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A MICROEARTHQUAKE SURVEY OF PARTS OF THE SNAKE RIVER PLAIN AND CENTRAL IDAHO

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ABSTRACT

A microearthquake survey of the Snake River plain and the Stanley-Sunbeam area of central Idaho was conducted during the summer of 1972 employing high-gain, high-frequency portable seismographs. In 3 weeks of recording at various localities in the Snake River plain, a major east-west trending zone of Pliocene to Holocene basalt and rhyolite, no earthquakes were observed. However, in 8 days of recording near Stanley, at the east edge of the Idaho batholith, more than 40 microearthquakes were recorded, of which 18 were accurately located. All of the events in the Stanley area occurred in the uppermost part of the crust, with focal depths of less than 6 km. A single focal mechanism cannot be determined by a composite plot of first motions. The events cluster in space and time, suggesting earthquake swarm development perhaps associated with the geothermal activity of the Sunbeam hot-springs district.

The relationship of the Snake River plain (SRP) to the northern Rocky Mountains and the Idaho batholith presents an intriguing geological problem. Hamilton and Myers (1966) have suggested that the Idaho batholith is moving as a rigid body northwestward in lee of which is a tension crack that has been filled by the Snake River basalts. Morgan (1972) has suggested that Snake River basalts are the track of a deep-mantle convection plume presently located under Yellowstone Park. Smith and Sbar (1974) have recently suggested that the Snake River plain is a zone of continental rifting, closely related to the separation of the Great Basin from the northern Rocky Mountains subplates. The purpose of our project was to conduct detailed investigations of the microearthquake activity of central Idaho and the SRP, in order to understand better the contemporary tectonics and seismicity of the area.

Central and eastern Idaho are known to be seismically active (Sbar *et al.*, 1972), and geothermal activity is common throughout the region, both in the batholith (Figure 2b) and in the SRP. Recent heat-flow measurements in the southern Idaho batholith and along the western part of the SRP have yielded anomalously high values (D. Blackwell, 1973, personal communication). Earthquakes of magnitude 6.1 and 6.0 occurred in 1944 and 1945, respectively, in central Idaho (Dewey *et al.*, 1972), and earthquake swarms are abundant. The most recent earthquake swarm began in 1963 and resulted in over 50 events reported by the USCGS in one month. Several events were of magnitude 4 and larger. Yet within the Snake River plain, 50 km to the south, no reliable earthquake epicenters have been reported in spite of the geologically recent volcanism and abundant geothermal activity.

Earlier work by Westphal and Lange (1966) described reconnaissance microearthquake investigations in the Sunbeam area during the summer of 1964. They observed 36 events and located nine, seven of which were roughly 25 km east of Stanley. The depths of these

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events were determined to range from 14.5 to 29.1 km. Their nearest station was about 25 km away from the activity, and the events were outside their small array. The events were found to cluster very strongly in time, ranging from 0 to 10 events in one day, suggestive of earthquake swarms.

Dewey *et al.* (1972) have relocated many of the events in the 1963 swarm using the master-event method. They found that the principal swarm region is probably smaller in size than the resolution of their locations (i.e., 4 km in length or less). They also observed that the character of the seismograms obtained from their Hailey, Idaho station to the south varied considerably among earthquakes within the swarm. This cannot be accounted for by a simple model for the earthquake mechanisms such as repeated slippage along a single fault.

The instrumentation used in our study is similar to that which has been reviewed by Ward *et al.* (1969). The magnifications were generally from about 10^6 to 3×10^6 at 5 Hz, with a sharp roll-off at 10 to 13 Hz. The seismometers were 2-Hz geophones. Second marks and daily radio time checks provided a timing accuracy to within ±0.1 sec.

Our recordings in the Snake River plain used fairly low magnifications less than 10^4 due to the ambient noise level. Stations were spaced about 30 km apart (Figure 1). Up to four stations recorded simultaneously, and arrays were operated continuously during periods of consecutive days as follows. The northeastern array, surrounding Craters of the Moon National Monument, was occupied from June 14 to June 19, 1972; the

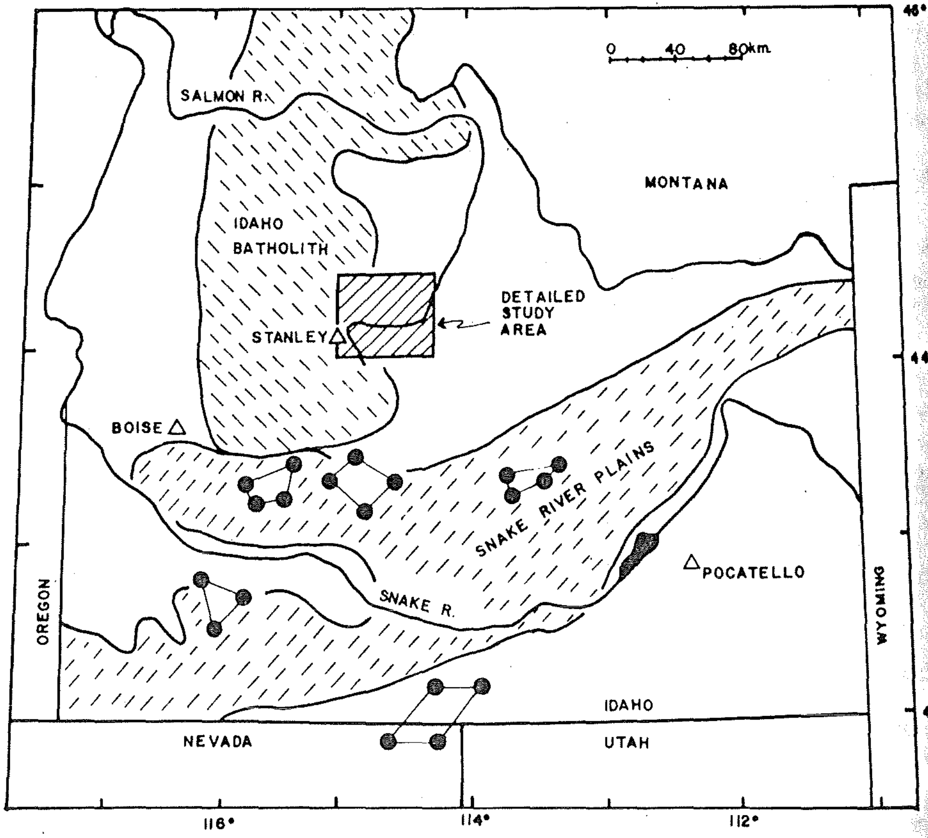

FIG. 1. Map of southern Idaho showing stations occupied in the Snake River plain. Stations operating contemporaneously are indicated by solid circles connected by lines. The striped area is shown in detail in Figures 2a and 2b.

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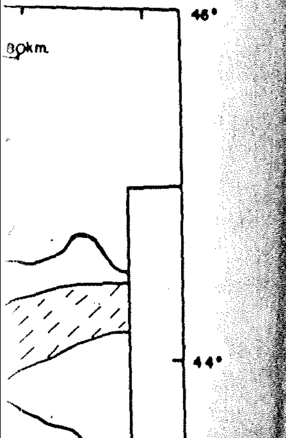

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northwestern array, east of Mountain Home, from June 22 to June 26; the Bennet Hills region, including part of Nevada, from June 29 to July 5; the Upper Camas Prairie, in the north-central part of the SRP, from July 6 to July 9; and around Bruneau, in the southwest, from July 24 to July 27. A small quarry blast 25 km outside the Mountain Home array was located to within 5 km using $(S-P)$ times. Thus, fairly small events at some distance from the arrays in the SRP would have been observed, if not located as well. No natural events were observed near any of the arrays in the Snake River plain.

In the Stanley-Sunbeam area, instrument magnifications as high as 3×10^6 were possible due to a low level of ground noise. The locations of the various sites occupied during the 8 days of recording are shown in Figure 2a. As many as nine stations were operated simultaneously. At these stations, more than 40 events were observed. Eighteen events were located from P (and S, when available) arrivals at three or more stations using a computer program written by Lee and Lahr (1971). A crustal model of 5.9 km/sec to 12 km and 6.3 km/sec from 12 to 40 km was used for the determinations. This velocity profile is based on comparison with refraction data from other batholith structures (Bott *et al.*, 1970) and from structures near the Idaho batholith (Hill and Pakiser, 1966). Additional layering within reasonable limits did not seem to alter the solutions significantly.

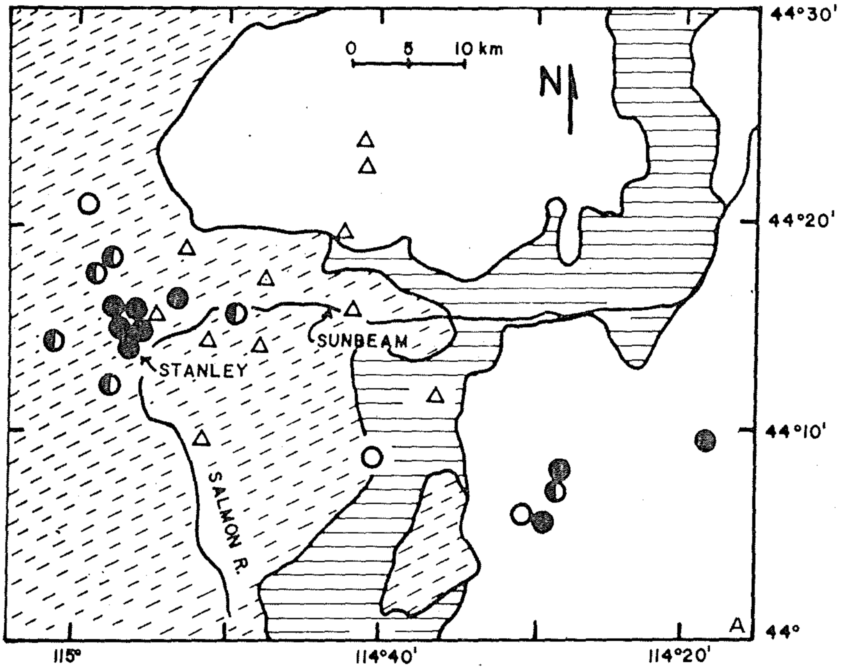

FIG. 2a. Stanley-Sunbeam area in Central Idaho. Seismograph stations are shown by open triangles. Earthquake epicenters are shown in circles. Open circles are poorly located events, half-filled circles are fairly well located, and solid circles are best located. The lightly shaded area is the Idaho batholith, the striped area is metamorphosed Paleozoic sedimentary rock, and the unshaded areas are the Eocene Challis volcanics. The geology is taken from the tectonic map of North America prepared by King (1969).

Epicenters of the 18 events are shown in Figure 2a. These can be divided into three groups as follows. The first five events occurred within the first 24 hr of recording and were all located within 3 km of Stanley. These events exhibited first motions which were consistently compressional for rays leaving upward and to the east. Of the next six events, five occurred from 3 to 5 days later, and all were located 30 km east-southeast of Stanley. These events were not consistent in first motion. The remaining seven events occurred during the following 24 hr and were located very near Stanley. Their first motions were also inconsistent. Almost all other events which could not be located took place contemporaneously in time with the first and third groups and appeared very near to Stanley. They were, for the most part, shallow, since the $(S-P)$ times at the nearest stations were less than 2 sec. On the time scale of 1 week, all of the events clustered closely in space and time.

The composite fault-plane solution is poorly determined (Figure 3) partly as a result of inadequate focal-sphere coverage but mostly because of the inconsistent nature of the

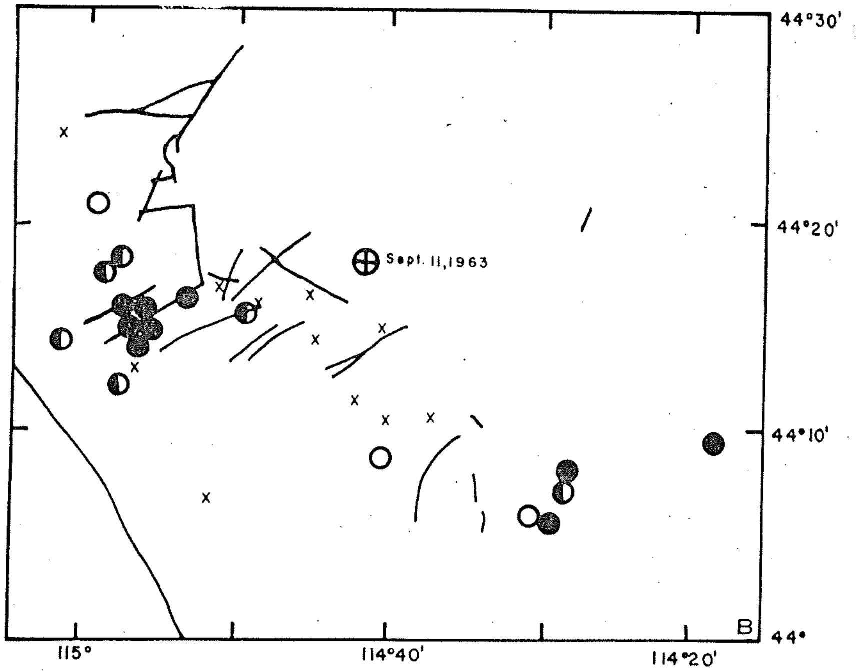

FIG. 2b. The same area as Figure 2a. Locations of epicenters determined in this study are replotted for comparison with locations of known faults, both known and inferred, taken from Westphal and Lange (1966) (*heavy lines*), with hot springs (*crosses*), and with the September 11, 1963 event.

first motions, particularly in the second and third group of events. We feel that this reflects real variations in source mechanisms of the earthquakes. In this situation, the applicability of a composite fault-plane solution should be questioned. The first group of events is the only reasonable grouping which results in a consistent mechanism. This mechanism is indeterminate due to inadequate distribution of station locations.

Focal-mechanism studies of the largest earthquake in the 1963 swarm show normal faulting on a fairly steeply dipping east-trending fault plane (Smith and Sbar, 1974). Note that the only internally consistent group in the present study, the first group, is not consistent with this solution. This set of first motions sets limits on the fault plane, i.e., it cannot strike east-west but may strike more northerly. The 1963 earthquake had its epicenter 25 km east of this activity and, hence, may represent motion in an entirely different fault zone (see Figure 2b).

The absence of microearthquakes in the Snake River plain, the high heat flow in the southern Idaho batholith, and the shallow nature of the events in the Stanley-Sunbeam area should lend insight to the origins of these features. Earthquake swarms, similar to the 1963 Stanley swarm, are frequently indicative of hydrothermal, volcanic, or magmatic activity, and often of rifting (Sykes, 1970). Shallow swarms in restricted regions have been observed (Ward and Bjornsson, 1971) in geothermal areas associated with fissure systems. Thus, the activity in the Stanley-Sunbeam area may be associated with geothermal and perhaps magmatic activity. The absence of large earthquakes and microearthquakes in the Snake River plain possibly indicates that the source of the lavas produced only 2,000 years ago (Prinz, 1970) has either become inactive or has migrated,

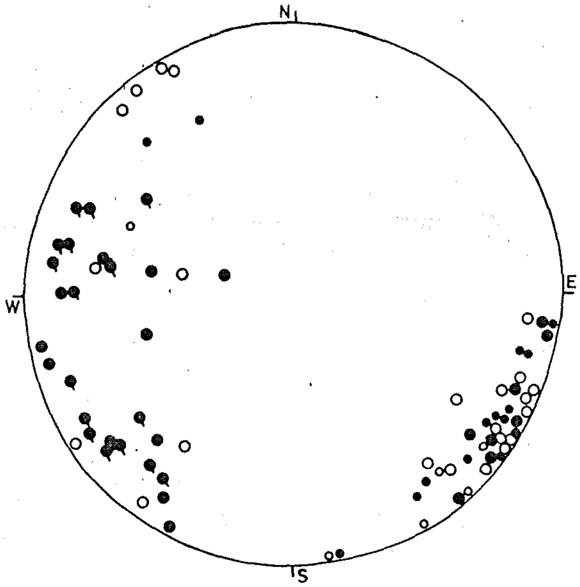

FIG. 3. Composite plot of first motion for events shown in Figures 2a and 2b on a lower-hemisphere projection. Solid circles are first-arrival compressions, and open circles are dilatations. Smaller circles indicate the least reliably located events. Events in the first group (see text) are identified by the attached short lines.

or that the strain energy is being relieved in the form of creep. Brace and Byerlee (1970) have shown that stable sliding may dominate over stick-slip failure as a method of strain-energy release for rocks at high temperatures. Thus, aseismic creep could quite possibly be occurring in the Snake River plain where quite high temperatures must still exist at a relatively shallow depth.

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