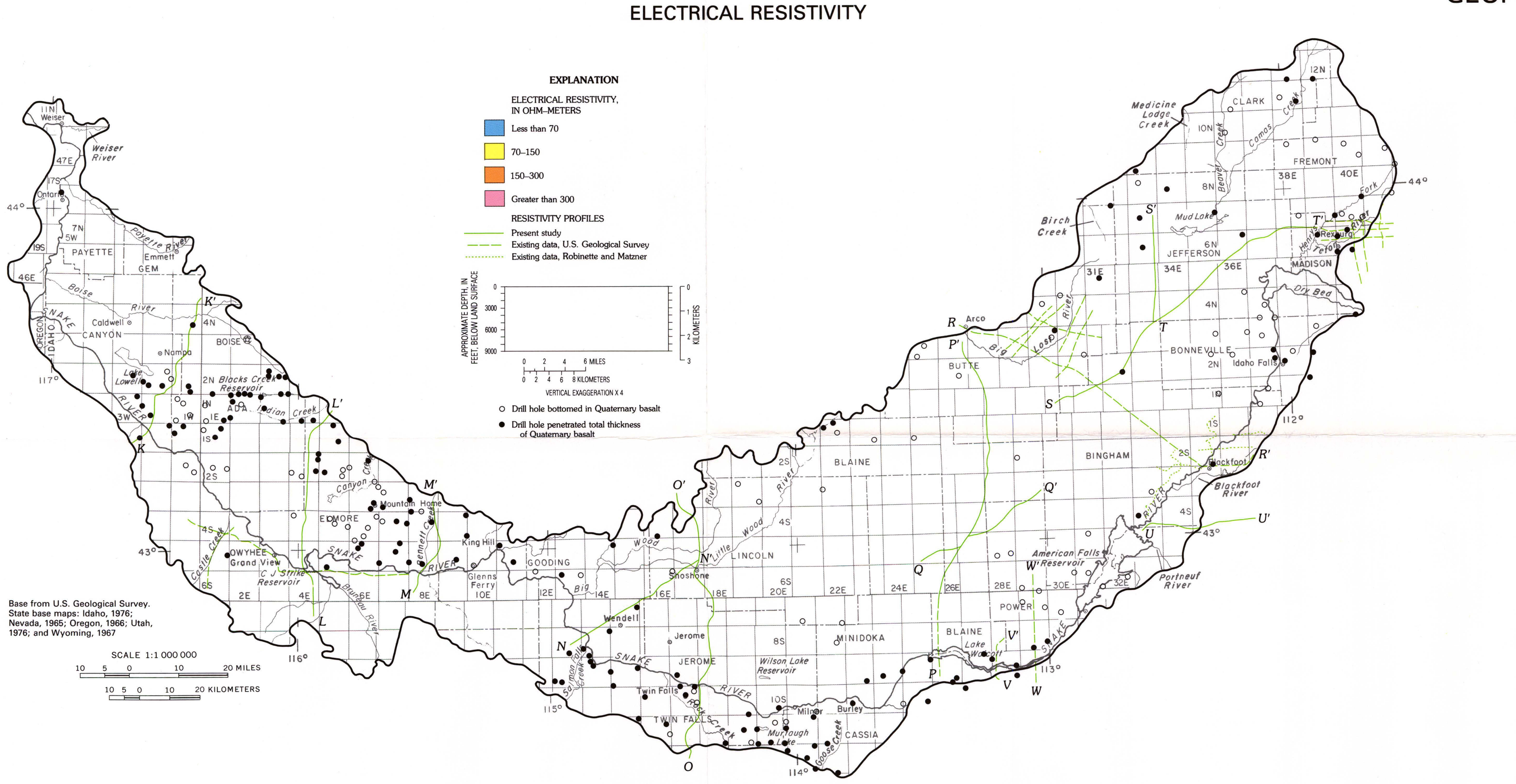
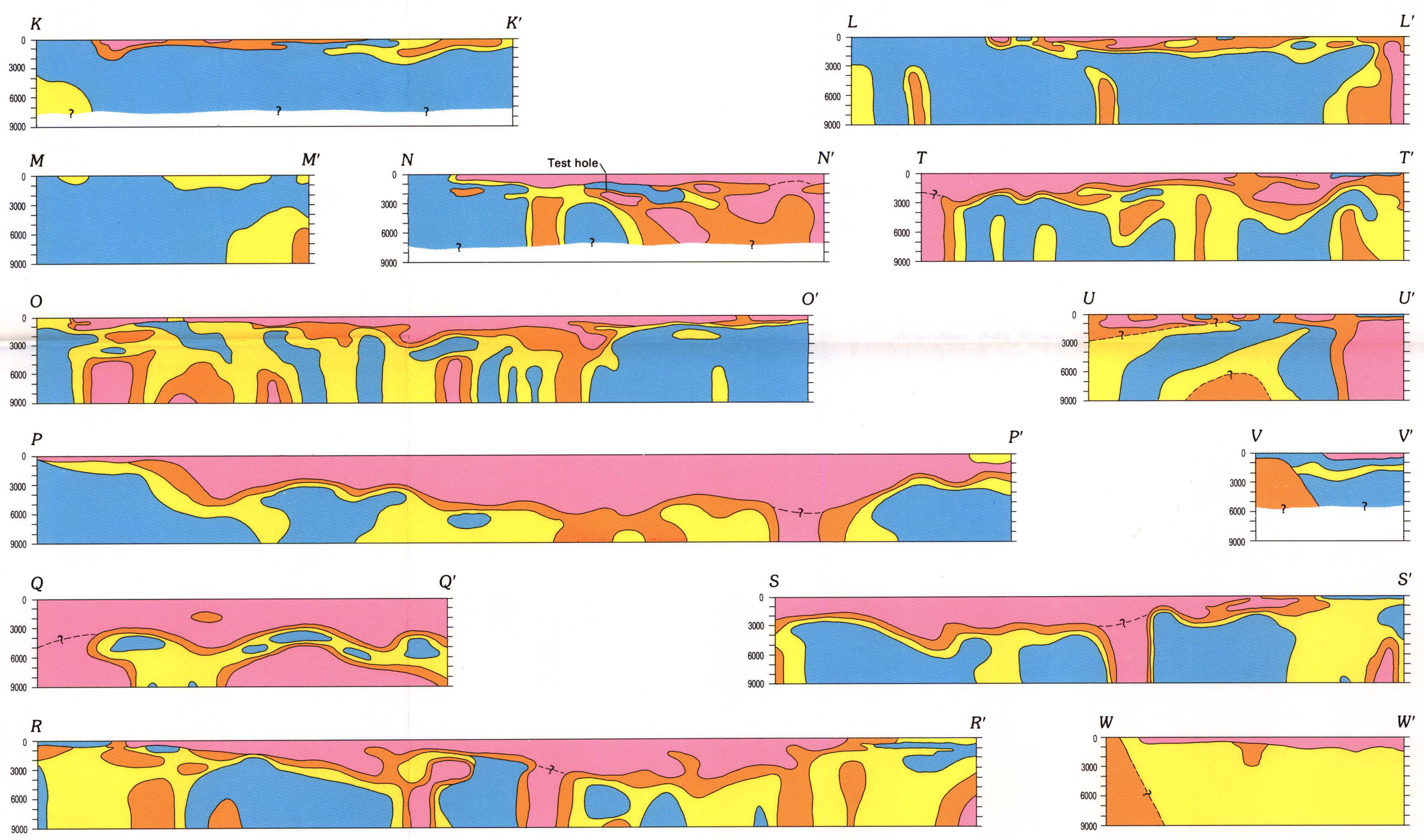
GEOPHYSICS

ELECTRICAL RESISTIVITY





VERTICAL ELECTRICAL SOUNDINGS INDICATE THAT QUATERNARY BASALT OF THE SNAKE RIVER GROUP UNDERLYING THE SNAKE RIVER PLAIN MAY BE AS MUCH AS 5,000 FEET THICK. To help define areal variations in basalt thickness, the U.S. Geological Survey, Geologic Division, Branch of Electromagnetism and Geomagnetism, completed 221 vertical electrical soundings as part of the Snake River Plain RASA study. These soundings, along with an equal number of soundings made for previous studies (Zohdy and Stanley, 1973; Crosthwaite, 1974; Jackson, 1974; Zohdy, Bisdorf, and Jackson, 1978; and Robinette and Matzner, 1980), provided sufficient regional coverage for mapping approximate thickness of Quaternary basalt. Zohdy (1974, p. 5) states:

The electrical properties of most rocks in the upper part of the Earth's crust are dependent primarily on the amount of water in the rock, the salinity of the water, and the distribution of the water in the rock. Saturated rocks have lower resistivities than unsaturated or dry rock. The higher the porosity of the saturated rock, the lower its resistivity, and the higher the salinity of the saturating fluid, the lower the resistivity. The presence of clays and conductive minerals also reduces the resistivity of the rock.

Electrical resistivity soundings were made using a symmetric Schlumberger array; current electrode spacings ranged from 4,000 to 28,000 ft; apparent resistivities ranged from 3.5 to 4,750 ohm-meters. Vertical electrical sounding curves were computer processed and interpreted using a modified version of Zohdy's (1973) inversion program. Computer-generated profiles were created for each of the traverse lines made during the present study and for the Arco to Blackfoot line from an earlier study. A total of about 450 mi of profiling was completed. Generalized computer-generated profiles are shown at right (K–K' through W–W').

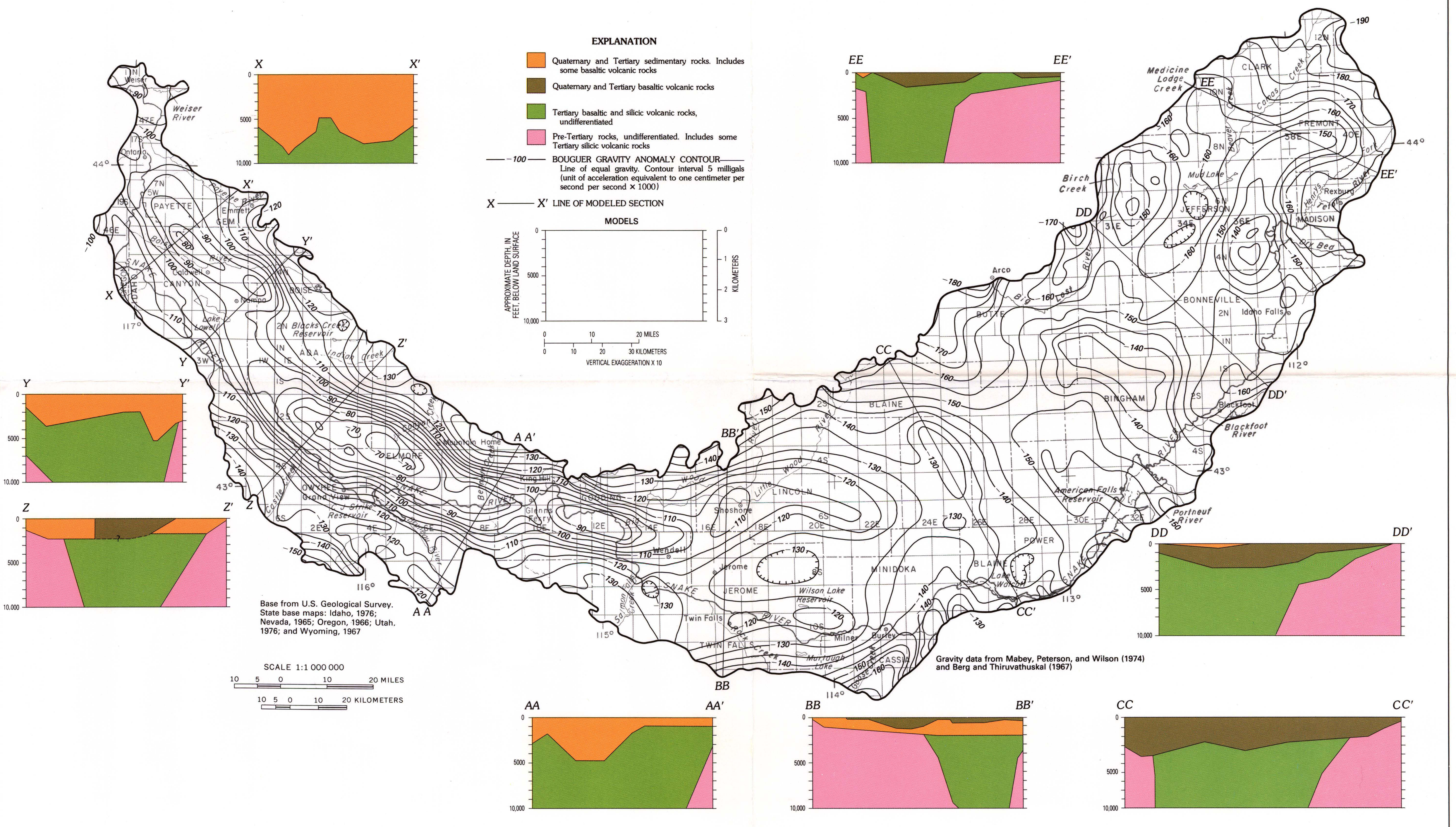
Because young basalts of the Snake River Group have a high resistance to electrical current even when saturated with water (because of low salinity), the vertical electrical sounding profiles were used to help estimate basalt distribution thickness (sheet 2). Correlation of the profiles with several deep drill holes indicated that resistivities of 300 ohm-meters and greater in the upper part of the stratigraphic section were indicative of young basalts of Quaternary age. To verify vertical electrical sounding interpretations, a 1,123-ft test hole was drilled 5 mi northeast of Wendell (NE¼NW¼SW¼ sec. 12, T. 7 S., R. 15 E.) along profile N–N'. Test-drilling results and geologic and hydrologic implications of the test hole were in good agreement with resistivity interpretations.

In some areas, particularly near the margins of the plain, unconsolidated and unsaturated gravels have a resistivity comparable to that of the basalts. Where saturated sedimentary rocks are intercalated with basalt, an apparent resistivity of 100 ohm-meters or greater was interpreted as basalt. Drillers' logs were available to aid in interpretation in many of these areas.

High resistivities at depths greater than 3,000 ft may be indicative of older consolidated sedimentary rocks or volcanic rocks. Where high resistivity zones apparently were continuous from the surface to depths in excess of the area average, an arbitrary cutoff was made at the average depth to regionalize the interpretation.

Although vertical electrical soundings are apparently useful to approximate basalt distribution and thickness, some complications in interpretation were noted. Lowest resistivities (less than 7 ohm-meters, not shown on profiles) appear to be indicative of fine-grained sedimentary rocks, thermal waters, or a combination of the two. Zones of faulting associated with the thermal water also may be surmised. The effect of thermal waters may mask lithologic variations (Jackson, 1974), as evidenced by the low resistivity of faulted areas flanking the western plain, where thermal waters occur in both sedimentary and volcanic rocks.

GRAVITY



GRAVITY MODELS WERE USED TO AID IN DEFINITION OF MAJOR GEOLOGIC FEATURES. All earth materials influence gravity measurements. However, the bulk of the Earth's gravitational force has little to do with crustal rocks. Only about 0.05 percent of the gravitational force is contributed by the upper 8 mi of crustal rock (Grant, 1965, p. 190). Most important is the fact that this very small contribution can be detected by gravity meters and accordingly mapped. Gravity measurements must be subjected to a series of reductions and corrections before they are suitable for interpretation of geologic features.

Gravity variations are measured in gals; one gal is equivalent to a force of acceleration of one centimeter per second per second. The Earth's average gravitational force is about 980 gals. Owing to the very small magnitude of variations measured, milligals (1/1,000 of a gal) are used for computational purposes.

The above Bouguer gravity anomaly map is a summation of all gravity effects in the area. Corrections for most major nongeologic effects are incorporated in the map.

Because interpretations are nonunique, gravity modeling was used only as a guide to help define major geologic features where no other definitive data were available.

The modeling program is based on a two-dimensional polygon method (Talwani and others, 1959). The program uses polygons of varying sizes, shapes, and assumed density contrasts (table at right) to represent possible geological bodies inferred from available information. The following assumptions were made: (1) Subsurface density variations are modeled using polygonal bodies of infinite strike length; (2) each polygon is of a constant assumed density contrast (compared to an average for crustal rocks of 2.65 g/cm³, see table at right); and (3) compaction of material with increasing depth of burial is negligible. The polygon's gravitational effects are calculated in the program and a summation of these effects is plotted against the measured residual gravity anomaly.

Polygons are changed, deleted, or added as necessary to comply with known geologic and physical constraints until a best fit between the gravity field curve and the theoretical curve is obtained.

Gravity modeling of the western plain was done using Bouguer anomaly values obtained directly from the above map. Modeling of the eastern plain required that the Bouguer anomalies be adjusted to compensate for the regional effects of a large body of rock either more areally extensive than the plain or deeply buried (more than 3 mi) under the plain (Mabey, 1978, p. 557). Data from a seismic refraction study (Sparlin and others, 1981, p. 53) suggest that the latter hypothesis is most likely correct. These data were used as a basis for the regional residual separation. The separation was made using several methods suggested by Dobrin (1952, p. 86–88). Actual modeling extended beyond the plain's boundary, but results shown in sections *X–X'* through *EE–EE'* are only for that part within the boundary. Sections were simplified because, in the modeling process, the ability to simulate several rock units of different densities exceeds present understanding of the subsurface distribution of rock units in the study area.

Delineation of major rock types by gravity modeling was marginally successful but did aid in understanding the regional structure. Seismic section *J–J'* and gravity section *Y–Y'* show good agreement in delineation of the sediment and Tertiary (Miocene) basalt unit contact. Although not shown on modified resistivity section *K-K'*, this contact was suggested by the original resistivity data as well.

[Modified from Telford and others (1976, p. 24-25) and Mabey (1976, p. 55). Values are in grams per cubic centimeter.]

Rock unit	Average density	Density contrasts used for modeling
Quaternary basalt	1.98	−0.67
Tertiary basalt	2.95	0.30
Granite	2.65	0
Undifferentiated pre-Tertiary rocks	2.65	0
Basalt and intercalated sedimentary rocks	1.98	−0.67
Consolidated sedimentary rocks	2.45	−0.20
Unconsolidated sedimentary rocks	2.20	−0.45
Upper unit, silicic volcanic rocks	2.43	−0.22
Lower unit, silicic volcanic rocks	2.53	−0.12

ASSUMPTION OF DENSITY VALUES FOR ROCK TYPES UNDERLYING THE SNAKE RIVER PLAIN IS A CRITICAL STEP IN THIS MODELING PROCESS. A constant density value of 2.65 g/cm³ was assumed to represent undifferentiated pre-Tertiary rocks. Assumed values of density differences for these and other associated rocks underlying the plain are shown in the table above.

SUMMARY

Aquifers underlying the eastern plain are composed chiefly of basaltic rocks with lesser amounts of intercalated, unconsolidated sedimentary rocks. Basalt several hundred to several thousand feet thick and permeable interflow zones between multiple successive lava flows result in high transmissivities underlying the eastern plain. Locally near mouths of tributary valleys and along the Snake River, unconsolidated sedimentary rocks are important aquifers. Older basaltic and silicic rocks are important aquifers in places, although generally they have lower transmissivities than the younger basalts.

Aquifers underlying the western plain are composed chiefly of sedimentary rocks having much lower transmissivities than basaltic aquifers underlying the eastern plain. The sedimentary section is a sequence of shales and clays several hundred to several thousand feet thick with thinner interbeds of sand and gravel. Volcanic rocks, with the exception of basalts of the Snake River Group in the eastern part of the western plain, are generally older and less permeable than those in the eastern plain. Secondary mineralization has greatly reduced the hydraulic conductivity of the older basalts, though their original hydraulic conductivity also may have been low. Quaternary basalt underlying the eastern plain may exceed 5,000 ft in thickness, based on vertical electrical soundings, gravity modeling, and drill-hole data.

The largest springs in the eastern plain issue from highly permeable pillow lava that fills old stream channels tributary to the Snake River from Milner to King Hill. A possibly widespread sedimentary unit underlying the Quaternary basalt in the springs area may be a control on spring locations. Sedimentary rocks occurring in a similar stratigraphic position in several places throughout the plain serve as important marker beds that separate the Quaternary and Tertiary basalts.

REFERENCES CITED

Berg, J. W., and Thiruvathuskal, J. K., 1967, Complete Bouguer gravity anomaly map of Oregon: Portland, Oregon Department of Geology and Mineral Resources, Map GMS-4b.

Bond, J. G., and others, 1978, Geologic map of Idaho: Idaho Department of Lands, Idaho Bureau of Mines and Geology, scale 1:500,000.

Braile, L. W., and others, 1981, The Yellowstone-Snake River Plain seismic profiling experiment - crustal structure of the eastern Snake River Plain: U.S. Geological Survey Open-File Report (Purdue University), Grant No. 14-08-0001-G-532, about 300 p.

Chapman, S. L., and Ralston, D. R., 1970, Ground-water resources of the Blue Gulch area in eastern Owyhee and western Twin Falls Counties, Idaho: Idaho Department of Water Administration, Water Information Bulletin no. 20, 36 p.

Crosthwaite, E. G., 1974, A progress report on results of test drilling and ground-water investigations of the Snake Plain aquifer, southeastern Idaho, part 3, Lake Walcott-Bonanza Lake area: Idaho Department of Water Resources, Water Information Bulletin no. 38, 20 p.

Dobrin, M. B., 1952, Introduction to geophysical prospecting: New York, McGraw-Hill, 443 p.

Fenneman, N. M., 1931, Physiography of the Western United States: New York, McGraw-Hill, 534 p.

Grant, F. S., and West, G. F., 1965, Interpretation theory in applied geophysics: New York, McGraw-Hill, 584 p.

Hayden, F. V., 1883, A report of progress of the exploration in Wyoming and Idaho for the year 1878: U.S. Geological and Geographical Survey of the Territories, Twelfth Annual Report, Part I, 809 p.

Hill, D. P., 1963, Gravity and crustal structure in the western Snake River Plain, Idaho: Journal of Geophysical Research, v. 68, no. 20, p. 5807–5819.

Jackson, D. B., 1974, Report on direct current soundings over a geothermal prospect in the Bruneau-Grand View area, Idaho: U.S. Geological Survey Open-File Report 74–240, 43 p.

Kuntz, M. A., 1978, Geology of the Arco-Big Southern Butte area, eastern Snake River Plain, and potential volcanic hazards to the Radioactive Waste Management Complex, and other waste storage and reactor facilities at the Idaho National Engineering Laboratory, Idaho, with a section on statistical treatment of the age of lava flows by J. O. Kork: U.S. Geological Survey Open-File Report 78–691, 70 p.

Kuntz, M. A., and Dalrymple, G. B., 1979, Geology, geochronology, and potential volcanic hazards in the Lava Ridge-Hells Half Acre area, eastern Snake River Plain, Idaho: U.S. Geological Survey Open-File Report 79–1657, 66 p.

LaFehr, T. R., and Pakiser, L. C., 1962, Gravity, volcanism, and crustal deformation in the eastern Snake River Plain, Idaho: U.S. Geological Survey Professional Paper 450–D, p. D75-D77.

Lewis, B. D., and Goldstein, F. J., 1982, Evaluation of a predictive ground-water solute-transport model at the Idaho National Engineering Laboratory, Idaho: U.S. Geological Survey Water-Resources Investigations 82–25, 71 p.

Lewis, R. E., and Young, H. W., 1982, Geothermal resources in the Banbury Hot Springs area, Twin Falls County, Idaho: U.S. Geological Survey Water-Supply Paper 2186, 27 p.

Lindgren, Waldemar, 1898, Description of the Boise quadrangle [Idaho]: U.S. Geological Survey Geologic Atlas, Folio 45, 4 pls., 7 p.

Lindgren, Waldemar, and Drake, N. F., 1904a, Description of the Nampa quadrangle [Idaho-Oregon]: U.S. Geological Survey Geologic Atlas, Folio 103, 5 p.

______1904b, Description of the Silver City quadrangle [Idaho]: U.S. Geological Survey Geologic Atlas, Folio 104, 6 p.

Lindholm, G. F., 1981, Plan of study for the regional aquifer system analysis of the Snake River Plain, Idaho and eastern Oregon: U.S. Geological Survey Open-File Report 81–689, 21 p.

Lindholm, G. F., Garabedian, S. P., Newton, G. D., and Whitehead, R. L., 1983, Configuration of the water table, March 1980, in the Snake River Plain regional aquifer system, Idaho and eastern Oregon: U.S. Geological Survey Open-File Report 82–1022, scale 1:500,000.

Love, J. D., Weitz, J. L., and Hose, R. K., 1952, Geologic map of Wyoming: U.S. Geological Survey, scale 1:500,000 (preliminary edition).

Mabey, D. R., 1976, Interpretation of a gravity profile across the western Snake River Plain, Idaho: Geology, v. 4, no. 1, p. 53–55.

______1978, Regional gravity and magnetic anomalies in the eastern Snake River Plain, Idaho: U.S. Geological Survey Journal of Research, v. 6, no. 5, p. 553–562.

Mabey, D. R., Peterson, D. L., and Wilson, C. W., 1974, Preliminary gravity map of southern Idaho: U.S. Geological Survey Open-File Report 74–78, scale 1:500,000.

Malde, H. E., 1959, Fault zone along the northern boundary of the western Snake River Plain: Science, v. 130, no. 3370, 272 p.

______1965, Snake River Plain, *in* The Quaternary of the United States: New Jersey, Princeton University Press, p. 255–263.

______1968, The catastrophic late Pleistocene Bonneville flood in the Snake River Plain, Idaho: U.S. Geological Survey Professional Paper 596, 52 p.

Malde, H. E., and Powers, H. A., 1962, Upper Cenozoic stratigraphy of the western Snake River Plain, Idaho: Geological Society of America Bulletin, v. 73, no. 10, p. 1197–1219.

Mansfield, G. R., 1920, Geography, geology, and mineral resources of the Fort Hall Indian Reservation, Idaho: U.S. Geological Survey Bulletin 713, 152 p.

______1927, Geography, geology, and mineral resources of part of southeastern Idaho: U.S. Geological Survey Professional Paper 152, 53 p.

______1929, Geography, geology, and mineral resources of the Portneuf quadrangle, Idaho: U.S. Geological Survey Bulletin 803, 110 p.

Mundorff, M. J., Crosthwaite, E. G., and Kilburn, Chabot, 1964, Ground water for irrigation in the Snake River basin in Idaho: U.S. Geological Survey Water-Supply Paper 1654, 224 p.

Piper, A. M., 1923, Geology and water resources of the Goose Creek basin, Cassia County, Idaho: Moscow, Idaho Bureau of Mines and Geology Bulletin no. 6, 78 p.

______1924, Geology and water resources of the Bruneau River basin, Owyhee County, Idaho: Moscow, Idaho Bureau of Mines and Geology Pamphlet no. 11, 56 p.

______1925, Ground water for irrigation on Camas Prairie, Camas and Elmore Counties, Idaho: Moscow, Idaho Bureau of Mines and Geology Pamphlet no. 15, 46 p.

Robertson, J. B., Schoen, Robert, and Barraclough, J. T., 1974, The influence of liquid waste disposal on the geochemistry of water at the National Reactor Testing Station, Idaho, 1952– 70: U.S. Geological Survey Open-File Report IDO– 22053, 210 p.

Robinette, M. S., and Matzner, R. A., 1980, Electrical resistivity investigations of the Springfield-Blackfoot area, Idaho: U.S. Water and Power Resources Service [U.S. Bureau of Reclamation], Project Completion Report, 119 p.

Russell, I. C., 1902, Geology and water resources of the Snake River Plain of Idaho: U.S. Geological Survey Bulletin 199, 192 p.

______1903, Notes on the geology of southwestern Idaho and southeastern Oregon: U.S. Geological Survey Bulletin 217, 83 p.

Sparlin, M. A., Braile, L. W., and Smith, R. B., 1981, Crustal structure of the eastern Snake River Plain determined from ray-trace modeling of seismic refraction data in the 1978 Yellowstone-Snake River Plain seismic profiling experiment: U.S. Geological Survey and Purdue University, Grant No. 14–08–0001–G–532, 54 p.

Stearns, H. T., and Bryan, L. L., 1925 [1926], Preliminary report on the geology and water resources of the Mud Lake basin, Idaho: U.S. Geological Survey Water-Supply Paper 560–D, 51 p.

Stearns, H. T., Bryan, L. L., and Crandall, Lynn, 1939, Geology and water resources of the Mud Lake region, Idaho, including the Island Park area: U.S. Geological Survey Water-Supply Paper 818, 125 p.

Stearns, H. T., Crandall, Lynn, and Steward, W. G., 1938, Geology and ground-water resources of the Snake River Plain in southeastern Idaho: U.S. Geological Survey Water-Supply Paper 774, 268 p.

Stewart, J. H., and Carlson, J. E., 1978, Geologic map of Nevada: U.S. Geological Survey, scale 1:500,000.

Stokes, W. L., 1963, Geologic map of Utah, northwest section: Utah State Land Board, scale 1:250,000.

Talwani, Manik, Worzel, J. L., and Landisman, M., 1959, Rapid gravity computations for two-dimensional bodies with application to the Mendocino submarine fracture zone: Journal of Geophysical Research, v. 64, p. 49–59.

Telford, W. M., Geldart, L. P., Sheriff, R. E., and Keip, D. A., 1976, Applied geophysics: Cambridge, England, Cambridge University Press, 860 p.

Walker, G. W., 1977, Geologic map of Oregon east of the 121st meridian: U.S. Geological Survey Miscellaneous Investigations Map I-902, scale 1:500,000, 2 sheets.

Whitehead, R. L., 1978, Water resources of the upper Henrys Fork basin in eastern Idaho: Idaho Department of Water Resources, Water Information Bulletin no. 46, 91 p.

Wood, S. H., and Anderson, J. E., 1981, Chapter 2, Geology, *in* Mitchell, J. C., ed., Geological, hydrological, geochemical, and geophysical investigations of the Nampa-Caldwell and adjacent areas, southwestern Idaho: Idaho Department of Water Resources, Water Information Bulletin no. 30, p. 9-31.

Wood, S. H., Applegate, J. K., and Donaldson, P. R., 1981, Chapter 6, Geophysics, *in* Mitchell, J. C., ed., Geological, hydrological, geochemical, and geophysical investigations of the Nampa-Caldwell and adjacent areas, southwestern Idaho: Idaho Department of Water Resources, Water Information Bulletin no. 30, p.115–130.

Zohdy, A. A. R., 1973, A computer program for the automatic interpretation of Schlumberger sounding curves over horizontally stratified media: Springfield, Va., U.S. Department of Commerce, National Technical Information Service, Report USGS–6D–74–017, PB–232 703, 25 p.

______1974, Electrical methods *in* Zohdy, A. A. R., Eaton, G. P., and Mabey, D. R., Application of surface geophysics to ground-water investigatons: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 2, Chapter D1, p. 6-66.

Zohdy, A. A. R., Bisdorf, R. J., and Jackson, D. B., 1978, Simple total field and Schlumberger soundings near Sugar City, Idaho: U.S. Geological Survey Open-File Report 78–709, 101 p.

Zohdy, A. A. R., Eaton, G. P., and Mabey, D. R., 1974, Application of surface geophysics to ground-water investigations: U.S. Geological Survey Techniques of Water-Resources Investigations, Book 2, Chapter D1, 116 p.

Zohdy, A. A. R., and Stanley, W. D., 1973, Preliminary interpretation of electrical sounding curves obtained across the Snake River Plain from Blackfoot to Arco, Idaho: U.S. Geological Survey Open-File Report, 3 p.

GEOHYDROLOGIC FRAMEWORK OF THE SNAKE RIVER PLAIN, IDAHO AND EASTERN OREGON

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