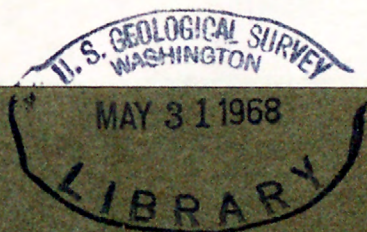


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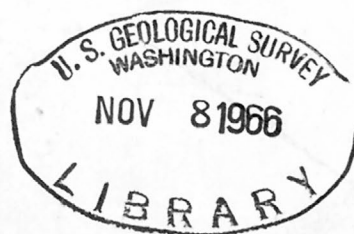
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Instrument installations for the study of coal  
mine bumps at Sunnyside, Utah

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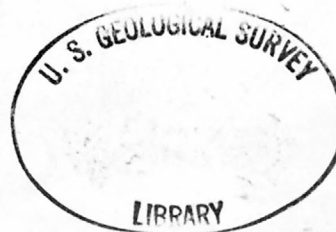
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Instrument installations for the study of coal mine bumps at  
Sunnyside, Utah

By John O. Maberry

The coal mine bumps project of the U.S. Geological Survey began in 1958 at the request of, and in cooperation with, the U.S. Bureau of Mines. Since then, geologic mapping of the Sunnyside mining district has been carried out, and a seismic detection and recording network has been installed. Experiments with portable seismometers began in 1960 and continued for 2 years. Parts of the present installation were built in 1962, and components of the installation were added as they were developed.

The immediate aim of the project is to gain as much knowledge of the natural and artificial causes of mine bumps as possible. The ultimate goal of this research project is to develop methods and techniques to help save lives and prevent property damage in any locale which is subject to these disruptions.

The installation at Pasture Canyon presently consists of two parts: a seismic recording station and a tiltmeter. Seismic signals are recorded simultaneously on continuous paper charts and on magnetic tape. The continuous-chart recorders and the tiltmeter are housed in an extension of one apex of a triangular housing for the tiltmeter (fig. 1). Each 40-foot leg of the tiltmeter is covered by a leg of the triangular building. The tiltmeter movements are recorded on two strip-charts, one recording north-south components of tilt and the other east-west



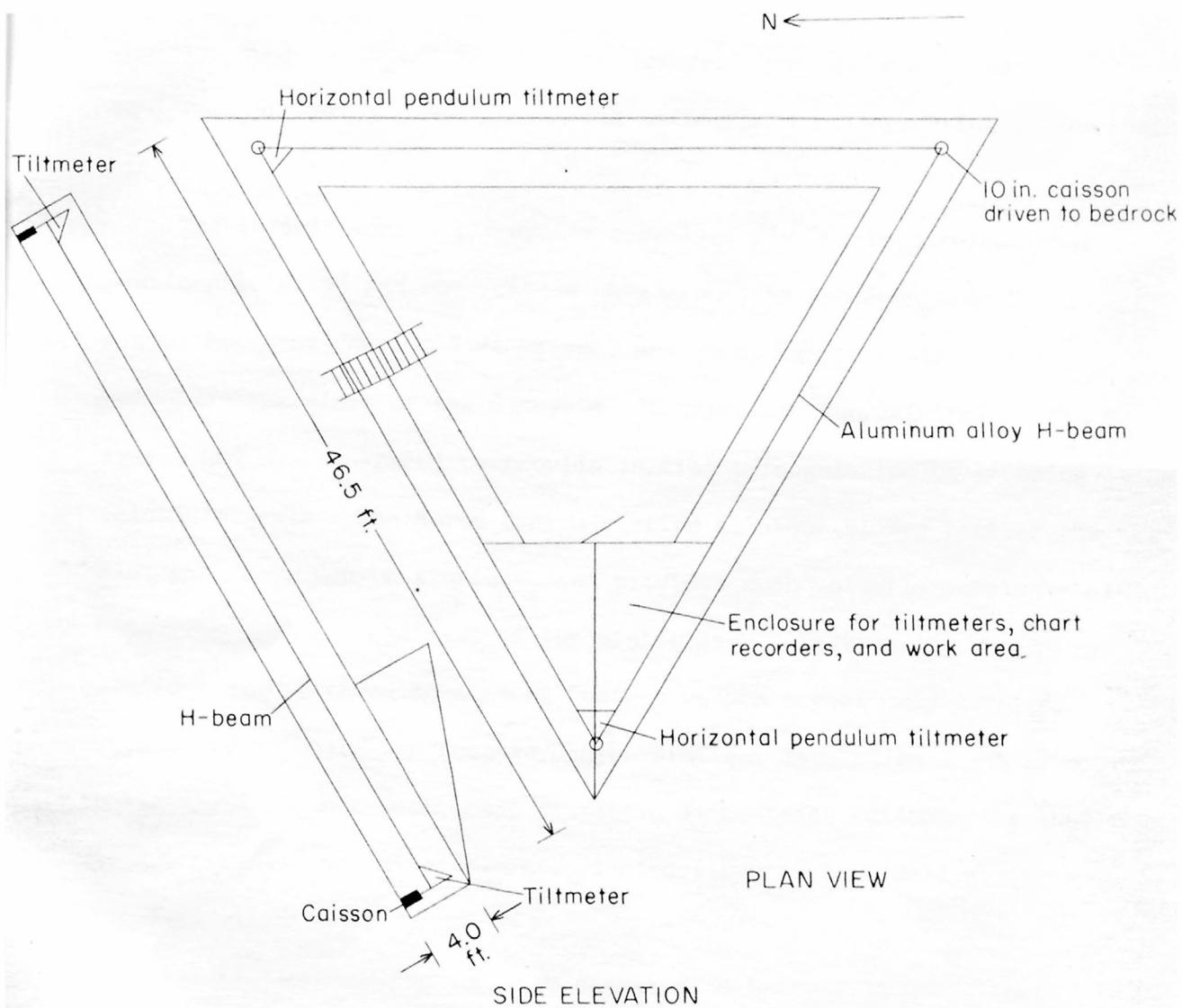


Fig 1.--Sketch of layout of tiltmeter and enclosure



components of tilt. The magnetic tape equipment is housed in a rectangular building which is a modified Army-surplus radar control center. Both buildings provide weatherproof protection for the equipment and provide work areas for maintenance and operation of the system.

The seismic monitoring system comprises five surface seismometer stations (fig. 2) and one station underground in the Sunnyside No. 1 mine. The Bear Canyon, Flat Canyon, and Sheep Canyon stations that encompass the mines of the Sunnyside district are approximately 15 km apart, and are so spaced to provide initial triangulation on incoming seismic signals. The Horse Canyon station is about midway between the Flat and Sheep Canyon stations, and provides much valuable supplemental data from the southern part of the mining area. Instruments at all stations except those located at Pasture Canyon detect only vertical ground vibrations. The Pasture Canyon station, located in the tiltmeter building, is a three-component station. It contains seismometers that detect north-south-and east-west-oriented vibrations as well as vertical vibrations.

All seismometer stations are anchored to bedrock in order that full use may be made of their sensitivity to ground vibrations. The Flat station is anchored to a resistant unit of the Mancos **Shale** of Late Cretaceous age; Sheep Canyon station is located in the lower part of the Colton Formation of early Tertiary age. The Bear Canyon, Horse Canyon, and Pasture Canyon stations are anchored in the top of the



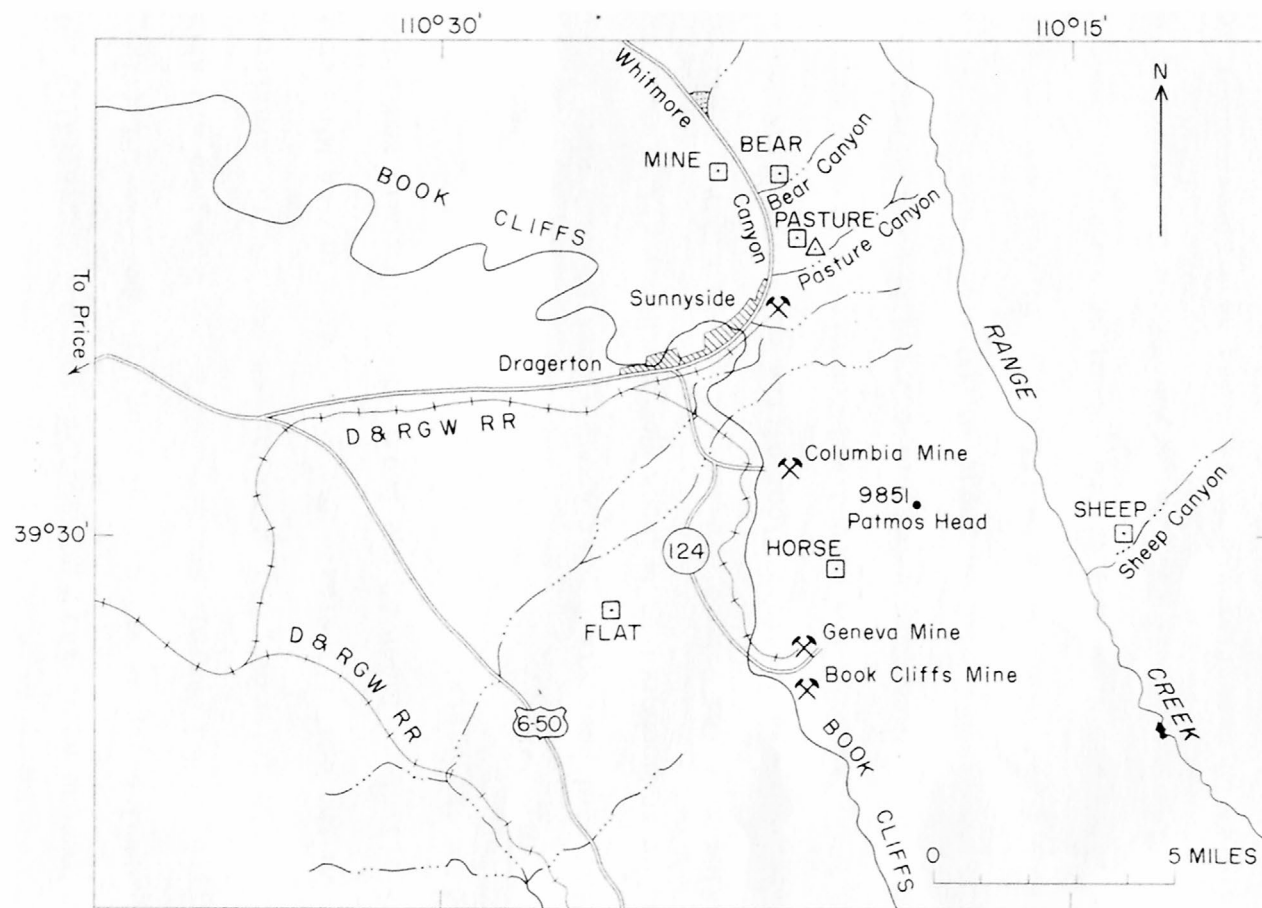


Fig 2.--Sketch map showing location of seismometer stations (□), recording station (△), and coal mine portals (X)



Bluecastle Sandstone Member of the Price River Formation of Late Cretaceous age. The Flat station is stratigraphically below the interval occupied by the coal seams of the district (fig. 3); Bear Canyon, Horse Canyon, and Pasture Canyon stations are stratigraphically above the interval, and Sheep Canyon station is stratigraphically far above the coal interval. The seismometer of the Mine station is on the siltstone floor of the Lower Sunnyside coal, the principal coal bed of the district.

In a typical station layout, a seismometer is housed in a reinforced concrete bunker about 4 feet on each side (fig. 4). The bunker is anchored to bedrock by lengths of drill steel which are included in the concrete walls and in the floor. A Willmore seismometer sitting on the concrete floor of the bunker is activated by vibrations traveling through the ground and converts them into electronic signals. The signals pass into a battery-powered transistorized preamplifier, where they are amplified about 30,000 times, and are fed into Army combat field telephone wire (fig. 5). Signals are transmitted through the wire, which is laid on the ground or strung in trees, to the central recording station in Pasture Canyon. Here the signal is amplified by a KinTel DC amplifier and is recorded on a Sprengnether drum recorder. The wire length from a seismometer station to the central recording station ranges from about 3 miles for Bear Canyon to about 12 miles for Sheep Canyon station.

The signal is fed simultaneously, without further amplification,

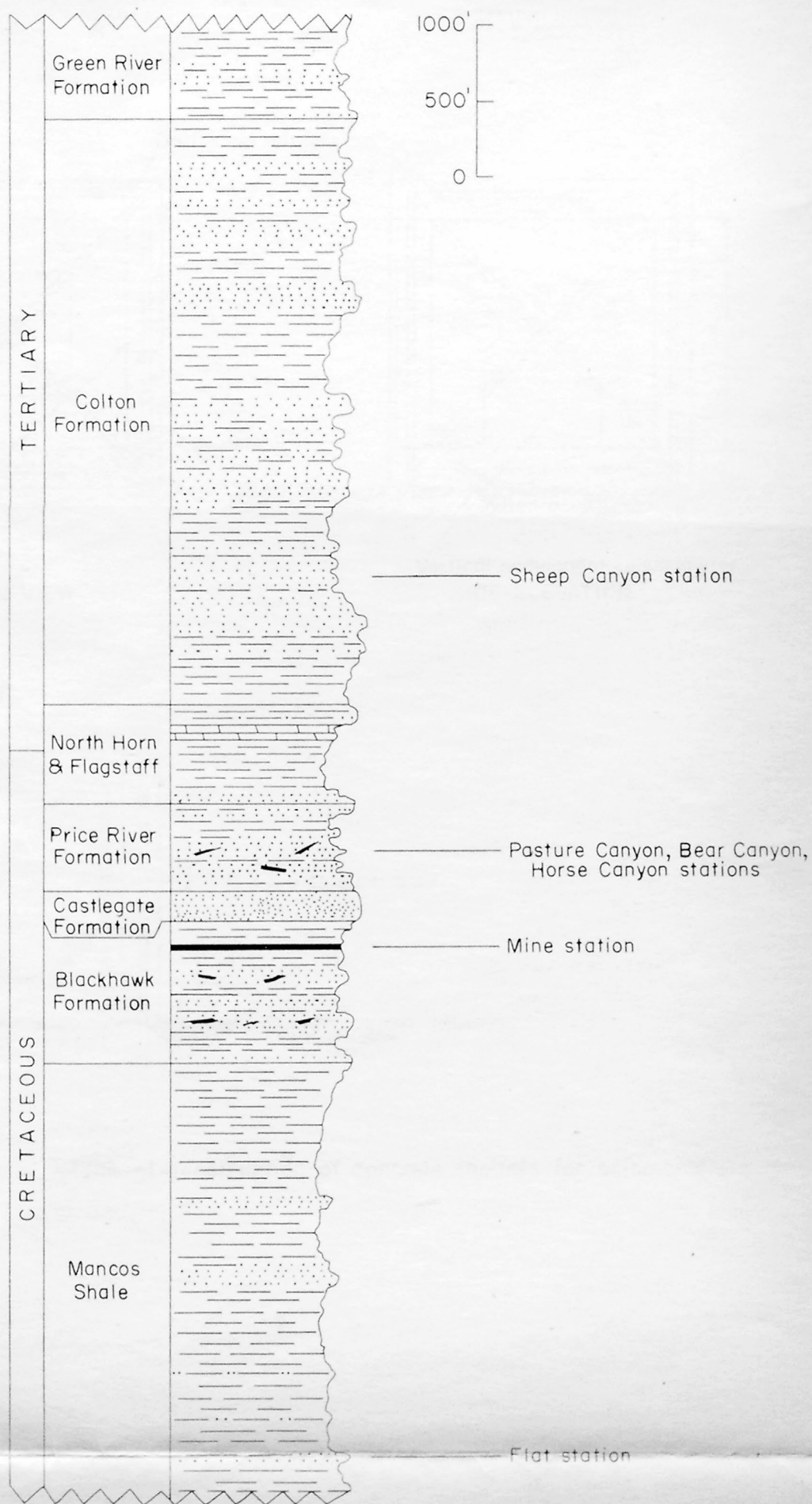


Figure 3.--Diagrammatic section in the Sunnyside area showing relative stratigraphic position of seismometer stations



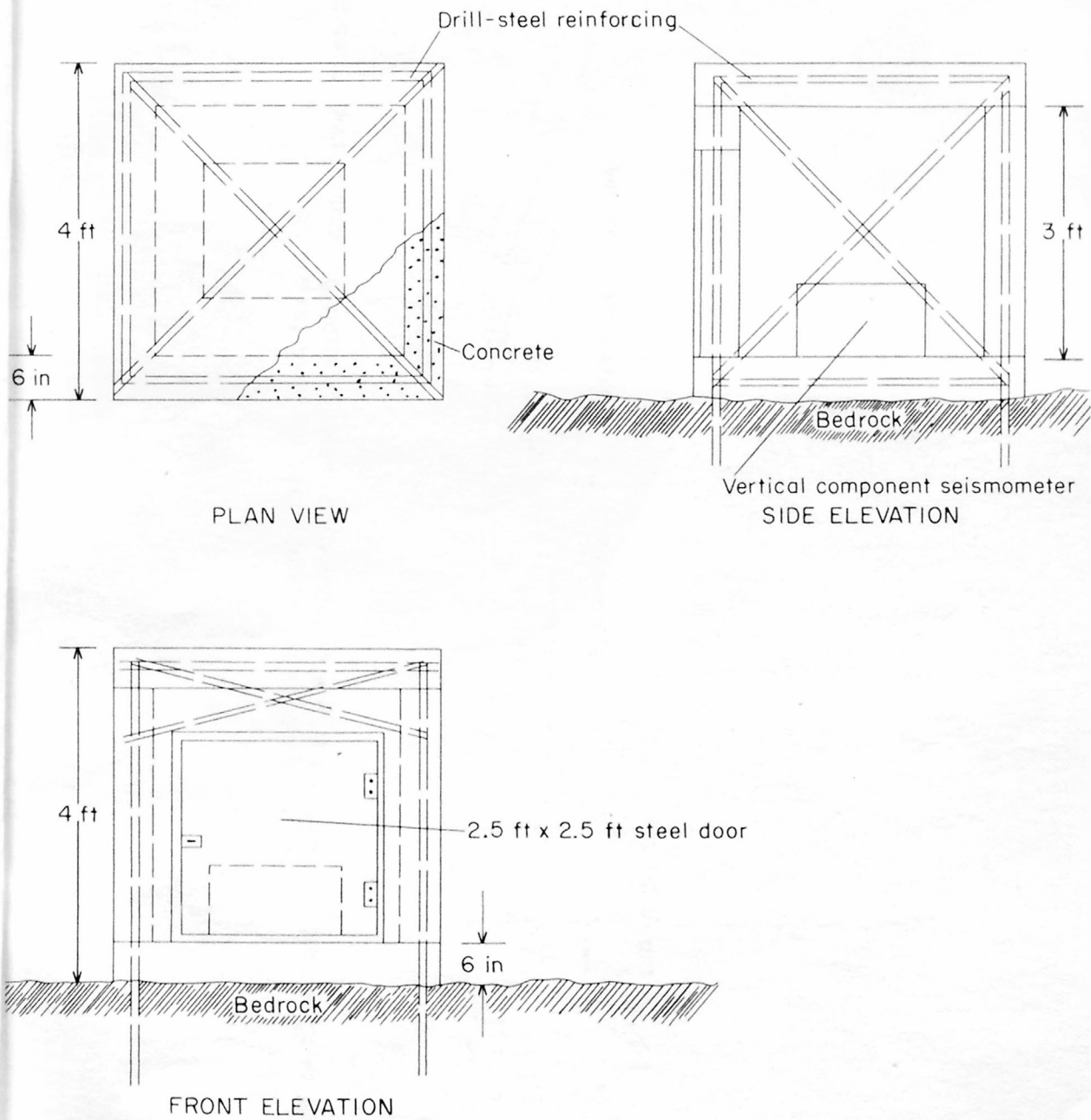


Fig 4.--Sketches showing details of construction of concrete shelters for seismometers

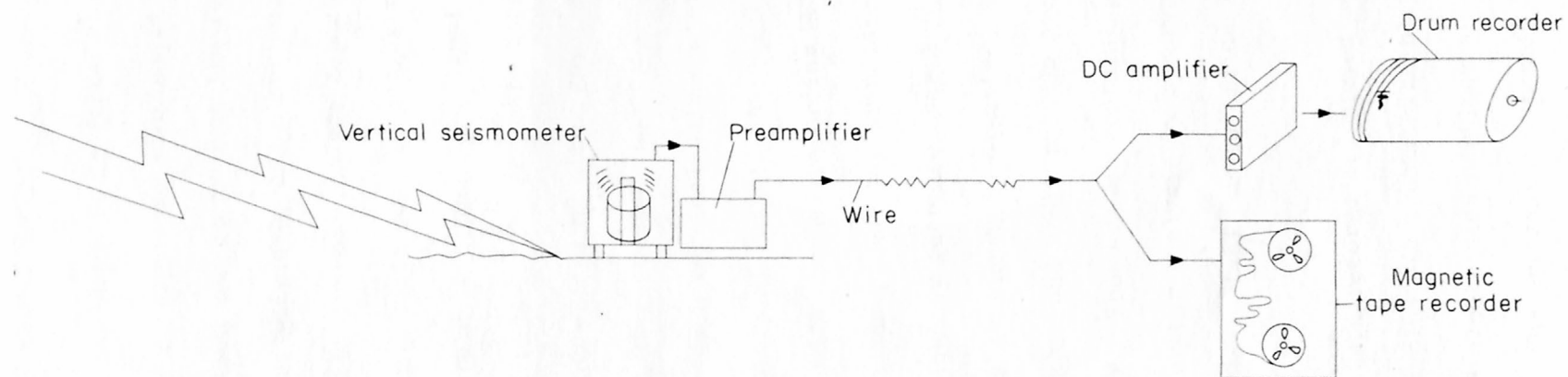


Fig 5.--Schematic sketch showing path of seismically induced electrical energy from the point where vibrations are received by seismometer to recording of event



onto the magnetic tape, where it is recorded as a deviation from a preset FM carrier frequency. The continuous chart recorder depends on an electrically powered pen to produce the records. The pen is subject to inertia, friction, whiplash, and other mechanical difficulties. The tape recorder, because its records are dependent only on variations in an electrical impulse, is more sensitive to small signals and therefore more accurate in timing the signal arrivals than is the continuous-chart recorder. The magnetic tape used in recording was obtained from surplus stocks of other government agencies. The tape is 1 inch wide and has 14 recording channels, of which 9 are presently in use: 1 channel for each vertical seismometer station and 2 for the horizontal seismometers at Pasture Canyon, 1 channel to record local chronometer time, and 1 channel recording WWV, the U.S. Bureau of Standards time broadcast. The tape-recording and playback equipment produces a flat frequency response over a range of DC to about 200 cps.

Tape reels are 14 inches in diameter, and each records for about 12 hours. Tapes and chart records are changed twice a day throughout the year. Those tapes containing records of seismic events judged worthy of further analysis by observation of the paper charts are mailed to the Geological Survey office in Denver for playback and analysis.

The magnetic-tape records are played back in a van mounted on the rear of an Army-surplus 6X6 truck. The playback tape unit with its power supplies and electronics sections are mounted in equipment racks in the van. The approximate location on the tape of a seismic

event is located by correlation with WWV, which is recorded on one channel of the tape; the signal is monitored on an oscilloscope, and the event is located. The event signal is then played into an oscillograph, an instrument that produces a highly accurate photographic record. In the oscillograph, time scale is expanded from 1 mm:5 seconds to 1 mm:0.1 second and timing accurate to 0.01 second is attained by the use of 0.01-second timing lines on the record. This expansion allows a more complete and exact analysis of the wave, leading to a more accurate solution of the position and depth of the source of a seismic signal. After the wave is photographed in the oscillograph, the record is removed and developed in a processor which develops, dries, and rolls up the record. These records are then analyzed by triangulation to obtain epicenter locations for the tremors.

The number of seismic signals generated by earth tremors that are received from each station in a single day varies from 0 to 1,500. Since January 1963 more than 50,000 earth tremors, most of them originating in or near the Sunnyside mining district, have been recorded at the central recording station.

From measurement of the differential arrival times of seismic signals to the stations to within 0.01 second, epicenters and foci of many tremors can be determined to within 500 feet (250-foot radius). Time marks are electronically put on both the records and the magnetic tape every minute by a chronometer which is checked for accuracy twice a day by comparison with radio time signals from the National Bureau of



Standards (WWV).

The tiltmeter is constructed of aluminum alloy H-beam, in the form of a triangle 40 feet on each side. It is mounted on precisely machined bearing plates at each corner and is accurately leveled by micrometer screws. On two corners of the triangle are mounted high<sup>ly</sup> modified horizontal pendulum seismometers. These instruments are precisely leveled with respect to the tiltmeter, and are capable of measuring displacements as small as 0.06 second of arc ( $0.000017^{\circ}$ ). These two instruments measure components of tilt of the earth's surface in the north-south and in the east-west directions. From the tiltmeter we hope to gain a better insight into the causes of bumps by studying the slight tilting movements that are due to both natural and artificial causes.

Much of the equipment in use in the buildings and in the seismic network was obtained at no cost to the Geological Survey from surplus stocks of other government agencies; and much of it has been designed and made or has been highly modified by project members. In addition, the project members have devoted considerable time to the construction and installation of seismometer stations, laying and maintaining signal wire, and interpreting seismograms.

The acquisition of knowledge of coal mine bumps is a long, time-consuming process, and every scrap of information is vital. We have gained some knowledge and capability, but there is a long way to go before we can predict bump activity in any certain place. Because the wide variance of number and severity of bumps with time

is an important part of the study, continuous operation is essential. If the instrument installations are out of service for even a short period of time, some important fact may be missed. We are constantly devising new ways to obtain information and are continuously revising our methods of interpretation as more effective procedures become apparent through experimentation.





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GEOLOGIC DIVISION  
U.S. GEOLOGICAL SURVEY  
Washington, D.C.

NOV 8 1966

For release NOVEMBER 8, 1966

The U. S. Geological Survey is releasing in open files the following reports. Copies are available for consultation in the U. S. Geological Survey Library, 1033 GSA Bldg., Washington, D. C., and in other offices as listed:

1. Geologic map of the Mount Harvard quadrangle, Gunnison and Chaffee Counties, Colorado, by M. R. Brock and Fred Barker. 1 map and cross-section, scale 1:62,500. Bldg. 25, Federal Center, Denver, Colo. 80225; 15426 Federal Bldg., Denver, Colo. 80202; 345 Middlefield Rd., Menlo Park, Calif. 94025.
2. Instrument installations for the study of coal mine bumps at Sunnyside, Utah, by John O. Maberry. 12 p., 5 figs. 8102 Federal Office Bldg., Salt Lake City, Utah, 84111; Bldg. 25, Federal Center, Denver, Colo. 80225; 345 Middlefield Rd., Menlo Park, Calif. 94025.
3. Coal in the Dardanelle Reservoir area, Yell, Pope, Logan, Johnson, and Franklin Counties, Arkansas, by Boyd R. Haley. 12 p., 5 charts, 6 figs., 1 table.

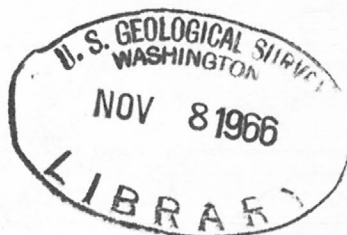
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Correction of title; and announcement of additional depositories:

On Oct. 15, 1966, the open-filing of a report was announced. Originally, it had been entitled "Recovery of rare earths as a byproduct of phosphate fertilizer production: a study in economic geochemistry," by Z. S. Altschuler, Sol Berman, and Frank Cuttitta. This title is hereby corrected to "Rare earths in phosphorites--geochemistry and potential recovery."

Two additional depositories are announced for this report: 8102 Federal Office Bldg., Salt Lake City, Utah 84111; and South 157 Howard St., Spokane, Washington 94111.

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