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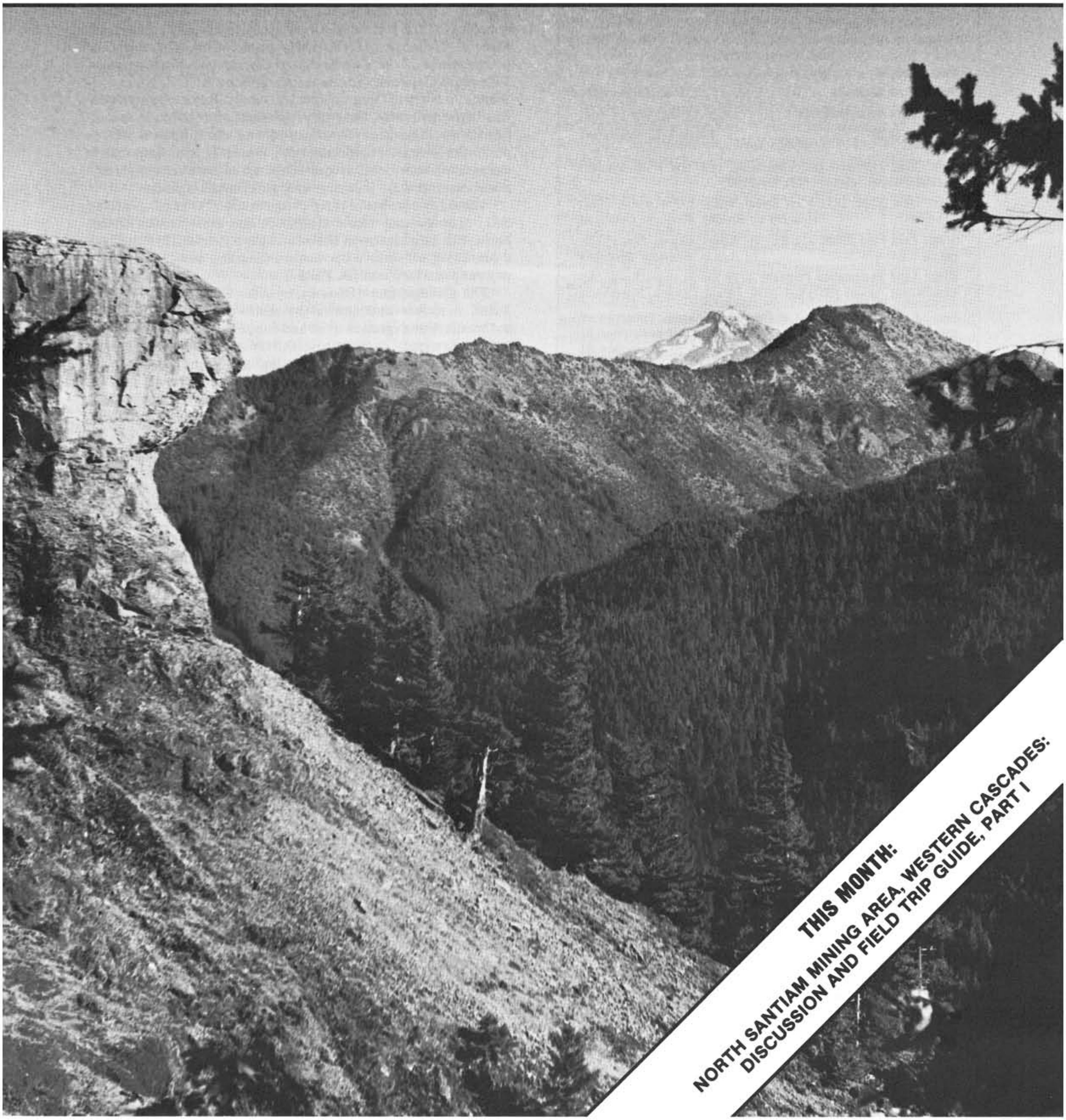

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The style to be followed is generally that of U.S. Geological Survey publications (see the USGS manual *Suggestions to Authors*, 6th ed., 1978). The bibliography should be limited to "References Cited." Authors are responsible for the accuracy of the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

Whetstone Mountain, in foreground, stands almost 1,000 m above North Santiam mining area in the valley below and provides spectacular views of Battle Ax volcano and Mount Jefferson in the distance. Tuffs exposed in this cliff are postulated to have been erupted from a volcanic center contemporaneous with mineralization in the district. Article beginning on next page discusses North Santiam mining area. Field trip guide to the mining area will be printed in January 1986 *Oregon Geology*.

DOGAMI releases study of oil and gas potential of Astoria basin

Discovery of commercial quantities of natural gas in northwest Oregon in 1979 has intensified exploration interest in the Astoria basin, which is located immediately west of the producing gas field at Mist. The lack of detailed published geologic information about this largely unexplored forearc basin in Clatsop and northern Tillamook Counties has been remedied by the release of a new Department of Geology and Mineral Industries (DOGAMI) publication, *Oil and Gas Investigation of the Astoria Basin, Clatsop and Northernmost Tillamook Counties, Northwest Oregon,* by Alan R. Niem and Wendy A. Niem of Oregon State University. Released as Oil and Gas Investigation 14, this study represents more than 13 years of field and laboratory work and the compilation of 18 unpublished master's and doctoral theses. It is an impressive example of coordination and cooperation between university researchers, private industry, and government agencies.

The study consists of three components: (1) Plate 1 — a five-color geologic map (scale 1:100,000) and cross section of the basin with a discussion of the oil and gas potential; (2) Plate 2 — a one-color subsurface correlation diagram; and (3) an eight-page explanatory text for Plate 2.

The geologic map (Plate 1), by Alan R. Niem and Wendy Niem, describes and shows the distribution of 55 Tertiary sedimentary and igneous units and subunits. A complex wrench tectonic system of conjugate northwest- and northeast-trending faults and major east-west-trending oblique-slip faults may approximate the structure of the Mist gas field to the east. A short discussion of potential reservoir units, porosity and permeability, source-rock potential (total organic carbon and maturation), and structure is provided.

The subsurface correlation chart (Plate 2), by Michael W. Martin, Moinoddin M. Kadri, Alan R. Niem, and Daniel R. McKeel, illustrates the subsurface distribution of geologic map units that were encountered in eight widely spaced wells in the Astoria basin. The plate includes detailed lithologic columns of the wells, electric and gamma-ray logs, reported gas shows, paleobathymetric data, and biostratigraphic and lithostratigraphic correlations of the Tertiary units. The diagram shows the major unconformities, the distribution of numerous intrusive basalts and the basement volcanic rocks, facies changes, and pinchouts.

The separate eight-page text, by Alan R. Niem, Wendy A. Niem, Michael W. Martin, Moinoddin M. Kadri, and Daniel R. McKeel, describes and interprets the age, biostratigraphic and lithologic correlations, and log characteristics of the units encountered in the subsurface. Drill-stem tests and gas shows in the wells are analyzed. For example, local thermogenic gas was encountered in some wells in which thick Miocene gabbroic intrusions baked the generally thermally immature sedimentary rocks for hundreds of feet.

Highlights of the report include recommendations of units and both onshore and offshore areas with the greatest hydrocarbon potential, emphasizing distribution and pinchout of the upper Eocene Clark and Wilson sandstone of the Cowlitz Formation, which is the producing unit in the Mist gas field. Other sandstone units may be potential reservoirs in the nearby offshore area, including the Miocene Astoria Formation, which was deposited as a wave-dominated delta of the ancestral Columbia River and associated submarine canyon, shelf, and slope facies.

The new report, Oil and Gas Investigation 14, is now available at the Oregon Department of Geology and Mineral Industries, 910 State Office Building, 1400 SW Fifth Avenue, Portland, OR 97201. The purchase price is $7. Orders under $50 require prepayment. □

North Santiam mining area, Western Cascades — relations between alteration and volcanic stratigraphy: Discussion and field trip guide

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Part I. Discussion*

INTRODUCTION

General

While it has been postulated for some time that porphyry copper mineralization develops beneath subduction-related stratovolcanos, little is known about the subvolcanic environment above the mineralized zones and about the ground surface at the time of mineralization. The nature of fluid movement within the volcanic pile, timing of porphyry mineralization relative to volcanic activity, timing of the development of alteration relative to porphyry and vein mineralization, and possible surface geothermal expressions of the system need evaluation. Uplift of the Western Cascade Range relative to the High Cascade Range, which began approximately 5-4 million years before the present (m.y. B.P.) (Priest and others, 1983), has resulted in a deeply dissected terrain in which more than a kilometer of the stratigraphy overlying the porphyry copper-related mineralization in the North Santiam mining area is preserved and exposed. Thus the mining area provides the necessary setting in which to study the subvolcanic portions of a porphyry copper system.

The North Santiam mining area is located near the headwaters of the Little North Santiam River (Figure 1). Metal mineralization and alteration are zoned and centered on intrusions with associated tourmaline-bearing breccia pipes (Figure 1). Disseminated copper mineralization typical of a porphyry copper deposit has been documented by Callaghan and Buddington (1938) and Olson (1978).

This paper and field trip guide are based on part of a Portland State University master's thesis on the geology and geochemistry of the eastern portion of the mining area (Pollock, 1985). The road log, which will appear in next month's issue, begins near Salem, Oregon, and proceeds to the edge of the mining area. The actual tour of the mining area is on foot and is 4.7 mi each way. An optional side trip by car over French Creek Ridge to Detroit is also included.

In addition to the maps in this guide, it is recommended that 15-minute topographic maps of the Mill City and Battle Ax quadrangles (available from the Oregon Department of Geology and Mineral Industries and many sporting goods stores) and the Willamette National Forest map (available from the Detroit Ranger Station, U.S. Forest Service [USFS]) be used on this trip.

Mining history

The North Santiam mining area is one of five mining districts located in the Western Cascades of Oregon. The geology of the districts and an overview of the mineralization contained therein were presented by Callaghan and Buddington (1938). Current and abandoned workings were described and production from base metal and gold veins was reported by the Oregon Department of Geology and Mineral Industries (1951) and Brooks and Ramp (1968). The history of the mining area has recently been compiled by the Willamette National Forest (Cox, 1985) and the Shiny Rock Mining Company (George, 1985).

Exploration for gold in the North Santiam mining area dates back to the 1860's. The Ruth Vein, which was discovered in the early part of this century near the eastern end of the mining district (Figure 1), has been the focus of mining efforts for zinc and lead periodically since its discovery. Callaghan and Buddington (1938) applied the name "North Santiam mining area" to all the mineral claims along the North Santiam River and its tributaries. However, the area has previously been known by many different names (George, 1985). Claims along the Little North Santiam and its tributaries to the east of Gold Creek are held by the Shiny Rock Mining Company. Jawbone Flats, which was constructed in 1932, originally consisted of more than 30 structures, approximately half of which still remain (Cox, 1985) and are actively used as the mill site and operational headquarters for the claim block. The current ore mill, which was constructed in 1976, utilizes equipment from the original Amalgamated Mill at Jawbone Flats and the Lotz-Larsen Mill, which stood near Gold Creek (Cox, 1985).

Recent exploration in the North Santiam mining area has focused on the potential for porphyry copper mineralization in the central portion of the mining area. Reconnaissance mapping, geological chip sampling, and drilling of two holes totaling 1,255 m were performed from 1976 to 1978 by Freeport Exploration Company under lease agreement with Shiny Rock Mining Company (Decker and Jones, 1977). Amoco Minerals Company, which optioned the Shiny Rock Mining Company claim block beginning in 1980, conducted additional field mapping, soil geochemistry, an induced polarization-resistivity survey, and additional drilling. Ten core holes totaling 1,518 m were drilled during 1981-1982 (Dodd and Schmidt, 1982). Amoco Minerals continues to hold a block of claims, primarily along Cedar Creek, west and south of the Shiny Rock Mining Company claims. Drilling has been conducted, especially at a breccia pipe along Cedar Creek.

GEOLOGIC SETTING

Stratigraphy

Stratigraphic relationships in the Western Cascades reflect the complicated nature of subaerial volcanism and have been further complicated by the stratigraphic names and interpretations proposed by various researchers. A correlation chart presented in Figure 2 shows the regional stratigraphy (Priest and others, 1983).

The strata along the Little North Santiam River are primarily those of the Sardine series of Thayer (1936), as extended by Peck and others (1964). The type locality of the Sardine series was defined at Sardine Mountain located northwest of Detroit. Peck and others (1964) reported the Sardine Formation between the Little North Santiam and the Sandy Rivers as comprising two units, the lower, 300 to 600 m

*Part II, field trip guide, will appear in the next issue (January 1986). References at the end of Part I are for both parts.

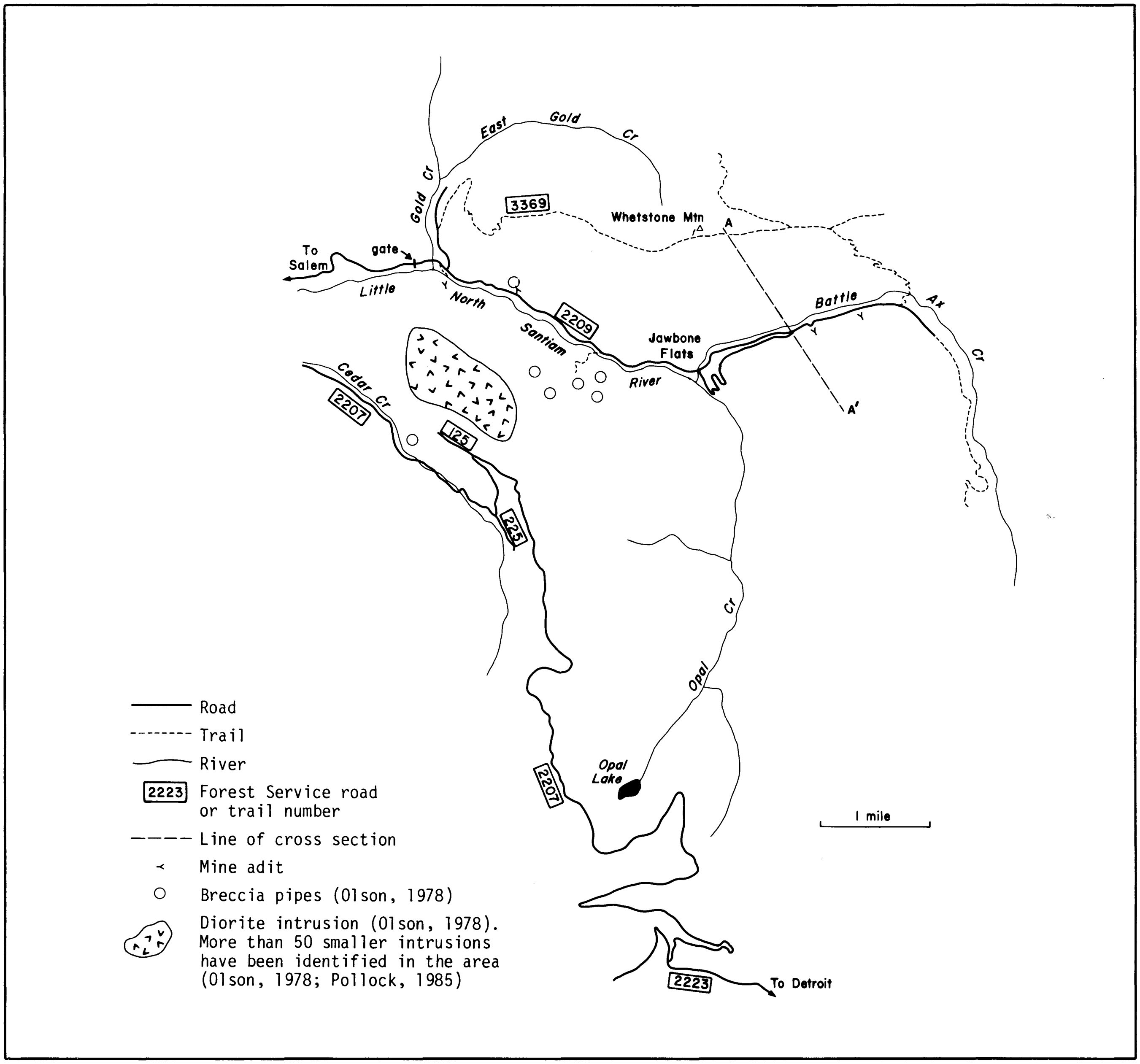

Figure 1. Map of the North Santiam mining area, located approximately 40 mi east of Salem in the Western Cascades. Map shows roads, streams, trails, major intrusions and breccia pipes, mine adits, and line for cross section A-A′ in Figure 4.

thick, of primarily fragmental andesites, and an upper unit, of approximately the same thickness, of hypersthene andesite flows.

White and McBirney (1979) separated the Elk Lake formation from the Sardine Formation on the basis of exposures in the Elk Lake area southeast of the mining area. They placed the Elk Lake formation as overlying and separated from the Sardine Formation by an angular unconformity.

Dyhrman (1976) named the pyroclastic rocks on Whetstone Mountain (Figure 1) the Whetstone Mountain volcaniclastic rocks. They are underlain in succession by the Thunder Mountain andesite, the Silver King andesite, and the Blister Creek tuff. The Blister Creek tuff was correlated by Dyhrman with the Little Butte Volcanic series of Thayer (1939); the other units were correlated with the Sardine series as mapped by Peck and others (1964).

Numerous plugs and dikes with compositions ranging from andesite or diorite to quartz monzonite and granodiorite apparently served as feeders for the middle and late Miocene volcanics of the Western Cascades (Thayer, 1939; Peck and others, 1964; White, 1980a). The center of volcanism for the Sardine Formation was interpreted by Peck and others (1964) to have been between the Middle Santiam River and the Collawash River.

Structure

Rocks of the Western Cascades are gently folded into a series of northeast-trending anticlines and synclines. The North Santiam mining area lies between the extensions of the Mehama anticline and the Sardine syncline, as defined by Thayer (1936). Callaghan and Buddington (1938) reported that dips north of the Little North Santiam River have a dominant northerly component, whereas those south of the river are dominantly southerly dipping, suggesting that the valley of the Little North Santiam River is near the crest of an anticline. White (1980b) estimated the age of northeast-trending fold structures to be between 15 and 11 m.y. on the basis of K-Ar dates for rocks of the Sardine Formation and the Elk Lake formation about 8 km southeast of the Ruth Mine.

Normal faults and intrusions with trends of N. 20° to 40° W. preceded and accompanied regional uplift of the Western Cascades relative to the High Cascades, which occurred 5 to 4 m.y. B.P. Northwest-trending lateral faulting spans a much longer time from 15 to 2 m.y. B.P. (Priest and others, 1983).

GEOLOGY OF THE NORTH SANTIAM MINING AREA

Stratigraphy

The stratigraphic units in the eastern portion of the mining area were assigned arbitrary letter designations by Pollock (1985) beginning with the lowest unit (Unit A) through the uppermost unit (Unit D). A generalized columnar section is shown in Figure 3.

Unit A: Unit A is comprised of moderately to extensively altered fragmental rocks of andesitic composition. The lapilli tuffs are generally medium to dark green in color; however, with increasing alteration, their clastic textures are obscured, and they are easily mistaken for porphyritic andesite flows. In zones of intense alteration, tuffs are "bleached" to a white color and primary textures are completely destroyed.

The lowest member of this stratigraphic unit is a distinctive polymictic breccia that is moderately to extensively altered and well indurated. It forms narrow, deep potholes or long, narrow chutes in the stream beds of the Little North Santiam River, Opal Creek, and Battle Ax Creek in secs. 28, 27, 33, and 29.

Overlying the polymictic breccia and forming the bulk of Unit A is a sequence of andesitic lapilli tuffs. Outcrop heights suggest that the thicknesses of individual cooling units range from 10 to 50 m. Lapilli-size lithic fragments are similar to the clasts in the polymictic breccia. Pumice is present in some units, and, from textures observed in thin section, glass is postulated as an original component of much of the groundmass. Flattened lapilli and pumice fragments in some tuffs suggest welding through parts of the units.

Unit B: Overlying and interlayed with the lapilli tuffs is a sequence of generally medium-gray, platy to block-fractured porphyritic andesite flows. Many fracture surfaces are a characteristic reddish brown. Phenocrysts of plagioclase and pyroxene are present in an aphanitic groundmass. Clinopyroxene dominates over orthopyroxene. Early-formed amphiboles are suggested by the shapes of masses of opaque minerals outlining relict phenocrysts.

Unit C: Unit C is a sequence of andesitic to dacitic or rhyodacitic tuffs and hornblende andesitic flows. The lower tuffs resemble the lithic tuffs of Unit A. On Whetstone Mountain, they contain distinctly smaller lithic clasts and a greater percentage of crystal fragments. Upper tuffs contain quartz and/or hornblende crystals and abundant pumice. A flow within Unit C contains hornblende phenocrysts and is exposed along the southern boundary of sec. 35.

Within Unit C on Whetstone Mountain at an elevation of 1,400 m is a distinctly laminated, fine-grained deposit that is between 20 and 25 m thick. Rocks in this deposit display parallel, 1- to 2-mm-thick laminations of alternating light- and dark-colored materials. Individual laminae may be traced for more than 10 m along the outcrop face. Where the rocks contain hydrothermally introduced carbonate, they form cliffs. Carbonized plant fragments, including twigs up to 5 cm in length, needles, and possible seed pods, are locally abundant. Although strong lineation in these fragments is commonly noted, the orientation among layers is not constant. Where the tuff is not strongly indurated, the resulting creep produces

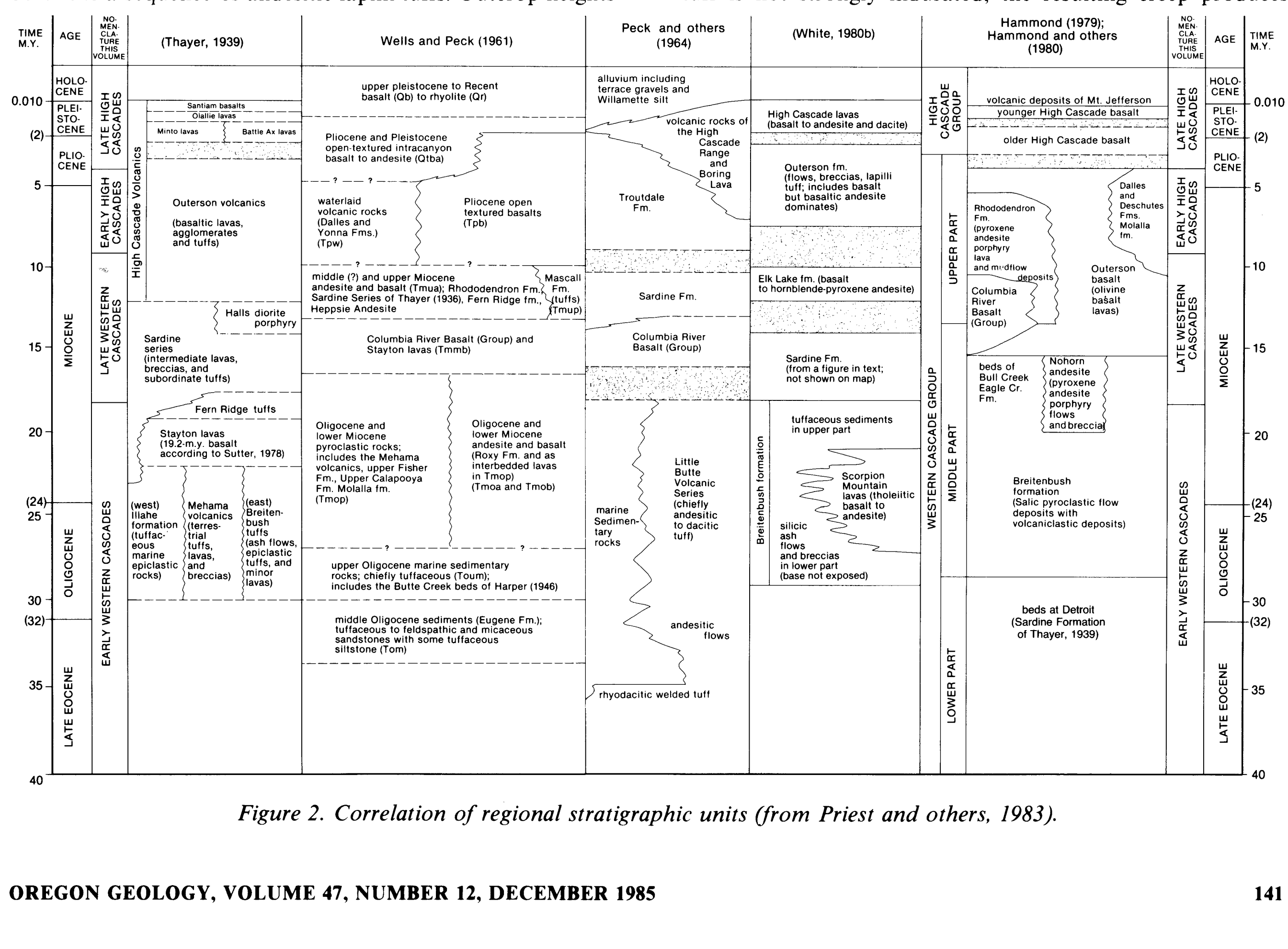

Figure 2. Correlation of regional stratigraphic units (from Priest and others, 1983).

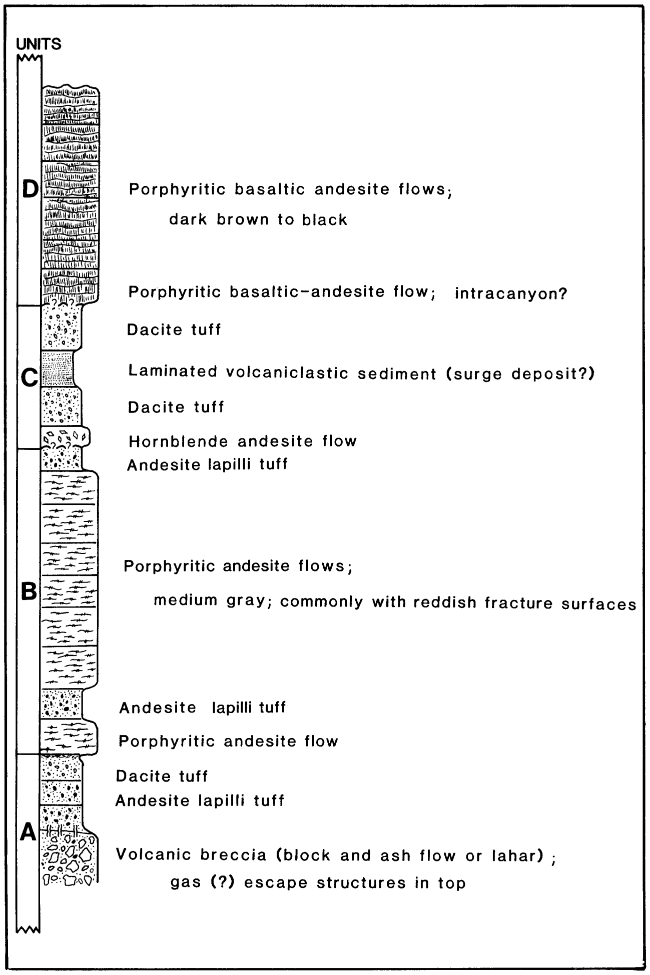

Figure 3. Generalized columnar section for the eastern portion of the North Santiam mining area (Pollock, 1985).

dramatically distorted tree growth in the old-growth timber. A distinct receding topographic bench and areas of significant creep at this stratigraphic position throughout the area south of Battle Ax Creek suggest that Unit C is present.

Unit D: Unit D consists of a sequence of dark-colored porphyritic basalts and basaltic andesite flows. Phenocrysts are plagioclase and pyroxene. Some flows are glomerophyric, and several have abundant lath-shaped pyroxene phenocrysts up to 2 mm in length. Orthopyroxene is the dominant pyroxene and is commonly partially to completely uralitized, whereas subordinate augite is fresh. Plagioclase anorthite contents range from 55 to 62 percent.

Capping Whetstone Mountain at an elevation of 1,480 m are two flows of Unit D, each 12-15 m thick. Flows of Unit D are found above an elevation of 1,040 m south of Battle Ax Creek. Lower flows in the sequence were deposited as intracanyon flows into the tuffs of Unit C.

Intrusions

Originally all intrusions in the mining area were reported as dioritic (Callaghan and Buddington, 1938). However, Olson (1978) divided the intrusions into seven units ranging in composition from basaltic andesite to quartz latite/rhyodacite. He interpreted the youngest unit to be a granodiorite typified by the large intrusion near the center of the mining area (sec. 32) and represented in the vicinity of the Ruth Mine by narrow, northwest-trending dikes. A K-Ar date for a hornblende separate from this large intrusion was reported as 13.4±0.9 m.y. (Power and others, 1981a).

In the eastern portion of the mining area, three major types of intrusions are distinguished (Pollock, 1985): an equigranular diorite, a porphyritic diorite, and a quartz-feldspar porphyry. Narrow aphanitic to porphyritic andesite dikes are also found at several locations, including Level 5 of the Ruth Mine, where they are associated with strong alteration halos but no base metal mineralization.

The equigranular diorite is best exposed along Battle Ax Creek, where it occurs as northwest-trending dikes. The equigranular texture of the feldspar and mafic phases produces a distinctive "salt and pepper" appearance. Vesicles are common, particularly near contacts. Contacts are sharp with narrow chilled margins. Locally, narrow, 0.5- to 3.0-cm-wide, white aplite veins cut these intrusions.

Porphyritic diorite intrusions also form northwest-trending dikes. The dikes commonly contain glomerocrysts of plagioclase and pyroxene. Dikes are best exposed adjacent to the portal of Level 5 of the Ruth Mine, in the adit, in a roadcut above the portal, and in Battle Ax Creek downstream from the portal. These intrusions are similar in mineralogy, texture, and chemistry to the large intrusion mapped by Olson (1978) in the central part of the mining area.

The third intrusion type is leucocratic quartz-feldspar porphyry. It is light gray to white in color and has 5 to 10 percent quartz phenocrysts that are 0.5 to 2 mm in diameter and euhedral to nearly round in shape. Plagioclase phenocrysts are also present, and potassium feldspar may have been present originally. Occasional hornblende crystals to 2 mm in length occur.

The geometry of the quartz-feldspar porphyry intrusions is very irregular. The contacts are steeply dipping to nearly horizontal at different outcrops and within the same outcrop. Below the portal of the Ruth Mine in Battle Ax Creek, a sill appears to intrude and dome the polymictic breccia of Unit A. Within the Ruth Mine, this intrusion is well exposed, and its margin serves as a host for mineralization. On Whetstone Mountain, the intrusion becomes increasingly jointed with increased elevation. At an elevation of 950 m, the highest exposures form a 30- to 35-m-high pinnacle that displays well-developed, steeply dipping columnar joints.

Structure

All units within the area are nearly horizontal to gently dipping to the southeast, as illustrated on the cross-section in Figure 4. Measured dips range from 5° to 20°. The dip of the contact between Units A and B is approximately 11°-13°. Dips decrease higher in the section and to the south. Units B and C thin to the north because of a decrease in the number of flows and tuffs and also as a result of a thinning of individual deposits. The base of Unit A is not exposed, and the top of Unit D has

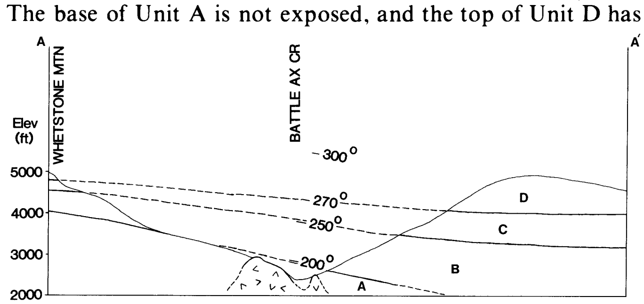

Figure 4. Geologic cross section of the Ruth Mine area, eastern portion of the North Santiam mining area. Cross-section line is shown in Figure 1. Geologic units are those shown in Figure 3. Minimum burial depths required to prevent boiling of geothermal solutions of the temperatures indicated are shown. Results of fluid-inclusion data (Table 1) suggest that the land surface at the time of mineralization was at or above the level of Units C and D (modified from Pollock, 1985).

been removed by erosion.

Three high-angle fracture and fault sets occur in the study area. The most prominent set is oriented N. 40° to 50° W. and controls the trends of several creeks and the emplacement of diorite dikes. The second is oriented N. 5° to 20° W. The third is oriented from N. 80° E. to east-west.

Displacements are difficult to determine because (1) exposure is poor; (2) lithologic units are similar in appearance; and (3) along Battle Ax Creek where exposures are the most extensive, faults have been the loci of dike emplacement. Slickensides are nearly horizontal. Where east-west faults and N. 45° to 50° W. faults intersect within the Ruth Mine, the east-west faults either offset or bend into alignment with the northwest faults with no apparent offset. The N. 5° to 20° W. fractures cross both sets without apparent displacement.

ALTERATION AND MINERALIZATION

Alteration types and distribution

Within the North Santiam mining area, Olson (1978) identified a zoned alteration system centered in the eastern half of sec. 19, T. 8 S., R. 5 E. The central potassium silicate zone contains an assemblage of biotite, quartz, sericite, kaolinite, and small quantities of potassium feldspar. Biotite, interpreted as replacing hornblende and augite, has been subjected to retrograde alteration to chlorite. Surrounding the potassic zone is phyllic alteration consisting of an assemblage of quartz, sericite, and kaolinite. Olson noted that the phyllic alteration is strongly controlled by structures, with the most extensive alteration along and adjacent to northwest-trending faults. Within this phyllic zone, tourmaline is found in breccias and is associated with quartz and sericite. Olson interpreted the geometry of these breccias to be "pipe-like." A whole-rock age in one of these breccias was reported as 11.0±0.4 m.y. (Power and others, 1981b). Outside of the phyllic zone, Olson reported pervasive propylitic alteration assemblages of chlorite, epidote, carbonate, and quartz extending well beyond the boundaries of the mining area and grading imperceptibly into unaltered rocks. The presence of breccia pipes and zoned alteration together with zoned mineralization from predominantly chalcopyrite/bornite outward to chalcopyrite/pyrite to base metals (Callaghan and Buddington, 1938; Olson, 1978) led Olson to propose a porphyry copper model for the area.

In the eastern portion of the mining area, alteration is most intense at lower elevations. Alteration decreases to the south and east (Pollock, 1985) and with increase in elevation.

Propylitic alteration consists of the replacement of (1) primary mafic minerals by one or more of the minerals chlorite, calcite, and epidote; and (2) plagioclase by albite and epidote or calcite. It is widespread but becomes more intense in the vicinity of northwest-trending structures and intrusions. In the least altered rocks, only amphiboles and uralitized pyroxenes are altered to chlorite. Rocks exhibiting this degree of alteration may contain calcite or chlorite-calcite veinlets.

At lower stratigraphic levels, epidote occurs as a replacement of mafic and plagioclase phenocrysts. Locally, epidote and quartz are precipitated in veinlets and as vesicle fillings. Veinlets and vesicles have halos extending up to 3 cm into their walls in which epidote replaces groundmass minerals. This is especially well illustrated by the alteration of the equigranular diorite dikes near the confluence of McCarver and Battle Ax Creeks.

Phyllic or quartz-sericite-pyrite alteration is characterized by the replacement of groundmass and phenocrysts by fine-grained micas and quartz. Phyllic alteration is recognized in the field by a loss of primary textures and bleached halos around veins, faults, and larger fractures. Bleaching destroys primary mafic phases and secondary phases such as chlorite. Iron removed from these phases is generally retained in the rock as disseminated pyrite.

Phyllic alteration is best developed in the tuffs near faults and within breccias in the quartz-feldspar porphyry intrusions.

Argillic alteration, characterized by moderate to total replacement of rocks by kaolinite, is best developed along N. 30°-40° W. and N. 80° E. faults. Argillic alteration is generally limited to hanging-wall breccia zones along faults. Clay zones range in thickness from a few centimeters up to 3-4 m at places in the Ruth Mine. Fragments of partially altered host rocks are found within the clay. X-ray analysis of clay zones confirms the presence of kaolinite as well as sericite and chlorite believed to be relict from previous alterations. Swelling clays are absent from all analyzed samples of vein clay.

Precipitated stilbite and laumontite have been identified as vein materials at lower elevations. The distribution of these zeolite veins has not been determined. Veins with fibrous laumontite near the vein walls and euhedral stilbite in the core cut an equigranular diorite dike along Battle Ax Creek.

Base metal veins

Quartz veins, with or without calcite, serve as hosts for sulfide mineralization in the eastern portion of the area. The following generalized paragenetic sequence occurred: Host rocks were propylitically altered and then brecciated. Growth of early quartz crystals in open space resulted in euhedral quartz attached to the breccia fragments and vein walls. Sulfide minerals seldom grew in contact with the vein walls but were precipitated with early quartz. Brecciation that followed quartz deposition apparently opened additional fracture surfaces in some veins. Coarse-grained calcite crystals completely or partially filled some of the open space.

A sample from a small vein located in Battle Ax Creek near the Morning Star Mine displays overgrowths of chalcedonic quartz. In this vein, sulfide deposition preceded the precipitation of the chalcedony and is in contact with it in several places. Many veins show a second stage of fine euhedral quartz crystals perpendicular to the faces of the first stage.

Base metal mineralization in the vicinity of the tourmaline-bearing breccia pipes consists of both disseminated and vein chalcopyrite. Veins display moderate to strong northwest orientations and strong phyllic alteration halos (Olson, 1978).

East of Jawbone Flats, the highest base metal concentrations are found in veins of the Beuche Group, the Ruth Mine, and the Morning Star Mine. Veins in these mineralized areas are localized along the N. 40° to 50° W. structural trend. They are most abundant and contain the highest quantities of ore minerals near contacts between intrusions and the tuffs of Unit A. In each of these three mineralized areas, sphalerite is the main ore mineral; galena and chalcopyrite occur in lower abundance. Pyrite is present in the veins but is also found in other veins in which base metal sulfides have not been detected. Chalcopyrite forms solitary grains and occurs as minute blebs commonly 0.05 mm in diameter within sphalerite grains. Within the Ruth Mine, sphalerite and galena are also deposited on fracture surfaces in an open-space "crackle" breccia developed in an intrusion of quartz-feldspar porphyry.

Fluid-inclusion data

Fluid-inclusion data on the composition and temperatures of crystal formation have been obtained for quartz from three veins displaying phyllic alteration in the eastern part of the mining area. Salinities are low, with a freezing-point depression range corresponding to 1 to 6 wt percent NaCl equivalent. No daughter salts or other solid phases have been identified within the fluid inclusions. The range of homogenization temperatures is shown in Table 1. Of these three veins, only the Beuche sample site contains significant sulfide mineralization other than pyrite.

In addition, fluid-inclusion data from quartz crystals

Table 1. *Fluid-inclusion data from quartz-calcite veins in the general area of the east end of the North Santiam mining area. All analyses were performed on quartz crystals.*

Location within study area	Vein name	Number of inclusions analyzed	Freezing range	Homogenization range	(median)	Comments
East	Morning Star(?)	10	-0.6° to -1.8°	216° to 245°	(220.5°)	Core of crystal on vein wall
		6	-1.4° to -2.1°	204° to 234°	(218.0°)	Inclusion-rich rim of same crystal
Central	Unnamed vein of Beuche claims	3	-0.6° to -1.0°	227° to 236°	(230.4°)	Core of crystal near center of vein; Inclusions very rare
		5	-0.6° to -1.7°	282° to 299°	(287.8°)	Crystals adjacent sphalerite/galena mineralized band
West	Unnamed prospect	5	-0.9° to -3.8°	225° to 256°	(247.1°)	Core of crystal near vein wall

collected from quartz-epidote veins cutting an equigranular diorite dike along Battle Ax Creek show homogenization temperatures ranging from 245° to 310° C. Salinities of these inclusions are below 2 wt percent NaCl equivalent. Base metal sulfide mineralization is absent in these veins, and pyrite is sparse.

DISCUSSION

The subvolcanic environment of a porphyry copper system can be inferred from the North Santiam mining area on the basis of stratigraphic relationships, absolute and relative age relations, intrusive history and its relation to volcanism and mineralization, and the chemistry of hydrothermal solutions responsible for alteration and mineralization during the history of the system. The following points are pertinent to construction of a model for the system.

1. The subvolcanic portions of a porphyry copper system are geothermal systems in which alteration patterns, mineralization, and boiling zones are related to depth beneath the ground surface at the time the system is active. Determination of the nature and position of the ground surface at the time of alteration and mineralization allows determination of those processes that occur at shallow depths within a developing porphyry system.

2. The homogenization temperatures of fluid inclusions from the North Santiam mining area indicate that the depth of formation of veins in the eastern part of the district was at least 800 m at the time of mineralization. The fluid inclusions do not indicate boiling of the ore solutions. The 800-m depth is the minimum depth required to prevent boiling of solutions of the temperature and salinity of those found in the study area. This depth of formation would place the ground surface at the time of mineralization near the level of unit C (see Figure 4).

3. In an unmapped area aong the west end of French Creek Ridge is a bedded pyroclastic deposit of probable rhyodacitic composition (Cummings and Pollock, 1984). Individual beds are from 5 to 10 cm thick and are distinguished by alternating light and dark layers. Based on elevation and apparent stratigraphic position, this unit is believed to be a member of the lower Elk Lake formation of White (1980b). Pollock (1985) argued that this unit is a surge deposit, the distal facies of which is the finely laminated deposit of Unit C on Whetstone Mountain 6.5 km to the north. Based on this correlation and the description of flows given by White (1980b), the flows of Unit D correlate with the upper Elk Lake formation. Dates reported by White (1980b) for rocks mapped as Elk Lake formation on French Creek Ridge range from 11.8 to 11.0 m.y. B.P.

4. Pollock (1985) postulated the order of intrusions in the eastern portion of the mining area to be (1) equigranular diorite, (2) porphyritic diorite, and (3) quartz-feldspar porphyry. Porphyritic diorite dikes penetrate strata correlative with Unit B (Olson, 1978), but no locations are known where intrusions are in intrusive contact with rocks of either Unit C or D. Based on geometry and similiarity in composition, the quartz-feldspar porphyry intrusion may have been a feeder for one of the tuffs of Unit C. These relations suggest that the exposed diorite intrusions probably were not the heat sources that drove the hydrothermal system in the area. The quartz-feldspar porphyry may have been the heat source, but this relation is not certain.

5. Mineralization is found in or along the margins of the major intrusion types including within "crackle" breccias developed in the quartz-feldspar porphyry. Thus mineralization, at least in part, postdates emplacement of the youngest intrusions. The porphyritic diorite intrusions are believed to be genetically related to the intrusion in the central portion of the mining area that was dated at 13.4 m.y. B.P. (Power and others, 1981a). Sericitic alteration associated with porphyry mineralization in the district has been dated at 11.0 m.y. B.P. (Power and others, 1981b). The quartz-feldspar porphyry intrusion has not been dated.

6. Mineral assemblages typical of propylitic alteration occur under two extremes of hydrothermal conditions. At low water-to-rock ratios, pervasive isochemical recrystallization to epidote-chlorite-calcite is analogous to greenschist facies metamorphism. This may occur as a result of burial depth and elevated thermal gradients resulting from emplacement of intrusions. At high water-to-rock ratios, propylitic alteration assemblages (Giggenbach, 1984) develop in downflow zones of geothermal systems. In contrast, phyllic and potassic alteration assemblages form in upflow zones (Giggenbach, 1984).

7. The alteration history of the study area is one of regional propylitic alteration developed at low water-to-rock ratios. Later, development of zones of fluid upflow occurred along the margins of dikes and along faults. The base metal sulfide mineralization occurred in quartz veins within sericitic envelopes of fluid upflow zones as ascending solutions cooled.

Argillic alteration developed later under conditions of an acidic system. Propylitic alteration associated with quartz-epidote veins may represent fluid recharge channels contemporaneous with mineralization. Fluids responsible for this alteration also utilized the vertical permeability of intrusion margins.

SUMMARY AND CONCLUSIONS

Base metal mineralization and alteration in the eastern portion of the North Santiam mining area developed in response to hydrothermal fluids circulating through faults and along fractured boundaries of intrusions. The ground surface at the time of mineralization was the developing volcanic structure from which tuffs of Unit C and flows of Unit D were erupted. This developing center was the source of heat that drove the hydrothermal circulation system and may be the center responsible for the porphyry-style mineralization in the district.

REFERENCES CITED

Baldwin, E.M., 1981, Geology of Oregon: Dubuque, Iowa, Kendall/Hunt Publishing Company, 170 p.

Brooks, H.C., and Ramp, L., 1968, Gold and silver in Oregon: Oregon Department of Geology and Mineral Industries Bulletin 61, 337 p.

Callaghan, E., and Buddington, A.F., 1938, Metalliferous mineral deposits of the Cascade Range in Oregon: U.S. Geological Survey Bulletin 893, 141 p.

Cox, J.B., 1985, Little North Santiam mining district: Cultural resources inventory report: Detroit, Oreg., USDA, Willamette National Forest.

Cummings, M.L., and Pollock, J.M., 1984, Field guide to the northern Cascade Range from Zigzag to Jawbone Flats, Oregon, with overviews of Poop Creek, Sisi Butte, and Pinhead Buttes: Portland State University, 59 p.

Decker, D.J., and Jones, M.B., 1977, North Santiam porphyry copper prospect, Marion County, Oregon, summary report: Unpublished report to Freeport Mining Company, 24 p.

Dodd, S.P., and Schmidt, E.A., 1982, Termination report, Shiny Rock Project (D-80-65B), Marion County, Oregon: Unpublished report to Amoco Minerals Company, 70 p.

Dyhrman, R.F., 1976, Geology of the Bagby Hot Springs area, Clackamas and Marion Counties, Oregon: Corvallis, Oreg., Oregon State University master's thesis, 78 p.

George, A.J., 1985, The Santiam mining district of the Oregon Cascades: A cultural property inventory and historical survey: Lyons, Oreg., Shiny Rock Mining Corporation, 336 p.

Giggenbach, W.F., 1984, Mass transfer in hydrothermal alteration systems — a conceptual approach: Geochimica et Cosmochimica Acta, v. 48, p. 2693-2712.

Hoffman, C.W., 1981, A stratigraphic and chemical investigation of ferruginous bauxite deposits in the Salem Hills, Marion County, Oregon: Portland, Oreg., Portland State University master's thesis, 130 p.

Hook, J.W., 1976, Ferruginous bauxites of the Pacific Northwest: Oregon Department of Geology and Mineral Industries Open-File Report 0-76-3, 26 p.

McBirney, A.R., Sutter, J.F., Naslund, H.R., Sutton, K.G., and White, C.M., 1974, Episodic volcanism in the central Oregon Cascade Range: Geology, v. 2, no. 12, p. 585-589.

Olson, J.P., 1978, Geology and mineralization of the North Santiam mining district, Marion County, Oregon: Corvallis, Oreg., Oregon State University master's thesis, 135 p.

Oregon Department of Geology and Mineral Industries, 1951, Oregon metal mines handbook: Oregon Department of Geology and Mineral Industries Bulletin No. 14-D, 166 p.

Orr, W.N., 1984, Western Cascades middle Tertiary stratigraphy [abs.]: Portland, Oreg., Pacific Northwest Metals and Minerals Conference, p. 53.

Peck, D.L., Griggs, A.B., Schlicker, H.G., Wells, F.G., and Dole, H.M., 1964, Geology of the central and northern parts of the Western Cascade Range in Oregon: U.S. Geological Survey Professional Paper 449, 56 p.

Pollock, J.M., 1985, Geology and geochemistry of alteration and mineralization, eastern portion of the North Santiam mining area: Portland, Oreg., Portland State University master's thesis, 80 p.

Power, S.G., Field, C.W., Armstrong, R.L., and Harakal, J.E., 1981a, K-Ar ages of plutonism and mineralization, Western Cascades, Oregon and southern Washington: Isochron/West, no. 31, p. 27-29.

- - -1981b, K-Ar ages of plutonism and mineralization, Western Cascades Oregon and southern Washington, additional information: Isochron/West, no. 32, p. 3.

Priest, G.R., Woller, N.M., Black, G.L., and Evans, S.H., 1983, Overview of the geology of the central Oregon Cascade Range, *in* Priest, G.R., and Vogt, B.F., eds., Geology and geothermal resources of the central Oregon Cascade Range: Oregon Department of Geology and Mineral Industries Special Paper 15, p. 3-28.

Thayer, T.P., 1936, Structure of the North Santiam River section of the Cascade Mountains in Oregon: Journal of Geology, v. 44, no. 6, p. 701-716.

- - -1939, Geology of the Salem Hills and the North Santiam River basin, Oregon: Oregon Department of Geology and Mineral Industries Bulletin 15, 40 p.

Tolan, T.L., Beeson, M.H., and Vogt, B.F., 1984, Exploring the Neogene history of the Columbia River: Discussion and geological field trip guide to the Columbia River Gorge: Oregon Department of Geology and Mineral Industries, Oregon Geology, v. 46, p. 87-97.

White, C.M., 1980a, Geology of the Breitenbush Hot Springs quadrangle, Oregon: Oregon Department of Geology and Mineral Industries Special Paper 9, 26 p.

- - -1980b, Geology and geochemistry of volcanic rocks in the Detroit area, Western Cascade Range, Oregon: Eugene, Oreg., University of Oregon doctoral dissertation, 178 p.

White, C.M., and McBirney, A.R., 1979, Some quantitative aspects of orogenic volcanism in the Oregon Cascades, *in* Smith, R.B., and Eaton, G.P., eds., Cenozoic tectonics and regional geophysics of the Western Cordillera: Geological Society of America Memoir 152, p. 369-388.

NEXT MONTH: FIELD TRIP GUIDE

Survey of Oregon offshore mapping released

The Oregon Department of Geology and Mineral Industries (DOGAMI) has released a survey of the needs of State agencies for offshore maps and the current status of available mapping products and programs that fill those needs.

A Survey of Oregon Offshore Mapping was compiled by Glenn W. Ireland, State Resident Cartographer, and has been published as DOGAMI Open-File Report 0-85-3. The 30-page report surveys, in its first part, all State agencies that coordinate their mapping through the State Map Advisory Committee and describes their programs and projects that require offshore maps. In its second part, the report identifies Federal agencies and independent sources that have produced offshore maps or are conducting offshore mapping programs. In both parts of the report, contact persons and addresses are provided for each agency.

The survey extends to the entire marine environment, including a variety of zones such as estuary, beach zone, shore, tidelands, near-shore zone, continental shelf, continental slope, and various ridges, rises, and fracture zones. It is intended to allow a variety of users to focus on offshore mapping needs for specific projects. It will also allow mapping planners to coordinate projects between different programs.

The new report, Open-File Report 0-85-3, is now available at the Oregon Department of Geology and Mineral Industries, 910 State Office Building, 1400 SW Fifth Avenue, Portland, OR 97201. The purchase price is $4. Orders under $50 require prepayment. □

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