PASSIVE SEISMIC RESULTS NEAR THE TUSCARORA PROSPECT, NEVADA

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ABSTRACT

Data from a 12-day passive seismic survey were collected near Tuscarora approximately 95 km northwest of Elko, Nevada. The high seismicity detected was characterized by extensive clustering activity. Poisson's ratio and focal-mechanism data indicate a seismically active fault intersection with extensive fluid saturation 2.5 km northeast of Hot Sulphur Springs.

INTRODUCTION

Microearthquake activity and the implied contemporary tectonism have been reported to be a necessary ingredient for a commercial geothermal system (Lange and Westphal, 1969; Ward and Björnsen, 1971; Hamilton and Muffler, 1972; Combs and Hadley, 1977). For this reason, a passive seismic survey was conducted from September 10 to 22, 1978 in the vicinity of Tuscarora, Nevada. This survey was designed to monitor the seismicity both locally and regionally. The Tuscarora prospect is located in northeastern Nevada, approximately 95 km northwest of Elko, Nevada (Figure 1). The survey was completed by MicroGeophysics Corporation under a contract to AMAX Exploration, Inc. The passive seismic method was one of more than seven exploration techniques utilized by AMAX over the geothermal prospect (Berkman, 1980). Data from a typical passive seismic survey and possible applications are discussed in this paper and specific results from the Tuscarora project follow. The work was funded by AMAX Exploration, Inc. and the U.S. Department of Energy, as part of their industry-coupled geothermal program. Earth Power Production Company and Supron Energy are partners with AMAX in this venture.

The determination of microearthquake hypocenters permits us to map active fault locations and their attitudes. In addition, focal mechanism studies establish styles of faulting and relative motion. Event occurrence statistics are used to compile histograms and recurrence curves, which are useful in comparing active and potential geothermal prospects. Microearthquake mapping and event signatures allow general rock properties, such as Poisson's ratio, or degree of fracturing and saturation to be delineated. Teleseisms and distant regional events, also recorded by the seismic array, are used to map wave delay areas and attenuation characteristics.

All of these passive seismic applications aid in understanding the geology of a geothermal prospect. Unfortunately, the method does not directly indicate sufficient temperature or water recharge adequate for a commercial geothermal system. Nevertheless, zones of increasing porosity and permeability as mapped by the seismic data can be an excellent guide for deploying more expensive techniques, such as heat flow and thermal gradient mapping. In addition, swarming of events has been found to be typical of known geothermal areas (Ward and Björnsen, 1971).

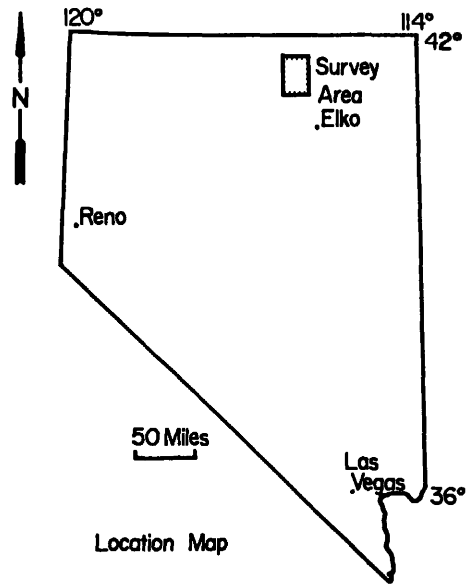

Figure 1

GEOLOGY AND HISTORICAL SEISMICITY

The area is underlain by a sequence of Paleozoic sediments covered with large bodies of Cenozoic, mainly rhyolitic, volcanics. Faulting in the area is complex with thrust, normal, and strike-slip types of motion. A major feature trending north-south through the area is the northern extension of the Independence Graben. A second major fault system trends generally northwestward with large right-lateral components, and still another northeastward, parallel to the Midas Trench (Berkman, 1980).

Figure 2 depicts the historical seismicity record for Nevada with data compiled from 1940-1974 (NOAA). Events with magnitudes of 3.0 or more are displayed. The area near Tuscarora has not experienced any nearby macroearthquake activity during the observed period.

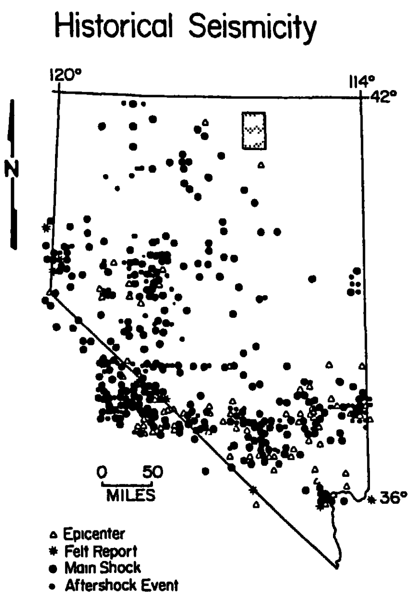

Figure 2

MICROEARTHQUAKE OCCURRENCE STATISTICS

MicroGeophysics Corporation commonly employs the use of 15-station high-gain recording arrays. Where areas of significant activity are indicated, stations can be moved to further surround these areas. This roving method enhances the event location and accuracy of the focal-mechanism.

At Tuscarora, a total of 28 different sites were utilized during the 12-day survey. A total of 108 microearthquakes were identified. Figure 3 depicts the number of events versus the day of the survey. On day 260 (September 17, 1978), 103 of the 108 detected events occurred. Figure 4 details the occurrence of events by the hour on day 260. Two distinct swarms are observed. In the first, an event with magnitude 1.4 began a sequence of more than 55 events. During the second swarm, a foreshock sequence of more than 30 events preceded one of magnitude 2.4, followed by an aftershock sequence of 15 events. These histograms are classic examples of swarming seismic activity.

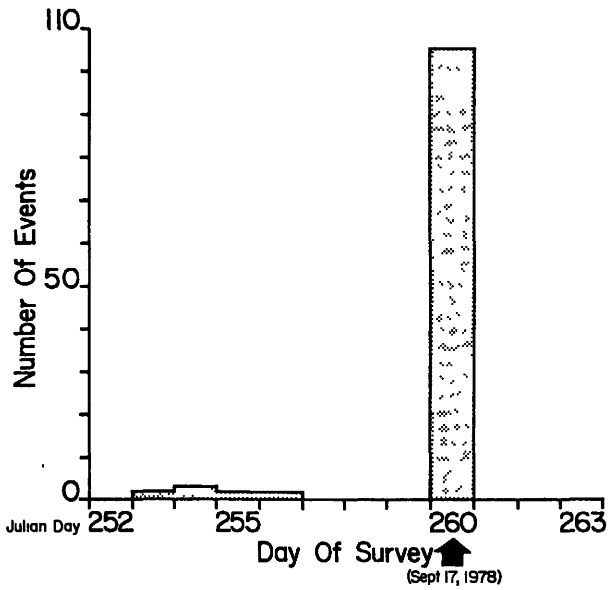

Figure 3

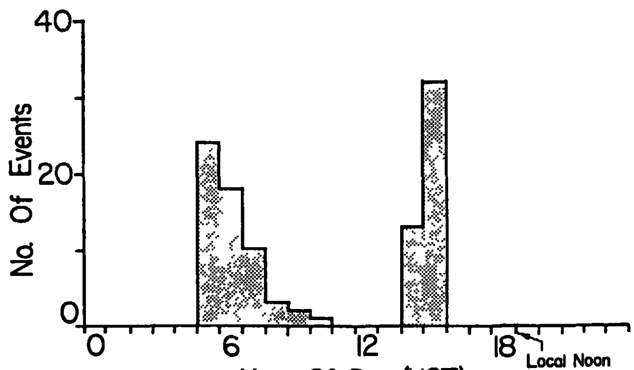

Figure 4

Events which were recorded on four or more stations were located by a least-squares fit to the arrival times and an origin time estimate. P-phase and S-phase time differences along with P-arrivals were incorporated into the origin time estimate. A total of 83 events were located, as depicted in Figure 5.

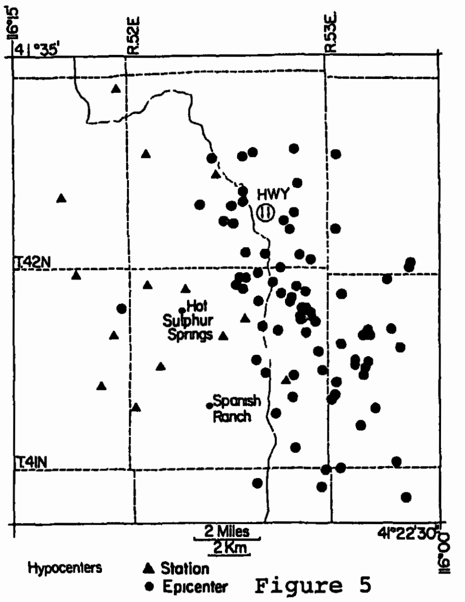

Figure 5

Another characteristic of seismicity is the compilation of a recurrence curve. Earthquake magnitudes versus the logarithm of the cumulative number of events are plotted. The typically linear plot indicates that increases in event frequency occurs with progressively lesser magnitudes. The most linear portion of the curve can be described by a line with a definitive slope, denoted the "b-slope". B-slope values can be used to compare active or potential geothermal areas. These, in conjunction with the degree of linearity and the presence of recurrence "knees", indicate modes of stress release related to earthquake magnitude.

Figure 6 depicts the recurrence curve compiled for the Tuscarora data, including all of the detected events. The b-slope of -0.96 is near average for worldwide seismicity. A small "knee" is observed at magnitude 0.9 ± 0.1, indicating increased frequency of these events over that indicated by the b-slope.

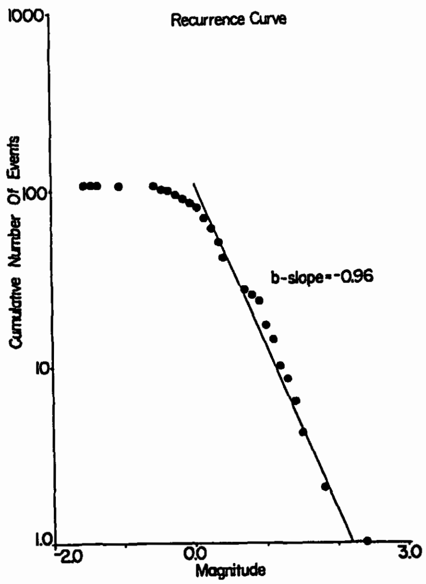

Figure 6

FOCAL MECHANISMS

When seismographs record the first-motion of the P-wave arrival at several different azimuths from the source, the double-couple model of rock fracture yields two orthogonal fault-plane solutions. The preferred solution is denoted the "fault-plane solution" and the alternate, the "auxiliary solution". Groups of hypocenters are combined whenever possible to determine composite solutions. Consistencies of relative fault motion are observed for specific hypocenter groups to eliminate ambiguous solutions. Trends of hypocenters are then utilized along with mapped geologic structures to determine the preferred solution.

Four good-quality fault-plane solutions were determined from these Tuscarora data. The plots displayed (Figure 7) are upper-hemisphere projections of the source-emergence angle. Fault areas 1,2, and 3 are all right-lateral strike-slip faults. Large dip-slip components are also seen in areas 2 and 3. Fault area 4 displays reverse motion with a steep dip towards the east. A possible intersection between areas 1 and 4 appears to occur 2.5 km northeast of Hot Sulphur Springs.

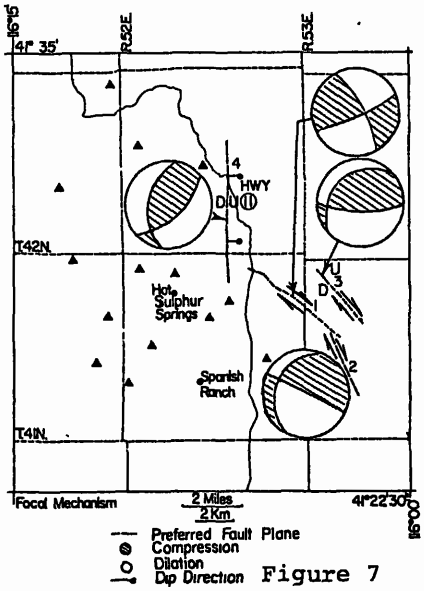

Figure 7

POISSON'S RATIO

If the S-P times for a specific event are plotted versus the P-phase arrival times at several detecting stations, the resultant points will fall on a straight line if the medium is homogeneous. The point where this line crosses the S-P = 0 axis corresponds to the origin time of the event. Since inhomogeneities exist and we have a known origin time from the event location solution, a straight line can be drawn between the origin-time and the data point for each station. This line defines the average crustal properties along the ray path from the source to the detector. The crustal property defined is the P-wave to S-wave velocity ratio, which can be directly converted to Poisson's ratio. This type of plot is known as a "Wadati Diagram" as shown in Figure 8. Wadati plots were made for each locatable event, and the resulting Poisson's ratio along each raypath were projected onto a map and contoured.

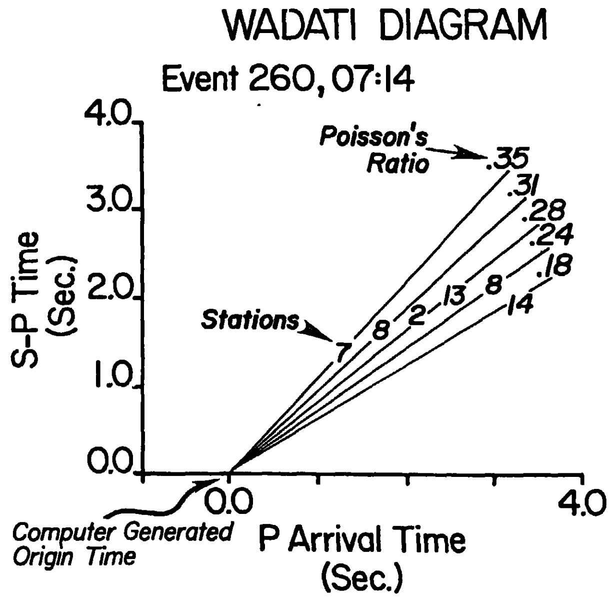

Figure 8

Interpretation of anomalous areas of Poisson's ratio is complex and depends on the degree of fracture, pressure, temperature, and fluid saturation. In general, Poisson's ratio tends to increase with an increase in temperature or an increase in fluid-filled fracturing. The ratio tends to decrease if the structure is unfractured hardrock, or if fractures exist which are dry or steam-filled.

A Poisson's ratio contour map is displayed in Figure 9. The anomalous areas of 0.30 and 0.35 closely follow fault trends 1 and 4 as outlined in the focal-mechanism discussion. These ratio values suggest fractured basin fill which is saturated. The low Poisson's ratio areas are indicative of the hardrock mountain ranges surrounding the basin.

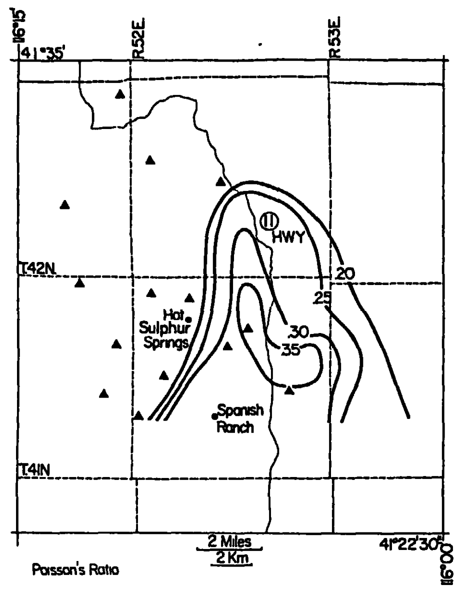

Figure 9

SUMMARY

The seismicity near Tuscarora contained one large swarm period during the 12-day survey. Focal-mechanisms and Poisson's ratio data indicate an active fault intersection approximately 2.5 -3.0 km northeast of Hot Sulphur Springs. Fluid saturation is also indicated at this intersection from the Poisson's ratio data. The majority of the seismic activity occurred along the northwest trending strike-slip structures extending into the deduced fault intersection.

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