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Stratigraphy of the Unsaturated Zone and the Snake River Plain Aquifer at and near the Idaho National Engineering Laboratory, Idaho

U.S. Geological Survey
Water-Resources Investigations Report 97-4183

Prepared in cooperation with the
U.S. DEPARTMENT OF ENERGY

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Idaho Falls, Idaho
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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
foot (ft)	0.3048	meter
mile (mi)	1.609	kilometer
square mile (mi^2)	2.590	square kilometer

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929—a geodetic datum derived from a general adjustment of the first-order level nets of the United States and Canada, formerly called Sea Level Datum of 1929.

Stratigraphy of the Unsaturated Zone and the Snake River Plain Aquifer at and near the Idaho National Engineering Laboratory, Idaho

by S.R. Anderson and Michael J. Liszewski

Abstract

The unsaturated zone and the Snake River Plain aquifer at and near the Idaho National Engineering Laboratory (INEL) are made up of at least 178 basalt-flow groups, 103 sedimentary interbeds, 6 andesite-flow groups, and 4 rhyolite domes. Stratigraphic units identified in 333 wells in this 890-mile^2 area include 121 basalt-flow groups, 102 sedimentary interbeds, 6 andesite-flow groups, and 1 rhyolite dome. Stratigraphic units were identified and correlated using the data from numerous outcrops and 26 continuous cores and 328 natural-gamma logs available in December 1993. Basalt flows make up about 85 percent of the volume of deposits underlying the area.

Several types of data were used to identify and correlate stratigraphic units. Basalt, sediment, andesite, and rhyolite were identified from outcrops and cores selectively evaluated for paleomagnetic inclination and polarity, potassium-argon and argon-argon geologic ages, petrographic characteristics, and major-oxide and trace-element chemical composition. Stratigraphic units were correlated using these data and natural-gamma logs, which respond to potassium contents of generally less than 1 percent in basalt to more than 4 percent in rhyolite. The best stratigraphic correlations at and near the INEL were obtained for basalt and sediment at the Contained Test Facility (CTF), Test Area North (TAN), the Naval Reactors Area, the Test Reactor Area, the Idaho Chemical Processing Plant, the Central Facilities Area, and the Radioactive Waste Management Complex (RWMC), where most cores and two thirds of the logs were obtained. Correlations range from good for units at the RWMC to uncertain for units in the eastern half of the INEL.

Fourteen composite stratigraphic units, each made up of 5 to 90 stratigraphic units of similar age, are used to describe the stratigraphy of the unsaturated zone and aquifer. Upper and lower boundaries of each composite unit were selected to show the main stratigraphic and structural features underlying the INEL and adjacent areas. Composite unit 1, the youngest unit, is made up of 78 basalt-flow groups and 12 sedimentary interbeds. Composite unit 14, the oldest unit, is made up of 4 basalt-flow groups and 1 sedimentary interbed. The decrease in the number of stratigraphic units assigned to each successively older composite unit is attributed partly to larger and less-frequent volcanic eruptions during the accumulation of these units and partly to the limited distribution of available cores used to identify stratigraphic units at greater depths in the subsurface. Composite units 1 through 7 generally range in age from about 200 to 800 thousand years and make up the unsaturated zone and the uppermost part of the Snake River Plain aquifer in most places. Composite units 8 through 14 range in age from about 800 thousand to 1.8 million years and make up the unsaturated zone and aquifer at and near the CTF and TAN and the lowermost part of the aquifer elsewhere. Water levels in the aquifer in 1996 coincided with composite units 4 and 5 in most places; water levels coincided with composite unit 12 at and near the CTF and TAN. Hydraulic gradients of the water table range from about 1 to 15 feet/mile, average about 4 feet/mile, and, in places, change abruptly near concealed uplifts in the aquifer. These abrupt changes indicate that dipping layers and increased sediment content of composite stratigraphic units near uplifts may affect the movement of water and waste in the aquifer.

INTRODUCTION

The Idaho National Engineering Laboratory (INEL) is operated by the U.S. Department of Energy (DOE) and covers about 890 mi^2 of the eastern Snake River Plain in eastern Idaho (fig. 1). Facilities at the INEL are used in the development of peacetime atomic-energy applications, nuclear safety research, defense programs, and advanced energy concepts. Liquid radionuclide and chemical wastes generated at these facilities have been discharged to onsite infiltration ponds and disposal wells since 1952. Liquid-waste disposal has resulted in detectable concentrations of several waste constituents in water from the Snake River Plain aquifer underlying the INEL (Bartholomay and others, 1995).

Concern about the potential for migration of radioactive and chemical wastes in the unsaturated zone and aquifer has resulted in numerous studies of the subsurface at the INEL. In 1988, the U.S. Geological Survey (USGS), in cooperation with the DOE, began a site-wide study of the stratigraphy of volcanic and sedimentary units underlying the INEL to determine stratigraphic relations that might affect the movement of wastes. Three early reports from the study, Anderson and Lewis (1989), Anderson (1991), and Anderson and Bowers (1995), describe stratigraphic relations and their implications regarding the movement of wastes at the Radioactive Waste Management Complex (RWMC), the Idaho Chemical Processing Plant (ICPP), the Test Reactor Area (TRA) and Test Area North (TAN) (fig. 1). Four other reports from the study, Anderson and Bartholomay (1995), Anderson and others (1996a), Anderson and others (1996b), and Anderson and others (1997), describe the method used to identify and correlate stratigraphic units, stratigraphic relations of volcanic and sedimentary units in 333 wells, thickness of surficial sediment, and geologic ages and accumulation rates of basalt and sediment in selected wells, respectively, at and near the INEL. Other facilities for which detailed stratigraphic studies were conducted include the Contained Test Facility (CTF), Naval Reactors Facility (NRF), Argonne National Laboratory-West (ANL-W), Central Facilities Area (CFA), and Experimental Breeder Reactor-1 (EBR-1) (fig. 1). Although the early reports contain important geologic discussions, detailed stratigraphic relations and the names used to identify stratigraphic units described therein are superseded by those in Anderson and others (1996a) and this report.

In this report, a stratigraphic unit is defined as the smallest layer of a rock sequence that can be correlated using the data available in December 1993 (Anderson and others, 1996a). Stratigraphic units described in this report include 178 basalt-flow groups, 104 sedimentary interbeds, 6 andesite-flow groups, and 4 rhyolite domes. Andesite, following the general usage of Kuntz and others (1994), refers to rocks such as those of Cedar Butte that consist mainly of trachyandesite and trachydacite (Le Bas and others, 1986; Hayden, 1992; Fishel, 1993).

Purpose and Scope

This report summarizes the results of the site-wide stratigraphic study since 1988 and is the first to describe stratigraphic relations for the entire INEL and adjacent areas. This report describes the distribution of 292 stratigraphic units and 14 composite stratigraphic units that make up the unsaturated zone and the Snake River Plain aquifer at and near the INEL. Stratigraphic units include the 121 basalt-flow groups, 102 sedimentary interbeds, 6 andesite-flow groups, and 1 rhyolite dome described by Anderson and others (1996a) in 333 wells at and near the INEL. Stratigraphic units also include an additional 57 basalt-flow groups, 1 sedimentary interbed, and 3 rhyolite domes described by Kuntz and others (1994) at the land surface in areas not penetrated by wells. Each composite stratigraphic unit is made up of 5 to 90 stratigraphic units of similar age. Areal coverage of wells and stratigraphic data in this report corresponds with that of the stratigraphic data base presented by Anderson and others (1996a) and the geologic map presented by Kuntz and others (1994); however, most wells from which data were obtained are within the boundary of the INEL. Wells are concentrated near major facilities (figs. 1-5; table 1, located at the end of this report) and are sparse elsewhere at the INEL.

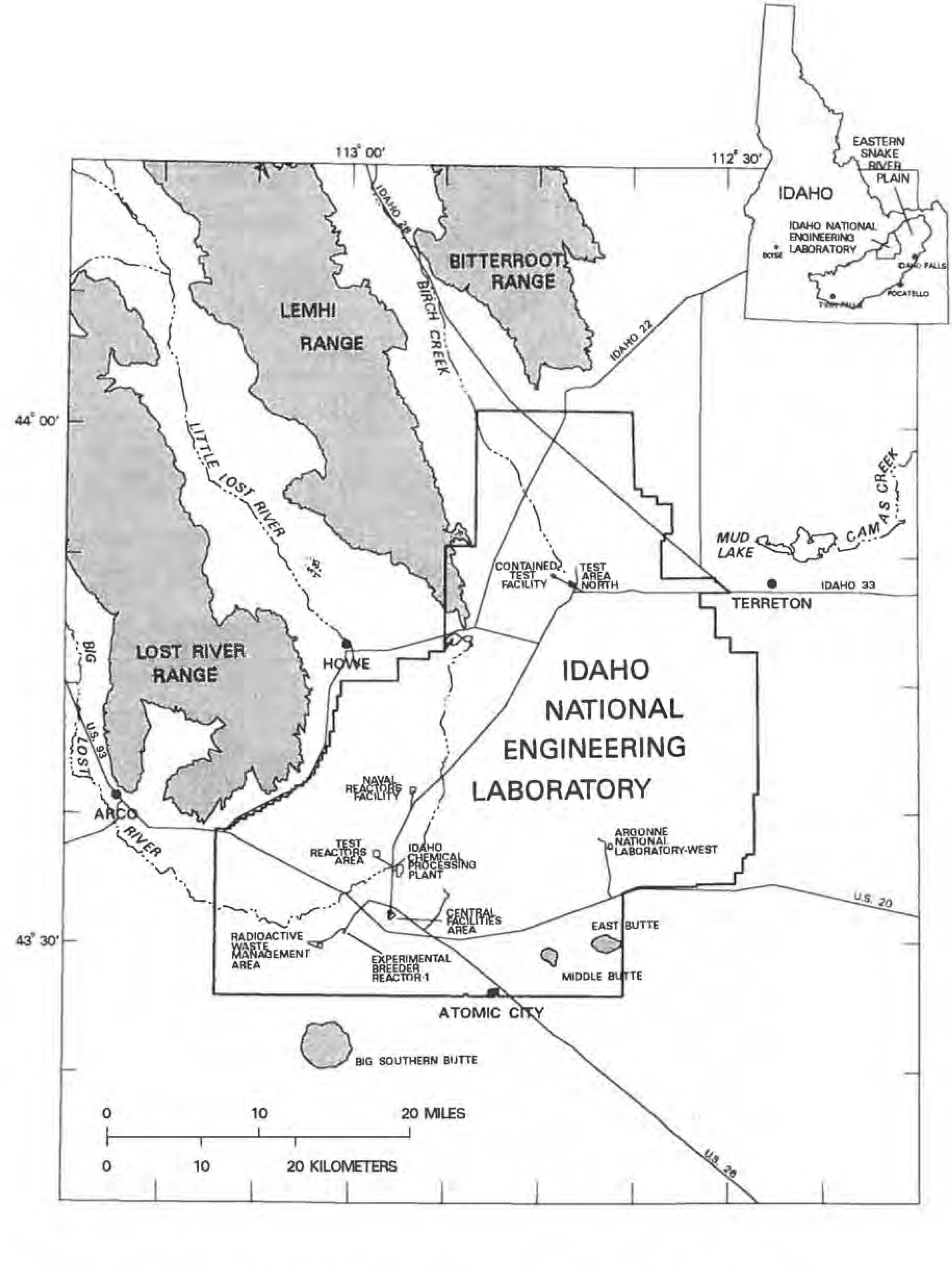

Figure 1. Location of the Idaho National Engineering Laboratory and selected facilities.

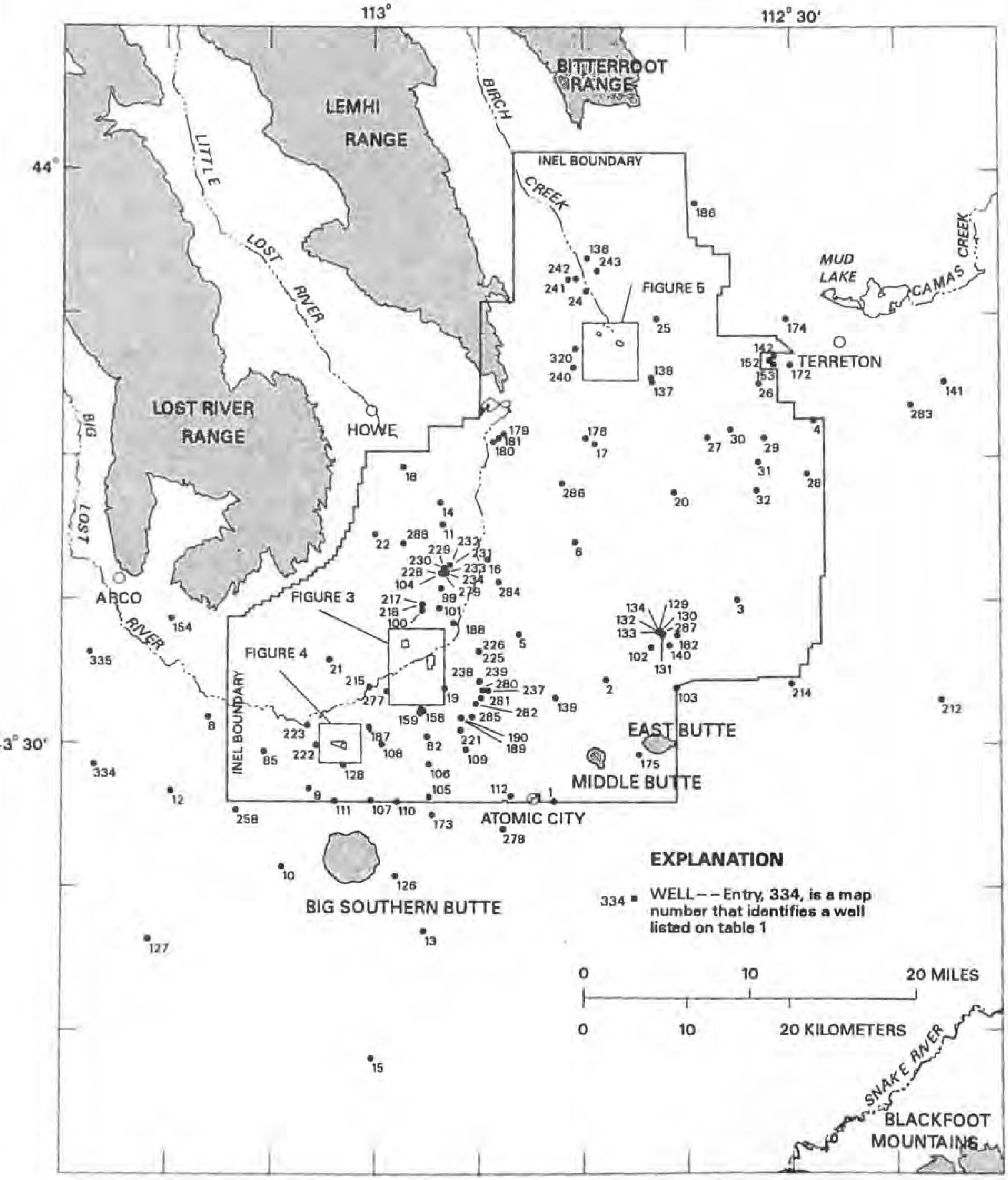

Figure 2. Locations of wells at and near the Idaho National Engineering Laboratory for which stratigraphic data are available.

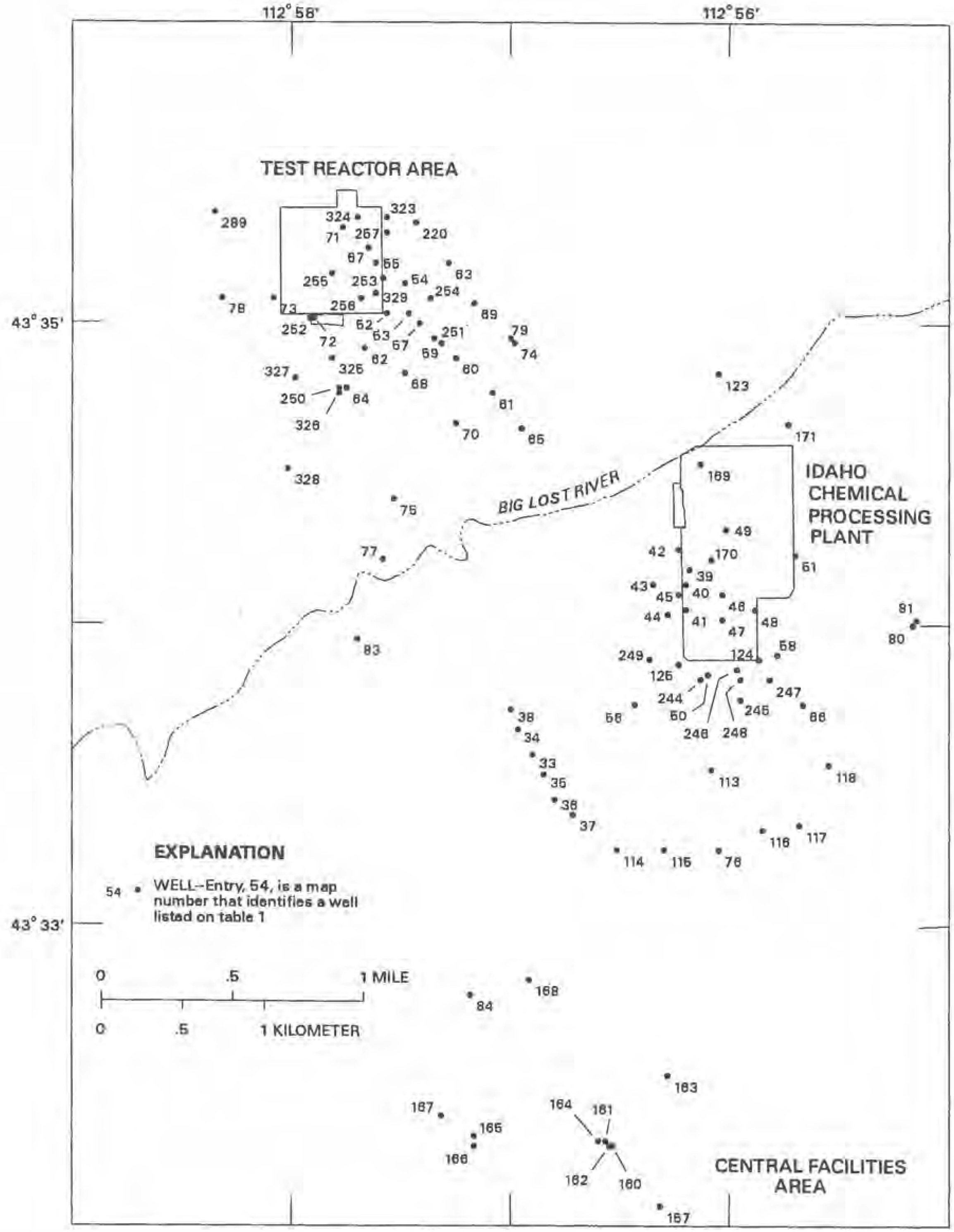

Figure 3. Locations of wells at and near the Idaho Chemical Processing Plant, Test Reactor Area, and Central Facilities Area for which stratigraphic data are available.

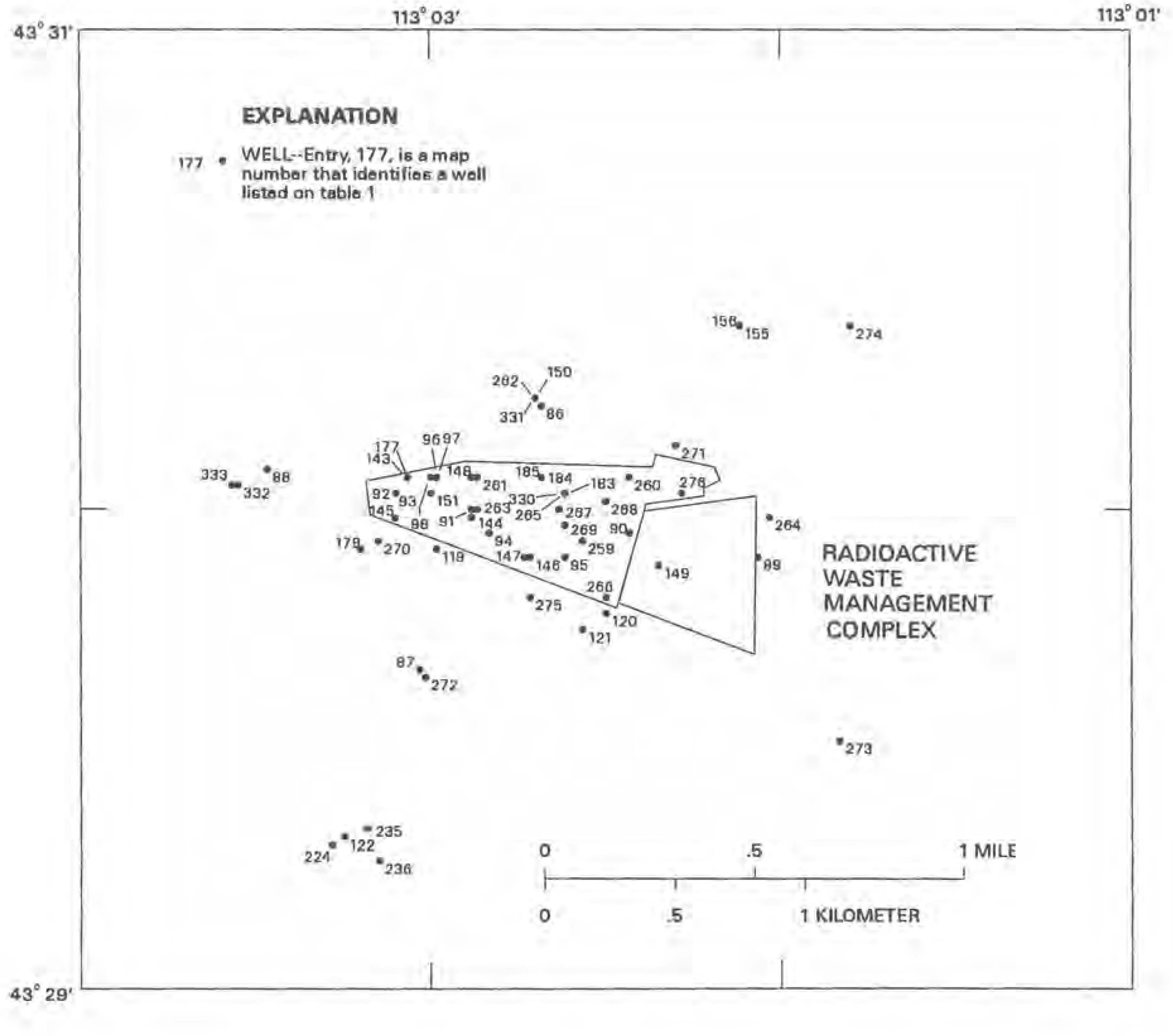

Figure 4. Locations of wells at and near the Radioactive Waste Management Complex for which stratigraphic data are available.

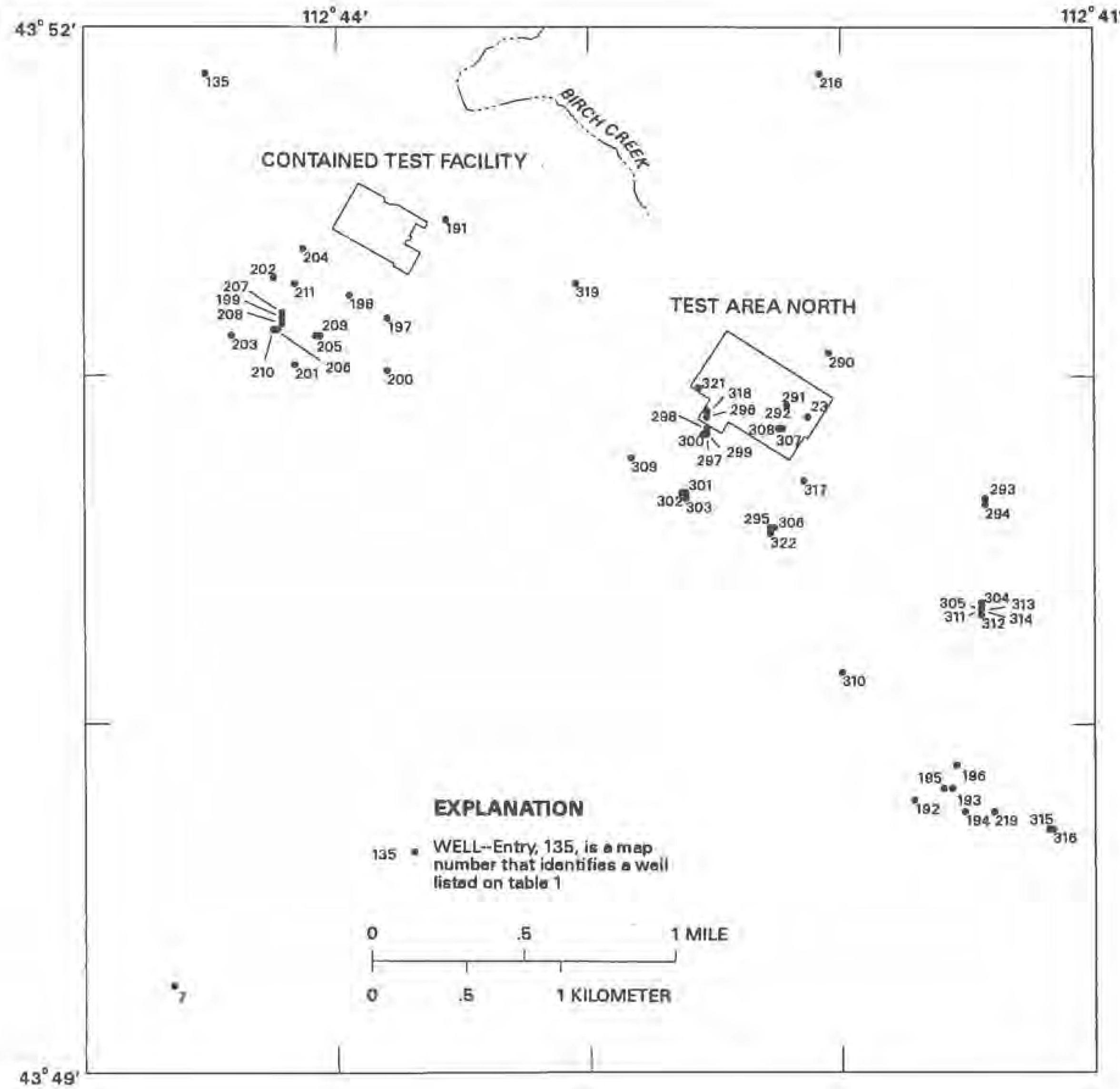

Figure 5. Locations of wells at and near the Contained Test Facility and Test Area North for which stratigraphic data are available.

Because most wells are completed in the unsaturated zone and uppermost part of the aquifer, stratigraphic data for the lowermost part of the aquifer are limited. The reader is referred to Anderson and others (1996a) for detailed stratigraphic data from wells at and near the INEL that form the basis of this report.

Approach

Several types of data were used to identify and correlate stratigraphic units underlying the INEL and adjacent areas. Volcanic and sedimentary units were identified from outcrops and cores selectively evaluated for paleomagnetic inclination and polarity, potassium-argon (K-Ar) and argon-argon ($^{40}Ar/^{39}Ar$) geologic ages, petrographic characteristics, and major-oxide and trace-element chemical composition. Stratigraphic units were correlated using these data and natural-gamma logs, which respond to potassium contents of generally less than 1 percent in basalt to more than 4 percent in rhyolite. The distribution and characteristics of basalt, sediment, andesite, and rhyolite outcrops are described by Kuntz and others (1994). The cores and sources of data used to identify stratigraphic units underlying the area are shown in figure 6 and summarized in table 2 (located at the end of this report). The method for correlating stratigraphic units using cores and natural-gamma logs is described by Anderson and Bartholomay (1995). Stratigraphic relations were determined using numerous outcrops and 26 continuous cores and 328 natural-gamma logs obtained from the wells shown in figures 2-5 and listed in table 1. Natural-gamma logs for many of these wells are available in a report by Bartholomay (1990). These and all other logs are on file at the INEL project office of the USGS. Cores are available for inspection at the INEL Lithologic Core Storage Library (Davis and others, 1997).

Upper and lower boundaries of each composite stratigraphic unit were selected to show the main stratigraphic and structural features underlying the INEL and adjacent areas. Selection of upper and lower boundaries of composite stratigraphic units was influenced by local and regional geologic considerations. Local considerations included the need for boundaries that show the relation of composite units with respect to the geologic ages and distributions of widespread stratigraphic units, clusters of volcanic vents, and interpreted structural features at and near the INEL. Regional considerations included the need for boundaries that show the relation of composite units with respect to previously described geologic formations at and near springs where the aquifer discharges to the Snake River in southern Idaho. Boundaries of composite stratigraphic units include the land surface, the effective base of the aquifer (table 3, located at the end of this report) and the tops of basalt flow groups BC(1), DE2(1), DE5(1), E(1), FG(1), I(1) LM1(1) LM5(1), M(1), NO(1), P(1), R1(1), and S2(1) (table 4, located at the end of this report). Geologic ages of these and other stratigraphic units are described by Anderson and others (1997); selected ages are shown in table 5 (located at the end of this report). The distribution of volcanic vents associated with these and other volcanic units is shown in figure 7. Structural features, which are attributed to past differential subsidence and uplift (Anderson and others, 1997) are shown in figure 6. Composite stratigraphic units 1 through 7 correlate with the Snake River Group, units 8 through 14 with the Bruneau Formation, and deposits older than unit 14, the effective base of the aquifer, with the Glenns Ferry Formation in southern Idaho (Armstrong and others, 1975; Kimmel, 1982; Whitehead and Lindholm, 1985; Whitehead, 1992; Repenning and others, 1995; Anderson and Bowers, 1995).

Acknowledgments

Technical assistance and data from numerous geologic investigations were obtained from Duane E. Champion, Marvin A. Lanphere, and Mel A. Kuntz, USGS, Geologic Division. David B. Frederick, State of Idaho, INEL Oversight Program, and Terrence D. Conlon, USGS, Water Resources Division, reviewed the report and provided many helpful suggestions concerning its content and organization.

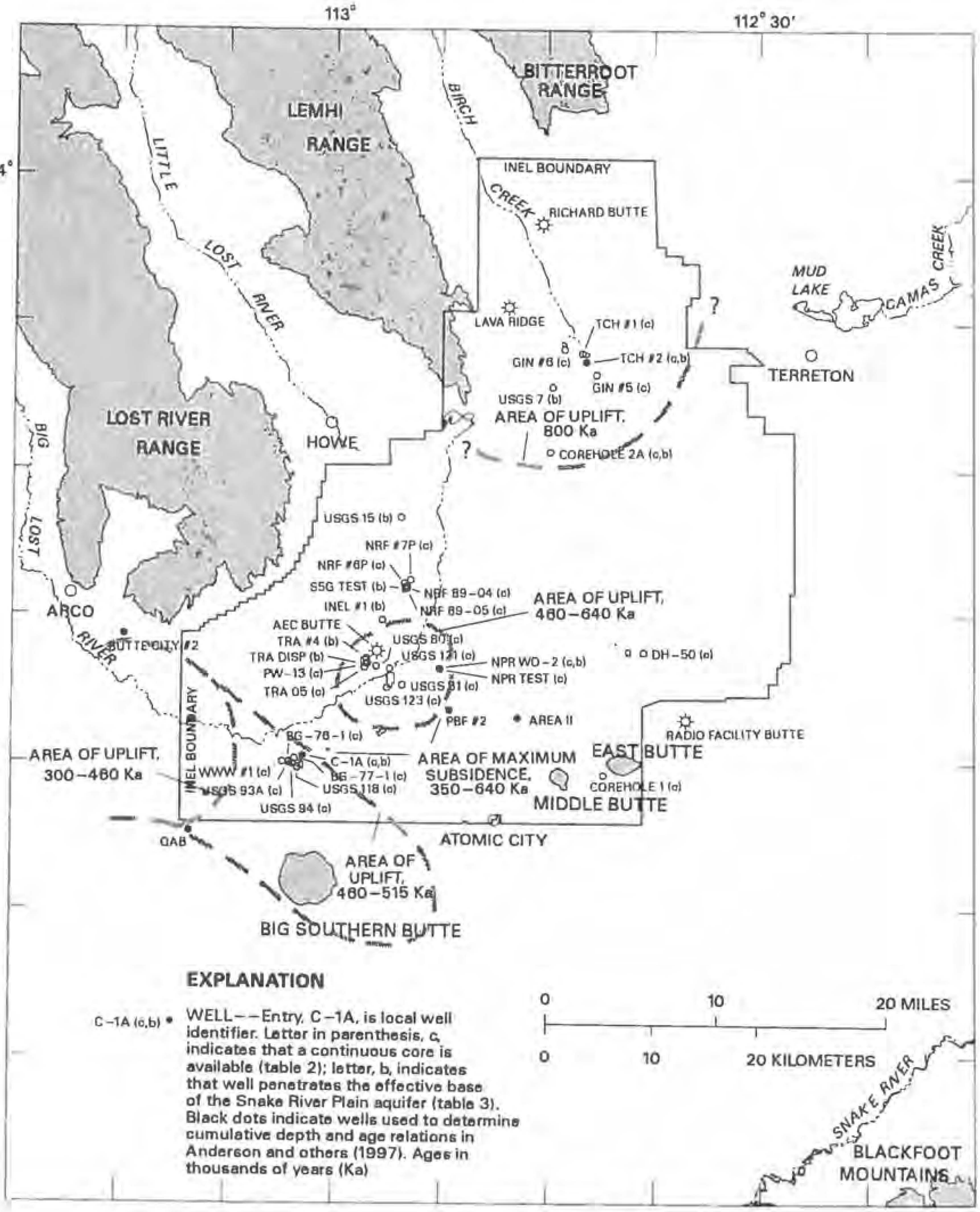

Figure 6. Locations of selected wells and cores used to evaluate geologic ages, accumulation rates, stratigraphy, and structure of basalt-flow groups and sedimentary interbeds in the unsaturated zone and the Snake River Plain aquifer at the Idaho National Engineering Laboratory.

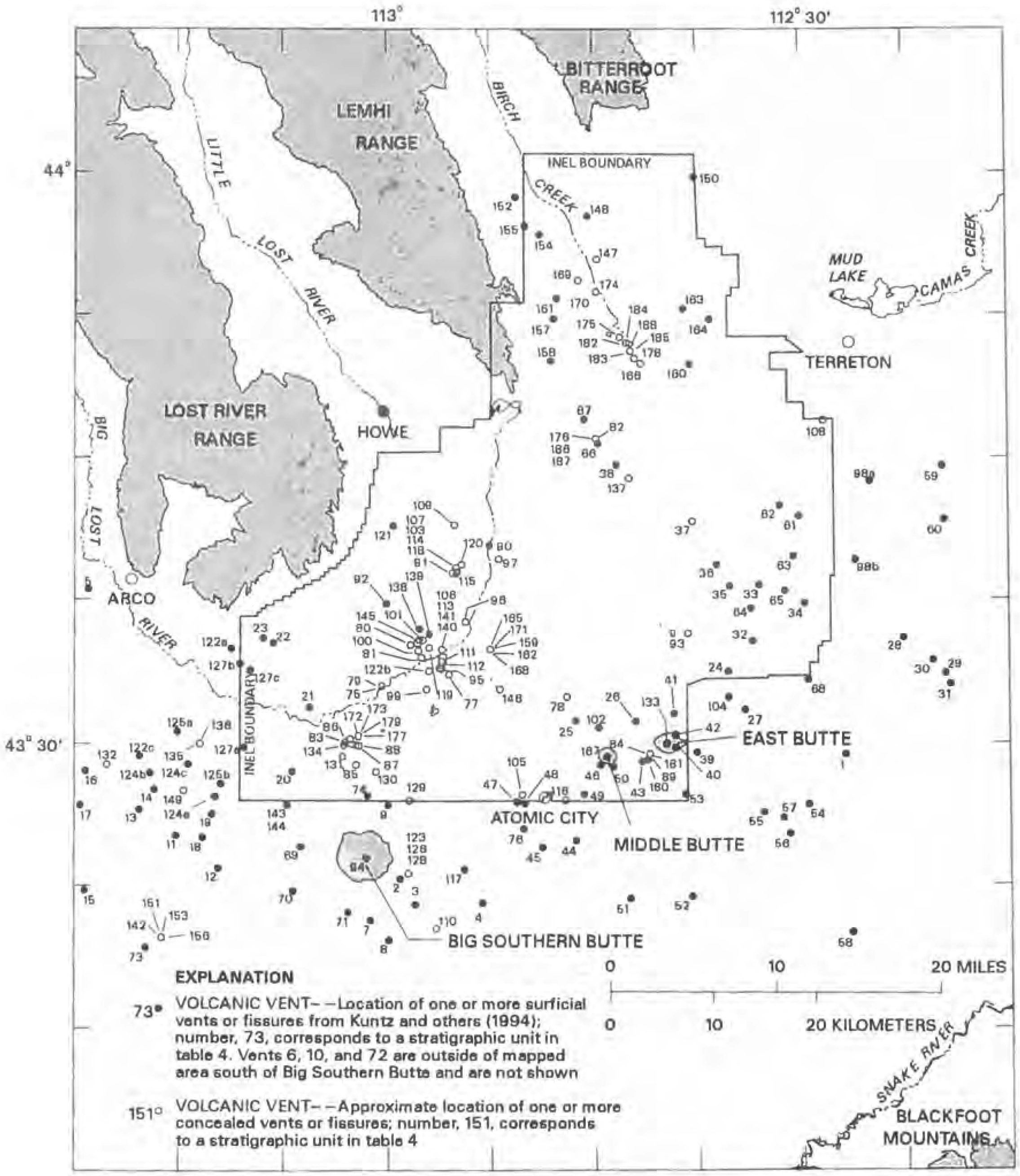

Figure 7. Locations of selected volcanic vents at and near the Idaho National Engineering Laboratory.

GEOHYDROLOGIC SETTING

The INEL is on the west-central part of the eastern Snake River Plain, a northeast-trending structural basin about 200 mi long and 50 to 70 mi wide (fig. 1). The INEL is underlain by a sequence of Tertiary and Quaternary volcanic rocks and sedimentary interbeds that is more than 10,000 ft thick (Walker, 1964; Doherty and others, 1979; Whitehead, 1992; Hackett and others, 1994; Smith and others, 1994). The volcanic rocks consist mainly of basaltic lava flows, ash, and cinders in the upper part and rhyolitic ash flows and tuffs in the lower part. In places, especially along the axis of the plain, Quaternary rhyolite domes stand as high as 2,000 ft above the surface of the plain. The basaltic rocks, which are interbedded with andesite and sediment, underlie the plain to depths ranging from about 2,200 to 3,800 ft in the southwestern part of the INEL. Volcanic vents for the basalt, andesite, and rhyolite (fig. 7) are concentrated in a volcanic zone along the axis of the plain and in volcanic rift zones that trend perpendicular to the axis of the plain (Kuntz and others, 1992; Kuntz and others, 1994).

The INEL is underlain by hundreds of basalt flows, basalt-flow groups, and sedimentary interbeds. Basalt flows make up about 85 percent of the volume of deposits in the unsaturated zone and aquifer; local deposits of sediment make up most of the remaining volume. A basalt flow is a solidified body of rock formed by a lateral, surficial outpouring of molten lava from a vent or fissure (Bates and Jackson, 1980). A basalt-flow group consists of one or more distinct basalt flows deposited during a single eruptive event (Kuntz and others, 1980). All basalt flows of a group erupted from the same volcanic vent or vents and have similar ages, paleomagnetic properties, potassium contents, and natural-gamma emissions (Anderson and Bartholomay, 1995). The basalt flows, which locally are altered (Fromm and others, 1994), consist mainly of medium- to dark-gray vesicular to dense olivine basalt and are as much as 100 ft thick. Sedimentary interbeds, which are most abundant between flow groups, accumulated on the ancestral land surface for hundreds to hundreds of thousands of years during periods of volcanic quiescence. Sedimentary interbeds are as much as 50 ft thick and consist of well- to poorly-sorted deposits of clay, silt, sand, and gravel of fluvial, lacustrine, and eolian origin. In places the interbeds contain cinders and basalt rubble.

The basalt and sediment underlying the INEL, where saturated, form the Snake River Plain aquifer. Depth to water at the INEL ranges from about 200 ft below land surface in the northern part to about 900 ft in the southern part (Ott and others, 1992); the general direction of ground-water flow is northeast to southwest. The effective base of the aquifer at the INEL generally coincides with the top of a thick and widespread layer of clay, silt, sand, and altered basalt that is older than about 1.8 million years (table 5) and equivalent in age to the Glenns Ferry Formation (Anderson and Bowers, 1995). The effective base of the aquifer ranges in depth from 815 to 1,710 ft below land surface in the western half of the INEL (table 3, located at the end of this report); depth to the base may be greater than 1,900 ft in the eastern half of the INEL. The saturated thickness of the aquifer ranges from 445 ft near the TRA to 1,200 ft east of the ICPP (table 3); saturated thickness may be greater than 1,200 ft in the eastern half of the INEL. Hydraulic properties of the aquifer differ considerably from place to place depending on saturated thickness and the characteristics of the basalt and sediment. In places, the basalt and sediment in the uppermost part of the aquifer yield thousands of gallons per minute of water to wells, with negligible drawdown (Ackerman, 1991). Hydraulic data for the basalt, sediment, ash, and tuff underlying the aquifer are sparse, but data from well INEL #1 (fig. 2; tables 1 and 3) indicate that these deposits are relatively impermeable compared with those in the aquifer (Mann, 1986). Localized zones of perched ground water, which are attributed mainly to infiltration of water from unlined percolation ponds and recharge from the Big Lost River, are present in basalt and sediment overlying the regional aquifer (Cecil and others, 1991).

STRATIGRAPHY

Stratigraphic units at and near the INEL consist of basalt-flow groups, surficial sediment/ sedimentary interbeds, andesite-flow groups, and rhyolite domes. About 100 basalt-flow groups, 1 andesite-flow group, 4 rhyolite domes, and surficial sediment cover the INEL and adjacent areas (Kuntz and others, 1994). Stratigraphic units identified in 333 wells completed in the unsaturated zone and the Snake River Plain aquifer include 121 basalt-flow groups, 102 sedimentary interbeds, 6 andesite-flow groups, and 1 rhyolite dome (Anderson and others, 1996a); these units exclude 57 basalt-flow groups, 3 rhyolite domes, and 1 sediment layer that were identified by Kuntz and others (1994) at the land surface but which are not present in wells. Outcrops and subsurface deposits comprise 292 stratigraphic units, each of which was assigned an informal alphanumeric name, from Au(1) to S5(1), that corresponds to its age relative to other units (table 4). The youngest of the 230 units identified in wells was designated Al(1) and the oldest was designated S5(1) (table 4). Basalt, andesite, and rhyolite erupted from numerous volcanic vents (fig. 7), many of which are now concealed by younger deposits (Anderson and Lewis, 1989; Anderson, 1991; Kuntz and others, 1994; Anderson and Bowers, 1995). Locations of concealed vents were approximated on the basis of the greatest thickness of each correlative volcanic unit in wells.

In this report, stratigraphic units and names were modified from and supersede those described in earlier reports about the RWMC (Anderson and Lewis, 1989), the ICPP and TRA (Anderson, 1991), and TAN (Anderson and Bowers, 1995). A numerical suffix was added to all names to describe the relative age of units having the same letter name; for the same letter name, the larger number is the older unit (table 4). For example, the earlier names of basalt-flow groups B, C, and F at the RWMC and LM(E), LM(W), and P at TAN were changed to B(1), C(1), F(1), LM6(2), LM6(3), and P(1), respectively, to show that each letter name corresponds with one or more units. The earlier name of the youngest flow group at the RWMC, A, was changed to Al(9) to show its age relative to the youngest unit at the INEL, Au(1). Many units, such as basalt-flow groups DE3-4(E) and DE3-4(W) at the ICPP and TRA, were subdivided and renamed on the basis of new data; these flow groups are now referred to as DE3-4(1), DE3-4(2), DE3-4(3), and DE3-4(4), respectively. The earlier names of sedimentary interbeds, such as C-D at the RWMC and P-Q at TAN, also were changed to correspond with the names used for volcanic units of the same or similar age; these interbeds are now referred to as CD(1) and PQ(1). Differences between this stratigraphic framework and earlier frameworks are least for units at TAN and greatest for units at the ICPP and TRA.

Determining the geologic ages of basalt flows at the INEL is difficult because all the flows are extremely young and many are altered in and below the lowermost part of the aquifer. The most reliable measured ages generally are obtained from outcrops, the unsaturated zone, and the uppermost part of the aquifer (table 5). Ages of selected basalt, andesite, and rhyolite outcrops and cores were measured using various methods (Champion and others, 1988; Forman and others, 1993; Lanphere and others, 1993; Forman and others, 1994; Kuntz and others, 1994; Lanphere and others, 1994; this report, tables 2 and 5). Ages of selected basalt-flow groups also were estimated using linear accumulation rates in selected wells to evaluate measured ages of flow groups with respect to their stratigraphic position in the subsurface (Anderson and others, 1997; this report, table 5) Measured ages of surficial volcanic units range from about 5.2 thousand to 1.40 million years (Kuntz and others, 1994). Measured ages of basalt-flow groups Al(9) through S5(1) in the unsaturated zone and aquifer range from about 100 thousand to 2.56 million years (table 5). Estimated stratigraphic ages of flow groups Al(9) through S5(1) range from about 100 thousand to 1.71 million years (table 5). Agreement between measured and estimated ages ranges from good for flow groups Al(9) through LM6(3) and R1(1) to poor for flow groups S1(1) through S5(1) (table 5). Flow groups S1(1) through S5(1), which were identified only in the subsurface at and near TAN, either yielded unreliable K-Ar ages (Anderson and Bowers, 1995) or are incorrectly assigned to the lowermost part of the aquifer (Anderson and others, 1996a). If flow groups S1(1) through S5(1) are in the lowermost part of the aquifer as interpreted in table 4, their ages must be less than about 1.8 million years. This conclusion is based on a flow group, TU(1), situated just below the effective base of the aquifer near the ICPP, that yielded a $^{40}Ar/^{39}Ar$ and paleomagnetic age of about 1.86 million years (M.A. Lanphere, USGS, written commun., 1995; this report, table 5). In general, $^{40}Ar/^{39}Ar$ ages are more reliable than K-Ar ages (Berggren and others, 1995), and all measured ages are improved by considering the paleomagnetic polarities and inclinations of their corresponding basalt flows.

Geologic ages of stratigraphic units are constrained by paleomagnetic polarity and inclination data obtained from 25 cores (table 2). Polarity, age, and stratigraphic data from these and three new cores (table 6, located at the back of this report) are consistent with two paleomagnetic chrons, the Brunhes Normal Polarity Chron and the Matuyama Reversed Polarity Chron, and two paleomagnetic subchrons, the Big Lost Reversed Polarity Subchron and the Olduvai Normal Polarity Subchron (Champion and others, 1988; Berggren and others, 1995). Polarity and stratigraphic data also suggest that three additional paleomagnetic subchrons are present in these cores, the Emperor Reversed Polarity Subchron, the Jaramillo Normal Polarity Subchron, and the Cobb Mountain Normal Polarity Subchron (table 6); however, preliminary measured ages of these polarity subchrons are uncertain (D.E. Champion and M.A. Lanphere, USGS, written commun., 1989-95). Stratigraphic units younger than about 780 thousand years generally have normal paleomagnetic polarity and are assigned to the Brunhes Normal Polarity Chron (tables 5 and 6). Basalt-flow group F(1), a unique stratigraphic marker in the lowermost part of the unsaturated zone and uppermost part of the aquifer in the southern part of the INEL, has reversed polarity, an age of about 550 thousand years in well BG-77-1, and is assigned to the Big Lost Reversed Polarity Subchron (Champion and others, 1988, 1996). Units older than about 780 thousand years generally have reversed paleomagnetic polarity and are assigned to the Matuyama Reversed Polarity Chron (tables 5 and 6). Flow group TU(1), a unique stratigraphic marker at the effective base of the aquifer near the ICPP, TAN, and ANL-W, has normal polarity, an age of about 1.86 million years in well NPR WO-2, and is assigned to the Olduvai Normal Polarity Subchron (M.A. Lanphere, USGS, written commun., 1995; this report, table 6). Paleomagnetic inclination of basalt-flow groups generally ranges from 40 to 80 degrees and is similar for all flows of each group. In well USGS 80, for example, inclination ranges from 53.9±1.9 degrees for flow group I(1) to 76.0±2.4 degrees for flow group DE5-6(3) (Lanphere and others, 1993). In well TCH #1, inclination ranges from -50.2±3.9 degrees for flow group R1(1) to -71.5±0.6 degrees for flow groups O(1), P(1), and Q(1) (Lanphere and others, 1994).

Most of the INEL is covered by basalt and sediment older than basalt-flow group A1(9) (table 4), a group that erupted from Quaking Aspen Butte (fig. 7, vent 12) about 100 thousand years ago (Kuntz and others, 1994; this report, table 5). Collectively, basalt-flow groups and sedimentary interbeds AB(1) through L(2) (table 4) range in age from about 200 to 800 thousand years, are widespread, and make up the unsaturated zone and uppermost part of the aquifer in most parts of the INEL. Basalt-flow groups and sedimentary interbeds LM(1) through S5(1), which range in age from about 800 thousand to 1.8 million years, make up the unsaturated zone and aquifer at and near the CTF and TAN (fig. 1) and the lowermost part of the aquifer elsewhere at the INEL (Anderson and Bowers, 1995). Basalt-flow groups and sedimentary interbeds AB(1) through S5(1) make up a stratigraphic section that is characterized by horizontal to inclined layers (Anderson and Lewis, 1989; Anderson, 1991; Anderson and Bowers, 1995). Each basalt-flow group in the section was deposited during an eruptive event that lasted no more than a few hundred years (Kuntz and others, 1980). The average length of time between these eruptions was about 10 to 20 thousand years, sufficiently long to accumulate thick layers of sediment in many areas. In places, the section is characterized by missing intervals of basalt and sediment. These interruptions in accumulation, which are referred to as hiatuses

(Anderson and others, 1997), generally represent no more than a few tens of thousands of years at any one place. However, prolonged hiatuses, which are defined as missing intervals of basalt representing periods of at least 200 thousand years, characterize the land surface in most parts of the INEL and nearby areas above basalt-flow groups AB(2) through AB(58) (table 4) and occur within the stratigraphic section at and near the ICPP, TRA, RWMC, CTF, and TAN (fig. 1). The prolonged hiatus at the land surface has resulted from significantly reduced volcanism during the past 200 thousand years; for millions of years before the past 200 thousand years, the frequency and volume of eruptions were much greater (Kuntz and others, 1994; Anderson and Bowers, 1995). Prolonged hiatuses at and near the ICPP, TRA, RWMC, CTF, and TAN are attributed to differential subsidence and uplift (fig. 6) during the past 1.8 million years (Smith and others, 1994; Anderson and others, 1997). Uplift, which last occurred about 300 to 800 thousand years ago (fig. 6), probably resulted from the emplacement of laccoliths and domes within or beneath the subsiding stratigraphic section (Anderson and others, 1997); alternatively, some of these areas can be interpreted as areas of past differential subsidence or faulting.

Composite Stratigraphic Units

Fourteen composite stratigraphic units, each made up of 5 to 90 stratigraphic units of similar age (table 4), are used to describe the stratigraphy of the unsaturated zone and the Snake River Plain aquifer at and near the INEL. Upper and lower boundaries of each composite unit were selected to show the main stratigraphic and structural features underlying the area. Composite unit 1, the youngest unit, is made up of 78 basalt-flow groups and 12 sedimentary interbeds between the tops of sedimentary interbed Au(1) and basalt-flow group BC(1). Composite unit 14, the oldest unit, is made up of 4 basalt-flow groups and 1 sedimentary interbed between the top of basalt-flow group S2(1) and the effective base of the aquifer. Composite units 2 through 13 collectively are made up of 96 basalt-flow groups, 90 sedimentary interbeds, 6 andesite-flow groups, and 4 rhyolite domes. Composite units 2 through 13 have upper and lower boundaries that coincide with the tops of basalt-flow groups BC(1), DE2(1), DE5(1), E(1), FG(1), I(1), LM1(1) LM5(1), M(1), NO(1), P(1), R(1), and S2(1) (table 4). All composite units locally include some, most, or all of the stratigraphic units assigned to each on table 4. The decrease in the number of stratigraphic units assigned to each successively older composite unit (table 4) is attributed partly to larger and less-frequent volcanic eruptions during the accumulation of these units and partly to the limited distribution of available cores used to identify stratigraphic units at greater depths in the subsurface (fig. 6; table 2).

The distributions, altitudes, and thicknesses of composite stratigraphic units 1 through 14 are shown in figures 8 through 30 and are summarized in table 7 (located at the end of this report). The average thickness of composite units ranges from 62 ft for unit 1 to 266 ft for unit 7; the average thickness of units 8 through 14, which are combined in figures 29 and 30 because of insufficient areal distribution of data for individual units, is 832 ft in six representative wells. Average sediment content of composite units ranges from 5 percent for unit 5 to 47 percent for unit 1. Topographic relief on the top of composite units, disregarding the relief of individual volcanic vents and rhyolite domes, ranges from 469 ft for unit 3 to 1,171 ft for units 8 through 14. Water levels in the aquifer in 1996 coincided with composite units 4 and 5 throughout most of the INEL and adjacent areas; water levels coincided with unit 12 at and near the CTF and TAN.

Composite stratigraphic unit 1.—Composite stratigraphic unit 1 (figs. 8-17) includes mainly surficial sediment in the central parts of the INEL and young basalt flows east through southwest of the INEL (Kuntz and others, 1994; Anderson and others, 1996b); this unit includes 78 basalt-flow groups and 12 sedimentary interbeds (table 7). Unit 1 is fully penetrated by 326 of the 333 wells evaluated by Anderson and others (1996a) at and near the INEL (fig. 2), including all 96 wells at the ICPP, TRA, and CFA (fig. 3), 54 of the 58 wells at the RWMC (fig. 4), and all 58 wells at the CTF and TAN (fig. 5). In the wells where it is present, the top of unit 1, which coincides with the land surface, ranges in altitude from 5,375 ft above sea level in well USGS 13 to 4,772 ft in well USGS 28. The base of the unit ranges in altitude from 5,362 ft in well USGS 13 to 4,721 ft in well GIN #6. Thickness of unit 1 ranges from 0 to 284 ft, averages 62 ft in the 326 wells that fully penetrate its base, and is greatest in well USGS 124. Sediment content of unit 1 ranges from none in wells USGS 16 and NPR WO-2 to 100 percent in many wells; content averages 47 percent in the 326 wells that fully penetrate its base. The number of sedimentary interbeds in the unit at any one place ranges from none in wells USGS 16 and NPR WO-2 to five in well Butte City #2. Composite unit 1 is made up of stratigraphic units Au(1) through B-BC(4) (table 4); geologic ages of these units range from about 5 to 250 thousand years (Kuntz and others, 1994; Anderson and others, 1997). Basalt-flow groups in composite unit 1 erupted from vents 1 through 78 (fig. 7), located mainly in the eastern through southwestern parts of the area.

Composite stratigraphic unit 2.—Composite stratigraphic unit 2 (figs. 8-15 and 17-19) includes 18 basalt-flow groups, 13 sedimentary interbeds, and 1 rhyolite dome, Big Southern Butte (fig. 8, table 7). The top of this composite unit is penetrated by 234 of the 333 wells evaluated by Anderson and others (1996a) at and near the INEL (fig. 2), including 93 of the 96 wells at the ICPP, TRA, and CFA (fig. 3), 54 of the 58 wells at the RWMC (fig. 4), and 1 of the 58 wells at the CTF and TAN (fig. 5). The base of this unit is penetrated by 178 wells at and near the INEL, including 75 wells at the ICPP, TRA and CFA, 22 wells at the RWMC, and 1 well at the CTF and TAN. In the wells where it is present, the top of composite unit 2 ranges in altitude from 5,299 ft above sea level in well Corehole 1 to 4,732 ft in well ANP #9. The base of the unit ranges in altitude from 5,175 ft in well Weaver and Lowe to 4,659 ft in the EFS well. Thickness of unit 2 ranges from 0 to 321 ft, averages 109 ft in the 178 wells that fully penetrate its base, and is greatest in well Corehole 1. Sediment content of unit 2 ranges from none to 100 percent in many wells and averages 11 percent in the 178 wells that fully penetrate its base. The number of sedimentary interbeds in the unit at any one place ranges from none in many wells to five in well USGS 59. Composite unit 2 is made up of stratigraphic units BC(1) through DE1-2(3) (table 4); geologic ages of these units range from about 250 to 350 thousand years (Kuntz and others, 1994; Anderson and others, 1997). Basalt-flow groups in composite unit 2 erupted from volcanic vents 79 through 97 (fig. 7), located mainly in the southern part of the area; Big Southern Butte (fig. 8), stratigraphic unit DE1(4), erupted from vent 94.

Composite stratigraphic unit 3.—Composite stratigraphic unit 3 (figs. 8-15 and 19-21) includes 17 basalt-flow groups, 17 sedimentary interbeds, and 1 andesite-flow group (table 7). The top of this composite unit is penetrated by 164 of the 333 wells evaluated by Anderson and others (1996a) at and near the INEL (fig. 2), including 78 of the 96 wells at the ICPP, TRA, and CFA (fig. 3), none of the 58 wells at the RWMC (fig. 4), and 1 of the 58 wells at the CTF and TAN (fig. 5). The base of this unit is penetrated by 143 wells at and near the INEL, including 66 wells at the ICPP, TRA, and CFA, none of the wells at the RWMC, and 1 well at the CTF and TAN. In the wells where it is present, the top of composite unit 3 ranges in altitude from 5,128 ft above sea level in well Butte City #2 to 4,659 ft in the EFS well. The base of the unit ranges in altitude from 5,048 ft in well Butte City #2 to 4,465 ft in well USGS 17. Thickness of unit 3 ranges from 0 to 305 ft, averages 164 ft in the 143 wells that penetrate its base, and is greatest in well Highway #2. Sediment content of unit 3 ranges from none to 100 percent in many wells and averages 15 percent in the 143 wells that fully penetrate its base. The number of sedimentary interbeds in the unit at any one place ranges from none in many wells to seven in wells Barney North, Site 14, and DH1B, located east through southwest of the CTF and TAN. Composite unit 3 is made up of stratigraphic units DE2(1) through DE4-5(5) (table 4); geologic ages of these units range from about 350 to 440 thousand years (Kuntz and others, 1994; Anderson and others, 1997). Basalt-flow groups in composite unit 3 erupted from volcanic vents 98a and 98b through 115 (fig. 7), located mainly in the eastern and southern parts of the area; andesite-flow group DE4(2), which could be related to the older flows of Cedar Butte (fig. 8), erupted from vent 110.

Composite stratigraphic unit 4.—Composite stratigraphic unit 4 (figs. 8-15 and 21-23) includes 9 basalt-flow groups, 11 sedimentary interbeds, and 4 andesite-flow groups (table 7); the youngest andesite flow group erupted from Cedar Butte (fig. 8). The top of this composite unit is penetrated by 172 of the 333 wells evaluated by Anderson and others (1996a) at and near the INEL (fig. 2), including 66 of the 96 wells at the ICPP, TRA, and CFA (fig. 3), 17 of the 58 wells at the RWMC (fig. 4), and none of the 58 wells at the CTF and TAN (fig. 5). The base of this unit is penetrated by 146 wells at and near the INEL, including 60 wells at the ICPP, TRA, and CFA, 17 wells at the RWMC, and none of the wells at the CTF and TAN. In the wells where it is present, the top of composite unit 4 ranges in altitude from 5,362 ft above sea level in well USGS 13 to 4,465 ft in well USGS 17. The base of the unit ranges in altitude from 5,257 ft in well Water table to 4,272 ft in well S5G Test. Thickness of unit 4 ranges from 0 to 482 ft, averages 138 ft in the 146 wells that penetrate its base, and is greatest in well USGS 124. Sediment content of unit 4 ranges from none to 100 percent in many wells and averages 11 percent in the 146 wells that fully penetrate its base. The number of sedimentary interbeds in the unit at any one place ranges from none in many wells to five in well DH2A southwest of the CTF and TAN. Composite unit 4 is made up of stratigraphic units DE5(1) through DE9(1) (table 4); geologic ages of these units range from about 440 to 515 thousand years (Kuntz and others, 1994; Anderson and others, 1997). Basalt-flow groups in composite unit 4 erupted from volcanic vents 116 through 128 (fig. 7), located mainly in the southwestern part of the area. Cedar Butte (fig. 8), stratigraphic unit DE5-6(1), erupted from vent 117; andesite-flow groups DE6(2), DE7(2), and DE8(2), which could be related to the younger flows of Cedar Butte, erupted from vents 123, 126, and 128, respectively.

Composite stratigraphic unit 5.—Composite stratigraphic unit 5 (figs. 8-15 and 23-25) includes 3 basalt-flow groups and 6 sedimentary interbeds (table 7). The top of this composite unit is penetrated by 143 of the 333 wells evaluated by Anderson and others (1996a) at and near the INEL (fig. 2), including 55 of the 96 wells at the ICPP, TRA, and CFA (fig. 3), 22 of the 58 wells at the RWMC (fig. 4), and none of the 58 wells at the CTF and TAN (fig. 5). The base of this unit is penetrated by 114 wells at and near the INEL, including 44 wells at the ICPP, TRA, and CFA, 20 wells at the RWMC, and none of the wells at the CTF and TAN. In the wells where it is present, the top of composite unit 5 ranges in altitude from 5,257 ft above sea level in well Water table to 4,272 ft in well S5G Test. The base of the unit ranges in altitude from 5,059 ft in well Water table to 4,093 ft in well EBR-1. Thickness of unit 5 ranges from 0 to 329 ft, averages 125 ft in the 114 wells that penetrate its base, and is greatest in well USGS 120. Sediment content of unit 5 ranges from none in many wells to 100 percent in wells Weaver and Lowe, USGS 15, and Cope; content averages 5 percent in the 114 wells that penetrate its base. The number of sedimentary interbeds in the unit at any one place ranges from none in many wells to four in well USGS 15 north of the NRF. Composite unit 5 is made up of stratigraphic units E(1) through F(2) (table 4); geologic ages of these units range from about 515 to 580 thousand years (Kuntz and others, 1994; Anderson and others, 1997). Basalt-flow groups in composite unit 5 erupted from volcanic vents 129, 130, and 131 (fig. 7), located between the RWMC and Big Southern Butte (fig. 8).

Composite stratigraphic unit 6.—Composite stratigraphic unit 6 (figs. 8-15 and 25-27) includes 5 basalt-flow groups, 8 sedimentary interbeds, and 1 rhyolite dome, East Butte (fig. 8; table 7). The top of this composite unit is penetrated by 118 of the 333 wells evaluated by Anderson and others (1996a) at and near the INEL (fig. 2), including 46 of the 96 wells at the ICPP, TRA, and CFA (fig. 3), 20 of the 58 wells at the RWMC (fig. 4), and none of the wells at the CTF and TAN (fig. 5). The base of this unit is penetrated by 68 wells at and near the INEL, including 35 wells at the ICPP, TRA, and CFA, 8 wells at the RWMC, and none of the wells at the CTF and TAN. In the wells where it is present, the top of composite unit 6 ranges in altitude from 5,089 ft above sea level in well USGS 16 to 4,093 ft in well EBR-1. The base of the unit ranges in altitude from 4,876 ft in well USGS 16 to 3,939 ft in well EOCR. Thickness of unit 6 ranges from 0 to 347 ft, averages 107 ft in the 68 wells that penetrate its base, and is greatest in well Water table. Sediment content of unit 6 ranges from none to 100 percent in many wells and averages 23 percent in the 68 wells that penetrate its base. The number of sedimentary interbeds in the unit at any one place ranges from none in many wells to four in well OW-1 at the RWMC. Composite unit 6 is made up of stratigraphic units FG(1) through HI(2) (table 4); geologic ages of these units range from about 580 to 650 thousand years (Kuntz and others, 1994; Anderson and others, 1997). Basalt-flow groups in composite unit 6 erupted from volcanic vents 132 through 137 (fig. 7), located mainly in the southern and southwestern parts of the area. East Butte (fig. 8), stratigraphic unit FG(2), erupted from vent 133.

Composite stratigraphic unit 7.—Composite stratigraphic unit 7 (figs. 8-15 and 27-29) includes 7 basalt-flow groups and 10 sedimentary interbeds (table 7). The top of this composite unit is penetrated by 70 of the 333 wells evaluated by Anderson and others (1996a) at and near the INEL (fig. 2), including 38 of the 96 wells at the ICPP, TRA, and CFA (fig. 3), 3 of the 58 wells at the RWMC (fig. 4), and none of the wells at the CTF and TAN (fig. 5). The base of this unit is penetrated by 15 wells at and near the INEL, including 2 wells at the ICPP, TRA, and CFA, and none of the wells at the RWMC, CTF, and TAN. In the wells where it is present, the top of composite unit 7 ranges in altitude from 4,876 ft above sea level in well USGS 16 to 3,939 ft in well EOCR. The base of the unit ranges in altitude from 4,592 ft in well USGS 16 to 3,807 ft in well PBF #2. Thickness of unit 7 ranges from 0 to 409 ft, averages 266 ft in the 15 wells that fully penetrate its base, and is greatest in well TRA Disp. Sediment content of unit 7 ranges from none in 4 wells to 59 percent in well INEL #1; content averages 13 percent in the 15 wells that fully penetrate its base. The number of sedimentary interbeds in the unit at any one place ranges from none in four wells to five in well INEL #1, between the TRA and NRF. Composite unit 7 is made up of stratigraphic units I(1) through L(2) (table 4); geologic ages of these units range from about 650 to 800 thousand years (Kuntz and others, 1994; Anderson and others, 1997). Basalt-flow groups in composite unit 7 erupted from volcanic vents 138 through 144 (fig. 7), located near the ICPP and TRA and southwest of the RWMC.

Composite stratigraphic units 8 through 14.—Composite stratigraphic units 8 through 14 (figs. 8-15, 29, and 30) include 41 basalt-flow groups, 26 sedimentary interbeds, 1 andesite-flow group, and 2 rhyolite domes, Middle Butte and the unnamed dome between Middle Butte and East Butte (fig. 8; table 7). The top of these combined units is penetrated by 86 of the 333 wells evaluated by Anderson and others (1996a) at and near the INEL (fig. 2), including 2 of the 96 wells at the ICPP, TRA, and CFA (fig. 3), 1 of the 58 wells at the RWMC (fig. 4), and all 58 of the wells at the CTF and TAN (fig. 5). The base of these combined units is penetrated by 8 of the 333 wells evaluated by Anderson and others (1996a) at and near the INEL, including 2 wells at the ICPP, TRA, and CFA, 1 well at the RWMC, and 2 wells at the CTF and TAN; two additional wells penetrate the effective base of the aquifer below the base of composite unit 7 where units 8 through 14 are not present. Preliminary core studies indicate that a new deep well, ANL-OBS-AQ-014 (Davis and others, 1997; this report (ANL-014), figs. 8, 14, and 15), also penetrates units 8 through 14 (D.E. Champion, USGS, written commun., 1996). In the 9 wells that fully penetrate units 8 through 14, the top of the combined units ranges in altitude from 4,978 ft above sea level in well Corehole 1 to 3,807 ft in well PBF #2. The base of the combined units ranges in altitude from 4,017 ft in well TRA Disp to 3,260 ft in well ANL-014. Thickness of the combined units 8 through 14 in 5 wells mountainward of the Big Lost River, wells USGS 15, S5G Test, INEL #1, TRA #4, and TRA Disp, ranges from 0 to 43 ft. Thickness of the combined units in other parts of the INEL ranges from 602 ft in well TCH #2 to 1,007 ft in well C-1A, a range that does not include the greater thickness, at least 1,609 ft, of the unnamed rhyolite dome and an underlying andesite-flow group in well Corehole 1. Average thickness of combined units is 832 ft in wells

TCH #2, USGS 7, Corehole 2A, NPR WO-2, and ANL-014 that penetrate a representative stratigraphic interval in areas basinward of the Big Lost River. In these wells, sediment content ranges from 4 to 13 percent, averages 7 percent, and is greatest in well C-1A at the RWMC; the number of sedimentary interbeds at any one place ranges from three to eight and is greatest in well NPR WO-2, east of the ICPP. Composite units 8 through 14 are made up of stratigraphic units LM1(1) through S5(1) (table 4); the most likely geologic ages of these units, using a combination of measured and estimated ages, range from about 800 thousand to 1.8 million years (Kuntz and others, 1994; Anderson and others, 1997). Basalt-flow groups in composite units 8 through 14 erupted from volcanic vents 145 through 188 (fig. 7), located mainly at and near the ICPP, RWMC, CTF, and TAN. The rhyolite of Middle Butte (fig. 8), composite unit 10 and stratigraphic unit M(2), erupted from vent 167; this age and vent number, which are based on the measured age of an older basalt flow overlying this dome (Kuntz and others, 1994), represent a maximum age for the rhyolite and its concealed vent. The adjacent unnamed rhyolite dome (fig. 8) and the underlying andesite-flow group in well Corehole 1, composite unit 12 and stratigraphic units QR(2) and QR(3), erupted from vents 180 and 181, respectively (fig. 7).

Evaluation of Stratigraphic Interpretations

Stratigraphic units Au(1) through S5(1) (Anderson and others, 1996a; this report, table 4) and composite stratigraphic units 1 through 14 (figs. 8-30) provide local- to regional-scale stratigraphic frameworks, respectively, for use in hydrologic investigations of the unsaturated zone and the Snake River Plain aquifer at and near the INEL. Stratigraphic relations that make up these frameworks are complex, represent the most reasonable interpretations of the data available in December 1993, and can be evaluated using these data and additional data collected since December 1993. Because stratigraphic relations are complex and core data are limited (fig. 6), some regional-scale relations, mainly those of individual basalt-flow groups, are uncertain in some areas. In addition, the stratigraphic method used in this study, a combination of paleomagnetism, geochronology, petrography, chemistry, and natural-gamma logs (Anderson and Bartholomay, 1995) could not resolve the distribution of some local-scale stratigraphic features, mainly those of individual basalt flows, beyond adjacent cores (Kuntz and others, 1980; Lanphere and others, 1993; Lanphere and others, 1994). Also, stratigraphic correlations of every scale are dependent on agreement between the diverse types of data used to identify and correlate units in the subsurface. Data for some areas agree (Anderson and Bartholomay, 1995) and for others disagree (Anderson and Bowers, 1995; Smith and others, 1996).

Of the youngest 73 basalt-flow groups identified in outcrops, units Au(2) through Au(5), A1(2) through Al(13), and AB(2) through AB(58), only 22 were identified in wells. This is due partly to the distribution of flow groups and partly to the distribution of wells from which cores and natural-gamma logs were obtained. Although some young flow groups were locally derived, most erupted from vents east through southwest of the INEL (Kuntz and others, 1994; this report, fig. 7) and did not have sufficient volume to cover the area now occupied by the CTF, TAN, NRF, TRA, ICPP, CFA, and RWMC, where most cores and two thirds of the natural-gamma logs were obtained. Identification and correlation of young flow groups in outlying areas were aided by knowing the distribution of outcrops; however, because cores and wells are sparse in these areas, identification and correlation of many older flow groups are uncertain and may be biased by data collected from the facilities located near the Big Lost River (fig. 6). Positive identifications and correlations, consistent with interpretations in this report, have been made for some older flow groups, such as flow group F(1) (table 6), using cores obtained from wells as many as 11 mi apart (Kuntz and others, 1980; Champion and others, 1988; Lanphere and others, 1993; Lanphere and others, 1994; Champion and others, 1996; Reed and others, 1997); however, additional cores are needed to verify similar interpretations made from natural-gamma logs for older flow groups in outlying areas. If the number and distribution of older flow groups are similar to those of young flow groups, there may be as many as 300 additional flow groups, not yet identified, in the unsaturated zone and aquifer in outlying areas.

Correlations made using the data obtained as of December 1993 are best for units at the CTF, TAN, NRF, TRA, ICPP, CFA, and RWMC, where most of these data were obtained, and range from good for units at the RWMC to uncertain for units in the eastern half of the INEL. Uncertain correlations mainly include those of basalt interpreted from natural-gamma logs that exceed the maximum known areal extent of basalt-flow groups determined by other methods (Champion and others, 1988; Kuntz and others, 1994; Champion and others, 1996). Data from outcrops and cores suggest that the largest flow groups in the subsurface may extend no more than 10 to 15 mi beyond their vents and cover areas of less than to much less than 300 mi^2. Basalt-flow groups reported by Anderson and others (1996a) that exceed these dimensions, such as flow group I(2) (fig. 7, vent 139; table 4), probably are aggregate flow groups, referred to as supergroups by Welhan and others (1997) and Wetmore and others (1997), made up of two or more individual flow groups. Although the number and distribution of flow groups are uncertain in some areas, the overall stratigraphic framework is consistent with the distribution of many widespread sedimentary interbeds. The most widespread interbeds, B-BC(2), CD(1), DE2-3(1), DE5-6(6), DE9(1), and HI(1) (table 4), are about 230, 285, 355, 470, 500, and 640 thousand years old, respectively (Anderson and others, 1997). These and other interbeds and the surficial sediment, stratigraphic units Au(1), Al(1), AB(1), and B(1) (table 4), were deposited over large areas during periods of general volcanic quiescence that include the past 200 thousand years.

The stratigraphic framework in the southern part of the INEL also is consistent with newly acquired chemical data from wells NPR Test, USGS 121, and USGS 123 (table 2), located at and near the ICPP (Knobel and others, 1995; Reed and others, 1997), and paleomagnetic data from wells STF-PIE-AQ-01 and ARA-COR-005, located about 7 and 11 mi east of the RWMC, respectively (Champion and others, 1996; Davis and others, 1997). Stratigraphic relations in many parts of this area were interpreted from natural-gamma logs, which respond to time-dependent changes in potassium contents of basalt-flow groups. Previously acquired potassium contents of basalt cores from wells at the RWMC range from about 0.25 percent in flow group E(1) to about 0.70 percent in flow groups D(1) and F(1) (Anderson and Bartholomay, 1995). Potassium contents of basalt cores from wells NPR Test, USGS 121, and USGS 123 range from about 0.20 percent in flow group DE8 to about 1.30 percent in flow group DE1-2(1). Potassium contents gradually increase from about 0.20-0.25 percent in flow groups DE8(1) and E(1), which erupted from vents 127a through 129 about 500 thousand years ago (fig. 7; tables 4 and 5), to about 1.30 percent in flow group DE1-2(1), which erupted from vent 95 at nearly the same time as the rhyolite of Big Southern Butte, vent 94, about 300 thousand years ago. This gradual increase in potassium contents correlates with gradual increases in natural-gamma emissions in many wells, including wells STF-PIE-AQ-01 and ARA-COR-005, in which the reversed-polarity basalt of flow group F(1) (table 6) was found beneath flow group E(1) or DE8(1) in cores at a depth similar to that estimated using natural-gamma logs from nearby wells (Champion and others, 1996; Anderson and others, 1996a). Although these newly acquired chemical and paleomagnetic data agree with earlier interpretations made using natural-gamma logs, the data also may indicate the need for two changes in the stratigraphic framework. Basalt-flow group E(1) at the ICPP probably is not the same as flow group E(1) at the RWMC because their potassium contents differ by about 0.30 percent. Also, basalt-flow group F(1), because of its greater-than-expected thickness in wells STF-PIE-AQ-01 and ARA-COR-005 and revised younger $^{40}Ar/^{39}Ar$ age (Champion and others, 1996), probably includes flow group EF(1) in most places. The previous age of flow group F, based on K-Ar measurements, was 565±14 thousand years (Champion and others, 1988). The revised measured age of flow group F(1) is 550±10 thousand years and is nearly identical to the age of 549 thousand years estimated for flow group EF(1) (Anderson and others, 1997).

Stratigraphic interpretations are dependent, in part, on geologic ages of volcanic units, especially those of basalt; however, ages have been measured for relatively few units, often have large associated uncertainties, and sometimes do not agree with ages suggested or required by paleomagnetic, petrographic, chemical, or geophysical-log data (Smith and others, 1996). Spurious measured ages are difficult to identify unless they are from a succession of ages in a single core, are from adjacent cores of identical or similar stratigraphic intervals, contradict known ages of paleomagnetic polarity intervals, or contradict known stratigraphic relations between outcrops and the subsurface. Spurious measured ages are suspected for some cores and outcrops, and many of these ages presently are being reevaluated. On the basis of estimated ages reported by Anderson and others (1997), measured ages of seven basalt outcrops, basalt-flow groups AB(8), AB(13), AB(37), AB(38), B(1), DE1(1), and DE6(1) (table 4), are suspected of being too young or too old (table 8). However, only one of these outcrops, flow group AB(8), has been remeasured at this time. The age of flow group AB(8), which corresponds to Crater Butte (Kuntz and others, 1994), was revised from 519±52 to 292±58 thousand years (M.A. Lanphere, USGS, written commun., 1994). Geologic ages of outcrops such as flow group AB(8) are, in places, difficult to evaluate with respect to those of units in the subsurface. However, based on the interpreted ages and distribution of units in the subsurface, ages of basalt-flow groups Al(2) through Al(13), vents 5 through 16 (fig. 7; table 4), probably all are less than 200 thousand years. Ages of basalt-flow groups AB(2) through AB(58), vents 17 through 73 (fig. 7; table 4), probably are between the measured ages of flow groups AB(10) and AB(29), 218±49 and 207±65 thousand years, respectively, and flow group BC(1), 247±46 thousand years (table 5). The relative ages among basalt-flow groups Al(2) through Al(13) and AB(2) through AB(58) are known only for adjacent flow groups (Kuntz and others, 1994) and are tentative elsewhere (fig. 7; table 4). Ages and paleomagnetic polarity of stratigraphic units Au(1) through Au(5), Al(1) through Al(13), AB(1) through DE3-4(2), DE3-4(3) through KL(1), and L(1) through S5(1) generally coincide with ages and polarity of geologic map units, Qba, Qbb, Qbc, Qbd, and Qbe (Kuntz and others, 1994), respectively; however, agreement between measured and estimated ages for many individual units is poor.

Hydrologic Implications

The movement of water and waste in the unsaturated zone and aquifer are dependent on many factors including the stratigraphy, structure, and lithology of deposits. Important local stratigraphic and lithologic features that affect the movement of water and waste at the INEL, described in other reports, include sedimentary interbed CD(1) at the RWMC (Anderson and Lewis, 1989), basalt-flow groups I(1) and I(2) at the ICPP and TRA (Anderson, 1991; Morin and others, 1993; Frederick and Johnson, 1996), and sedimentary interbed QR(1) at TAN (Kaminsky and others, 1994; Anderson and Bowers, 1995). Local stratigraphic, structural, and lithologic features, which include inclined layers, possible fractured basalt flows, and abrupt lateral changes in ages and sediment content of stratigraphic intervals attributed to past differential subsidence and uplift (fig. 6), also may affect the movement of water and waste (Anderson, 1991; Anderson and Bowers, 1995). The locations of concealed stratigraphic and lithologic features attributed to areas of past differential subsidence and uplift at and near the CTF, TAN, and RWMC (figs. 6 and 8-15) and past differential subsidence beneath the Big Lost River (Anderson and others, 1997) coincide with the locations of observed changes in hydraulic gradients of the water table at the INEL (Lewis and Goldstein, 1982; Pittman and others, 1988; Orr and Cecil, 1991; Bartholomay and others, 1995). Hydraulic gradients range from about 1 to 15 ft/mi, average about 4 ft/mi, and are greatest between the areas of interpreted uplift at and near the CTF, TAN, and RWMC and the area mountainward of the Big Lost River (fig. 6). Average hydraulic gradients change from less than 1 ft/mi at and near the CTF and TAN to about 8 ft/mi in the areas immediately south of these facilities. This change coincides with changes in sediment content ranging from about 10 percent in composite units 8 through 14 (Anderson and Bowers, 1995) to as much as 100 percent in the younger stratigraphic intervals of composite units 1 through 7 on and near the concealed uplift (figs. 6, 9, 13, and 15; table 9). Average hydraulic gradients change from about 8 ft/mi immediately north of the area of interpreted uplift at and near the RWMC to less than 2 ft/mi within this area of uplift. This change in hydraulic gradients coincides with northeastward dips of about 270 ft/mi, opposite the direction of ground-water flow, in stratigraphic intervals of composite units 4 through 12 near the concealed uplift (figs. 6 and 12). This uplift and the associated change in hydraulic gradients also coincide with a zone of numerous fissures, dikes, and past eruptions of basalt, andesite, and rhyolite (fig. 7; table 4) referred to as the Arco-Big Southern Butte volcanic rift zone (Lewis and Goldstein, 1982; Kuntz and others, 1992). Average hydraulic gradients mountainward of the Big Lost River, although difficult to determine because of few wells in this area (fig. 2), generally are greater than those basinward of the river. The area mountainward of the river has the least saturated thickness of the aquifer at the INEL (figs 10 and 11; table 3), and is underlain, in places, by thick layers of sediment (Anderson and others, 1996a). The coincidence of changes in hydraulic gradients and concealed stratigraphic and lithologic features attributed to past differential subsidence and uplift (fig. 6) suggests that these features may affect the movement of water and waste in the aquifer at and near the INEL. Possible effects of the area of interpreted uplift at and near the ICPP, TRA, CFA, and NRF (fig. 6) are uncertain because hydraulic gradients in this area are complicated by intermittent recharge from the Big Lost River.

SUMMARY AND CONCLUSIONS

The unsaturated zone and the Snake River Plain aquifer are made up of at least 178 basalt-flow groups, 103 sedimentary interbeds, 6 andesite-flow groups, and 4 rhyolite domes at and near the INEL. Stratigraphic units identified in 333 wells include 121 basalt-flow groups, 102 sedimentary interbeds, 6 andesite-flow groups, and 1 rhyolite dome. Stratigraphic units were identified and correlated using the data from numerous outcrops and 26 continuous cores and 328 natural-gamma logs available in December 1993. Basalt flows make up about 85 percent of the volume of deposits underlying the area.

Several types of data were used to identify and correlate stratigraphic units. Basalt, sediment, andesite, and rhyolite were identified from outcrops and cores selectively evaluated for paleomagnetic inclination and polarity, K-Ar and $^{40}Ar/^{39}Ar$ geologic ages, petrographic characteristics, and major-oxide and trace-element chemical composition. Stratigraphic units were correlated using these data and natural-gamma logs, which respond to potassium contents of generally less than 1 percent in basalt to more than 4 percent in rhyolite. The best stratigraphic correlations at and near the INEL were obtained for basalt and sediment at the CTF, TAN, NRF, TRA, ICPP, CFA, and RWMC, where most cores and two thirds of the logs were obtained. Correlations range from good at the RWMC to uncertain in the eastern half of the INEL.

Fourteen composite stratigraphic units, each made up of 5 to 90 stratigraphic units of similar age, are used to describe the stratigraphy of the unsaturated zone and aquifer. Upper and lower boundaries of each composite unit were selected to show the main stratigraphic and structural features underlying the area. Composite unit 1, the youngest unit, is made up of 78 basalt-flow groups and 12 sedimentary interbeds. Composite unit 14, the oldest unit, is made up of 4 basalt-flow groups and 1 sedimentary interbed. The decrease in the number of stratigraphic units assigned to each successively older composite unit is attributed partly to larger and less-frequent volcanic eruptions during the accumulation of these units and partly to the limited distribution of available cores used to identify stratigraphic units at greater depths in the subsurface. Composite units 1 through 7 generally range in age from about 200 to 800 thousand years and make up the unsaturated zone and the uppermost part of the Snake River Plain aquifer in most places. Composite units 8 through 14 range in age from about 800 thousand to 1.8 million years and make up the unsaturated zone and aquifer at and near the CTF and TAN and the lowermost part of the aquifer elsewhere. Water levels in the aquifer in 1996 coincided with composite units 4 and 5 in most places; water levels coincided with composite unit 12 at and near the CTF and TAN.

Hydraulic gradients of the water table range from about 1 to 15 ft/mi, average about 4 ft/mi, and, in places, change at or near stratigraphic and lithologic features attributed to past differential subsidence and uplift. Average hydraulic gradients change from less than 1 ft/mi at and near the CTF and TAN, an area of interpreted uplift, to about 8 ft/mi in the areas immediately south of these facilities. This change coincides with changes in sediment content ranging from about 10 percent in composite units 8 through 14 to as much as 100 percent in the younger stratigraphic intervals of composite units 1 through 7 on and near the concealed uplift. Average hydraulic gradients change from about 8 ft/mi immediately north of an area of interpreted uplift at and near the RWMC to less than 2 ft/mi within this area of uplift. This change coincides with northeastward dips of about 270 ft/mi, opposite the direction of ground-water flow, in stratigraphic intervals of composite units 4 through 12 near the concealed uplift and the Arco-Big Southern Butte volcanic rift zone. Average hydraulic gradients mountainward of the Big Lost River, an area of reduced stratigraphic thickness attributed to past differential subsidence, generally are greater than those basinward of the river. The area mountainward of the river has the least saturated thickness of the aquifer at the INEL, and is underlain, in places, by thick layers of sediment. The coincidence of changes in hydraulic gradients and concealed stratigraphic and lithologic features attributed to past differential subsidence and uplift suggests that these features may affect the movement of water and waste in the aquifer at and near the INEL. Possible effects of an area of interpreted uplift at and near the ICPP, TRA, CFA, and NRF are uncertain because hydraulic gradients in this area are complicated by intermittent recharge from the Big Lost River.

Additional cores and data would improve interpretations of stratigraphic relations and their possible hydrologic effects at and near the INEL. Three cores, drilled to a depth of about 1,500 ft near wells USGS 30A, EBR-1, and Site 14 are needed to test the main conceptual elements of the stratigraphic framework presented in this report. Four additional cores, drilled to a depth of at least 750 ft at the NRF, TRA, CFA, and immediately south of the RWMC, are needed to resolve important stratigraphic uncertainties and their possible effects on the movement of water and waste in the unsaturated zone and aquifer. Additional paleomagnetic, geochronologic, petrographic, chemical, and geophysical-log data also are needed for existing cores and wells to improve stratigraphic interpretations at these and other facilities. In some places, stratigraphic interpretations made from K-Ar ages and natural-gamma logs might be improved by $^{40}Ar/^{39}Ar$ ages and gamma-spectral logs.

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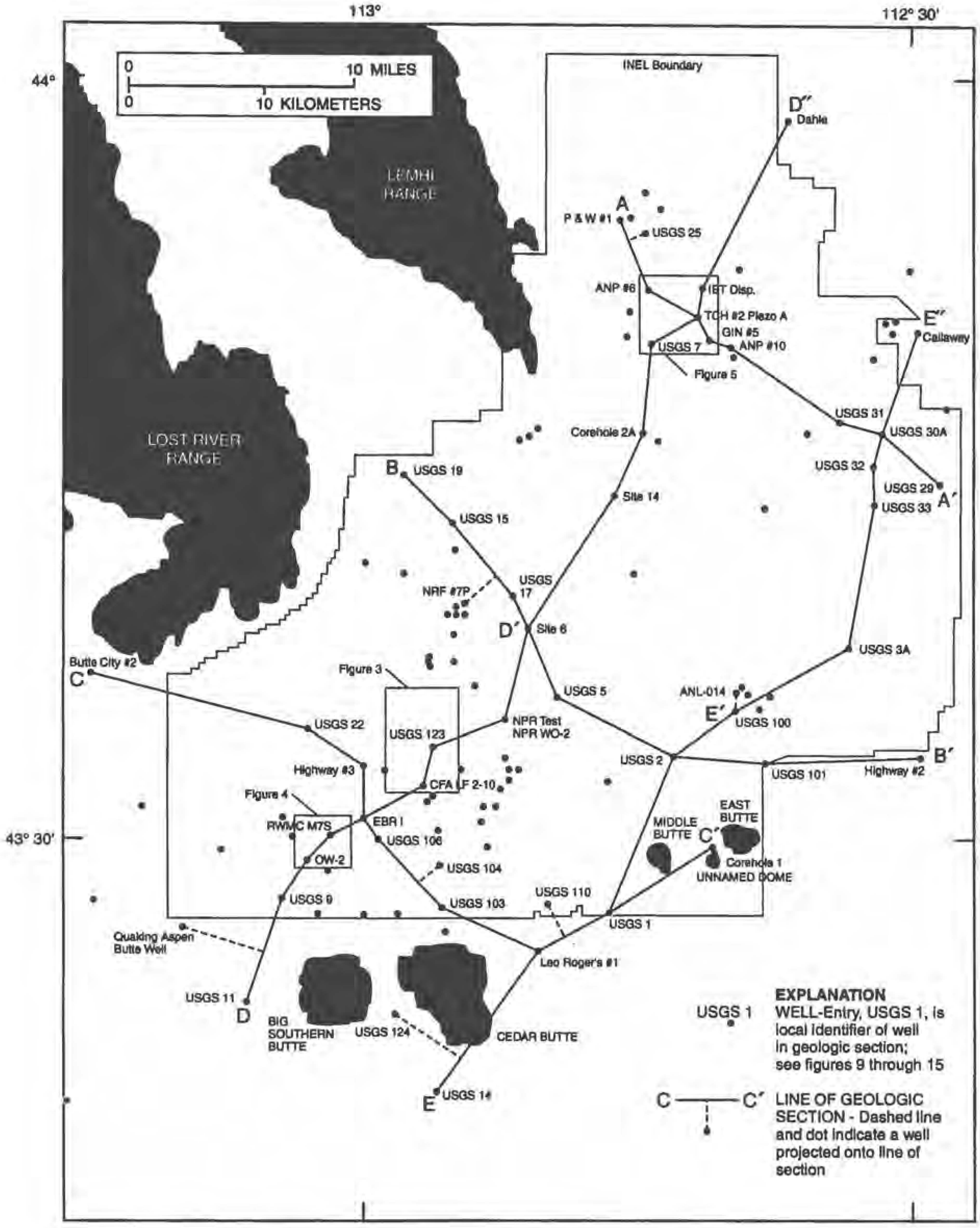

Figure 8. Locations of geologic sections A-A' through E'-E'' at and near the Idaho National Engineering Laboratory

EXPLANATION (figures 9 through 15)

BASALT-FLOW GROUPS AND SEDIMENTARY INTERBEDS A THROUGH L – Includes unaltered basalt and sediment in the youngest part of the unsaturated zone and the Snake River Plain aquifer; locally includes andesite and rhyolite. Age of sequence generally ranges from about 200 to 800 thousand years (ka) and is consistent with that of the Snake River Group. Number, 4, is a composite stratigraphic unit from table 4

BASALT-FLOW GROUPS AND SEDIMENTARY INTERBEDS LM1 THROUGH S5 – Includes unaltered to altered basalt and sediment in the oldest part of the unsaturated zone and the Snake River Plain aquifer; locally includes andesite and rhyolite. Age of sequence generally ranges from about 800 thousand to 1.8 million years (ma) and is consistent with that of the Bruneau Formation. Number, 10, is a composite stratigraphic unit from table 4

BASALT-FLOW GROUPS AND SEDIMENTARY INTERBEDS, UNDIFFERENTIATED – Includes altered basalt and sediment that form the effective base of the Snake River Plain aquifer; locally may include andesite and rhyolite. Age of sequence generally ranges from about 1.8 to 4.0 million years and is consistent with that of the Glenns Ferry Formation

GEOLOGIC CONTACT – Queried where uncertain

USGS 25 / BL / BM / O / 5,000

WELL – Dashed where projected to sections. Entry, USGS 25, is local well identifier; see figure 8. Dashed horizontal line indicates measured or estimated water level in aquifer in 1996. Arrows indicate tops of probable paleomagnetic chrons and subchrons; solid arrows indicate data from cores. E (Emperor, 465 ka), BL (Big Lost, 550 ka), BM (Brunhes/ Matuyama, 780 ka), J (Jaramillo, 1.0 ma), and O (Olduvai, 1.8 ma). Number, 5,000, at bottom of well is total depth of well, in feet below land surface

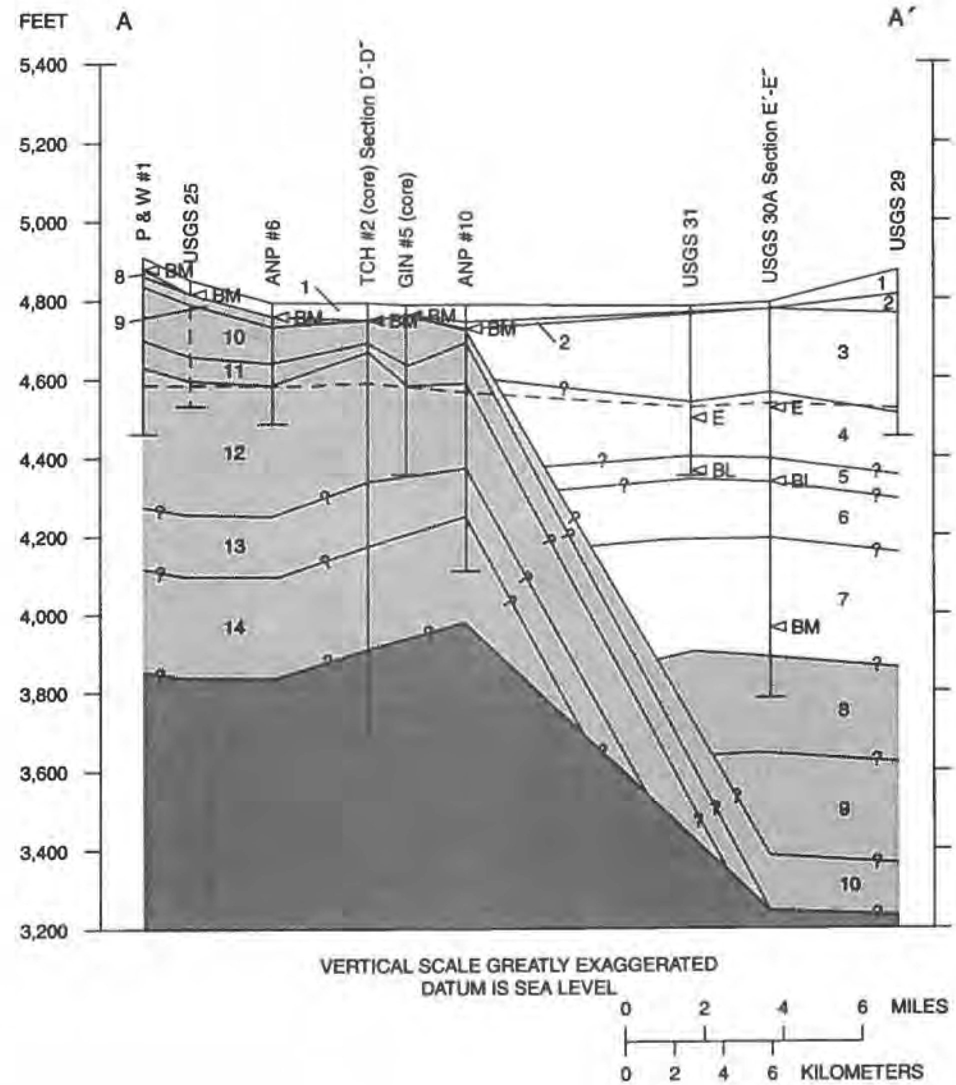

Figure 9. Geologic section A-A' at the Idaho National Engineering Laboratory.

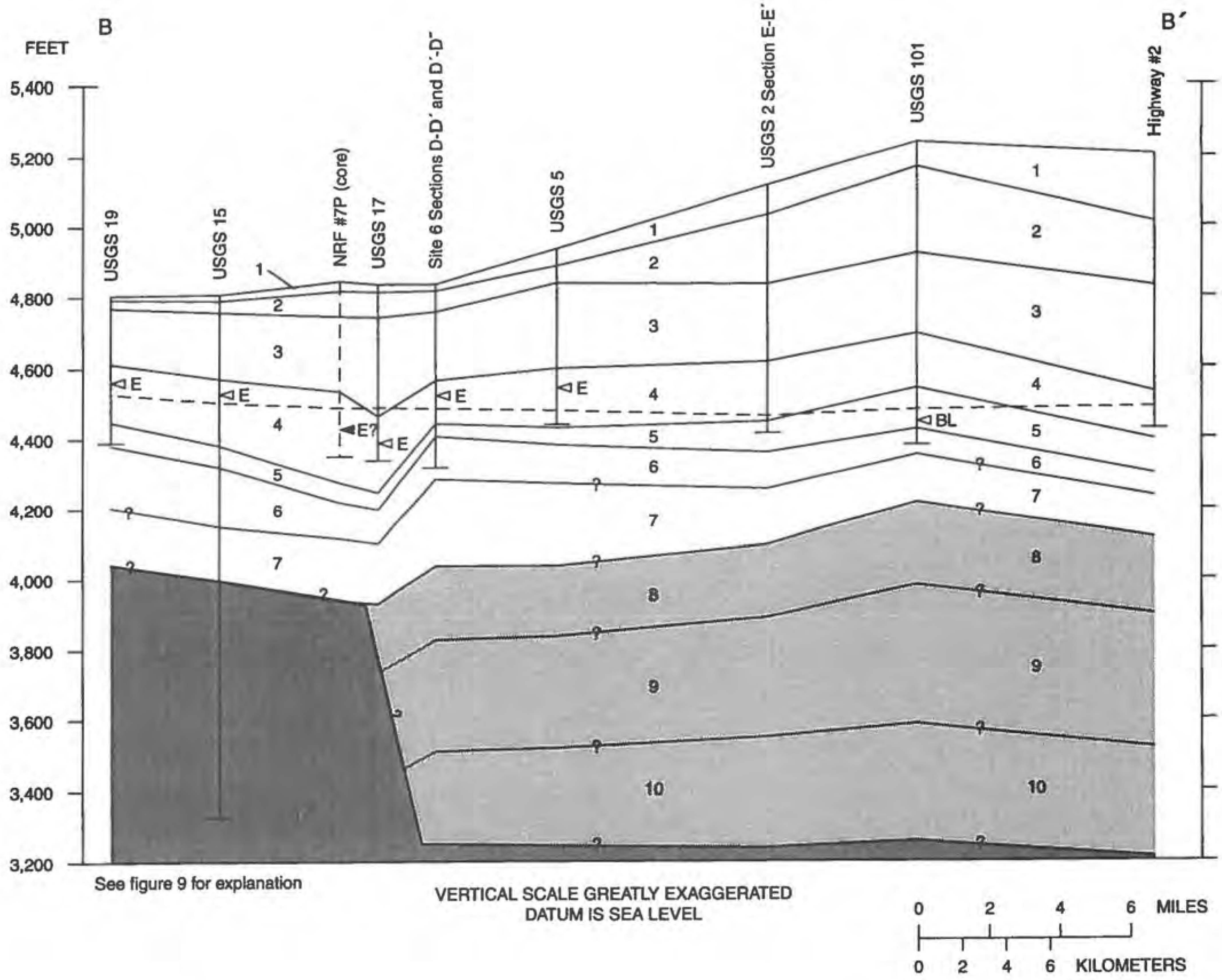

Figure 10. Geologic section B-B' at the Idaho National Engineering Laboratory.

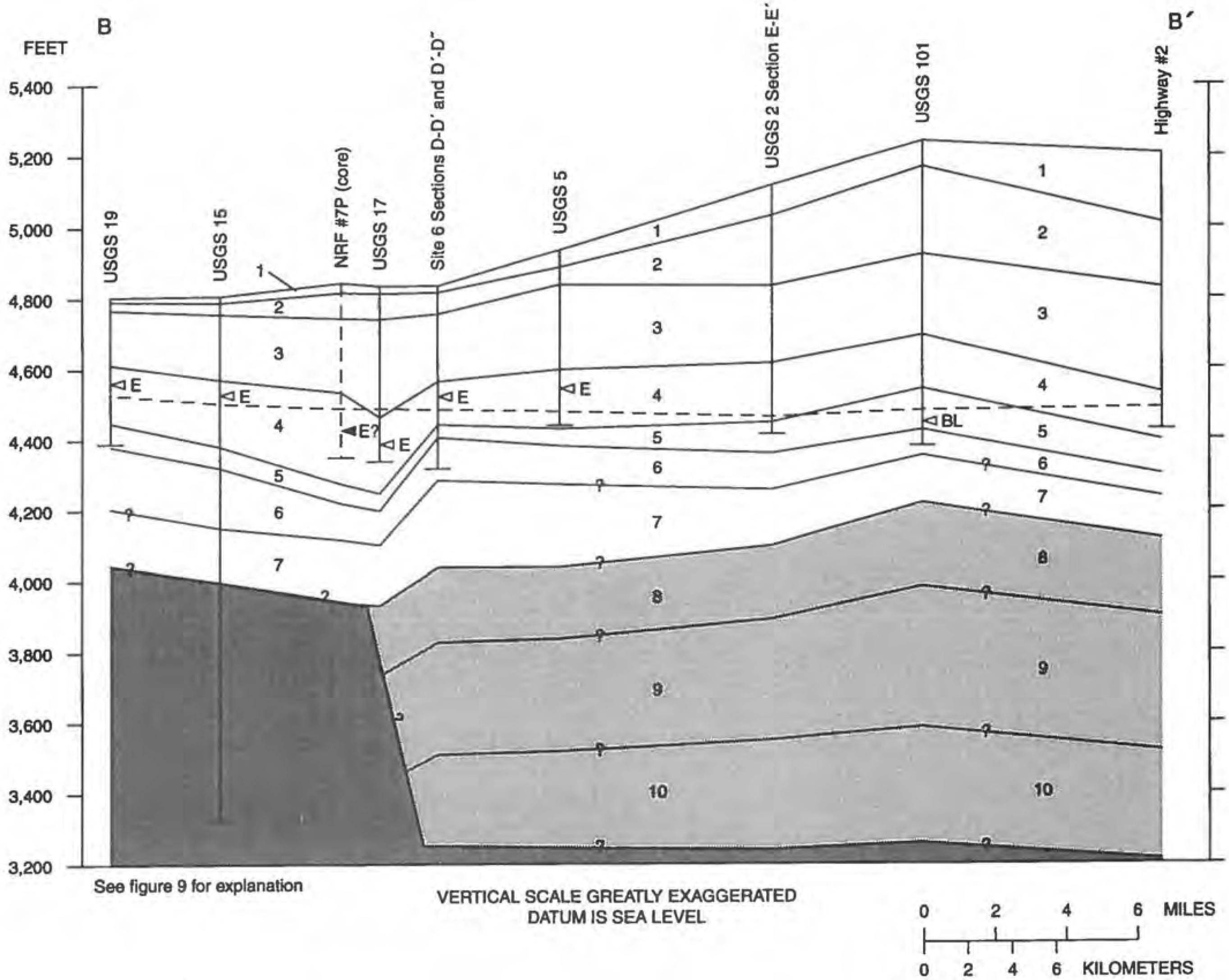

Figure 10. Geologic section B-B' at the Idaho National Engineering Laboratory.

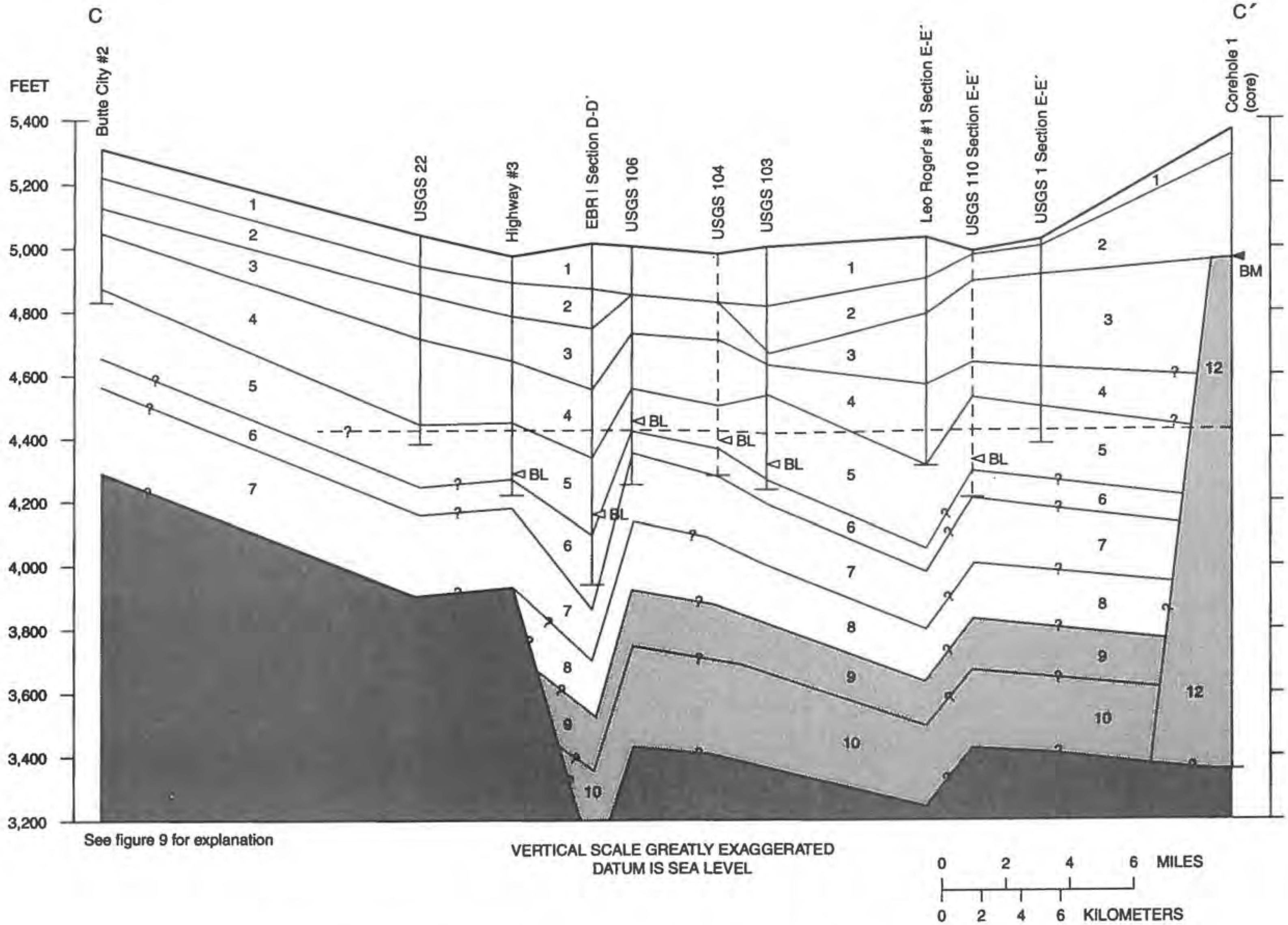

Figure 11. Geologic section C-C' at the Idaho National Engineering Laboratory.

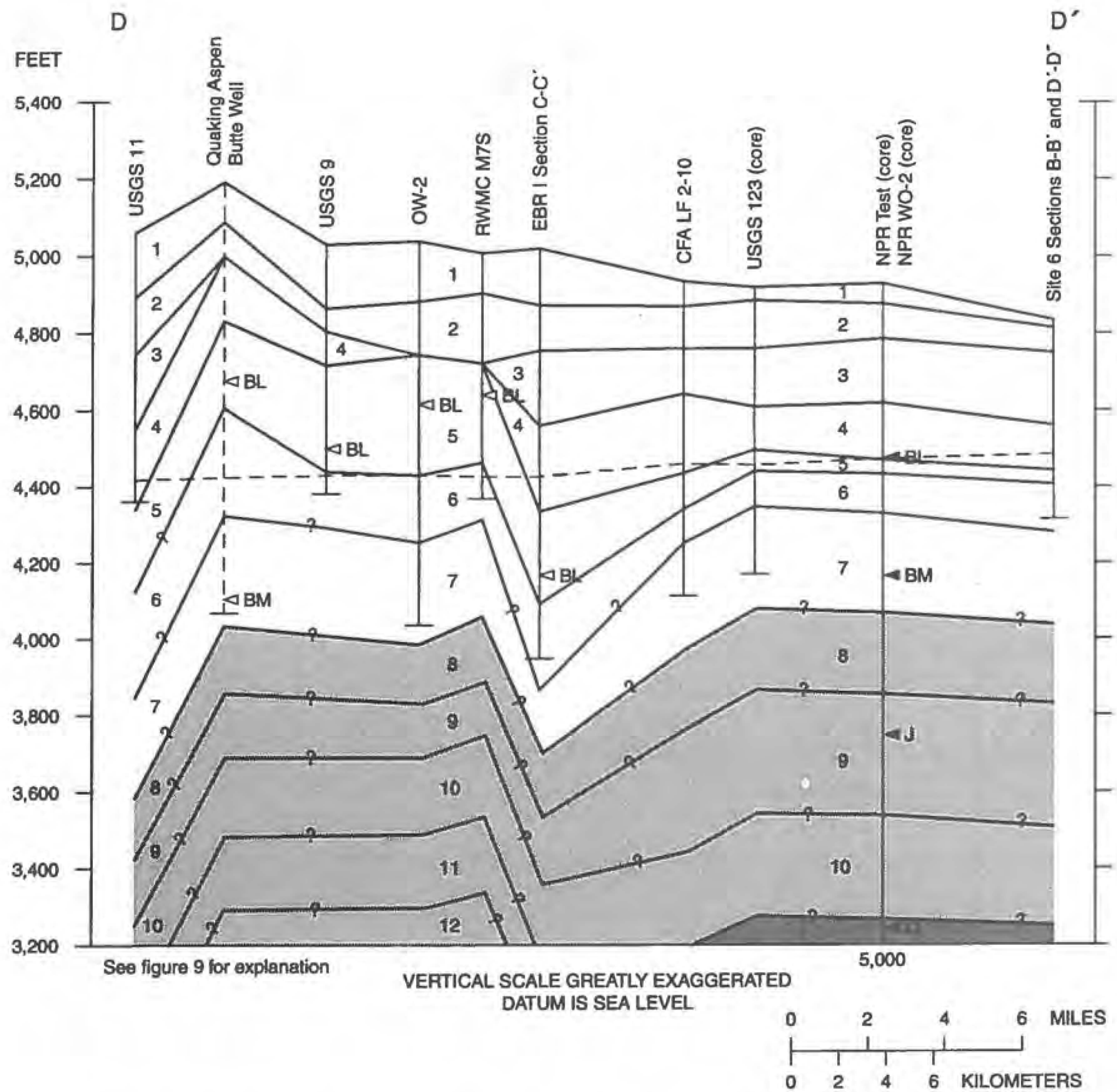

Figure 12. Geologic section D-D' at the Idaho National Engineering Laboratory.

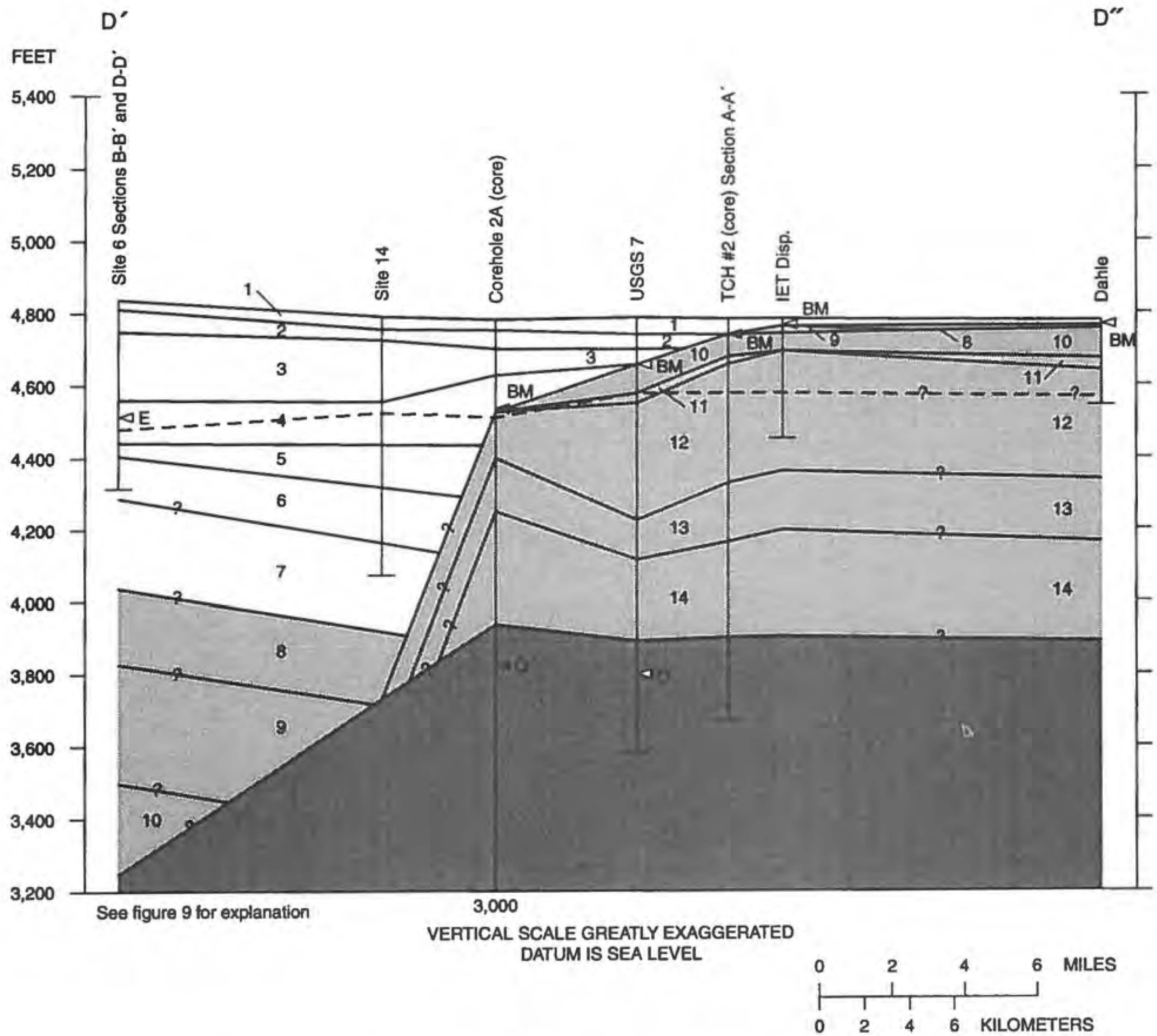

Figure 13. Geologic section D'-D" at the Idaho National Engineering Laboratory.

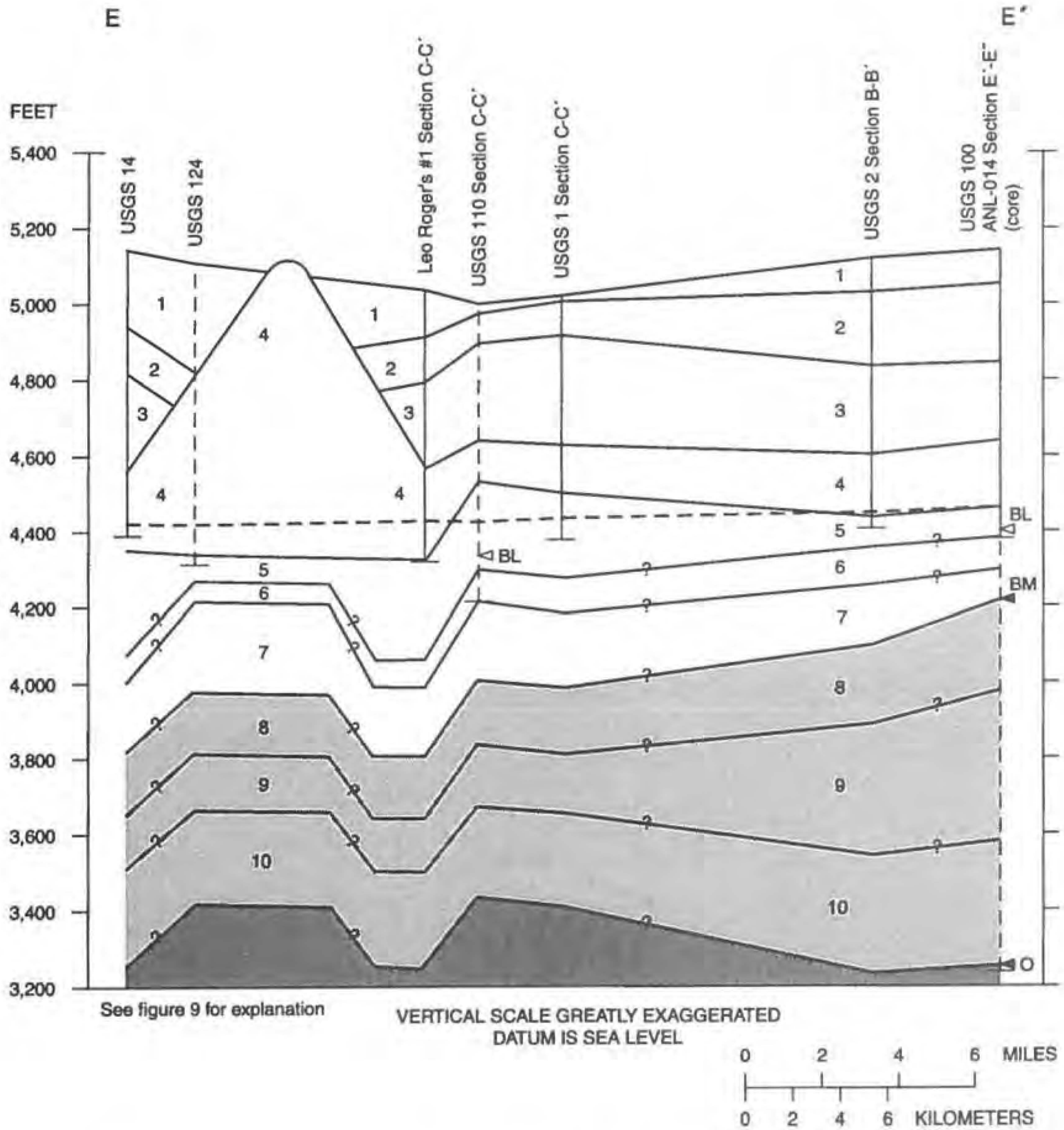

Figure 14. Geologic section E-E' at the Idaho National Engineering Laboratory.

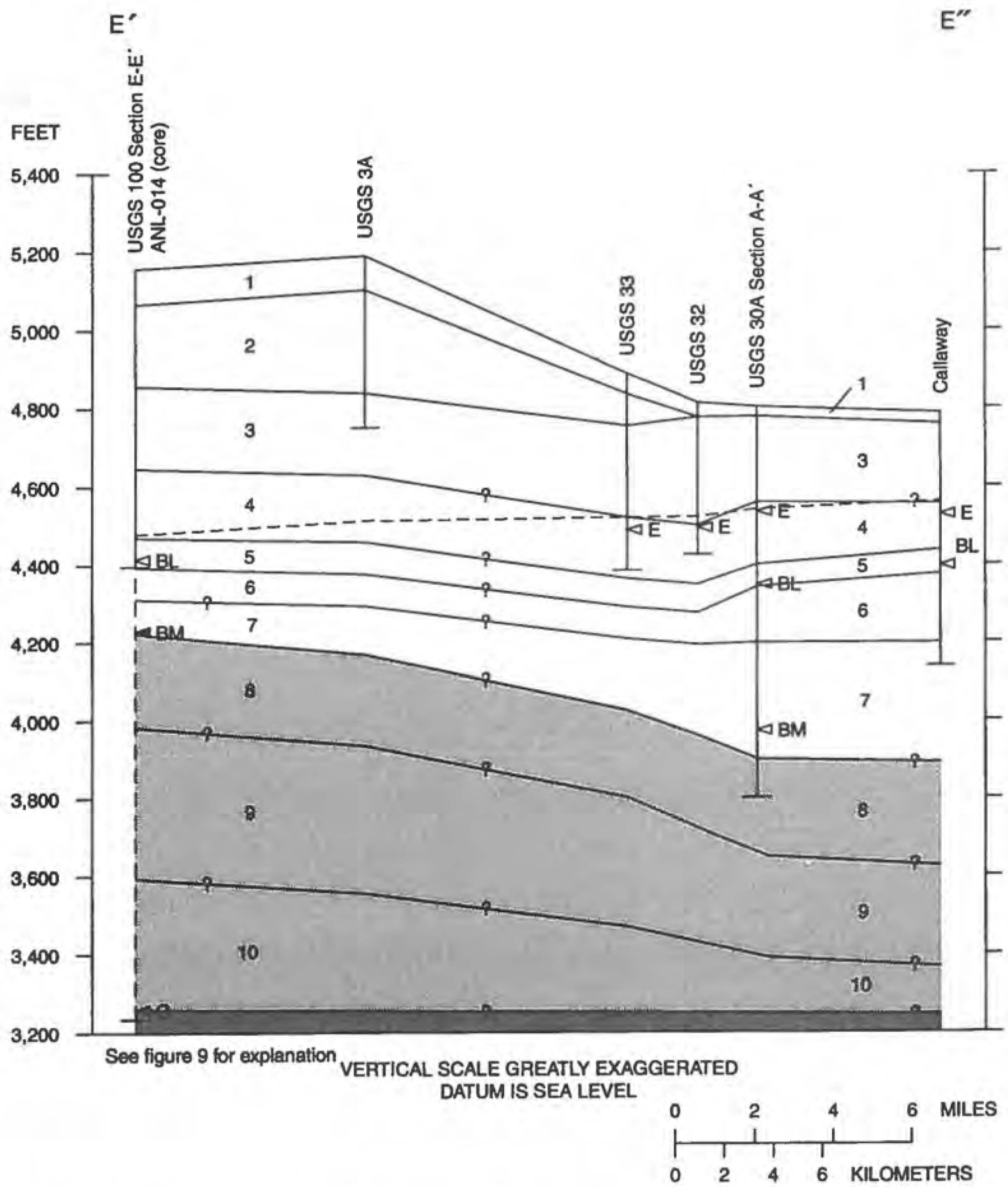

Figure 15. Geologic section E'-E" at the Idaho National Engineering Laboratory.

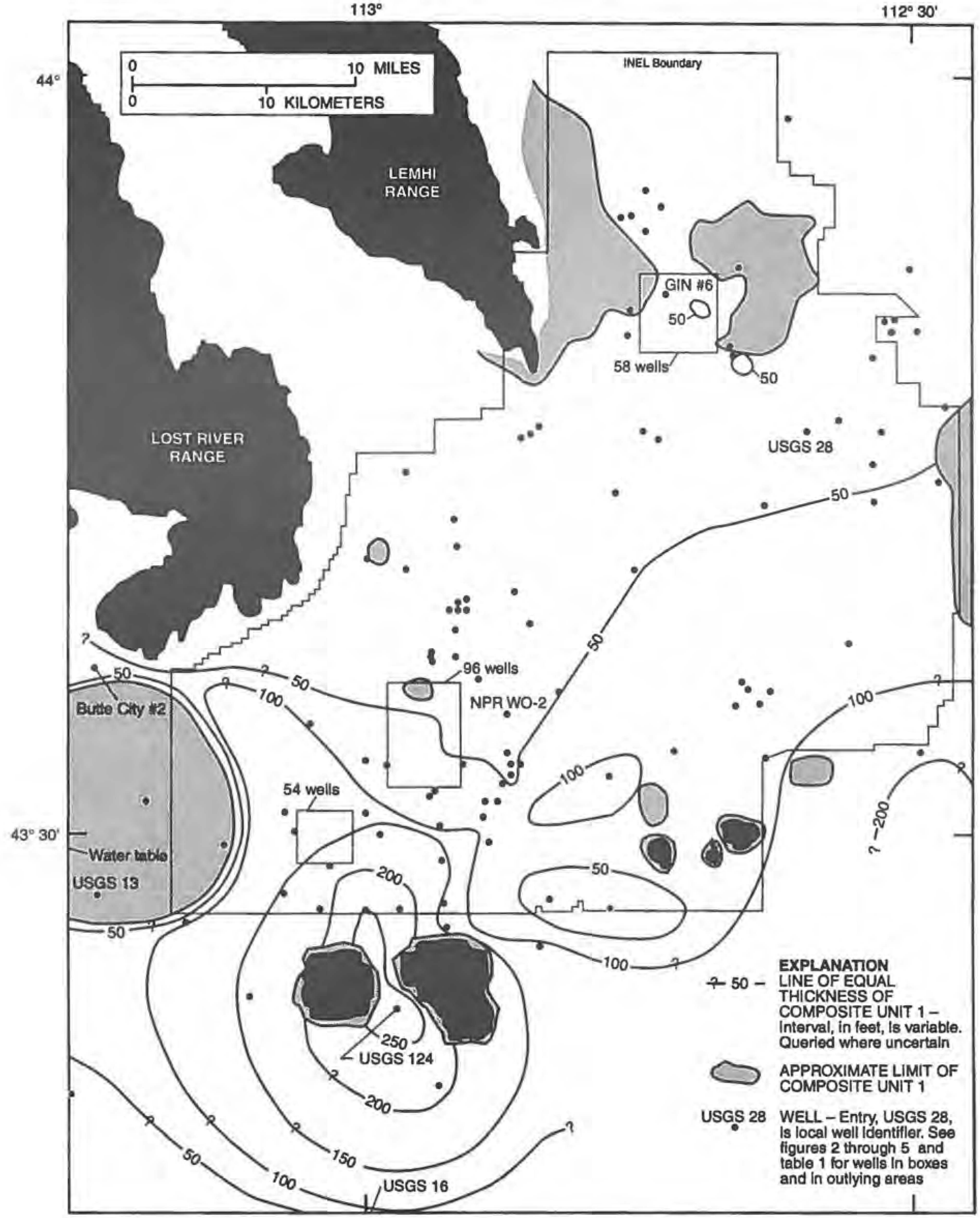

Figure 16. Thickness of composite stratigraphic unit 1 at the Idaho National Engineering Laboratory.

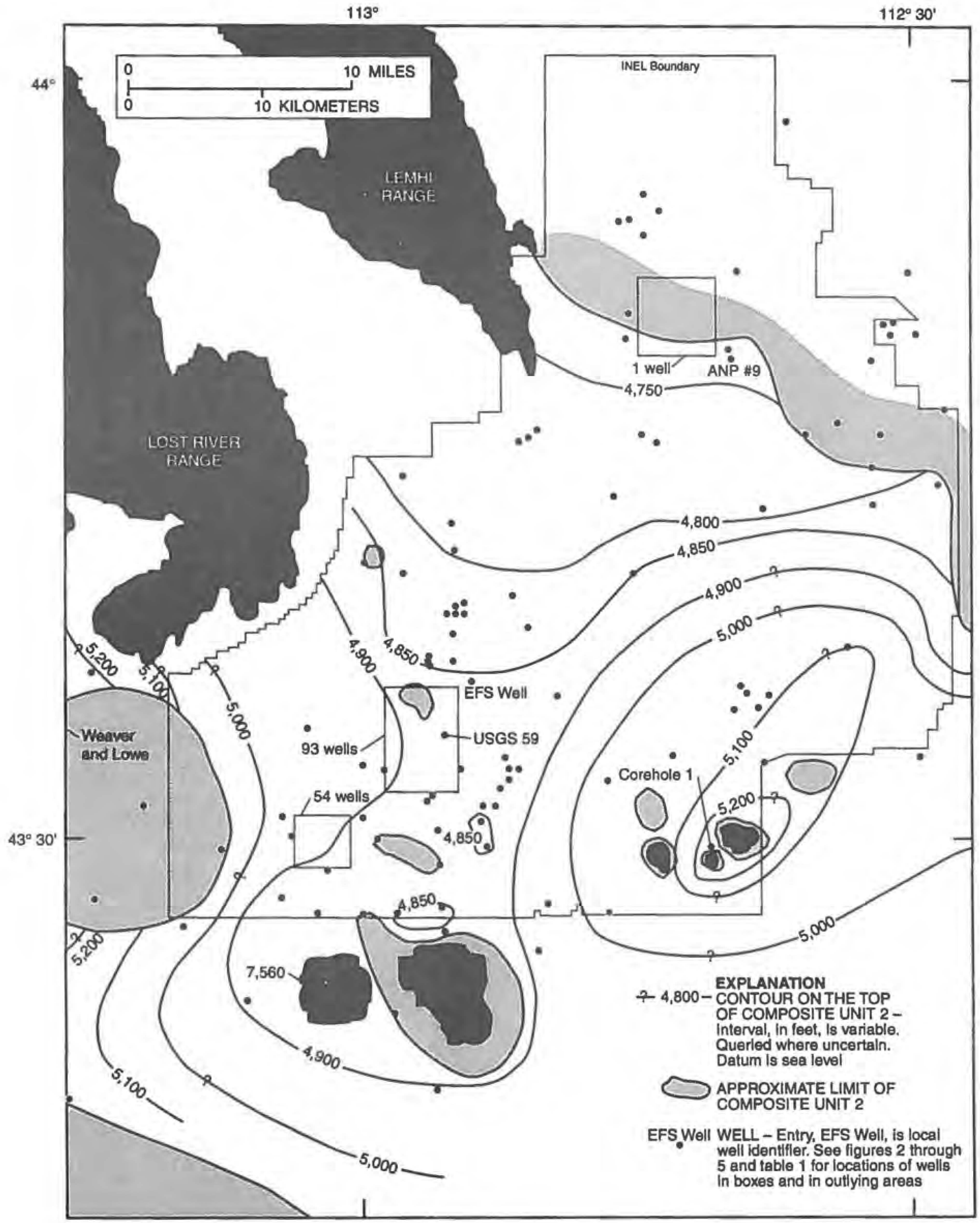

Figure 17. Altitude of the top of composite stratigraphic unit 2 at the Idaho National Engineering Laboratory.

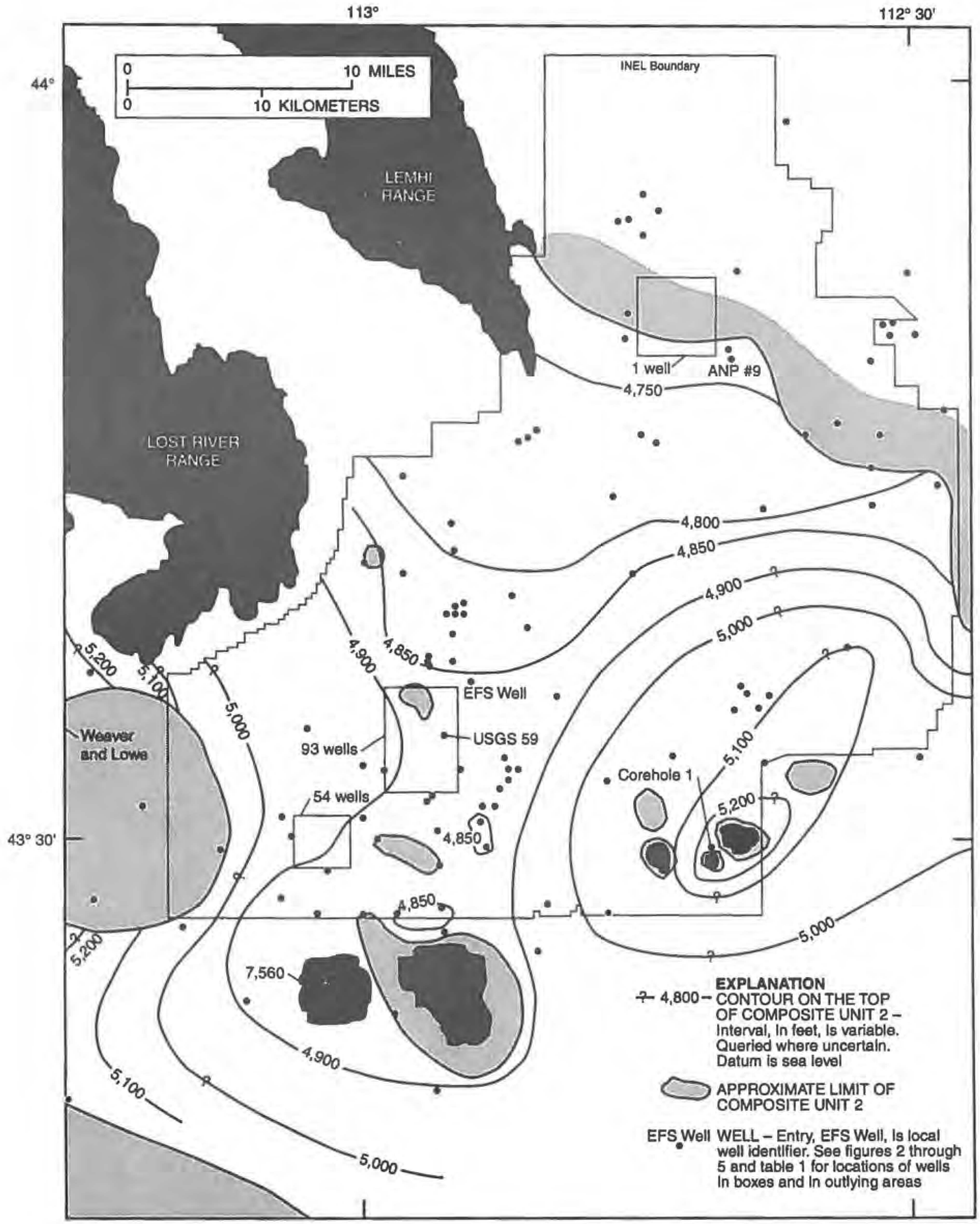

Figure 17. Altitude of the top of composite stratigraphic unit 2 at the Idaho National Engineering Laboratory.

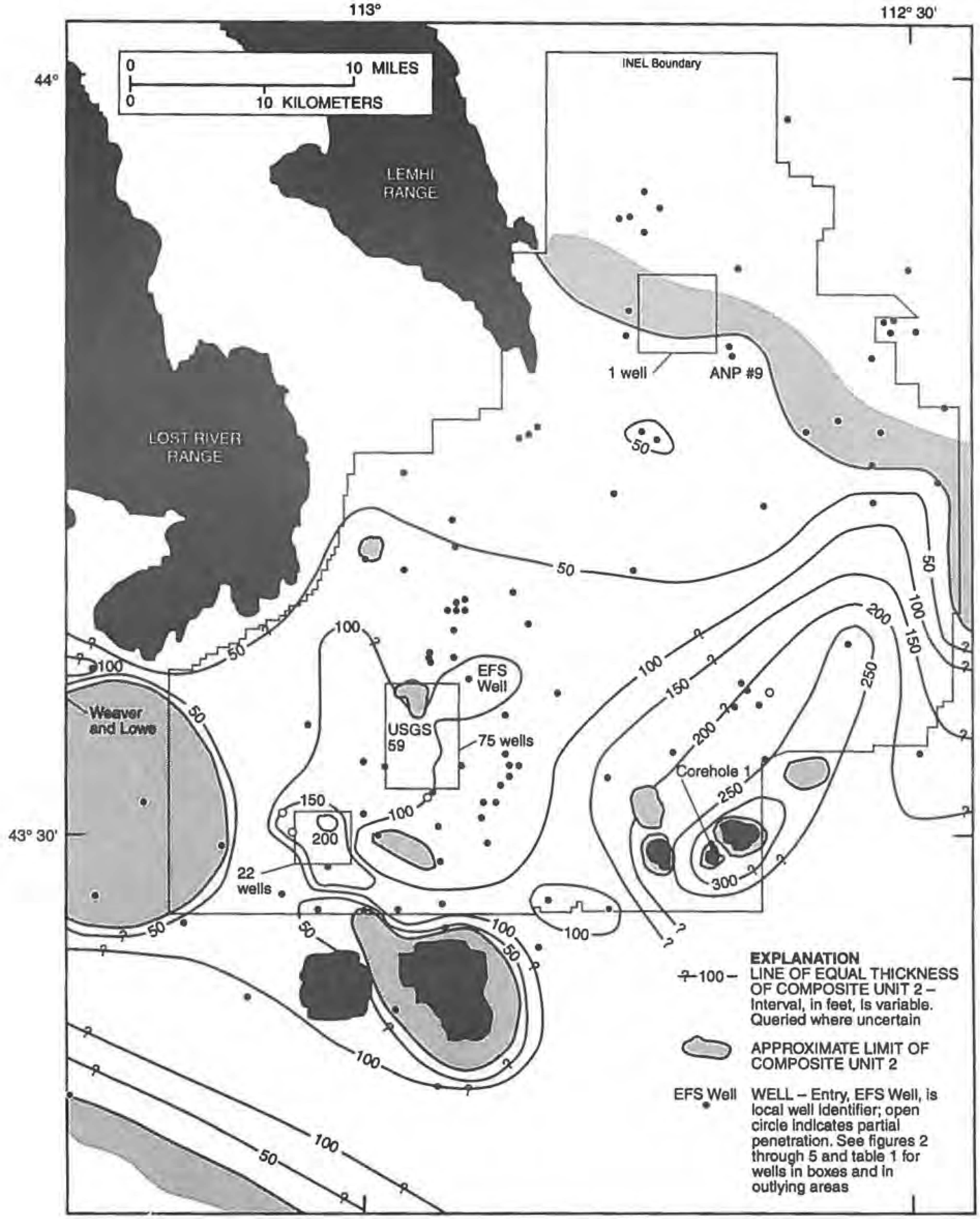

Figure 18. Thickness of composite stratigraphic unit 2 at the Idaho National Engineering Laboratory.

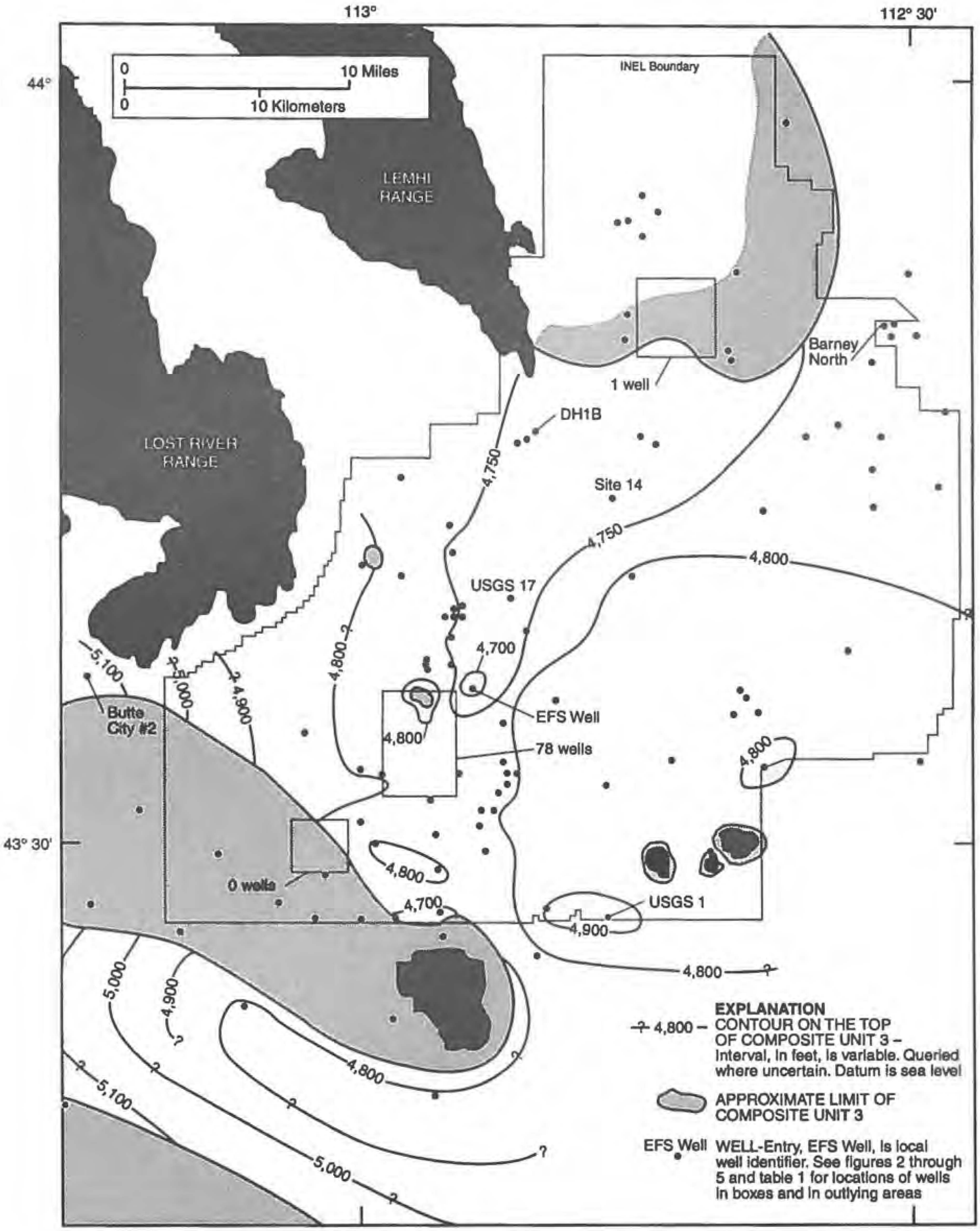

Figure 19. Altitude of the top of composite stratigraphic unit 3 at the Idaho National Engineering Laboratory.

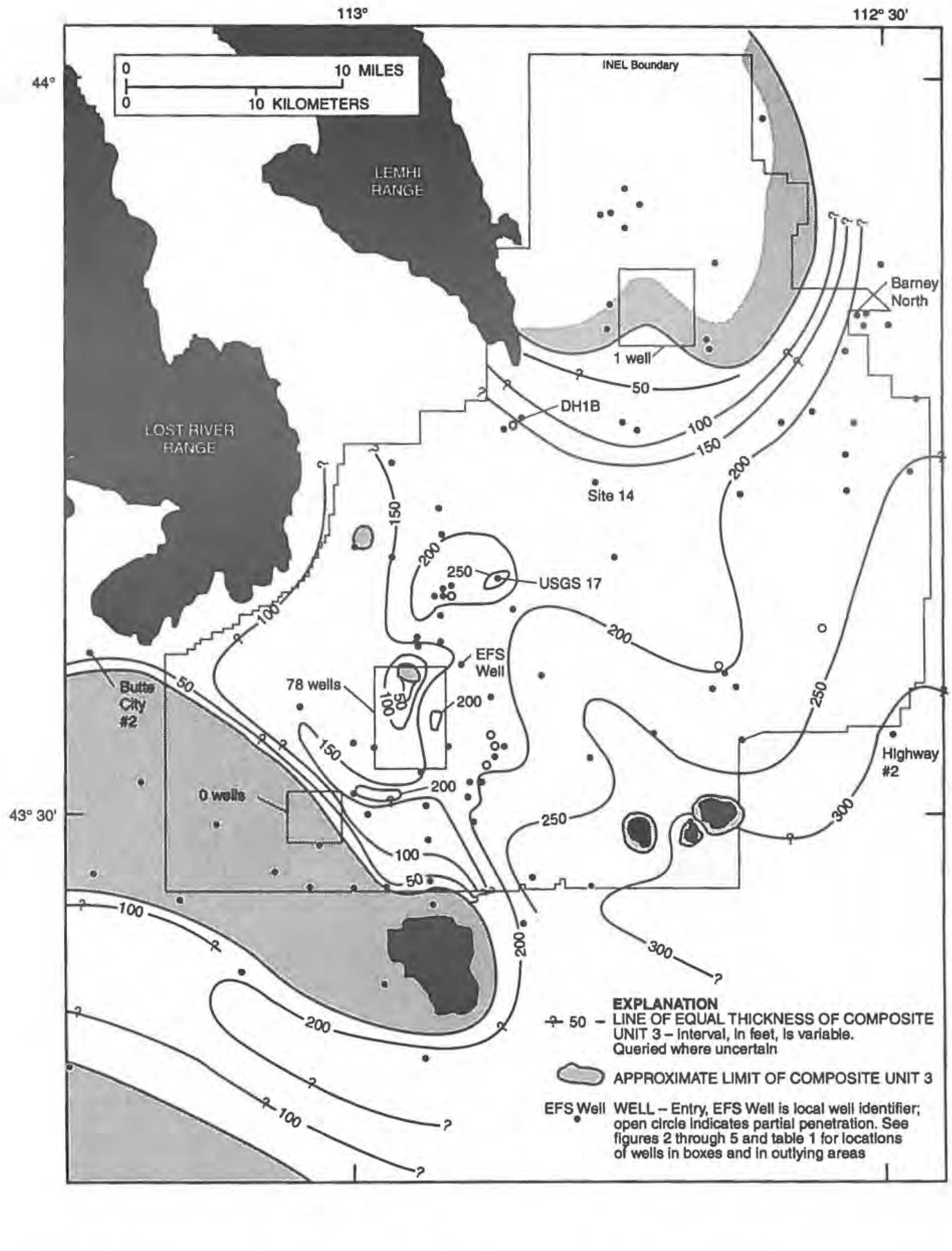

Figure 20. Thickness of composite stratigraphic unit 3 at the Idaho National Engineering Laboratory.

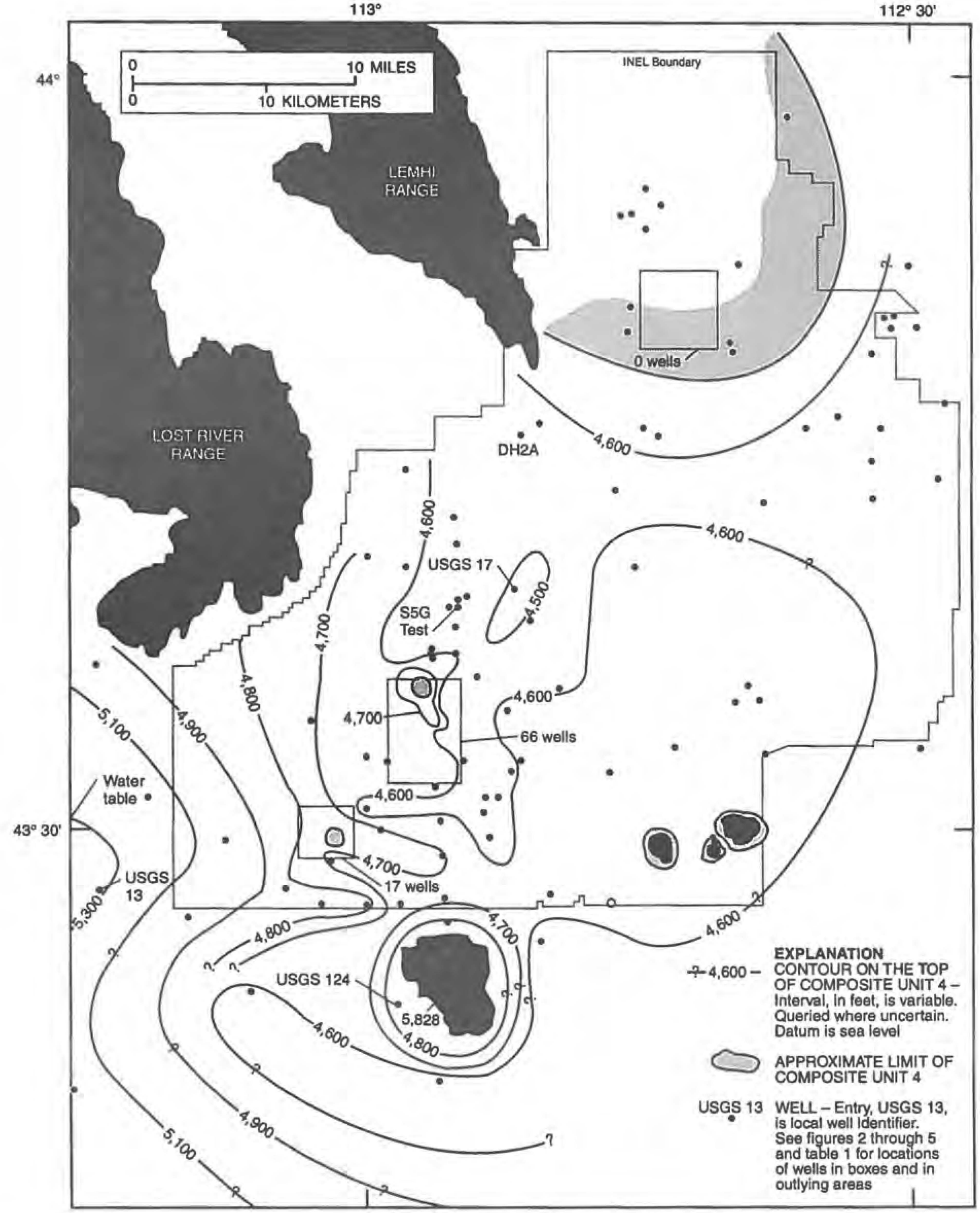

Figure 21. Altitude of the top of composite stratigraphic unit 4 at the Idaho National Engineering Laboratory.

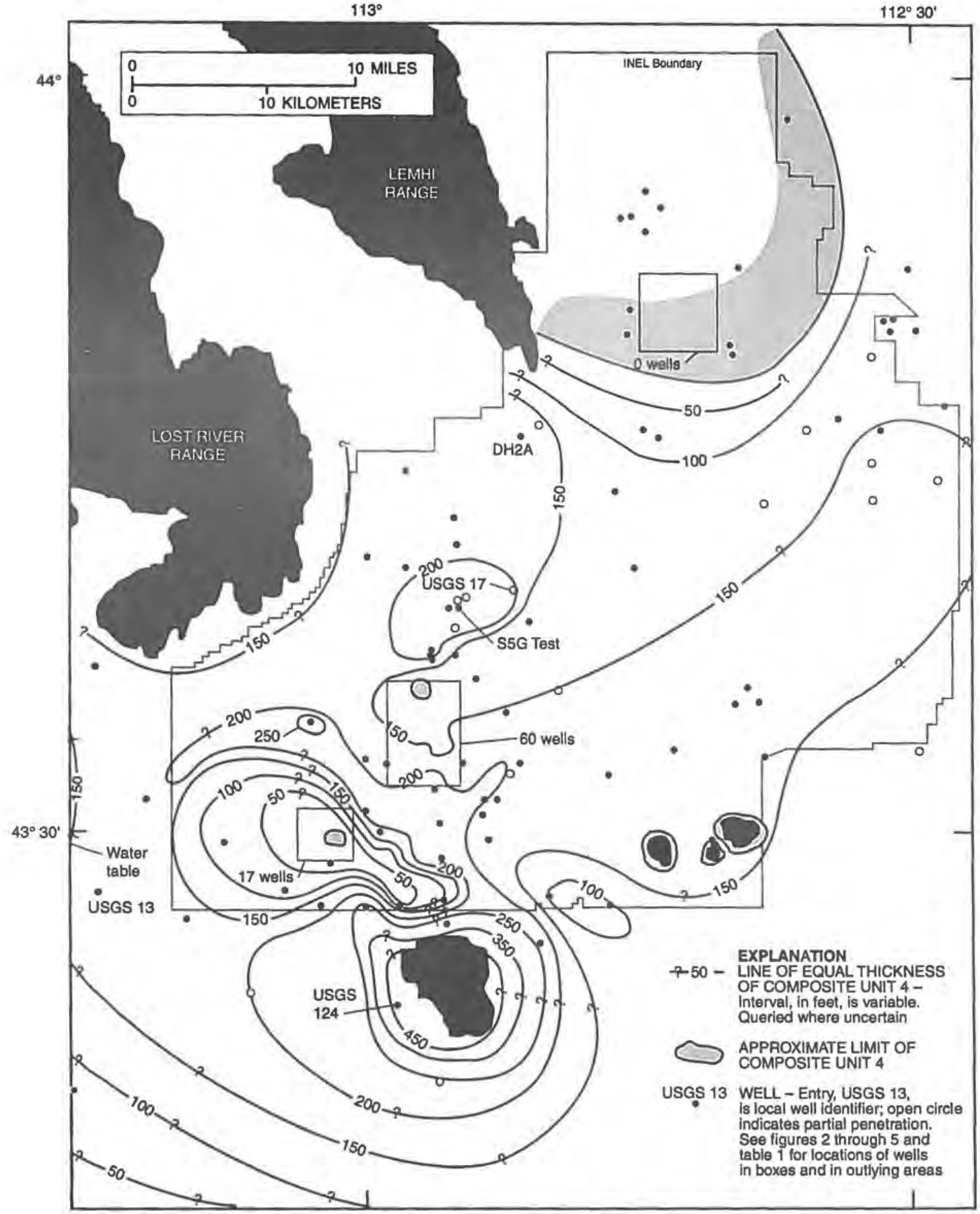

Figure 22. Thickness of composite stratigraphic unit 4 at the Idaho National Engineering Laboratory.

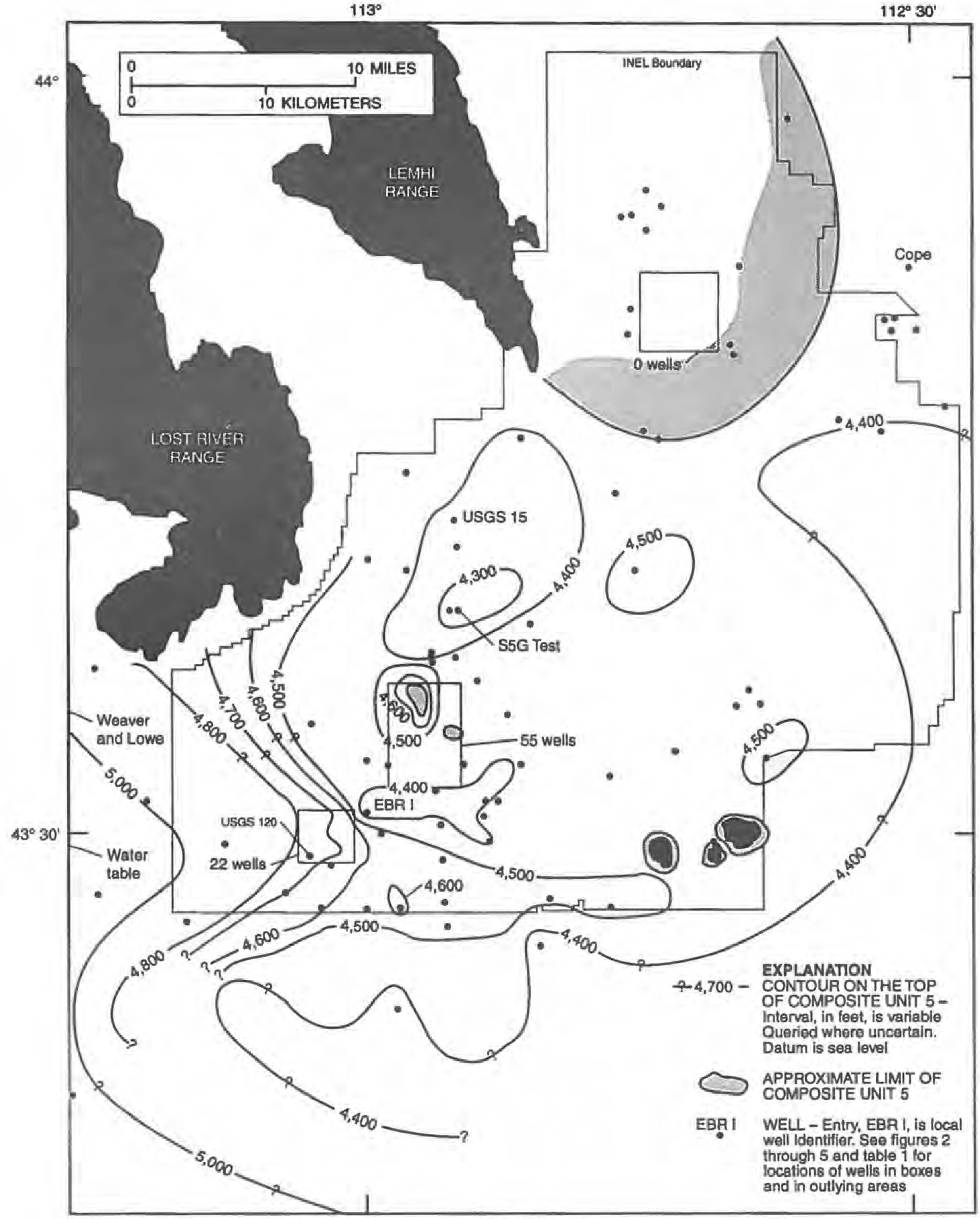

Figure 23. Altitude of the top of composite stratigraphic unit 5 at the Idaho National Engineering Laboratory.

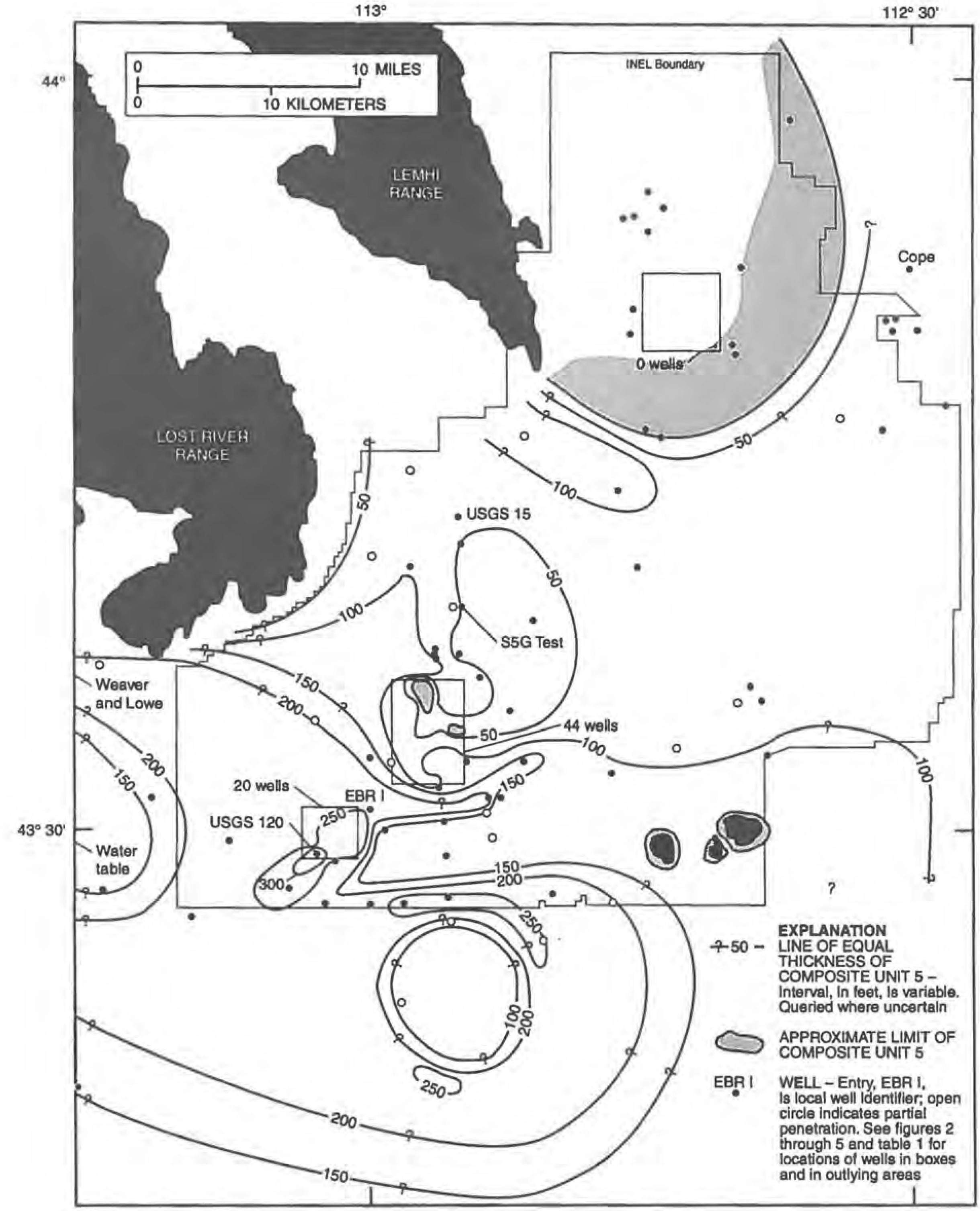

Figure 24. Thickness of composite stratigraphic unit 5 at the Idaho National Engineering Laboratory.

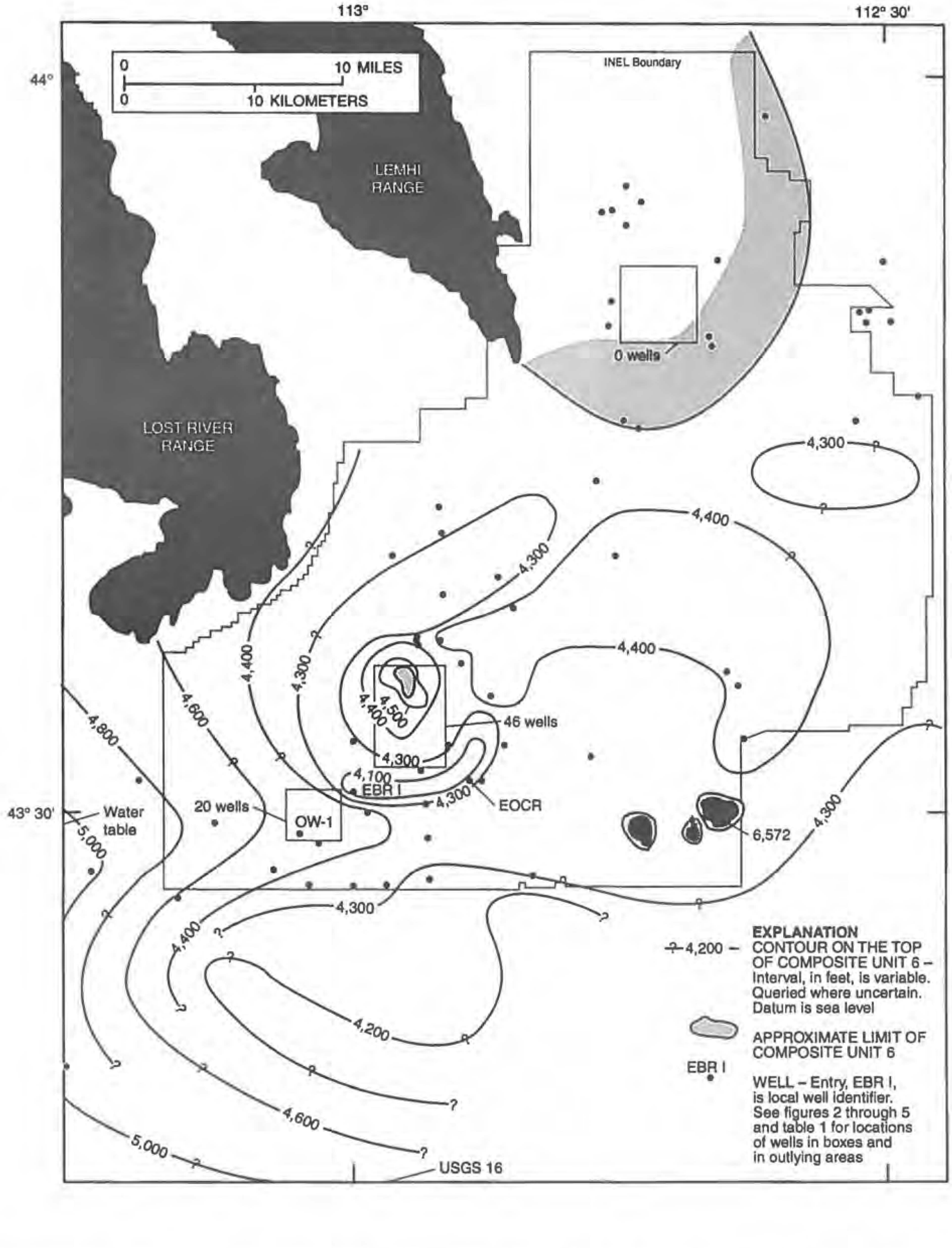

Figure 25. Altitude of the top of composite stratigraphic unit 6 at the Idaho National Engineering Laboratory.

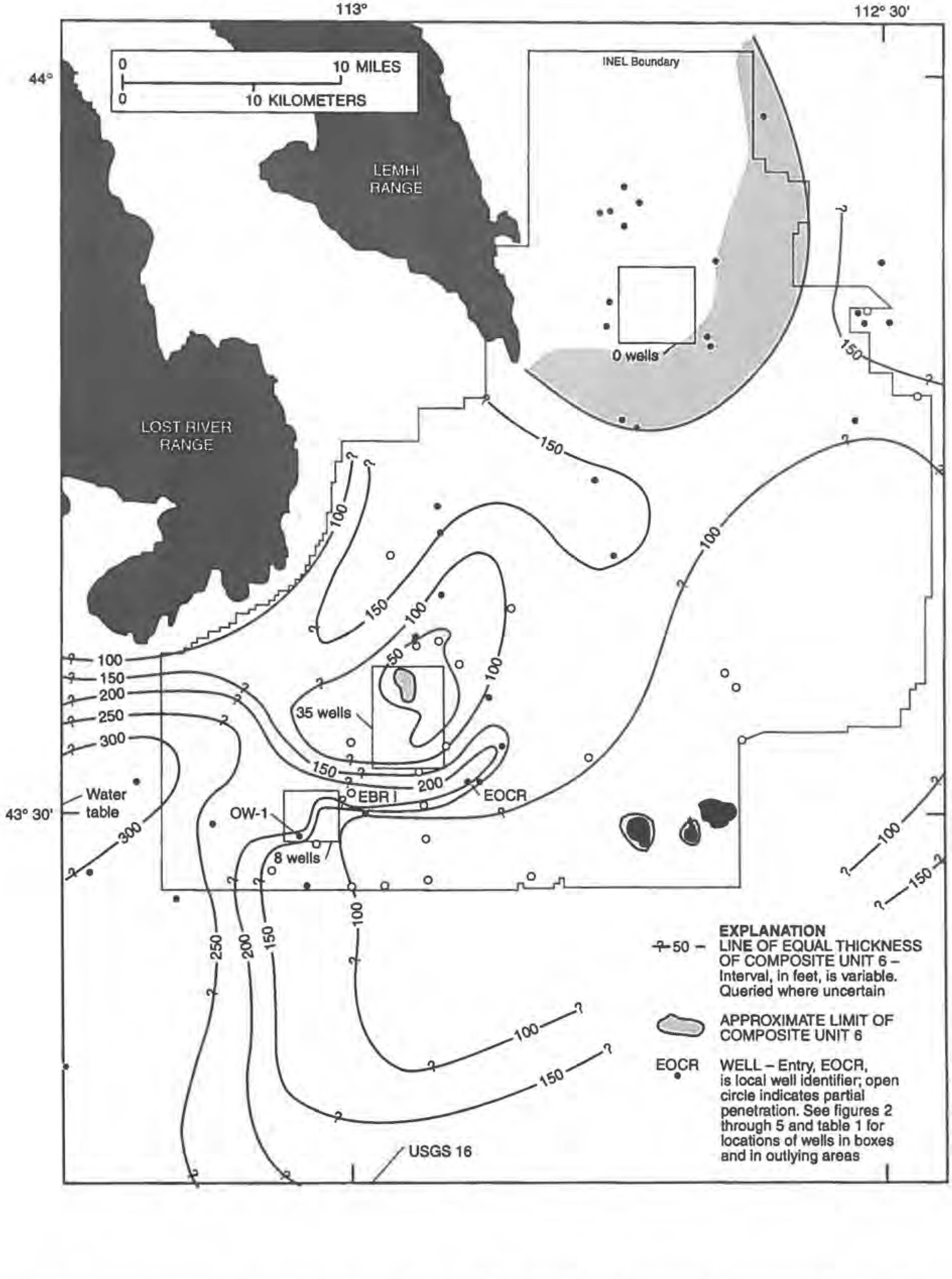

Figure 26. Thickness of composite stratigraphic unit 6 at the Idaho National Engineering Laboratory.

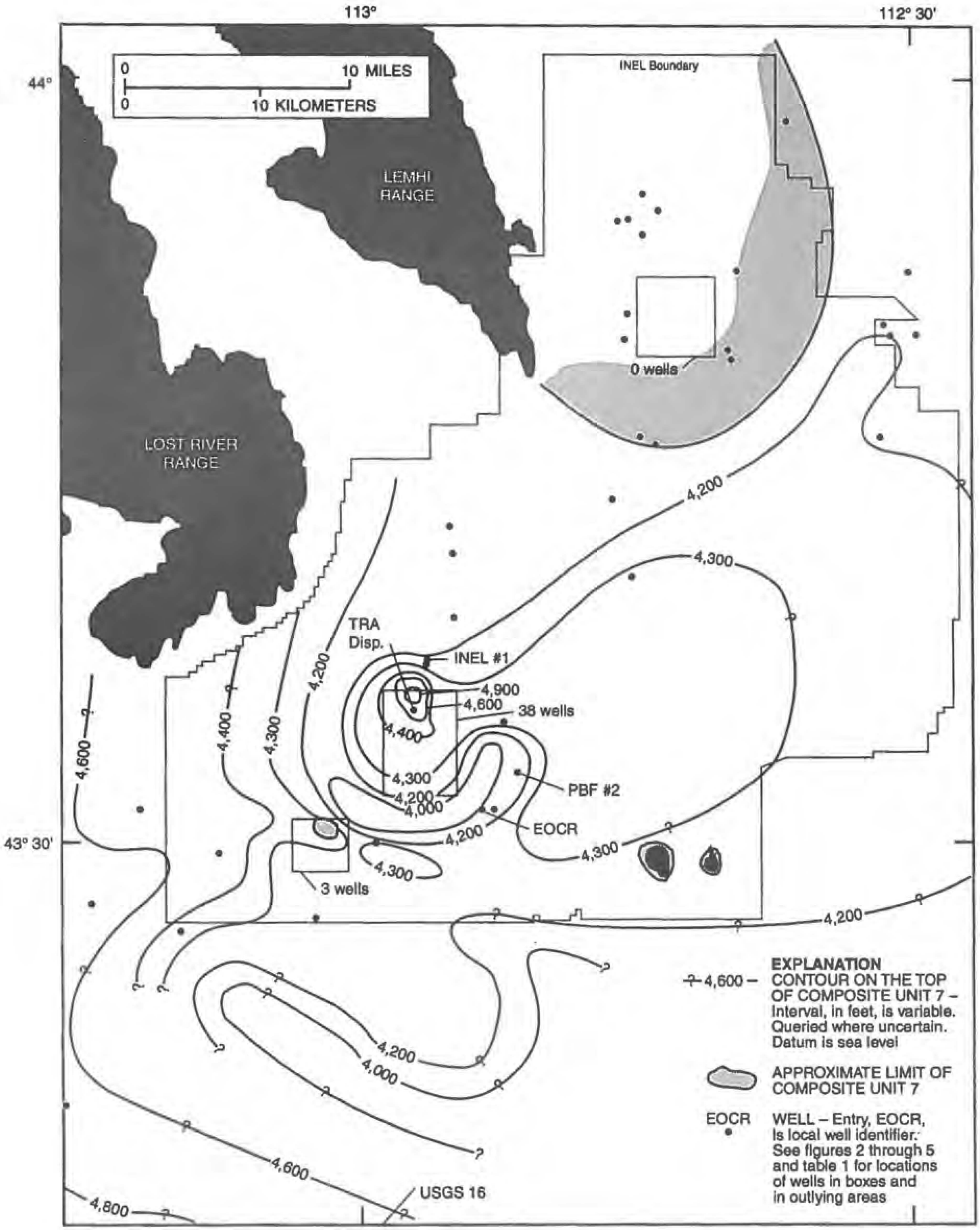

Figure 27. Altitude of the top of composite stratigraphic unit 7 at the Idaho National Engineering Laboratory.

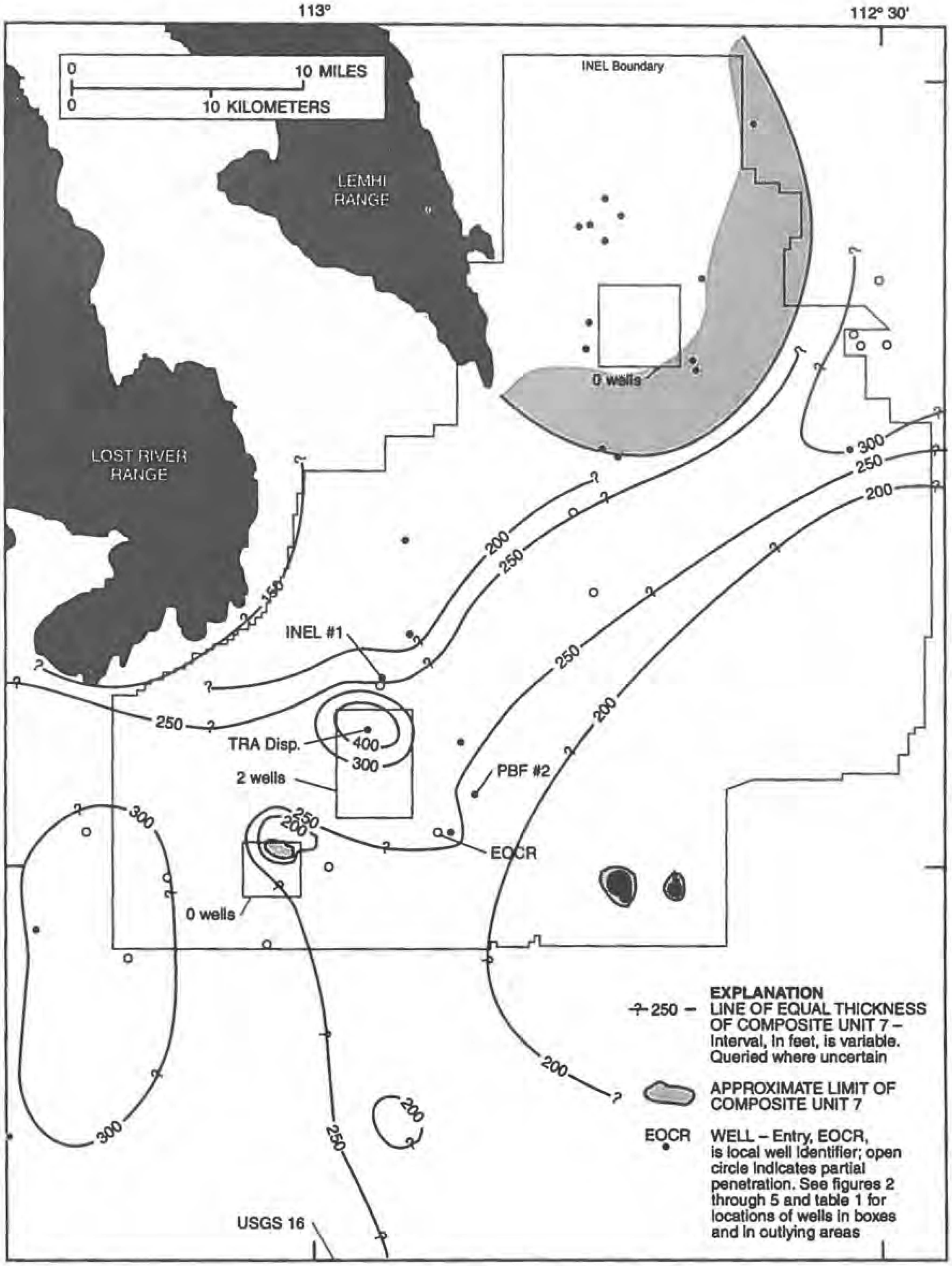

Figure 28. Thickness of composite stratigraphic unit 7 at the Idaho National Engineering Laboratory.

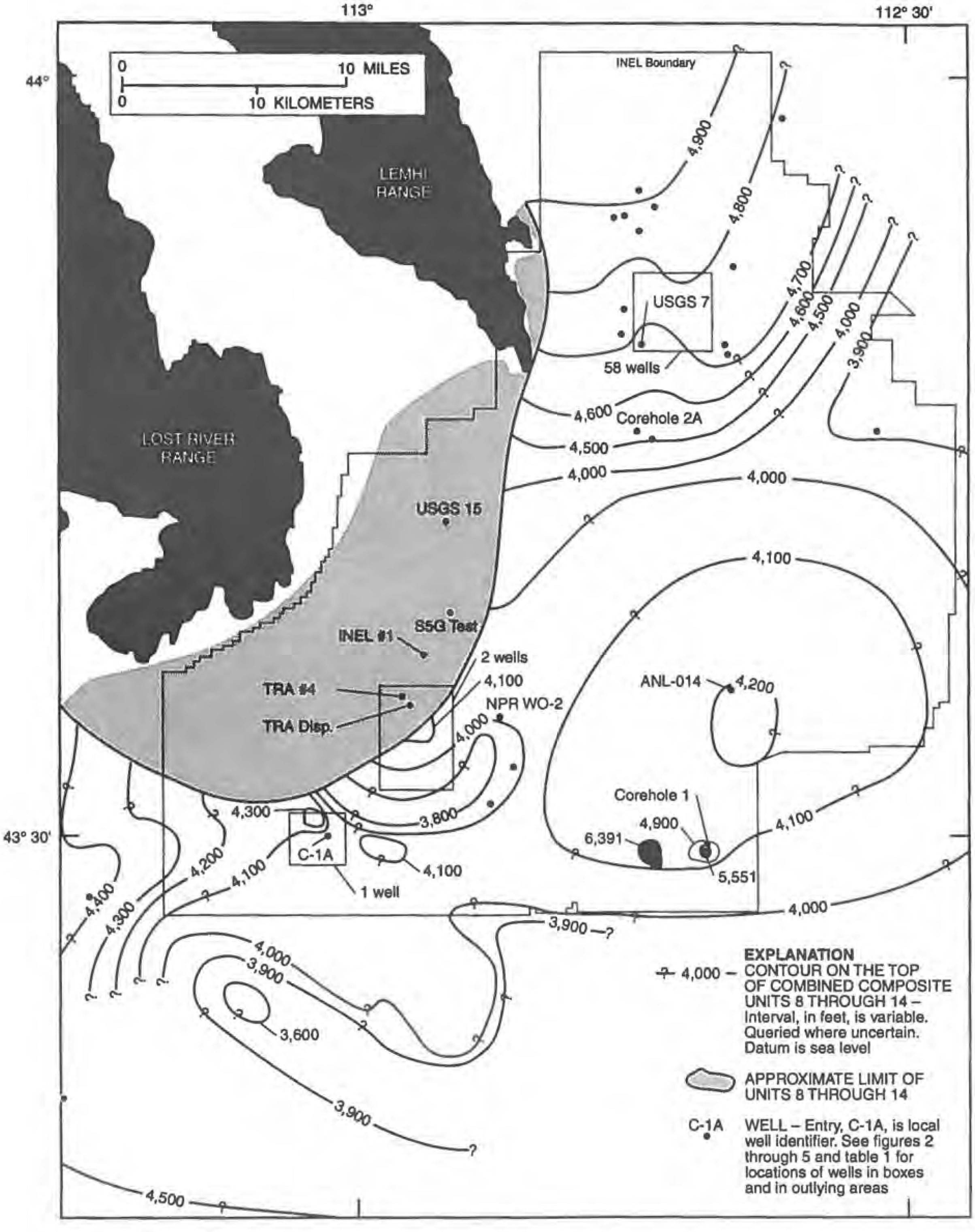

Figure 29. Altitude of the top of combined composite stratigraphic units 8 through 14 at the Idaho National Engineering Laboratory.

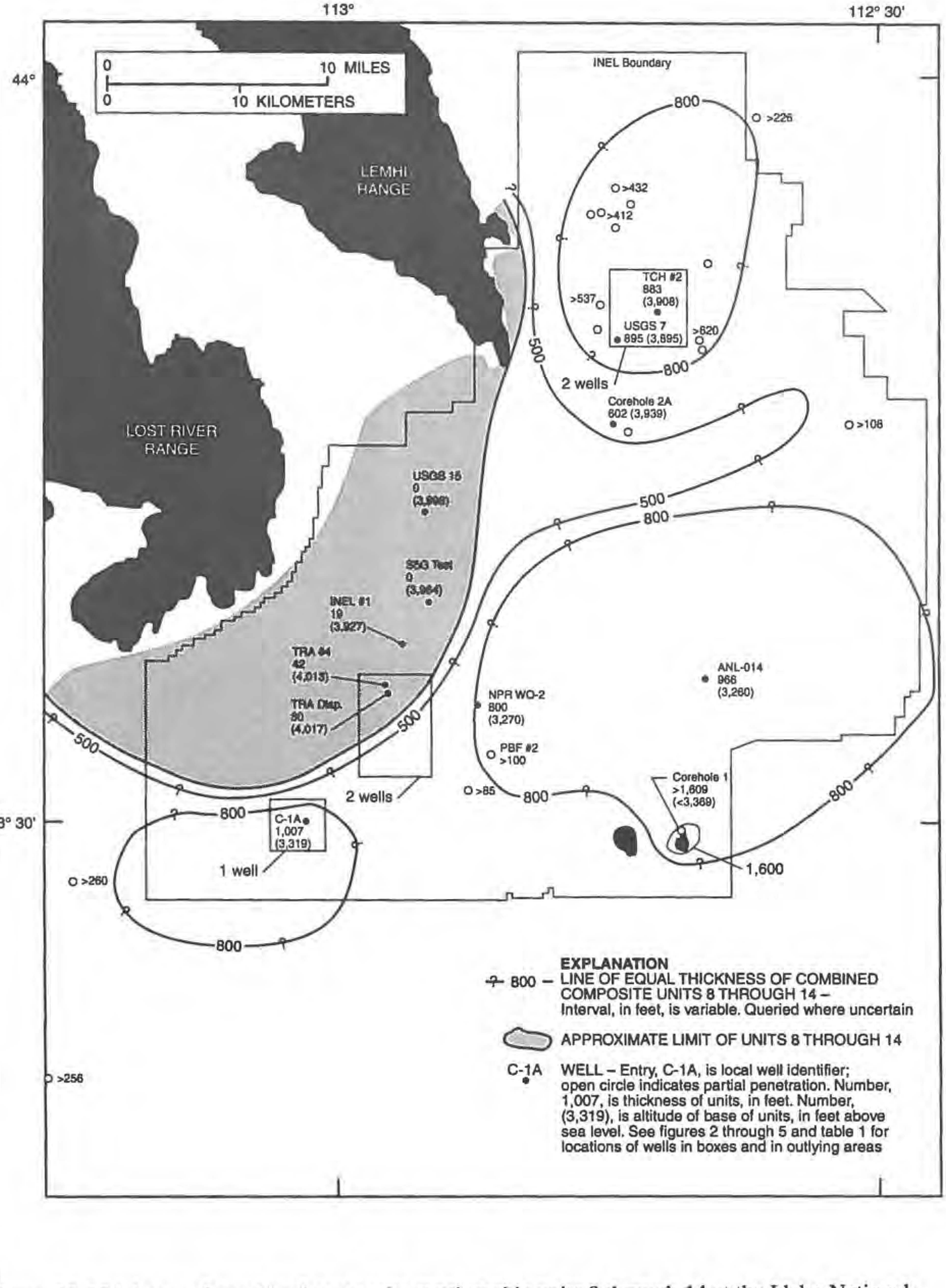

Figure 30. Thickness of combined composite stratigraphic units 8 through 14 at the Idaho National Engineering Laboratory.

Table 1. Wells at and near the Idaho National Engineering Laboratory for which stratigraphic data are available

[Well: Entry, USGS 1, is a well for which stratigraphic data are available (Anderson and others, 1996a). Figure number indicates the figure number of the map on which a well is located. Map number: Entries, 1 through 335, indicate the map number for each well on figures 2, 3, 4, or 5 and the page number for each well in Anderson and others (1996a, table 6); numbers, 213 and 227 not used. Composite units are composite stratigraphic units in figures 9 through 30 and table 4; commas indicate missing stratigraphic intervals]

Well identifier	Figure number	Map number	Composite units
USGS 1	2	1	1-5
USGS 2	2	2	1-5
USGS 3A	2	3	1-3
USGS 4	2	4	1, 3-6
USGS 5	2	5	1-4
USGS 6	2	6	1-7
USGS 7	5	7	1-3, 10-14
USGS 8	2	8	1, 4-7
USGS 9	2	9	1, 2-6
USGS 11	2	10	1-4
USGS 12	2	11	1-7
USGS 13	2	12	1, 4-9
USGS 14	2	13	1-4
USGS 15	2	14	1-7
USGS 16	2	15	1, 6-9
USGS 17	2	16	1-4
USGS 18	2	17	1-4, 12
USGS 19	2	18	1-5
USGS 20	2	19	1-6
USGS 21	2	20	1-4
USGS 22	2	21	1-5
USGS 23	2	22	1-5
USGS 24	5	23	1, 10, 12
USGS 25	2	24	1, 9-12
USGS 26	2	25	1, 10-12
USGS 27	2	26	1-4
USGS 28	2	27	1, 3-4
USGS 29	2	28	1-4
USGS 30A	2	29	1, 3-8
USGS 31	2	30	1, 3-5
USGS 32	2	31	1, 3-4
USGS 33	2	32	1-4
USGS 34	3	33	1-7
USGS 35	3	34	1-6
USGS 36	3	35	1-6
USGS 37	3	36	1-6
USGS 38	3	37	1-7
USGS 39	3	38	1-7
USGS 40	3	39	1-7
USGS 41	3	40	1-7
USGS 42	3	41	1-7
USGS 43	3	42	1-7
USGS 44	3	43	1-7
USGS 45	3	44	1-7
USGS 46	3	45	1-7
USGS 47	3	46	1-7
USGS 48	3	47	1-7
USGS 49	3	48	1-7
USGS 50	3	49	1-4
USGS 51	3	50	1-7
USGS 52	3	51	1-4, 6-7
USGS 53	3	52	1-2
USGS 54	3	53	1-2
USGS 55	3	54	1-2
USGS 56	3	55	1-2
USGS 57	3	56	1-7
USGS 58	3	57	1-4, 6-7
USGS 59	3	58	1-7
USGS 60	3	59	1-2
USGS 61	3	60	1-2
USGS 62	3	61	1-3
USGS 63	3	62	1-2
USGS 64	3	63	1-4
USGS 65	3	64	1-6
USGS 66	3	65	1-7
USGS 67	3	66	1-7
USGS 68	3	67	1-2
USGS 69	3	68	1-2
USGS 70	3	69	1, 3-4
USGS 71	3	70	1-3
USGS 72	3	71	1-3
USGS 73	3	72	1-2
USGS 74	3	73	1-3
USGS 75	3	74	1, 3-4, 7
USGS 76	3	75	1-7
USGS 77	3	76	1-5
USGS 78	3	77	1-3
USGS 79	3	78	1-7
USGS 80	3	79	1,3-4, 7
USGS 81	3	80	1-2
USGS 82	3	81	1-4, 6-7
USGS 83	2	82	1-6

Table 1. Wells at and near the Idaho National Engineering Laboratory for which stratigraphic data are available—Continued

Well identifier	Figure number	Map number	Composite units
USGS 84	3	83	1-6
USGS 85	3	84	1-6
USGS 86	2	85	1, 4-7
USGS 87	4	86	1-2, 5-6
USGS 88	4	87	1-2, 4-6
USGS 89	4	88	1-2, 4-6
USGS 90	4	89	1-2, 5-6
USGS 91	4	90	1-2
USGS 92	4	91	1-2
USGS 93	4	92	1-2
USGS 93A	4	93	1-2
USGS 94	4	94	1-2, 4-5
USGS 95	4	95	1-2
USGS 96	4	96	1-2
USGS 96A	4	97	1-2
USGS 96B	4	98	1-2
USGS 97	2	99	1-4
USGS 98	2	100	1-6
USGS 99	2	101	1-6
USGS 100	2	102	1-5
USGS 101	2	103	1-6
USGS 102	2	104	1-4
USGS 103	2	105	1-6
USGS 104	2	106	1, 3-6
USGS 105	2	107	1, 4-6
USGS 106	2	108	1, 3-7
USGS 107	2	109	1-5
USGS 108	2	110	1-6
USGS 109	2	111	1-2, 4-7
USGS 110	2	112	1-6
USGS 111	3	113	1-5
USGS 112	3	114	1-5
USGS 113	3	115	1-5
USGS 114	3	116	1-5
USGS 115	3	117	1-6
USGS 116	3	118	1-6
USGS 117	4	119	1-2, 4-6
USGS 118	4	120	1-2, 4-6
USGS 119	4	121	1-2, 4-6
USGS 120	4	122	1-2, 4-6
USGS 121	3	123	1-7
USGS 122	3	124	1-5
USGS 123	3	125	1-7
USGS 124	2	126	1, 4-5
1-27-14	2	127	1, 4-9
A11A31	2	128	1-2, 4-6
ANL-IWP-M1	2	129	1
ANL-IWP-M2	2	130	1-2
ANL-IWP-M3	2	131	1
ANL-IWP-M4	2	132	1-2
ANL-IWP-M5	2	133	1
ANL-IWP-M6	2	134	1-3
ANP #6	5	135	1, 9-12
ANP #7	2	136	1, 8-12
ANP #9	2	137	1-2, 10-12
ANP #10	2	138	1-2, 10-14
AREA II	2	139	1-6
Arbor Test 1	2	140	1-6
R. Archer	2	141	1, 3-4
Ashcraft	2	142	1-6
BG-76-1	4	143	1-2
BG-76-2	4	144	1-2
BG-76-3	4	145	1-2
BG-76-4	4	146	1-2
BG-76-4A	4	147	1-2
BG-76-5	4	148	1-2
BG-76-6	4	149	1-2
BG-77-1	4	150	1-2, 4-6
BG-77-2	4	151	1
Barney North	2	152	1, 3-7
Barney South	2	153	1, 3-7
Butte City #2	2	154	1-5
C-1	4	155	1-2, 4-6
C-1A	4	156	1-2, 4-6, 9-12
CFA 1	3	157	1-7
CFA 2	2	158	1-6
CFA 4	2	159	1-2
CFA LF 2-8	3	160	1-5
CFA LF 2-9	3	161	1-6
CFA LF 2-10	3	162	1-7
CFA LF 2-11	3	163	1-5
CFA LF 2-12	3	164	1-4
CFA LF 3-8	3	165	1-5
CFA LF 3-9	3	166	1-4
CFA LF 3-10	3	167	1-5
CFA LF 3-11	3	168	1-5
CPP 2	3	169	1-7
CPP Disp.	3	170	1-7
CPP 4	3	171	1-7
Callaway	2	172	1, 3-7
Cerro Grande	2	173	1, 4-5
Cope	2	174	1, 3-7

Table 1. Wells at and near the Idaho National Engineering Laboratory for which stratigraphic data are available—Continued

Well identifier	Figure number	Map number	Composite units
Corehole 1	2	175	1-2, 12
Corehole 2A	2	176	1-4, 12-14
D-10	4	177	1-2
D-15	4	178	1-2
DH1B	2	179	1-4
DH2A	2	180	1-5
DH3	2	181	1-3
DH-50	2	182	1-2
DO-2	4	183	1-2
DO-6	4	184	1-2
DO-6A	4	185	1
Dahle	2	186	1, 8-12
EBR I	2	187	1-6
EFS Well	2	188	1-6
EOCR	2	189	1-7
EOCR (Disp)	2	190	1-3
FET-Disp-1	5	191	1, 10-12
GIN #1	5	192	1, 10-12
GIN #2	5	193	1, 10-12
GIN #3	5	194	1, 10-12
GIN #4	5	195	1, 10-12
GIN #5	5	196	1, 10-12
GIN #6	5	197	1, 10-12
GIN #7	5	198	1, 9-11
GIN #8	5	199	1, 10-11
GIN #9	5	200	1, 10-11
GIN #10	5	201	1, 10
GIN #11	5	202	1, 10
GIN #12	5	203	1, 10
GIN #13	5	204	1, 9-10
GIN #14	5	205	1, 10
GIN #15	5	206	1, 10
GIN #16	5	207	1, 10
GIN #17	5	208	1, 10
GIN #18	5	209	1, 10-11
GIN #19	5	210	1, 10-11
GIN #20	5	211	1, 9-11
Highway #1 Piezo A	2	212	1-9
Highway #2	2	214	1-4
Highway #3	2	215	1-6
IET Disp.	5	216	1, 9-12
INEL #1	2	217	1-8
Water Supply for INEL #1	2	218	1-7
LPTF Disposal	5	219	1, 10-12
MTR Test	3	220	1-5, 7
Main Gate Well	2	221	1-5
NA 89-1	2	222	1-2
NA 89-2	2	223	1-2
NA 89-3	4	224	1-2
NPR Test	2	225	1-7
NPR WO-2	2	226	1-4, 6-10
NRF #4	2	228	1-5
NRF #6	2	229	1-4
NRF #6P	2	230	1-4
NRF #7	2	231	1-4
NRF #7P	2	232	1-4
NRF 89-04	2	233	1-3
NRF 89-05	2	234	1-3
OW-1	4	235	1-2, 4-7
OW-2	4	236	1-2, 4-7
PBF#2	2	237	1-8
PBF (CW)	2	238	1-3
PBF (WW)	2	239	1-3
PSTF Test	2	240	1-2, 9-12
P & W #1	2	241	1, 8-12
P & W #2	2	242	1, 8-12
P & W #3	2	243	1, 8-12
PW-1	3	244	1-2
PW-2	3	245	1-2
PW-3	3	246	1-2
PW-4	3	247	1-3
PW-5	3	248	1-2
PW-6	3	249	1-2
PW-7	3	250	1-3
PW-8	3	251	1-3
PW-9	3	252	1-3
PW-10	3	253	1-3
PW-11	3	254	1-3
PW-12	3	255	1-2
PW-13	3	256	1-2
PW-14	3	257	1-3
Quaking Aspen Butte Well	2	258	1-2, 4-7
RWMC-78-1	4	259	1
RWMC-78-2	4	260	1-2
RWMC-78-3	4	261	1-2
RWMC-78-4	4	262	1-2, 4-5
RWMC-78-5	4	263	1-2
RWMC-79-1	4	264	1-2
RWMC-79-2	4	265	1-2
RWMC-79-3	4	266	1-2
RWMC-88-1D	4	267	1-2
RWMC-88-02D	4	268	1-2

Table 1. Wells at and near the Idaho National Engineering Laboratory for which stratigraphic data are available—Continued

Well identifier	Figure number	Map number	Composite units
RWMC-89-01D	4	269	1-2
RWMC M1SA	4	270	1-2, 4-6
RWMC M3S	4	271	1-2, 5-6
RWMC M4D	4	272	1-2, 4-7
RWMC M6S	4	273	1-2, 5-6
RWMC M7S	4	274	1-2, 4-6
RWMC M10S	4	275	1-2, 4-6
RWMC Prod.	4	276	1-2, 5-6
Rifle Range Well	2	277	1-5
Leo Roger's #1	2	278	1-5
S5G Test (NRF #5)	2	279	1-7
Sdd-1	2	280	1-3
Sdd-2	2	281	1-4
Sdd-3	2	282	1-3
Siddoway	2	283	1, 3-7
Site 6	2	284	1-6
Site 9	2	285	1-8
Site 14	2	286	1-7
Site 16	2	287	1-6
Site 17	2	288	1-6
Site 19	3	289	1-7
TAN #3	5	290	1, 10-12
TAN #4	5	291	1, 12
TAN #5	5	292	1, 10, 12
TAN #6	5	293	1, 10, 12
TAN #7	5	294	1, 10, 12
TAN #8	5	295	1, 9-10, 12
TAN #9	5	296	1, 10, 12
TAN #10	5	297	1, 10-12
TAN #10A	5	298	1, 10-12
TAN #11	5	299	1, 10-12
TAN #12	5	300	1, 10-12
TAN #13	5	301	1, 10-12
TAN #13A	5	302	1, 10-12
TAN #14	5	303	1, 10-12
TAN #15	5	304	1, 9-10, 12
TAN #16	5	305	1, 9-10, 12
TAN #17	5	306	1, 10, 12
TAN #18	5	307	1, 10, 12-13
TAN #19	5	308	1, 10, 12
TAN #20	5	309	1, 10-12
TAN #21	5	310	1, 10-13
TAN #22	5	311	1, 9-10, 12-13
TAN #22A	5	312	1, 9-10, 12-13
TAN #23	5	313	1, 9-10, 12-13
TAN #23A	5	314	1, 9-10, 12
TAN #24	5	315	1, 9-12
TAN #24A	5	316	1, 9-12
TAN Drainage Disp.#1	5	317	1, 10-12
TAN Drainage Disp.#2	5	318	1, 10, 12
TAN Drainage Disp.#3	5	319	1, 10, 12
TAN Exploratory Well	2	320	1, 9-13
TCH #1	5	321	1, 10-14
TCH #2 Piezo A	5	322	1, 10-14
TRA #3	3	323	1-7
TRA #4	3	324	1-8
TRA 05/PZ1	3	325	1-4
TRA 06A	3	326	1-7
TRA 07	3	327	1-6
TRA 08	3	328	1-6
TRA Disp.	3	329	1-8
TW-1	4	330	1-2
VZT-1	4	331	1-2
WWW#1	4	332	1-2
WWW#2	4	333	1
Water table	2	334	1, 4-9
Weaver and Lowe	2	335	1-2, 4-9

Table 2. Selected cores and sources of data used to evaluate stratigraphic units underlying the Idaho National Engineering Laboratory

[Well is one from which continuous core was obtained; core locations shown in figure 6. Depth is total depth of well and approximate total depth of core, in feet below land surface. Data include paleomagnetic inclination and polarity, K-Ar (potassium-argon) and $^{40}Ar/^{39}Ar$ (argon-argon) ages, petrographic descriptions, and major-oxide and trace element chemistry. Symbol: -- indicates no data. Numbers in columns 3-6 indicate the following data references: 1 = Kuntz and others (1980); 2 = Champion and others (1988); 3 = Lanphere and others (1993); 4 = Lanphere and others (1994); 5 = Knobel and others (1995); 6 = Reed and others (1997); 7 = Duane E. Champion, USGS, written commun., 1989-95; 8 = Marvin A. Lanphere, USGS, written commun., 1989-95; 9 = Mel A. Kuntz, USGS, written commun., 1989-95; and 10 = Roy C. Bartholomay, written commun., 1989-95. Additional data for deposits in and underlying the Snake River Plain aquifer are indicated by the following references: 11 = Shervais and others, 1994; 12 = Lawrence and Hackett, 1994; and 13 = Hackett and others, 1994]

Well and core identifier	Depth (feet)	Source of paleomagnetic data	Source of geochronologic data	Source of petrographic data	Source of chemical data
BG-76-1	228	1	1	1	--
BG-77-1	600	1	1, 2	1	10
C-1A	1,805	7	8	--	--
Corehole 1	2,002	7	--	--	--
Corehole 2A	3,000	7	8	--	--
DH-50	250	7	--	--	--
GIN #5	430	4	--	--	--
GIN #6	200	4	--	--	--
NPR Test	609	2	2	--	5, 10, 11
NPR WO-2	5,000	7, 13	8, 13	12	11
NRF #6P	500	7	--	--	--
NRF #7P	500	7	8	--	--
NRF 89-04	248	3	3	--	--
NRF 89-05	242	3	3	3	--
PW-13	148	7	--	--	--
TCH #1	600	4	4	4	5
TCH #2 Piezo A	1,114	4	4	4	5
TRA 05/PZ1	297	7	8	--	5
USGS 80	204	3	3	3	--
USGS 81	108	7	--	--	--
USGS 93A	233	--	--	1	--
USGS 94	302	1	1	1	--
USGS 118	570	7	--	--	10
USGS 121	746	7	8	9	6
USGS 123	744	3	3	3	6
WWW #1	265	7	--	--	--

Table 3. Wells that penetrate the effective base of the Snake River Plain aquifer at the Idaho National Engineering Laboratory

[Depth is total depth of well, in feet below land surface. Base is the depth to the effective base of the Snake River Plain aquifer, in feet below land surface. Saturated thickness is approximate saturated thickness of aquifer, in feet, based on 1990 water levels from these or nearby wells (Ott and others, 1992). Lithology indicates the relative abundance of basalt (B) and sediment (S) below the base of the aquifer to a depth of 500 feet; greatest abundance is listed first. Core indicates the availability of continuous core (table 2)]

Well identifier	Depth (feet)	Base (feet)	Saturated thickness (feet)	Lithology	Core
C-1A	1,805	1,710	1,120	B, S	Yes
Corehole 2A	3,000	846	580	S, B	Yes
INEL #1	10,365	965	660	S, B	No
NPR WO-2	5,000	1,660	1,200	B, S	Yes
S5G TEST	1,276	884	515	B, S	No
TCH #2	1,114	883	680	B, S	Yes
TRA #4	970	909	445	B, S	No
TRA Disp	1,275	907	445	B, S	No
USGS 7	1,200	895	685	B, S	No
USGS 15	1,497	815	500	S, B	No

Table 4. Stratigraphic units on or underlying the Idaho National Engineering Laboratory and adjacent areas

[Stratigraphic unit is a volcanic or sedimentary unit from Anderson and others (1996a); units listed from youngest, Au(1), to oldest, S5(1). Composite unit is a composite stratigraphic unit in figures 9 through 30 and table 1; bold type indicates first entry of a composite unit. Lithologic type indicates the following generalized lithologic types: Bas = basalt; Sed = sediment; And = Andesite; and Rhy = rhyolite; basalt, andesite, and rhyolite are flow groups that consist of one or more flows from a single eruptive event. Vent number indicates the location of a volcanic vent in figure 7. Wells indicates the number of wells in which each stratigraphic unit is present]

Stratigraphic unit	Composite unit	Lithologic type	Vent number	Wells
Au(1)	**1**	**Sed**		**0**
Au(2)	1	Bas	1	0
Au(3)	1	Bas	2	0
Au(4)	1	Bas	3	0
Au(5)	1	Bas	4	0
Al(1)	1	Sed		288
Al(2)	1	Bas	5	0
Al(3)	1	Bas	6	2
Al(4)	1	Bas	7	0
Al(5)	1	Bas	8	2
Al(6)	1	Bas	9	1
Al(7)	1	Bas	10	0
Al(8)	1	Bas	11	0
Al(9)	1	Bas	12	34
Al(9)	1	Sed		12
Al(10)	1	Bas	13	0
Al(11)	1	Bas	14	0
Al(12)	1	Bas	15	0
Al(13)	1	Bas	16	0
AB(1)	1	Sed		211
AB(2)	1	Bas	17	0
AB(3)	1	Bas	18	0
AB(4)	1	Bas	19	0
AB(5)	1	Bas	20	0
AB(6)	1	Bas	21	0
AB(7)	1	Bas	22	0
AB(8)	1	Bas	23	3
AB(9)	1	Bas	24	12
AB(10)	1	Bas	25	9
AB(11)	1	Bas	26	8
AB(11)	1	Sed		11
AB(12)	1	Bas	27	1
AB(13)	1	Bas	28	2
AB(14)	1	Bas	29	0
AB(15)	1	Bas	30	0
AB(16)	1	Bas	31	1
AB(17)	1	Bas	32	0
AB(17)	1	Sed		1
AB(18)	1	Bas	33	1
AB(18)	1	Sed		1
AB(19)	1	Bas	34	0
AB(20)	1	Bas	35	0
AB(21)	1	Bas	36	0
AB(22)	1	Bas	37	1
AB(23)	1	Bas	38	1
AB(24)	1	Bas	39	0
AB(25)	1	Bas	40	0
AB(26)	1	Bas	41	1
AB(27)	1	Bas	42	0
AB(28)	1	Bas	43	1
AB(29)	1	Bas	44	0
AB(30)	1	Bas	45	1
AB(31)	1	Bas	46	2
AB(32)	1	Bas	47	0
AB(33)	1	Bas	48	0
AB(34)	1	Bas	49	0
AB(35)	1	Bas	50	0
AB(36)	1	Bas	51	0
AB(37)	1	Bas	52	0
AB(38)	1	Bas	53	0
AB(39)	1	Bas	54	0
AB(40)	1	Bas	55	0

Table 4. Stratigraphic units on or underlying the Idaho National Engineering Laboratory and adjacent areas—Continued

Stratigraphic unit	Composite unit	Lithologic type	Vent number	Wells	Stratigraphic unit	Composite unit	Lithologic type	Vent number	Wells
AB(41)	1	Bas	56	0	BC(4)	2	Bas	82	2
AB(42)	1	Bas	57	0	C(1)	2	Bas	83	131
AB(43)	1	Bas	58	0	C(1)	2	Sed		13
AB(44)	1	Bas	59	0	CD(1)	2	Bas	84	31
AB(45)	1	Bas	60	0	CD(1)	2	Sed		76
AB(46)	1	Bas	61	0	CD(2)	2	Bas	85	4
AB(47)	1	Bas	62	1	D(1)	2	Bas	86	95
AB(48)	1	Bas	63	0	D(1)	2	Sed		9
AB(49)	1	Bas	64	1	D(2)	2	Bas	87	2
AB(50)	1	Bas	65	0	D(2)	2	Sed		3
AB(51)	1	Bas	66	2	D(3)	2	Bas	88	6
AB(52)	1	Bas	67	0	D(4)	2	Bas	89	11
AB(53)	1	Bas	68	1	DE1(1)	2	Bas	90	5
AB(54)	1	Bas	69	0	DE1(1)	2	Sed		2
AB(55)	1	Bas	70	0	DE1(2)	2	Bas	91	10
AB(56)	1	Bas	71	0	DE1(3)	2	Bas	92	57
AB(57)	1	Bas	72	0	DE1(3)	2	Sed		10
AB(58)	1	Bas	73	0	DE1(4)	2	Bas	93	4
B(1)	1	Bas	74	143	DE1(4)	2	Rhy	94	0
B(1)	1	Sed		85	DE1(4)	2	Sed		2
B-BC(1)	1	Bas	75	6	DE1-2(1)	2	Bas	95	28
B-BC(1)	1	Sed		5	DE1-2(1)	2	Sed		37
B-BC(2)	1	Bas	76	10	DE1-2(2)	2	Bas	96	2
B-BC(2)	1	Sed		161	DE1-2(2)	2	Sed		11
B-BC(3)	1	Bas	77	32	DE1-2(3)	2	Bas	97	1
B-BC(3)	1	Sed		2	DE1-2(3)	2	Sed		1
B-BC(4)	1	Bas	78	2	**DE2(1)**	**3**	**Bas**	**98a,b**	**103**
B-BC(4)	1	Sed		5	DE2(1)	3	Sed		42
BC(1)	**2**	**Bas**	**79**	**101**	DE2-3(1)	3	Bas	99	24
BC(1)	2	Sed		27	DE2-3(1)	3	Sed		67
BC(2)	2	Bas	80	79	DE2-3(2)	3	Bas	100	10
BC(2)	2	Sed		10	DE2-3(2)	3	Sed		10
BC(3)	2	Bas	81	11	DE2-3(3)	3	Bas	101	1
BC(3)	2	Sed		42	DE3(1)	3	Bas	102	118

Table 4. Stratigraphic units on or underlying the Idaho National Engineering Laboratory and adjacent areas—Continued

Stratigraphic unit	Composite unit	Lithologic type	Vent number	Wells
DE3(1)	3	Sed		16
DE3(2)	3	Bas	103	10
DE3(2)	3	Sed		23
DE3-4(1)	3	Bas	104	42
DE3-4(1)	3	Sed		4
DE3-4(2)	3	Bas	105	3
DE3-4(2)	3	Sed		8
DE3-4(3)	3	Bas	106	103
DE3-4(3)	3	Sed		22
DE3-4(4)	3	Bas	107	29
DE3-4(4)	3	Sed		39
DE3-4(5)	3	Bas	108	13
DE3-4(5)	3	Sed		4
DE3-4(6)	3	Sed		1
DE4(1)	3	Bas	109	115
DE4(1)	3	Sed		9
DE4(2)	3	And	110	2
DE4-5(1)	3	Bas	111	4
DE4-5(1)	3	Sed		16
DE4-5(2)	3	Bas	112	19
DE4-5(2)	3	Sed		1
DE4-5(3)	3	Bas	113	46
DE4-5(3)	3	Sed		36
DE4-5(4)	3	Bas	114	10
DE4-5(4)	3	Sed		2
DE4-5(5)	3	Bas	115	1
DE4-5(5)	3	Sed		2
DE5(1)	**4**	**Bas**	**116**	**122**
DE5(1)	4	Sed		9
DE5-6(1)	4	And	117	8
DE5-6(1)	4	Sed		1
DE5-6(2)	4	Bas	118	8
DE5-6(3)	4	Bas	119	3
DE5-6(3)	4	Sed		9
DE5-6(4)	4	Bas	120	7
DE5-6(5)	4	Sed		2
DE5-6(6)	4	Bas	121	33
DE5-6(6)	4	Sed		71
DE6(1)	4	Bas	122a,b,c	81
DE6(1)	4	Sed		25
DE6(2)	4	And	123	1
DE6-7(1)	4	Bas	124a,b,c	7
DE6-7(1)	4	Sed		33
DE7(1)	4	Bas	125a,b	120
DE7(1)	4	Sed		6
DE7(2)	4	And	126	1
DE7-8(1)	4	Sed		27
DE8(1)	4	Bas	127a,b,c	123
DE8(1)	4	Sed		4
DE8(2)	4	And	128	1
DE9(1)	4	Sed		51
E(1)	**5**	**Bas**	**129**	**135**
E(1)	5	Sed		7
E(2)	5	Sed		24
EF(1)	5	Bas	130	96
EF(1)	5	Sed		7
EF(2)	5	Sed		5
F(1)	5	Bas	131	98
F(1)	5	Sed		9
F(2)	5	Sed		6
FG(1)	**6**	**Bas**	**132**	**84**
FG(1)	6	Sed		26
FG(2)	6	Rhy	133	0
FG(2)	6	Sed		8
G(1)	6	Bas	134	98
G(1)	6	Sed		9
G(2)	6	Sed		3
GH(1)	6	Bas	135	7

Table 4. Stratigraphic units on or underlying the Idaho National Engineering Laboratory and adjacent areas—Continued

Stratigraphic unit	Composite unit	Lithologic type	Vent number	Wells	Stratigraphic unit	Composite unit	Lithologic type	Vent number	Wells
GH(1)	6	Sed		14	LM3(1)	8	Bas	151	10
H(1)	6	Bas	136	51	LM3(2)	8	Bas	152	1
H(1)	6	Sed		14	LM3(2)	8	Sed		3
HI(1)	6	Bas	137	11	LM4(1)	8	Bas	153	7
HI(1)	6	Sed		55	LM4(1)	8	Sed		1
HI(2)	6	Sed		1	LM4(2)	8	Bas	154	0
I(1)	**7**	**Bas**	**138**	**66**	LM4(2)	8	Sed		4
I(1)	7	Sed		3	LM4(3)	8	Bas	155	2
I(2)	7	Bas	139	58	LM4(3)	8	Sed		2
I(2)	7	Sed		2	**LM5(1)**	**9**	**Bas**	**156**	**7**
IJ(1)	7	Bas	140	2	LM5(2)	9	Bas	157	0
IJ(1)	7	Sed		12	LM5(2)	9	Sed		1
J(1)	7	Bas	141	34	LM5(3)	9	Bas	158	0
J(1)	7	Sed		3	LM6(1)	9	Bas	159	3
JK(1)	7	Sed		3	LM6(2)	9	Bas	160	9
K(1)	7	Bas	142	18	LM6(3)	9	Bas	161	11
K(1)	7	Sed		6	LM6(3)	9	Sed		2
KL(1)	7	Bas	143	15	LM7(1)	9	Bas	162	1
KL(1)	7	Sed		4	LM7(2)	9	Bas	163	0
KL(2)	7	Sed		1	LM7(2)	9	Sed		4
L(1)	7	Bas	144	16	LM7(3)	9	Bas	164	0
L(1)	7	Sed		1	LM8(1)	9	Bas	165	2
L(2)	7	Sed		2	LM8(2)	9	Sed		1
LM1(1)	**8**	**Bas**	**145**	**3**	**M(1)**	**10**	**Bas**	**166**	**60**
LM1(1)	8	Sed		7	M(2)	10	Rhy	167	0
LM1(2)	8	Bas	146	3	M(2)	10	Sed		15
LM1(2)	8	Sed		7	M(2)	10	Bas	168	1
LM1(3)	8	Bas	147	1	MN(1)	10	Bas	169	64
LM1(4)	8	Bas	148	1	MN(2)	10	Sed		7
LM1(4)	8	Sed		2	N(1)	10	Bas	170	64
LM2(1)	8	Bas	149	6	N(2)	10	Sed		1
LM2(1)	8	Sed		2	N(3)	10	Bas	171	1
LM2(2)	8	Bas	150	0	N(4)	10	Bas	172	2
LM2(2)	8	Sed		2	N(5)	10	Sed		1

Table 4. Stratigraphic units on or underlying the Idaho National Engineering Laboratory and adjacent areas—Continued

Stratigraphic unit	Composite unit	Lithologic type	Vent number	Wells
NO(1)	**11**	**Bas**	**173**	**1**
NO(1)	11	Sed		8
O(1)	11	Bas	174	40
O(1)	11	Sed		2
OP(1)	11	Sed		10
P(1)	**12**	**Bas**	**175**	**55**
P(2)	12	Bas	176	3
P(3)	12	Bas	177	1
PQ(1)	12	Sed		19
Q(1)	12	Bas	178	41
Q(2)	12	Bas	179	1
QR(1)	12	Sed		14
QR(2)	12	Rhy	180	1
QR(3)	12	And	181	1
R1(1)	**13**	**Bas**	**182**	**9**
R1(2)	13	Sed		10
R2(1)	13	Bas	183	11
R2(2)	13	Sed		1
S1(1)	13	Bas	184	5
S1(2)	13	Sed		1
S2(1)	**14**	**Bas**	**185**	**5**
S2(2)	14	Sed		4
S3(1)	14	Bas	186	3
S4(1)	14	Bas	187	1
S5(1)	14	Bas	188	2

Table 5. Measured and estimated geologic ages of selected basalt-flow groups underlying the Idaho National Engineering Laboratory and adjacent areas

[Each basalt-flow group, AI(9) through TU(1), includes one or more basalt flows deposited during a single eruptive event. Measured age is analytical age determined mainly by the K-Ar method; ages for AI(9), 101±7 ka, and F(1), 550±10 ka, and TU(1), 1.865±0.024 ma, determined by thermoluminescence and $^{40}Ar/^{39}Ar$ methods, respectively. Estimated age is age from Anderson and others (1997) that was estimated using all measured ages and linear accumulation rates in selected wells; line segment, (1b), indicates selected regression equation from Anderson and others (1997). Ages are listed in thousands (ka) or millions (ma) of years before present. Paleomagnetic polarity indicates normal (N) or reversed (R) polarity. Sample location indicates well or outcrop from which sample was obtained. Sample depth indicates depth or depth interval of core sample, in feet below land surface; letter, S, indicates surface or near-surface sample. Hydrologic unit indicates that sample was obtained from: 1 = the unsaturated zone, 2U = the uppermost 300 feet of the Snake River Plain aquifer, 2L = the lowermost part of the aquifer; or 3 = below the effective base of the aquifer. Large differences between measured and estimated ages, such as for flow groups S1(1), S2(1), and S5(1) at TAN, indicate that additional study of these groups is needed. See table 2 for data references]

Basalt-flow group	Measured age	Estimated age (line segment)	Paleomagnetic polarity	Sample location	Sample depth	Hydrologic unit
AI(9)	95±50 ka	100 ka (--)	N	BG-77-1	30	1
	101±7 ka		N	RWMC	S	1
AB(10)	218±49 ka	198 ka (1a)	N	NPR Test	23	1
B(1)	<200 ka	221 ka (1a)	N	BG-77-1	81	1
BC(1)	247±46 ka	254 ka (1a)	N	NPR Test	81	1
DE1(2)	303±30 ka	302 ka (1a)	N	NRF 89-05	79	1
DE2(1)	350±40 ka	350 ka (1a,1b)	N	NPR Test	157	1
DE5(1)	441±77 ka	437 ka (1b)	N	NPR Test	352	1
DE8(1)	491±80 ka	488 ka (1b)	N	NPR Test	444	1
E(1)	515±85 ka	512 ka (1b)	N	BG-77-1	300 to 329	1
F(1)	565±14 ka	570 ka (1b)	R	BG-77-1	426 to 544	1
FG(1)	580±93 ka	581 ka (1b)	N	NPR Test	508	2U
H(1)	619±22 ka	619 ka (1b,1c)	N	USGS 123	540	2U
I(1)	641±54 ka	660 ka (1c)	N	NPR Test	606	2U
LM1(4)	807±33 ka	800 ka (1c, 3a)	R	Richard Butte	S	1
LM6(3)	939±154 ka	959 ka (3a)	R	Lava Ridge	S	1
N(1)	1.044±0.035 ma	1.152 ma (3b)	R	TCH#1	87	1
P(1)	1.248±0.069 ma	1.415 ma (3b)	R	TCH#1	175	1
R1(1)	1.581±0.057 ma	1.572 ma (3b)	R	TCH#1	413	2U
S1(1)	1.936±0.083 ma	1.618 ma (3b)	R	TCH#1	523	2L
S2(1)	2.115±0.046 ma	1.648 ma (3b)	R	TCH#2 Piezo A	637	2L
S5(1)	2.556±0.035 ma	1.708 ma (3b)	R	TCH#2 Piezo A	785	2L
TU(1)	1.865±0.024 ma	1.790 ma (3c)	N	NPR WO-2	1708	3

Table 6. Paleomagnetic chrons and subchrons in cores at and above the effective base of the Snake River Plain aquifer at the Idaho National Engineering Laboratory

[Paleomagnetic chrons and subchrons from Berggren and others (1995) and Champion and others (1988); letter, (B), is abbreviation used in figures 9-15. Paleomagnetic ages in thousands (ka) or millions (ma) of years before present. Paleomagnetic polarity indicates normal (N) or reversed (R) polarity. Core identifiers from table 2; identifiers in parentheses indicate new cores from Davis and others (1997). Stratigraphic units from table 4 and Anderson and others (1996a). Depths and measured ages of polarity boundaries from Kuntz and others (1994) and data references in table 2; letters in parentheses are paleomagnetic chrons and subchrons indicated by spurious or conflicting ages. Estimated ages from Anderson and others (1997, table 6); line segment, (1b), indicates selected regression equation from Anderson and others (1997). -- indicates no data]

Paleomagnetic chron or subchron	Paleomagnetic age	Paleomagnetic polarity	Core identifier	Stratigraphic unit	Depth to top (feet)	Measured age	Estimated age (line segment)
Brunhes (B)	0 to 780 ka	N	All cores	Au(1) to KL(2)	0	5.20±0.15 ka to 739±126 ka	0 to 759 ka (1a,1b,1c)
Emperor (E)	465 ka	R	NRF #6P	DE5-6(6)	418	(BL, M)	473 ka (1b)
		R	NRF #7P	DE5-6(6)	428	(BL, M)	473 ka (1b)
Big Lost (BL)	550 ka	R	(ARA-COR-005)	F(1)	712	--	570 ka (1b)
		R	BG-77-1	F(1)	364	550±10 ka	570 ka (1b)
		R	C-1A	F(1)	399	--	570 ka (1b)
		R	NPR Test	F(1)	456	--	570 ka (1b)
		R	(STF-PIE-AQ-01)	F(1)	524	--	570 ka (1b)
		R	USGS 118	F(1)	381	--	570 ka (1b)
Matuyama (M)	780 ka to 2.58 ma	R	(ANL-OBS-AQ-014)	L(1)	923	--	759 ka (1c)
		R	NPR WO-2	L(1)	767	(B)	759 ka (1c)
		R	C-1A	LM8(1)	703	(B)	1.06 ma (3a,3b)
		R	GIN #5	M(1)	26	--	1.08 ma (3b)
		R	GIN #6	M(1)	57	--	1.08 ma (3b)
		R	TCH #1	MN(1)	44	1.044±0.035 ma	1.08 ma (3b)
		R	TCH #2 Piezo A	M(1)	40	--	1.08 ma (3b)
Jaramillo (J)	990 ka to 1.07 ma	N	NPR WO-2	LM7(1)	1,187	(CM)	991 ka (3a)
Cobb Mountain (CM)	1.21 to 1.24 ma	N	C-1A	NO(1)	1,074	(M)	1.23 ma (3b)
Olduvai (O)	1.77 to 1.95 ma	N	(ANL-OBS-AQ-014)	TU(1)	1,890	--	1.79 ma (3c)
		N	Corehole 2A	TU(1)	970	(M)	1.79 ma (3c)
		N	NPR WO-2	TU(1)	1,696	1.865±0.024 ma	1.79 ma (3c)

Table 7. Summary of composite stratigraphic units 1 through 14 in wells at and near the Idaho National Engineering Laboratory

[Composite unit is a composite stratigraphic unit in figures 9 through 30 and table 1. Number of stratigraphic units indicates the number of basalt-flow groups (Bas), sedimentary interbeds (Sed), andesite-flow groups (And), and rhyolite domes (Rhy) in a composite unit. [BSB] = Big Southern Butte, [CB] = Cedar Butte, [EB] = East Butte, [MB] = Middle Butte, and [UD] = unnamed dome (figure 8). Number of wells indicates the number of wells that penetrate the top and base of a unit; altitude of top and base in feet above sea level. Geologic age is the age of a unit, in thousands (ka) or millions (ma) of years before present. Vent number indicates the location of a volcanic vent in figure 7; number in brackets indicates the location of a vent for a butte or dome in the same composite unit]

Composite unit	Number of stratigraphic units	Number of wells (top)	Number of wells (base)	Altitude of top (feet)	Altitude of base (feet)	Thickness (feet) [average]	Sediment content (percent) [average]	Geologic age	Vent number
1	78 Bas 12 Sed	333	326	5,375-4,772	5,362-4,721	0-284 [62]	0-100 [47]	5-250 ka	1-78
2	18 Bas 13 Sed 1 Rhy [BSB]	234	178	5,299-4,732	5,175-4,659	0-321 [109]	0-100 [11]	250-350 ka	79-97 [94]
3	17 Bas 17 Sed 1 And	164	143	5,128-4,659	5,048-4,465	0-305 [164]	0-100 [15]	350-440 ka	98a-115 110
4	9 Bas 11 Sed 4 And [CB]	172	146	5,362-4,465	5,257-4,272	0-482 [138]	0-100 [11]	440-515 ka	116-128 [117], 123, 126, 128
5	3 Bas 6 Sed	143	114	5,257-4,272	5,059-4,093	0-329 [125]	0-100 [5]	515-580 ka	129-131
6	5 Bas 8 Sed 1 Rhy [EB]	118	68	5,089-4,093	4,876-3,939	0-347 [107]	0-100 [23]	580-650 ka	132-137 [133]
7	7 Bas 10 Sed	70	15	4,876-3,939	4,592-3,807	0-409 [266]	0-59 [13]	650-800 ka	138-144
8-14	41 Bas 26 Sed 1 And 2 Rhy [MB, UD]	86	9	4,978-3,807	4,017-3,260	0->1,609 [832]	4-13 [7]	0.8-1.8 ma	145-188 181 [167, 180]

Table 8. Measured and estimated geologic ages of selected surficial stratigraphic units at and near the Idaho National Engineering Laboratory

[Stratigraphic unit is a basalt-flow group from table 4. Vent number corresponds to volcanic vent in figure 7. Field number, flow name, and map unit correspond to number, name, and unit of a basalt-flow group on the geologic map of the INEL and adjoining areas (Kuntz and others, 1994). Measured age, 519±52 ka, is K-Ar age of unit reported by Kuntz and others (1994), in thousands of years before present (ka); remeasured age, [292±58 ka], is revised K-Ar age of unit AB(8) (M.A. Lanphere, USGS, written commun., 1994). Alternative stratigraphic unit is alternative unit from table 4 indicated by measured age. Estimated age is from Anderson and others (1997, table 6). Alternative map unit is alternative unit from Kuntz and others (1994) indicated by estimated age; -- indicates no alternative map unit required]

Stratigraphic unit	Vent number	Field number	Flow name	Map unit	Measured age [remeasured]	Alternative stratigraphic unit	Estimated age	Alternative map unit
AB(8)	23	84lLe-20	Crater Butte	Qbd	519±52 ka [292±58 ka]	E(1) [DE1(2)]	198 to 221 ka	Qbc
AB(13)	28	84lLe-1	Kettle Butte	Qbc	316±75 ka	DE1(2)	198 to 221 ka	--
AB(37)	52	84lLe-15	Taber Butte	Qbb	165±22 ka	AI(14)	198 to 221 ka	Qbc
AB(38)	53	84lLe-17	Vent 5183 flow	Qbd	454±28 ka	DE5-6(1)	198 to 221 ka	Qbc
B(1)	74	(none)	Vent 5206, flow north of Big Southern Butte	Qbb	<200 ka	AI(15)	221 ka	Qbc
DE1(1)	90	84lLe-24	State Butte	Qbd	579±130 ka	FG(1)	302 ka	Qbc
DE6(1)	122a	84lLe-30	Unnamed flow, Arco-Big Southern rift zone	Qbd	609±92 ka	H(1)	473 ka	--

Table 9. Average sediment content of composite stratigraphic units 1 through 7 in selected wells east through southwest of Test Area North at the Idaho National Engineering Laboratory

[Well is one that is located in a zone of steep water-level gradients (Bartholomay and others, 1995) and thick surficial sediment (Anderson and others, 1996b). Map number indicates location of well in figure 2. Composite units are composite stratigraphic units in figures 9 through 28 and in table 4. Total thickness, number of sediment layers, and total sediment thickness from Anderson and others (1996a, table 6). Average sediment content is the total sediment thickness divided by the total thickness, in percent; number in brackets indicates content for saturated interval in 1989-90. Average sediment content for all INEL wells is a weighted average determined from the average content of each composite unit in all 333 wells evaluated for stratigraphic relations at and near the INEL. -- indicates no data or not applicable]

Well	Map number	Composite units	Total thickness (feet)	Number of sediment layers	Total sediment thickness (feet)	Average sediment content (percent) [saturated interval]
USGS 18	17	1-4	254	6	181	71 [--]
USGS 27	26	1-4	312	8	154	49 [15]
USGS 28	27	1-4	334	4	55	16 [8]
USGS 31	30	1-5	428	5	62	14 [6]
Ashcraft	142	1-6	420	12	188	45 [29]
Barney North	152	1-7	660	9	172	26 [7]
Barney South	153	1-7	596	9	167	28 [15]
Callaway	172	1-7	650	10	265	41 [43]
Cope	174	1-7	784	11	249	32 [22]
Corehole 2A	176	1-4	244	6	182	74 [100]
DH1B	179	1-4	400	17	348	87 [100]
DH2A	180	1-5	430	16	339	79 [83]
DH3	181	1-3	203	12	203	100 [--]
Site 14	286	1-7	717	19	395	55 [28]
All INEL wells	1-335	1-7	--	--	--	15 [--]