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GEOLOGICAL SURVEY

Preliminary geological interpretation and lithologic log of the exploratory geothermal test well (INEL-1), Idaho National Engineering Laboratory, eastern Snake River Plain, Idaho

by

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ABSTRACT

A 10,365 ft (3,159 m) geothermal test well was drilled in the spring of 1979 at the Idaho National Engineering Laboratory, eastern Snake River Plain, Idaho. The majority of rock types encountered in the borehole are of volcanic origin. An upper section above 2,445 ft (745 m) consists of basaltic lava flows and interbedded sediments of alluvial, lacustrine, and volcanic origin. A lower section below 2,445 ft (745 m) consists exclusively of rhyolitic welded ash-flow tuffs, air-fall ash deposits, nonwelded ash-flow tuffs, and volcaniclastic sediments. The lithology and thickness of the rhyolitic rocks suggest that they are part of an intracaldera fill.

INTRODUCTION

The U.S. Department of Energy drilled a 10,365 ft (3,159 m) exploratory geothermal test well at the Idaho National Engineering Laboratory (INEL), eastern Snake River Plain, Idaho, from February 15 to May 19, 1979. The well is designated INEL-1 and is located in the SE 1/4 NE 1/4, sect. 1, T. 3 N., R. 29 E. in the Circular Butte 3 SW U.S. Geological Survey 7 1/2-minute topographic quadrangle (fig. 1). This is the deepest well drilled to date on the eastern Snake River Plain. INEL-1 was sited primarily on the basis of resistivity and seismic refraction anomalies defined by the U.S. Geological Survey in cooperation with the U.S. Department of Energy. Well cuttings were collected every 10 ft (3 m) during the drilling process, and seven cores were obtained at various depths. Few cuttings were collected from the upper 1,600 ft (488 m), where loss of circulation of drilling fluids to porous basaltic rocks and alluvial sediments was a major problem.

Samples are also missing from one other thick zone, from 2,750 to 2,940 ft (838-896 m). The first casing was set at a depth of 1,511 ft (460 m) and drilling proceeded in a normal fashion below that depth. Approximately 90 percent of the bore is represented by cuttings and core. The maximum temperature yet recorded is 302°F (150°C) at a depth of 10,110 ft (3,081 m).

GEOLOGY

Basaltic lava flows, interbedded with silty to sandy alluvial and lacustrine sediments, rhyolitic air-fall ash deposits, and ash-flow tuffs, constitute the upper 3,000 ft (900 m) of the eastern Snake River Plain in the vicinity of the INEL (Walker, 1964; Zohdy and Stanley, 1973; Nace and others, 1975; Kuntz and others, 1979; Kuntz and Dalrymple, 1979; and Doherty, 1979). Rocks below 3,000 ft (900 m) have been inferred from geological models and limited geological data and had not been drilled until INEL-1. The drilling data from INEL-1 support the hypothesis that upper crustal rocks beneath the basalt-sediment layer of the eastern Snake River Plain are chiefly rhyolitic tuffs and ash-flows that formed collapsed calderas. Precambrian, Paleozoic, and Mesozoic sedimentary rocks found in mountain ranges north and south of the eastern Snake River Plain may also be present locally below the volcanic cover of the Plain (Armstrong and others, 1975; Eaton and others, 1975; and Christiansen and McKee, 1978).

LITHOLOGY OF ROCKS IN INEL-1

The rocks encountered in INEL-1 comprise 10,365 ft (3,159 m) of volcanic rocks and interbedded sediments of alluvial, lacustrine, and volcanic origin (fig. 2). The upper 2,445 ft (745 m) consist of basaltic lava flows interbedded with cinders, silt, sand, and tuffaceous silt. The basalts are mostly fresh, diktytaxitic olivine basalts that are typical of eastern Snake River Plain tholeiitic basalts. Below 1,600 ft (488 m), propylitic alteration and secondary zeolite mineralization in the denser vesicular to amygdaloidal basalts are common. Alteration is most intense from depths of 2,000 ft (610 m) to 2,160 ft (658 m). The depth intervals of the altered basalt in INEL-1 compare closely to similar zones of alteration in basaltic lavas in core hole 2-2A (fig. 2), located about 9 mi (15 km) northeast of INEL-1 (Doherty, 1979).

The overlying basalt section is separated from a rhyolitic ash-flow tuff section below by 275 ft (84 m) of slightly altered, tuffaceous silt and silty clay. In the rhyolitic ash-flow tuff section, individual ash-flow sheets typically are separated from one another by 10-100 ft (3-30 m) of altered vitroclastic air-fall ash, nonwelded ash-flow tuffs, or reworked tuffaceous sand. Several of the welded ash-flow tuff sheets are over 500 ft (152 m) thick, and one sheet is nearly 1,100 ft (335 m) thick. Most of the rhyolitic rocks are devitrified and dense.

Hydrothermal alteration is most evident on fracture surfaces within the rhyolitic rocks. Nearly all fractures are sealed by propylitic alteration products, including calcite, quartz, hematite, pyrite, a septechlorite mineral, and a variety of clay minerals.

A dense, hydrothermally altered, recrystallized, aphanitic rhyodacite porphyry occurs below a depth of 8,070 ft (2,460 m). This unit is at least 2,295 ft (700 m) thick. Gamma and electrical logs suggest a slight change in the characteristics of the rhyodacite, at approximately 8,950 ft (2,728 m) (A. Zohdy, U.S. Geological Survey, oral commun., 1979). The rhyodacite above 8,950 ft (2,728 m) may have sustained more hydrothermal alteration than rock below that depth.

Petrographic evidence such as broken and resorbed phenocrysts of plagioclase, sanidine, and quartz suggests that the rhyodacite may be a thick ash-flow tuff. An alternate possibility is that the rhyodacite represents a high-level intrusive rock, possibly the source for the hydrothermal alteration and mineralization within the overlying rhyolitic welded tuffs and basaltic lava flows.

GEOLOGIC INTERPRETATION

Without the intervening basaltic lava flows and alluvial sediments, the thick sequence of rhyolitic rocks encountered in INEL-1 suggests that it constitutes the fill of a collapsed rhyolitic caldera. The ring-fracture zone for such an inferred caldera is probably buried beneath younger rhyolitic rocks, basaltic lava flows, and associated sediments of the eastern Snake River Plain. We wish to emphasize that the inferred ring-fracture zone, shown in figure 1, has been located with a minimum of geological and geophysical data and should not be used alone as a guide for future drilling.

Rhyolitic domes typically are emplaced along ring-fractures of calderas about 10^5 to 10^6 years after the major caldera collapse, as in the model presented by Smith and Bailey (1968). On the basis of unpublished regional geologic studies of the eastern Snake River Plain by us and our colleagues, and of radiometric studies by Armstrong and others (1975), we believe that the ash-flow sheets associated with the caldera inferred in this study are about 7-9 million years old. Thus, rhyolitic domes on the inferred ring-fracture zone should be no younger than about 6 million years old. Radiometric ages of rhyolitic domes (East Butte and an unnamed dome between East and Middle Buttes) and the basalt capping Middle Butte on the ring-fracture of the inferred caldera are less than 2 million years old (Kuntz and Dalrymple, 1979). This suggests that either they are related to a longer and more complex caldera history than the model presented by Smith and Bailey or else they are rhyolitic domes emplaced by processes and structures unrelated to a caldera. We favor the first hypothesis based on the thick sequence of rhyolitic rocks present, the absence of numerous basaltic vents within the inferred rim of the caldera, recent faulting with the downthrown side toward the plain, on the north side of the plain, and the positions of East, Middle, Cedar, and Big Southern Buttes and the unnamed dome between East and Middle Buttes. (Middle Butte is capped with Snake River Plain basalts and its slopes are covered with talus from the capping basalt. Magnetic and gravity data suggest the core of Middle Butte is rhyolitic.)

Some calderas have eruption and thermal histories lasting at least 3-4 million years. If the inferred caldera of this study is of that type, it may represent a significant geothermal resource for many of the facilities at the Idaho National Engineering Laboratory. Porous and fractured rocks in ring-fracture zones provide channelways for circulation and storage of water and, therefore, rocks in these zones may be likely targets for future geothermal explorations.

Post-Pliocene, north- to northwest-trending faults with displacements of several hundred to several thousand feet are exposed in the Lemhi and Lost River Ranges a few miles north of the inferred caldera (M. H. Hait, U.S. Geological Survey, oral commun., 1979). The faults may intersect the suspected caldera ring-fracture zone and increase the potential for a geothermal resource.

Extensive geological and geophysical studies need to be performed before a more precise location for the ring fracture zone can be determined.

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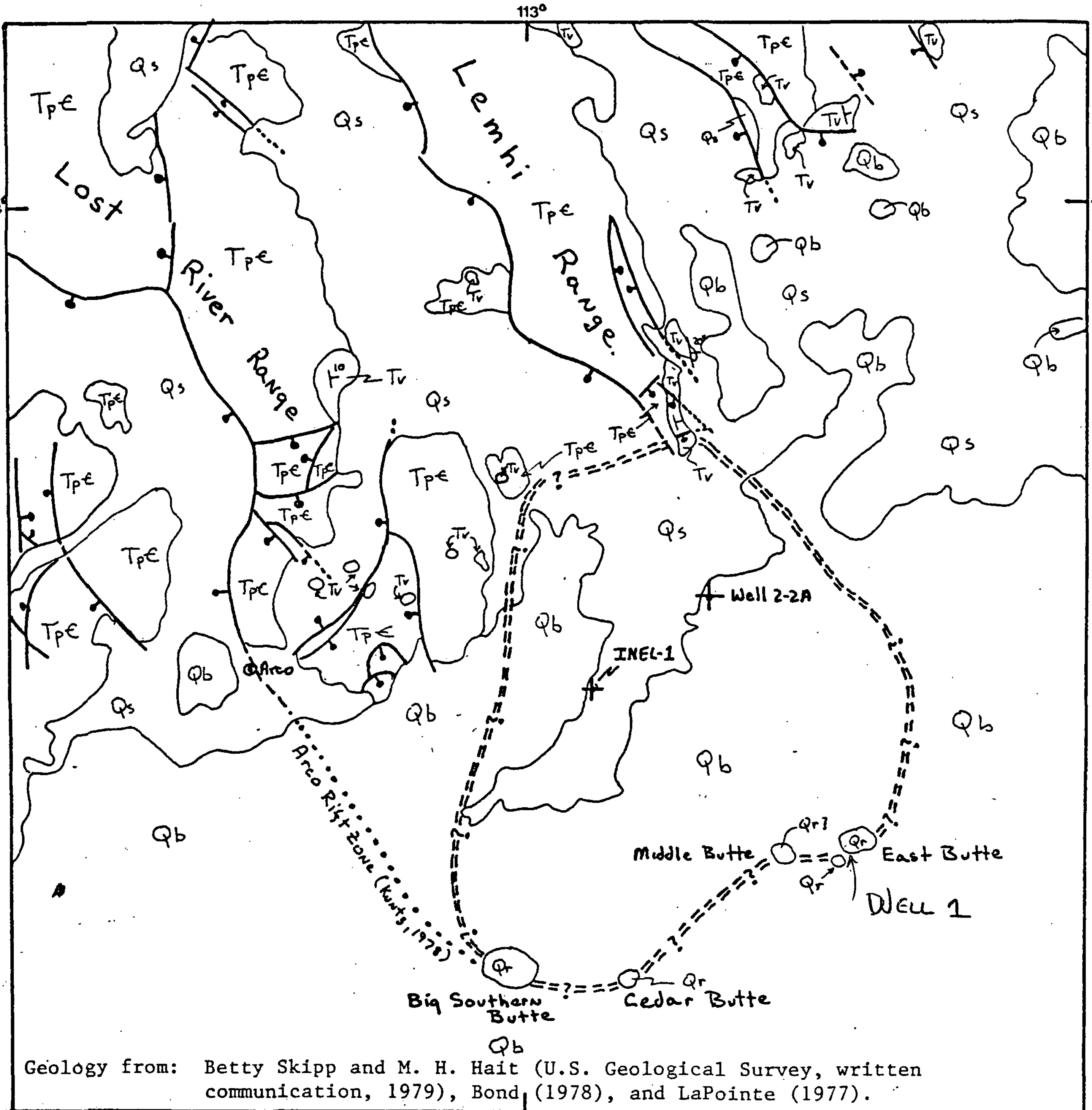

Geology from: Betty Skipp and M. H. Hait (U.S. Geological Survey, written communication, 1979), Bond (1978), and LaPointe (1977).

Scale

0 3 6 miles

0 5 10 kilometers

EXPLANATION

Qs Holocene to Pleistocene surficial deposits

Qb Holocene to Pleistocene basalt flows

Qr Holocene to Pleistocene rhyolitic domes

Tv Pliocene rhyolitic ash-flow tuffs

Tp€ Eocene to Precambrian

Fault, bar and ball on downthrown side

Inferred fault, bar and ball on downthrown side

Rift zone

Inferred caldera rim

Figure 1. Generalized geologic map of the area surrounding INEL-1.

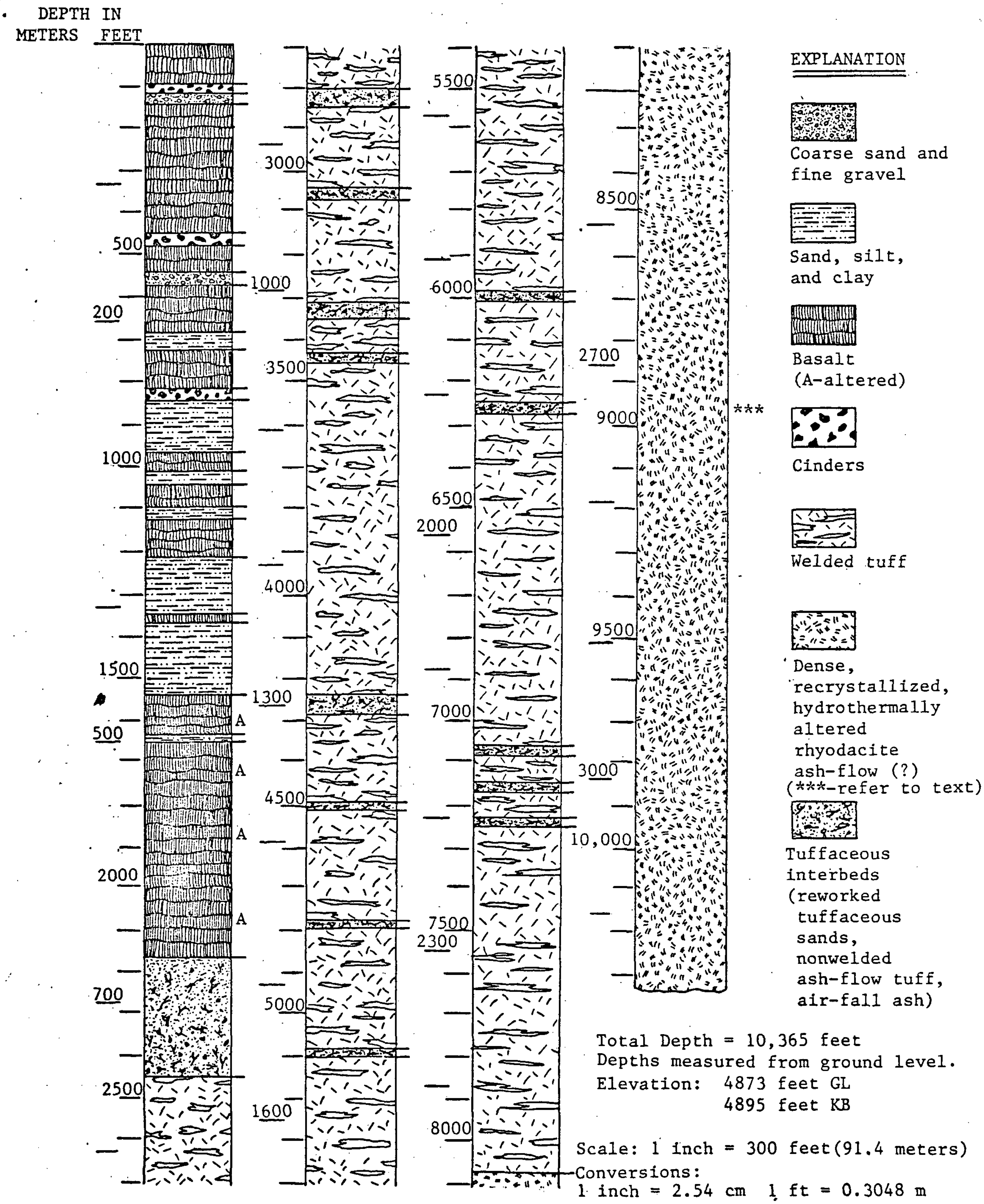

Figure 2.--Generalized lithologic log from exploration geothermal well (INEL-1), Idaho National Engineering Laboratory, Idaho.