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POST-COLUMBIA RIVER BASALT GROUP STRATIGRAPHY AND MAP COMPILATION OF THE COLUMBIA PLATEAU, OREGON

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INTRODUCTION

Purpose

This report presents the results of reconnaissance mapping of sedimentary deposits and volcanic rocks overlying the Columbia River Basalt Group in the area between longitudes 117° 15' W. and 121° 30' W. and latitude 44° 15' N. and the Oregon-Washington border. The project area, shown in Figure 1, covers parts of The Dalles, Pendleton, Grangeville, Baker, Canyon City, and Bend 1° X 2° quadrangles (scale 1:250,000).

The mapping was done by Shannon and Wilson, Inc., under the supervision of the Oregon Department of Geology and Mineral Industries (DOGAMI), to provide stratigraphic data on the sedimentary deposits and volcanic rocks overlying the Columbia River Basalt Group. These data are needed to understand the tectonic framework of the Oregon portion of the Columbia Plateau and adjacent terranes and will be used by Rockwell Hanford Operations in their assessment, for the U. S. Department of Energy, of the feasibility of locating a long-term nuclear waste repository in the Pasco Basin. A companion report on rocks overlying the Columbia River Basalt Group in Washington was completed earlier (Rigby and Othberg, 1979).

Scope of Work

A total of 308 U. S. Geological Survey (USGS) quadrangles were mapped in the project area. Ninety (90) 7.5-minute quadrangles were mapped by rapid field reconnaissance. A total of 215 7.5-minute and three 15-minute quadrangles were mapped by office compilation. One to two man-days per quadrangle were alloted for both the field and office compilation maps. A uniform, consistent explanation was developed for the map units throughout the project area. The field and office maps were then transferred onto 1:250,000-scale 1° X 2° quadrangles by DOGAMI personnel. This report presents (1) the stratigraphic nomenclature and lithologic descriptions of the post-Columbia River Basalt Group units along with evaluations of previous mapping and problems of stratigraphic correlation; (2) a listing of sample localities; (3) an index map showing literature used in mapping; and (4) a brief description of significant faults in the post-Columbia River Basalt Group units, or late Cenozoic units.

Project Personnel

Shannon and Wilson, Inc., personnel involved in this study were

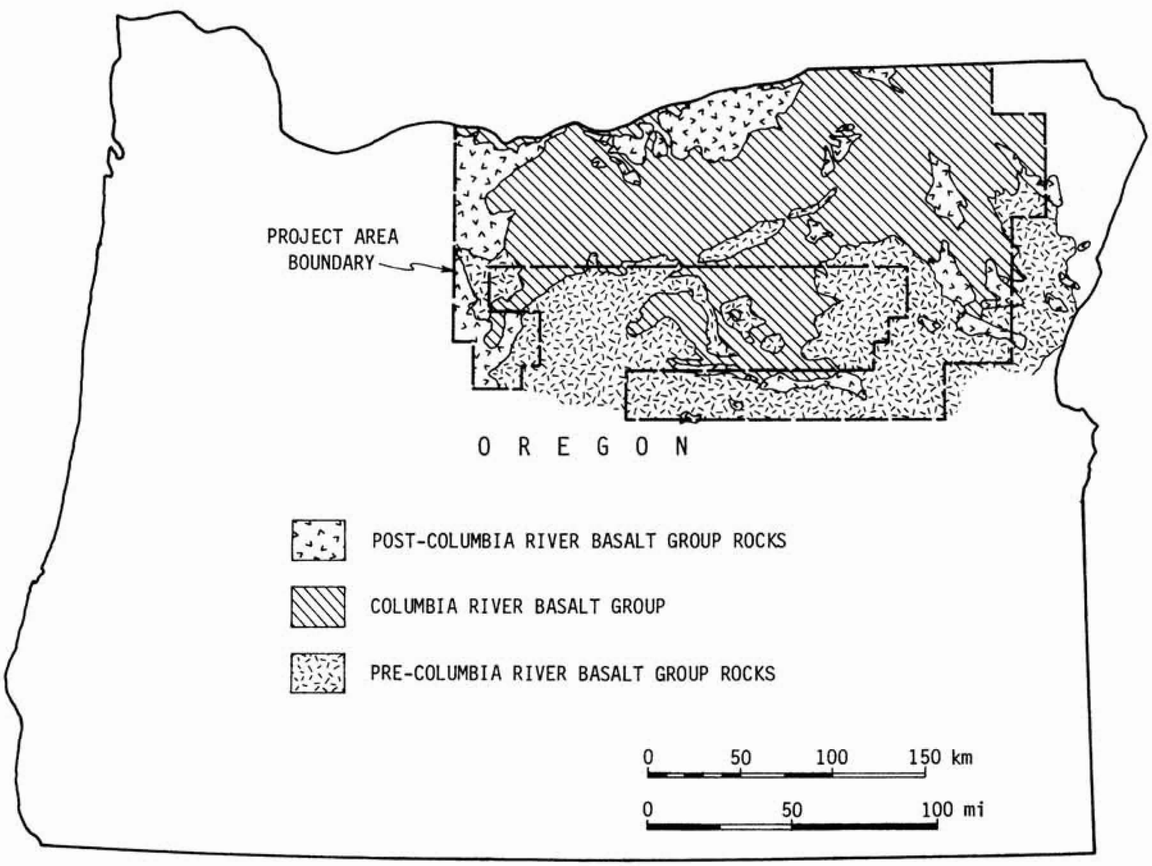


Figure 1. Location and geologic setting of the project area.

S. M. Farooqui, R. C. Bunker, D. C. Clayton, R. J. Deacon, and R. E. Thoms. R. J. Deacon was the overall project director within Shannon and Wilson, Inc. John D. Beaulieu of DOGAMI was project manager. S. M. Farooqui coordinated day-to-day activities. Field mapping was by Bunker, Clayton, Deacon, Farooqui, and Thoms; office compilation mapping was by Bunker and Farooqui. J. L. Bela (DOGAMI) prepared the final compilation of the 1:250,000-scale 1° X 2° quadrangle maps.

Acknowledgements

J. D. Beaulieu, J. L. Bela, H. C. Brooks, and M. L. Ferns of DOGAMI, and J. A. Caggiano, J. T. Lillie, and A. M. Tallman of Rockwell provided useful discussions and prompt assistance. J. L. Anderson (USGS) and R. D. Bentley (Central Washington State University) offered useful data, discussions, and field review. J. B. Gonthier, D. A. Swanson, and G. W. Walker, all of the U. S. Geological Survey (USGS), also provided useful discussions and data, as did R. C. Newcomb (Consultant, Portland, Oregon), D. E. Stensland (Southwestern Oregon Community College), and E. M. Taylor (Oregon State University). The Environmental Remote Sensing Applications Laboratory (ERSAL, Oregon State University) and the U. S. Department of Agriculture's Agricultural Stabilization and Conservation Service (USDA-ASCS) allowed use of their aerial photograph collections.

We especially thank J. D. Beaulieu and A. M. Tallman for their deep interest and inspirational criticism.

METHODS

Mapping was done on USGS 7.5- and 15-minute topographic quadrangle maps. Field and office compilation mapping was done concurrently from April 1980 until June 1981. Appendix 1 lists the field and office compilation maps.

Monthly conferences were held with DOGAMI and Rockwell to review progress of the mapping, new geologic data, nomenclature problems and solutions, and the project's budget. Problems and data requiring attention at times other than the monthly meetings were dealt with immediately. Two field reviews were held to review field problems.

Office Compilation Mapping Methods

Previous geologic mapping, aerial photographs, and LANDSAT and SLAR imagery were used to compile the 218 office maps. Figure 2 shows the areas covered by previous published and unpublished mapping. Where previous maps conflicted, precedence usually was given to the more recent map. Farooqui's (1980) preliminary compilation map was used as a guide in resolving conflicts between maps. Map units from previous mapping that differed from those used in this report were evaluated and incorporated into the map units used here.

Compilation of geologic data from source maps onto the office maps was done either visually or with proportional dividers. Some imprecision resulted from the transfer process because of the difficulty inherent in transferring data from small- to large-scale maps by these methods.

High-altitude 1:130,000-scale National Aeronautics and Space Administration (NASA) false-color infrared stereopair prints and diapositive color infrared stereopair transparencies were generally used as an aid in mapping. Other variously scaled NASA color infrared stereopair prints and low-altitude USGS black-and-white photo-index sheets were also used to provide detailed information in selected areas. LANDSAT and SLAR imagery was only useful in broadly delineating loess-covered areas and regional structures and lineaments.

Field Mapping Methods

The 90 field maps were mapped by automobile road traverses and supplemented by aerial-photograph interpretation and low-altitude aerial reconnaissance. Some low-altitude aerial reconnaissance was also utilized

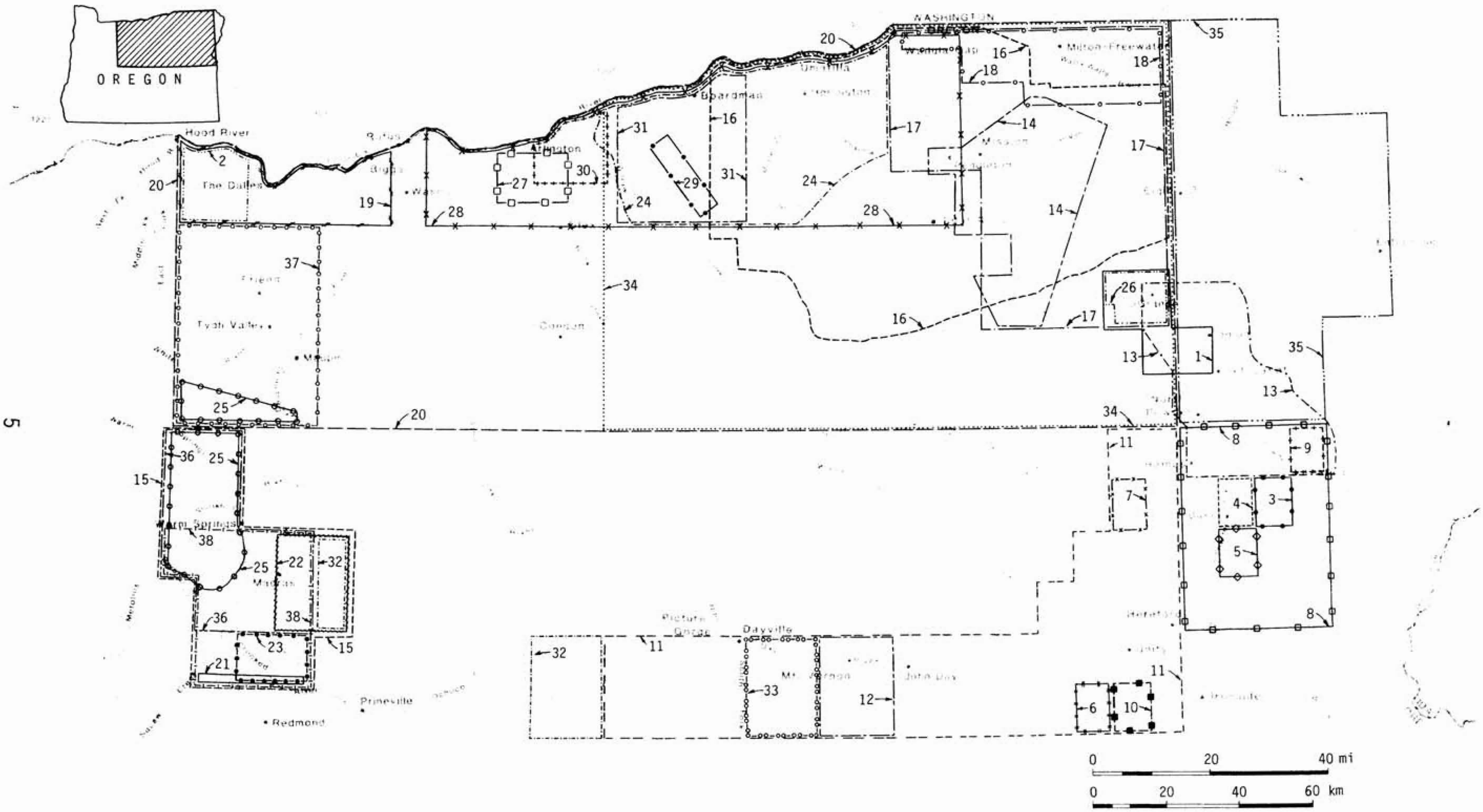


Figure 2. Source index map for the project area. (For key to sources, see Figure 2A.)

Figure 2A. Key to Source Index Map

Map	Source	Map	Source
1	Barrash and others (1980)	20	Newcomb (1970)
2	Beaulieu (1977)	21	Peterson and others (1976)
3a	Brooks (1977)		
3b	Brooks and McIntyre (1977a)	22	Robinson (1975)
4	Brooks and McIntyre (1977b)	23	Robinson and Stensland (1979)
5	Brooks and McIntyre (1978)	24	Robison (1971)
6	Brooks and Ferns (1979)	25	Robison and Laenen (1976)
7	Brooks and Ferns (1981)	26	Schlicker and Deacon (1971)
8	Brooks and others (1976)	27	Shannon and Wilson (1971)
9	Brooks and others (1977)	28	Shannon and Wilson (1972)
10	Brooks and others (1979)	29	Shannon and Wilson (1973)
11	Brown and Thayer (1966a)	30	Shannon and Wilson (1975a)
12	Brown and Thayer (1966b)	31	Shannon and Wilson (1975b)
13	Gardner and others (1974)	32	Swanson (1969)
14	Gonthier and Harris (1977)	33	Thayer and Brown (1966c)
15	Hodge (1941)	34	Walker (1973)
16	Hogenson (1964)	35	Walker (1979a)
17	Kienle and others (1979)	36	Waters (1968a)
18	Newcomb (1965)	37	Waters (1968b)
19	Newcomb (1969)	38	Williams (1957)

to check the final versions of the maps compiled in the office.

Because of the reconnaissance nature of the study, outcrop examination was generally restricted to those outcrops near roads. Columnar sections were measured where needed to characterize formal and informal stratigraphic units. Field observations were recorded in field notes or on map margins, where problems of stratigraphic correlation and nomenclature are also discussed. Copies of the field notes and field and office maps are maintained by Rockwell Hanford Operations, Richland, Washington, and by DOGAMI in Portland, Oregon.

As an aid to field mapping and formulation of stratigraphic framework, caliche and rock samples were collected for chemical characterization, age dating, or both. Some caliche horizons were dated by the Th^{230}/U^{234} method (Ku and others, 1979). This method has been modified by Ku during subsequent work for Rockwell. Lavas and welded tuffs were samples for K/Ar dating; the dating was by Krueger Enterprises. Appendix 2 summarizes this information.

Final Map Compilation Procedure

The final 1:254,000-scale 1° X 2° quadrangle maps were compiled from the 7.5- and 15-minute quadrangle maps. The quadrangle maps were traced onto acetate overlays and photographically reduced by the photo-mechanical transfer (PMT) process. The reductions were transferred to the 1° X 2° quadrangle base maps directly or by use of a zoom transfer scope. Because of the large-scale reduction involved in compiling from 1:24,000- and 1:62,500-scale quadrangles to the 1:250,000-scale 1° X 2° quadrangle maps, only those units at least 0.4 to 0.5 km wide are shown. In some cases, units on the field and office maps are combined or omitted so that the units depicted on the 1:250,000-scale maps are clearly visible.

Loess, colluvium, and residual soil are depicted on the maps by a pattern overlay on the underlying geologic units in order to show both the bedrock and the surficial geologic units. Alluvium and terrace sediment are generally omitted from perennial and intermittent streams where those deposits are less than 0.2 km wide; usually only those deposits 0.4 km or more in width are shown. In all other places, the stream itself indicates the presence of limited alluvial deposits in the stream valleys.

Geologic structure was not the major emphasis of this study; therefore, only faults that may displace units younger than the Columbia River Basalt Group or that may define contacts between the Group and pre-Group units are shown. Depicted faults include some "inferred" faults from previously published geologic maps which are not separately distinguished in this compilation.

The compiled 1:250,000-scale geologic maps are shown in Plates I to VI.

GEOLOGIC SETTING

The project area, which is characterized by geomorphic variety reflecting a complex geologic history, includes parts of the Columbia Plateau, Cascade Range, and Basin and Range physiographic provinces (Fenneman, 1931). The Columbia Plateau encompasses most of the project area and includes the Deschutes-Umatilla Plateau, Blue Mountains, Joseph Upland, and High Lava Plains subdivisions of Dicken (1965).

The stratigraphy in the project area is divided into three major divisions: (1) pre-Columbia River Basalt Group rocks; (2) Columbia River Basalt Group; and (3) post-Columbia River Basalt Group sedimentary deposits and volcanic rocks. Figure 1 shows the general areal distribution of these three divisions. The divisions are briefly described below. Map symbols are given after the name of each map unit.

Pre-Columbia River Basalt Group Rocks (pm)

Rocks pre-dating the Columbia River Basalt Group range in age from Devonian to Miocene. The pre-Tertiary rocks include Paleozoic and Mesozoic eugeosynclinal sedimentary and volcanic rocks, ophiolites, melange, and granitic intrusions (Gilluly, 1937; Thayer, 1963, 1977; Dickenson and Vigrass, 1965; Walker, 1973, 1977, 1979a; Brown and Thayer, 1966a; Baldwin, 1976; Brooks and others, 1976; Swanson, 1969; Brooks and Vallier, 1978; Brooks, 1979a; Ferns and Brooks, 1981). The Paleozoic and Mesozoic rocks were folded, faulted, and locally metamorphosed prior to the Eocene Epoch.

The early Cenozoic rocks include the Clarno and John Day Formations, which are of Eocene to early Miocene age (Oles and Enlows, 1971; Robinson and Brem, 1981). These formations consist of lava flows, mudflow deposits, ash-flow tuffs, and tuffaceous sedimentary rocks. A red saprolite is developed on top of the Clarno Formation. Although the Strawberry Volcanics are partially coeval with the Columbia River Basalt Group (Thayer and Brown, 1966a,b; Robyn, 1977; Robyn and others, 1977), they are included here with the pre-Columbia River Basalt Group rocks as a matter of convenience because they are distinct from the Group.

Regionally extensive unconformities recording episodic tectonic activity separate many of the pre-Columbia River Basalt Group rocks (Oles and Enlows, 1971). The youngest regional unconformities occur at or near the tops of both the Clarno and John Day Formations. The pre-Tertiary rocks have rotated clockwise $60° \pm 29°$ (Wilson and Cox, 1980), whereas the Clarno Formation has rotated clockwise $15° \pm 22°$ (Beck and others, 1978).

Columbia River Basalt Group (Tcr)

The Columbia River Basalt Group (Tcr) is a thick tholeiitic flood-basalt sequence of Miocene age that covers parts of Oregon, Washington, and Idaho (Waters, 1962). The Group includes, from oldest to youngest, the Imnaha, Picture Gorge, Grande Ronde, Wanapum, and Saddle Mountains Basalts (Swanson, Anderson, and others, 1979; Swanson, Wright, and others, 1979). The youngest flow in Oregon is the 10.5-m.y.-old (McKee and others, 1977) Elephant Mountain Member of the Saddle Mountains Basalt.

Sedimentary interbeds between basalt flows are common, but they are not included as part of the Group (Swanson, Wright, and others, 1979). These interbeds are referred to the Ellensburg Formation (Schmincke, 1964, 1967; Newcomb, 1971b; Shannon and Wilson, 1972, 1975a, 1976; Rigby and Othberg, 1979; Swanson, Wright, and others, 1979). Because this project emphasizes post-Columbia River Basalt Group units, the Ellensburg Formation interbeds were included with the Columbia River Basalt Group in this study.

The Columbia River Basalt Group unconformably overlies older rocks and is folded and faulted. Disconformities and unconformities separate the Group from overlying rocks.

Post-Columbia River Basalt Group Sedimentary Deposits and Volcanic Rocks

Varied epiclastic and volcaniclastic deposits, as well as volcanic rocks, overlie the Columbia River Basalt Group. This study concentrates on mapping these units, describing them, and determining their stratigraphic relationships.

The sedimentary deposits and volcanic rocks overlying the Columbia River Basalt Group range from late Tertiary, or Neogene, to Quaternary age. They are subdivided into four major groupings: (1) Neogene deposits; (2) Quaternary deposits; (3) Quaternary-Tertiary deposits; and (4) volcanic rocks of Neogene or Quaternary, or both, ages. Distribution of these units is shown in Plates I to VI.

NEOGENE DEPOSITS

General

Indurated tuff, siltstone, sandstone, conglomerate, and interbedded lava flows and ash-fall tuff comprise Neogene deposits of the project area. The Neogene includes the Miocene and Pliocene Epochs. The age assignment of epochs is based on Berggren and van Couvering (1974), who revised the time boundaries between the Oligocene-Miocene, Miocene-Pliocene, and Pliocene-Pleistocene Epochs to 22.5, 5.0, and 1.8 m.y., respectively. This revision has been adopted by the U. S. Geological Survey (Sohl and Wright, 1978). For this study these revised epoch boundaries have been integrated with previous reports on the geology of north-central and northeastern Oregon, which used older ages for epoch boundaries.

Stratigraphic Nomenclature

Neogene deposits in the project area occur in ten geographically discrete basins (Figure 14). Our regional assessment and field reconnaissance of these deposits has allowed us, in some cases, to assign new terminology to previously mapped units. Newly defined Neogene deposits include the Dalles group (Farooqui and others, 1981) and the Baker, Unity, Ironside, and LeRoux deposits. Other Neogene deposits include the previously defined Mascall and Rattlesnake Formations. The Neogene deposits underlying the Walla Walla and Ukiah basins are not discussed because of a lack of stratigraphic and lithologic control.

The distribution of the Neogene units is shown on Plates I to VI. The regional stratigraphic framework of these deposits is shown in Figure 3.

Dalles Group

Neogene deposits consisting chiefly of fluvial silt, sand, and gravel; volcaniclastic lahar and tuff; air-fall tuff; and basalt flows overlie the Columbia River basalt and older rocks along the northern flank of the Blue Mountains from the Cascade Range to nearly 118° W. longitude. These deposits, referred to variously in previous literature as described below, were laid down in northeasterly-trending, probably isolated and discrete basins.

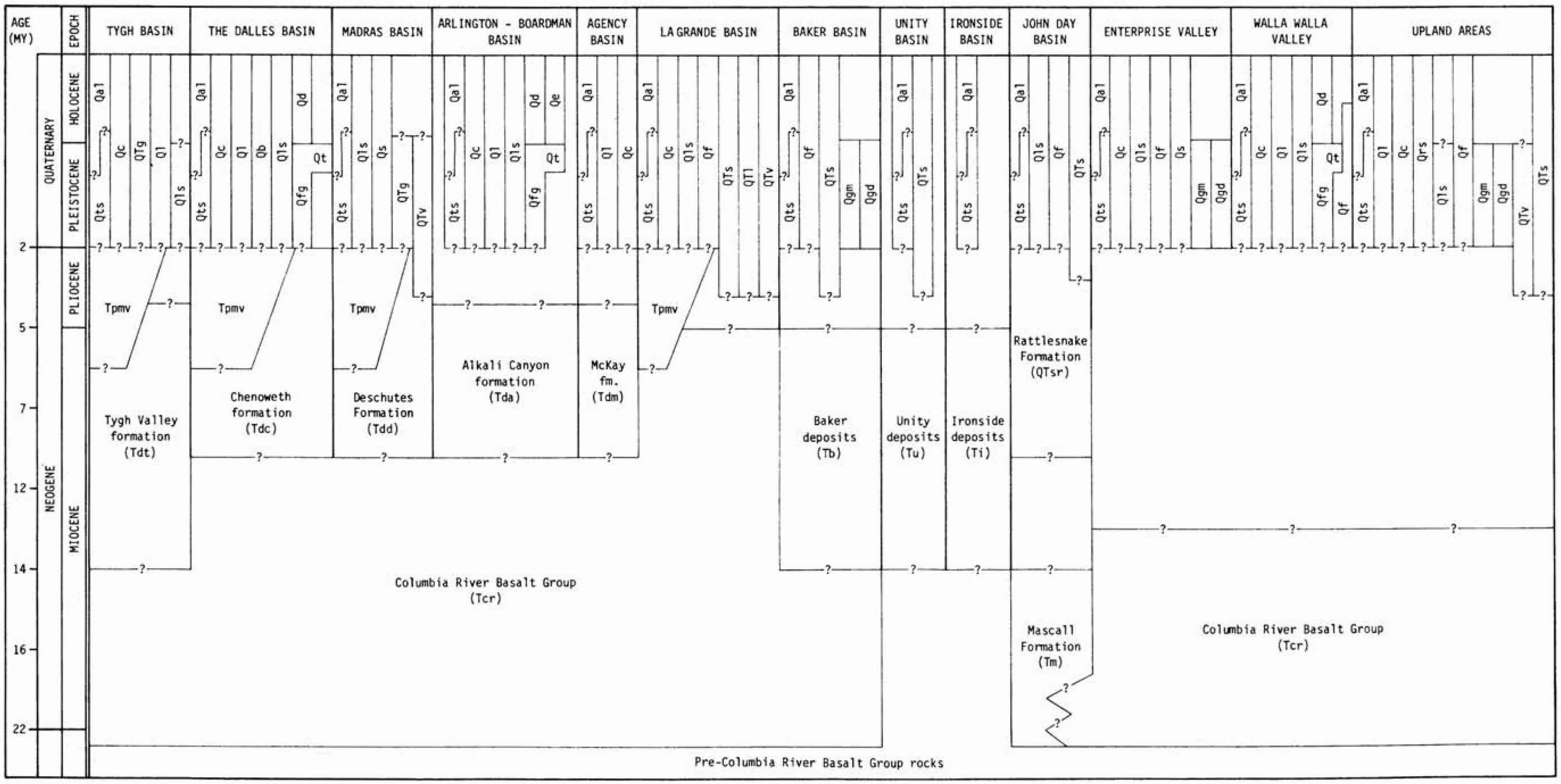


Figure 3. Correlation of rock-stratigraphic units within the project area.

Review of Nomenclature

Condon (1874) originally called sedimentary rocks above basalt flows in The Dalles area the "Dalles Group" (Cope, 1880; McCornack, 1928). Subsequent mapping has extended "Dalles" nomenclature away from The Dalles eastward to Pendleton and southward to the Madras-Redmond area.

Condon's "Dalles Group" was briefly studied by Knowlton (1902), Williams (1916), Collier (1916), Bretz (1917, 1921), and Buwalda and Moore (1929, 1930). Piper (1932) mapped these deposits as the Dalles formation, suggesting they were approximately correlative with the Ellensburg of Smith (1903) and Mascall formations.

Newcomb (1966, 1969) formalized the Dalles Formation and extended it eastward to the Arlington area. He discarded the name Shutler formation, applied earlier to supra-basalt deposits in the Arlington area (Hodge, 1941), because of its stratigraphic and lithologic ambiguity. Newcomb (1971b) and Shannon and Wilson (1971, 1972, 1975a, 1976, 1981) demonstrated that the Dalles Formation overlies both the Columbia River Basalt Group and interbeds of the Ellensburg Formation where the interbeds occur beyond the edge of the more restricted overlying basalt.

Because of lithologic similarity, Shannon and Wilson (1971, 1973, 1975a, 1976) extended the Dalles Formation eastward from Arlington to the Boardman and Pendleton-Pilot Rock areas so as to include Hogenson's (1964) fanglomerate and Shotwell's (1956) McKay beds.

South of The Dalles, Hodge (1941) extended the Dalles formation beyond Bend to latitude 44° N. He also mapped a fault sliver of the John Day Formation along the south flank of Tygh Ridge; these rocks are here included in the Dalles group. Wells and Peck (1961) mapped these sediments as the Mascall Formation. Waters (1968b) mapped it as Ellensburg Formation. He (1968a,b) also mapped the Dalles Formation in Tygh Valley and near Madras.

Application of the term "Dalles" to stratigraphic nomenclature for the Madras area has a history independent of that for the Dalles Formation at and east of The Dalles. Russell (1905) termed the heterogeneous assemblage of sediments, ash-flow tuffs and lava flows exposed in the Deschutes and Crooked River Canyons the Deschutes sands. Stearns (1930) termed these rocks the Deschutes formation. Hodge (1928, 1940) termed similar rocks near Madras the Madras formation, but later (Hodge, 1942) called them Dalles formation. Williams (1957), Robinson and Price (1963), and Robinson and Stensland (1979) used the name Madras Formation. Waters (1968a), Robinson (1975), and Robison and Laenen (1976) used the name Dalles Formation. Stensland (1970), Peterson and others (1976), and Taylor (1980) used the name Deschutes Formation, citing its priority.

Basis for Revision of Stratigraphic Nomenclature

The Dalles group is recognized for those units in Oregon which historically have been referred to as the Dalles Formation and which overlie the Columbia River basalt or which can be demonstrated laterally to overlie the Columbia River basalt. This effort conforms to the provisions of the Code (American Commission on Stratigraphic Nomenclature, 1970), does not prejudge the situation outside the study area, and follows many decades of work in Oregon.

A confusing rock-stratigraphic nomenclature presently exists for the "Dalles Formation." A systematic nomenclature based on the criteria for establishing formal rock-stratigraphic units is desirable. Data now are sufficient to elevate the Dalles Formation informally to group status and to identify its constituent units, as related but distinctly mappable formations. Each formation is sufficiently unique to permit its mapping as a geographically discrete unit. The group is confined to the Dalles, Arlington, Boardman, Pendleton, Pilot Rock, Tygh Valley, Madras, and Redmond areas, where the term "Dalles" was used previously.

The informal Dalles group is defined specifically and conforms to the Code (American Commission on Stratigraphic Nomenclature, 1970) as follows:

- The Dalles group is composed of five discrete mappable formations, some of which may have been locally connected. The nature of such connections is not critical and is buried beneath volcanic rocks.

- The formations of the group are mappable units and have been treated extensively in the literature.

- The formations overlie the Columbia River Basalt Group by definition. Contact relations with the basalt are sharp and well defined. Where younger flows in the Columbia River basalt overlie sediments, these sediments and their mappable extensions are <u>not</u> considered part of the Dalles group.

- The group is overlain by a variety of Quaternary deposits. Contacts with these deposits are both sharp and gradational and are defined for each formation. The gradational contacts are based on the lithologic criteria that provide the greatest utility in mapping. The Quaternary units are excluded from the underlying formations.

- All five formations are of middle(?) Miocene to Pliocene age.

- Historic priorities and popular usage of older nomenclature is maintained. Further, the term Dalles group is applied only to those units for which the term Dalles Formation has been used previously. It is not the intent to extend the term Dalles group into other areas of analogous rocks for which other terminology is in common usage.

The five formations of the Dalles group are the Chenoweth, Alkali Canyon, Deschutes, Tygh Valley, and McKay formations. These units are used informally in this report but will be formalized in a forthcoming publication (Farooqui and others, in press).

Chenoweth Formation (Tdc)

Indurated deposits overlying the Columbia River Basalt Group in the Dalles basin are herein informally named the Chenoweth formation of the Dalles group. The name Chenoweth comes from Chenoweth Creek in T. 2 N., Rs. 12 and 13 E., near The Dalles, Wasco County, Oregon. The formation was previously named the Dalles Formation (Condon, 1874; Cope, 1880; Piper, 1932; Newcomb, 1966, 1969).

The Chenoweth formation occupies the western end of The Dalles-Umatilla syncline. North of the Columbia River, the Chenoweth formation occurs as isolated remnants at the base of Stacker Butte and west and east of Lyle, Washington. It is more extensive in Oregon, extending from the Columbia River south to Tygh Ridge. West of The Dalles, it is well represented in the valley formed by the Mosier syncline. The Ortley anticline separates the Mosier and Dalles-Umatilla synclines, but it plunges southwestward, allowing the connection of the formation between the two synclines. The western limit of the Chenoweth formation is unclear because as it approaches the Cascades, it is overlain by andesite flows. Eastward from The Dalles, it extends to the Deschutes River. East of the Deschutes River, however, it occurs only as remnants immediately south of the Columbia River, as near Biggs and Rufus.

Piper (1932) and Newcomb (1969) described the formation in the most detail. It is an eastward-spreading volcaniclastic debris fan consisting of interbedded agglomerate; tuff breccia; pumiceous lapilli tuff; lithic lapilli tuff; andesitic and basaltic conglomerate and sandstone; and tuffaceous sandstone, siltstone and clay shale. The tuff breccia commonly consists of angular andesite clasts, 2 to 10 cm in diameter, isolated in a tuff matrix. The agglomerate consists of large, angular boulder- and cobble-size andesite clasts in a sandy, tuffaceous matrix. The tuff breccia and agglomerate are interpreted to be lahar deposits owing to the common occurrence of these deposits in lenticular channels. The other rock types are commonly thick bedded and lenticularly bedded. Beds are commonly less than 1 m thick. The beds are discontinuous laterally, and rapid lithofacies changes are common. The formation also contains a 15-m-thick interbedded basalt flow along Fulton Ridge (Tps. 1 and 2 N., Rs. 14 and 15 E.; Newcomb, 1969). Figure 4 shows representative columnar sections of the Chenoweth formation.

Lahars and interbedded conglomerate and sandstone rich in andesite clasts dominate the western part of the deposit near the foothills of the Cascade Range. Farther northward and eastward, the proportion of lahars decreases, while "normal" fluvial deposits of conglomerate, sandstone and siltstone become more common. Newcomb (1969) interpreted the formation as consisting of a proximal "volcanic-sedimentary" debris fan deposit that changes distally to a "sedimentary" deposit.

The source area for the volcanic sediment lies toward the Cascade Range, but its precise location is uncertain. Because the Chenoweth formation is overlain by andesite flows toward the Cascade Range, it cannot be easily traced to its source. These andesite flows overlie the Chenoweth formation with angular uniformity southwest of The Dalles, and they are disconformable on it further south, as near Tygh Ridge (Waters, 1968b). Reconnaissance suggests that other andesite flows may be interbedded with the formation; however, none were observed directly. However, because the flows unconformably above the Chenoweth formation are of the same general age as the Chenoweth formation, it is possible some of the flows were derived from the same source as the Chenoweth formation.

Thickness of the Chenoweth formation varies. Newcomb (1969) reported a total thickness of approximately 550 m for the "volcanic-sedimentary" facies. He noted that thicknesses decrease distally to approximately 137 m near the Deschutes River and to 30 m north of the Columbia River. Piper (1932) reported thicknesses of 275 m (sec. 28, T. 1 N., R. 12 E.) and 198 m (sec. 29, T. 2 N., R. 13 E.).

The Chenoweth formation lies upon the Priest Rapids and Frenchman Springs Members of the Columbia River Basalt Group (Swanson and others, 1981). South of approximately latitude 44° 33' N., it overlies only the Frenchman Springs Member. It has not been observed interfingering with the basalt. Piper (1932) noted that the Chenoweth formation lies on the basalt with an erosional unconformity with a relief of about 30 m. He also noted the relief of the unconformity is no greater than that of local unconformities in the basalt sequence itself, which suggested to him that little time elapsed between emplacement of the basalt and deposition of the Chenoweth formation. In most places, the Chenoweth formation is conformable with the basalt.

In most places, the Chenoweth formation is not overlain by mappable younger units, but it is locally overlain by loess near the Columbia River. The loess is distinguishable from tuffaceous siltstone of the Chenoweth formation by its relatively nonindurated state and its lack of stones. Southwest of The Dalles, Quaternary(?) intracanyon basalt lies in the valleys of Fivemile and South Fork-Mill Creeks, both of which are cut into the Chenoweth formation. To the west, as mentioned earlier, andesite lavas overlie the formation.

The Chenoweth formation is both folded and faulted. The major folds that affect the formation are the Ortley, Bingen, and Mill Creek Ridge anticlines and the Dalles-Umatilla and Mosier synclines (Newcomb, 1969). Faults are also common in the Chenoweth formation (Piper, 1932; Newcomb, 1969), most of which trend west or northwestward. The largest fault is the west-trending Chenoweth fault that juxtaposes the Columbia River basalt on its northern, upthrown side with Chenoweth formation on its southern side.

The Chenoweth formation is of late Miocene to Pliocene age. Buwalda and Moore (1930) dated vertebrates in the formation as late Miocene to early Pliocene. Chaney (1944) dated leaves as early Pliocene. These paleontologic ages are uncorrected with respect to Berggren and

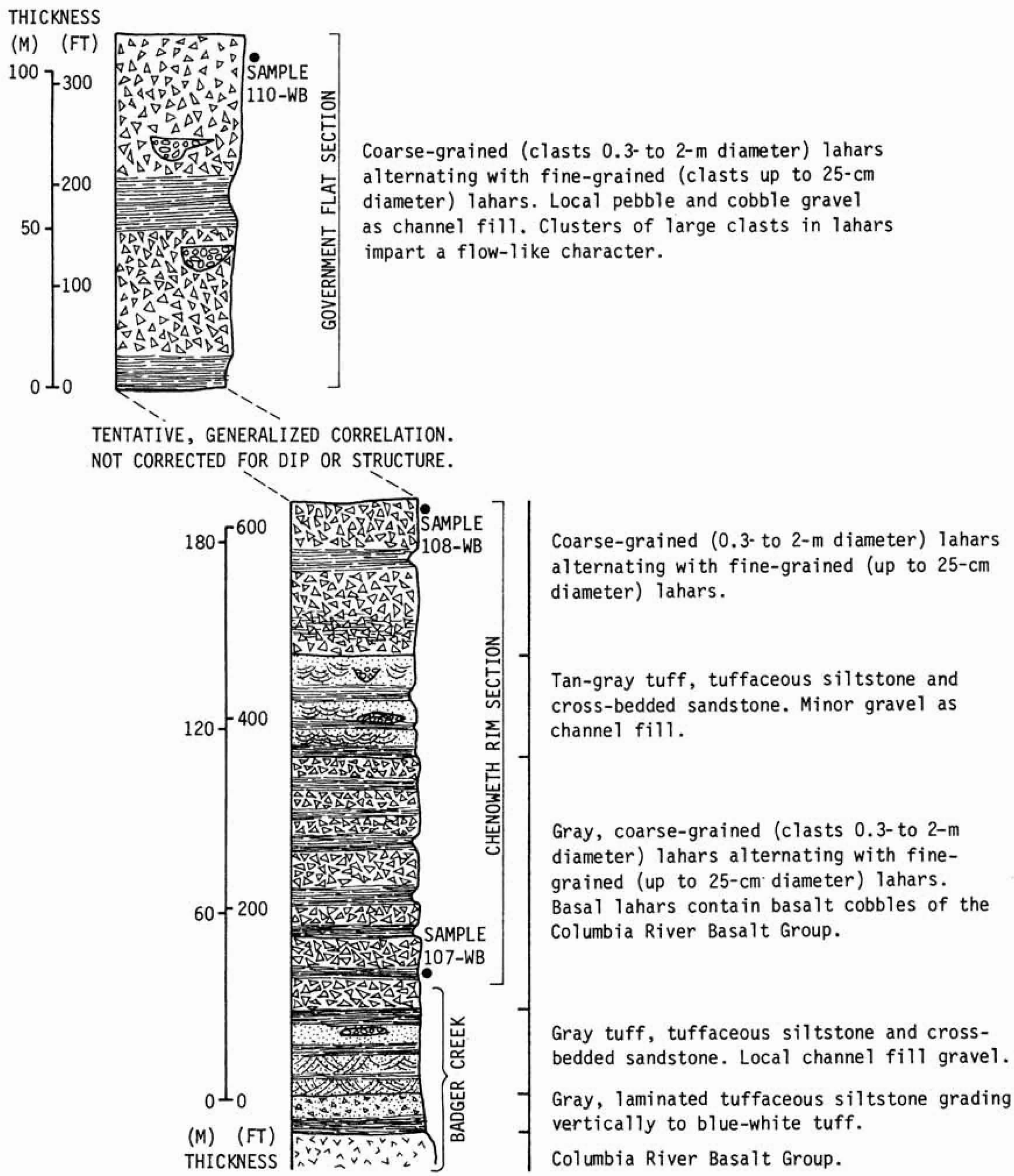


Figure 4. Representative columnar sections of the Chenoweth formation. Locations: Badger Creek and Chenoweth Rim sections in NE¼ sec. 30, T. 2 N., R. 13 E.; Government Flat section in NE¼ sec. 10, T. 1 N., R. 12 E.

van Couvering's (1974) epoch boundaries. K/Ar dates are 5.1±0.5 (109-WB), 5.7±0.6 (110-WB), 7.5±0.7 (105-WB), 41.1±2.8 (107-WB), and 47.5±5.7 (108-WB) m.y. (Appendix 2). Newcomb (1966) reported K/Ar dates of 10.6 and 15.2 m.y. for the flow at Fulton Ridge.

Alkali Canyon Formation (Tda)

Indurated basalt gravel and tuffaceous silt and sand overlying the Columbia River Basalt Group in the Arlington-Boardman area are here informally named the Alkali Canyon formation after exposures in Alkali Canyon, 16 km southwest of Arlington, Gilliam County, Oregon.

The formation was previously named the Alkali lake beds (Hodge, 1932), the Shutler Formation (Hodge, 1941, 1942), fanglomerate (Hogenson, 1964), Dalles Formation (Newcomb, 1969, 1971b; Shannon and Wilson, 1971, 1972, 1973, 1975a,b; Farooqui, 1980), and Tertiary sedimentary rocks (Walker, 1973).

The formation occurs within the Dalles-Umatilla syncline, along the northern slope of the Blue Mountains. West of Arlington, it extends northward to the edge of the Columbia River canyon. East of Arlington, it crops out along the relatively flat floor of the Deschutes-Umatilla Plateau (Dicken, 1965). However, east of Sixmile Creek, it extends northward only to approximately 45° N. latitude. North of this latitude, it is either absent or buried by catastrophic flood deposits.

The most representative section is in Alkali Canyon (Figure 5), where the basal Alkali Canyon formation is a 5-m-thick light-gray vitric tuff overlying the Selah member (Ellensburg Formation). This vitric tuff is here assigned to the Alkali Canyon formation. Newcomb (1971b) tentatively assigned it to his Dalles Formation, noting its presence above the Pomona Member (Saddle Mountain Basalt). This relation is confirmed by subsurface data (Shannon and Wilson, 1981). North of this section, the vitric tuff underlies much of the Chem-Security Systems waste disposal site but extends westward only as far as the W½ sec. 25, T. 3 N., R. 20 E. (Shannon and Wilson, 1971, 1981).

The vitric tuff is overlain at this section by 2 to 3 m of tan, iron-stained, carbonate-veined tuffaceous silty clay. The upper surface of the clay is scoured with channels as much as 2 m in width and depth and filled with basalt gravel. The basalt gravel in total comprises the 3-m-thick middle part of the section. East of this section along the northern wall of Alkali Canyon, the middle part is 6 to 15 m thick (Newcomb, 1971b). The gravel is partially carbonate cemented, ranging from granules to small boulders; cobbles are most common. A sand matrix partially fills interstices among the clasts, while other gravel is openwork. Tuffaceous, micaceous, cryptocrystalline-quartz sand comprises the matrix. The gravel is commonly massive, but 1-m-thick horizontal and lenticular beds also occur. The cobbles commonly dip southwards, indicating a generally northward transport direction.

The upper 10 m of this section is comprised of red-tan, carbonate-cemented, tuffaceous sandy silt. The sandy silt is interbedded with 1-

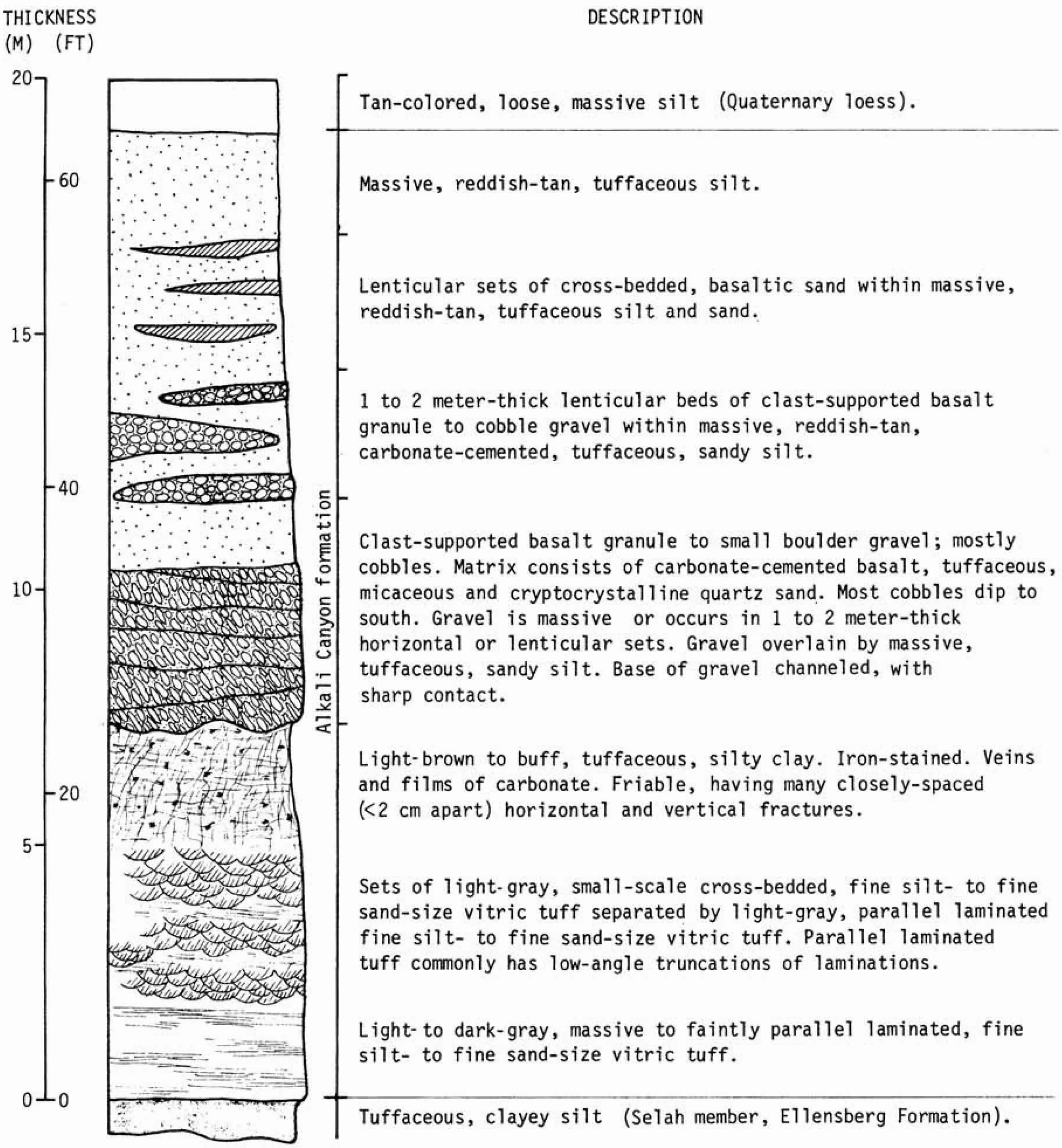


Figure 5. Representative columnar section of the Alkali Canyon formation. Location: Chem-Security Systems site access road, SE¼ sec. 25, T. 2 N., R. 20 E.

to 2-m-thick lenticular, cross-stratified gravel beds in the lower 3 m. Lenticular sets of cross-bedded basaltic sand, isolated in sandy silt, generally comprise the middle part of this 10-m-thick upper section. The uppermost 2 to 5 m of section consists of loose to compact, massive tuffaceous silt.

This four-fold division of the Alkali Canyon formation only occurs locally. Another section near Olex (Figure 6) consists entirely of basalt cobble gravel in a quartzose and basaltic sand matrix. There the Alkali Canyon formation rests directly on the Frenchman Springs Member (Wanapum Basalt).

Other exposures reveal more diversity within the Alkali Canyon formation (Shannon and Wilson, 1974b, 1975a,b). Gravel pit exposures commonly display horizontal, 1- to 2-m-thick beds of massive and cross-stratified cobble gravel. The cobbles show southward-dipping imbrication, indicating general northward transport. Tuffaceous sand and silt lenses are interbedded with and truncated by the gravel beds. Temporary exposures in trench walls at the Chem-Security Systems site (sec. 25, T. 3 N., R. 20 E.) reveal a lenticular, 1-m-thick clay bed lying atop gravel near the top of the formation. The clay is thinly laminated and is interbedded with a thin, vitric tuff bed. Gravel overlies the clay and tuff.

The depositional environment of the Alkali Canyon formation is poorly understood. Hogenson (1964) interpreted it as fanglomerate. The earlier described sedimentary structures suggest the Alkali Canyon represents a type of "proximal braided stream" deposit such as that described by Rust (1978). However, local alluvial fans also constitute part of the depositional system of the Alkali Canyon formation (Figure 7).

Thickness of the Alkali Canyon formation varies. It is 20 to 40 m thick at the Alkali Canyon and Olex sections. Newcomb (1971b) reported 18- to 30-m thicknesses near the Alkali Canyon section. Borings show the Alkali Canyon is 3 to 5 m thick at the Chem-Security Systems waste disposal site (Shannon and Wilson, 1971, 1981). These latter thicknesses are minimums, however, because catastrophic flood erosion locally removed part of the Alkali Canyon formation in the waste disposal site area.

Regionally, the Alkali Canyon formation lies disconformably and with angular unconformity on the Columbia River Basalt Group. The basalt units that it overlies include the Elephant Mountain and Pomona Members (Saddle Mountains Basalt) and the Priest Rapids and Frenchman Springs Members (Wanapum Basalt of the Columbia River Basalt Group) and tuffaceous interbeds of the Ellensburg Formation. A slight angular unconformity is present where the formation overlies the edges of the basalt members (Shannon and Wilson, 1971, 1973, 1974a, 1981; Newcomb, 1971b; Swanson and others, 1981).

Our mapping concurs with previous mapping by Newcomb (1971b) and Shannon and Wilson (1972; 1975a,b) and shows that the Alkali Canyon formation is a post-Columbia River basalt unit and that it does not interfinger with it, as do interbeds of the Ellensburg Formation (Figure 15).

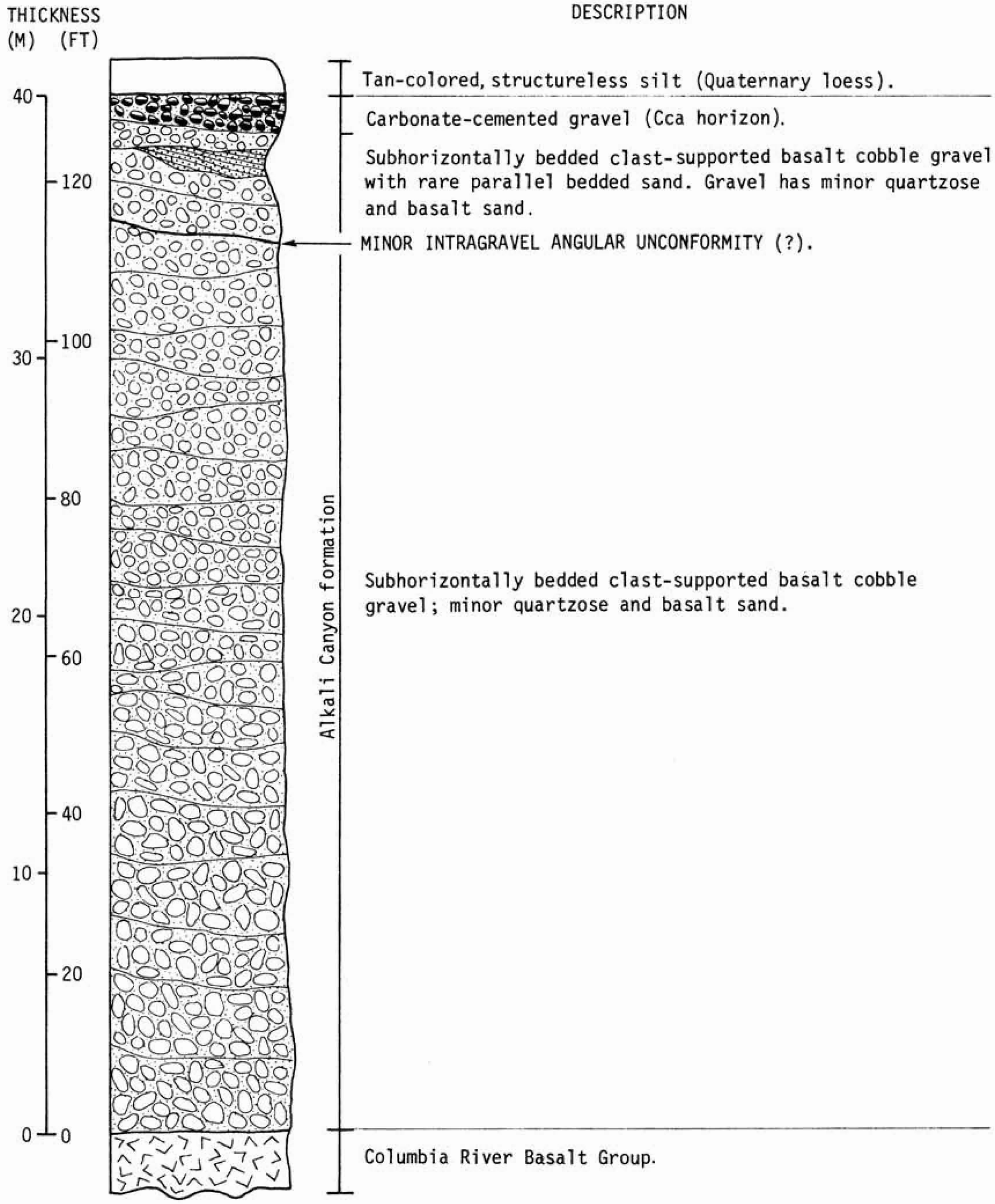


Figure 6. Representative columnar section of the Alkali formation. Location: NW¼ NW¼ sec. 21, T. 1 S., R. 21 E. Below the unconformity(?), beds trend N. 10° W. to N. 50° E.; apparent dips are 40° to 60° W. Above the unconformity(?), beds trend N. 10° E.; apparent dip is 10° W.

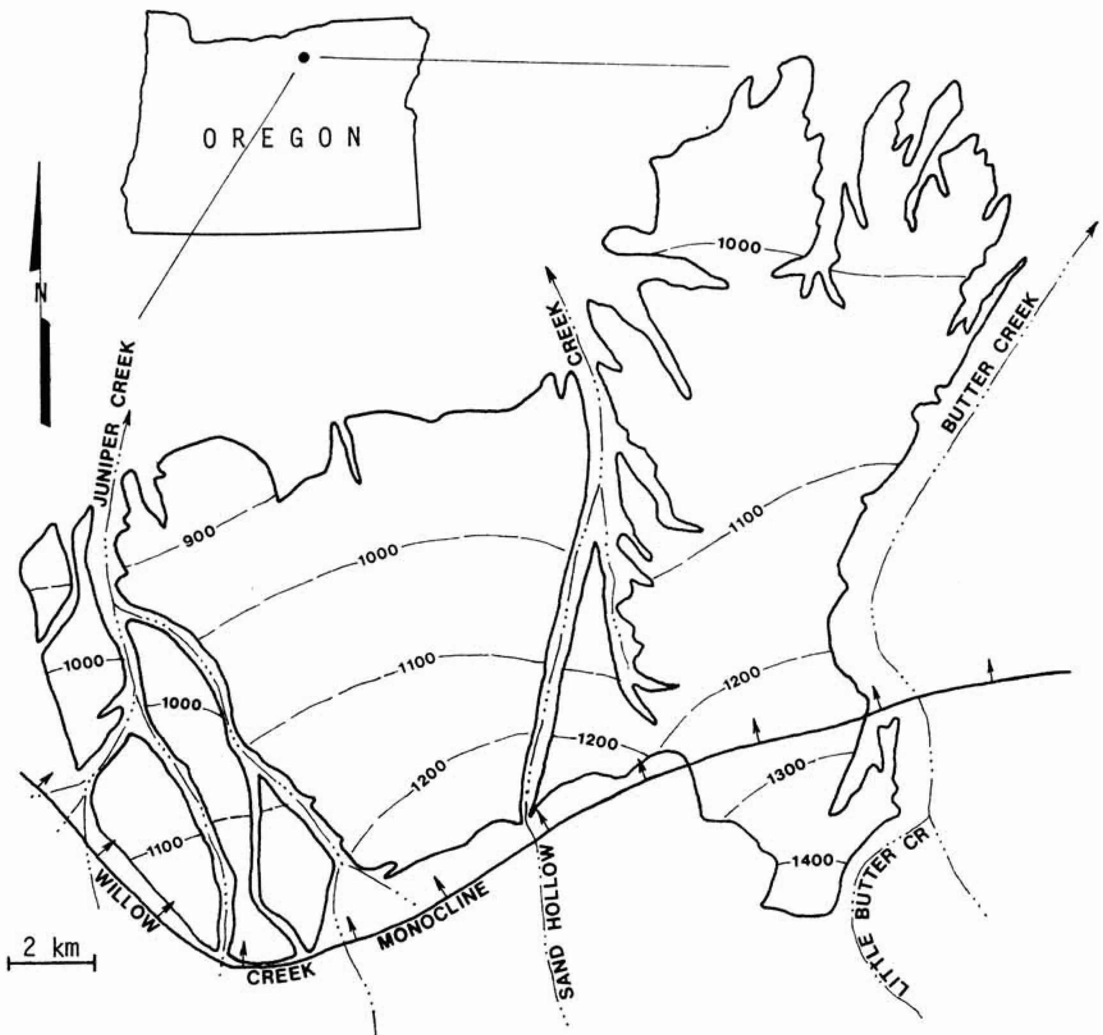


Figure 7. Generalized elevation contours atop preserved alluvial fans of the Alkali Canyon formation. Location: Tps. 1, 2, 3 N., Rs. 25, 26, 27, 28 E. Contours drawn from U. S. Geological Survey Butter Creek Junction; Service Buttes NW; Strawberry Canyon NE, SE, and SW; and Well Spring 7.5-minute quadrangle maps.

The Alkali Canyon formation is locally folded and faulted most commonly along the Turner Butte and Arlington-Shutler lineaments and west-trending anticlines between the lineaments (Shannon and Wilson, 1971, 1974b). It is also folded with the Willow Creek monocline and the Dalreed Butte and Poverty Ridge anticlines (Shannon and Wilson, 1973, 1974b, 1975b). The formation is tilted northward at the western end of the Willow Creek monocline near Olex, where gravel beds trend N. 10° W. to N. 50° E., having apparent dips of 49° to 60° NW.

The Alkali Canyon formation is of late Miocene to early Pliocene(?) age, based on vertebrate fossils assigned to the Hemphillian (Shotwell, 1956). According to Berggren and van Couvering (1974), the Hemphillian is late Miocene to early Pliocene. The Alkali Canyon formation is not older than late Miocene, however, because it overlies the 10.5-m.y. (McKee and others, 1977) Elephant Mountain Member (Saddle Mountains Basalt) (Shannon and Wilson, 1975b).

Deschutes Formation (Tdd)

Distinctively fluvial and volcaniclastic beds within the broad Madras basin comprise the Deschutes Formation. It also includes welded and nonwelded ash-flow tuff, intracanyon and plateau-forming basalt flows, basaltic intrusions and cinder cones, mudflow deposits, and diatomite.

Russell (1905) termed the heterogeneous assemblage of interbedded volcanic, volcaniclastic, pyroclastic, and epiclastic rocks exposed in the Deschutes and Crooked River canyons in the Prineville-Redmond-Madras-Warm Springs area the "Deschutes sands." Stearns (1930) introduced the name Deschutes Formation for these rocks. Hodge (1928, 1940) termed similar rocks near Madras the Madras Formation and later (1942) called them Dalles formation. Williams (1957) and Robinson and Price (1963) used the name Madras Formation. Waters (1968a), Robinson (1975), and Robison and Laenen (1976) used the name Dalles Formation. Stensland (1970), Peterson and others (1976), and Taylor (1980) used the name Deschutes Formation. Robinson and Stensland (1979) used the name Madras Formation. We herein restore the name Deschutes Formation because that name has historic priority, the unit is well exposed along the Deschutes River, and it is desirable to simplify the nomenclature (Roger Swanson, 1981, written communication).

The Deschutes Formation occurs in the Madras basin. The Madras basin is centered near Madras and is bordered on the north by the Mutton Mountains, on the east by the foothills of the Ochoco Mountains, and on the west by the Cascade Range. The southern boundary of the basin is obscure, extending almost to Bend, where the Deschutes Formation is buried beneath younger volcanic rocks.

Stensland (1970) provided detailed information on the Deschutes Formation. It consists of epiclastic and pyroclastic sedimentary rocks; welded and nonwelded ash-flow tuff; interbedded, intracanyon and plateau-forming basalt flows; basaltic intrusions and cinder cones; diatomite; and

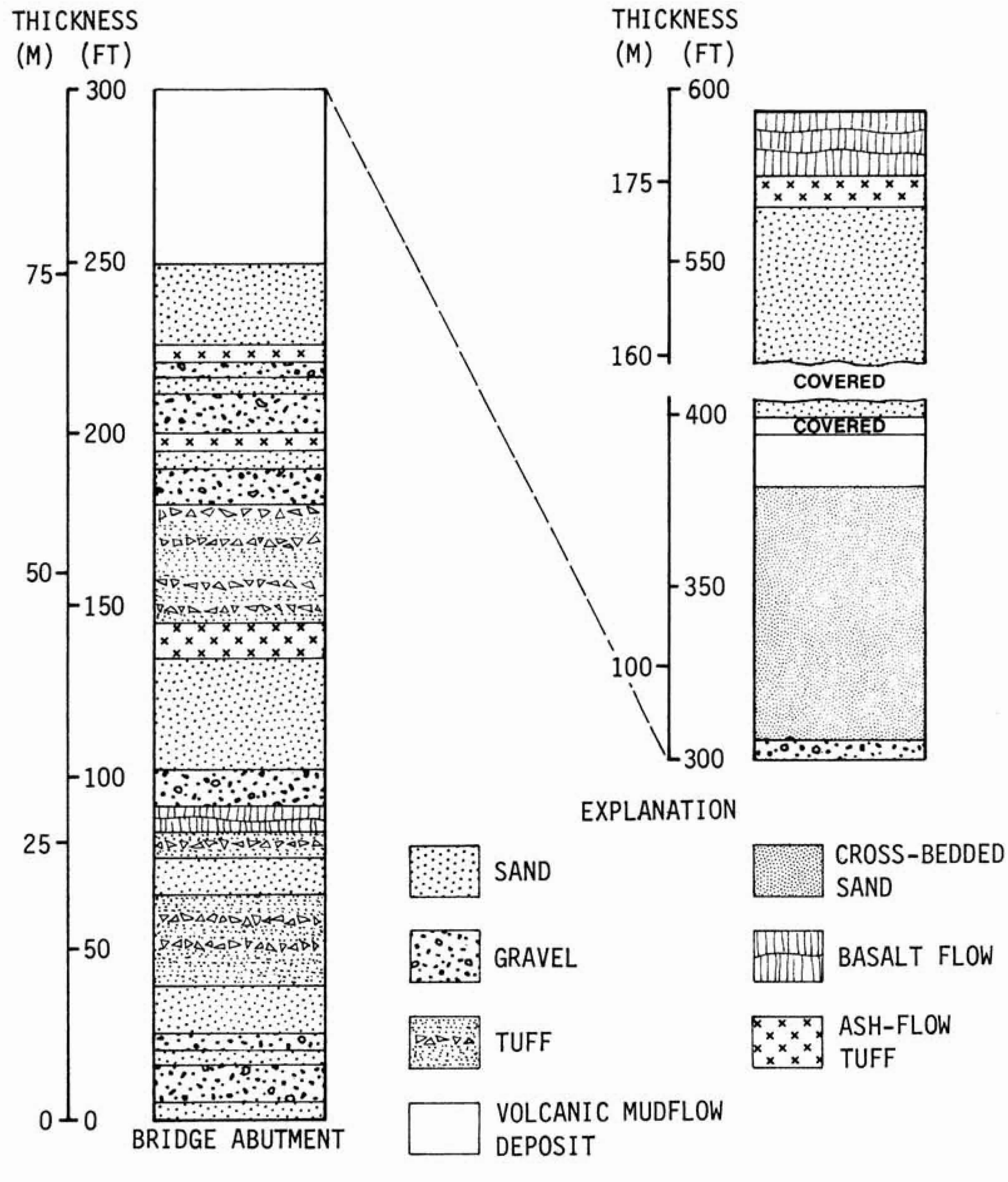


Figure 8. Representative columnar section of the Deschutes Formation. Location: Roadcut on west side of Lake Billy Chinook, secs. 16 and 21, T. 12 S., R. 12 E.

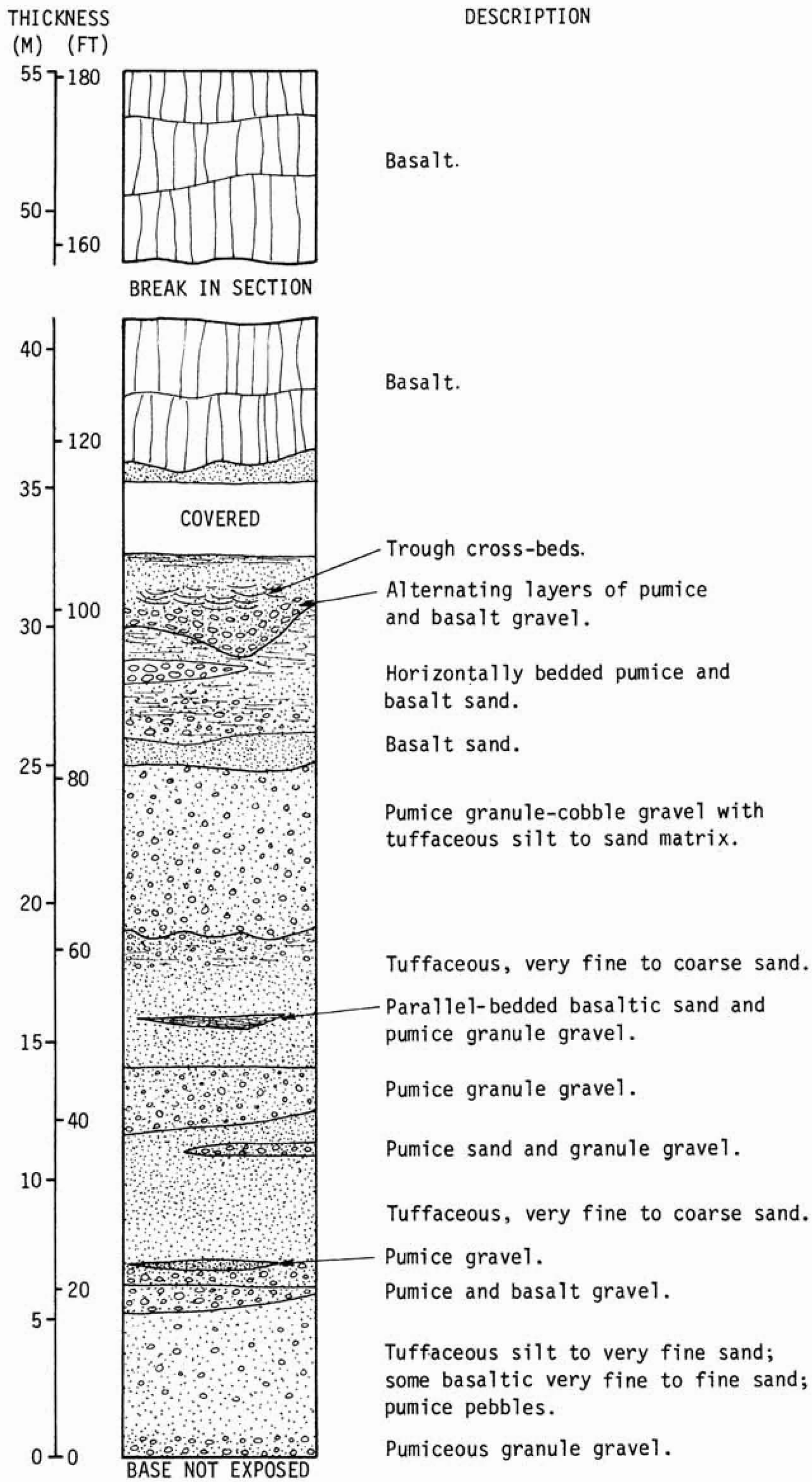


Figure 9. Representative columnar section of the Deschutes Formation. Location: SW¼ sec. 16, E½ sec. 17, T. 9 S., R. 12 E. along U.S. Highway 26.

mudflow deposits. The rock types are complexly interbedded, resulting in rapid lithofacies changes. Individual units are commonly lenticular, wedge-shaped, and 1 to 20 m thick. Lateral continuity is poor except for the basalt flows and ash-flow tuffs. The sedimentary deposits are particularly varied. They consist of basaltic sandstone and conglomerate, pumice gravel, and tuffaceous siltstone and sandstone. Vitric ash, cindery ash, lapilli, pumice lapilli, and volcanic breccia are common (Stensland, 1970). These rock types are common in two representive sections of the Deschutes Formation within the project area (Figures 8 and 9).

Thickness of the Deschutes Formation varies. Stensland (1970) reported thicknesses of less than 30 m to as much as 240 m, noting that the formation fills the irregular pre-existing topography, wedging out against hills eroded in older rocks. Hodge (1940) reported a 300-m thickness near Warm Springs. The measured sections at the Crooked River Reservoir (Figure 8) and northwest of Warm Springs (Figure 9) are 190 m and 55 m thick, respectively.

The Deschutes Formation is unconformable on the John Day and Clarno Formations and the Grande Ronde(?) Basalt of the Columbia River Basalt Group. The Deschutes Formation is locally overlain by Quaternary deposits and lava flows. Near the Cascade Range, the formation is overlain by andesite flows and andesite and basalt gravel.

Within the project area, few structures affect the Deschutes Formation. Only two new, minor faults were mapped: a normal fault (sec. 14, T. 7 S., R. 11 E.) and a reverse fault (NW$\frac{1}{4}$ sec. 35, T. 9 S., R. 14 E.). Outside the project area, Waters (1968a), Stensland (1970), and Taylor (1980) reported several major faults offsetting the Deschutes Formation.

The Deschutes Formation is middle Miocene to early Pliocene. Chaney (1938, 1944, 1959) described its flora as early to middle Pliocene. Evernden and James (1964) reported K/Ar dates of 4.3 and 5.3 m.y., and Armstrong and others (1975) reported K/Ar dates of 4.9 ± 0.5, 5.8 ± 1.0 and 15.9 ± 3.0 m.y. Dates from this study for plateau-forming basalts in the Deschutes Formation are 8.9 and 10.7 m.y.; one interbedded basalt flow is 13.2 m.y. (Appendix 2; samples 5F, 6F, and 7F). Except for the anomalous 15.9 m.y. date, these dates place the Deschutes Formation in middle Miocene to early Pliocene.

Tygh Valley Formation (Tdt)

Basalt lava and indurated deposits overlying the Columbia River Basalt Group in the Tygh Valley-Juniper Flat area are here informally named the Tygh Valley formation, after exposures near the town of Tygh Valley. Hodge (1941) mapped these rocks as Dalles formation. He also mapped a fault sliver of the Tygh Valley formation of this report as John Day Formation along the northern side of Tygh Valley. Wells and Peck (1961) mapped the sliver as Mascall Formation; Waters (1968b) mapped it as Ellensburg Formation. Waters (1968b) also mapped the Dalles Formation in the Tygh Valley area but separately mapped overlying olivine basalt and andesite flows.

The Tygh Valley formation occupies the Tygh basin, which is bordered on the north by Tygh Ridge, on the south by the Mutton Mountains, on the west by the Cascade Range, and on the east by basalt highlands east of the Deschutes River.

The formation is composed of volcanic, volcaniclastic, and epiclastic rocks. Basalt flows are dominant in the western end of the basin, whereas sedimentary rocks are more common in the eastern end of the basin near Tygh Valley. The basalts generally form plateaus that are disconformable over the sedimentary rocks. Locally, however, the basalts are intracanyon flows where they occur in small valleys or channels cut in the sedimentary rocks. We include the "Juniper Flat" basalt, mapped by Waters (1968b) as olivine basalt in the Juniper Flat area (T. 4 S., Rs. 11, 12 and 13 E., T. 5 S., Rs. 11, 12 and 13 E.), in the Tygh Valley formation.

The sedimentary rocks consist of weakly cemented basaltic, andesitic, and pumiceous sandstone and conglomerate; tuffaceous siltstone and sandstone; tuff; pumice lapilli tuff; tuff breccia; and agglomerate. The tuff breccia and agglomerate, which are similar to those in the Chenoweth formation, are also interpreted as lahar deposits. Beds are lenticular and 1 and 20 m thick. Because rapid horizontal and vertical lithofacies changes are common, no single section is entirely representative of the formation.

One section near Tygh Valley is reasonably representative of the heterogeneity of the formation (Figure 10). Here it consists of interbedded siltstone, sandstone, conglomerate, tuff, and a basalt flow. The basalt, the "Juniper Flat" basalt, is discontinuous at this section and is interbedded(?) with gravel, suggesting it is here an intracanyon flow.

Westward up Badger Creek and northwestward up Tygh and Jordan Creeks, the "Juniper Flat" basalt is overlain by andesite-rich lahars that pass upward into andesite lavas. These andesite lavas are mapped separately from the Tygh Valley formation, but the contact between them and the formation is difficult to locate precisely. The contact may be gradational: westward thickening of the lavas and concomitant thinning of sediment suggests interbedding of lavas with sediment. This relation would be similar to that suggested for the Chenoweth formation. Trimble (1963) and Taylor (1980) reported similar relations for the Rhododendron and Deschutes Formations, respectively.

The exact contact of the Tygh Valley formation with the Chenoweth formation is difficult to locate precisely. The Tygh Valley formation is generally distinguished from the Chenoweth formation by location and paucity of lahars. Also, south of the former hamlet of Friend, on the western end of Tygh Ridge, andesite-rich lahars typical of the Chenoweth formation overlie basalt inferred to be the "Juniper Flat" basalt. This suggests that part of the Chenoweth formation or its equivalent may overlie the Tygh Valley formation. The present location of the contact between the two formations, however, is only approximate.

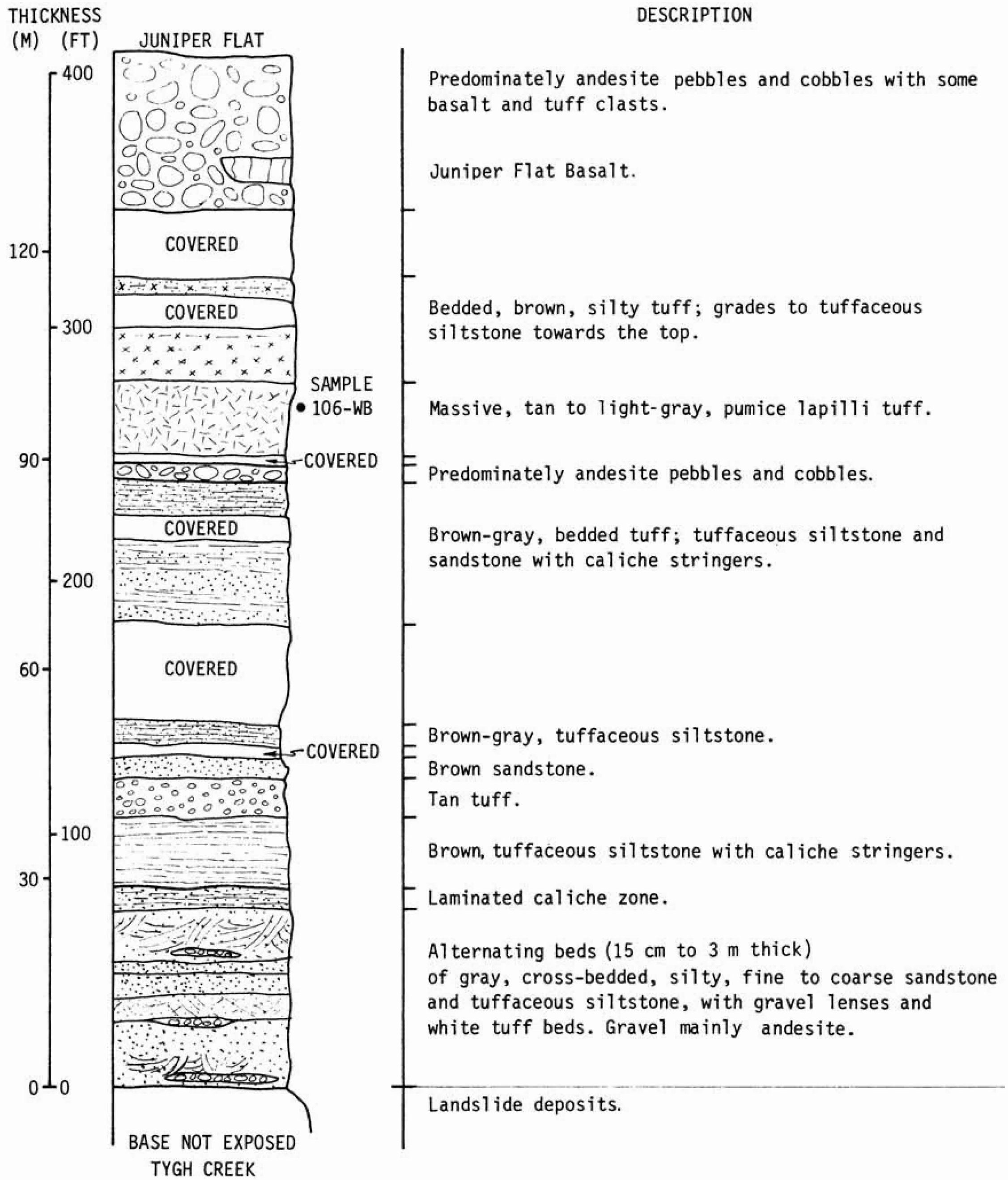


Figure 10. Representative columnar section of the Tygh Valley formation. Location: North-facing roadcut along Tygh Valley-Wamic road, sec. 4, T. 4 S., R 13 E.

The Tygh Valley formation lies disconformably on the Frenchman Springs Member (Wanapum Basalt) along the northern edge of the basin and on the Grande Ronde Basalt along the southern edge of the basin (Swanson and others, 1981). Only local deposits of alluvium and gravel overlie the formation in the basin, and andesite flows overlie it along the margin of the Cascade Range.

The formation is folded and faulted. At Graveyard Butte on the north side of the White River, a normal fault juxtaposes a basalt flow and volcaniclastic sediments on the east against basalt flows on the west side of the fault. The fault is oriented N. 25° E. 60° SE; striations on the fault plane are vertical. Elsewhere, the lower part of the formation is steeply folded with the underlying basalt along the southern flank of Tygh Ridge. The dips are approximately 40° to 50°, but they flatten out to the south within 2 to 3 km. These steep dips occur south of a reverse fault along the base of Tygh Ridge. An intraformational unconformity in the Tygh Valley formation occurs near Tygh Ridge in the SE¼SE¼SE¼ sec. 26, T. 3 S., R. 12 E. (J. Anderson, 1980, oral communication). This unconformity is not traceable away from Tygh Ridge, and it may be a local consequence of faulting at Tygh Ridge. Alternatively, it may be widespread, with the sparse exposures precluding its recognition elsewhere. Development of the unconformity predates the overlying "Juniper Flat" basalt, as well as the sedimentary rock immediately below it, because they are not folded.

The Tygh Valley formation overlies the approximately 14-m.y.-old Frenchman Springs Member (Swanson and others, 1981). The "Juniper Flat" basalt is 7.5±0.8 m.y. (Appendix 2, sample 101-WB). Thus, the Tygh Valley formation is of middle to late Miocene age. A pumice lapilli tuff stratigraphically below the "Juniper Flat" basalt, however, is dated at 4.9±0.5 m.y. (Figure 10; Appendix 2, sample 106-WB).

McKay Formation (Tdm)

Indurated, partially cemented basalt gravel and interbedded tuffaceous sand and silt overlie the Columbia River Basalt Group in the Pendleton-Pilot Rock area. These deposits are herein informally named the McKay formation after exposures near McKay Reservoir (T. 1 N., R. 32 E.). The deposits were earlier named McKay beds (Shotwell, 1956), fanglomerate (Hogenson, 1964), Dalles Formation (Shannon and Wilson, 1972; Gonthier and Harris, 1977; Farooqui, 1980), and Tertiary sedimentary rocks (Walker, 1973).

A representative section of the formation is west of McKay Reservoir (Figure 11). Dense, aphyric basalt cobbles comprise most of the gravel, but less common cobbles and small boulders of red vesicular basalt also occur. The gravel contains an estimated 10 percent sand-silt matrix, ranging from very coarse sand to silt. The matrix is commonly carbonate cemented, with the very coarse to fine sand fraction composed of subrounded to angular basalt grains and the finer matrix of carbonate "nodules" and quartzose fine sand to silt.

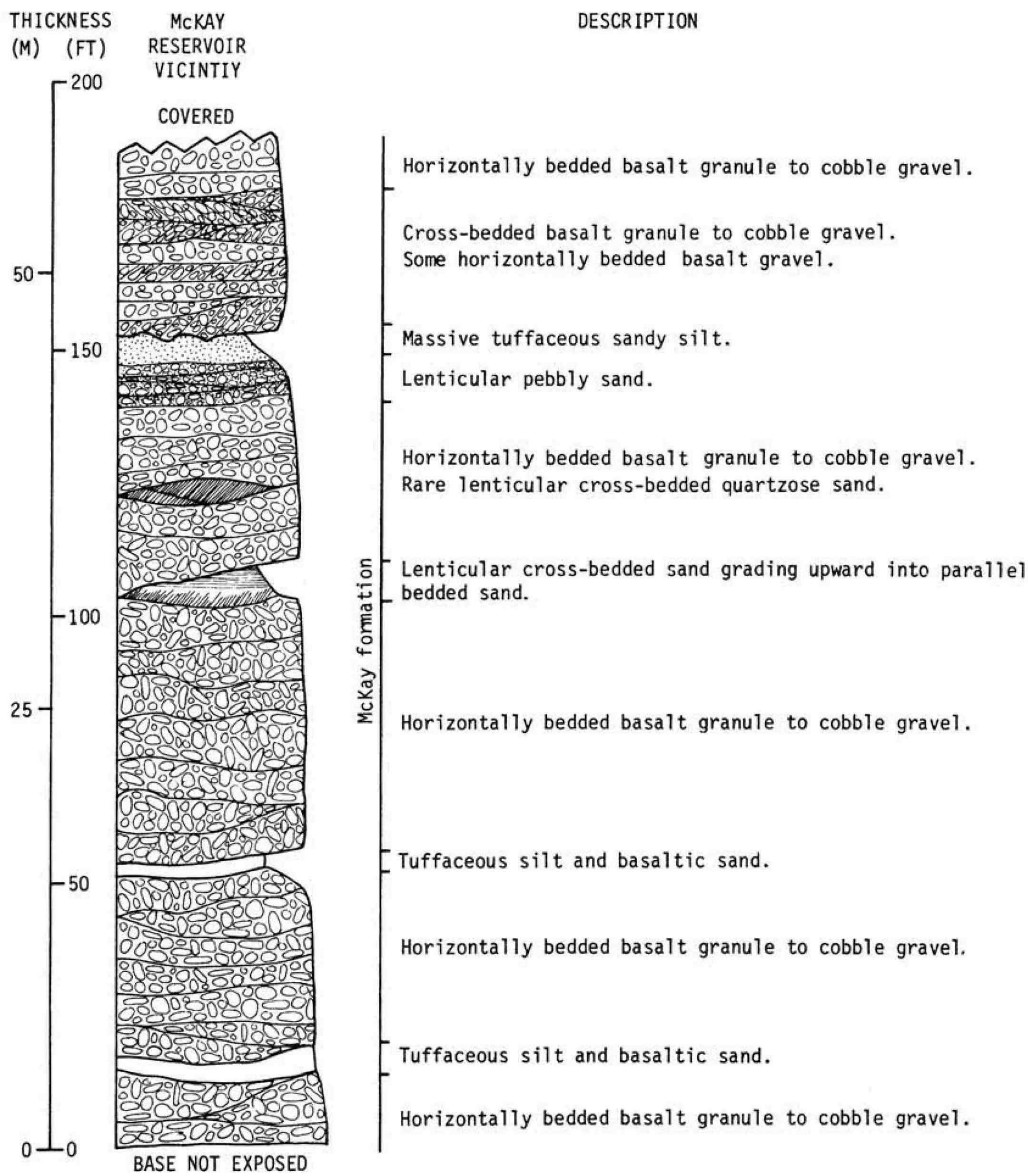


Figure 11. Representative columnar section of the McKay formation. Location: E½ sec. 33, T. 2 N., R. 32 E.

Rare sand-silt lenses fill depressions atop gravel beds in the lower half of the section. The lenses have laminations showing low-angle truncations. The silt is quartzose; the sand is mostly basalt. Gravel beds overlie these sand-silt lenses along irregularly scoured contacts.

From approximately 40 to 43 m, this representative section consists of lenticular, 0.5-m-thick sand beds. The sand beds are weakly carbonate cemented and iron stained. They interfinger with 5- to 10-cm-thick lenticular pebble layers. The sand beds are overlain by approximately 2 m of tuff. The upper surface of the tuff is channeled and is overlain by cobble gravel. The gravel contains several boulders of calichified silt.

Another representative section is near Mission (Figure 12), where the McKay formation consists of 0.5- to 1-m-thick lenticular cosets of cross-stratified sandy basalt granule to cobble gravel. A minor sand matrix coats the gravel; however, most gravel is openwork. The cross-bedding dips westward.

Elsewhere, where observed in road cuts, the McKay formation consists of sandy basalt pebble to cobble gravel. The gravel is commonly massive to poorly bedded but also occurs in lenses that interfinger with tuffaceous sand and silt.

The McKay formation was earlier mapped by Hogenson (1964) as fanglomerate; however, it may, in part, be a valley-fill deposit. The thickest observed sections are in, or near, the Birch-McKay Creek and Umatilla River valleys. Away from these valleys, the McKay formation thins rapidly, suggesting it was deposited within the ancestral valleys of these steams.

Thickness of the McKay formation varies. The McKay Reservoir section, whose base is not exposed, is 55 m thick. The Mission section is estimated to be 15 m thick. The formation disappears or thins to a thickness of 2 to 5 m within 5 km west of Birch Creek. Well logs (Gonthier and Harris, 1977) show the unit is 4 to 77 m thick between McKay Creek and the Blue Mountains.

The McKay formation is conformable atop the Frenchman Springs Member and Grande Ronde Basalt of the Columbia River Basalt Group (Swanson and others, 1981) within the broad, flat Agency syncline. An angular unconformity between it and the basalt can, however, be inferred where horizontal beds of the McKay formation are adjacent to the flanks of the bordering Blue Mountain uplift and the Reith and Horse Heaven anticlines. The upper contact of the McKay formation is with Quaternary loess; however, this contact is commonly difficult to locate precisely because gravel-free tuffaceous silt in the upper McKay is similar to, and underlies, the loess. Because 0.5 to 1 m of loess commonly overlies basalt outcrops near the McKay formation, this loess thickness was used locally to approximately locate the contact between loess and silt of the underlying McKay formation.

No folds or faults were observed in the McKay formation. However, two poorly understood fractures of possible tectonic origin are near the

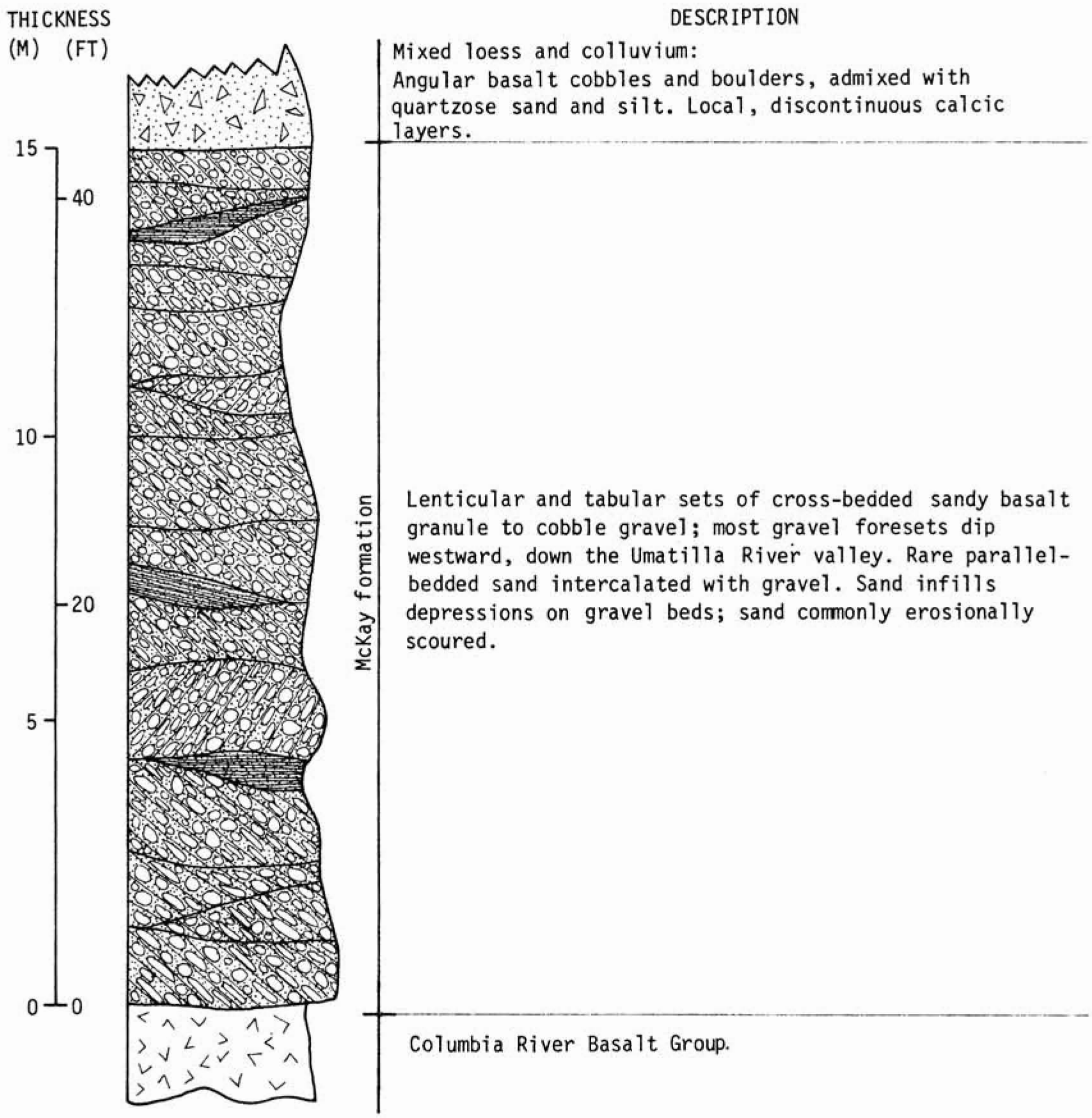


Figure 12. Representative columnar section of the McKay formation. Location: North-facing roadcut, NW¼ NE¼ NE¼ sec. 12, T. 2 N., R. 32 E.

top of the McKay Reservoir section. The fractures are parallel, about 1.2 m apart, 15 to 25 cm wide each, and dip northward. The orientation of the northern fracture is N. 41° W. 60° N., that of the southern fracture is N. 60° W. 60° N. They do not extend into the overlying loess. The fractures are marked by carbonate-coated gravel. This contrasts with relatively noncarbonate-coated gravel outside the fractures.

The McKay formation is of late Miocene to early Pliocene age. Shotwell (1956) described its fauna as Hemphillian. By Berggren and van Couvering's (1974) chronology, the Hemphillian was approximately from 10 to 4.5 m.y., or late Miocene to early Pliocene. The formation is not older than middle Miocene, however, because it overlies the approximately 14-m.y.-old Frenchman Springs Member (Wanapum Basalt).

Mascall Formation (Tm)

The Mascall Formation consists of tan and white tuff, cross-bedded sandstone, conglomerate, and minor lignitic coal (Merriam, 1901; Merriam and others, 1925).

Within the project area, the Mascall Formation (of Merriam, 1901) occurs in the John Day basin (Brown and Thayer, 1966a). Outside the project area, it occurs in the Beech Creek, Fox, Paulina, and Harney basins (Brown and Thayer, 1966a; Enlows, 1973; Davenport, 1971).

Merriam (1901) interpreted the Mascall Formation largely as of lacustrine origin because it is fine-grained and contains fish fossils. Mammal and plant fossils, together with the sandstone and conglomerate, also suggest a fluvial environment for part of the formation.

The Mascall Formation is 637 m thick at the type section (Merriam and others, 1925). Within the type area, it is at least 240 to 305 m thick (Merriam, 1901). Thayer and Hay (1950) estimated it as 510 m thick.

The Mascall Formation is conformable on the Picture Gorge Basalt(?) of the Columbia River Basalt Group. Local angular unconformities exist only where the formation overlies irregular relief atop the basalt (Merriam and others, 1925). The Mascall Formation is locally intercalated with the Columbia River Basalt Group (Merriam, 1901; Thayer and Hay, 1950; Thayer and Brown, 1966b). The Rattlesnake Formation lies with angular unconformity on the Mascall Formation.

The Mascall Formation is folded and faulted (Brown and Thayer, 1966a,b; Thayer and Brown, 1966c). The formation occurs chiefly in downfaulted blocks north of the John Day fault.

Chaney (1925, 1948, 1951, 1959) described the Mascall flora as of middle or upper Miocene age. Downs (1956) dated the fauna as Hemingfordian and Barstovian. Berggren and van Couvering's (1974) chronology puts Hemingfordian time at about 21 to 17 m.y. (early Miocene) and

Barstovian time at about 17 to 11.5 m.y. (early to middle Miocene). The Mascall Formation is thus of early to middle Miocene age.

Rattlesnake Formation (QTsr)

Merriam (1901) defined the Rattlesnake Formation as sandstone, conglomerate, and an interbedded ignimbrite that unconformably overlie the Mascall Formation in the John Day River valley. But Walker (1979b) redefined the Rattlesnake Formation and restricted the name Rattlesnake to the ignimbrite, which he termed the Rattlesnake Ash-flow Tuff, thus leaving a problem of unresolved nomenclature for the sedimentary deposits above and below the ignimbrite. We do not resolve this problem but instead follow Merriam's (1901) and Enlow's (1976) usage of the name "Rattlesnake" for ease of discussion.

Within the project area, the formation occurs in the John Day valley, extending eastward from Picture Gorge to Prairie City. It crops out near Dutchman Flat and in Murderers Creek basin, 20 km south-southeast of Dayville.

Enlows (1976) divided the Rattlesnake Formation into three members: a lower "fanglomerate" member; a middle member, his "Rattlesnake Ignimbrite Tongue"; and an upper "fanglomerate" member. The "fanglomerate" members consist of lenticular beds of coarse, poorly sorted conglomerate, sandstone, mudstone, and tuff. The ignimbrite (Rattlesnake Ash-flow Tuff of Walker, 1979b) is disconformable on the lower member and is separated by an erosional disconformity from the upper member.

Rock types in the conglomerate reflect local provenance, such as metavolcanic and metasedimentary rocks, chert, phaneritic igneous rocks, and andesite (Enlows, 1976). Conglomerate in the upper member contains clasts of the underlying ignimbrite, but other rock types are more common. Both Merriam and others (1925) and Enlows (1976) described abrupt changes in lithofacies in the upper and lower members. Merriam and others (1925) described interlensing conglomerate, sandstone, and tuff. Cross-bedded sandstone lenses are common. Thickness of the formation varies, ranging from 78 to 274 m in thickness (Merriam and others, 1925; Enlows, 1976).

The Rattlesnake Formation unconformably overlies the Mascall Formation, the Columbia River Basalt Group, and locally, Paleozoic rocks adjacent to the John Day valley (Merriam, 1901; Enlows, 1976). Terrace sediment along the John Day River and its tributaries locally overlies the formation. Brown and Thayer (1966a) reported "Quaternary basalt" overlying the Rattlesnake Formation at Dutchman Flat.

The Rattlesnake Formation is faulted along the John Day fault, a high-angle reverse fault with a strike-slip component (Thayer and Brown, 1966c), and faults conjugate to it. Because the ignimbrite is locally faulted, movement occurred after 6.5 m.y. The Rattlesnake Formation is also faulted near Dutchman Flat (Brown and Thayer, 1966a).

Merriam and others (1925) originally assigned the Rattlesnake Formation to the Pliocene. Wood and others (1941) and Shotwell (1956) assigned the formation specifically to the Hemphillian, now considered late Miocene to early Pliocene (Berggren and van Couvering, 1974). However, K/Ar dates of the ignimbrite range from 5.4 to 6.8 m.y. (Evernden and others, 1964; Dalrymple and others, 1967; Parker and Armstrong, 1972; Greene and others, 1972; Enlows, 1976; Walker, 1979b). The most recent judgment of a 6.5-m.y.-age by Walker (1979b) is probably most accurate. Thus, the Rattlesnake Formation as used here is of late Miocene to Pliocene. Thayer (1956a,b,c) suggested the uppermost part of the Rattlesnake Formation may extend into the Pleistocene.

Baker Deposits (Tb)

Tuffaceous clay, siltstone, sandstone, conglomerate, and ash-flow tuffs in the Baker Valley and adjacent valleys are here informally called the Baker deposits. Gilluly (1937) referred to them as lacustrine and fluvial deposits. The deposits are also mapped as Tertiary tuffaceous sedimentary rocks (Brooks and others, 1976; Brooks, 1977; Brooks and McIntyre, 1977a,b, 1978); Tertiary tuff, sandstone, conglomerate, and terrace gravel (Gardner and others, 1974); and Tertiary sedimentary rocks (Walker, 1979a).

The Baker deposits of this report occur only in Virtue Flat, the Baker Valley, the Bowen valley-Sutton Creek valley area, and the Lower Powder River valley near Keating. They are also mapped near Telocaset.

The Baker deposits consist largely of weakly cemented, tuffaceous clay, siltstone, sandstone, and conglomerate. Sandy pebble to small cobble conglomerate constitutes the bulk of the Baker deposits. The conglomerate is commonly massive and apparently unbedded, or less commonly, cross-bedded. Thin gravel lenses, less than 2 m thick, are locally interbedded with tuffaceous siltstone and sandstone. Rock types in the gravel reflect local provenance. The most common rock type is basalt, but adjacent to the southern end of the Elkhorn Mountains, clasts of metamorphic rock are common. Near Dooley Mountain, a Miocene volcanic center (Brooks and others, 1976), the gravel consists largely of rhyolite and obsidian.

The Baker deposits are locally interbedded with ash-flow tuffs that were separately mapped by Brooks and others (1976). We have followed this practice; however, the exact number and distribution of the tuffs are unknown. We consider them to be informal members of the Baker deposits.

The thickness of the Baker deposits is variable. Gardner and others (1974) estimated thicknesses of 60 m; Prostka (1962) reported thicknesses of 90 m just outside the project area.

The Baker deposits are unconformable or disconformable on older rocks. Brooks and others (1976) considered the deposits to be largely younger than basalts they correlated with the Columbia River Basalt Group. Relations observed in this study suggest the Baker deposits are locally unconformable atop the Columbia River Basalt Group. Pleistocene(?) to Holocene age stream deposits occur in valleys incised into the Baker deposits.

The Baker deposits are gently folded in a series of northwest-trending synclines that broadly define present-day valleys. However, most of the deformation that isolated the Baker deposits into the present-day valleys was by downfaulting (Gilluly, 1937; Brooks and others, 1976). Dip-slip displacements are difficult to determine because the faults commonly juxtapose similar rock types within the Baker deposits. Faults observed in this study typically have displacements of 1 to 2 m but range up to at least 15 m. Because the faults are so numerous, it seems likely that downfaulting in step-fault fashion occurred across many of the faults rather than being confined to a few "master" faults.

Vertebrate fossils in deposits outside the project area, which probably are correlative with the Baker deposits, are of Clarendonian, or middle to late Miocene age (Shotwell _in_ Prostka, 1962; _in_ Brooks and others, 1976; _in_ Brooks, 1979b; Berggren and van Couvering, 1974). Gardner and others (1974) report a 12.5±0.9-m.y. middle Miocene date for andesites overlying the Baker deposits west of Sawtooth Crater. This study dates these andesites as 13.1±0.8 m.y. (Appendix 2, sample 506). Ash-flow tuff units in the Baker deposits are dated at 12.0±0.5 and 14.1±0.6 m.y. (Appendix 2, samples 504 and 505). These dates place the Baker deposits in the middle Miocene, roughly agreeing with the paleontologic age.

Unity Deposits (Tu)

Tuffaceous sandstone and siltstone deposits in the Unity-Hereford area are here informally called the Unity deposits. Smith and Packard (1919) termed correlative rocks near Ironside the "Ironside Formation." The same deposits are listed in the 1938 Lexicon of Geologic Names of the United States as the "Ironside beds" (Wilmarth, 1938). Lowry (1943), working in the former 30-minute Ironside quadrangle which encompassed the deposits near both Ironside and Unity-Hereford, termed the deposits the "Ironside formation." Later, Lowry (1968) stated that because his "Ironside formation" was stratigraphically above the Columbia River basalt, it was equivalent to the Idaho Formation of Kirkham (1931) and the Idaho Group of Baldwin (1959) and Malde and Powers (1962). Brown and Thayer (1966a) and Brooks and Ferns (1979) mapped the Unity deposits as Tertiary fluvial and lacustrine deposits. In the Burnt River valley east of 188° W. longitude, Brooks and others (1976) mapped the deposits as tuffaceous sedimentary rock.

The Unity deposits occur mostly in the Unity basin (Brown and Thayer, 1966a). They extend eastward out of the basin down the Burnt River valley. They also are in the North Fork-Burnt River valley. These deposits are separated from the correlative Ironside deposits (discussed later) to the southeast in the headwaters of Willow Creek by a belt of the Strawberry Volcanics.

The Unity deposits consist mostly of stratified, tuffaceous fine siltstone and sandstone as well as minor diatomite, vitric tuff, and gypsiferous beds. The deposits are mostly lacustrine (Brown and Thayer, 1966a; Lowry, 1968; Brooks and others, 1979; Brooks and Ferns, 1979). Along the southern Unity basin, the Unity deposits also contain coarse gravel which Brown and Thayer (1966a) mapped as a separate Quaternary unit.

The maximum thickness of the Unity deposits is unknown. Lowry (1968) reported a 500-m-deep oil test well that did not reach "hard" bed rock, perhaps indicating the deposits are at least 500 m thick. However, this is uncertain because the tuffaceous rock in the lower half of the well may instead be Strawberry Volcanics. Examination of outcrop thicknesses, as determined from topographic maps, suggests the Unity deposits are at least 60 to 150 m thick.

The deposits are disconformable or slightly discordant on the older Tertiary rocks but lie with angular unconformity on pre-Tertiary rocks (Lowry, 1968).

The Unity deposits are faulted. A northwest-trending belt of Strawberry Volcanics and Clarno Formation (?) separates the Unity deposits in the North Fork valley from the main Unity basin. This belt locally forms the northern side of the basin. Several northwest-trending faults are along or south of this belt. They are all southside-down, thus forming a series of step-faults lowering the basin floor to the south. These faults and an east-west-trending fault in the southern part of the basin broadly define the basin. Another north-side-down fault along the front of Bullrun Mountain at the southern end of the basin may also define the basin.

Vertebrate fossils in the correlative Ironside deposits were dated as late Miocene to middle Pliocene (Merriam, 1916). Lowry (1968) reported Clarendonian vertebrates in the Unity deposits. The Clarendonian is of middle to late Miocene age (Berggren and van Couvering, 1974).

Ironside Deposits (Ti)

Tuffaceous siltstone, fine sandstone, and gravel in upper Willow Creek west of 118° W. longitude are here informally called the Ironside deposits. The name is derived from the nearby town of Ironside, where the deposits also occur.

The nomenclatural history of the Ironside deposits is identical to that of the earlier discussed Unity deposits. Both deposits, although treated as a single unit by earlier workers, are here discussed as separate, but correlative, informal units using local names. This separation is to draw attention to the separate basins in which these deposits occur.

Like the Unity deposits, the Ironside deposits are mostly stratified, tuffaceous siltstone and fine sandstone interpreted as lacustrine in origin (Brown and Thayer, 1966a; Lowry, 1968; Brooks and others, 1976). Lowry (1968) reported local diatomite, vitric tuff, and gypsiferous beds. Lowry also described interbedded pebble and cobble gravel (secs. 20 and 29, T. 14 S., R. 38 E.), noting that vertebrate fossils are commonly found in pebble gravel near Ironside.

Thickness of the Ironside deposits within the project area is unknown. Outcrop thicknesses, as determined from topographic maps, suggest the Ironside deposits are at least 60 to 150 m thick.

The Ironside deposits are conformable on the underlying Tertiary bed rock (Brown and Thayer, 1966a) and are unconformable on pre-Tertiary rocks (Brown and Thayer, 1966a; Lowry, 1968). No mapped Quaternary deposits, except alluvium along Willow Creek, occur atop the Ironside deposits within the study area.

The Ironside deposits are folded and faulted within the study area (Brown and Thayer, 1966a). We tentatively map a new fault that offsets the Ironside deposits. This fault(?) begins in sec. 11, T. 15 S., R. 38 E. and arcs northwestward to the NW¼ sec. 19, T. 14 S., R. 38 E., where it may connect with a fault previously mapped by Brown and Thayer (1966a). This previously unmapped fault is inferred on the basis of (1) aligned springs, (2) aligned 30- to 60-m-high northeast-facing escarpments, and (3) aligned notches in ridges.

The age of the Ironside deposits is at least late Miocene, based on the same reasons used for the Unity deposits.

LeRoux Deposits (QTl)

Thick clay, silt, sand, and gravel deposits underlying the La Grande basin are here informally termed the LeRoux deposits after the LeRoux property, where a deep well penetrates them. This well (3/39-5J1, Hampton and Brown, 1964) offers the best data on the deposits, which Hampton and Brown (1964) and Gardner and others (1974) termed Quaternary lacustrine deposits. Walker (1979a) termed them Quaternary sedimentary deposits and Barrash and others (1980) termed them Quaternary alluvium. The deposits are poorly exposed, and most of the data describing them are derived from well logs.

The LeRoux deposits are mainly clay, silt, and fine sand, but gravel is common in the upper 160 m of well 3/39-15J1. The interbedded gravel represents buried stream channels, as well as interfingering fan deposits and colluvium derived from nearby slopes (Hampton and Brown, 1964). The clay changes color from yellow-brown to green or blue at 11- to 186-m depths. Water-well logs reveal the top of the blue clay to be at 760- to 823-m elevation (Hampton and Brown, 1964).

Thickness of the LeRoux deposits varies from a trace at the edge of the valley to at least 617 m in its center, the depth of well 3/39-5J1.

In well 1/38-24R1, the LeRoux deposits extend to a depth of 203 m where they overlie the Columbia River Basalt Group (Hampton and Brown, 1964).

Walker (1979a) showed these deposits offset along faults extending eastward into the Grande Ronde Valley from the adjacent basalt highlands. Walker (1973) also showed faults extending eastward into the valley north-northwest of La Grande, where they offset fan deposits. It is unknown if these faults also extend into the LeRoux deposits that are just east of the fan deposits.

Age of the LeRoux deposits is uncertain. Earlier reports consider them to be Quaternary, presumably because of their poorly consolidated, uncemented character where exposed at the surface and their stratigraphic position above the Miocene Columbia River Basalt Group. However, their great thickness suggests they may extend into the Tertiary. Therefore, we tentatively consider them to span Quaternary and late Tertiary time.

QUATERNARY DEPOSITS

A variety of chiefly nonindurated deposits of known and inferred Quaternary age occur in the project area. Where a Quaternary age of a deposit is inferred, it is based on some or all of the following criteria: (1) a relatively noneroded character; (2) a generally noncemented and nonconsolidated state; and (3) an unconformable position over Miocene-Pliocene, or older, bed rock. Some of the deposits contain white, coarse volcanic ash that may be the Mazama ash, the approximate 7,000-years-B.P.-age (Kittleman, 1973) of which provides a maximum age for the deposits. Identity of the ash is unknown, however, and it could actually be several ash deposits of different sources and ages.

The Quaternary deposits are described as informal rock-stratigraphic units; however, they were commonly mapped as morphostratigraphic units because of their ease of recognition; for example, fan deposits are readily apparent as fans on both topographic maps and aerial photographs. Thus, the descriptions in this report reflect this dual nomenclature, and the deposits are discussed in terms of both their lithologic and geomorphic character.

Figure 3 shows the correlation and Plates I through VI show the distribution of the Quaternary deposits within the project area.

Alluvium (Qal)

Alluvium occurs throughout the project area in stream channels and flood plains. Terrace sediment is locally included with alluvium where it was not areally extensive enough to map separately. Alluvium is composed of silt, sand, and gravel of local bed rock types. Basal alluvium commonly consists of angular to rounded granules to cobbles; these grade upward to massive to horizontally bedded gravelly sand and then sand and silt.

Alluvium in streams draining areas of extensive loess-covered basalt bed rock may contain little or no gravel and largely consist of loess-derived quartzose fine sand to silt. This type of alluvium is common near Pendleton, Condon, and Wasco.

Terrace Sediment (Qts)

Terrace sediment, which is common throughout the project area, is variously composed of silt, sand, and gravel. The sediment is either mostly gravel or mostly sand and silt but is rarely areally extensive enough to map at a scale of 1:250,000. One of the most extensive terrace systems is along the Umatilla River upstream from Pendleton, where several terrace levels occur between Pendleton and Mission. The lowest terrace, which is 1 to 2 m above the Umatilla River, is the modern flood plain. The middle terrace is about 10 m above the Umatilla River near Mission. The high terrace near Mission is 25 to 60 m above the Umatilla River. This range of elevations for the high terrace is obtained from two possibly correlative terraces north and south of the Umatilla River and may indicate two, rather than one, high terraces.

The age of the Umatilla River terrace sediment is uncertain, but a Quaternary age can be inferred because the terraces occur in a valley cut into the late Miocene-early Pliocene McKay formation. The middle and high terrace levels near Mission are underlain by carbonate cemented gravel. This carbonate cement, based on Th^{230}/U^{234} dates, indicates that (1) the high terrace has a probable age of > 199,000 years and a maximum age of 199,000±14,000 years (Appendix 2; sample 202-EB), and (2) that the middle terrace has a probable age of 47,000±13,000 years, and a maximum age of 63,000±4,000 years (Appendix 2; sample 201-EB).

The Walla Walla River valley contains two terrace levels in the Bowlus Hill quadrangle. The low terrace, which is paired, occurs as an extensive valley flat 1 to 3 m above the river. The high terrace, about 18 m above the river, is discontinuous and nonpaired.

Other terraces include those along Rock and China Creeks near Arlington and along Shitike Creek and the Deschutes River in the Warm Springs Indian Reservation. Several terrace levels occur along Shitike Creek and the Deschutes River; these terraces have been affected by landsliding. The Rock Creek terraces are underlain by alluvium; however, the China Creek terraces are underlain by Touchet Beds (discussed later). Terraces also occur along the John Day River (Brown and Thayer, 1966a,b; Thayer and Brown, 1966c). Ages of these terraces are uncertain; only a general Quaternary age can be inferred on the basis of geomorphic positions of the terraces and their commonly weakly cemented sediment. However, terrace sediment may locally postdate 7,000 years B.P. because it contains lentils of white volcanic Mazama(?) ash.

Terracelike deposits of cemented sand and gravel occur near Enterprise and along Trout Creek, north of Enterprise. Although Walker (1979a) mapped these deposits as Tertiary sedimentary rocks, they are included in this report with terrace sediment because of their restricted occurrence only along Trout Creek.

Fine-grained terrace sediment containing the Mazama(?) ash is common throughout the project area, suggesting that the upper parts of the terraces may be correlative across the area. Recent work shows, however, that terraces in semi-arid drainage basins are unlikely to be correlative from basin to basin (Patton and Schumm, 1975, 1981).

Sedimentary Deposits (Qs)

This unit includes undifferentiated deposits of fluvial silt, sand and gravel, eolian silt, slopewash, and residual soil that thinly veneer (0.5 to 2 m thick) plateaulike surfaces atop the Deschutes Formation in the Madras area. This unit also includes undifferentiated alluvium, glacial drift, and fan deposits in the Enterprise valley.

Alluvial Fan Deposits (Qf)

Alluvial fans are common in the project area, ranging in area from small fans (0.25 km^2) at the mouths of low-order streams in side canyons to large fans (10 to 40 km^2) as at Milton-Freewater, in the Grande Ronde Valley, and along the western side of the Baker Valley.

The fans are mapped largely on the basis of their morphology as shown on topographic maps and air photos and as identified by aerial reconnaissance. Fans were not mapped unless their apices were visible. This criterion eliminated various "high-level" deposits mapped by others as fans even though they lacked fan morphology. The fan deposits consist mostly of poorly sorted angular to subangular gravel reflecting the bed rock of the source area; basalt is the most common rock type.

Many of the smaller fans are evidently of Holocene age because they commonly contain the Mazama(?) ash. The ash is reworked into 1- to 4-m-thick lenses that are interbedded with sand and gravel.

Several of the fans are notably large. An extensive fan in the Walla Walla Valley extends downvalley from the mouth of the Walla Walla River canyon at Milton-Freewater. The age of this fan deposit is uncertain. It predates the late Pleistocene Touchet Beds that largely overlie it. Its surface is locally capped by 1- to 2(?)-m-thick petrocalcic K horizons. One horizon was Th^{230}/U^{234}-dated at >350,000 years (Appendix 2; sample 101-EB), or middle-late Pleistocene as a minimum.

The Baker Valley contains several large fans along its western edge adjacent to the Elkhorn Mountains. Earlier workers mapped these fans as a single compound fan, alluvium, or terrace gravel (Gilluly, 1937; Trauger, 1950; Lystrom and others, 1967; Brooks and others, 1976). However, separate fans can be discriminated (Figure 13).

Lindgren (1901) and Trauger (1950) described the Baker Valley fan deposits, but their ages of the fans are uncertain. The undissected morphology of the fans suggests a late Pleistocene age. Glacial moraines along Rock Creek descend into the Baker Valley and merge with the Rock Creek fan, suggesting that the Rock Creek fan is partly composed of Pleistocene glacial outwash. The Pine Creek fan may be of Quaternary age because a white volcanic ash, possibly Mazama, locally overlies it (Grant and Cady, 1914).

Five large alluvial fans occur in the Grande Ronde Valley at the canyon mouths of the Grande Ronde River: Ladd Creek; Catherine, Little and Pyle Creeks; Mill and Warm Creeks; and Willow Creek. The fan along Willow Creek is a composite fan. Water-well logs show that these fans consist of interbedded sand and basalt gravel (Hampton and Brown, 1964). Ages of these fans are uncertain.

The Catherine-Little-Pyle Creeks fan may be faulted along its northeastern margin. Three km north of Union, the margin of the fan, is a linear, 1- to 3-m-high northeast-facing escarpment (in sec. 36, T. 3 S., R. 39 E.; sec. 31, T. 3 S., R. 40 E.; and secs. 6, 7, 8, T. 4 S., R. 40 E.) that is along the projected trend of a bedrock fault (sec. 17, T. 4 S., R. 40 E.) mapped by Walker (1979a). A terrace origin for this escarpment seems unlikely because terraces several meters high on fans in the Grande Ronde Valley are rare to nonexistent.

Landslide Deposits (Qls)

Landslides are common throughout the project area. They consist of unsorted debris derived from basaltic, andesitic, sedimentary, and tuffaceous bed rock. The unit includes rock topples; rock, debris and earth slumps; and debris and earth flows (terminology of Varnes, 1978). The largest slides are rock slumps and earth flows that occur at interbed horizons in the Columbia River Basalt Group and in tuff of the John Day and Mascall Formations. Such landslides are common along the Columbia, Deschutes, and John Day Rivers and in the La Grande-Elgin area (Schlicker and Deacon, 1971; Shannon and Wilson, 1972, 1975a,b; Walker, 1977, 1979b; Barrash and others, 1980).

Exact ages of the landslides are uncertain, but the degree of their erosional dissection suggests they are mostly Pleistocene. However, some landslides are still active.

Colluvium (Qc)

This unit includes colluvium, slope wash, and talus derived mostly from the Columbia River Basalt Group. Slopes of valleys incised into the Columbia River Basalt Group are commonly covered by angular, poorly sorted, pebble- to boulder-size basalt blocks derived from upslope outcrops. Talus piles and cones are also present on valley slopes. Mixing of light-colored, tuffaceous, interbed-derived sediment with basalt debris is common where interbeds are present in the basalt sequence.

White Mazama(?) volcanic ash is locally mixed with colluvium. Partial caliche-cementation of colluvium is common. Also, loess is mixed with colluvium below 975-m elevation near the Columbia River valley.

The mapping of colluvium in reconnaissance field and office studies is by nature subjective and often a relative process, but it is indicative

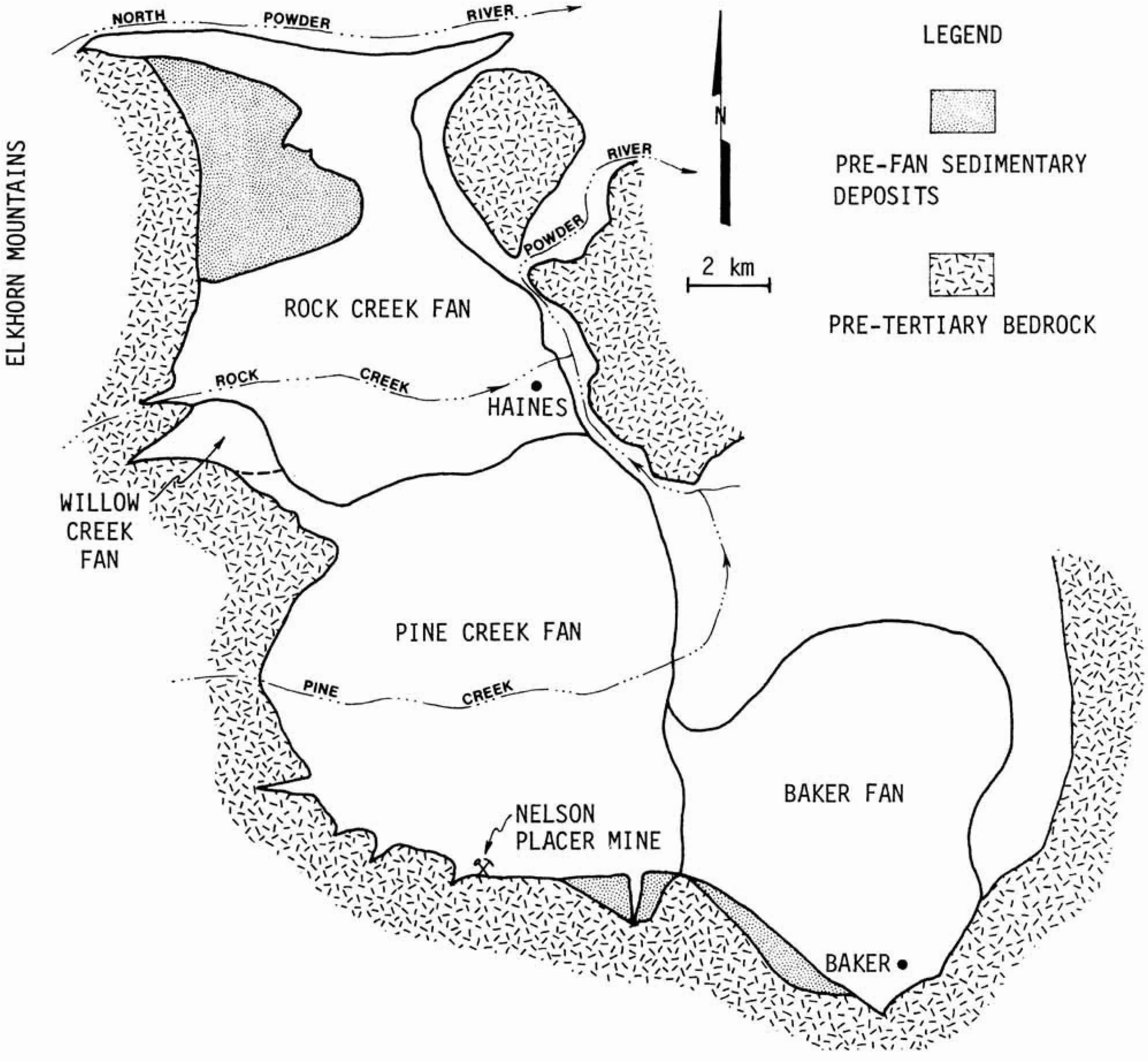


Figure 13. Generalized map of the major fans in the Baker Valley. The Pine Creek fan consists of several smaller fans, of which only the Willow Creek fan is shown. Pre-fan sedimentary deposits may be erosional remnants of older fans.

of active geomorphic processes of downslope movement. Relative distinctions are most appropriate on the Columbia Plateau; mapping becomes more arbitrary or impossible as mountainous terrain surrounding the Plateau is encountered.

Eolian Deposits (Qe)

This unit includes undifferentiated loess, sand sheets, and sand dunes where these types of eolian deposits are too restricted in area to map separately. In the project area, the unit is restricted to the Boardman-Umatilla area, where fine-grained catastrophic flood deposits are windworked into sand sheets and longitudinal dunes.

The longitudinal dunes trend southwest-northeast, parallel to prevailing southwest winds. Blowouts between the longitudinal dunes have gravel pavements in places. The eolian deposits are inferred to be of mostly Holocene age because they consist chiefly of reworked late Pleistocene flood deposits.

Sand Dunes (Qd)

Small, active dune fields occur near The Dalles and Boardman, where sandy, catastrophic flood deposits are windworked into barchan and sigmoidal dunes. Quartzose fine sand to silt comprise the dunes. Dune crests are generally transverse to prevailing southwest winds. Because the dunes are derived from late Pleistocene catastrophic flood deposits, the dunes are most likely of Holocene age.

Loess (Ql)

Massive, quartzose silt to fine sand comprise loess that mantles upland surfaces and hillslopes in the Deschutes-Umatilla Plateau, the Horse Heaven Hills, and the low western slopes of the Blue Mountains near Pendleton. The loess is commonly 5 to 10 m thick near the Columbia River but thins to less than 1 m in upland areas away from the river. It is not present above an elevation of approximately 900 to 1,070 m.

Two general loess units occur in the project area. They can be distinguished by their color, weathering characteristics, and stratigraphic positions. The youngest loess is tan colored, nonconsolidated, and noncohesive, with only weakly developed soil profiles. Carbonate commonly occurs in veins or nodules, but only rarely as platy carbonate in structural Cca horizons. The tan loess is typically 1 to 2 m thick and locally contains white volcanic ash (Mazama?).

The tan loess locally overlies an older red-brown loess. The older loess is cohesive and slightly plastic to plastic when wet. It is commonly marked by well-developed soil profiles having multiple strong Cca, petrocalcic K horizons, or both. Two to three calcic horizons are common in single exposures. Thickness of the older loess is uncertain; it ranges from 1 to 7 m thick in partial exposures that do not extend completely to the underlying basalt bed rock.

The older loess was not deposited as a single unit but instead represents several episodes of loess deposition. Roadcut exposures show that episodes of older loess deposition were separated by soil-forming intervals. Loess deposition may have been controlled by pre-existing topography. In the Horse Heaven Hills area near Pendleton, the thickest loess deposits commonly occur on east-facing hills or valley walls sheltered from present-day prevailing southwest winds.

The unweathered nature of the young loess suggests it is late Pleistocene to Holocene, an age supported by the presence of the Mazama(?) ash. Also, because the color, grain size, and mineralogy of sand in the young loess and the Touchet Beds are identical, the young loess was probably derived, locally at least, from the late Pleistocene Touchet Beds (Newcomb, 1965) and hence postdates them.

Age of the older loess is uncertain. The calcic and petrocalcic horizons in the older loess resemble those of the Palouse and pre-Palouse loesses of eastern Washington. The Palouse loess is correlated with the pre-Wisconsin (Pierce and others, 1976) Bull Lake Glaciation of the northern Rocky Mountains (Richmond and others, 1965). Thus, the older loess in the project area may be of pre-Wisconsin age.

Glacial Moraines (Qgm)

Glacial moraines are mapped in the Elkhorn, Strawberry, and Wallowa Moutains only where the moraines are obvious as landforms. Most moraines were mapped from air photos or from their contour pattern on topographic maps. Lateral moraines flanking Anthony, Rock, and Antone Creeks and the North Powder River in the eastern Elkhorn Mountains were field checked. These moraines consist of loose, unweathered, bouldery gravel and sand. Some of the same and fine gravel is grus, derived from the local diorite bed rock. Large, angular, partially buried diorite blocks occur along the crests and sides of the moraines.

Precise age of the moraines is uncertain. Moraines of several ages are recognized immediately east of the eastern boundary of the project area. Stovall (1929) and Lowell (1939) interpreted moraines at and near Wallowa Lake as deposited by two glacial episodes. Crandell (1967) interpreted the Wallowa Lake moraines as recording two Wisconsin (10,000 to 80,000 years B.P.) and two pre-Wisconsin (> 130,000 years B.P.) glacial episodes. Burke (1980) reinterpreted the Wallowa Lake moraines as recording three glacial episodes. Kiver (1974) recognized three Holocene glacial episodes in the Wallowa Mountains, with ages greater than 6,000 years B.P., between 3,000 to 1,800 years B.P., and less than 400 years B.P.

The glacial histories of the Elkhorn and Strawberry Mountains are even less certain. The fresh appearance and unweathered character of the moraines checked in the field suggests they are late Wisconsin in age. These moraines are mostly in single sets. Two moraines are present along the North Powder River near Bulgar Flat (secs. 19, 20, 29, 30, 31, T. 7 S., R. 38 E.) and may record two glaciations.

Glacial Drift (Qgd)

This unit includes undifferentiated glacial drift and glaciofluvial deposits, exclusive of moraines, in the Elkhorn, Strawberry, and Wallowa Mountains. Only those deposits previously mapped by other workers or large enough to be visible on air photos are mapped here. Glaciated topography in the Wallowa Mountains suggests that unmapped glacial drift exists locally.

Glacial drift includes much material that earlier workers mapped as glacial moraine (Brown and Thayer, 1966a; Walker, 1973, 1979a). Limited field-checking revealed, however, that many of these "moraines" actually consist of till, outwash, and periglacial fan deposits. Ages of specific portions of the drift are unknown, but most of it is presumed to be of late Pleistocene age.

Catastrophic Flood Deposits

Sediment deposited by late Pleistocene catastrophic floods is present along the Columbia River valley from Wallula Gap to the western border of the project area near The Dalles. These floods were released from glacial Lake Missoula in northwestern Montana. The floods swept through eastern Washington, exiting into Oregon at Wallula Gap (Bretz, 1959, 1969). The number and timing of the floods is uncertain, but several pre-Wisconsin (> 130,000 years B.P.) and late Wisconsin (>12,000, <20,000 years B.P.) floods are recognized (Bretz and others, 1956; Bretz, 1969; Baker, 1978; Foley, 1976; Hammatt, 1977; Waitt, 1980; Mullineaux and others, 1978; Patton and Baker, 1978; Tallman and others, 1978; Bunker, 1980; Bjornstad, 1980). Because flood deposits in Oregon are unweathered and only weakly carbonate cemented, they are likely of late Wisconsin age. This age is based on flood deposits in eastern Washington of known late Wisconsin age that are also unweathered and weakly cemented.

Within the project area, these deposits are mapped as catastrophic flood gravel and Touchet Beds as described below.

Catastrophic Flood Gravel (Qfg)

This unit was formerly mapped as a glaciofluvial deposit (Newcomb, 1969; Shannon and Wilson, Inc., 1971, 1972, 1973, 1975a,b). It is now preferable to map it as catastrophic flood gravel, because that term more precisely describes it.

The unit consists chiefly of angular, poorly sorted, granule to large boulder gravel. Other rock types include crystalline and metamorphic rocks, as well as clasts of caliche and calichified tuff from older, pre-flood deposits. The gravel is commonly openwork, although coarse sand matrix partially fills interstices. Bedding types vary with the depositional setting. Downstream from Wallula Gap along the relatively flat floor of the Columbia River valley, the deposit resembles a large fan. The gravel is massive or in subhorizontal or lenticular cross-stratified sets as thick as several meters. Large-scale foreset beds occur where gravel avalanched into pre-flood valleys. Excellent examples are located 3 km southeast of Arlington in Alkali Canyon; in the John Day River valley south of the "Nook" (secs. 11, 12, 13, T. 2 N., R. 18 E.; and sec. 18, T. 2 N., R. 19 E); and at Fairbanks Gap (sec. 25, T. 2 N., R. 14 E.) and a similar, unnamed gap 5 km west of Fairbanks Gap. These "sidehill" (Allison, 1933) deposits consist of poorly sorted basalt granule to boulder gravel in large-scale foreset beds that dip away from the spillover channels.

West of Arlington, flood gravel also occurs in eddy bar deposits, similar to those described by Baker (1973), at the mouths of canyons tributary to the Columbia River. The gravel is in 0.5- to 2-m-thick beds that dip in many angles in different directions. The beds are commonly lenticular, and they interfinger with lenticular, discontinuous beds of massive or parallel-laminated sand. Large, 1- to 2-m-wide blocks of columnar basalt are scattered within the eddy bar deposits. The eddy bars have been trenched by post-flood erosion.

Touchet Beds (Qt)

Rhythmically bedded, normal-graded sand and silt deposits in the Walla Walla Valley were named Touchet Beds after the town of Touchet (Flint, 1938). Although Flint did not agree with their flood origin, later workers showed that catastrophic floods deposited them (Newcomb, 1965; Farooqui, 1977; Bjornstad, 1980; Waitt, 1980). Similar deposits in the project area were earlier recognized and mapped as Touchet Beds (Shannon and Wilson, 1972, 1973, 1975a,b). We continue this usage.

The Touchet Beds occur in tributary valleys of the Columbia River that were backflooded by catastrophic floods. These beds are the "slack-water" distal equivalent of the higher energy flood gravel deposits.

The Touchet Beds grade laterally upcanyon from interbedded sandy basalt gravel and basalt and quartzose sand to fine-grained, dominantly quartzose sand and silt. Mica is also present. The beds are rhythmic and normal graded. This upvalley, proximal-to-distal variation in grain size is common to the Touchet Beds and is interpreted as being caused by diminishing currents surging upvalley during flooding. The deposits are confined below 335-m elevation in the Walla Walla Valley and other valleys tributary to the Columbia River.

The Touchet Beds also contain isolated stones of exotic, nonbasalt rock types probably released as dropstones from icebergs. Clastic dikes are also common in the Touchet Beds and, in places, in the flood gravel (Shannon and Wilson, 1974a, 1975b).

Residual Soil (Qrs)

This unit consists of in-place soil on top of the Grande Ronde and Wanapum Basalts along the broad upland surface of the Blue Mountains anticline. The soil occurs above 1,070-m elevation on horizontal or gently undulating terrain. It consists of a red to red-brown, clayey silt or silty clay matrix containing angular to subangular pebble- to boulder-size basalt stones. The stones are mostly decomposed. The proportion of stones increases downwards to large, spheriodally weathered basalt blocks or intact basalt bed rock. The soil is commonly 1 to 10 m thick, but it may be less than 1 m in thickness.

Gravel Deposits (QTg)

Gravel deposits of partially consolidated, poorly sorted, sandy basalt and andesite cobble to boulder gravel comprise this unit. It is confined to the eastern margin of the Cascade Range and forms an eastward-thinning wedge atop the upper, bench-forming basalt flows of the Deschutes and Tygh Valley formations.

The age of this gravel is uncertain. It overlies the middle Miocene to early Pliocene Deschutes Formation and Tygh Valley formation, but no mappable younger units cover it in the project area.

QUATERNARY-TERTIARY SEDIMENTARY DEPOSITS (QTs)

This unit includes undifferentiated terrace, pediment, glacial outwash, waterlaid tuff, alluvial fan, slope-wash, and colluvial deposits. We have not differentiated the different types of deposits because of sparse exposures and their limited distribution.

This unit occurs throughout the project area and is confined to intra- or intermontane basins. These basins include the upper John Day River valley near Prairie City; the Phipps Meadow (T. 11 S., Rs. 35 and 36 E.) and Whitney areas (Tps. 10 and 11 S., R. 36 E.); Big Summit Prairie; the North Fork Burnt River valley; the Burnt River Valley; the southern Unity basin; Sumpter Valley; the Baker Valley near Baker, Haines, and North Powder; the Indian Valley near Elgin; and the Ukiah basin.

The stratigraphic relation of these deposits to older or younger units is largely unknown. In the Baker Valley, these deposits are mapped separately from the alluvial fans there because (1) they are more dissected than the fans, and (2) their surfaces are topographically higher than those of the fans. These QTs deposits may, however, be erosional remnants of older fans.

These Quaternary-Tertiary sedimentary deposits in the Baker Valley are locally folded. At a location 8.5 km northwest of Baker, at the mouth of Washington Gulch (NW¼ sec. 11, T. 9 S., R. 39 E., Wingville, Oregon, 7.5-minute quadrangle), beds are tilted northwards. Lenticular pebble layers, 0.25 to 0.5 m thick, have apparent dips of 36° to 42° N. Strike could not be determined. The tilted layers are isolated in structureless tan silt to very coarse sand. The tilted layers may be related to motion along nearby faults mapped by Trauger (1950) and Brooks and others (1976).

These Quaternary-Tertiary sedimentary deposits in the Indian Valley consist of tuffaceous silt and sand and basalt gravel, as exposed at the surface. Three water-well logs (Hampton and Brown, 1964) indicate local thicknesses of 11 m (well 1N/39-22B1) to 15 m (wells 1N/39-15J1 and 1N/39-16G1). The deposits overlie clay and sand that Hampton and Brown (1964) interpret to be a separate lacustrine unit.

These same deposits in the Ukiah basin have been locally confused with interbeds. Walker (1973) mapped Tertiary sedimentary rocks of post-Columbia River Basalt Group age near Ukiah; however, our mapping shows that some of these deposits are instead locally exhumed interbeds capped by thin flow remnants. The deposits themselves consist of subangular basalt cobble gravel that overlies tan-brown, tuffaceous mudstone and silt. Locally, the deposit consists solely of cobble gravel.

The Quaternary-Tertiary sedimentary deposits in the Ukiah basin locally faulted along normal faults (Walker, 1973). We recognize one new fault that is exposed in a roadcut north of Camas Creek (SW¼ SE¼ NW¼ sec. 7, T. 5 S., R. 32 E.). The fault is on trend with a fault mapped by Walker (1973) to the north. The fault consists of a 2-m-wide shear zone that juxtaposes basalt on its eastern side against basalt and overlying siltstone and sandstone on its western side. Gravel mapped as Quaternary-Tertiary sediments overlies the fault but is not offset. It does, however, thicken westward across the fault. Beneath the gravel, bedding in siltstone and sandstone also mapped as these sediments may be offset along a secondary fault 10 m west of the main fault. This offset is tenuous, however, because the bedding is poorly defined.

QUATERNARY AND LATE TERTIARY VOLCANIC ROCKS

A variety of volcanic rocks and deposits occurs in the project area, and they are grouped here into three categories: Tertiary volcanic rocks, undifferentiated Quaternary-Tertiary volcanic rocks and deposits, and Quaternary basalt flows. They are described below.

Tertiary Volcanic Rocks (Tpmv)

This unit consists of two subunits: (1) andesite flows along the eastern margin of the Cascade Range; and (2) andesitic and basaltic cinder cones (Gardner and others, 1974; Walker, 1979a) southeast of Union, in the southeastern Grande Ronde Valley.

The andesite flows along the eastern margin of the Cascade Range unconformably overlie the Chenoweth formation near The Dalles (Newcomb, 1969). Elsewhere, the flows are disconformable on the Chenoweth formation (as near Tygh Ridge) and on the Tygh Valley formation and Deschutes Formation. The andesite flows that locally overlie the Tygh Valley formation and Deschutes Formation are distinct from the basalt flows interbedded with these formations.

Available K/Ar dates indicate an overlap in the ages of the Chenoweth formation and andesite, suggesting they could be contemporaneous. The Chenoweth formation is approximately 5 to 7 m.y.; the adjacent Cascade Range andesites are dated at 8.0 ± 0.8 m.y. (Appendix 2; sample 103-WB-B) and 3 to 7 m.y. (Wise, 1969).

The andesite flows overlying the Deschutes Formation near the Madras-Redmond area are inferred to be of late Tertiary age because (1) they overlie the middle Miocene to early Pliocene Deschutes Formation; and (2) they are laterally adjacent, but perhaps not equivalent, to 3.9-m.y.-old central High Cascades volcanic rocks (Taylor, 1980).

Quaternary-Tertiary Volcanic Rocks and Deposits (QTv)

This unit includes a variety of undifferentiated volcanic rocks and deposits such as andesite and basalt flows, cinder cones, breccia, tuff breccia, volcanic debris flow deposits, and ash-flow tuffs. The ages of these rocks are commonly unknown; previous mappers inferred Tertiary or Quaternary ages for them. For this report all such units are grouped into a single, general unit of Quaternary-Tertiary age. An andesite vent near Elgin (Jones Butte; Appendix 2, sample 507) is dated as 2.0 m.y., and an intracanyon basalt flow in the Crooked River canyon near Redmond is dated at 7.1 m.y. (Appendix 2, sample 1F).

Quaternary Basalt Flows (Qb)

This unit specifically includes intracanyon basalt flows near The Dalles along the eastern margin of the Cascade Range. These flows are mapped separately because Newcomb (1969) specifically recognized them as basalt flows. The age of the flows is important because they unconformably overlie the Chenoweth formation. Newcomb (1969) considered them to be Quaternary, but precise radiometric ages of the flows are unknown.

GEOLOGIC STRUCTURES

This section summarizes (1) the major structures that define structural basins in which post-Columbia River Basalt Group deposits accumulated; and (2) major faults that cut the Neogene and Quaternary deposits. Minor structures that locally affect specific deposits are discussed earlier within the descriptions of those deposits.

Structural Basins

Major structurally defined basins that are also modern topographic basins occur in the project area. These basins are separated by regional anticlines, and none of them are geographically connected.

Each basin contains deposits of post-Columbia River Basalt Group age. The basins are variously developed in the basalts of the Columbia River Basalt Group and older rocks. The basins are of two fundamental types: (1) flat-bottomed, plunging synclinal basins; and (2) fault-controlled basins. The synclinal basins are the Agency, Arlington-Boardman, The Dalles, Tygh Valley, Madras, and John Day basins. The fault-controlled basins are the La Grande, Baker, Unity, and Ironside basins. The basins and their deposits are shown in Figure 14. The major anticlines, also shown in Figure 14, are not described here because they are composed of the folded Columbia River Basalt Group and older rocks, which are not part of this investigation.

The ages of the basins are uncertain but can be estimated by considering the age of the youngest unit involved in basining and the age of the infilling deposit. Estimates of the ages of the basins are shown in Table 1. The discordant ages of the rocks that floor the basins suggest that these basins developed at different times with respect to each other.

Synclinal Basins

The Agency basin is defined by the Agency syncline, which is bordered on the west by the Reith anticline and on the east by the Blue Mountains anticline. The basin contains the McKay formation. The syncline is doubly-plunging; its northern terminus is north of Pendleton against the southern dipslope of the Horse Heaven Hills anticline. Its southern terminus is defined by the gradually rising floor of the Agency syncline.

The Arlington-Boardman basin extends along the Dalles-Umatilla syncline from the John Day River eastward to the Service anticline, its eastern border. The Columbia Hills anticline is the northern boundary

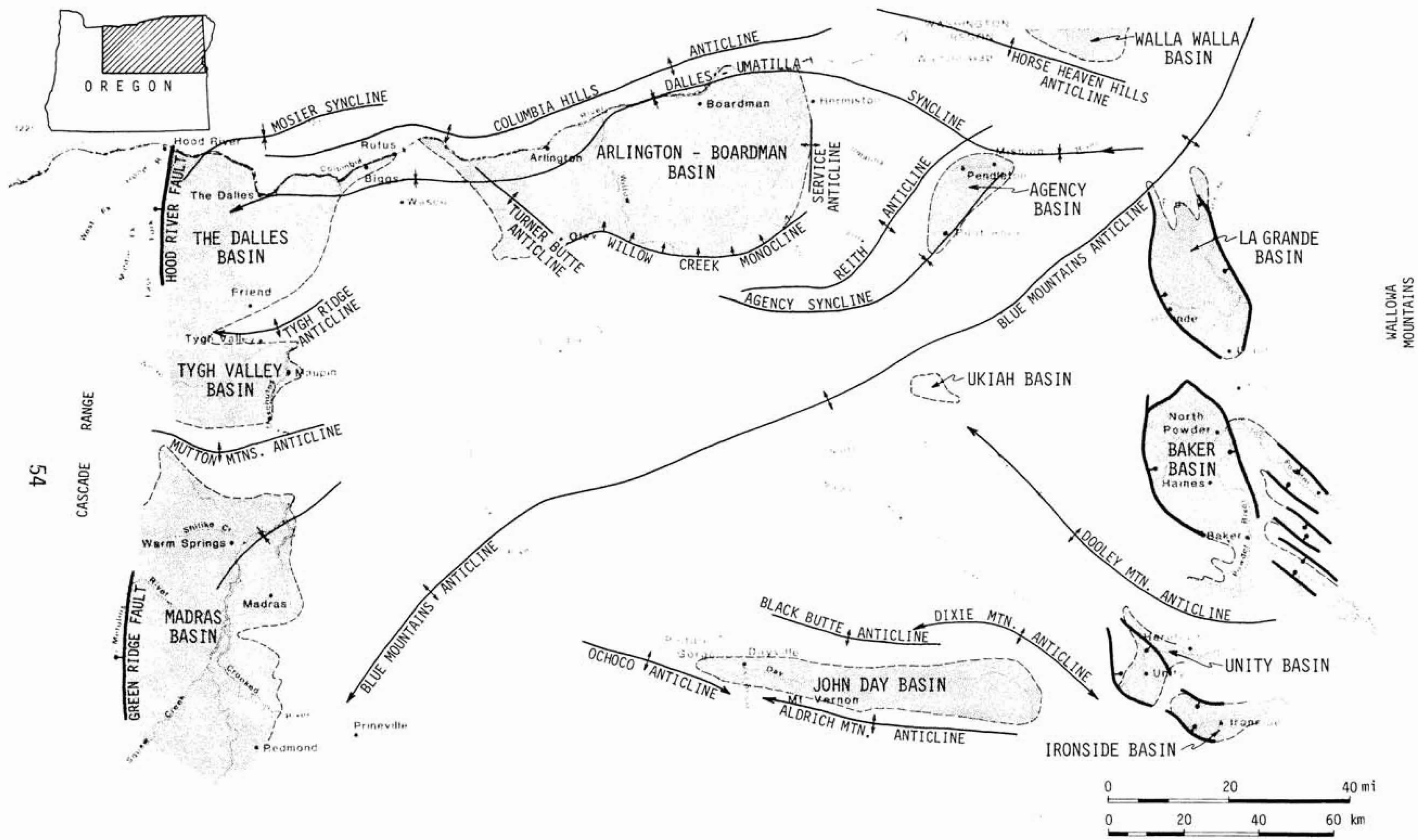


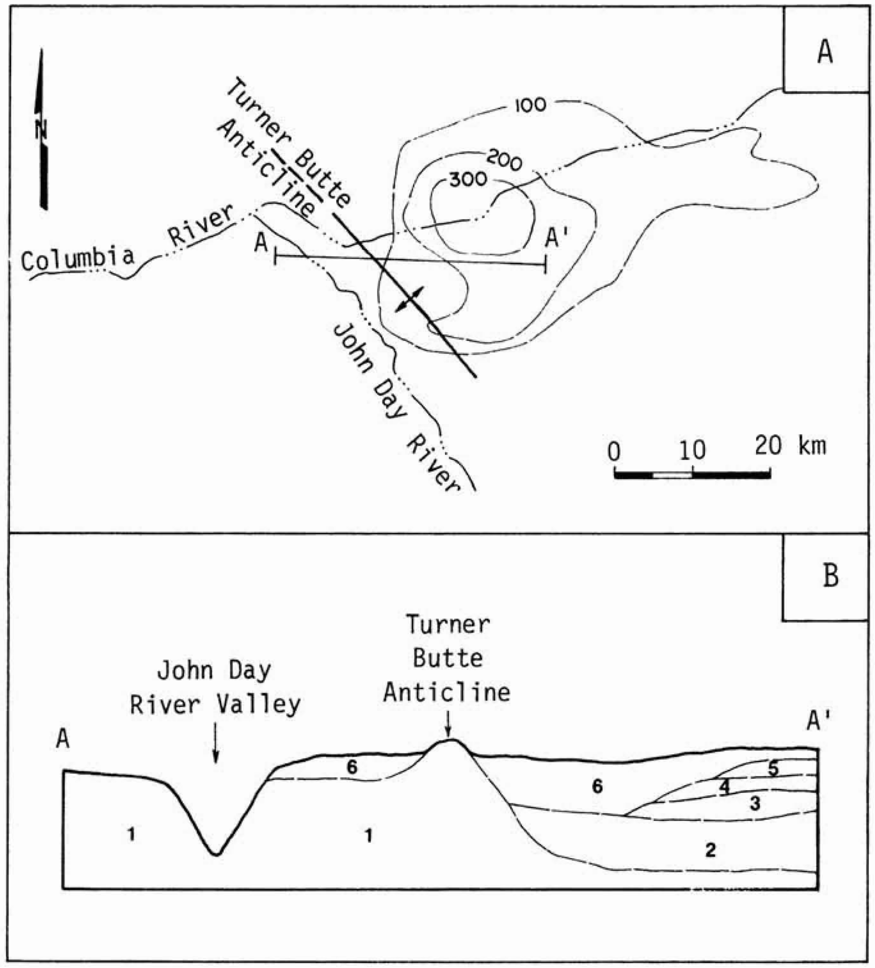
Figure 14. Generalized locations of Neogene basins and major structures. Only the Oregon portions of the basins are shown. Baker basin continues southeastward beyond the project area. Former western extent of The Dalles, Tygh Valley and Madras basins obscured by faulting and burial beneath andesite flows. Structures generalized from Newcomb (1970) and Shannon & Wilson, Inc. (1972).

Table 1. Estimated time of Neogene basin development

BASIN	UNIT[1]	AGE OF DEPOSITS	YOUNGEST BASIN FLOOR Unit[2]	YOUNGEST BASIN FLOOR Age (m.y.)	ESTIMATED TIME OF BASIN DEVELOPMENT
Agency	Tdm	Late Miocene-early Pliocene	Frenchman Spgs. Mbr.	12-14	Middle-late Miocene
Arlington-Boardman	Tda	Late Miocene-early Pliocene	Elephant Mtn. Mbr.	10.5	Middle-late Miocene
The Dalles	Tdc	Late Miocene-Pliocene	Priest Rapids Member	12-14	Middle-late Miocene
John Day	QTsr Tm	Late Miocene-early Pliocene(?) Early-middle Miocene	Picture Gorge Basalt	14-16	Early Miocene
La Grande	QTs QTl	? Late Miocene(?)-Pleistocene	Grande Ronde Basalt	14-16	Early-late Miocene(?)
Madras	Tdd	Middle Miocene-Pliocene	Grande Ronde Basalt	14-16	Middle-late Miocene
Tygh Valley	Tdt	Middle Miocene-early Pliocene	Frenchman Spgs. Mbr.	12-14	Middle Miocene
Baker	Tb	Middle-late Miocene	Grande Ronde Basalt	14-16	Early-middle Miocene
Ironside	Ti	Middle-late Miocene	Strawberry Volcanics	12-14	Early-middle Miocene
Unity	Tu	Middle-late Miocene	Strawberry Volcanics	12-14	Early-middle Miocene

[1] See description of individual units in text for explanation.

[2] Except for the Strawberry Volcanics, all units belong to the Columbia River Basalt Group.



1 Undifferentiated Columbia River Basalt Group

2 Selah member, Ellensburg Formation

3 Pomona Member, Saddle Mountains Basalt

4 Rattlesnake Ridge member, Ellensburg Formation

5 Pomona Member, Saddle Mountains Basalt

6 Alkali Canyon formation, Dalles Group

Figure 15. Stratigraphic relations of the Alkali Canyon formation, Ellensburg Formation and Columbia River Basalt Group near western end of the Arlington - Boardman basin. Turner Butte anticline may have acted as basin boundary. Isopachs drawn in feet for Selah member (modified from Kent, 1978).

of the basin. Its southern boundary is defined by the northern flank of the Blue Mountains anticline, specifically along the Willow Creek monocline, a north-dipping flexure. The western boundary of the basin is less obvious but appears to be the Turner Butte anticline east of the John Day River. The basin contains the Alkali Canyon formation, formerly thought to be an eastward extension of the Dalles Formation (Newcomb, 1966). However, our mapping shows that the Alkali Canyon formation does not extend west of the John Day River. The Turner Butte anticline is the only mapped structure that could act as a basin boundary. Subsurface data (Kent, 1978) show that the anticline acted as a basin boundary during deposition of the Selah member (Ellensburg Formation) (Figure 15). The anticline may have continued its role as a basin boundary through Alkali Canyon time.

The Chenoweth formation is confined to the Dalles basin. The Dalles basin is broadly defined by the southwest-plunging Dalles-Umatilla and Mosier synclines. The northern boundary of the basin is the Columbia Hills anticline. Its southern boundary is the Tygh Ridge anticline. Its eastern boundary is basalt upland. The western boundary is obscure because the Chenoweth formation is disrupted by the Hood River fault and is overlain by younger andesite flows of the Cascade Range.

The Tygh Valley formation is confined to the Tygh Valley basin, whose northern boundary is the Tygh Ridge anticline. The southern boundary of the basin is the Mutton Mountains, a pre-Columbia River Basalt Group structure developed in the John Day and Clarno Formations. The basin itself is a west-plunging syncline. The eastern boundary of the basin approximately coincides with the Deschutes River where the Columbia River basalt that floors the syncline rises eastward. The western extent of the basin is obscured and buried by younger andesite flows of the Cascade Range.

The Madras Basin contains the Deschutes Formation. The basin consists of several broad synclines developed on the southwest-plunging Blue Mountains anticline. Its northern boundary is the Mutton Mountains. The eastern and southern boundaries are formed by highlands eroded on the Blue Moutains anticline. The western boundary is obscured beneath andesite flows of the Cascade Range.

The John Day basin contains the Mascall and Rattlesnake Formations. It trends east-west between the Black Butte and Richmond anticlines on the north and the Aldrich Mountain anticline on the south. The basin is terminated at its eastern and western ends by the Dixie and Ochoco anticlines, respectively.

Fault-Controlled Basins

The La Grande basin is a complex graben that is interpreted as a pull-apart basin (Gehrels and others, 1980). It contains the LeRoux deposits in the Grande Ronde Valley and the Quaternary-Tertiary sedimentary deposits in Indian Valley.

The Unity basin contains the Unity deposits and is defined by northwest-trending faults that form a graben. The Ironside basin lies southeast of the Unity basin and is also defined by northwest-trending faults.

The Baker deposits are contained within structural basins that correspond to present-day valleys. The present structural basins are bounded by northwest-trending faults, and they represent the down-faulted remnants of the original depositional basin(s) (Brooks and others, 1976). The Baker deposits are separated from the Unity and Ironside deposits by the Dooley Mountain anticline.

Neogene Faults

Major faults cutting the Neogene deposits are here named Neogene faults. The latest ages of faulting are not known. Most of the faults are directly observable; however, some are inferred on the basis of offset stratigraphic units and changes in thickness of stratigraphic units.

The Alkali Canyon formation appears to be locally faulted along the Arlington-Shutler lineament (Shannon and Wilson, 1973). This northwest-trending lineament consists of doubly-plunging anticlines and minor faults.

The Chenoweth formation is cut by two major faults. They are the Hood River and Chenoweth faults (Newcomb, 1969). The Hood River fault runs along the eastern side of the Hood River Valley and is a north-trending fault with the western side downthrown. It extends along the base of a 300-m-high fault-line scarp exposing, from bottom to top, the Columbia River Basalt Group, the Chenoweth formation, and volcanic rocks. The Chenoweth fault is about 16 km long (Newcomb, 1969) and juxtaposes the Columbia River Basalt Group on the north side with the Chenoweth formation on the south side. The Chenoweth fault consists of a wide fault zone with brecciation extending tens of meters into the Columbia River Basalt Group. The west end of the Chenoweth fault is buried by volcanic rocks. Vertical displacement on this fault decreases eastward, and it is not detectable east of Badger Creek (sec. 30, T. 2 N., R. 13 E.).

The Tygh Valley formation is cut by a northeast-trending reverse fault along the southern side of the Tygh Ridge anticline. The fault is inferred to cut the Tygh Valley formation on the basis of 4C° to 50° S. dips in the formation near the fault that abruptly flatten out away from the fault.

Outside of the project area, the Deschutes Formation is cut by a major fault, the Green Ridge fault. This fault is a 30-km-long north-trending fault that extends along the base of Green Ridge east of the Metolius River (Williams, 1957; Newcomb, 1970, Taylor, 1980). The fault juxtaposes the Deschutes Formation on the east with 3-m.y.-old volcanic rocks on the west (Taylor, 1980). Vertical displacement is at least 700 m (Taylor, 1980).

The Mascall and Rattlesnake Formations are cut by the John Day fault and faults conjugate to it (Brown and Thayer, 1966a,b). The John Day fault is a high-angle reverse fault that approximately follows the trough of the John Day basin. Total vertical offset along the John Day fault is unknown. The Rattlesnake ignimbrite is offset 122 m, but the basal Rattlesnake Formation may be offset at least 305 m (Brown and Thayer, 1966b).

The Baker, Ironside, LeRoux, and Unity deposits are cut by numerous faults, most of which trend northwest. The faults collectively define the basins in which each unit occurs.

Quaternary(?) Faults

A few faults of probable Quaternary age occur in the Walla Walla, Milton-Freewater, and La Grande areas (Bingham and others, 1970; Swanson, Anderson, and others, 1979; Kienle and others, 1979; Farooqui, 1979; Slemmons and O'Malley, 1980). The presence of these faults is based both on direct observations of faulted Quaternary(?) deposits and on linear features observed in Quaternary deposits that overlie the Columbia River Basalt Group.

The Wallula fault, a major fault that trends northwestward from near Milton-Freewater to the Wallula Gap area, shows evidence for probable Quaternary faulting (Bingham and others, 1970; Farooqui, 1979). The Thorn Hollow and Little Dry Creek faults in the Milton-Freewater and Pendleton areas offset loess and colluvium (SW¼ NE¼ sec. 2, T. 4 N., R. 35 E.; and NE¼ sec. 11, T. 4 N., R. 35 E.) (Kienle and others, 1979; Swanson, Anderson, and others, 1979). Kienle and others (1979) also reported faulted Touchet Beds south of Umapine, near Milton-Freewater. Slemmons and O'Malley (1980) interpret recent faulting to have occurred along the northeastern side of the La Grande basin.

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APPENDIX 1.

List of Mapped Quadrangles

7.5-Minute Quadrangles

Baker AMS Sheet

Baker (F)
Blue Canyon (F)
Bowen Valley (F)
Brannon Gulch (0)
Dooley Mountain (0)
Encina (0)
French Gulch (0)
Haines (F)
Keating (0)
Keating NW (0)
Lost Basin (0)
Magpie Peak (F)
Oxman (0)
Sawtooth Ridge (0)
Virtue Flat (0)
Wingville (F)

Bend AMS Sheet

Brewer Reservoir (F)
Buck Butte (F)
Culver (F)
Gray Butte (F)
Hehe Butte (F)
Keys Creek (0)
Madras East (F)
Madras West (F)
Metolius Bench (F)
Mt. Pisgah (0)
Opal City (F)
Peterson Point (0)
Potters Ponds (F)
Round Butte (F)
Seekseequa Junction (F)
Simnasho (0)
Steelhead Falls (F)
Teller Butte (F)
Warm Springs (0)
Williams Prairie (0)

Canyon City AMS Sheet

Aldrich Gulch (0)
Aldrich Mtn. North (0)
Anthony Lakes (F)
Antone (0)
Austin (0)
Beaverdam Creek (0)
Big Weasel Springs (0)
Bourne (F)
Bullrun Rock (0)
Canyon Mountain (0)
Castle Creek (0)
Day Basin (0)
Dayville (0)
Deardorff (0)
Derr Meadows (0)
Eldorado Pass (0)
Elkhorn Peak (F)
Fall Mountain (0)
Hereford (0)
John Day (0)
Little Baldy Mountain (0)
Little Summit Prairie (0)
McClellen Mountain (0)
Mount Vernon (0)
Phillips Lake (F)
Pine Creek Mountain (0)
Pogue Point (0)
Rail Gulch (0)
Rastus Mountain (0)
Rock Creek (F)
Shop Gulch (0)
Six Corners (0)
Sumpter (0)
Unity (0)
Unity Reservoir (0)
Whitney (0)
Williams Prairie (0)
Wolfinger Butte (0)
Wolf Mountain (0)

APPENDIX 1.
(continued)

7.5-Minute Quadrangles

Grangeville AMS Sheet

Akers Butte (0)
Bone Spring (0)
China Cap (0)
Conley (F)
Cove (F)
Craig Mountain (F)
Cricket Flat (F)
Deep Creek (0)
Elbow Creek (0)
Elgin (F)
Flagstaff Butte (0)
Fox Point (0)
Fry Meadow (0)
Gasset Bluff (F)
Howard Butte (0)
Imbler (F)
Jim White Ridge (0)
Jubilee Lake (0)
Little Catherine Creek (0)
Medical Springs (0)
Miriam (0)
Mount Moriah (0)
Mount Fanny (0)
North Powder (F)
Partridge Creek (0)
Rondowa (0)
Telocaset (F)
Union (F)
Wallowa (0)
Wenaha Forks (0)

Pendleton AMS Sheet

Adams (F)
Alderdale (0)
Andies Prairie (F)
Anthony Butte (0)
Arbuckle Mountain (0)
Athena (F)
Bally Mountain (0)
Balm Canyon (0)
Barnhardt (0)
Bassey Creek (0)

Pendleton AMS Sheet (cont.)

Big Meadows (F)
Big Rock Flat (0)
Bingham Springs (F)
Blalock Island (0)
Blalock Mountain (F)
Boardman (0)
Bowlus Hill (F)
Bridge Creek (0)
Butter Creek Junction (F)
Buttermilk Canyon (0)
Cabbage Hill (0)
Carney Butte (0)
Cayuse (F)
Chapin Creek (0)
Cecil (0)
Clarke (0)
Coombs Canyon (0)
Crow Butte (0)
Dalreed Butte (0)
Deerhorn Creek (0)
Drunhill Ridge (0)
Duncan (0)
Echo (0)
Echo SE (0)
Echo SW (0)
Eightmile (0)
Ella (0)
Fly Valley (0)
Franklin Hill (0)
Freezeout Ridge (0)
Gibbon (F)
Glass Hill (0)
Gleason Butte (0)
Gooseberry (0)
Granite Meadows (0)
Gurdane (0)
Hardman (0)
Hat Rock (0)
Helix (F)
Heppner (0)
Hilgard (0)
Hermiston (0)
Hildman (F)
Holdman SE (F)

APPENDIX 1.
(continued)

7.5-Minute Quadrangles

Pendleton AMS Sheet (cont.)

Hoodlum Canyon (O)
Huron (O)
Ione North (O)
Ione South (O)
Irrigon (O)
Juniper (O)
Juniper Canyon (F)
Kamela SE (O)
La Grande Reservoir (O)
La Grande SE (O)
Lake Penland (O)
Lefevre Prairie (O)
Lehman Springs (O)
Lena (O)
Lexington (O)
Limber Jim (O)
Little Beaver Creek (O)
Lone Rock (O)
Lone Rock Creek (O)
Madison Butte (O)
Marley Creek (O)
Matlock Prairie (O)
McIntyre Creek (O)
Meacham (O)
Meacham Lake (O)
McKay Reservoir (O)
Milton-Freewater (F)
Mission (F)
Nolin (O)
Nye (O)
Ordnance (O)
Owens Butte (O)
Paterson (O)
Pearson Ridge (O)
Pendleton (O)
Peterson Ridge (F)
Pilot Rock (O)
Ring (F)
Ruggs (O)
Sanderson Spring (O)
Service Buttes (O)
Service Buttes NW (O)
Sevenmile Creek (O)
Skinners Fork (O)

Pendleton AMS Sheet (cont.)

Smeltz (F)
Stanfield (O)
Stanfield SE (O)
Strawberry Canyon NE (O)
Strawberry Canyon SE (O)
Strawberry Canyon SW (O)
Sugarbowl Creek (O)
Sullivan Gulch (O)
Summerfield Ridge (O)
Summerville (O)
Swaggart Buttes (O)
Table Rock (O)
Tamarack Gulch (O)
Thimbleberry Mountain (O)
Thompson Flat (O)
Thorn Hollow (F)
Tollgate (F)
Tower Mountain (O)
Tucker Flat (O)
Ukiah (F)
Ukiah SE (O)
Umatilla (O)
Utts Butte (O)
Vey Ranch (O)
Vinson (O)
Waterman (F)
Well Spring (O)
Weston Mountain (F)

The Dalles AMS Sheet

Arlington (O)
Bath Canyon (O)
Biggs Junction (F)
Bronx Canyon (O)
Brown Creek (F)
Buckhorn Canyon (O)
Chimney Springs (O)
Condon (O)
Criterion (O)
Dart (O)
Dead Dog Canyon (O)
Devils Backbone (O)

APPENDIX 1.
(continued)

7.5-Minute Quadrangles

The Dalles AMS Sheet (cont.)

Devils Gap (O)
Dufur East (O)
Dufur West (F)
Emerson (F)
Erskine (O)
Esau Canyon (O)
Fivemile Butte (F)
Flat Point (F)
Foreman Point (F)
Fossil North (O)
Friend (F)
Grass Valley (O)
Harmony (O)
Heppner Junction (O)
Hickland Butte (O)
Horn Butte (O)
Horseshoe Bend (O)
Igo Butte (O)
Indian Cove (O)
Indian Spring (O)
Gwendolen (O)
Kent (O)
Ketchum Reservoir (F)
Klondike (F)
Locust Grove (F)
Lyle (F)
Macken Canyon (O)
Matney Flat (O)
Maupin (O)
Maupin SW (F)
McDonald (F)

The Dalles AMS Sheet (cont.)

Mikkalo (O)
Moro (O)
Petersburg (F)
Postage Stamp Butte (F)
Quinton (F)
Rock Creek Reservoir (F)
Rosebush (O)
Rufus (F)
Salmon Fork (O)
Schott Canyon (O)
Shaniko (O)
Sherars Bridge (O)
Shoestring Ridge (O)
Shutler Flat (F)
Sinamox (O)
Stacker Butte (F)
Summit Ridge (O)
Sundale (F)
Sundale NW (F)
The Dalles North (F)
The Dalles South (F)
Turner Butte (F)
Tygh Valley (F)
Wamic (F)
Wapinitia (F)
Wasco (F)
White Salmon (F)
Wishram (F)
Wolf Hollow Falls (O)
Wolf Run (F)
Wood Gulch (O)

15-Minute Quadrangles

Canyon City AMS Sheet

Prairie City (O)

Grangeville AMS Sheet

Enterprise (O)
Sled Springs (O)

Explanation:

O = Office Compilation Map
F = Field Map

APPENDIX 2.

Radiometric Ages and Locations of Samples

Sample	Location	Sample Description	Age
101-EB	NW¼ sec. 3, T. 5 N., R. 36 E. and following	Caliche horizon in Qf, Walla Walla Valley	Probable >350,000 yr[1/] Maximum >350,000 yr[1/]
201-EB	S½ NW¼ sec. 9, T. 2 N., R. 33 E.	Caliche horizon in Umatilla River terrace	Probable 47 ± 13 (x 10^3) yr[1/] Maximum 63 ± 4 (x 10^3) yr[1/]
202-EB	SW¼ sec. 1, T. 2 N., R. 33 E.	Caliche horizon in Umatilla River terrace	Probable ≥199,000 yr[1/] Maximum 199 ± 14 (x 10^3) yr[1/]
101-WB	SE¼ SW¼ SE¼ sec. 26, T. 3 S., R. 12 E.	"Juniper Flat basalt," Tygh Valley formation (Tdt)	7.6 ± 0.8 m.y.[2/]
103-WB	NW¼ NW¼ NE¼ sec. 16, T. 2 S., R. 11 E.	Andesite (Tpmv) over Chenoweth formation (Tdc)	8.0 ± 0.8 m.y.[2/]
105-WB	SE¼ SE¼ sec. 24, T. 2 N., R. 14 E.	Basalt flow interbedded with Chenoweth formation (Tdc) at Fulton Ridge	7.2 ± 0.7 m.y.[2/]
106-WB	S½ NE¼ sec. 9, T. 4 S., R. 13 E.	Tuff in Tygh Valley formation (Tdt) stratigraphically below "Juniper Flat basalt"	4.9 ± 0.5 m.y.[2/]
107-WB	W½ NE¼ sec. 30, T. 2 N., R. 13 E.	Tuff within lahar, Chenoweth formation (Tdc)	41.1 ± 2.8 m.y.[2/]
108-WB	NE¼ SW¼ sec. 30, T. 2 N., R. 13 E.	Andesite block within lahar, Chenoweth formation (Tdc)	47.5 ± 5.7 m.y.[2/]
109-WB	NE¼ sec. 6, T. 3 S., R. 12 E.	Andesite (Tpmv) overlying Chenoweth formation (Tdc)	5.1 ± 0.5 m.y.[2/]

Sample	Location	Sample Description	Age
504	SW¼ sec. 19, T. 10 S., R. 42 E.	Welded tuff (Tbt), Baker deposits (Tb)	12.0 ± 0.5 m.y.[2/]
505	NE¼ SW¼ sec. 11, T. 9 S., R. 42 E.	Welded tuff (Tbt), Baker deposits (Tb)	14.1 ± 0.6 m.y.[2/]
506	NE¼ sec. 5, T. 7 S., R. 42 E.	Andesite(?) flow overlying Baker deposits (Tb)	13.1 ± 0.8 m.y.[2/]
507	NW¼ sec. 4, T. 1 N., R. 39 E.	Andesite (?) vent in Indian Valley near Elgin (QTv)	2.0 ± 0.8 m.y.[2/]
1F	SW¼ sec. 11, T. 12 S., R. 12 E.	Crooked River intracanyon basalt flow (QTv)	7.1 ± 1.8 m.y.[2/]
5F	NW¼ sec. 21, T. 12 S., R. 12 E.	Plateau-forming basalt flow of Deschutes Formation (Tdd)	10.7 ± 1.2 m.y.[2/]
6F	NW¼ sec. 21, T. 12 S., R. 12 E.	Basalt flow interbedded with Deschutes Formation (Tdd)	13.2 ± 1.5 m.y.[2/]
7F	NE¼ sec. 17, T. 9 S., R. 12 E.	Plateau-forming basalt flow of Deschutes Formation (Tdd)	8.9 ± 1.0 m.y.[2/]
8F	SW¼ sec. 11, T. 11 S., R. 12 E.	Plateau-forming basalt flow of Deschutes Formation (Tdd)	22.0 ± 8.0 m.y.[2/]
9FB	SE¼ sec. 13, T. 11 S., R. 12 E.	Round Butte cinder cone Deschutes Formation (Tdd)	5.9 ± 0.6 m.y.[2/]

1/ Th^{230}/U^{234} dating of caliche.

2/ K/Ar dating.

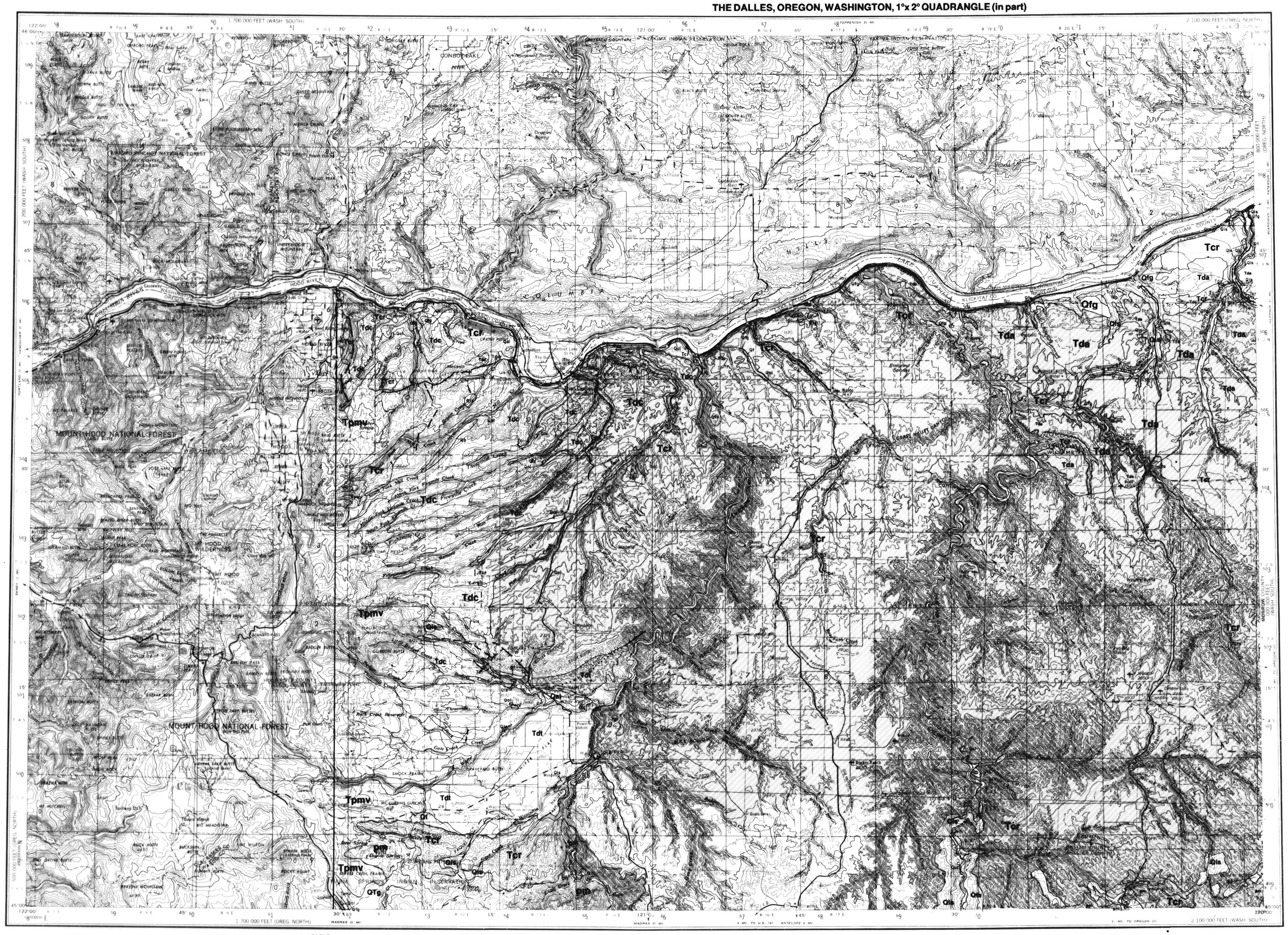
STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
DONALD A. HULL, STATE GEOLOGIST

O-81-10

PLATE I

RECONNAISSANCE GEOLOGIC MAP OF THE LATE CENOZOIC SEDIMENTS AND VOLCANIC ROCKS OVERLYING COLUMBIA RIVER BASALT GROUP IN NORTHEASTERN OREGON

THE DALLES, OREGON, WASHINGTON, 1°x 2° QUADRANGLE (in part)



Scale 1:250,000

CONTOUR INTERVAL 200 FEET
WITH SUPPLEMENTARY CONTOURS AT 100 FOOT INTERVALS
TRANSVERSE MERCATOR PROJECTION

THE DALLES

EXPLANATION

Qal — ***Alluvium:** Unconsolidated silt, sand, and gravel in channels and flood plains along present intermittent and perennial streams; locally includes lacustrine, paludal, colluvial, and eolian deposits as well as terrace sediment (**Qts**) where terraces are not mapped separately. Basal alluvium frequently consists of angular to rounded granule- to cobble-size material, grading upward to massive to horizontally bedded gravelly sand and then sand and silt; stream deposits in areas of extensive loess-covered basalt bed rock often contain little or no gravel but largely consist of loess-derived sediment as near Condon and Wasco. Includes small remnants of catastrophic flood gravel (**Qfg**) and Touchet Beds (**Qt**) up to 800- to 1,000-ft elevations where larger deposits of units **Qfg** and **Qt** occur farther downstream

Qts — ***Terrace sediment:** Unconsolidated to semiconsolidated silt, sand, and gravel underlying fill terraces along present streams; in and near the Blue Mountains predominantly gravel, while predominantly sand and silt in loess-covered (**Ql**) areas of the Deschutes-Umatilla Plateau; oldest terrace sediment occasionally caliche cemented; younger terrace sediment commonly contains lenticular volcanic ash beds; generally restricted to perennial streams or rivers, with active alluvium (**Qal**) deposits entrenched below the terrace level or flood plain but not shown due to scale

Qf — **Alluvial fan deposits:** Primarily unconsolidated sand and angular basalt gravel in active alluvial fans; usually poorly sorted and bedded; commonly contains volcanic ash; locally includes erosional remnants of inactive fans or, as at Milton-Freewater, fans that are partially buried. Deposits range from small fans at the mouths of streams in side canyons of larger drainages to more extensive deposits of several to many square miles at the base of mountainous terrain

Qls — **Landslide deposits:** Mostly unstratified, unsorted mixtures of basaltic, andesitic, sedimentary, and tuffaceous bed rock. Some slides retain stratigraphic relations of units involved. Includes rock falls and topples; rock, debris, and earth slumps; and debris and earthflows; largest rock slumps and earthflows are common where basalt flows overlie clayey, tuffaceous interbeds or subbasalt formations, as common in the Arlington area and along the Columbia River. Age unknown; dissection suggests Pleistocene age, but Holocene slides probably also included; major movement probably Pleistocene, but some landslides still active. Landslide areas may include areas with extensive colluvial cover as well

Qe — **Eolian deposits:** Undifferentiated sand sheets and transverse and longitudinal dunes. Longitudinal dunes commonly extend downwind from blowouts. Generally confined to the Umatilla-Boardman area (Pendleton 1° by 2° quadrangle), where catastrophic flood sediment is windworked. Deposits consist primarily of fine to coarse basalt sand; locally includes volcanic ash. Mostly Holocene age inferred

Qd — **Sand dunes:** Quartzose fine to medium sand in active transverse dune fields. Confined to Columbia River valley near The Dalles and Boardman (Pendleton 1° by 2° quadrangle), where sandy, catastrophic flood deposits (**Qfg**, **Qt**) have been windworked into dunes. Mostly Holocene age inferred

Loess: Massive wind-deposited quartzose silt to fine sand deposits mantling upland surfaces and hillslopes in the Deschutes-Umatilla Plateau; unit is 15 to 30 ft thick near the Columbia River, but thins to less than 3 ft in upland areas away from the river; not generally present above 2,700- to 3,200-ft elevation, where colluvium (**Qc**), residual soil, or exposed basalt (**Tcr**) predominates. Consists of two units that are here undifferentiated: (1) a younger, tan, unconsolidated loess, typically 3 to 7 ft thick; and (2) an older, reddish-brown, consolidated loess ranging from 3 to 21 ft in thickness. Younger loess commonly contains volcanic ash and usually lies on top of older loess, which has strong CCa and petrocalcic K horizons, but locally also rests on basalt or older sedimentary deposits. Age of unit is uncertain; younger loess is probably in part derived from late Pleistocene Touchet Beds (**Qt**) (Newcomb, 1965); older loess may be equivalent to pre-Palouse and Palouse loesses of eastern Washington. In loess-covered areas, alluvium (**Qal**) is often mantled by loess. Narrow stream drainages and canyons usually contain distinct elements of bed rock, colluvium, and/or loess; in this map, however, these units are often all combined into one most representative unit (generally colluvium) due to scale. Areas of both loess and colluvium (**Qc**) are common in basaltic terrain

Colluvium: Primarily unsorted cobble- and boulder-size angular basalt debris covering slopes in basaltic terrain; unit is often several to 6 ft thick; locally includes sand, silt, and clay slope wash derived from loess and sedimentary interbeds within the basalt sequence; commonly caliche cemented. Includes talus slopes and cones. Often includes up to 300-ft-wide alluvium (**Qal**) deposits in the bottoms of incised canyons in basaltic terrain. Narrow stream drainages and canyons usually contain distinct elements of bed rock, colluvium, and/or loess, but due to the scale of this map such units are all combined into one most representative unit (generally colluvium). Colluvial deposits below 3,200-ft elevation and close to the Columbia River valley generally contain loess (**Ql**) intermixed with basalt clasts

Qfg — **Catastrophic flood gravel:** Coarse, unsorted, chaotically to poorly bedded basalt gravel and sand deposited by catastrophic floods in the Columbia River valley. Other rock types include crystalline and metamorphic rocks, as well as clasts of caliche and calichified tuff from older pre-flood deposits. Gravels are commonly openwork, with coarse sand matrix partially filling interstices; foreset beds are common along southern side of Columbia River valley where floodwaters overtopped valley walls and spilled into adjacent valleys, notably southeast of Arlington and along John Day River; includes eddy bar deposits (characterized by 2- to 7-ft-thick cross-bedding) west of Arlington at mouths of canyons tributary to Columbia River. May include some terrace sediment (**Qts**) and alluvium (**Qal**) along tributary rivers and streams where catastrophic flood gravel was previously deposited from spillover channels

Qt — **Touchet Beds** (after Flint, 1938): Unweathered, noncemented, rhythmically and horizontally bedded, micaceous, quartzose silt, sand, and basalt gravel deposited in slackwater areas during Pleistocene catastrophic floods in the Columbia River valley. Unit contains diagnostic granule- to boulder-sized erratic crystalline (nonbasalt) and metamorphic rocks and clastic dikes; occurs in now-terraced valley-fill deposits, generally below 1,100-ft elevation, which generally grade laterally up-canyon from interbedded sandy basalt gravel and basalt and quartzose sand, to fine-grained, dominantly quartzose sand and silt. May include some terrace sediment (**Qts**) and alluvium (**Qal**) along tributary rivers and streams, where previously deposited from spillover channels

Qb — **Basalt flows:** Andesitic basalt and basalt as intracanyon flows in valleys eroded in the Chenoweth formation (**Tdc**) southwest of The Dalles. Includes Qvc of Newcomb (1969) and Qb of Hammond (1980)

Dalles group:

Tdc — **Chenoweth formation:** Volcaniclastic and sedimentary rock consisting primarily of eastward-spreading laharic deposits of andesitic agglomerate and tuff breccia that are interbedded with conglomerate and sandstone rich in andesite clasts near foothills of the Cascade Range. Grading laterally eastward and northward into more fluvial deposits (with proportion of lahars decreasing) of conglomerate and tuffaceous sandstone and siltstone; locally includes tuff and minor basalt flows. Maximum thickness is 1,800 ft; thins laterally to approximately 200 ft near Biggs and Rufus (Newcomb, 1966, 1969). Overlies Columbia River Basalt Group (**Tcr**) and is of late Miocene to early Pliocene age. Previously named Dalles Formation by earlier workers (Condon, 1874; Cope, 1880; Piper, 1932; Newcomb, 1966, 1969). Vertebrates dated as late Miocene to early Pliocene (Buwalda and Moore, 1930); leaves dated as early Pliocene (Chaney, 1944). K/Ar dates are 5.1, 5.7, and 7.2 m.y. (this study), and 10.6 and 15.2 m.y. (Newcomb, 1966). Locally overlain by nonindurated loess near the Columbia River

Tda — **Alkali Canyon formation:** Poorly sorted, basaltic cobble gravel and minor interbedded tuffaceous sand and silt, with cobble imbrication indicating northern transport from Blue Mountains; commonly carbonate cemented. Unit varies in thickness from 32 to 130 ft. Locally includes 16-ft-thick light-gray vitric tuff at base of unit in Alkali Canyon. Overlies Columbia River Basalt Group (**Tcr**) and associated sedimentary interbeds with slight angular unconformity. Includes Shutler formation of Hodge (1932, 1941, 1942). Partially includes Tf of Hogenson (1964) and Dalles formation of Newcomb (1966, 1971b). Age is late Miocene to early Pliocene; vertebrates dated as Hemphillian (Shotwell, 1956). Generally overlain by loess (**Ql**)

Tdt — **Tygh Valley formation:** Volcanic, volcaniclastic, and sedimentary rocks, often interbedded, derived from source areas in the Cascade Range. Basalt flows dominant in the west, with sedimentary rocks more common in the east near Tygh Valley. Complex area of volcanic centers at Graveyard Butte. Generally distinguished from Chenoweth formation (**Tdc**) by relative paucity of lahars and location. Basalt flows generally form plateaus but may occur as intracanyon flows. Sedimentary and volcaniclastic rocks comprised of weakly cemented basaltic, andesitic, and pumiceous sandstone and conglomerate; tuffaceous siltstone and sandstone; tuff; pumice lapilli tuff; and laharic deposits of agglomerate and tuff breccia. Includes Ta, Tob, and Td of Waters (1968b). Overlies Columbia River Basalt Group (**Tcr**). K/Ar dated at 4.9 and 7.6 m.y. (this study); age middle Miocene to early Pliocene

Tpmv — **Volcanic rocks:** Andesite flows along the eastern margin of the Cascade Range; unconformable on the Chenoweth formation (**Tdc**) near The Dalles (Newcomb, 1969); elsewhere disconformable on the Chenoweth formation (**Tdc**) (near Tygh Ridge) and on the Tygh Valley formation (**Tdt**). Includes Qtv of Newcomb (1969), QTv of Beaulieu (1977), QTa of Robison and Laenen (1976), Ta of Waters (1968a,b), QTb of Hammond (1980); and Qad of Waters (1968b). Available K/Ar dates of 5.1 ± 0.5 m.y. and 8.0 ± 0.8 m.y. (this study) and 3 to 7 m.y. (Wise, 1969) indicate an overlap in ages of Chenoweth formation (**Tdc**) and these volcanic rocks, suggesting they could be contemporaneous

Tcr — **Columbia River Basalt Group:** Thick tholeiitic flood-basalt sequence of Miocene age covering parts of Oregon, Washington, and Idaho; sedimentary interbeds are here included with the basalt flows. Includes Tcr of Beaulieu (1977), Farooqui (1980), Newcomb (1969), Robison and Laenen (1976), and Waters (1968b); Tcrt of Newcomb (1969); Tcp of Shannon and Wilson, Inc. (1972, 1975a,b); Tcm of Shannon and Wilson, Inc. (1971, 1972, 1975a,b); Tcbp and Tcbu of Shannon and Wilson, Inc. (1971); Tcpr of Shannon and Wilson, Inc. (1975a); and Tcu of Shannon and Wilson, Inc. (1972, 1975a,b)

pm — **Pre-Miocene, pre-Columbia River Basalt Group rocks:** Undifferentiated Paleozoic, Mesozoic, and early Cenozoic metamorphic, plutonic, volcanic, and sedimentary rocks

* Generally only those alluvium and terrace sediment deposits wider than 0.1 to 0.25 mi (500 to 1,600 ft) can be shown due to scale; instead stream symbols indicate presence of more limited deposits, as is common along intermittent streams

Contact

Fault: Dotted where concealed; queried where existence or extension uncertain; ball and bar on downthrown side; includes approximately located, probable, and inferred faults, undifferentiated. Generally only those faults are shown which displace units younger than **Tcr** or which form contacts between older geologic units.

Reverse fault: Dotted where concealed; teeth on upper plate

Anticline

Syncline

Monocline: Arrowhead touching line indicates foot of monocline

Sources of data used in compilation of map. See bibliography in text.

Beaulieu (1977)
Newcomb (1969)
Newcomb (1970)
Robison and Laenen (1976)
Shannon and Wilson (1971)
Shannon and Wilson (1972)
Shannon and Wilson (1975a)
Waters (1968b)

The Dalles
Field reconnaissance by
Saleem M. Farooqui, Richard E. Thoms, Russell C. Bunker
Shannon and Wilson, Inc., 1980 and 1981
Map compilation by
James L. Bela
Oregon Department of Geology and Mineral Industries
1981

Prepared and Published by the Cartographic Section
of the Department of Geology and Mineral Industries
C. A. Schumacher, Chief Cartographer
1981

STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
DONALD A. HULL, STATE GEOLOGIST

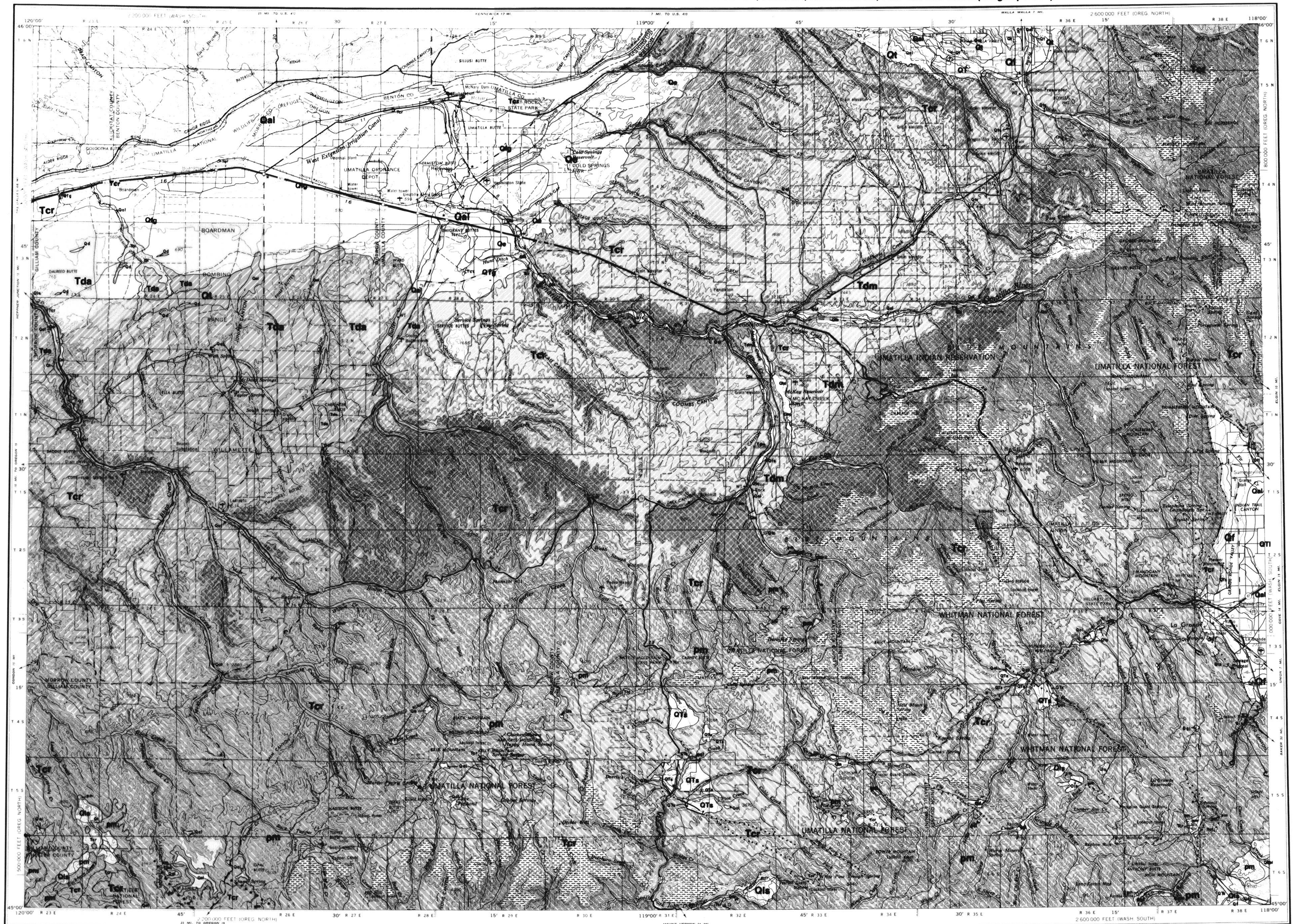
POST-COLUMBIA RIVER BASALT GROUP STRATIGRAPHY AND MAP COMPILATION OF THE COLUMBIA PLATEAU, OREGON

RECONNAISSANCE GEOLOGIC MAP OF THE LATE CENOZOIC SEDIMENTS AND VOLCANIC ROCKS OVERLYING COLUMBIA RIVER BASALT GROUP IN NORTHEASTERN OREGON

PENDLETON, OREGON, WASHINGTON, 1°x 2° QUADRANGLE (Oregon portion)

O-81-10

PLATE II



PENDLETON

EXPLANATION

Qal — ***Alluvium:** Unconsolidated silt, sand, and gravel in channels and flood plains along present intermittent and perennial streams; also includes extensive sand and gravel bars along the Columbia River. Locally includes lacustrine, paludal, colluvial, and eolian deposits as well as terrace sediment (**Qts**) where terraces are not mapped separately. Basal alluvium frequently consists of angular to rounded granule- to cobble-size material, grading upward to massive to horizontally bedded gravelly sand and then sand and silt; stream deposits in areas of extensive loess-covered basalt bed rock often contain little or no gravel but largely consist of loess-derived quartzose fine sand to silt, as common near Pendleton

Qts — ***Terrace sediment:** Unconsolidated to semiconsolidated silt, sand, and gravel underlying fill terraces along present rivers and streams; in and near the Blue Mountains predominantly gravel, while predominantly sand and silt in loess-covered (**Ql**) areas of the Deschutes-Umatilla Plateau; oldest terrace sediment occasionally caliche cemented; younger terrace sediment commonly contains lenticular volcanic ash beds; generally restricted to perennial streams or rivers, with active alluvium (**Qal**) deposits entrenched below the terrace level or flood plain (as common along Umatilla River) but not shown due to scale or relative predominance of unit **Qts** over unit **Qal**. Includes 200- to 700-ft-wide deposits of alluvium (**Qal**) along Umatilla River upstream from Echo and upstream from Mission that are not shown due to scale; includes multiple terrace levels in vicinity of Mission

Qf — **Alluvial fan deposits:** Primarily unconsolidated sand and angular basalt gravel in active alluvial fans; usually poorly sorted and bedded; commonly contains volcanic ash; locally includes erosional remnants of inactive fans or, as at Milton-Freewater, fans that are partially buried. Deposits range from small fans at the mouths of streams in side canyons of larger drainages to more extensive deposits covering 5 to 12 sq mi at the base of mountainous terrain; largest fans occur at Milton-Freewater and in the Grande Ronde Valley near La Grande

Qls — **Landslide deposits:** Mostly unstratified, unsorted mixtures of basaltic, andesitic, sedimentary, and tuffaceous bed rock. Some slides retain stratigraphic relations of units involved. Includes rock falls and topples; rock, debris, and earth slumps; and debris and earthflows; largest rock slumps and earthflows are common where basalt flows overlie clayey, tuffaceous interbeds or subbasalt formations, as common in the Arlington area, along the Columbia River, and in the La Grande-Elgin area. Age unknown; dissection suggests Pleistocene age, but Holocene slides probably also included; major movement probably Pleistocene. Some landslides still active. Landslide areas may include areas with extensive colluvial cover as well

Qe — **Eolian deposits:** Undifferentiated sand sheets and transverse and longitudinal dunes. Longitudinal dunes commonly extend downwind from blowouts. Generally confined to the Umatilla-Boardman area, where catastrophic flood sediment is windworked; most extensive north and east of Stanfield. Deposits consist primarily of fine to coarse basalt sand; locally includes volcanic ash. Mostly Holocene age inferred

Qd — **Sand dunes:** Quartzose fine to medium sand in active transverse dune fields. Confined to Columbia River valley near The Dalles (The Dalles 1° by 2° quadrangle) and Boardman, where sandy, catastrophic flood deposits (**Qfg**, **Qt**) have been windworked into dunes. Mostly Holocene age inferred

Loess: Massive wind-deposited quartzose silt to fine sand deposits mantling upland surfaces and hillslopes in the Deschutes-Umatilla Plateau; unit is 15 to 30 ft thick near the Columbia River but thins to less than 3 ft in upland areas away from the river; not generally present above 2,700- to 3,200-ft elevation, where colluvium (**Qc**), residual soil (**Qrs**), or exposed basalt (**Tcr**) predominates. Consists of two units that are here undifferentiated: (1) a younger, tan unconsolidated loess, typically 3 to 7 ft thick; and (2) an older, reddish-brown consolidated loess ranging from 3 to 21 ft in thickness. Younger loess commonly contains volcanic ash and usually lies on top of older loess, which has strong CCa and petrocalcic K horizons, but locally also rests on basalt or older sedimentary deposits. Age of unit is uncertain; younger loess is probably in part derived from late Pleistocene Touchet Beds (**Qt**) (Newcomb, 1965); older loess may be equivalent to pre-Palouse and Palouse loesses of eastern Washington. In loess-covered areas, alluvium (**Qal**) is often mantled by loess. Narrow stream drainages and canyons usually contain distinct elements of bed rock, colluvium, and/or loess; in this map, however, these units are often all combined into one most representative unit (generally colluvium) due to scale. Areas of both loess and colluvium (**Qc**) are common in basaltic terrain; such areas may include alluvium (**Qal**) or loess-covered alluvium up to 0.2 mi wide in flatter and wider canyon bottoms. Loess is often preferentially deposited along only one side of canyon walls, particularly north from Pendleton to the Columbia River

Colluvium: Primarily unsorted cobble- and boulder-size angular basalt debris covering slopes in basaltic terrain; unit is often several to 6 ft thick; locally includes sand, silt, and clay slope wash derived from loess and sedimentary interbeds within the basalt sequence; commonly caliche cemented. Common along step sides of incised canyons but not shown if less than 0.1 mi (500 to 600 ft) in width. Where thin (1 to 2 ft), scattered bed rock outcrops generally comprise less than 50 percent of a given area. Includes talus slopes and cones. Often includes up to 300-ft-wide alluvium (**Qal**) deposits in the bottoms of incised canyons in basaltic terrain. Narrow stream drainages and canyons usually contain distinct elements of bed rock, colluvium, and or loess, but due to the scale of this map such units are all combined into one most representative unit (generally colluvium). Colluvial deposits below 3,200-ft elevation and close to the Columbia River valley generally contain loess (**Ql**) intermixed with basalt clasts; such areas may also include alluvium (**Qal**) or loess-covered alluvium up to 0.2 mi wide in flatter and wider canyon bottoms. The presence of colluvium is indicative of active geomorphic processes of downslope movement. Areas of colluvium on flatter slopes may also include residual soil (**Qrs**) that is indistinguishable in air photos and aerial reconnaissance due to tree cover

Residual soil: In-place material (regolith) derived from decomposition of Grande Ronde and Wanapum Basalts of Columbia River Basalt Group (**Tcr**) along axial crest of Blue Mountains. Consists of reddish-brown, stony silty clay and small, mostly decomposed stones; grades downward into large, partially decomposed, spheroidally weathered basalt blocks. Commonly 3 to 40 ft thick but locally less than 3 ft thick. In flatter upland areas, unit also contains local, unmappable areas of colluvium (**Qc**)

Qfg — **Catastrophic flood gravel:** Coarse, unsorted, chaotically to poorly bedded basalt gravel and sand deposited by catastrophic floods in the Columbia River valley; unit is most extensive in the Boardman-Umatilla area, where deposits resemble a large fan; there gravels are massive or occur in subhorizontal or lenticular sets up to 6 to 8 ft thick. Other rock types include crystalline and metamorphic rocks, as well as clasts of caliche and calichified tuff from older pre-flood deposits. Gravels are commonly openwork, with coarse sand matrix partially filling interstices; foreset beds are common along southern side of Columbia River valley where floodwaters overtopped valley walls and spilled into adjacent valleys, notably southeast of Arlington and along the John Day River (The Dalles 1° by 2° quadrangle)

Qt — **Touchet Beds** (after Flint, 1938)**:** Unweathered, noncemented, rhythmically and horizontally bedded, micaceous, quartzose silt, sand, and basalt gravel deposited in slackwater areas during Pleistocene catastrophic floods in the Columbia River valley. Most prominent in the Walla Walla valley, which is the type locality. Unit contains diagnostic granule- to boulder-sized erratic crystalline (nonbasalt) and metamorphic rocks and clastic dikes; occurs in now-terraced valley-fill deposits, generally below 1,100-ft elevation, which generally grade laterally up-canyon from interbedded sandy basalt gravel and basalt and quartzose sand to fine-grained, dominantly quartzose sand and silt. Loess-covered (**Ql**) in the Boardman area

Qgm — **Glacial moraines:** Unsorted, bouldery gravel and sand in lateral and end moraines in the Elkhorn, Strawberry, and Wallowa Mountains; moraines occur mostly in single sets in the Elkhorn and Strawberry Mountains. Generally fresh appearance and unweathered character suggest late Wisconsin age

Qgd — **Glacial drift:** Undifferentiated glacial and glaciofluvial deposits, exclusive of moraines, in the Elkhorn, Strawberry, and Wallowa Mountains. Consists of till, outwash, ice-contact deposits, and periglacial fans. Unit includes deposits that earlier workers mapped as glacial moraines (Walker, 1973). Late Pleistocene age inferred

QTl — **LeRoux deposits:** Predominantly clay, silt, and fine sand with minor gravel underlying the La Grande basin. Generally poorly exposed; most data are derived from well logs; limited outcrops are generally poorly consolidated and uncemented. Red and yellowish-brown clay changes color to green and blue with depth. Thickness varies from trace at basin edge to at least 2,025 ft near center. Overlies Columbia River Basalt Group (**Tcr**). Includes Ql of Hampton and Brown (1964), Qs of Gardner and others (1974), and Qs of Walker (1979a). Age uncertain, but great thickness suggests possible Quaternary-Tertiary time span

QTs — **Sedimentary deposits:** Undifferentiated terrace, pediment, glacial outwash, waterlaid tuff, alluvial fan, slope wash, and colluvial deposits. Generally confined to intra- or intermontane basins, as at Ukiah, where deposits consist of subangular basalt-cobble gravel locally overlying tan tuffaceous mudstone and siltstone; also may include some partially exhumed interbeds of the Columbia River Basalt Group (**Tcr**). Includes Ql of Barrash and others (1980) and part of Qfc and Ts of Walker (1973). Ages uncertain; high-level dissected nature of some deposits suggests Pliocene to middle (?) Pleistocene age

Dalles group:

Tda — **Alkali Canyon formation:** Poorly sorted, basalt cobble gravel and minor interbedded tuffaceous sand and silt, with cobble imbrication indicating northern transport from Blue Mountains; commonly carbonate cemented. Thickness varies from 32 to 130 ft; locally includes 16-ft-thick light-gray vitric tuff at base of unit in Alkali Canyon (The Dalles 1° by 2° quadrangle). Overlies Columbia River Basalt Group (**Tcr**) and associated sedimentary interbeds with slight angular unconformity. Includes Shutler formation of Hodge (1932, 1941, 1942); partially includes Tf of Hogenson (1964) and Dalles formation of Newcomb (1966, 1971b). Age is late Miocene to early Pliocene; vertebrates dated as Hemphillian (Shotwell, 1956). Generally overlain by loess (**Ql**)

Tdm — **McKay formation:** Predominantly poorly sorted, clast-supported basalt pebble, cobble, and small boulder gravel with minor interbedded tuff and tuffaceous silt and sand in the vicinity of Pendleton and Pilot Rock. Massive to poorly bedded; gravel beds commonly lenticular; commonly carbonate cemented; sand-silt matrix locally; some gravels essentially openwork; sand beds often weakly cemented and iron stained. Thickness varies from 10 to 250 ft, with thickest observed sections in or near Birch and McKay Creeks and the Umatilla River valley; unit generally thins away from valleys. Overlies Columbia River Basalt Group (**Tcr**). Partly includes Tf of Hogenson (1964); Td of Newcomb (1966); McKay beds of Shotwell (1956); Ts of Walker (1973); and Td of Shannon and Wilson, Inc. (1972), Gonthier and Harris (1977), and Farooqui (1980). Age is late Miocene to early Pliocene; vertebrates dated as Hemphillian (Shotwell, 1956). Generally overlain by loess (**Ql**)

Tcr — **Columbia River Basalt Group:** Thick tholeiitic flood-basalt sequence of Miocene age covering parts of Oregon, Washington, and Idaho; sedimentary interbeds are here included with the basalt flows. Includes Tcr of Farooqui (1980), Gonthier and Harris (1977), Kienle and others (1979), and Walker (1973); Tcb of Hogenson (1964); Ta of Kienle and others (1979); Tgr, Tgh, Tghd, Tghy, Tgho, Tghi, Tmm, and Tcm of Barrash and others (1980); Tcfs, Tcm, Tcp of Shannon and Wilson, Inc. (1973, 1975b); and Tcu of Shannon and Wilson, Inc. (1975b)

pm — **Pre-Miocene, pre-Columbia River Basalt Group rocks:** Undifferentiated Paleozoic, Mesozoic, and early Cenozoic metamorphic, plutonic, volcanic, and sedimentary rocks

* Generally only those alluvium and terrace sediment deposits wider than 0.1 to 0.25 mi (500 to 1,600 ft) can be shown due to scale; instead stream symbols indicate presence of more limited deposits, as is common along intermittent streams or perennial streams like Little Butter Creek south of Hermiston

Prepared by the U.S. Army Topographic Command (TPCSX), Washington, D.C. Compiled in 1954 by photogrammetric methods. Planimetry revised from aerial photographs taken 1952. Photographs field annotated 1953. Revised in 1973 by the U.S. Geological Survey from aerial photographs taken 1973

Transverse Mercator Projection. 10,000-meter Universal Transverse Mercator grid, zone 11. 100,000-foot grid ticks based on Oregon coordinate system, north zone and Washington coordinate system, south zone. 1927 North American Datum. To place on the predicted North American Datum 1983 move the projection lines 19 meters north and 84 meters east

Location of geodetic control established by government agencies is shown on corresponding 1:250,000-scale Geodetic Control Diagram

There may be private inholdings within the boundaries of the National or State reservations shown on this map

LEGEND

Figures in red denote approximate distances in miles between stars

POPULATED PLACES
- Over 500,000 — LOS ANGELES
- 100,000 to 500,000 — OMAHA
- 25,000 to 100,000 — GALVESTON
- 5,000 to 25,000 — Durango
- 1,000 to 5,000 — Grand Coulee
- Less than 1,000 — Sun Valley

RAILROADS (Single track, Double or Multiple)
- Standard gauge
- Narrow gauge

BOUNDARIES
- International
- State
- County
- Park or reservation

ROADS
- Primary, all-weather, hard surface
- Secondary, all-weather, hard surface
- Light-duty, all-weather, hard or improved surface
- Fair or dry weather, unimproved surface
- Trail
- Interchange

Route markers: Interstate, U.S., State

- Landplane airport
- Landing area
- Seaplane airport
- Seaplane anchorage
- Woods-brushwood
- Mine
- Landmark: School, Church, Other
- Spot elevation in feet
- Marsh or swamp
- Intermittent or dry stream
- Power line

Scale 1:250,000

5 0 5 10 15 20 Statute Miles

5 0 5 10 15 20 25 30 Kilometers

5 0 5 10 15 Nautical Miles

CONTOUR INTERVAL 200 FEET
WITH SUPPLEMENTARY CONTOURS AT 100 FOOT INTERVALS

MAGNETIC DECLINATION FOR 1970 IS 20° (355 MILS) EASTERLY OVER THE ENTIRE AREA

Contact

Fault: Dotted where concealed; queried where existence or extension uncertain; ball and bar on downthrown side; includes approximately located, probable, and inferred faults, undifferentiated. Generally only those faults are shown which displace units younger than **Tcr** or which form contacts between older geologic units.

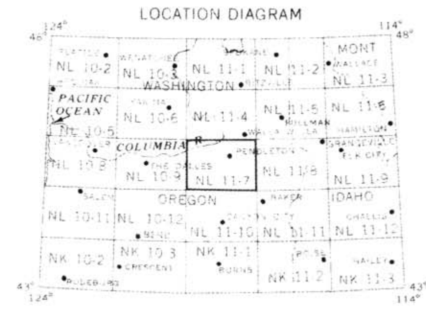
Reverse fault: Dotted where concealed; teeth on upper plate

Anticline

Syncline

Monocline: Arrowhead touching line indicates foot of monocline

LOCATION DIAGRAM



SECTIONIZED TOWNSHIP

6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

Pendleton
Field reconnaissance by
Saleem M. Farooqui, Daniel C. Clayton, Russell C. Bunker
Shannon and Wilson, Inc., 1980 and 1981
Map compilation by
James L. Bela
Oregon Department of Geology and Mineral Industries
1981

Sources of data used in compilation of map. See bibliography in text.

Barrash and others (1980)
Gardner and others (1974)
Gonthier and Harris (1977)
Hogenson (1964)
Kienle and others (1979)
Newcomb (1965)
Robison (1971)
Schlicker and Deacon (1971)
Shannon and Wilson (1973)
Shannon and Wilson (1975b)
Walker (1973)

CARTOGRAPHY by C. A. Schumacher

Prepared and Published by the Cartographic Section
of the Department of Geology and Mineral Industries
C. A. Schumacher, Chief Cartographer
1981

STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
DONALD A. HULL, STATE GEOLOGIST

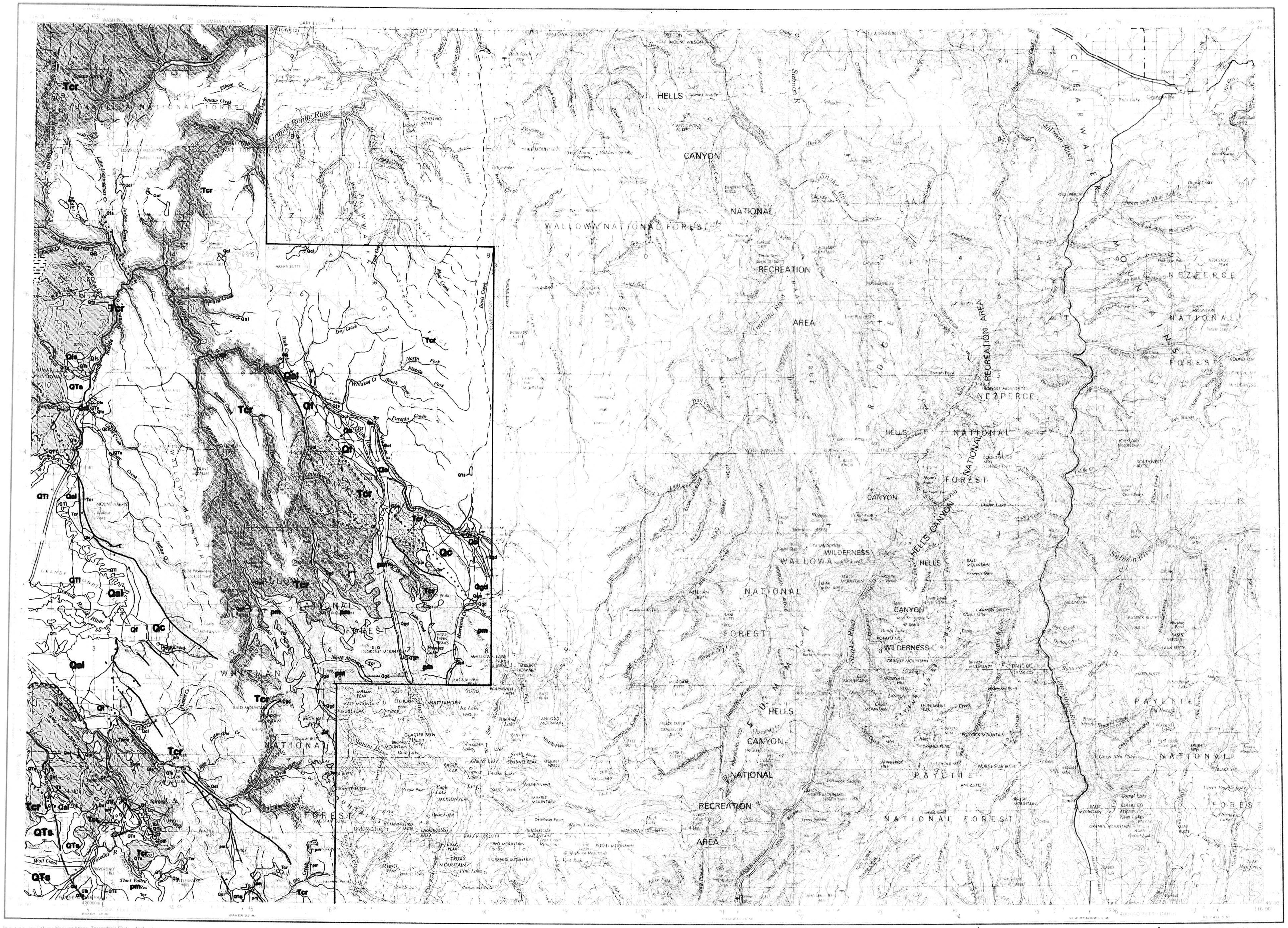
POST-COLUMBIA RIVER BASALT GROUP STRATIGRAPHY AND MAP COMPILATION OF THE COLUMBIA PLATEAU, OREGON

O-81-10

RECONNAISSANCE GEOLOGIC MAP OF THE LATE CENOZOIC SEDIMENTS AND VOLCANIC ROCKS OVERLYING COLUMBIA RIVER BASALT GROUP IN NORTHEASTERN OREGON

GRANGEVILLE, IDAHO, OREGON, WASHINGTON, 1°x 2° QUADRANGLE (northwest portion)

PLATE III



GRANGEVILLE

EXPLANATION

Qal — ***Alluvium:** Unconsolidated silt, sand, and gravel in channels and flood plains along present intermittent and perennial streams; forms extensive broad valley fill in the Grande Ronde valley. Locally includes lacustrine, paludal, and colluvial deposits as well as terrace sediment (**Qts**) where terraces are not mapped separately. Basal alluvium frequently consists of angular to rounded granule- to cobble-size material, grading upward to massive to horizontally bedded gravelly sand and then sand and silt

Qts — ***Terrace sediment:** Unconsolidated to semiconsolidated silt, sand, and gravel underlying fill terraces along present rivers and streams; in and near the Blue Mountains predominantly gravel, while predominantly sand and silt in loess-covered areas of the Deschutes-Umatilla Plateau; oldest terrace sediment occasionally caliche cemented; younger terrace sediment commonly contains lenticular volcanic ash beds; generally restricted to perennial streams or rivers, with active alluvium (**Qal**) deposits entrenched below the terrace level or flood plain but not shown due to scale or relative predominance of unit **Qts** over unit **Qal**. Cemented sand and gravel near Enterprise

Qf — **Alluvial fan deposits:** Primarily unconsolidated sand and angular basalt gravel in active alluvial fans; usually poorly sorted and bedded; commonly contains volcanic ash; locally includes erosional remnants of inactive fans or, as at Milton-Freewater (Pendleton 1° by 2° quadrangle), fans that are partially buried. Deposits range from small fans at the mouths of streams in side canyons of larger drainages to more extensive deposits covering 5 to 12 sq mi at the base of mountainous terrain. Largest fans occur in the Grande Ronde valley; large fan near Union possibly faulted along northeastern margin

Qls — **Landslide deposits:** Mostly unstratified, unsorted mixtures of basaltic, andesitic, sedimentary, and tuffaceous bed rock. Some slides retain stratigraphic relations of units involved. Includes rock falls and topples; rock, debris, and earth slumps; and debris and earthflows; largest rock slumps and earthflows are common where basalt flows overlie clayey, tuffaceous interbeds or sub-basalt formations, as common in the La Grande-Union-Elgin area. Age unknown; dissection suggests Pleistocene age, but Holocene slides probably also included; major movement probably Pleistocene. Some landslides still active. Landslide areas may include areas with extensive colluvial cover as well

Qc — **Colluvium:** Primarily unsorted cobble- and boulder-size angular basalt debris covering slopes in basaltic terrain, often several to 6 ft in thickness; locally includes sand, silt, and clay slope wash derived from loess and sedimentary interbeds within the basalt sequence; commonly caliche cemented. Common along steep sides of incised canyons, but not shown if less than 0.1 mi (500 to 600 ft) wide. Where thin (1 to 2 ft), scattered bedrock outcrops generally comprise less than 50 percent of a given area. Includes talus slopes and cones. Prominent along eastern margin of Grande Ronde valley and near Enterprise. Often includes up to 300-ft-wide alluvium (**Qal**) deposits in the bottoms of incised canyons in basaltic terrain. Narrow stream drainages and canyons usually contain distinct elements of bed rock and colluvium, but due to the scale of this map such units are all combined into one most representative unit (generally colluvium). The presence of colluvium is indicative of active geomorphic processes of downslope movement. Areas of colluvium on flatter slopes may also include residual soil (**Qrs**), which is indistinguishable in air photos and aerial reconnaissance due to tree cover

Residual soil: In-place material (regolith) derived from decomposition of Grande Ronde and Wanapum Basalts of Columbia River Basalt Group (**Tcr**) along axial crest of Blue Mountains. Consists of reddish-brown, stony, silty clay and small, mostly decomposed stones; grades downward into large, partially decomposed, spheroidally weathered basalt blocks. Unit is commonly 3 to 40 ft thick, but locally less than 3 ft thick. In flatter upland areas, also contains local, unmappable areas of colluvium (**Qc**)

Qgm — **Glacial moraines:** Unsorted, bouldery gravel and sand in lateral and end moraines in the Elkhorn, Strawberry, and Wallowa Mountains; moraines occur mostly in single sets in the Elkhorn and Strawberry Mountains. Generally fresh appearance and unweathered character suggest late Wisconsin age. Moraines of several ages (Wisconsin, 10,000 to 80,000 years B.P.; and pre-Wisconsin, more than 130,000 years B.P.) recognized east of project area near Wallowa Lake (Crandell, 1967). Three Holocene glacial episodes noted in Wallowa Mountains (Kiver, 1974)

Qgd — **Glacial drift:** Undifferentiated glacial and glaciofluvial deposits, exclusive of moraines, in the Elkhorn, Strawberry, and Wallowa Mountains. Includes till, outwash, ice-contact deposits, and periglacial fans. Unit includes deposits that earlier workers mapped as glacial moraines (Walker, 1979a). Late Pleistocene age inferred

Qs — **Quaternary sediment:** Undifferentiated alluvium (**Qal**), glacial drift (**Qgd**), and alluvial fan deposits (**Qf**) in the Enterprise valley

QTl — **LeRoux deposits:** Predominantly clay, silt, and fine sand with minor gravel underlying the Grande Ronde valley. Generally poorly exposed; most data are derived from well logs; limited outcrops are generally poorly consolidated and uncemented. Red and yellowish-brown clay changes color to green and blue with depth. Thickness varies from trace at basin edge to at least 2,025 ft near center. Overlies Columbia River Basalt Group (**Tcr**). Includes Ql of Hampton and Brown (1964), Qs of Gardner and others (1974), and Qs of Walker (1979a). Age uncertain, but great thickness suggests possible Quarternary-Tertiary time span

QTs — **Sedimentary deposits:** Undifferentiated terrace, pediment, glacial outwash, water-laid tuff, alluvial fan, slope-wash, and colluvial deposits. Generally confined to intra- or intermontane basins, as Indian Valley near Elgin, where exposed deposits consist of tuffaceous silt and sand and basalt gravel; there well logs indicate deposits are 35 to 50 ft thick and overlie clay and sand. Also prominent in Baker Valley near North Powder and Baker (Baker 1° by 2° quadrangle), where deposits may represent erosional remnants of older fans. Includes Ql of Barrash and others (1980), and partially includes Qs and Ts of Walker (1979a). Ages uncertain; high-level dissected nature of some deposits suggests Pliocene to middle (?) Pleistocene age

QTv — **Volcanic rocks and deposits:** Undifferentiated andesite, olivine basalt, and basaltic andesite flows; basaltic and andesitic cinder cones; breccia; tuff breccia; volcanic debris flows; and rhyolitic ash-flow tuff. Ages uncertain; probably late Miocene to late Pleistocene. Here limited to Jones Butte, an andesite vent near Elgin; K/Ar dated at 2.0 ± 0.8 m.y. (this study). Includes part of Tmv of Walker (1979a)

Tpmv — **Volcanic rocks:** Basaltic and andesitic cinder cones occurring south of the Grande Ronde Valley near Union. Includes QTp of Walker (1979a) and Tp of Gardner and others (1974). Basalt flows from northernmost cinder cone interlayered with andesitic flows of the Columbia River Basalt Group (**Tcr**) (Gardner and others, 1974). Age late (?) Cenozoic (Pliocene or Miocene), possibly as old as middle to late Miocene (Walker, 1979a)

Tb / Tbt — **Baker deposits:** Lacustrine and fluviatile deposits comprised of tuffaceous clay, siltstone, sandstone, and conglomerate occurring in the Baker Valley and adjacent valleys; primarily occurring in Baker 1° by 2° quadrangle. Predominantly massive sandy pebble to small cobble conglomerate; locally contains thin gravel lenses (6 ft thick) interbedded with tuffaceous siltstone and sandstone. Rock types reflect provenance: basalt most common; metamorphic rock common south of Elkhorn Mountains; rhyolite and obsidian predominant near Dooley Mountain. Locally interbedded with ash-flow tuff (**Tbt**) mapped separately. Unconformable or disconformable on older rocks (**pm**); unit mostly overlies (locally unconformably) basalts correlated with Columbia River Basalt Group (**Tcr**) (Brooks and others, 1976). Thickness variable, with maximum estimated thickness of 200 ft within project area (Gardner and others, 1974). Partially includes Tst of Brooks (1977), Brooks and McIntyre (1977a,b; 1978), and Brooks and others (1976). Age is middle to late Miocene; vertebrates in correlative deposits outside of the project area dated as Clarendonian (Shotwell, in Prostka, 1962; in Brooks and others, 1976; and in Brooks, 1979b). Andesites overlying the Baker deposits west of Sawtooth Crater (Baker 1° by 2° quadrangle) dated at 12.5 ± 0.9 m.y. (Gardner and others, 1974) and 13.1 ± 0.8 m.y. (this study)

Tcr — **Columbia River Basalt Group:** Thick tholeiitic flood-basalt sequence of Miocene age covering parts of Oregon, Washington, and Idaho; sedimentary interbeds are here included with the basalt flows. Includes Tcr of Farooqui (1980); part of Tba, Tls, Tbf, Tbfi, and Tmv of Walker (1979a); Tba, Tls, Tbf, Tbfi, and part of Tmv of Walker (1979a); and Tgr, Tgh, Tghd, Tghy, Tgho, Tghi, Tmm, and Tcm of Barrash and others (1980)

pm — **Pre-Miocene, pre-Columbia River Basalt Group rocks:** Undifferentiated Paleozoic, Mesozoic, and early Cenozoic metamorphic, plutonic, volcanic, and sedimentary rocks

* Generally only those alluvium and terrace sediment deposits wider than 0.1 to 0.25 mi (500 to 1,600 ft) can be shown due to scale; instead stream symbols indicate presence of more limited deposits

Contact

Fault: Dotted where concealed; queried where existence or extension uncertain; ball and bar on downthrown side; includes approximately located, probable, and inferred faults, undifferentiated. Generally only those faults are shown which displace units younger than **Tcr** or which form contacts between older geologic units.

Reverse fault: Dotted where concealed; teeth on upper plate

Anticline

Syncline

Monocline: Arrowhead touching line indicates foot of monocline

Grangeville
Field reconnaissance by
Saleem M. Farooqui, Russell C. Bunker
Shannon and Wilson, Inc., 1980 and 1981
Map compilation by
James L. Bela
Oregon Department of Geology and Mineral Industries
1981

CONTOUR INTERVAL 200 FEET
WITH SUPPLEMENTARY CONTOURS AT 100 FOOT INTERVALS
TRANSVERSE MERCATOR PROJECTION

GRANGEVILLE

Sources of data used in compilation of map. See bibliography in text.

Barrash and others (1980) | Gardner and others (1974) | Walker (1979a)

GRANGEVILLE, IDAHO; OREG; WASH.

CARTOGRAPHY by C. A. Schumacher

Prepared and Published by the Cartographic Section
of the Department of Geology and Mineral Industries
C. A. Schumacher, Chief Cartographer
1981

STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
DONALD A. HULL, STATE GEOLOGIST

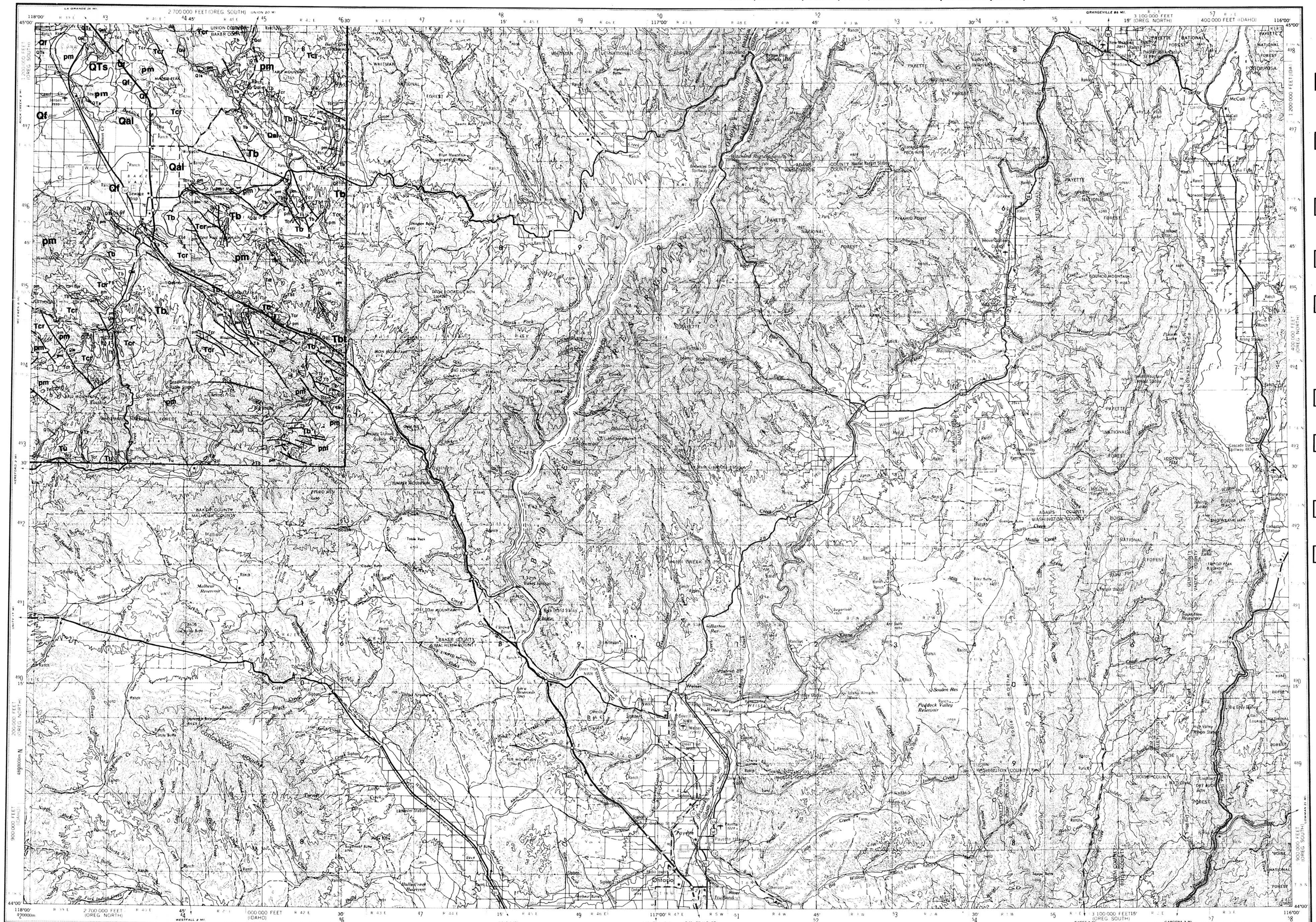
O-81-10

PLATE IV

RECONNAISSANCE GEOLOGIC MAP OF THE LATE CENOZOIC SEDIMENTS AND VOLCANIC ROCKS OVERLYING COLUMBIA RIVER BASALT GROUP IN NORTHEASTERN OREGON

BAKER, OREGON, IDAHO, 1°x 2° QUADRANGLE (northwest portion)

WESTERN UNITED STATES 1:250,000



BAKER

EXPLANATION

Qal — **Alluvium:** *Unconsolidated silt, sand, and gravel in channels and flood plains along present intermittent and perennial streams; forms extensive broad valley fill in the Baker Valley. Locally includes lacustrine, paludal, and colluvial deposits as well as terrace sediment where terraces are not mapped separately. Basal alluvium frequently consists of angular to rounded granule- to cobble-size material, grading upward to massive to horizontally bedded gravelly sand and then sand and silt. Generally only those deposits of alluvium wider than 0.1 to 0.25 mi (500 to 1,600 ft) can be shown due to scale; instead stream symbols indicate presence of more limited deposits*

Qf — **Alluvial fan deposits:** *Primarily unconsolidated sand and angular gravel in active alluvial fans; usually poorly sorted and bedded; commonly contains volcanic ash; locally includes erosional remnants of inactive fans or, as at Milton-Freewater (Pendleton 1° by 2° quadrangle), fans that are partially buried. Deposits range from small fans at the mouths of streams in side canyons of larger drainages to more extensive deposits covering 5 to 15 sq mi at the base of mountainous terrain. Largest fans occur along the western side of the Baker Valley adjacent to Elkhorn Mountains, where three separate large fans can be distinguished. Age of Baker Valley fan deposits is uncertain: undissected morphology and periglacial aspects in Rock Creek suggest late Pleistocene; the Pine Creek fan is overlain by white volcanic ash, possibly Mazama, and therefore may be Quaternary*

Qls — **Landslide deposits:** *Mostly unstratified, unsorted mixtures of basaltic, andesitic, sedimentary, and tuffaceous bed rock. Some slides retain stratigraphic relations of units involved. Includes rock falls and topples; rock, debris, and earth slumps; and debris and earthflows; largest rock slumps and earthflows are common where basalt flows overlie clayey, tuffaceous interbeds or sub-basalt formations. Age unknown; dissection suggests Pleistocene age, but Holocene slides probably also included; major movement probably Pleistocene. Some landslides still active. Landslide areas may include areas with extensive colluvial cover as well*

QTs — **Sedimentary deposits:** *Undifferentiated terrace, pediment, glacial outwash, water-laid tuff, alluvial fan, slope-wash, and colluvial deposits. Generally confined to intra- or intermontane basins. Unit occurs primarily in Baker Valley near Baker, where deposits may represent erosional remnants of older alluvial fans. Partially includes Qal and Qtg of Brooks and others (1976). Ages uncertain; high-level dissected nature of some deposits suggests Pliocene to middle (?) Pleistocene age*

Tb — **Baker deposits:** *Lacustrine and fluviatile deposits comprised of tuffaceous clay, siltstone, sandstone, and conglomerate occurring in the Baker Valley and adjacent valleys. Predominantly massive sandy pebble of small cobble conglomerate; locally contains thin gravel lenses (6 ft thick) interbedded with tuffaceous siltstone and sandstone. Rock types reflect provenance: basalt most common; metamorphic rock common south of Elkhorn Mountains; rhyolite and obsidian predominant near Dooley Mountain. Locally interbeded with ash-flow tuff (**Tbt**) mapped separately. Unconformable or disconformable on older rocks (**pm**); unit mostly overlies (locally unconformably) basalts correlated with Columbia River Basalt Group (**Tcr**) (Brooks and others, 1976). Thickness variable, with maximum estimated thickness of 200 ft within project area (Gardner and others, 1974). Partially includes Tst of Brooks (1977), Brooks and McIntyre (1977a,b; 1978), and Brooks and others (1976). Age is middle to late Miocene; vertebrates in correlative deposits outside of the project area dated as Clarendonian (Shotwell, in Prostka, 1962; in Brooks and others, 1976; and in Brooks, 1979b). Andesites overlying the Baker deposits west of Sawtooth Crater dated at 12.5 ± 0.9 m.y. (Gardner and others, 1974) and 13.1 ± 0.8 m.y. (this study)*

Tbt — **Baker deposits, ash-flow tuff:** *Light-gray to orange-brown silicic welded and nonwelded ash-flow tuff. Welded tuff grades laterally into nonwelded tuff. Local characteristics include columnar jointing, flow banding, and pumice fragments. Usually interbedded with lower Baker deposits (**Tb**) but outside of map area locally overlies pre-**Tb** rocks. Partially includes Twt of Brooks and others (1976). K/Ar dates of 12.0 ± 0.5 and 14.1 ± 0.6 m.y. (this study)*

Tu — **Unity deposits:** *Primarily stratified lacustrine tuffaceous fine siltstone and sandstone within the Unity basin (Canyon City 1° by 2° quadrangle) and Burnt River Valley; also includes minor diatomite, vitric tuff, gypsiferous beds, and coarse gravel deposits locally. Coarser alluvial fan deposits grade northward to semiconsolidated lacustrine tuffaceous sediments in the central Unity basin. Unit is similar and correlative to the Ironside deposits (**Ti**) (Canyon City 1° by 2° quadrangle). Disconformable or slightly discordant on underlying Tertiary bed rock but unconformable on pre-Tertiary bed rock (**pm**); unit overlies and interfingers (?) with basalt flows of the Miocene Strawberry Volcanics (**pm**). Maximum thickness unknown but probably at least 200 to 500 ft thick. Partially includes Tst of Brooks and others (1976). Age is middle to late Miocene; vertebrates dated as Clarendonian (Lowry, 1968)*

Tcr — **Columbia River Basalt Group:** *Thick tholeiitic flood-basalt sequence of Miocene age covering parts of Oregon, Washington, and Idaho; sedimentary interbeds are here included with the basalt flows. Includes Tcr of Farooqui (1980); Tpb, Tab, and Tabc of Brooks and others (1976); Tba of Brooks (1977) and Brooks and McIntyre (1977a); Tpa of Brooks and others (1977); Tb of Brooks and others (1977) and Brooks and McIntyre (1977a,b; 1978)*

pm — **Pre-Miocene, pre-Columbia River Basalt Group rocks:** *Undifferentiated Paleozoic, Mesozoic, and early Cenozoic metamorphic, plutonic, volcanic, and sedimentary rocks*

——— **Contact**

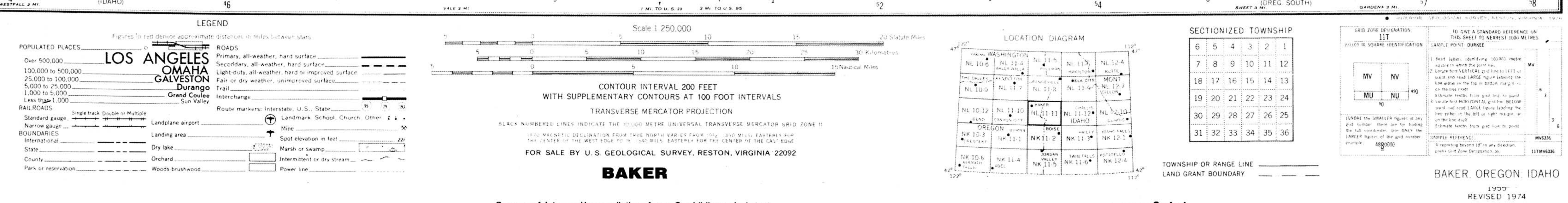
Fault: Dotted where concealed; queried where existence or extension uncertain; ball and bar on downthrown side; includes approximately located, probable, and inferred faults, undifferentiated. Generally only those faults are shown which displace units younger than **Tcr** or which form contacts between older geologic units.

Revised in 1974 by the U. S. Geological Survey from aerial photographs taken 1973

Area covered by dashed light-blue pattern is subject to controlled inundation

100,000 foot grids based on Idaho coordinate system, west zone and Oregon coordinate system, north and south zones

Location of geodetic control established by government agencies is shown on corresponding 1:250,000-scale Geodetic Control Diagram



CONTOUR INTERVAL 200 FEET
WITH SUPPLEMENTARY CONTOURS AT 100 FOOT INTERVALS
TRANSVERSE MERCATOR PROJECTION

FOR SALE BY U. S. GEOLOGICAL SURVEY, RESTON, VIRGINIA 22092

BAKER

BAKER, OREGON, IDAHO
1955
REVISED 1974

Sources of data used in compilation of map. See bibliography in text.

Brooks (1977)
Brooks and others (1977)
Brooks and McIntyre (1977a)
Gardner and others (1974)
Brooks and McIntyre (1977b)
Brooks and McIntyre (1978)
Brooks and others (1976)

Baker
Field reconnaissance by
Saleem M. Farooqui, R. L. Deacon
Shannon and Wilson, Inc., 1980 and 1981
Map compilation by
James L. Bela
Oregon Department of Geology and Mineral Industries
1981

CARTOGRAPHY by C. A. Schumacher

Prepared and Published by the Cartographic Section
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C. A. Schumacher, Chief Cartographer
1981

STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
DONALD A. HULL, STATE GEOLOGIST

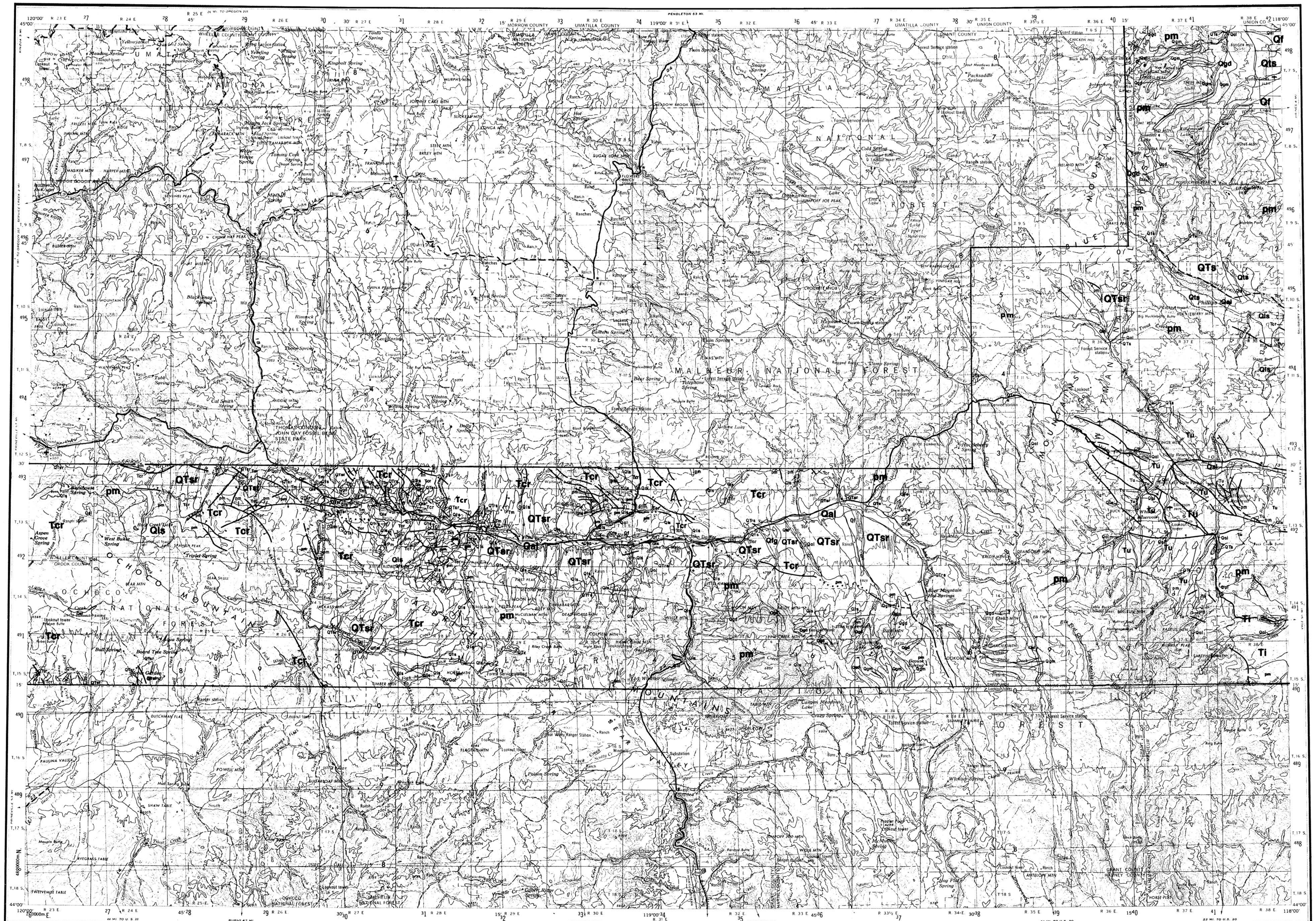
O-81-10

PLATE V

RECONNAISSANCE GEOLOGIC MAP OF THE LATE CENOZOIC SEDIMENTS AND VOLCANIC ROCKS OVERLYING COLUMBIA RIVER BASALT GROUP IN NORTHEASTERN OREGON

CANYON CITY, OREGON, 1°x 2° QUADRANGLE (north portion)

WESTERN UNITED STATES 1:250,000



CANYON CITY

EXPLANATION

Qal — ***Alluvium:*** *Unconsolidated silt, sand, and gravel in channels and flood plains along present intermittent and perennial streams; forms extensive valley fill along the John Day River. Locally includes lacustrine, paludal, and colluvial deposits as well as terrace sediment (**Qts**) where terraces are not mapped separately. Basal alluvium frequently consists of angular to rounded granule- to cobble-size material, grading upward to massive to horizontally bedded gravelly sand and then sand and silt*

Qts — ***Terrace sediment:*** *Unconsolidated to semiconsolidated silt, sand, and gravel underlying fill terraces along present rivers and streams; oldest terrace sediment occasionally caliche cemented; younger terrace sediment commonly contains lenticular volcanic ash beds; generally restricted to perennial streams or rivers; most common along flanks of the John Day River valley*

Qf — **Alluvial fan deposits:** *Primarily unconsolidated sand and angular gravel in active alluvial fans; usually poorly sorted and bedded; commonly contains volcanic ash; locally includes erosional remnants of inactive fans or, as at Milton-Freewater (Pendleton 1° by 2° quadrangle), fans that are partially buried. Deposits range from small fans at the mouths of streams in side canyons of larger drainages to more extensive deposits covering 5 to 15 sq mi at the base of mountainous terrain. Largest fans occur along the western side of the Baker Valley adjacent to Elkhorn Mountains, where separate fans can be distinguished. Age of Baker Valley fan deposits is uncertain: undissected morphology and periglacial aspects in Rock Creek suggest late Pleistocene age; the Pine Creek fan is overlain by white volcanic ash, possibly Mazama, and therefore may be Quaternary*

Qls — **Landslide deposits:** *Mostly unstratified, unsorted mixtures of basaltic, andesitic, sedimentary, and tuffaceous bed rock. Some slides retain stratigraphic relations of units involved. Includes rock falls and topples; rock, debris, and earth slumps; and debris and earthflows; largest rock slumps and earthflows are common where basalt flows overlie clayey, tuffaceous interbeds or sub-basalt formations. Such large landslide areas along the John Day valley occur in tuffs of the pre-Miocene (**pm**) John Day and Mascall (**Tm**) Formations. Age unknown; dissection suggests Pleistocene age, but Holocene slides probably also included; major movement probably Pleistocene. Some landslides still active. Landslide areas may include areas with extensive colluvial cover as well*

Qgm — **Glacial moraines:** *Unsorted bouldery gravel and sand in lateral and end moraines in the Elkhorn, Strawberry, and Wallowa Mountains; moraines occur mostly in single sets in the Elkhorn and Strawberry Mountains. Lateral moraines flanking Anthony, Rock, and Antone Creeks and the North Powder River in Elkhorn Mountains consist of loose, unweathered, bouldery gravel and sand and also contain large angular, partially buried diorite blocks. Generally fresh appearance and unweathered character suggest late Wisconsin age. May include some glacial drift (**Qgd**) along drainages between lateral moraines*

Qgd — **Glacial drift:** *Undifferentiated glacial and glaciofluvial deposits, exclusive of moraines, in the Elkhorn, Strawberry, and Wallowa Mountains. Includes till, outwash, ice-contact deposits, and periglacial fans. Includes deposits that earlier workers mapped as glacial moraines (Brown and Thayer, 1966a). Late Pleistocene age inferred*

QTs — **Sedimentary deposits:** *Undifferentiated terrace, pediment, glacial outwash, water-laid tuff, alluvial fan, slope-wash, and colluvial deposits. Generally confined to intra- or intermontane basins. These basins include the upper John Day River valley near Prairie City, the Austin and Whitney areas, the Powder River area near Phillips Lake, the Baker Valley near Baker, and the southern Unity basin. Includes Qo and Tf of Brown and Thayer (1966a), Qo of Thayer and Brown (1966c), and Qtg of Brooks and Ferns (1981). Ages uncertain; high-level dissected nature of some deposits suggests Pliocene to middle (?) Pleistocene age*

QTsr — **Rattlesnake Formation:** *Partly indurated conglomerate, sandstone, and mudstone and a prominent interbedded ignimbrite occurring along the John Day River valley above present streams. Comprised of three members (Enlows, 1976): (1) lower fanglomerate; (2) middle ignimbrite; (3) upper fanglomerate. Fanglomerate members consist of lenticular beds of coarse, poorly sorted conglomerate, sandstone, mudstone, and tuff; rock types in conglomerate reflect local provenance and include metavolcanic and metasedimentary rocks, chert, phaneritic igneous rocks, and andesite. Interlensing conglomerate, sandstone, and tuff and cross-bedded sandstone common. Ignimbrite locally faulted. Thickness of unit is variable, ranging from 255 to 900 ft. Unconformable over the Mascall Formation (**Tm**), basalts of the Columbia River Basalt Group (**Tcr**), and locally over Paleozoic rocks (**pm**). Includes the Rattlesnake Formation of Merriam (1901), Merriam and others (1925), Brown and Thayer (1966a,b), Thayer and Brown (1966c), and Enlows (1976); also includes Rattlesnake Ash-flow Tuff of Walker (1979b). Age is late Miocene to early Pliocene, possibly extending into the Pleistocene. Vertebrates dated as Hemphillian (Wood and others, 1941; Shotwell, 1956); K/Ar dates of ignimbrite average 6.5 m.y.*

QTv — **Volcanic rocks and deposits:** *Undifferentiated andesite, olivine basalt, and basaltic andesite flows; basaltic and andesitic cinder cones; breccia; tuff breccia; volcanic debris flows; and rhyolitic ash-flow tuff. Ages uncertain; probably late Miocene to late Pleistocene. Here limited to Qb (Pleistocene basalt and basaltic cinders) of Brown and Thayer (1966a,b) and Thayer and Brown (1966c)*

Ti — **Ironside deposits:** *Primarily stratified lacustrine tuffaceous siltstone and fine sandstone within the Ironside basin; also includes interbedded pebble and cobble gravel, diatomite, vitric tuff, and gypsiferous beds locally. Similar and correlative to the Unity deposits (**Tu**). Conformable on underlying Tertiary bed rock but unconformable on pre-Tertiary bed rock (**pm**). Exact thickness unknown but probably at least 200 to 500 ft thick. Partially includes Tf of Brown and Thayer (1966a) and Tst of Brooks and others (1976). Age at least late Miocene*

Tu — **Unity deposits:** *Primarily stratified lacustrine tuffaceous fine siltstone and sandstone within the Unity basin and Burnt River Valley; also includes minor diatomite, vitric tuff, gypsiferous beds, and coarse gravel deposits locally. Coarser alluvial fan deposits grade northward to semiconsolidated lacustrine tuffaceous sediments in the central Unity basin. Similar and correlative to the Ironside deposits (**Ti**). Disconformable or slightly discordant on underlying Tertiary bed rock but unconformable on pre-Tertiary bed rock (**pm**); unit overlies and interfingers (?) with basalt flows of the Miocene Strawberry Volcanics (**pm**). Maximum thickness unknown but probably at least 200 to 500 ft thick. Partly includes Qo and Tf of Brown and Thayer (1966a), Tst of Brooks and others (1976), and Tf of Brooks and others (1979). Age is middle to late Miocene; vertebrates dated as Clarendonian (Lowry, 1968)*

Tm — **Mascall Formation:** *Thick deposits comprised of fluvial sandstone, ash, light-colored tuff, and well-rounded conglomerate primarily occurring in the John Day valley; this formation also occurs in discrete basins which are outside of the project area. Predominantly drab to cream-colored water-laid tuff and ash near Dayville, becoming coarser eastward with increasing proportion of polished-pebble conglomerate and rhyolitic welded tuff; some local lignitic beds (Brown and Thayer, 1966a). Conformable on Picture Gorge Basalt (?) of the Columbia River Basalt Group (**Tcr**); locally intercalated with unit **Tcr**. Maximum thickness is 2,000 ft. Age is early to middle Miocene. Vertebrates dated as Hemingfordian and Barstovian (Downs, 1956). The Mascall Formation occurs chiefly in downfaulted blocks north of the John Day fault. Extensive landslides (**Qls**) along the flanks of the John Day River valley are associated with this formation*

Tcr — **Columbia River Basalt Group:** *Thick tholeiitic flood-basalt sequence of Miocene age covering parts of Oregon, Washington, and Idaho; sedimentary interbeds are here included with the basalt flows. Includes Tcr of Brown and Thayer (1966b) and Farooqui (1980); Tcu of Brown and Thayer (1966a) and Thayer and Brown (1966c); and Tp of Brown and Thayer (1966a,b) and Thayer and Brown (1966c)*

pm — **Pre-Miocene, pre-Columbia River Basalt Group rocks:** *Undifferentiated Paleozoic, Mesozoic, and early Cenozoic metamorphic, plutonic, volcanic, and sedimentary rocks. Early Cenozoic rocks include the Clarno and John Day Formations of Eocene to early Miocene age; these formations consist of lava flows, mudflow deposits, ash-flow tuffs, and tuffaceous sedimentary rocks. Although the Strawberry Volcanics are partially coeval with the Columbia River Basalt Group (**Tcr**) (Thayer and Brown, 1966a,b; Robyn, 1977; Robyn and others, 1977), they are here included with the pre-Columbia River Basalt Group rocks as a matter of convenience because they are distinct from unit **Tcr**. Rocks of the Strawberry Volcanics occur in the vicinity of the topographic high separating the John Day valley and the Unity basin and also along the eastern portions of the Unity basin, where they separate the Unity deposits (**Tu**) from the Ironside deposits (**Ti**)*

* *Generally only those alluvium and terrace sediment deposits wider than 0.1 to 0.25 mi (500 to 1,600 ft) can be shown due to scale; instead stream symbols indicate presence of more limited deposits*

Contact

Fault: Dotted where concealed; queried where existence or extension uncertain; ball and bar on downthrown side; includes approximately located, probable, and inferred faults, undifferentiated. Generally only those faults are shown which displace units younger than **Tcr** or which form contacts between older geologic units.

CONTOUR INTERVAL 200 FEET
WITH SUPPLEMENTARY CONTOURS AT 100 FOOT INTERVALS

TRANSVERSE MERCATOR PROJECTION

BLACK NUMBERED LINES INDICATE THE 10,000 METER UNIVERSAL TRANSVERSE MERCATOR GRID, ZONE 11

1970 MAGNETIC DECLINATION FROM TRUE NORTH VARIES FROM 19½° (350 MILS) EASTERLY FOR THE CENTER OF THE WEST EDGE TO 19° (340 MILS) EASTERLY FOR THE CENTER OF THE EAST EDGE

Sources of data used in compilation of map. See bibliography in text.

Brown and Thayer (1966a)
Brown and Thayer (1966b)
Thayer and Brown (1966c)
Brooks and Ferns (1979)
Brooks and Ferns (1981)
Brooks and others (1979)

CANYON CITY, OREGON
1955
REVISED 1970

Canyon City
Field reconnaissance by
Saleem M. Farooqui, Russell C. Bunker
Shannon and Wilson, Inc., 1980 and 1981
Map compilation by
James L. Bela
Oregon Department of Geology and Mineral Industries
1981

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DONALD A. HULL, STATE GEOLOGIST

POST-COLUMBIA RIVER BASALT GROUP STRATIGRAPHY AND MAP COMPILATION OF THE COLUMBIA PLATEAU, OREGON

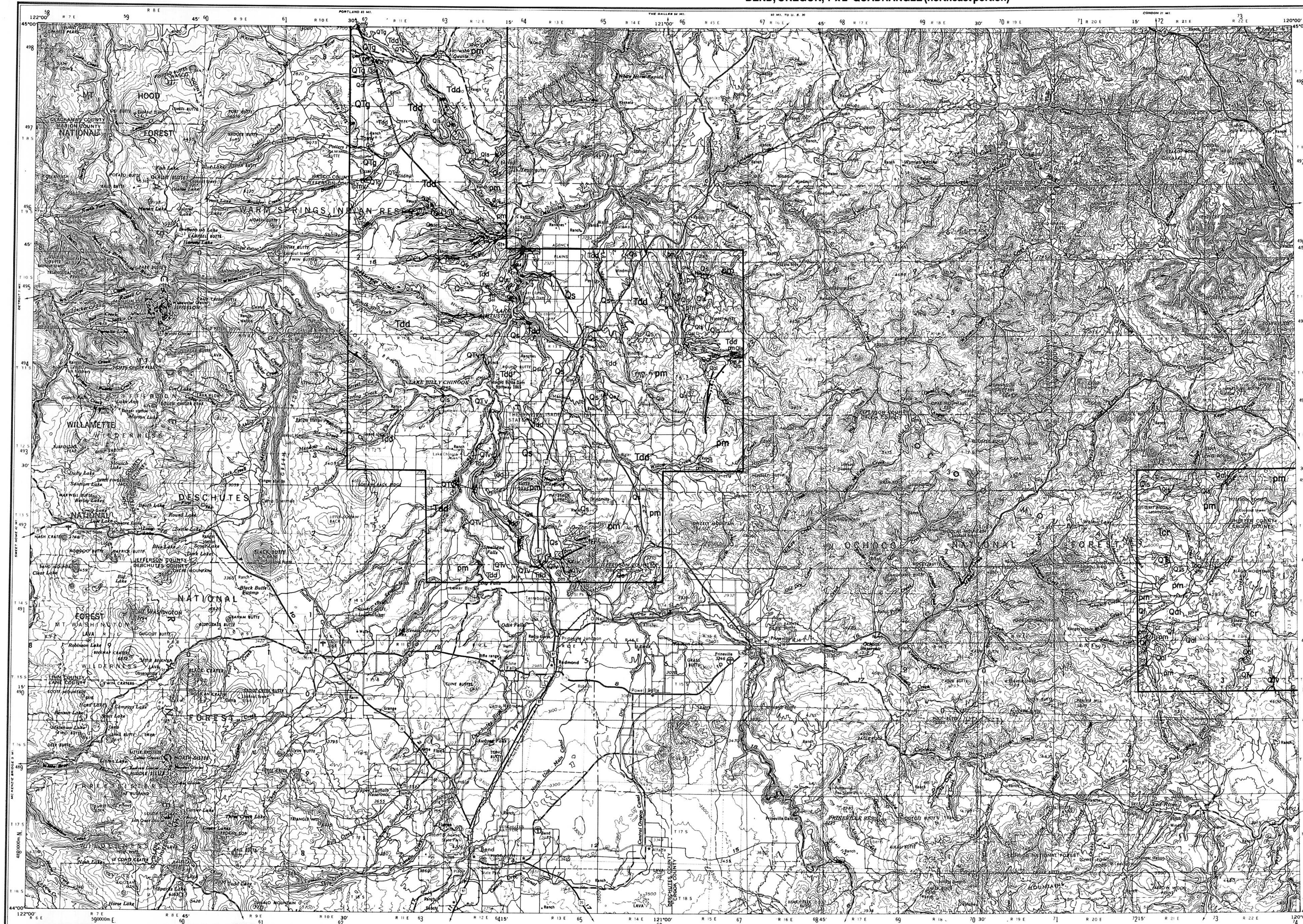
O-81-10

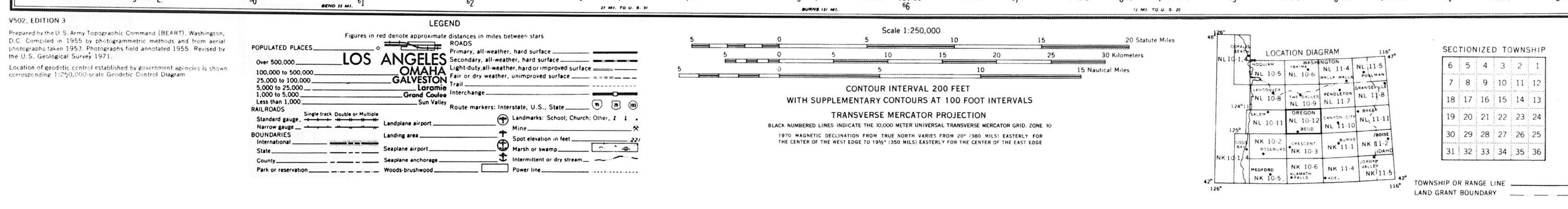
RECONNAISSANCE GEOLOGIC MAP OF THE LATE CENOZOIC SEDIMENTS AND VOLCANIC ROCKS OVERLYING COLUMBIA RIVER BASALT GROUP IN NORTHEASTERN OREGON

PLATE VI

WESTERN UNITED STATES 1:250,000

BEND, OREGON, 1°x 2° QUADRANGLE (northeast portion)





BEND

EXPLANATION

Qal — ***Alluvium:** *Unconsolidated silt, sand, and gravel in channels and flood plains along present intermittent and perennial streams; forms extensive broad valley fill at Big Summit Prairie. Locally includes lacustrine, paludal, and colluvial deposits as well as terrace sediment (**Qts**) where terraces are not mapped separately. Basal alluvium frequently consists of angular to rounded granule- to cobble-size material, grading upward to massive to horizontally bedded gravelly sand and then sand and silt*

Qts — ***Terrace sediment:** *Unconsolidated to semiconsolidated silt, sand, and gravel underlying fill terraces along present rivers and streams; oldest terrace sediment occasionally caliche cemented; younger terrace sediment commonly contains lenticular volcanic ash beds; generally restricted to perennial streams or rivers; most common along Shitike Creek near Warm Springs, where multiple terraces occur*

Qf — **Alluvial fan deposits:** *Primarily unconsolidated sand and angular basalt gravel in active alluvial fans; usually poorly sorted and bedded; commonly contains volcanic ash; locally includes erosional remnants of inactive fans. Deposits range from small fans at the mouths of streams in side canyons of larger drainages to more extensive deposits covering 5 to 12 sq mi at the base of mountainous terrain. Here limited to deposits up to 1 sq mi in area in vicinity of Big Summit Prairie*

Qls — **Landslide deposits:** *Mostly unstratified, unsorted mixture of basaltic, andesitic, sedimentary, and tuffaceous bed rock. Some slides retain stratigraphic relations of units involved. Includes rock topples and rock falls; rock, debris, and earth slumps; and debris and earthflows; largest rock slumps and earthflows are common where basalt flows or welded tuff overlie clayey, tuffaceous interbeds or underlying units. Large landslide areas typical of basalt are common along the Deschutes River near Pelton Dam and south of Warm Springs, along the Warm Springs River and Shitike and Seekseequa Creeks, and north of Big Summit Prairie. Deposits in vicinity of Teller Butte are related to tuff and tuffaceous sedimentary rock of the John Day Formation (**pm**). Dissection suggests Pleistocene age; major movement probably Pleistocene, but Holocene slides probably also included. Some landslides still active. Landslide areas may include areas with extensive colluvial cover as well*

Qs — **Quaternary sediment:** *Undifferentiated and generally thin deposits 1 to 6 ft thick of fluvial silt, sand, and gravel; loess; slope wash; and residual soil veneering plateaulike surfaces atop the Deschutes Formation (**Tdd**) in the Madras area. Thin deposits north of Lake Billy Chinook not mapped; mostly residual soil 0.5 to 2 ft thick in vicinity of Juniper Butte and Haystack Reservoir*

QTg — **Gravel deposits:** *Predominantly poorly to well-sorted, unconsolidated to semiconsolidated, sandy andesite- and basalt-boulder gravel deposited by streams emerging from the Cascade Mountains to the west. Forms an eastward-thinning wedge atop bench-forming basalt flows of the Deschutes Formation (**Tdd**) in the Warm Springs Indian Reservation. Thickness varies from 1 to 100 ft but frequently is only 1 to 10 ft. Includes QTg of Robison and Laenen (1976) and Qg of Waters (1968a). Probably Pliocene or Pleistocene age*

QTs — **Sedimentary deposits:** *Undifferentiated terrace, pediment, glacial outwash, water-laid tuff, alluvial fan, slope-wash, and colluvial deposits. Generally confined to intra- or intermontane basins. Here unit is limited to Big Summit Prairie, where it includes Qf of Swanson (1969). Ages uncertain; dissected nature of some deposits suggests Pliocene to middle (?) Pleistocene age*

QTv — **Volcanic rocks and deposits:** *Undifferentiated andesite, olivine basalt, and basaltic andesite flows; basaltic and andesitic cinder cones; breccia; tuff breccia; volcanic debris flows; and rhyolitic ash-flow tuff. Here primarily limited to intracanyon olivine basalt flows prominent along the present-day Crooked and Deschutes Rivers, where the unit includes Qb of Peterson and others (1976) and QTb of Robinson and Stensland (1979) and part of Tdb and Qob of Waters (1968a) and Qyb of Williams (1957). Also includes Qtb and Twt of Swanson (1969) near Big Summit Prairie. Ages uncertain; probably late Miocene to late Pleistocene. One sample from Crooked River intracanyon basalt flow near Cove Palisades State Park K/Ar-dated at 7.1 ± 1.8 m.y. (this study)*

Tdd — **Deschutes Formation:** *Distinctively fluvial, prominently bedded volcaniclastic and sedimentary rock within the broad Madras basin. Predominantly poorly sorted, cross-bedded basaltic, andesitic, and pumiceous sand and gravel; includes interbedded volcanic mudflow deposits; welded and nonwelded ash-flow tuffs; capping intracanyon and plateau-forming basalt flows; basaltic intrusions and cinder cones; volcanic breccias; vitric, lithic, and lapilli tuff; and diatomite. Rock types complexly interbedded with rapid lithofacies changes; individual rock-type units commonly lenticular or wedge shaped and 3 to 65 ft in thickness. Colors of fluvial sediments are gray, dark gray, tan, and white, alternating with individual beds. Volcanic vents include Round Butte and a vent located just south of Teller Butte. Total thickness variable from 100 to 1,000 ft, with maximum reported thickness near Warm Springs. Unconformably overlies pre-Columbia River Basalt Group (**pm**) rocks of the John Day and Clarno Formations, with prominent red saprolite marking top of Clarno Formation. Also unconformably overlies Columbia River Basalt Group (**Tcr**). Includes Deschutes Formation of Stensland (1970), QTd of Peterson and others (1976), Tms of Robinson and Stensland (1979), QTm and QTmt of Williams (1957), and Tob and Td of Waters (1968a). Age of unit is middle Miocene to early Pliocene; flora dated as early to middle Pliocene (Chaney, 1938, 1944, 1959). K/Ar dates includes 4.3 and 5.3 m.y. (Evernden and James, 1964); 4.9 ± 0.5, 5.8 ± 1.0; 15.9 ± 3.0 m.y. (Armstrong and others, 1975); and 8.9 ± 1.0, 10.7 ± 1.2, 13.2 ± 1.5 m.y. (this study)*

Tpmv — **Volcanic rocks:** *Andesite flows along the eastern margin of the Cascade Range; disconformable on the Deschutes Formation (**Tdd**). Unit includes Qta of Robison and Laenen (1976) and Ta of Waters (1968a). Inferred late Tertiary age based on (1) stratigraphic position above middle Miocene to early Pliocene Deschutes Formation (**Tdd**); and (2) possible stratigraphic equivalence to 3.9-m.y.-old central High Cascades volcanic rocks (Taylor, 1980)*

Tcr — **Columbia River Basalt Group:** *Thick tholeiitic flood-basalt (Grand Ronde (?)) sequence of Miocene age; minor sedimentary interbeds of Waters (1968a) are here included with the basalt flows for convenience only. Includes Tcr of Farooqui (1980), Robinson (1975), Robinson and Stensland (1979), Robison and Laenen (1976), Waters (1968a), and Williams (1957); Tcp of Swanson (1969); and Mcb of Hodge (1941); unit also partially includes Tpp of Peterson and others (1976)*

pm — **Pre-Miocene, pre-Columbia River Basalt Group rocks:** *Undifferentiated Paleozoic, Mesozoic, and early Cenozoic metamorphic, plutonic, volcanic, and sedimentary rocks. Early Cenozoic rocks here include the Clarno and John Day Formations of Eocene to early Miocene age. The John Day Formation generally consists of varicolored air-fall and waterlaid ash and tuff, welded tuff, and volcanic (rhyolite) flows; it overlies a prominent red saprolite developed on top of the underlying Clarno Formation. The Clarno Formation consists of altered dark, greenish-gray andesite and basalt, flow breccia, mudflows, tuff, and tuffaceous sedimentary rock*

* *Generally only those alluvium and terrace sediment deposits wider than 0.1 to 0.25 mi (500 to 1,600 ft) can be shown due to scale; instead stream symbols indicate presence of more limited deposits*

Sources of data used in compilation of map. See bibliography in text.

Hodge (1942)	Robison and Laenen (1976)
Peterson and others (1976)	Swanson (1969)
Robinson (1975)	Waters (1968a)
Robinson and Stensland (1979)	Williams (1957)

Contact

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Bend
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