ANALYSIS OF SHORT TERM MICROEARTHQUAKE ACTIVITY RELATED TO POTENTIAL GEOTHERMAL AREAS IN ARIZONA

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ABSTRACT

A minimum of twelve high sensitivity microearthquake instruments were operated for two week periods in the San Bernardino, Clifton-Safford - Morenci, and Springerville - St. Johns areas of Arizona during the Summer of 1978. The purpose of this program was to assess the seismicity of these areas and to relate any earthquakes detected to faulting and the regional tectonics of the areas. Only one earthquake, which was located in the southern part of the San Bernardino area, was recorded. This activity is less than that observed during the same summer in Prescott, Arizona and in the southern extension of the San Bernardino valley, into northern Sonora. It is evident that a two week period is not adequate to properly assess the seismicity of these areas.

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INTRODUCTION

Shallow microearthquake activity of the swarm type (no single large event but rather many events of the maximum size observed), is often associated with geothermal areas. Yellowstone and the Imperial valley in California are examples of this behavior. The activity is shallow (5 km or less) because the temperature below this depth is thought to be high enough to enable rocks to yield by ductile failure rather than in a brittle mode. Earthquake swarm behavior may be related to the heterogeniety of the stress field, which in turn may be controlled by repeated failure of the rocks due to high thermal gradients. A heterogeneous stress field does not provide a sufficiently large uniform area of high stress for large earthquakes to occur. Instead local regions of stress concentration fail separately, triggering nearby regions into failure and so on, producing a swarm of earthquakes. Earthquake swarms are commonly found in volcanic areas. An association with geothermal regions is therefore logical and expected.

Nonetheless, not all geothermal areas exhibit microearthquake activity. We can rationalize this within the above model by simply stating that these areas are (1) too hot at all depths for earthquakes to occur, (2) the regional tectonic stresses are too low, or (3) these are not pre-existing faults of the proper orientation to permit failure.

The second possibility seems most reasonable for Arizona. If microearthquake activity were identified in an area, we could use it to locate active faults. These in turn might act as conduits for hot fluids. We would also be in a position to interpret the local stress field and evaluate the seismic hazard to any development in the region.

With this background in mind, we embarked on a study of potential geothermal areas in Arizona. A glance at the historic seismicity of the State (Figure 1) and reference to other microearthquake work done in the northern part of Arizona (Sbar et al., 1972) indicate that we might be able to record one event every one or two days on the average. We also assumed that it was possible for areas of swarm type seismicity to exist, but to have had no earthquake large enough to have been felt or recorded by the sparse distribution of seismic stations in this area.

PROGRAM

Three areas of interest were outlined by the Geothermal Group of the Arizona Bureau of Geology and Mineral Technology: San Bernardino, Clifton - Safford - Morenci, and Springerville - St. Johns. Since we only have eight portable seismographs, it was decided to join forces with groups from the University of New Mexico at Las Cruces and the University of Texas at El Paso. They were under contract with Los Alamos Scientific Laboratory to investigate other potential geothermal areas in Arizona and New Mexico, namely the Aquarius Mountains area and an area to the east of St. Johns (see Figure 2). We also assisted them with refraction profiles in New Mexico. A schedule of the areas studied and the number of instruments used in each is shown in Figure 3.

We operated for approximately two-week intervals in each of the areas of interest to the Arizona Bureau of Geology. Because of the UTEP group's prior commitments, we had twelve instruments available for the San Bernardino area. Nineteen instruments were then deployed in both the Clifton and Springerville - St. Johns area. During late July and early August, the instruments were divided between the

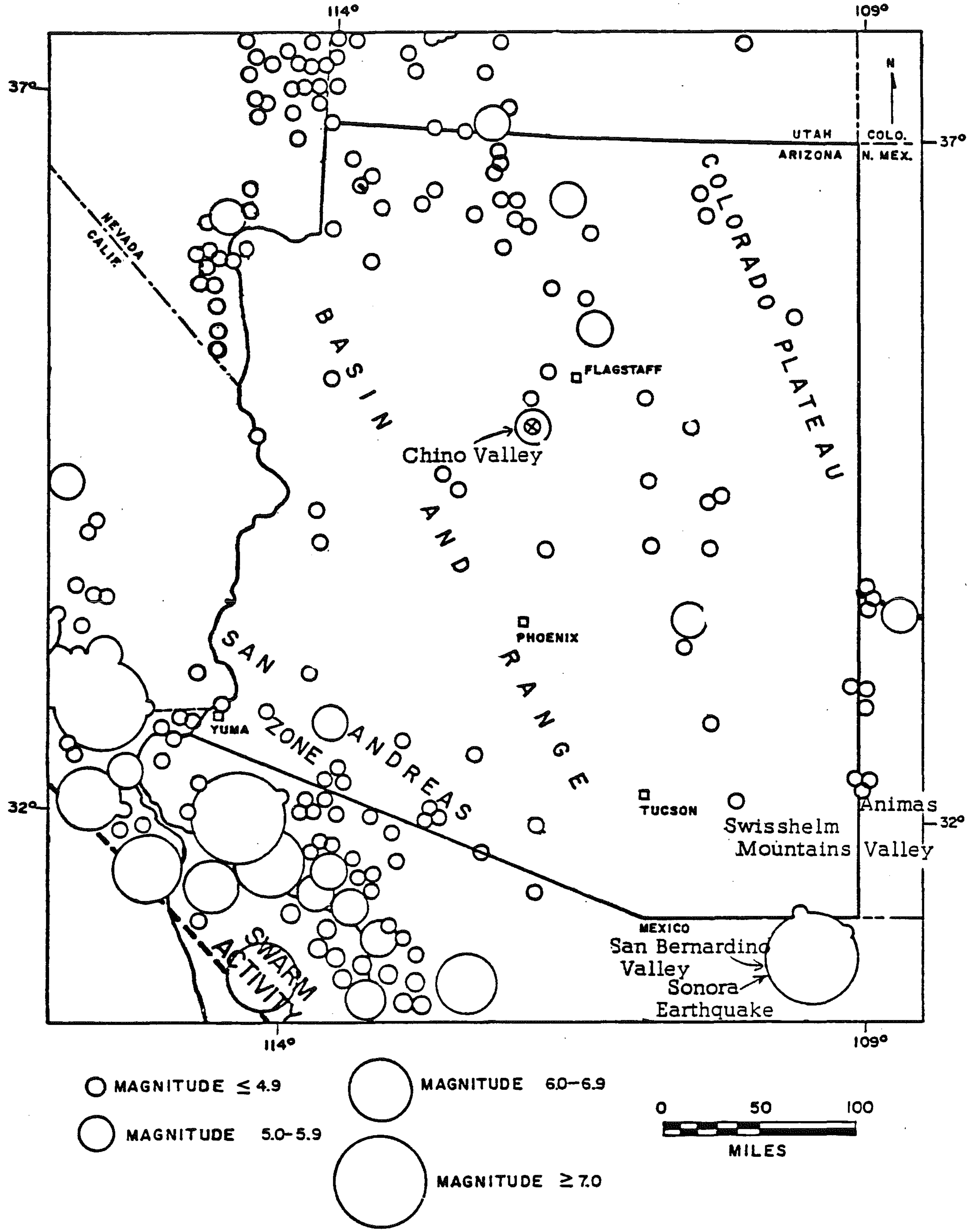


Figure 1. Seimicity of Arizona from 1850 to 1976.

Adapted from Sumner, 1976.

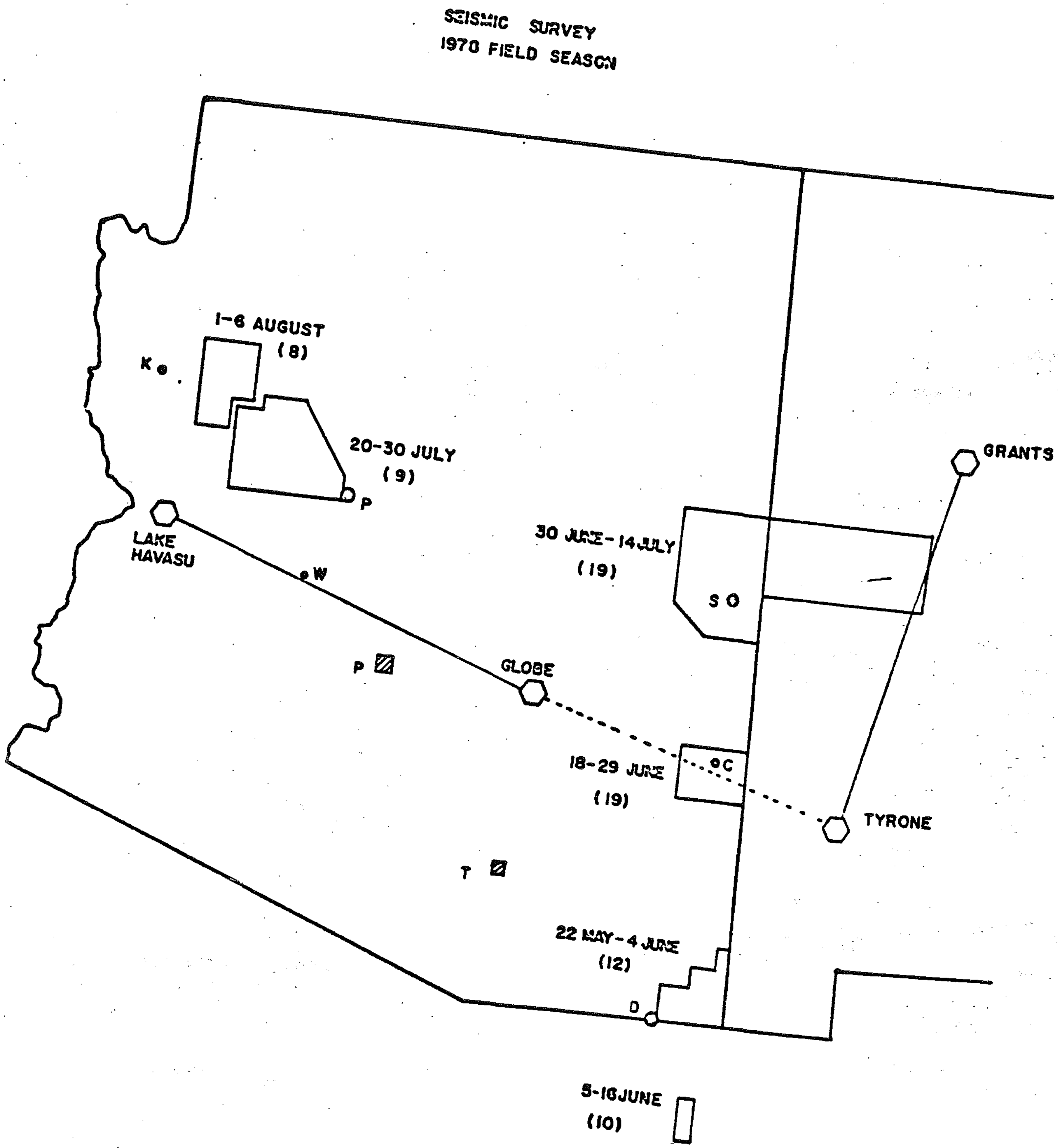


Figure 2. Areas surveyed during summer 1978. Cities are shown by letters. D - Douglas, C - Clifton, S - Springerville, T - Tucson, P - Phoenix (square), P - Prescott (circle), K - Kingman, and W - Wickenburg. The San Bernardo area is east of Douglas and the Aquarius Mountains are just east of Kingman. The refraction lines completed during the summer is between Grants and Tyrone.

Aquarius Mountains microearthquake study and a refraction profile between Tyrone and Grants, New Mexico.

As a separate project funded by the National Science Foundation, ten instruments were used to monitor the residual activity associated with northern Sonora's magnitude 7-7 1/2 earthquake of 1887. The monitoring (6-16 June, 1978) occurred a mere 60 km south of Arizona's San Bernardino Geothermal Prospect. The significantly higher level of seismic activity will be compared in this paper with the other areas studied.

INSTRUMENTATION

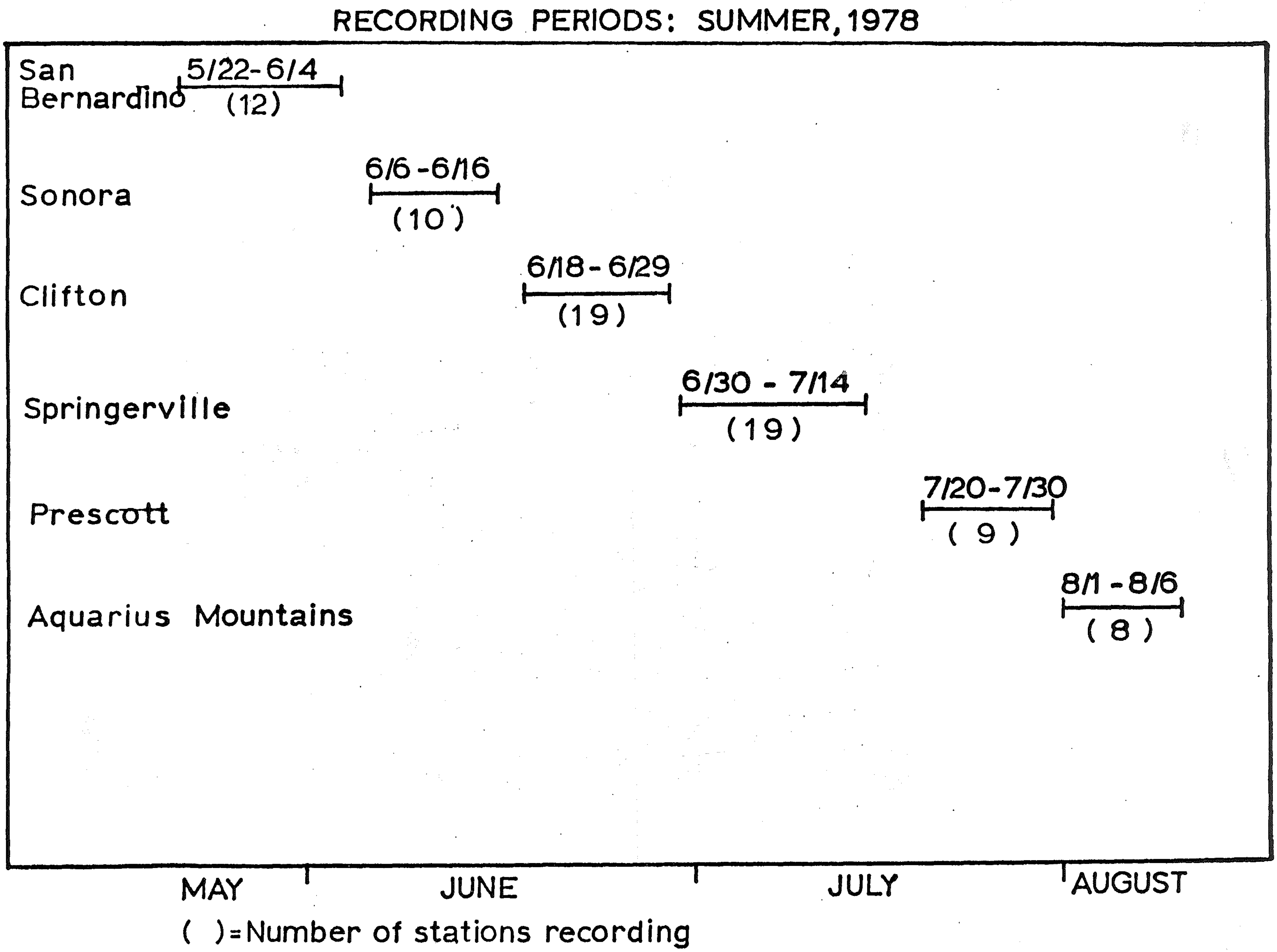
Both Sprengnether MEQ 800's and Geotech Portacorders were used as the primary instruments for microearthquake detection. Under optimum conditions, the recorded traces on these smoked-drum recorders magnified ground motion by 5 million times at a frequency of 10 Hz. At lower frequencies (1 Hz), this gain typically rolled off to between 300,000 and 600,000 times ground displacement. Most of the seismic signal generated by micro-earthquakes occurs in this frequency band (between 1 and 10 Hz). To provide high-resolution information that can be readily analyzed by computer, five Sprengnether and one Terra-Technology three-component digital recorders were operated alongside smoked-drum recorders.

The instruments were spaced about 10 to 15 km apart in the San Bernardino and Clifton areas and about 20 km apart in Springerville. It is difficult to accurately determine the detection capability of the networks at such short hypocentral distances, since the attenuation characteristics of the local region are unknown. We estimate, using a formula from Brune and Allen (1967), that a single station operating at a gain of 2.5 million can detect a magnitude 0 event at a distance of 10 km. Thus, at the above station spacing, a magnitude 0 is an approximate threshold for the detection capability of the networks operated.

RESULTS

Of the three areas of interest, San Bernardino, Clifton and Springerville, only one microearthquake was recorded, and that was in the southern part of the San Bernardino area near the Mexican border (Figure 4). The seismogram and location are shown in Figure 5. This is in marked contrast to the San Bernardino valley's southern extension into Sonora, Mexico. Along the 1887 Fault scarp, sixteen events were recorded during a ten-day period. This tremendous variation in seismic activity within the same valley is puzzling, and remains to be explained. Furthermore, in the Aquarius Mountains region near Prescott, six events were recorded by the nine-station network during an eleven-day period. Three of these were outside the networks and were poorly located (Figure 6). At all of the stations mine blasts were routinely recorded indicating proper operation of the equipment. Precise depths cannot be determined from the available data, since the velocity structure of the region is poorly known. They appear, however, to be in the normal range for earthquakes in the Basin and Range Province (0-15 km).

Before trying to make some statements about the implications of these results, it should be noted that microearthquake activity in the western United States is sporadic and that two weeks of recording is not sufficient to characterize the activity of a region. For the short time interval of the sample the three areas of interest are essentially aseismic. They are certainly less active than the Prescott and San



RECORDING PERIODS: SUMMER, 1978
San Bernardino
5/22-6/4
(12)
Sonora
6/6-6/16
(10)
Clifton
6/18-6/29
(19)
Springerville
6/30 - 7/14
(19)
Prescott
7/20-7/30
(9)
Aquarius Mountains
8/1-8/6
(8)
MAY
JUNE
JULY
AUGUST
( )=Number of stations recording

Fig. 3.

Fig. 4.

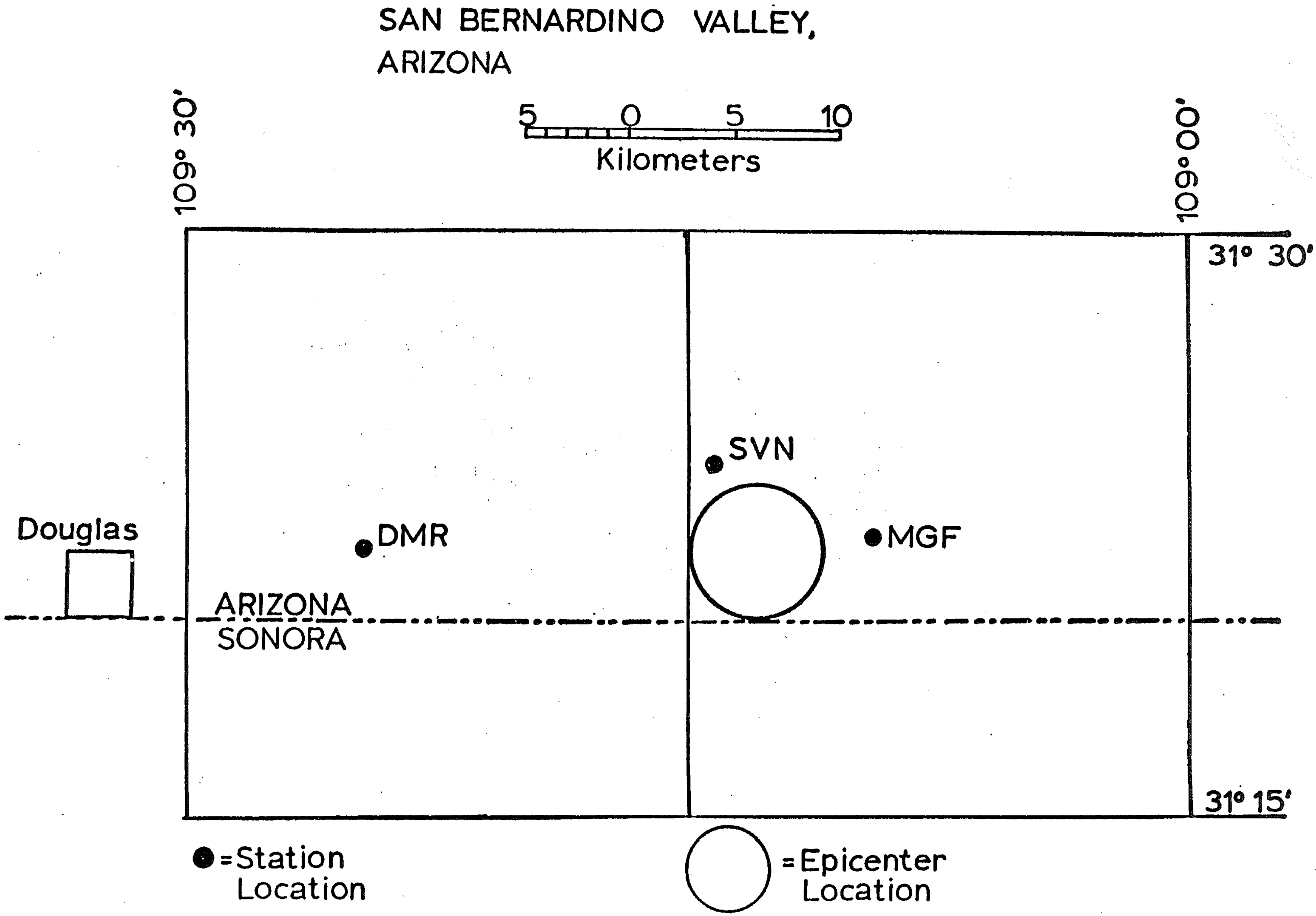

SAN BERNARDINO VALLEY, ARIZONA
5 0 5 10
Kilometers
109° 30'
109° 00'
31° 30'
31° 15'
SVN
DMR
MGF
Douglas
ARIZONA
SONORA
= Station Location
= Epicenter Location

Figure 5. Earthquake recorded on Station MGF in San Bernardino Valley, Arizona. See Figure 4 for location of event.

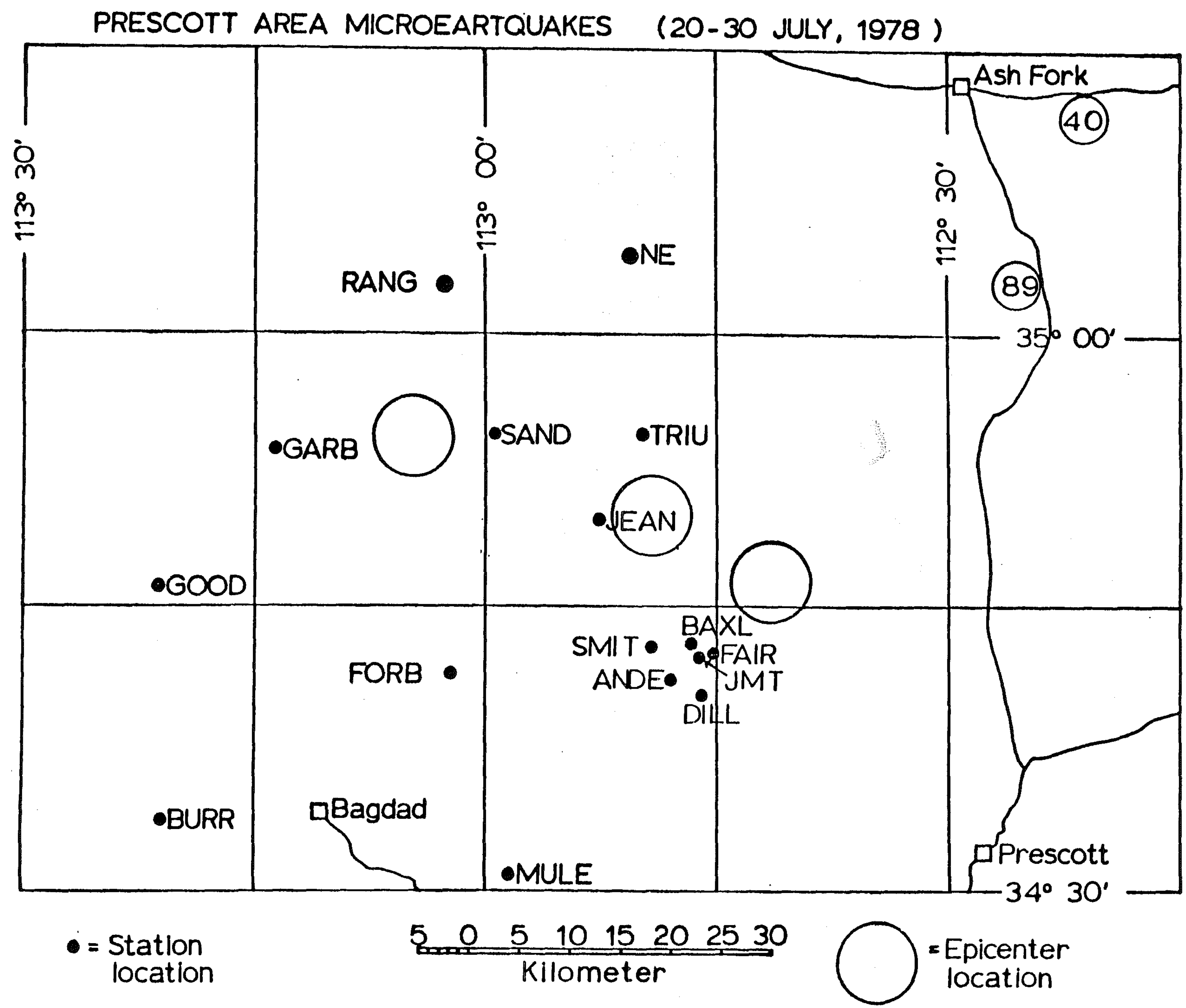


Figure 6. Prescott network and well-located epicenters.

Bernardino, Sonora areas which are in the same geologic province.

In both the Prescott and San Bernardino, Sonora areas significant earthquakes have occurred during the 100 year record in Arizona. Essentially no earthquakes were reported in any of the three potential geothermal areas studied. Tectonically there may be fundamental differences in these areas, although at this time we cannot identify these differences.

At this stage to do anything useful from the microearthquake point of view, it appears necessary to spend a considerably longer time recording in each of the above areas with a network at least as dense as used in this study. In this way, enough events might be detected to map faults and determine the tectonics of the region.

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