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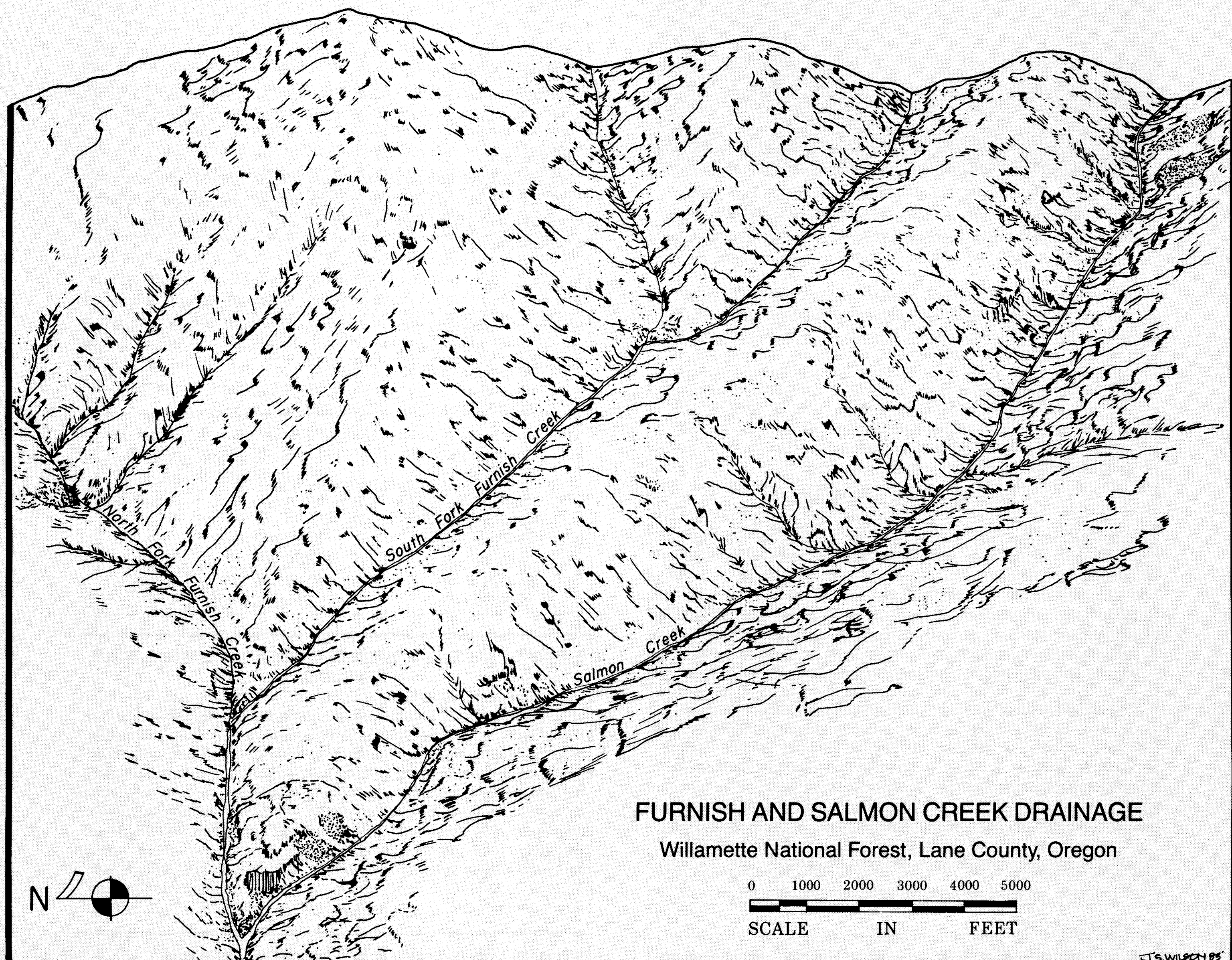

THIS MONTH:

PLEISTOCENE INTERGLACIAL VOLCANISM IN THE CENTRAL OREGON HIGH CASCADES

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The style to be followed is generally that of U.S. Geological Survey publications (see the USGS manual *Suggestions to Authors*, 6th ed., 1978). The bibliography should be limited to "References Cited." Authors are responsible for the accuracy of their bibliographic references. Names of reviewers should be included in the "Acknowledgments."

Authors will receive 20 complimentary copies of the issue containing their contribution. Manuscripts, news, notices, and meeting announcements should be sent to Beverly F. Vogt, Publications Manager, at the Portland office of DOGAMI.

COVER PHOTO

Sketch of the drainage area of Furnish and Salmon Creeks near Oakridge, Lane County, Oregon. In the ridge between Salmon Creek and South Fork Furnish Creek, informally known as Quick Ridge, lava flows have been found interlayered with glacial deposits. See article beginning on next page. (Diagram by Jeff S. Wilson, ASLA)

OIL AND GAS NEWS

Columbia County—Mist Gas Field

The redrill of Reichhold Energy Corporation's Adams 32-34 in NE¼ sec. 34, T. 7 N., R. 5 W., was dry and was abandoned September 14, 1984, at total depth of 3,109 ft.

Concurrently with the activity at the Adams well, Reichhold was also redrilling Paul 34-32, in SE¼ sec. 32, T. 7 N., R. 5 W., a former producer that developed water problems. Two redrills, to 2,915 and 2,719 ft, were unsuccessful. The well was plugged and abandoned September 26, 1984.

Douglas County

Amoco Production Company's Weyerhaeuser 1-13, located in SW¼ sec. 13, T. 25 S., R. 9 W., is drilling ahead to a projected total depth of 13,500 ft. Amoco has recently changed the name of this well to Weyerhaeuser "B" No. 1.

Hutchins and Marrs' Great Discovery 2 in NW¼ sec. 20, T. 30 S., R. 9 W., drilled to a total depth of 3,510 ft, remains idle.

Lane County

Leavitt Exploration & Drilling's Maurice Brooks 1 in sec. 34, T. 19 S., R. 3 W., a 3,000-ft test, encountered mechanical problems after drilling to a total depth of 952 ft. Operator is preparing to plug and abandon.

Recent permits

Permit no.	Operator, well, API number	Location	Status, proposed total depth (ft)
273	Oregon Nat. Gas Dev. Corp. Buck 44-16 36-047-00016	SE¼ sec. 16 T. 5 S., R. 2 W. Marion County	Location; 3,500.
274	Oregon Nat. Gas Dev. Corp. Cunningham 32-21 36-047-00017	NE¼ sec. 21 T. 5 S., R. 2 W. Marion County	Location; 3,500.
275	Oregon Nat. Gas Dev. Corp. Catchpole 13-22 36-047-00018	SW¼ sec. 22 T. 5 S., R. 2 W. Marion County	Location; 3,500.
276	Steele Energy Corp. Keys #1 36-069-00008	NW¼ sec. 28 T. 9 S., R. 23 E. Wheeler County	Location; 8,000.

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Pleistocene interglacial volcanism: Upper Salmon Creek drainage, Lane County, Oregon

by Michael T. Long and Mark A. Leverton, U.S. Forest Service, Willamette National Forest, South Engineering Zone, 49098 Salmon Creek Road, Oakridge, Oregon 97463

INTRODUCTION

The lava flows and glacial deposits described in this paper are located in the upper Salmon Creek drainage, approximately 12 mi east of Oakridge, Lane County, Oregon, in secs. 35 and 36, T. 20 S., R. 5 E.; and secs. 1 and 2, T. 21 S., R. 5 E. (Figure 1). The area lies above an elevation of 2,500 ft within the High Cascade province, which was formed by the Quaternary eruptions of the High Cascade volcanoes (Williams, 1957). Remnants of alpine glacial activity, in the form of till deposits in road cuts, ground and end moraines, outwash sediments, proglacial lake deposits, and several cirques in the upper valleys of the adjoining Black and Ranger Creeks (Figure 2), are prominent in the area.

In this study, the authors have attempted to bracket the age of two early glacial advances in the study area by means of radiometric dating, paleomagnetic measurements, and petrographic analyses of samples taken from three interglacial lava flows which lie above and beneath till deposits of these advances. A third glacial advance, the most recent to occur, was also identified, and the date of this advance was inferred by (1) stratigraphic position, (2) correlation with periods of high ice accumulation as determined by Birchfield and others (1981) from the oxygen-isotope record obtained from equatorial Pacific drill core, and (3) correlation with the Cascade glacial advances identified by other workers. The study is site specific in nature, and it is the intent of the authors to expand the area of study in a future project.

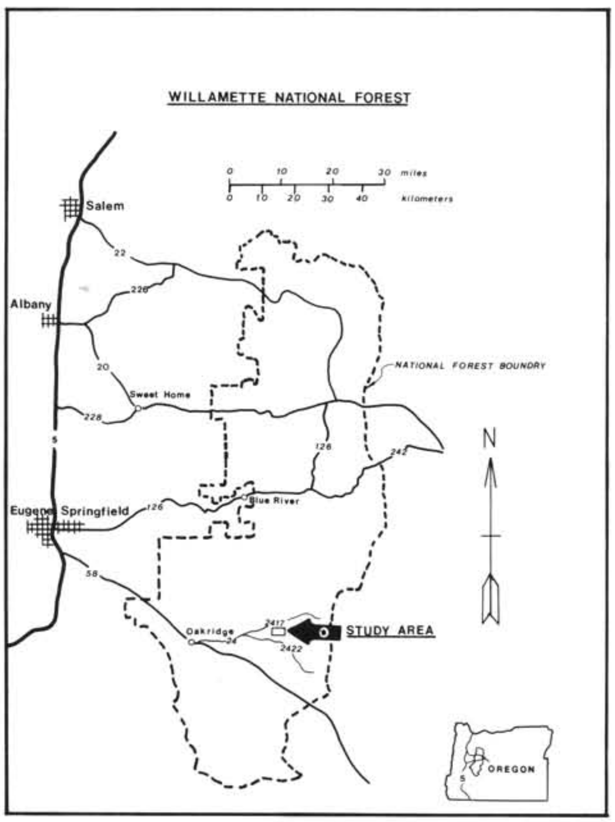

Figure 1. Map showing location of study area.

Figure 2. Upper Salmon Creek basin, showing glacially contoured topography and collapsed slopes due to removal of lateral support after ice recession.

PREVIOUS WORK

During the Quaternary, the topography of the Cascade Range in Oregon and Washington was altered by igneous activity and glacial processes. At least three Pleistocene periods of major alpine glacial advance have been identified by previous workers. Thayer (1939) described three Pleistocene glacial periods which occurred in the North Santiam River Basin of western Oregon. He named these periods the Mill City, Detroit, and Tunnel Creek (late Wisconsin) glaciations. The Mill City advance, which was the most extensive, left till ranging in thickness from 175 to 200 ft. Thayer described such glacial features as outwash gravels, varved lake silts, terminal moraines, and glacial erratics. He estimated ice thickness in the High Cascades to have been between 500 and 1,000 ft. Page (1939) also recognized three main glacial advances, the Peshastin, Leavenworth, and Stuart glaciations, in his study of the Wenatchee Valley area of eastern Washington. Such alpine glacial features as cirques, striated rock surfaces, lakes which were not filled with sediments, swamps, meadows, and abandoned stream valleys filled with glacial deposits were noted in his study area. He estimated ice thickness in the area to have been greater than 1,000 ft.

Mackin (1941) showed that the alpine glaciers of western Washington did not contribute to the Puget Lowland glacier that was part of the continental ice sheet. He recognized and described bedded clay and silt deposits in the Snoqualmie Valley, interpreting them as varves. These varves were interfingered with and overlapped by till and outwash gravels, which Mackin interpreted as evidence of several oscillations of the ice front. He also concluded that the earlier glacial stages were larger and more extensive than later ones.

From differences in the degree of weathering of till deposits, Crandell (1965) inferred the existence of three periods of glaciation in the Olympic Mountains during the Pleistocene. He also postulated that an extensive Pleistocene ice sheet had covered the High Cascades of Oregon from Olallie Butte in the north to Mount McLoughlin in the south.

During the last 20 years, more advanced and readily available dating and stratigraphic techniques—such as potassium-argon

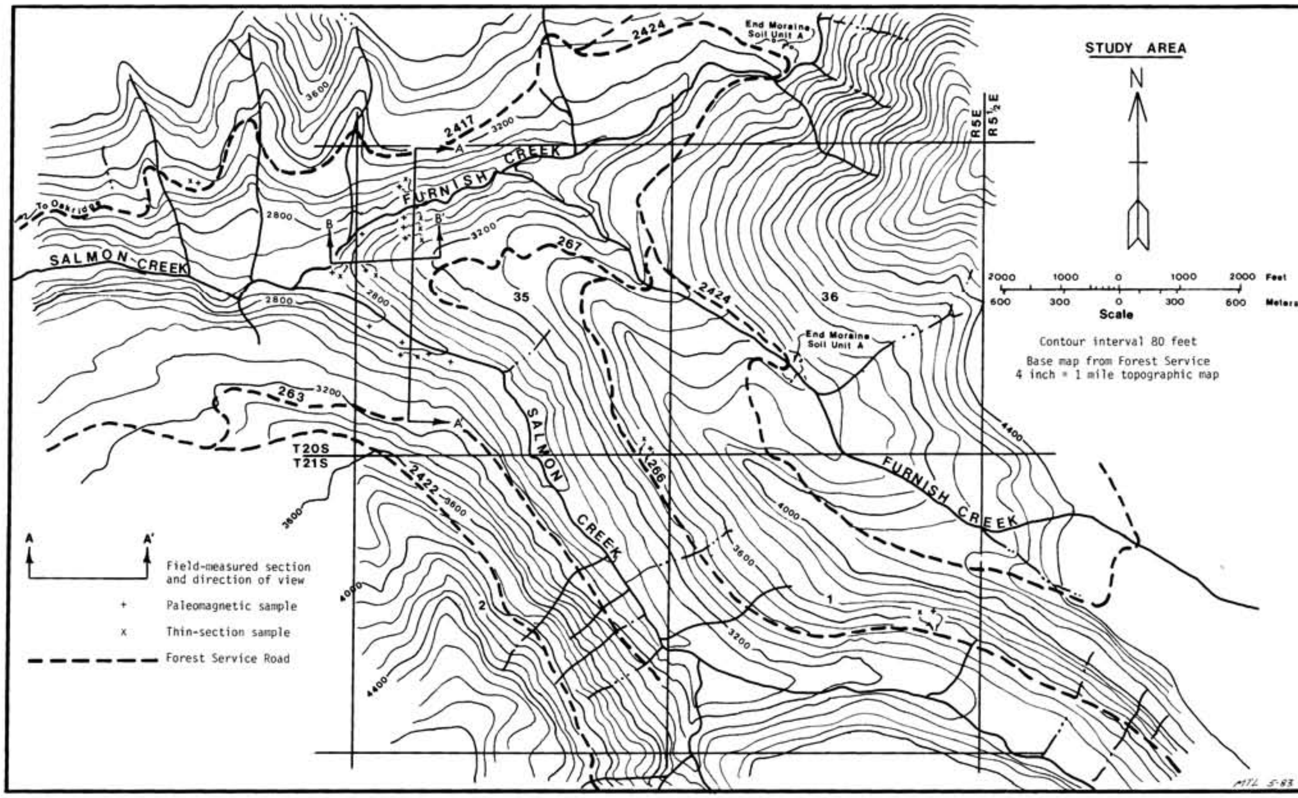

Figure 3. Map of study area showing locations of features discussed in text. Cross sections appear in Figure 4.

(K-Ar) dating, paleomagnetism, atomic-absorption spectrophotometry, and the oxygen-isotope record used to infer periods of high ice accumulation – have made it possible for workers to assign tentative ages to the various Cascade alpine glacial stages. Porter (1975) developed a method by which the weathering rind on the rock fragments within a till deposit could be measured and statistically correlated with other local deposits. He used this method, as well as several other techniques, to describe and correlate three glacial advances (Thorp, Kittitas, Lakedale) in the Yakima Valley of southern Washington (Porter, 1976). Porter found the Thorp Drift to be older than 700,000 years, based on paleomagnetic evidence. He assigned the Kittitas Drift a tentative age of greater than 120,000 years, based on the global marine record of glacial and interglacial stages and correlated it with the Salmon Springs Drift of the Puget Lowland of western Washington. The Salmon Springs Drift was first described by Crandell and others (1958) and had been used by other workers to correlate glacial events that occurred before the last advance of the continental ice sheet. Although the Salmon Springs Drift had been considered to be early Wisconsin (Easterbrook and others, 1967; Easterbrook, 1969; Birkeland and others, 1971; Porter, 1971), Porter (1976) noted that, based upon current evidence, a pre-Wisconsin date could not be ruled out. Easterbrook and others (1981) have recently dated the tephra beds within the Salmon Springs Drift by fission-track methods at 840,000 ± 210,000 years before the present (B.P.). They also noted that the overlying silt beds are reversely magnetized, indicating that the Salmon Springs glacial advance occurred more than 730,000 years ago. The Lakedale Drift of Porter's (1976) study in the Yakima Valley is believed to be between 13,500 and 15,000 years old, based on radiocarbon dating of wood found within glacial gravel, and can be correlated to the Vashon Drift of the Puget Lowland.

Scott (1977) reported evidence of three major glacial advances in the Metolius River area on the eastern side of the High Cascades in Oregon. He observed igneous extrusions and pyroclastic depositions that occurred during two Pleistocene interglacial periods. Scott's methods of dating included statistical analysis of weathering rinds, soil development on moraine crests, and atomic-absorption spectrophotometry of the free iron oxide within the soil profile on till layers. Based on the oxygen-isotope record of the equatorial Pacific, he assigned tentative ages of less than 30,000 years to the Cabot Creek glaciation, 40,000 to 200,000 years to the Jack Creek glaciation, and 200,000 to 900,000 years to the Abbott Butte glaciation. He stated that it was "unlikely, although remotely possible that Abbott Butte glaciation is as young as 120,000 to 200,000 years... but it could have occurred at any time during the high ice periods from 120,000 to 1 million years" (Scott, 1977).

EXPLORATION

A ridge at the confluence of Salmon and Furnish Creeks, informally known as Quick Ridge (Figure 3), was initially investigated by the Geotechnical Group of the Willamette National Forest Supervisor's Office for potential use as a rock quarry for road construction material. The exploration, which was conducted May 28, 1981, to June 18, 1981, consisted of a site survey, area mapping, and diamond core drilling (Long, 1981). Additional field work was done in 1982.

Site survey

The site was surveyed with a Brunton compass, clinometer, and cloth tape. A baseline and two field-measured cross sections (Figure 4) were completed, and a topographic map of the area was constructed from the data at a scale of 1 in. = 50 ft. Vertical control was established by setting a temporary bench mark on a 5-ft stump on the south side of Forest Service Road 2424267 near the west edge of an existing clear cut. The temporary bench mark elevation (3,120 ft) was taken from the nearest 80-ft contour line of a Forest Service topographic base map (scale: 4 in. = 1 mi).

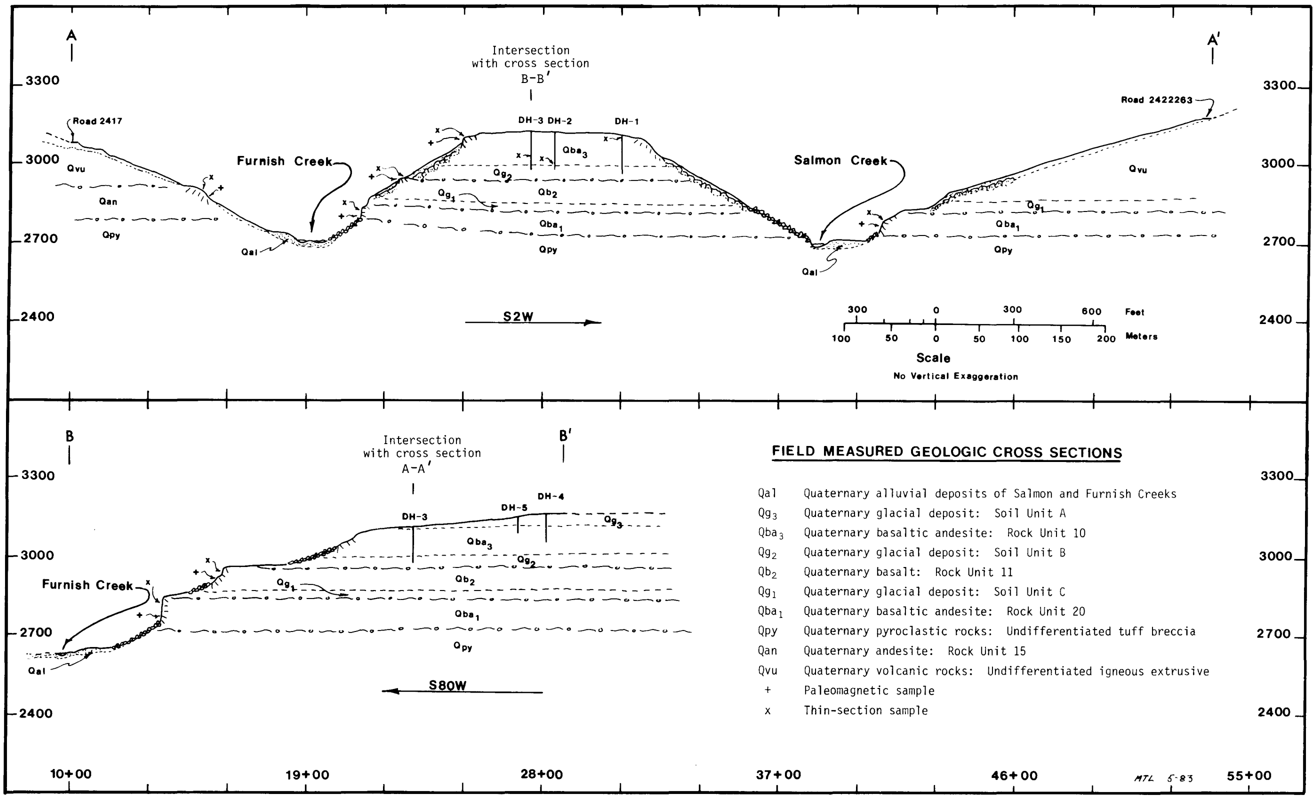

Figure 4. Field-measured cross sections. Locations of lines A-A' and B-B' are shown in Figure 3.

Area mapping

During the site survey, it was noted that Quick Ridge was composed of a series of lava flows, which were designated Rock Units 10, 11, and 20 (also referred to as RU-10, RU-11, RU-20) in descending order of elevation, as each would be encountered in the drilling operation. (Rock Unit 20 was assigned a number out of sequence in order to identify it as visually distinct from the overlying units.) These flows are separated from each other by deposits of glacial till which were similarly designated Soil Units A, B, and C (also referred to as SU-A, SU-B, SU-C) (Figures 4 and 5).

ROCK UNITS

High Cascade volcanism has occurred during the past 2 to 3 million years with a high episodic maximum occurring during the last 1.5 million years (McBirney and others, 1974). Priest and others (1982) informally termed this volcanic episode "the late High Cascade episode" and dated its beginning at 4 million years ago. The authors' work in the study area suggests that RU-10, -11, and -20 of Quick Ridge were extruded from late High Cascade volcanoes from approximately 600,000 to more than 730,000 years ago.

In this report, classification of these rock units is based on the Ab/An ratio of the plagioclase phenocrysts, assuming that the average composition of plagioclase in basalts is more calcic than Ab_1An_1, while in andesites it is more sodic. When chemical analysis is available, a silica content less than 52 percent denotes basaltic composition (Williams and others, 1954). Classification of RU-10 was confirmed by silica content (Table 1).

Natural remanent magnetism of all rock units was measured at the outcrop by fluxgate magnetometer. Oriented samples were measured in the laboratory for confirmation of field readings. RU-10 and RU-11 were determined to have normal magnetic polarity. RU-20 was found to have reversed magnetic polarity, which indicates an age greater than 730,000 years (Mankinen and Dalrymple, 1979). A K-Ar date of 675,000 ± 12,000 years B.P. was obtained from RU-10. This date provided a means to bracket events between 730,000 and 675,000 years. Age, thickness, and petrography of each rock unit are included in Table 2.

Table 1. *Chemical composition of Rock Unit 10 in weight percent (X-ray fluorescence analysis by University of Oregon. All iron as Fe_2O_3)*

SiO_2	52.19
TiO_2	0.88
Al_2O_3	17.14
MgO	7.09
Fe_2O_3	7.95
MnO	0.12
CaO	8.84
Na_2O	3.62
K_2O	0.75
P_2O_5	0.24
Loss	0.20
Total	99.02

Table 2. *Rock unit data*

Rock Unit 10 (RU-10)	
Rock type:	Basaltic andesite (see Table 1)
Magnetic polarity:	Normal
Age:	675,000 ± 12,000 years
Thickness:	Approximately 120 ft
Description:	Outcrops are exposed along Quick Ridge and Forest Service Road 2424266. A local strike and dip of N. 25° E. 2° NW. was measured from the bottom contact exposed in the roadcut. In hand sample, RU-10 is visually distinct from RU-11 and RU-20, being light gray with phenocrysts of plagioclase and olivine.
Petrography:	RU-10 contains up to 62 percent plagioclase laths, ranging in length from 0.1 to 1 mm. Composition of the plagioclase grains ranges from An_{38-28} near the top of the flow to An_{67-52} near the bottom of the flow.

	Glomerocrysts of plagioclase grains with olivine are common, occasionally with granular pyroxene. Small amounts of brown interstitial glass are found between some plagioclase grains. Olivine (up to 10 percent) is anhedral to subhedral, ranging from 0.1 to 1 mm in size. Near the top of the flow, olivine is cracked and deeply embayed, with extensive alteration to iddingsite and magnetite. Orthopyroxene rims are common, and partial to total replacement by magnetite occurs in some grains, particularly groundmass olivine. Near the bottom of the flow, olivine grains are anhedral to subhedral and somewhat embayed. Magnetite inclusions and orthopyroxene rims are scarce, and groundmass olivine is relatively unaltered. Hypersthene (up to 15 percent) occurs in the groundmass and as microphenocrysts (Figure 6).
Rock Unit 11 (RU-11)	
Rock type:	Basalt
Magnetic polarity:	Normal
Inferred age:	715,000±15,000 years. This age has been inferred from the following evidence: (1) RU-11 lies between Soil Units B and C, which are assumed to have been deposited during periods of high ice accumulation and which have been assigned inferred ages of 685,000-700,000 years and 730,000-750,000 years, respectively. (2) RU-11 is bracketed by the age of RU-10 and the paleomagnetic polarity boundary of 730,000 years B.P. (3) This age correlates with the $^{16}O/^{18}O$ record of Schackleton and Opdyke (1973).
Description:	RU-11 is exposed on the north side of Quick Ridge and at the confluence of Furnish and Salmon Creeks. Outcrops are medium gray and blocky jointed, and rocks are fine grained in hand sample.
Petrography:	RU-11 is characterized by abundant olivine (up to 8 percent) occurring with calcic plagioclase. The olivine grains are anhedral to subhedral and are typically cracked and embayed. Iddingsite and magnetite are common and were observed as reaction rims and embayments in the cracks. Plagioclase (up to 61 percent) occurs as laths ranging from 0.1 to 0.5 mm in length. The composition is generally An_{52-54}. Up to 15 percent of RU-11 is composed of subophitic augite up to 2 mm in diameter.
Rock Unit 20 (RU-20)	
Rock type:	Basaltic andesite
Magnetic polarity:	Reversed
Minimum age:	775,000 years, based on the paleomagnetic reversal boundary and the inferred age of overlying SU-C.
Thickness:	80 ft
Description:	RU-20 has reversed magnetic polarity. Outcrops are found along the north side of Quick Ridge, the south bank of the Salmon Creek flood plain, and the confluence of Furnish and Salmon Creeks. The dip is approximately 8° WSW., with the bottom contact exposed for 200 ft along Furnish Creek. RU-20 outcrops are medium gray with columnar jointing, and rocks are fine grained in hand sample. Slope collapse has obscured the nature of the underlying rock unit, but small exposures in the creek beds along the north bank of Furnish Creek indicate a pyroclastic origin.
Petrography:	In thin section, RU-20 contains up to 9 percent olivine, ranging from 0.1 to 1 mm long, with inclusions of magnetite less than 0.1 mm in size. Olivine is anhedral to subhedral, with the margins typically iddingsitized. Plagioclase (up to 60 percent) ranges from 0.1 to 0.4 mm in length and shows normal zoning (An_{55-40}). Cloudy brown glass is found in many interstices between plagioclase laths and accounts for 2 percent of the rock. Subophitic augite with plagioclase laths is common and ranges up to 0.3 mm in size.

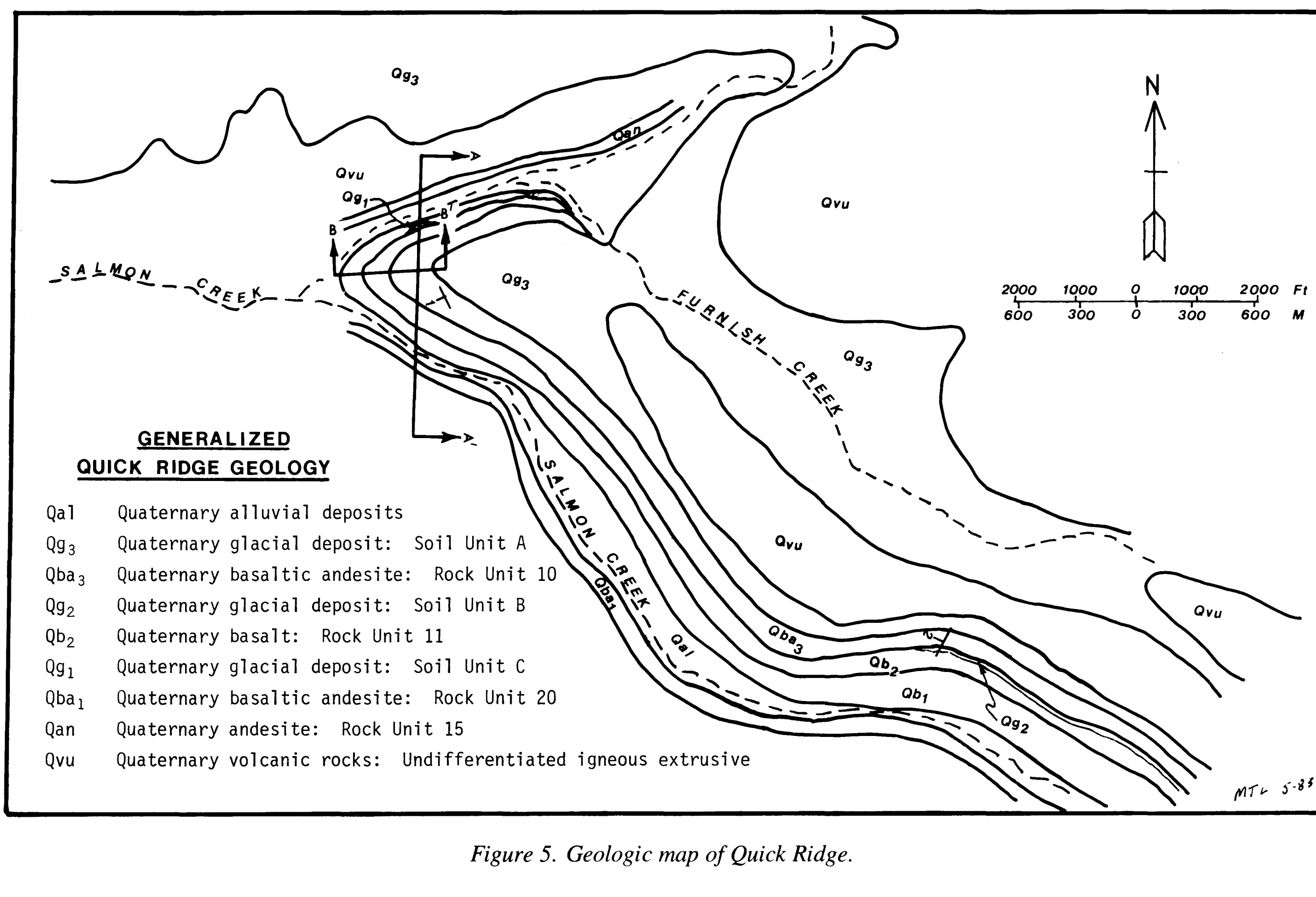

Figure 5. Geologic map of Quick Ridge.

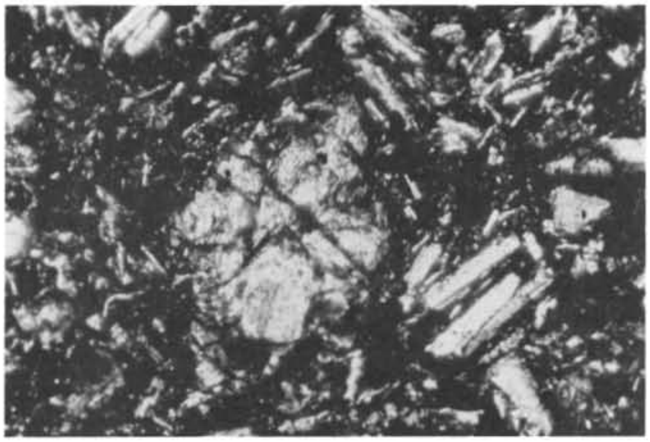

Figure 6. Photomicrograph of sample from Rock Unit 10. Actual size of large olivine phenocryst=0.25 mm.

SOIL UNITS

The area above an elevation of 3,000 ft is covered by a layer of glacial till which ranges in thickness from 3 to 40 ft. This upper layer was designated Soil Unit A (SU-A) and is found in extensive deposits (Figure 7). An end moraine was recognized in the Furnish Creek valley on Road 2424 immediately west of the Furnish Creek bridge (Figure 8). Approximately 2 mi south, another end moraine is present on Road 2424 (Figure 3). The channel of the south fork of Furnish Creek has been filled with deposits from the most recent glacial advance. This is evident from the asymmetry of Quick Ridge and the extensive erosion of the south side by Salmon Creek. Page (1939) described a similar feature in the Chiwaukum Creek (eastern Washington) area of his study.

Approximately 2.2 mi southeast of the drilling site used in the exploration, in a roadcut on Forest Service Road 2424266 at the 3,500-ft elevation, a basaltic andesite flow (RU-10) approximately 90 ft thick was observed overlying a second layer of glacial till (Figure 9). This layer was designed Soil Unit B (SU-B) and was also observed below 2,800 ft along Forest Service Road 2417 in consolidated deposits of till and proglacial lake sediments. Within these sediments, grain size increases toward the top, from clay and silt to cobble and boulder size. In addition to cut-and-fill stratification (Figure 10), rafted fragments are evident in silt-varved sediments (Figure 11). Porter (1976) described similar features in Kittitas deposits of eastern Washington and inferred that increasing grain size toward the top was a response to the advance of the glacial front. The local strike and dip (N. 25° E. 2° NW.) of the RU-10 outcrop on Road 2424266 was noted, and a trace projection was made from the lower contact elevation (3,500 ft) so that an intercept depth could be predicted and correlation be made between the outcrop and the drill hole. Correlation was later confirmed by drill hole contact (RU-10/SU-B), stratigraphic position, mass attitude (by three-point analysis and trace projection), paleomagnetic data, and petrographic analyses of the outcrop and drill core.

Figure 7. Soil Unit A – typical ground moraine.

Figure 8. End moraine near Furnish Creek bridge (Soil Unit A).

A third layer of glacial till was observed during the survey of cross section A-A′ (Figure 4) between Furnish and Salmon Creeks. This layer, designated Soil Unit C (SU-C), lies between Rock Units 11 and 20. SU-C was not observed at any other location in the Upper Salmon Creek basin. Description of the soil units encountered in the study area are included in Table 3. Soil units were classified according to the Unified Soil Classification (American Society for Testing Materials, 1969).

Table 3. *Soil unit data*

Soil Unit A (SU-A)	
Soil type:	Silty sandy gravel with rock fragments
Unified Soil Classification:	GM
Inferred age:	13,500 to 15,000 years
Thickness:	3 to 40 ft
Description:	1- to 12-in., subrounded to rounded, fresh-state to stained-state (Williamson, 1980) rock fragments of High Cascade origin in a strong-brown (7.5 YR 4/6) silty sand (SM) matrix, nonplastic, loose to compact, low dry strength, quick dilatancy.
Soil Unit B (SU-B)	
Soil type:	Silty gravel with rock fragments
Unified Soil Classification:	GW-GM

Figure 9. Rock Unit 10 overlying Soil Unit B.

Figure 10. Cut-and-fill stratification along Forest Service Road 2417.

Table 3. *Soil unit data – continued*

Inferred age:	685,000 to 700,000 years
Thickness:	40 to 50 ft
Description:	1- to 18-in., angular to subrounded, stained-state to partially decomposed state rock fragments in a dark-brown (7.5 YR 4/4) silty sand (SM) matrix, plastic, stiff, medium dry strength, medium dilatancy.
Soil Unit C (SU-C)	
Soil type:	Silty gravel with rock fragments
Unified Soil Classification:	GW
Inferred age:	730,000 to 750,000 years
Thickness:	25 to 30 ft
Description:	1- to 12-in., subrounded to rounded, stained-state to completely decomposed-state rock fragments in a very dark grayish brown (10 YR 3/3) sandy silt (ML) matrix, plastic, stiff, medium dry strength, medium dilatancy.

DRILLING

Subsurface exploration was restricted to RU-10 and was accomplished by using a track-mounted core drill with a 2¾-in. diamond bit and an NQ wireline inner barrel. Three holes were drilled to an average depth of 142 ft to confirm the mass attitude (interpreted from plan and cross-section analysis), rock quality and quantity, and vertical and horizontal distribution of materials. Four additional holes were drilled to an average depth of 67 ft to determine the depth of SU-A and the excavation limits (Figure 12).

Figure 11. Proglacial lake sediments along Forest Service Road 2417, with ice-rafted fragment. Increasing grain size toward top indicates glacial advance.

Figure 12. Quick Ridge at confluence of Salmon and Furnish Creeks. This view is to the north toward Forest Service Road 2417. Drilling exploration occurred at ridge top in clear cut (right center).

The contact between RU-10 and underlying SU-B was penetrated at a depth of 114 ft in drill hole 1, 122 ft in drill hole 2, and 124 ft in drill hole 3, with corresponding elevations of 2,993 ft, 3,000 ft, and 2,997 ft, respectively. These contacts were used to compute a site mass attitude of N. 28° W. 1° SW. An average mass attitude of N. 14° E. 2.5 ° NW. for the Quick Ridge extrusive series was calculated from the elevation of drill-hole contacts and the elevation of the outcrop contact on Road 2424266. This is consistent with an average thalweg of 2.6° (240 ft/mi) for Salmon Creek from 2,800-ft to 2,500-ft elevations. A comparison of the site mass attitude of the Quick Ridge extrusive series supports the conclusion that an erosional surface exists between SU-B and RU-10 and is related to the past Salmon Creek drainage.

AGE DETERMINATION

In order to chronologically bracket the glacial advances in the study area that correspond to SU-B and SU-C, we obtained a K-Ar date for a sample taken from RU-10, took oriented samples from each rock unit at several locations, and measured the natural remanent magnetism of the rock samples with a fluxgate magnetometer. All rock units were identified by petrographic analysis and stratigraphic position in the field-measured sections. The oxygen-isotope record from Pacific drill core was used to assign tentative dates to soil units, based upon periods of high ice accumulation which would imply glacial conditions of deposition.

The sample of RU-10 taken from a core sample from 70 ft below the surface in drill hole 3 (SE¼ SW¼ NW¼ sec. 35, T. 20 S., R. 5 E., at the end of Forest Service Road 2424267) was sent to the School of Oceanography at Oregon State University for K-Ar radiometric dating. The test, which was conducted from October to November 1982, yielded an age of 675,000 ± 12,000 years.

MAGNETIC POLARITY

Paleomagnetism (natural remanent magnetism) is based upon electron spin direction and magnetic moments within the atoms that comprise the magnetic minerals within a rock. As an igneous rock congeals from liquid to solid state, the magnetic minerals within the magma cool through the Curie point, which is the temperature at which the electron spin directions and magnetic moments align themselves within the polarity of the existing magnetic field (Irving, 1964). The polarity of the Earth's magnetic field has reversed at intervals throughout geologic time. The last complete reversal occurred 730,000 years B.P. (Bruhnes-Matuyama polarity boundary) (Mankinen and Dalrymple, 1979).

Four samples, weighing approximately 10 lb each, were oriented with a Brunton compass and taken from outcrops within each rock unit, and the natural remanent magnetic polarity was measured with a fluxgate magnetometer (Doell and Cox, 1967). RU-10 and RU-11 were recorded as normal. Constant reversed meter deflections confirmed that RU-20 was magnetically reversed. This indicates an origin prior to the Bruhnes-Matuyama polarity boundary of 730,000 years B.P.

OXYGEN-ISOTOPE RECORD

The oxygen-isotope ($^{16}O/^{18}O$) record provides a means by which to infer the paleoclimate as it pertains to ice-mass accumulation. The ratio of the isotopes ^{16}O and ^{18}O found in sea water can be determined by measuring the amounts of each isotope contained in the calcium carbonate of planktonic foraminifera tests. $H_2{}^{16}O$, having a higher vapor pressure than $H_2{}^{18}O$, evaporates more easily at lower temperatures; therefore, during periods of widespread glaciation as the temperature decreases, the oceans are enriched with $H_2{}^{18}O$, and $H_2{}^{16}O$ is stored in glacial ice as a result of increased evaporation and precipitation. This results in ^{18}O-rich calcium carbonate secretions in the tests of foraminifera during periods of high ice accumulation. Glacial melt, the result of increased world-wide temperature, increases the amount of ^{16}O present in sea water. This results in ^{16}O-rich calcium secretions during such periods (Flint, 1971).

Schackleton and Opdyke (1973) analyzed drill core from the Pacific Ocean floor and correlated six glacial and interglacial stages with those of Emiliani (1955) in the Caribbean. The correlations of Schackleton and Opdyke were based upon a uniform rate of sedimentation (17.1 cm/10^4 years), magnetic polarity boundaries, and the oxygen-isotope ratio in foraminifera tests. More recently, Birchfield and others (1981) have formulated a model that enables prediction of the growth and decay of ice sheets on a 100,000-year periodicity, based on insolation (solar radiation) anomalies caused by changes in the earth's orbit. Their findings correlate well with the oxygen-isotope record. By referencing RU-10, -11, and -20 to the model of Birchfield and others (1981), a tentative date may be inferred for SU-B and SU-C, based on periods of high ice accumulation (Figure 13).

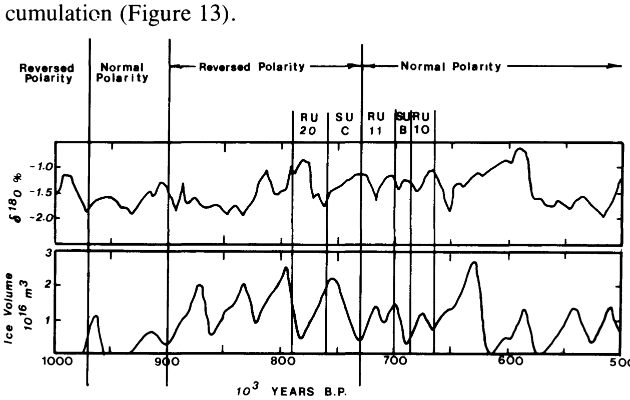

Figure 13. Oxygen-isotope record (top); ice volume prediction (bottom). After Birchfield and others (1981).

CONCLUSION

Based upon K-Ar dating, paleomagnetic stratigraphy, and the indirect correlation with periods of high ice accumulation from the oxygen-isotope record, the glacial advances represented by Soil Units A, B, and C, in the Upper Salmon Creek drainage are assigned the following tentative dates: SU-A, 13,500-15,000 years B.P.; SU-B, 685,000-700,000 years B.P.; SU-C, 730,000-760,000 years B.P. The relationship between these dates and those of other studies is shown in Table 4.

Davie's (1980) study of the Three Fingered Jack area and Avramenko's (1981) study of the Echo Mountain area, both in the central Oregon Cascades, described rock units similar to RU-10, -11, and -20 of this study. Avramenko (1981) correlated his Bunchgrass Ridge unit with the Jorn Lake unit of Davie. This correlation was based upon a K-Ar age of 680,000 years (Lauresen and Hammond, 1978) and normal magnetic polarity. Both of these rock units overlie rock units of reversed polarity (the plateau lavas of Avramenko and the Suttle Lake unit of Davie). Based upon age, magnetic polarity, and petrographic analysis, RU-10, -11, and -20 can be reasonably correlated with the Bunchgrass/Jorn Lake (normal polarity) and plateau lavas/Suttle Lake (reversed polarity) units of Avramenko and Davie.

Davie (1980) also inferred that erosional disconformities may exist between the Suttle Lake unit and Jorn Lake unit and between the Jorn Lake unit and the overlying lower summit series. These disconformities are represented by distinct breaks in the topography and the lack of an intimate contact between the rock units. In the present study, during cross-section analysis, the authors observed that soil and rock unit boundaries occurred at radical slope changes, similar to those described by Davie, and that erosion of the underlying lower strength material resulted in a vertical rock-slope collapse of the overlying rock unit and concealment of the underlying layers beneath a talus slope. This condition may exist in the erosional disconformities of Davie's study.

Soil Unit A is similar in weathering characteristics (rock fragments from fresh to stained state), morphology (distinguishable end and lateral moraines), and geographical location (above 3,000 ft) to other late Wisconsin glacial deposits of Washington and Oregon and can be correlated with the Cabot Creek Glaciation of Scott (1977), the Lakedale Drift of Porter (1976), and the Tunnel Creek Glaciation of Thayer (1939). Soil Unit B may be generally equivalent to the Kittitas Drift of Porter (1976) and the Abbott Butte Glaciation of Scott (1977). Soil Unit C may be generally equivalent to the Thorp Drift of Porter (1976), the lower Portland Hills Silt (Lentz, 1981), and the Salmon Springs Drift of Easterbrook and others (1981).

Refinement of the ages of Soil Units A, B, and C may be made by further study of the area and the adjacent valley of the North Fork Willamette River and by obtaining K-Ar dates from the remaining lava flows in the study area.

Table 4. *Quick Ridge glaciation age correlation with previous studies.*

Years B.P.	Unit of this study	Unit of previous studies	
13,500			
	SU-A	Cabot Creek Glaciation (Scott, 1977) Lakedale Drift (Porter, 1976) Tunnel Creek Glaciation (Thayer, 1939)	
15,000			
665,000			
	RU-10	Bunchgrass Ridge unit (Avramenko, 1981) Jorn Lake unit (Davie, 1980)	
685,000			
	SU-B	Kittitas Drift (Porter, 1976) Abbott Butte Glaciation (Scott, 1977)	
700,000			
	RU-11	Bunchgrass Ridge unit (Avramenko, 1981) Jorn Lake unit (Davie, 1980)	
730,000	-----------	Bruhnes-Matuyama Magnetic Polarity Boundary	(normal) ------------ (reversed)
	SU-C	Thorp Drift (Porter, 1976) Lower Portland Hills Silt (Lenz, 1981)	
760,000			
	RU-20	Plateau lava unit (Avramenko, 1981) Suttle Lake unit (Davie, 1980)	
790,000			
840,000 ±210,000		Salmon Springs Drift (Easterbrook and others, 1981)	
900,000	-----------	Jarmillo Magnetic Polarity Boundary	(reversed) ------------ (normal)

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