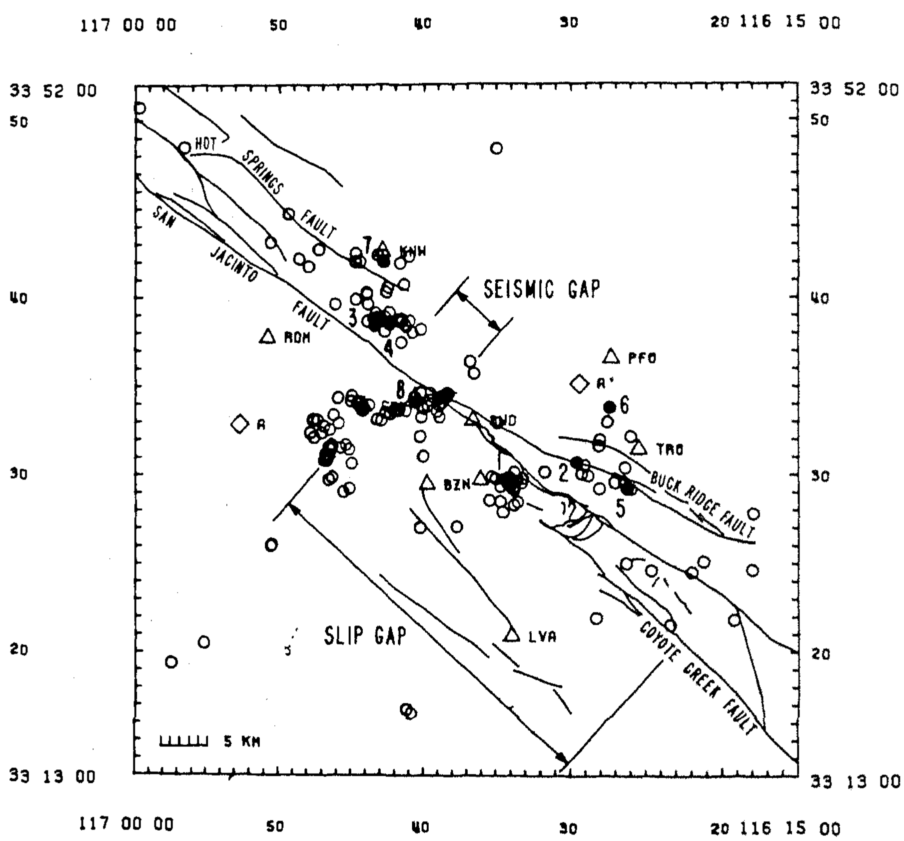
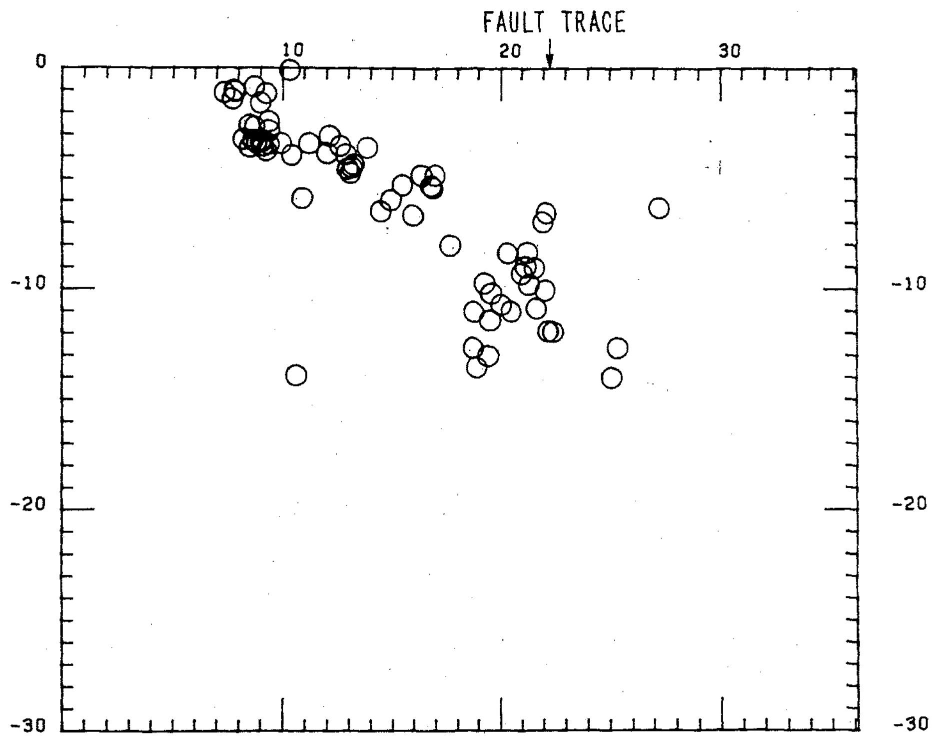


Figure 1. Seismicity for the ten months beginning Oct. 1982. Earthquake epicenters are represented by circles. The dots are the eight largest events to occur in the data set. The dot north of the Buck Ridge fault had the highest stress drop, 250 bars. The diamonds denote the limits of the cross section shown in Figure 2.



CROSS-SECTION A-A'

Figure 2. Cross section through the east-west trend. Note how the seismicity appears to stop at the San Jacinto fault and the depths of the earthquakes.