

Lake

HARNEY

FIGURE 2.—Physiographic regions of Oregon (modified from Dicken, 1965)

INTRODUCTION

In October 1982, a 4-year study of the Columbia River Basalt regional aquifer system was begun. The Columbia River Basalt regional aquifer system is one of 29 regional aquifer systems in the United States being studied by the U.S. Geological Survey as part of it's Regional Aquifer Systems Analysis (RASA) program. The purpose of these studies is to provide information on the geohydrology and geochemistry of the regional aquifer systems that will aid in the effective management of these systems (Bennett, 1979). Regional aquifer systems commonly extend across State boundaries and are extremely important natural resources for the regions which they underlie. The regional aquifer system described in this report consists of a great thickness of basalt made up of numerous individual basalt lava flows belonging to the Miocene Columbia River Basalt Group, of Miocene sediments interbedded with the basalt and collectively assigned to the Ellensburg Formation, and of undifferentiated overlying Miocene to Holocene sediments. The area underlain by these rocks in Oregon, Washington, Idaho, and the area in Oregon covered by this report are shown in figure 1. The study area in Oregon is entirely within the Deschutes-Umatilla Plateau and the Blue Mountains physiographic regions (fig. 2) of Oregon (Dicken, 1965). These physiographic regions are part of the much broader Columbia Plateau physiographic province described by Fenneman (1931); this province also includes all of the area in Washington and Idaho underlain by the Columbia River Basalt Group (fig. 1), as well as the High Lava Plains, the Owyhee Uplands in southeast Oregon (fig. 2), and the Snake River Plain adjacent to southwestern Idaho (not shown here). The area underlain by the Columbia River Basalt Group is drained by the Columbia River and its tributaries and is both a topographic and structural basin with its deepest point near Pasco, Washington

This report describes the geologic framework of most of the Oregon part of the regional aquifer system. A similar report by Drost and Whiteman (1985) describes the geologic framework of the aquifer system beneath the Columbia Plateau in Washington. The format of this report follows theirs. A future report will describe the hydrology of the regional aquifer system. These reports are a necessary first step in developing a conceptual model of the aquifer system and in quantifying the hydrologic properties of the system. Eleven maps on 6 sheets are included.

NUMBER Geologic map of the north and northeastern Columbia Plateau, Oregon Structure map of the Oregon part of the Columbia Plateau Structure contours on the Grande Ronde Basalt Thickness of the Wanapum-Grande Ronde Structure contours on the Wanapum Basalt Thickness of the Wanapum unit Thickness of the Umatilla-Wanapum interbed Thickness of the Pomona-Umatilla interbed Thickness of the Saddle Mountains unit Altitude of the top of the Columbia River Basalt Group beneath the sedimentary Thickness of the overburden

PREVIOUS STUDIES The basis for Sheet 1 was a series of geologic reconnaissance maps by Swanson and others (1981); these maps were the starting point for the interpretations in this report. A report delineating the stratigraphic nomenclature of the Columbia River Basalt Group (Swanson and others, 1979a)

are included in the list of selected references. METHODS OF INVESTIGATION AND ACCURACY OF DATA

culminated the work of numerous earlier investigators of the geology and

hydrogeology of the Columbia Plateau. Some of the more important of these

Approximately 9,000 well reports were reviewed for this study; about 1,200 of these wells were field located. Field located wells were visited by personnel of the U.S. Geological Survey or of the Oregon Water Resources Department during this and earlier studies. In general, wells that were field located were the best available for analysis at the time they were selected for field location. Because of time and economic constraints, geologic mapping was not attempted during this study. All data used to compile the interpretive maps in this report are from well logs prepared by water well drillers during construction of wells. Generally these logs contain well drillers' terminology and describe the rock

type, the color, the firmness, and other physical characteristics of the rock.

Comments on the water-bearing properties of the materials being drilled are

also included. More recent well logs also list water-level data observed by the Sedimentary interbeds were thickest and therefore were most consistently recognized and identified by well drillers in an area within a few tens of miles south of the Columbia River between Arlington and Irrigon. As a consequence, the subsurface data and the resulting interpretations are most reliable in that area. Elsewhere the interpretations are more tenuous because (1) the Columbia River Basalt Group is covered by younger sedimentary overburden, (2) drillers were unable to differentiate between basalt flows and thin sedimentary interbeds, and (3) the older basalt formations contain few or no sedimentary interbeds that serve as marker beds to differentiate position within the units. Compilation at 1:250,000 scale also has resulted in generalization of geologic structures. However, in spite of these problems, the interpretations presented are reasonably accurate and are adequate in all respects for their intended uses.

More accurate delineation of the surface and subsurface geology will

require much additional detailed geologic mapping, collection of rock

chemistry data, and collection of sample logs, geologist logs, and geophysical

logs. Acquisition of these types of data will probably be gradual.

Accuracy of the interpretive maps is dependent not only on reliable identification of geologic units but also on the accurate determination of landsurface position of the wells and on the land-surface altitude at each site. In general, it is believed that the well locations are within 300 feet of their actual position and that the recorded land-surface altitude is within 20 feet of

The maps compiled in this report, except for one area, were initially

prepared at a scale of 1:250,000, starting generally with the uppermost

youngest) unit and progressing downward to successively deeper (older) units. This was a logical sequence because data for the uppermost shallow units were much more abundant. First, the geologic and structure maps (sheets 1 and 2) were simplified and compiled from existing sources (Swanson and others, 1981). Next, maps of the top of basalt bedrock were prepared for those areas covered by overburden; then maps of the tops of the Wanapum Basalt and the Grande Ronde Basalt were prepared. From these maps and from thickness data at data points, thickness maps for the overburden, the Saddle Mountains unit and the Wanapum unit were prepared in that order. Finally the maps of the sedimentary interbeds were compiled from thickness data for each unit.

The above compilation sequence was modified slightly for the Hermiston-Ordnance area, where data are more abundant. In that area, data maps were first compiled at 1:24,000 scale from field located wells, and these data were supplemented by data from less accurately located wells to guide the positioning of the contours.

GEOLOGIC MAP The regional aquifer system underlying part of the Columbia Plateau in

Oregon consists of numerous basalt lava flows, some sedimentary interbeds. and some overlying younger sediments. The basalt flows are part of the Miocene Columbia River Basalt Group, and the interbeds collectively are assigned to the Miocene Ellensburg Formation (Swanson and others, 1979). The sediments overlying the basalt range from Miocene to Holocene in age but have not been differentiated for this report. The Columbia River Basalt Group is a geologic unit made up of several basalt formations differentiated from each other by small variations in the

chemical composition of the basalt layers or by their physical characteristics and their time-stratigraphic relationships. The basalt flows were extruded from fissures in eastern Oregon and Washington between 16.5 and 6 million years before present (Swanson and others, 1980). Each basalt formation than 0.5 percent). Sedimentary interbeds are thin and not extensive. Because consists of a few to tens of separate individual basalt flows; some formations of the absence of extensive interbeds, distinguishing lithologies, or physical contain a few to several members, some of which are local in extent. Figure 3 shows the stratigraphy of the study area generalized from Swanson and others (1981). The sedimentary interbeds were deposited on lava flows between periods of active lava extrusion. Generally the interbeds are thickest and most extensive in the upper (younger) units of the basalt. Deposition of the interbeds apparently took place in local depressions and in the larger structural

The above geologic map is simplified from Swanson and others (1981) and covers that part of northeastern Oregon east of the Cascade Range, west of the Snake River, and north of the Blue Mountains anticline and the Wallowa Mountains, as shown in figure 1. Some areas underlain by the Columbia River Basalt Group, east of the Cascades and in the Blue Mountains in Oregon, are not included in the study area. These are not included because of the presence of natural physical barriers, such as the Cascade Range and the Blue Mountains anticline, that more or less isolate them hydrologically from the main portion of the regional aquifer system. In addition, little or no well data are available from these areas, and the geologic mapping needed to subdivide the Columbia River Basalt Group has not been completed. The rocks cropping out on the periphery of the project area and those underlying the Columbia River Basalt Group in Oregon range from Paleozoic

to Holocene in age and consist of a wide variety of sedimentary and igneous rocks. Little is known, however, about the distribution or types of rocks underlying the basalt in Oregon, because only one exploratory oil well is known to have penetrated the full thickness of the basalt. Presumably these rocks are Paleozoic to pre-Miocene sedimentary and igneous rocks, similar to those bordering the basalt outside the project area.

HYDROGEOLOGIC UNITS

The regional aquifer system can be logically subdivided along stratigraphic boundaries into four principal hydrogeologic units (fig. 3) Subdivision of the system into hydrogeologic units is an important and necessary first step in developing both a conceptual and a physical model of the system. However, there is considerable uncertainty as to whether each hydrogeologic unit identified in this report is indeed a distinct aquifer unit. Therefore, as the study of the system progresses and as new data become available, it is possible that changes may be required.

BASALT STRATIGRAPHY

Elephant Mountain Member

Frenchman Springs Member

Umatilla Membe

Roza Member

Basalt

PRE-MIOCENE Pre-Columbia River Basalt Group rocks

Picture Gorge Basalt

Elephant Mountain-Pomona Interbed

Pomona-Umatilla Interbed

Umatilla-Wanapum Interbed

Wanapum-Grande Ronde Interbed

(Saddle Mountains-Wanapum Interbed

EPOCH

HOLOCENE

PLEISTOCENE

PLIOCENE

MIOCENE

MIOCENE

Because of the uncertainty of our present aquifer identification system, the major subdivisions of the aquifer system defined here will be referred to as hydrogeologic units in the discussions that follow. From oldest to youngest, the hydrogeologic units are the Grande Ronde, the Wanapum, the Saddle Mountains and the overburden aquifer. The equivalent basalt stratigraphic units are the Grande Ronde Basalt, Wanapum Basalt and Saddle Mountains Basalt, respectively. The hydrogeologic units include sedimentary interbeds whereas stratigraphic units refer only to the basalt within the Columbia River Basalt Group or to the sedimentary interbeds which collectively are part of the Ellensburg Formation. Specifically, sedimentary interbeds enclosed by basalt flows belonging to the Grande Ronde Basalt are considered part of the Grande Ronde unit; the Grande Ronde unit also includes the Imnaha and Picture Gorge Basalts. The interbed between the Grande Ronde Basalt and Wanapum Basalt, where present, is included in the Wanapum unit; the interbed between the Wanapum Basalt and the overlying Saddle Mountains Basalt is included with the Saddle Mountains unit; and sedimentary interbeds within the Saddle Mountains Basalt are part of the Saddle Mountains hydrogeologic unit. All sediments that overlay the Columbia River Basalt Group are considered as overburden and are undifferentiated. Use of these groupings equires no substantial change in the positions of geologic contacts on the

published geologic maps used to prepare this report.

The Grande Ronde unit is the thickest and most extensive of the ydrogeologic units, and it underlies nearly all of the area underlain by the Columbia River Basalt Group shown in figure 1. In the report area, the Grande Ronde unit crops out along a wide band in the east and south, along the John Day and Deschutes River valleys, along the Columbia River near the mouth of the John Day River, and west of The Dalles. Near the Hood River County-Wasco County line in the west, it is overlain by overburden and by younger Cascade Range volcanic rocks. Thickness of the Grande Ronde Basalt ranges from a few feet, where it pinches out against older rocks, to 3,000 feet or more. One exploratory oil well near Condon (Sheet 2) in southern Gilliam County penetrated 2,439 feet, presumably of Grande Ronde Basalt, before reaching lower Tertiary volcaniclastic rocks. The Imnaha Basalt and the Picture Gorge Basalt are the oldest formations within the Columbia River Basalt Group and they crop out extensively east and south, respectively, of the Blue Mountains anticline. Both formations are probably not extensive west of or north of the Blue Mountains anticline and, for this reason, both formations have been included in the Grande Ronde hydrogeologic unit in this report. Sections of the Grande Ronde Basalt exposed in the Blue Mountains are commonly about 2,000 feet thick (Swanson and others, 1979a). The Grande Ronde Basalt consists of fine-grained dense aphyric basalt, containing olivine as a groundmass constituent in small amounts (less characteristics among flows within the Grande Ronde Basalt, it could not be further subdivided using drillers' well-log data. A zone of weathering or a thin sedimentary interbed commonly marks the position of the top of the Grande Ronde Basalt. The sedimentary interbed is probably equivalent to the Vantage Member of the Ellensburg Formation in Washington; in this report it is referred to as the Wanapum-Grande Ronde interbed. The top of

The Wanapum hydrogeologic unit overlies the Grande Ronde Basalt but is much thinner and less extensive. It crops out in a band of varying width, north of the band of Grande Ronde outcrops, and forms much of the gently rolling and dipping plateau surface in eastern Wasco and Sherman Counties. In other counties the outcrops are far less extensive because the Wanapum is overlain by younger geologic units. Well data in Oregon suggest that the Wanapum unit rarely exceeds 800 feet in thickness; however, maps prepared by Drost and Whiteman (1985) for adjacent areas in Washington indicate that thickness of the Wanapum unit probably exceeds 1,000 feet in the Boardman area near the axis of the Dalles-Umatilla syncline (Sheet 2) and in the Milton-

The Wanapum Basalt consists of a sequence of medium-grained olivine-

Eolian and glacio-

Volcaniclastic and

fluvial deposits

fluvio-lacustrine

Overburden

(Overburden aquifer

Saddle Mountains Unit

Wanapum Unit

Grande Ronde Unit

bearing, slightly to moderately plagioclase-phyric flows that generally have a high content of iron and titanium oxide. Sedimentary interbeds are present in the Wanapum unit but are generally thin and local in extent. A sedimentary interbed commonly occurs between the Wanapum Basalt and the overlying Saddle Mountains Basalt (fig. 3). This interbed may be equivalent to the Mabton interbed (informal) of the Ellensburg Formation; in this report it will be referred to as the Umatilla-Wanapum interbed.

SEDIMENT STRATIGRAPHY

Ellensburg Formation

(Nomenclature not formalized)

Dalles Group

Chenoweth Formation

and others, 1981)

Alkali Canyon Formation

McKay Formation (Farooqui

The Saddle Mountains Basalt is the least extensive and most diverse of the basalt formations in the Columbia River Basalt Group and is estimated to represent less than 1 percent of the total volume (Swanson and others, 1979a). Long periods of time between extrusion of the major basalt members of the Saddle Mountains Basalt allowed development of relatively thick sedimentary interbeds locally. Each member of the Saddle Mountains Basalt may consist of a single flow or of only a few individual flows, and some members are very limited in extent or are absent. The thickness of the Saddle Mountains hydrogeologic unit, with its included interbeds, ranges from 0 to over 600 feet. The thickest sections probably underlie the area near Boardman and the summits of the Blue Mountains in Wallowa and Union counties. The Umatilla Member of the Saddle Mountains Basalt has a distinct chemistry and is consistently finer grained than all other flows of the Columbia River Basalt Group. The Pomona Member is sparsely phyric and the Elephant Mountain Member is generally fine-grained and aphyric. The chemistry of each member is distinctive. The Pomona-Umatilla interbed ranges from 0 to over 300 feet and is thickest in the Arlington-Boardman area. The Elephant Mountain-Pomona interbed is also present in the Arlington-Boardman area; generally it

The youngest hydrogeologic unit is referred to as the overburden unit and consists of undifferentiated unconsolidated to semiconsolidated sediments ranging from Miocene to Holocene in age. It includes all of the sedimentary units overlying the Columbia River Basalt Group. In places this may include beds of undifferentiated Miocene sediments belonging to the Ellensburg Formation; Pliocene fanglomerate, tuff, sand, gravel, clay, claystone, siltstone, and sandstone belonging to the Dalles Group (Farooqui and others, 1981) and fluviolacustrine deposits; Pleistocene glaciofluvial deposits, loess, and Holocene alluvium. Only a few of these units may be present at a given

The thickness of the overburden ranges from 0 to over 2,000 feet. The maximum thicknesses are found in the Grande Ronde Valley, the Milton-Freewater area, and in Wasco County. The overburden exceeds 2,000 feet in the Grande Ronde Valley, 800 feet in the Milton-Freewater area, and 600 feet in The Dalles area. Elsewhere it is generally less than 250 feet thick. Within the major basalts, individual flows range in thickness from a few to a few hundred feet. The typical internal structure of an individual flow consists (from the bottom up) of three sections: the colonnade, the entablature, and the flow top (fig. 4). The colonnade consists of nearly vertical prismatic three- to eight-sided columns which average about 3 feet in diameter and about 25 feet in length. The columns are commonly cross-cut by systems of joints, and a vesicular zone is often present at the base. The entablature consists of small-diameter (averaging less than a foot) columns in fan-shaped arrangements. Hackly joints are common, and the upper portion of the

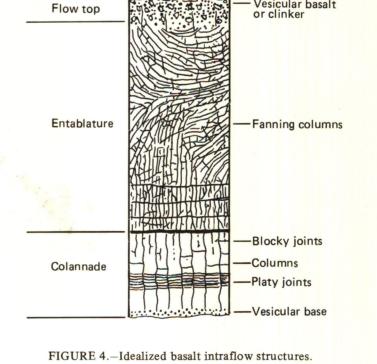
entablature is often vesicular. The flow top (sometimes called the interflow)

generally consists of vesicular basalt and clinker; this interflow zone between

individual basalt flows is the principal water bearing zone in the basalt. Not

all of the sections of structure described above are found in each individual

he Grande Ronde Basalt is extremely difficult to define in drillers' logs, where either the weathered zone or the interbed are absent.



ACKNOWLEDGMENTS

A significant part of the basic well-log interpretations upon which this report is based was made by hydrologist Ann Davies-Smith, formerly of the U.S. Geological Survey, WRD, Oregon District staff, as she worked on a cooperative project with the Oregon Water Resources Department. Her effort in constructing cross-sections and interpreting well drillers' logs made our task much easier. The author is also grateful to Susan Hartford, Gregory Kupillas, Donald Anderson, and Donald Sabol, also of the U.S. Geological Survey (RASA) staff, who ably continued Davies-Smith's work and who coded that data for entry into the computerized data base. The well drillers of the region are also commended for their conscientious examination of drill cuttings and diligent recording of that information.

DEFINITION OF TERMS

For the convenience of readers unfamiliar with some of the geologic terms used in this report, the following glossary has been prepared. Alluvium. A general term for clay, silt, sand, gravel, or similar unconsolidated material deposited by a stream or other body of running water during comparatively recent geologic time. Andesite. A dark-colored, fine-grained extrusive rock composed primarily of plagioclase and one or more minerals composed primarily of iron and Anticline. A fold, the core of which contains the stratigraphically older rocks; it is convex upward Aphyric. The texture of a fine-grained igneous rock lacking phenocrysts. Aquifer. A formation, group of formations, or part of a formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs.

Basalt. A dark- to medium-dark-colored, usually extrusive, igneous rock composed chiefly of calcium-rich plagioclase, clinopyroxene and minerals high in iron and magnesium Clinker. Rough, jagged rock fragments formed by volcanic explosions. Clinopyroxene. A group of dark silicate minerals generally high in calcium and magnesium, iron, or aluminum, and having a similar symmetry in their

perpendicular to the trend of the structure Eolian. Formed by the wind. Fanglomerate. A sedimentary rock consisting of slightly waterworn fragments. of all sizes, originally deposited in an alluvial fan and subsequently cemented into a firm rock Fault. A surface or zone of rock fracture along which the rocks on opposite sides have moved relative to each other. A thrust (or reverse) fault is one in which the upper material has moved upward relative to the lower

Dip. The angle that a structural surface makes with the horizontal measured

Fluvial. Produced by the action of moving water. Fold. A curve or bend in rock strata, usually a product of deformation. Geophysical log. A record of some physical property of the rock material or

Graben. An elongate, depressed part of the earth's crust that is bounded by faults on its long sides. Glaciofluvial. Formed by the action of glaciers and moving water. Holocene. A period of geologic time extending from about 10,000 years ago Igneous rock. Formed by solidification from a molten or partially molten Joint. A fracture in rock strata without any displacement of the strata. A

hackly joint is one with a jagged surface. Lacustrine. Formed in a lake Lava. Molten extrusive material. Loess. Wide-spread material consisting chiefly of silt-sized rock particles thought to be windblown dust. Commonly is unstratified. Mesozoic. An era of geologic time extending from about 225 million years ago to about 65 million years ago.

Metamorphosed. Process by which consolidated rocks are altered by heat and Miocene. An epoch of geologic time extending from about 23.5 million years ago to about 5.3 million years ago. Olivine. An olive-green, grayish-green, or brown silicate mineral composed primarily of iron and magnesium. Overburden. As defined for this RASA project, referes to any rock materials overlying basalt belonging to the Columbia River Basalt Group. In the study area these materials generally are sediments or volcaniclastic deposits. Paleozoic. An era of geologic time extending from about 570 million years

ago to about 225 million years ago. Permeability. The measure of the relative ease with which water can move through rock material. It is a property of the rock material dependent upon the shape, size, and interconnection of the openings in the material. Phenocryst. A relatively large, conspicuous crystal in a fine-grained groundmass. A microphenocryst is a phenocryst visible only under magnification. but is still relatively large compared to the groundmass.

Phyric. Fine-grained, containing phenocrysts.

sediment such as silt or clay

Plagioclase. A silicate material composed primarily of aluminum, sodium, Pleistocene. An epoch of geologic time covering the span of time between million and about 10,000 years ago. Commonly referred to as the "Ice Pliocene. An epoch of geologic time extending from about 5.3 million years ago to about 2-3 million years ago. Quaternary. An epoch of geologic time extending from about 2 to 3 million Sediment. Fragments of rocks that originate from weathering of rock and is transported and deposited by air, water, or ice. Shear zone. A tabular zone of rock that has been crushed and brecciated by many parallel fractures due to shear strain. Syncline. A fold, the core of which contains the stratigraphically younger rocks: it is concave upward. Tertiary. Geologic time period covering the span of time between 63 and about 2 million years ago Tuff. Volcanic ash and dust deposit that may contain up to 50 percent of

SELECTED REFERENCES

Anderson, J. L., 1980, Pomona Member of the Columbia River Basalt Group:

Vesicular. A rock texture characterized by abundant holes (vesicles) formed

Volcaniclastic. Fragmented rock materials formed by volcanic explosion.

by the expansion of gases during the fluid stage of lava.

An intracanyon flow in the Columbia River Gorge, Oregon: Oregon Department of Geology and Mineral Industries, Oregon Geology, v. 42, no. Barash, W., Bond, J. E., Kauffman, J. D., and Vekatakrishnan, R., 1980, Geology of the La Grande area, Oregon: State of Oregon Department of Geology and Mineral Industries, Special Paper 6, 47 p. Bela, J. L., 1982, Geologic and neotectonic evaluation of north-central Oregon: The Dalles 1°x 2° Quadrangle: State of Oregon Department of Geology and Mineral Industries, Geological Map Series 27 Bennett, G. D., 1979, Regional ground water systems analysis: U.S. Army Corps of Engineers, Water Spectrum, v. 11, no. 4, p. 36-42. Brown, J. C., 1978, Discussion of geology and ground-water hydrology of the

Columbia Plateau, with specific analysis of the Horse Heaven, Sagebrush Flat, and Odessa-Lind areas, Washington: Washington State University, College of Engineering Research Report 78/15-23, 51 p. ____1979, Investigation of stratigraphy and ground-water hydrology, Columbia River Basalt Group, Washington: Washington State University College of Engineering Research Report 79/15-37, 61 p. Prepared for Rockwell-Hanford Operations under subcontract no. SA-920. ____1980, Stratigraphy and ground-water hydrology of selected areas, Columbia Plateau, Washington: Washington State University, College of Engineering Research Report 80/15-39, 20 p. Prepared for Washington Department of Ecology under contract 80-061. Davies-Smith, A., Collins, C. A., and Olson, L. J., 1983, Selected ground-

water data in parts of Gilliam, Morrow, and Umatilla Counties, Oregon: U.S. Geological Survey Open-File Report 83-34, 43 p. Dicken, S. N., 1965, Oregon geography, the people, the place and the time: Edwards Brothers, Inc., Ann Arbor Michigan, 4th Edition, 127 p. Drost, B. W. and Whiteman, K. J., 1985, Surficial geology, structural features, and thickness and tops of selected geohydrologic units in the Columbia Plateau, Washington: U.S. Geological Survey Water-Resources Investigations Report 84-4326, 10 sheets. Farooqui, S. M., Clayton, D. C., Bunker, R. C., Bela, J. L., and Thoms, R. E., 1981, Post Columbia River Basalt Group stratigraphy and map compilation of the Columbia Plateau, Oregon: Oregon Department of Geology and Mineral Industries Open-File Report 0-81-10, 79 p., scale 1:250,000.

Farooqui, S. M., Beaulieu, J. B., Bunker, R. C., Stensland, D. E., and Thoms, R. E., 1981, Dalles Group: Neogene formations overlying the Columbia River Basalt Group in north-central Oregon: Oregon Department of Geology and Mineral Industries, Oregon Geology, v. 43, no. 10, p.131-140. Fenneman, N. M., 1931, Physiography of western United States: McGraw-Hill, New York, New York, 534 p. Hogenson, G. M., 1964, Geology and ground water of the Umatilla River basin, Oregon: U.S. Geological Survey Water-Supply Paper 1620, 162 p. MacNish, R. D. and Barker, R. A., 1976, Digital simulation of a basalt aquifer

system, Walla Walla River basin, Washington-Oregon: Washington Depart-

ment of Ecology Water-Supply Bulletin 44, 51 p.

McKee, E. H., Swanson, D. A., and Wright, T. L., 1977, Duration and volume of Columbia River basalt volcanism, Washington, Oregon, and Idaho: Geological Society of America Abstracts with Programs, v. 9, no. 4, Meyers, C. W. and Price, S. M., 1979, Geologic studies of the Columbia Plateau, a status report: Rockwell International, Rockwell-Hanford Operations RHO-BWI-ST-4. Newcomb, R. C., 1961, Storage of ground water behind subsurface dams in the Columbia River Basalt, Washington, Oregon, and Idaho: U.S.

Geological Survey Professional Paper 383-A, 15 p. 1965, Geology and ground-water resources of the Walla Walla River basin, Washington-Oregon: Washington Division of Water Resources Water-Supply Bulletin, no. 21, 151 p. _____1969, Effect of tectonic structure on the occurrence of ground water in the basalt of the Columbia River Group of The Dalles area, Oregon and Washington: U.S. Geological Survey Professional Paper 383-C. 33 p.

1970, Tectonic structure of the main part of the basalt of the Columbia River Group, Washington, Oregon and Idaho: U.S. Geological Survey Miscellaneous Ivnestigations Map I-587, 1 sheet. Scale 1:500,000. 1972. Quality of the ground water in basalt of the Columbia River Group, Washington, Oregon, and Idaho: U.S. Geological Survey Water-Shannon and Wilson, Inc., 1972, Geologic and subsurface investigation-Proposed mid-Columbia thermal powerplant sites, Morrow, Gilliam and Umatilla Counties, Oregon: Report to Portland General Electric Company, Portland, Oregon.

_____1973a, Geologic studies of Columbia River Basalt structures and age of deformation, The Dalles-Umatilla region, Washington and Oregon Boardman Nuclear Project: Report to Portland General Electirc Company, 1973b, Supplemental studies, Robison "fault" investigation, Boardman Nuclear Project, Morrow County, Oregon: Report to Portland General Electric Company, Portland, Oregon. Swanson, D. A., Wright, T. L., Hooper, P. R., and Bentley, R. D., 1979a Revisions in stratigraphic nomenclature of the Columbia River Basalt Group: U.S. Geological Survey Bulletin 1457-G, 59 p. Swanson, D. A., Wright, T. L., and Zeitz, I.,1979b, Aeromagnetic map and geologic interpretation of the west-central Columbia Plateau, Washington

and adjacent Oregon: U.S. Geological Survey, Map GP-917. Scale Swanson, D. A., Wright, T. L., Camp, V. E., Gardner, J. N., Helz, R. T., Price, S. M., Reidel, S. P., and Ross, M. E., 1980, Reconnaissance geologic map of the Columbia River Basalt Group, Pullman and Walla Walla quadrangles, southeast Washington and adjacent Idaho: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-1139, 2 sheets. Scale 1:250,000. Swanson, D. A., Anderson, J. L., Camp, V. E., Hooper, P. R., Taubeneck W. H., and Wright, T. L., 1981, Reconnaissance geologic map of the

Columbia River Basalt Group, northern Oregon and western Idaho: U.S. Geological Survey Open-File Report 81-797, 35 p. U.S. Geological Survey, 1979, Aeromagnetic map of Pendleton and vicinity Oregon and Washington, U.S. Geological Survey Open-File Report 79-278, 1 plate. Scale 1:125,000.

CONVERSION FACTORS

square kilometers (km²)

☆ U.S. GOVERNMENT PRINTING OFFICE: 1990-591-887

For use of readers who prefer to use International System (SI) units, rather than the inch-pound terms used in this report, the following conversion factors may be used: To obtain 1.609 miles (mi) kilometers (km)

2.590

square miles (mi²)

National Geodetic Vertical Datum of 1929 (NGVD of 1929): The reference to which relief features and altitude data of the conterminous United States and Alaska are related is the National Geodetic Vertical Datum of 1929, a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada and formerly called "Mean Sea Level". NGVD of 1929 is referred to as sea level in this report.



FIGURE 3.— Generalized stratigraphy of the Oregon part of the Columbia Plateau.