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surface expression of the geothermal system includes numerous hydrogen sulfide seeps, native sulfur deposits, and intense acid leaching developed over a deep water table.

In 1975 Union Oil Co. initiated an exploration program to assess the geothermal potential of the area for generation of electric power. Temperature gradient drilling, an electrical resistivity survey, and geologic studies resulting from the Union Oil exploration program have been supplemented by detailed studies completed by the Earth Science Laboratory: electrical resistivity and aeromagnetic surveys, detailed geologic mapping, and interpretation of a suite of geophysical logs for exploration wells 799, 1591, and 2358 m deep.

A numerical model interpretation of the dipole-dipole resistivity data allows identification of faults in areas of alluvial cover and clearly indicates the rise of conductive thermal waters along structures. A 3 km^2 area with in-situ resistivities of four Ω-m corresponds to near-surface portions of the geothermal system. Aeromagnetic and temperature gradient data are also useful in understanding the geothermal system.

A full suite of geophysical well logs from three deep exploration wells, interpreted for structural and lithologic information, permits further integration of geophysical data with mapped geology. Severe lost circulation problems reduced the quality and quantity of drill chip returns, and well logs were useful for identifying and locating lithologic units in the drill holes. Production logging indicated large intraformation flow in the well bore and a near isothermal reservoir.

Seismic Profiling in the Snake River Plain-Yellowstone Region GT-5

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The Snake River Plain (SRP) and Yellowstone (Y) region is one of the world's largest areas of Cenozoic volcanism and one of the remaining unexplored areas for petroleum and geothermal sources in the U.S. A cooperative seismic refraction/reflection profiling experiment was conducted in September 1978 to determine the velocity structure of the crust in this unusual volcano-tectonic province. Twenty-two profiles, extending from 50 to 300 km with an average station spacing of 3 km were recorded from explosions (50 to 3600 kg). Interpretations of the data employed the use of wide-angle reflections and refracted arrivals that were modeled by comparisons with traveltimes, time-terms, and synthetic seismograms. True-amplitude seismograms provided constraints on the anelasticity of the crust and properties of velocity transitions. The crustal structure of the SRP-Y region was found to be remarkably homogeneous but different from the surrounding tectonic provinces. A surface layer ($\sim$4.9 km/sec) compressional velocity) interpreted to include Late Cenozoic volcanics thins systematically from 3 km at the SW to 0 km at Yellowstone. The upper-crustal layer ($\sim$6 km/sec) is unusual because it thickens systematically from about 3 km at the SW to 10 km beneath Yellowstone. These layers overlie a thickened lower-crust ($\sim$6.8 km/sec) of 25-30 km. Focused, wide-angle reflections suggest a positive velocity gradient at the Moho boundary. The most significant differences between the SRP-Y crust, in contrast to the surrounding provinces, are the systematic NE-thinning of the surface volcanic layer, the systematic NE thickening of the upper-crust, and the thick lower crust. Passage by a thermal center of active volcanism northeastward along the eastern SRP during the last 15 m.y. has apparently thinned the upper crust and thickened the lower crust. The top surface of the crystalline crust has been faulted or subsided 1-2 km below the equivalent surface in the adjacent provinces. This seismic experiment demonstrates the advantages of a unified interpretation of refraction and reflection data and suggests exploration strategies for effective utilization of both types of data — where one technique is complemented by the other.

Geothermal II

Magma Chambers and Geothermal Energy GT-6

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During the past 5 years, the U.S. Geological Survey has carried out teleseismic *P*-wave delay experiments in several volcanic and geothermal areas to look for anomalous crust and upper-mantle structure. These experiments are of three types: (1) to study major volcano-tectonic features such as the Yellowstone-Snake River Plain system; (2) detect and delineate magma chambers associated with volcanoes known to be active at present; and (3) identify magmatic heat sources in known geothermal resource areas. Of these, the first objective and the last, which should be of special interest to this meeting, have met with success. A large magma body has been identified under the Yellowstone caldera, and there is evidence for an anomalous mantle under the eastern Snake River Plain. Low-velocity bodies, interpreted to be magmatic, have been identified in Long Valley, The Geysers, and the Coso Mountains, California, and Roosevelt Hot Springs, Utah. In contrast, the Cascades volcanoes Mt. Hood and Newberry do not seem to have detectable (minimum 10 km diameter) magma bodies. In order to use this technology for geothermal exploration, the relevant questions to be answered are: (1) how are large crustal magma chambers related to the productivity and longevity of geothermal systems; (2) can smaller chambers and deep vents provide adequate heat sources to make associated geothermal systems useful; and (3) how can thermal energy of magma chambers be related to available geothermal energy? In order to answer (1) and (2), more case histories are needed and techniques should be developed to detect small magma bodies. To answer (3), in addition to *P*-wave data, *S*-wave, attenuation, petrologic, and laboratory data are needed to estimate the extent of melt and physical properties of the material in the magma bodies.

Mapping Seismic Attenuation within Geothermal Systems GT-7

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The reduced spectral ratio has been adapted to map successfully the 3-D variation of seismic attenuation within geothermal systems, using records of teleseismic *P*-waves. The technique requires estimation of the power density spectra, which is performed using the maximum entropy method. The reduced spectral ratio, expressed by δt_i^* is inverted to infer a 3-D Q^{-1} model for the earth's crust, composed of homogeneous cells with sides typically between 5 and 10 km in length.

The effect of small errors in δt^* data has a pronounced effect on the reliability of the inferred Q^{-1} model. Errors arise in several ways

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§Preprint available from SEG Business Office.