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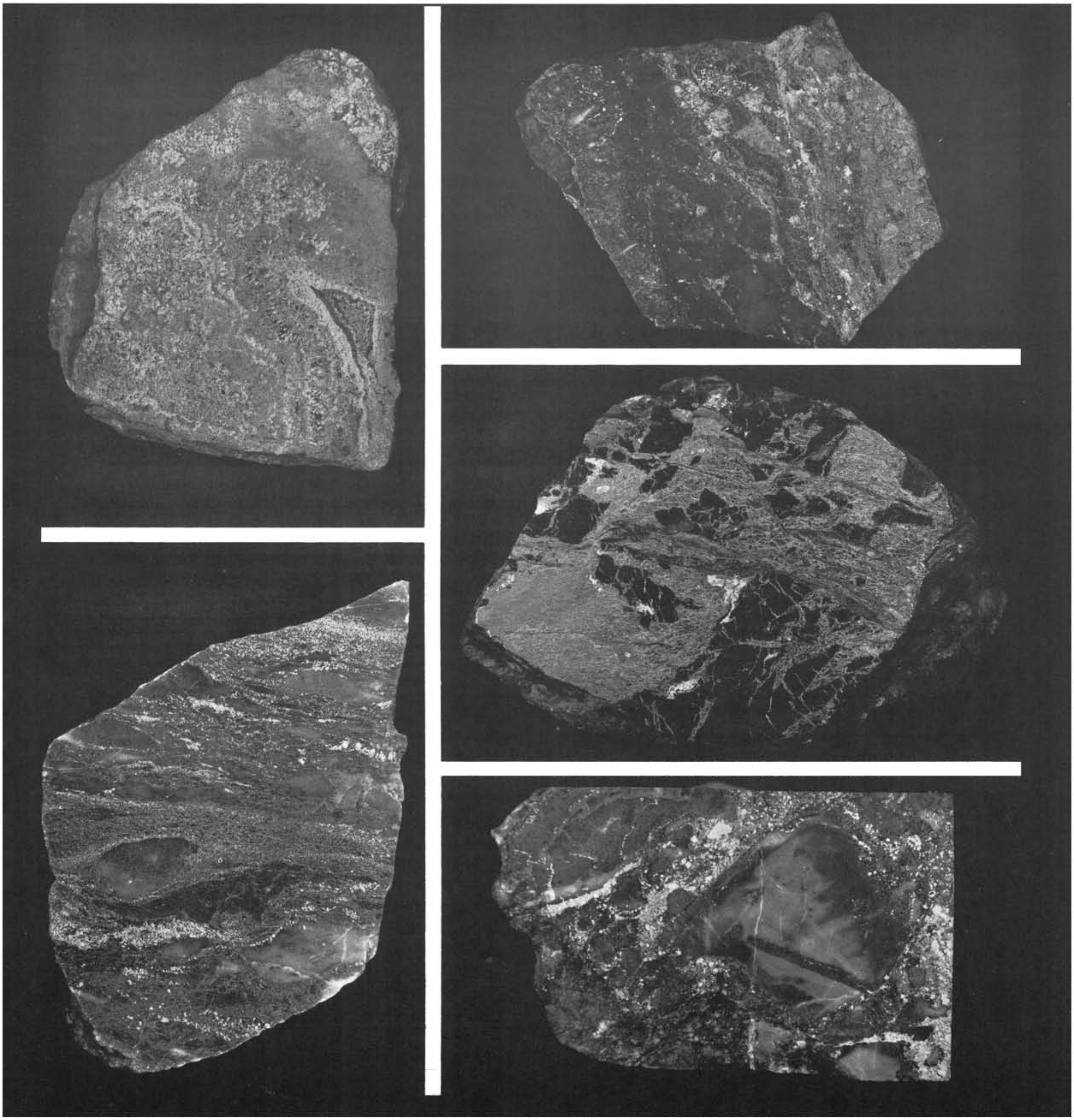

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COVER PHOTO

Polished slabs from massive sulfide deposits in southwestern Oregon. Clockwise, from upper left: massive pyrite (light and medium gray) and sphalerite (dark gray) with colloform banding, Queen of Bronze Mine; coarse breccia composed of pyrite and chalcopyrite (concentrated in right half) and mafic rock fragments, Queen of Bronze Mine; sheared chalcopyrite-pyrrhotite lenses (light) and chloritic matrix (dark), Waldo Mine; mixed chert-volcanic-sulfide (pyrite and chalcopyrite) breccia, Turner-Albright Mine; layered sulfide (pyrite, chalcopyrite, and sphalerite) and barite with numerous barite lenses, Silver Peak Mine. All samples are approximately 10 cm across. Photographed by Lowell Kohnitz, U.S. Geological Survey. See article beginning next page.

DOGAMI releases new bibliography, map index, lineation study, and geologic maps

The Oregon Department of Geology and Mineral Industries (DOGAMI) announces the release of the following new publications:

Bulletin 102—*Bibliography of the Geology and Mineral Resources of Oregon (Seventh Supplement, January 1, 1976, to December 31, 1979)*, compiled by Debbie Burnetti, Editor, GeoRef, and Klaus Neuendorf, Editor/Librarian, Oregon Department of Geology and Mineral Industries. Produced in cooperation with GeoRef, the computerized information system of the American Geological Institute, this 68-page book presents bibliographic information from 1976 through 1979 on the geology and mineral resources of Oregon. Entries are indexed by author's name, subject, county, and rock unit. Bulletin 102, the seventh supplement to the Department's original bibliography compiled in 1936 by R.C. Treasher and E.T. Hodge, sells for $4.00.

Special Paper 13—*Faults and Lineaments of the Southern Cascades, Oregon*, by C.F. Kienle, C.A. Nelson, and R.D. Lawrence, Foundation Sciences, Inc. This lineament and fault analysis of topographic maps and SLAR, Landsat, and U-2 high-flight imagery was completed as the initial stage of the geothermal assessment of the southern Cascades funded by a grant from the U.S. Department of Energy to the Oregon Department of Geology and Mineral Industries. The 23-page text describes procedures used to interpret data, criteria used to define lineaments, and geologic control of the expression of faults and lineaments and presents a tectonic interpretation of the study area. Included with the text are two two-color topographic maps (scale 1:250,000) on which thermal and nonthermal springs, lineaments, and known faults are plotted. Cost of Special Paper 13 is $4.00.

Geological Map Series GMS-14—*Index to Published Geologic Mapping in Oregon, 1898-1979*, by C.A. Schumacher, Cartographer, Oregon Department of Geology and Mineral Industries. GMS-14 shows areas in Oregon that have been covered by geological, geophysical, ground-water, mineral-locality, and other types of maps that have appeared in publications by DOGAMI, U.S. Geological Survey, Bureau of Mines, and others. The index, which replaces DOGAMI's Miscellaneous Paper 12 (*Index to Published Geologic Mapping in Oregon, 1898-1967*), consists of six two-color maps (scale 1:1,000,000) on a U.S. Geological Survey quadrangle-index base, with county names and boundaries for easy reference. Each map has an extensive bibliography and is designed so that the reader may easily determine available maps, along with authors, titles, and dates, for any given area in Oregon. GMS-14, the only available comprehensive index to

(Continued, page 126)

CONTENTS

Massive sulfide deposits in oceanic-crust and island-arc terranes of southwestern Oregon

by Randolph A. Koski, U.S. Geological Survey, 345 Middlefield Road, Menlo Park, California 94025, and Robert E. Derkey, Department of Geology, University of Idaho, Moscow, Idaho 83843

INTRODUCTION

Massive sulfide deposits containing significant amounts of base and precious metals occur in oceanic-crust and island-arc terranes of the northern Klamath Mountains in southwestern Oregon. These terranes constitute parts of two major lithotectonic belts separated by an east-dipping thrust fault: the upper-plate western Paleozoic and Triassic belt and the lower-plate western Jurassic belt. Irwin (1960, 1966) first proposed and elaborated the concept of internally complex north-south-trending arcuate lithic belts of regional extent juxtaposed in the Klamath Mountains. Subsequently, the geologic and tectonic settings of coherent terranes within these belts have been identified (for example, Irwin, 1972, 1977; Garcia, 1979; Johnson, 1980); and plate-tectonic models for Klamath evolution through plate convergence, eastward-directed subduction, and accretion of oceanic rocks to the western continental margin of North America have been evolved (Hamilton, 1969, 1978; Davis and others, 1978).

In this report we discuss the massive sulfide deposits of southwestern Oregon within this recently established plate-tectonic framework. These deposits (Figure 1) include the Queen of Bronze, the Cowboy, and others occurring in tectonic mélange of the western Paleozoic and Triassic belt; the Turner-Albright in ophiolite of the western Jurassic belt; and the Silver Peak and Almeda in fragmental island-arc volcanic rocks of the western Jurassic belt. Together, these deposits have produced nearly one-third (approximately 4,000 tons) of Oregon's total copper output, more than 70,000 troy ounces of silver and 2,000 troy ounces of gold, and minor amounts of lead and zinc. Although none of these deposits is currently being mined, all have been the focus of company activity during the last decade, and exploration activity continues at present.

DEPOSITS IN OCEANIC-CRUST TERRANES

Ophiolites are pseudostratigraphic assemblages of ultramafic and mafic rocks that appear to represent displaced and uplifted fragments of ancient oceanic crust and the upper mantle. Where complete, an ophiolite assemblage includes tectonized harzburgite and dunite, layered gabbro, sheeted diabase dike complexes, and pillow basalt. The basalt is commonly overlain by fine-grained marine sedimentary rocks, such as chert, shale, and limestone. Pillow lavas of ophiolite complexes in Cyprus, Turkey, Newfoundland, Italy, and many other localities are important hosts for "Cyprus-type" massive Fe-Cu sulfide deposits.

The occurrence of ophiolite assemblages within the major tectonic belts of the northern Klamath Mountains was summarized by Irwin (1977). Two of the largest and best known exposures of ophiolite—the Preston Peak ophiolite in the western Paleozoic and Triassic belt and the Josephine ophiolite in the western Jurassic belt—are associated with massive-sulfide mineralization.

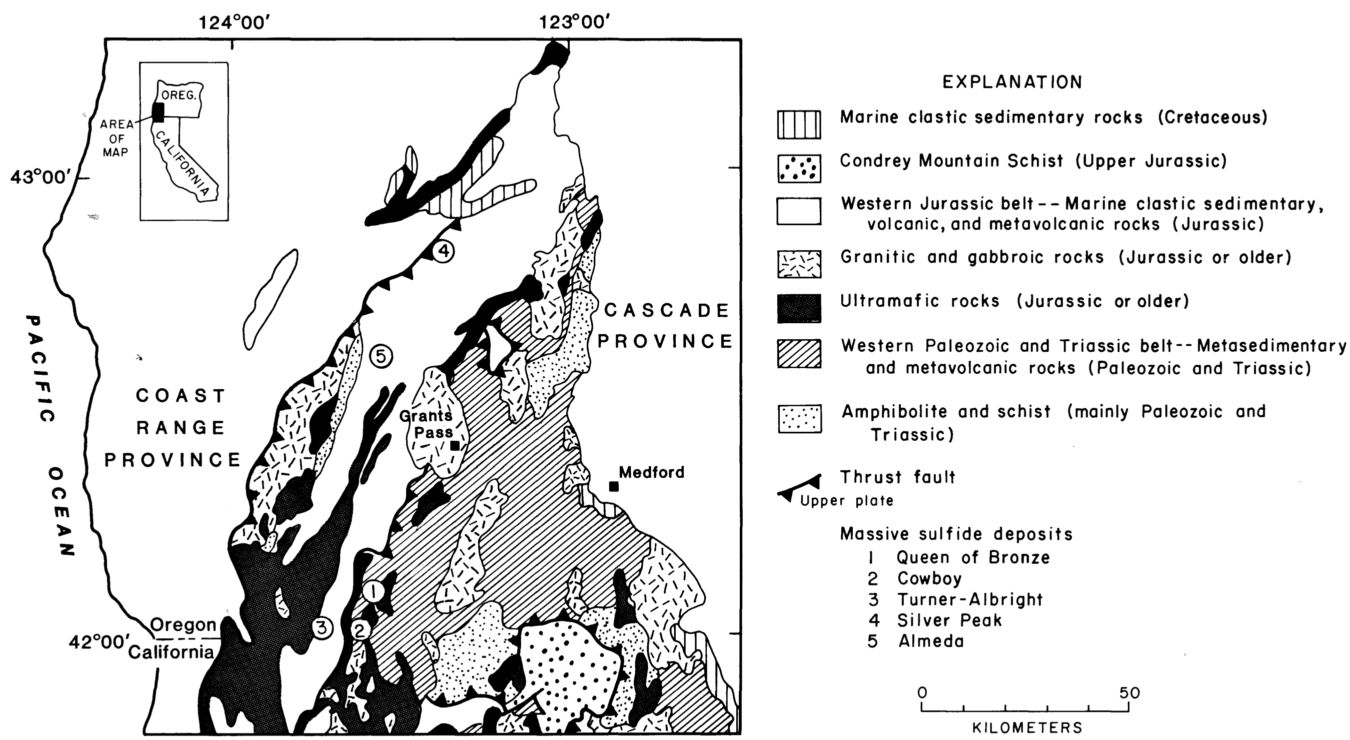

Figure 1. Generalized geologic map of northern Klamath Mountains, showing location of major massive sulfide deposits. (Geology modified from Hotz, 1971)

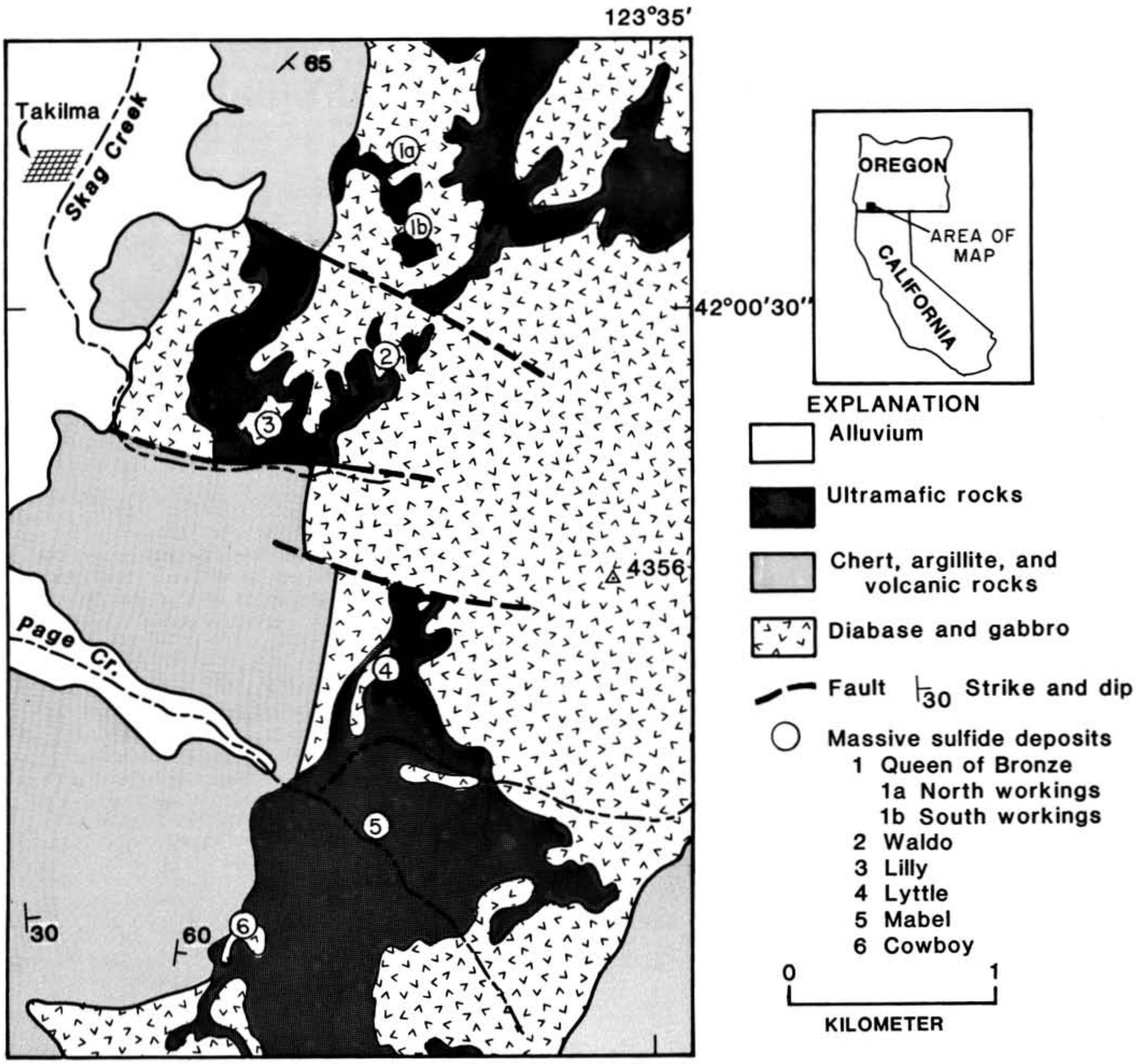

Figure 2. Geologic map of the Takilma area, Oregon, showing location of massive sulfide deposits.

Takilma-area deposits

Near Takilma, Oregon, at the west edge of the western Paleozoic and Triassic belt, small masses of pyritic and pyrrhotitic massive sulfide are dispersed within tectonic mélange composed of mafic and ultramafic rocks (Figure 2). The mafic rocks include diabase and diabase breccia, gabbro, diorite, and minor basalt showing varying degrees of greenschist-facies metamorphism. Exposures at the Queen of Bronze Mine and along the east fork of the Illinois River show that the diabasic and gabbroic rocks form dike or sill aggregates, although a well-developed sheeted-dike complex has not been identified. The mafic assemblage is in apparent fault contact with, and is overlain by, a sequence of thin-bedded gray radiolarian chert, argillite, graywacke, pebble conglomerate, rare limestone, and intercalated vesicular mafic lava flows.

The mafic rocks and overlying strata are intruded and engulfed by large irregular masses of strongly serpentinized peridotite. Subrounded blocks of metadiabase, metagabbro, chert-argillite, and massive sulfide ranging in size from smaller than a meter to hundreds of meters across are incorporated into the ultramafic bodies. Contacts between the larger inclusions and serpentinite are typically sheared. The rock assemblage in the Takilma area is lithologically similar to that in the Preston Peak ophiolite 15 km to the south (Snoke, 1977). Field and geochemical evidence indicate to Snoke (1977) and Snoke and others (1977) that the ophiolitic ultramafic, mafic, and sedimentary rocks at Preston Peak represent the vestiges of an immature island-arc complex floored by oceanic lithosphere.

More than 40,000 tons of ore averaging greater than 5 weight percent Cu have been mined from at least six localities in the Takilma district (Shenon, 1933a). The sulfide mineralization is discontinuous and occurs within a 4-km-long north-south-trending zone that follows the irregular contact between mafic and ultramafic rocks (Figure 2). Deposits in the diabasic wall rocks (Queen of Bronze, Waldo, Lilly, and Lyttle) consist of sharply defined pods, wedges, tabular lenses, and thin discontinuous seams of sulfide and quartz; these bodies generally have sharp contacts with unmineralized diabase. Sulfide textures range from fine-grained massive-granular to coarse-brecciated; a few crudely layered and colloform features are also preserved. The mafic wall rocks show pervasive but varying degrees of recrystallization and alteration to the spilitic assemblage chlorite-actinolite-epidote-albite-calcite. Furthermore, the mafic rocks in contact with serpentinite are locally altered to pale-green rodingite composed of hydrogarnet, idocrase, chlorite, diopside, and prehnite.

Mineralization in the ultramafic rocks (Cowboy and Mabel) consists of aggregates of closely spaced rounded massive sulfide "boulders" (Shenon, 1933a) in highly sheared serpentinite. Sulfide textures typically are coarse grained massive-granular, banded, or foliated. These textures appear to reflect metamorphic recrystallization and deformation by flowage. In addition to serpentine-group minerals (mostly antigorite), the ultramafic wall rock locally contains talc and magnesite.

Principal sulfide minerals at the Queen of Bronze deposit (both the north and south workings) are, in decreasing abundance, pyrite, chalcopyrite, sphalerite, and pyrrhotite. At the Waldo deposit, pyrite, pyrrhotite, and chalcopyrite are all abundant; sphalerite and arsenopyrite are minor constituents. Pyrrhotite and chalcopyrite are the major phases in massive sulfide from the Lyttle, Mabel, and Cowboy deposits. Sphalerite and cubanite are abundant phases in some samples, and pyrite is very minor. Shenon (1933a) also reports the presence of cobaltite in "boulder" ore from the Cowboy Mine. The sulfide minerals are accompanied by varying amounts of interstitial quartz and less abundant chlorite, calcite, and serpentine minerals. Serpentinite at the Cowboy deposit hosts minute stringers and blebs of pyrrhotite and chalcopyrite.

The deposits in the Takilma area appear to represent a discontinuous zone of sulfide mineralization within a complex of diabase and gabbro dikes and diabasic breccia, analogous to the mafic complex in the Preston Peak ophiolite described by Snoke (1977). Locally, the form and texture of primary sulfide mineralization indicate that open-space precipitation was an important process. Subsequent faulting and the movement and serpentinization of peridotite have resulted in disruption, brecciation, recrystallization, and deformation of the sulfide bodies in the serpentinite.

Turner-Albright deposit

Thirteen km southwest of Takilma, the Turner-Albright copper-gold deposit occurs in basaltic lavas and lava breccia of the Josephine ophiolite associated with the western Jurassic belt (Figure 1). Cunningham (1979) reports that the average grade of the deposit is 2.5 weight percent Cu, 0.5 weight percent Zn, and 0.025 troy ounces Au per ton. No production of base metals has been reported from the Turner-Albright Mine, although the gossans have been treated for small amounts of gold. Recent regional geologic studies by Vail (1977) and Harper (1980) have led to a recognition of a complete ophiolite section that includes the Josephine Peridotite, a harzburgite tectonite, at its base. The peridotite is tectonically overlain by ultramafic and gabbroic cumulate, massive gabbro, sheeted diabase dikes, mixed pillow lava and pillow-lava breccia, and a thin layer of metalliferous chert and mudstone. Thick flysch deposits containing interbedded graywacke, slate, and conglomerate conformably overlie the ophiolite section (Harper, 1980). Figure 3 is a geologic section through the Josephine ophiolite. Field relations and petrographic and geochemical data indicate that the Josephine ophiolite formed in a marginal

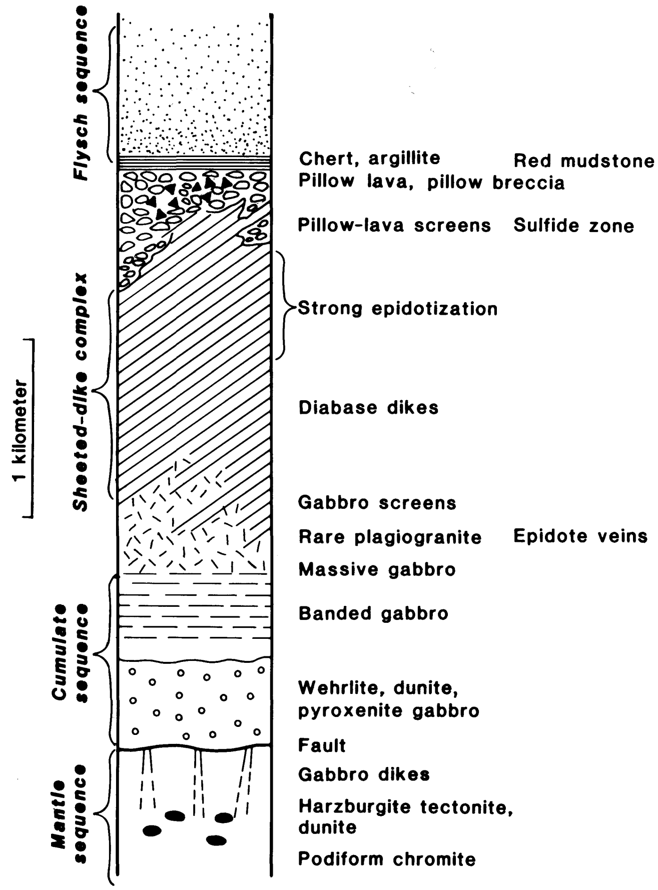

Figure 3. Geologic section of the Josephine ophiolite. (Modified from Harper, 1980)

basin between the North American Plate margin and an offshore volcanic arc during Jurassic time (Dick, 1977; Vail, 1977; Harper, 1980).

Cunningham (1979) recently described the geology and geochemistry of the Turner-Albright deposit and the associated ophiolitic rocks. The mineralization occurs within the upper plate of an east-dipping thrust fault; the footwall of the thrust is barren peridotite (Figure 4a). The rocks hosting massive, vein, and disseminated sulfide consist of spilitized mafic lavas and volcanic breccia intruded by comagmatic diabase and gabbro. Pyritic lenses of bedded fossiliferous tuff and tuffaceous shale intercalated within the volcanic pile are supportive evidence for a submarine eruptive episode.

As shown by cross section A-A' (Figure 4b), the steeply northeast-dipping layer of massive sulfide breccia, expressed by prominent linear gossan zones at the surface, grades northward into a columnar zone of mixed volcanic rocks, chert, and sulfide breccia. The sulfide assemblage is dominated by pyrite, although chalcopyrite and sphalerite are common and locally abundant. In the zone of massive sulfide breccia, subangular to subrounded pyritic sulfide fragments occur in a matrix of finer grained pyrite, quartz, altered lithic fragments, chalcopyrite, and sphalerite. Many individual sulfide fragments display thin alternating bands of pyrite and sphalerite. Pyrite-, chalcopyrite-, and sphalerite-bearing veinlets that crosscut massive pyrite and banded pyrite-sphalerite fragments provide evidence for multiple episodes of sulfide deposition.

The mixed-breccia zone has the characteristics of a hydrothermal feeder system. The zone contains discontinuous sulfide veinlets and disseminations; many lithic fragments are

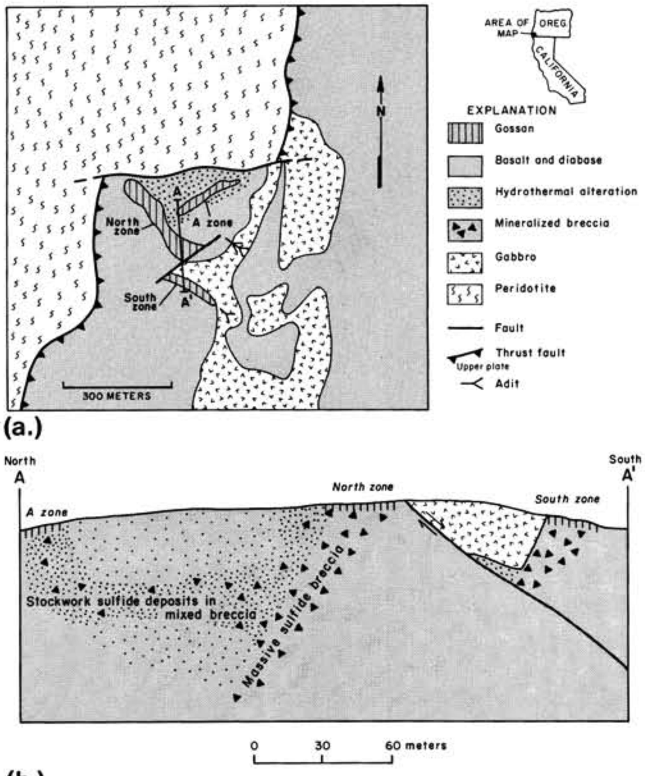

Figure 4. Geologic map (a) and cross section A-A' (b) of the Turner-Albright Mine. (Modified from Cunningham, 1979)

replaced by sulfides along their margins. Microcrystalline hematitic jasper forms veinlets and fills interstices between altered volcanic fragments. Adjacent volcanic wall rocks are strongly chloritized and silicified. The configuration of the feeder zone and tabular massive sulfide body suggests that the Turner-Albright deposit may be overturned to the southwest.

DEPOSITS IN ISLAND-ARC TERRANES

Felsic submarine lavas and pyroclastic rocks in calc-alkaline island-arc sequences host the important class of Kuroko-type massive sulfide deposits. These volcanogenic polymetallic deposits generally consist of one or more strati-form massive sulfide layers and lenses intercalated with volcanic strata and an underlying discordant stockwork mineralization of lower grade. The latter feature may represent the hydrothermal feeder system for the layered sulfide accumulations. Kuroko-type deposits in the Miocene Green Tuff province in Japan and in other island-arc complexes are important sources of base and precious metals.

Stratiform volcanogenic massive sulfide deposits occur in fragmental metavolcanic rocks of the Rogue and Galice Formations in the western Jurassic belt of southwestern Oregon. The texture, composition, and major- and trace-element patterns of the metavolcanic and volcaniclastic metasedimentary rocks indicate that the Rogue and Galice Formations represent a Jurassic island-arc sequence (Garcia, 1979). Much of the sulfide occurs within felsic pyroclastic units along two northeast-trending zones: (1) a northern zone southwest of Canyonville, and (2) a southern zone that crosses the Rogue River near Galice. The Silver Peak and Almeda are the most important deposits in the northern and southern zones, respectively (Figures 1 and 5).

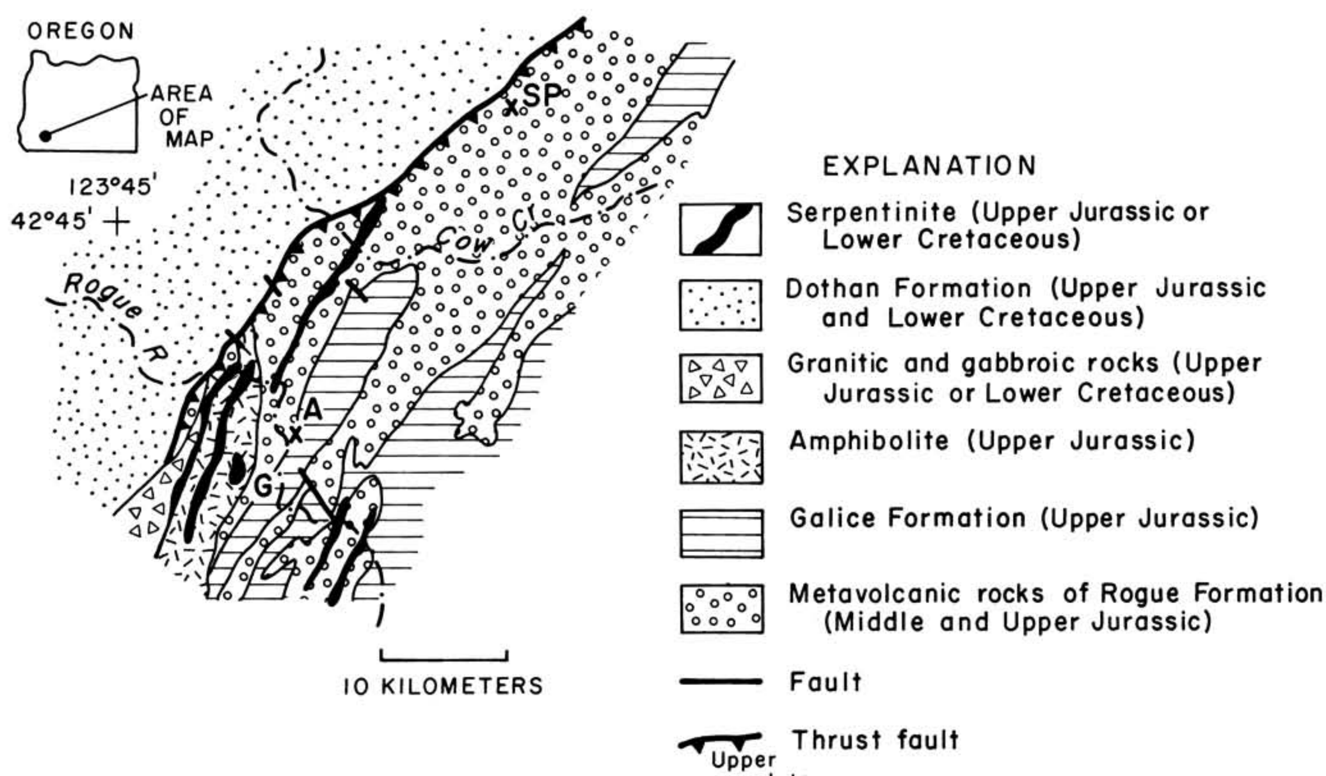

Figure 5. Regional geology surrounding the Silver Peak and Almeda Mine areas. G = Galice, SP = Silver Peak Mine, A = Almeda Mine. (Modified from Wells and Walker, 1953)

Silver Peak deposit

During the years 1926, 1928-31, and 1936-37, the Silver Peak Mine had a recorded production of 6,620 tons of ore from which 735,600 pounds of Cu, 21,980 troy ounces Ag, and 490 troy ounces Au were recovered (Ramp, 1972). During the period 1976-79, more than 12,000 ft of diamond drilling at the Silver Peak Mine and along the South Fork of Middle Creek 3 km southwest of Silver Butte penetrated several massive pyritic lenses, but copper-zinc mineralization comparable to that exposed in the Silver Peak Mine was not detected.

Jurassic metavolcanic rocks hosting the Silver Peak deposit lie in the upper plate of the Coast Ranges thrust and structurally overlie sedimentary rocks of the Dothan Formation (Figure 5). Johnson and Page (1979) have subdivided the greenschist-facies volcanic rocks near Silver Peak (previously the Rogue Formation) into a predominantly southeast-dipping sequence of rhyodacitic to andesitic flows, tuff, tuff breccia, agglomerate, and pillow basalt. Lava and tuff higher in the section (to the east) are interbedded with thin-bedded gray shale. The sequence is disrupted by southeast-dipping thrust faults and narrow slivers of serpentinite.

Figure 6 is a generalized geologic cross section of the Silver Peak deposit. The stratigraphically lowest unit exposed in the mine area, a vesicular andesite flow, is overlain by dacitic to rhyodacitic tuff and flows that grade upward into foliated tuff and tuff-breccia deposits. The uppermost unit in the sequence, exposed on nearby Silver Butte, consists of thin-bedded to massive siliceous tuff and interbedded tuffaceous sandstone.

All known mineralization in the Silver Peak area occurs within the foliated-tuff horizon (Figure 6), which is locally altered to aggregates of chlorite-talc-sericite or quartz-sericite. Flattened lapilli and pumice fragments also are present in the tuff. Graded tuff beds, fragments with altered margins, and load and flame structures within the mineralized zone all indicate subaqueous deposition.

Lenticular bodies of massive sulfide and barite as thick as 4 m parallel the plane of foliation over an exposed strike length of 90 m; layering within the massive sulfide also parallels the foliation. Lenses of foliated tuff as thick as 1 m occur in the massive sulfide. Additional sedimentary structures in the massive sulfide include load structures on the underlying tuff, graded bedding, and flame structures into the overlying tuff. Numerous disturbed structures disrupt bedding continuity.

Pyrite, the predominant sulfide mineral in the massive sulfide, generally occurs as subrounded grains in a matrix of one or more of the following minerals: quartz, barite, chalcopyrite, sphalerite, bornite, and Zn-rich tennantite. The individual pyrite grains appear to be detrital fragments cemented by other sulfide and gangue minerals. Small blebs of chalcopyrite, bornite, tennantite, and sphalerite are present in the pyrite, particularly pyrite grains surrounded by copper and zinc minerals. Galena is a very minor constituent of the ores at Silver Peak, and no silver minerals have been found.

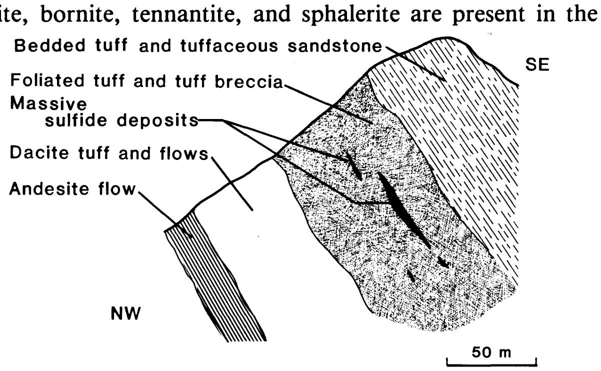

Figure 6. Generalized geologic cross section through the Silver Peak deposit.

Vertical zonation similar to that found in Kuroko-type deposits is evident in several underground exposures in which loosely bound massive pyrite (friable yellow ore) yields upward to dense massive pyrite-chalcopyrite (yellow ore), massive pyrite-sphalerite, tennantite-bornite-barite (black ore), and massive barite. Barite lenses are present in the black ore zone. Although massive ferruginous chert typical of Kuroko-type deposits is absent at Silver Peak, hematitic chert fragments as large as 3 cm in diameter are present in flow-banded tuff overlying the massive sulfide and massive barite. This flow-banded tuff unit also contains as much as 10 percent disseminated lapilli-size pyrite and chalcopyrite grains. The massive ore is locally underlain by 1-2 m of silicified tuff containing veinlets of pyrite, as well as disseminated pyrite, chalcopyrite, and bornite. However, no deep feeder system underlying the massive sulfide has been identified.

Almeda deposit

The Almeda Mine is situated on the north bank of the Rogue River, approximately 30 km southwest of the Silver Peak Mine. Shenon (1933b) reports that, between 1911 and 1916, 16,619 tons of ore produced from the Almeda deposit yielded 259,800 pounds of Cu, 7,197 pounds Pb, 1,540 troy ounces Au, and 48,387 troy ounces Ag.

Sulfide mineralization occurs in highly altered fragmental rhyolitic to dacitic metavolcanic rocks assigned to the Rogue Formation, immediately below the depositional contact with overlying slate and graywacke of the Galice Formation. Sill-like masses of dacite porphyry are emplaced along the Rogue-Galice boundary. The volcanic and sedimentary sequence occurs east of, and is in fault contact with, an ophiolite assemblage of amphibolite, metagabbro, and ultramafic rocks. Garcia (1979) suggests that this mafic-ultramafic complex represents the oceanic crust upon which the island arc that parented the Rogue and Galice Formations was constructed.

At the Almeda Mine, a 60-m-thick steeply east-dipping mass of intensely silicified fragmental rock known as the "Big Yank lode" occurs between clastic sedimentary rocks of the Galice Formation and coarse rhyolitic agglomerate. The mass contains lenses and fragments of massive sulfide and barite in a silicified volcanic matrix. Lenses of massive sulfide have a fragmental texture and contain clasts of sulfide, barite, and altered volcanic rock. Locally, alternating layers of sulfide and barite appear to be bedded deposits. The most abundant hypogene sulfide is pyrite, although chalcopyrite, sphalerite, and galena are locally concentrated in massive accumulations. Diller (1914, p. 75) refers to the stratiform mineralization here as "copper ore with barite."

Disseminated and vein sulfide, mostly pyrite, is present in silicified rock between the sulfide and barite lenses and lithic fragments and also forms an extensive stockwork in silicified volcanic breccia stratigraphically below the Big Yank lode. This low-grade stockwork zone reportedly contains anomalous gold and silver values (Shenon, 1933b) and is referred to as "siliceous gold-silver ore" by Diller (1914, p. 75). Quartz-sericite alteration and pyritization decrease in intensity below the Almeda deposit but extend southward from the Rogue River along the contact between the Rogue and Galice Formations. Sill-like masses of dacite porphyry emplaced near the contact are locally altered to fine-grained quartz and sericite accompanied by disseminated pyrite. With depth below the stratiform sulfide, quartz-sericite alteration diminishes, and the felsic volcanic rocks contain chlorite and epidote.

Table 1. Characteristics of principal massive sulfide deposits in southwestern Oregon

Deposit	Host rocks	Metals	Mineralization	Stockwork	Classification
Takilma area					
Queen of Bronze	Diabase, gabbro	Cu (Zn, Co, Au)	Pyrite, chalcopyrite, sphalerite, quartz, chlorite	No	Cyprus type(?)
Cowboy	Serpentinite	Cu (Co, Ni, Au, Zn)	Pyrrhotite, chalcopyrite, sphalerite, cubanite, cobaltite(?), quartz, antigorite, chlorite	No	Cyprus type(?)
Turner-Albright	Basalt, volcanic breccia	Cu (Au, Zn, Co)	Pyrite, chalcopyrite, sphalerite, quartz	Yes	Cyprus type
Almeda	Rhyolite to dacite breccia	Cu (Au, Ag, Zn, Pb)	Pyrite, chalcopyrite, sphalerite, galena, tetrahedrite, barite, quartz	Yes	Kuroko type
Silver Peak	Dacite to rhyodacite tuff	Cu (Au, Zn)	Pyrite, chalcopyrite, sphalerite, tennantite, bornite, barite, quartz	?	Kuroko type

CONCLUSIONS

Table 1 lists major characteristics of the Queen of Bronze, Cowboy, Turner-Albright, Silver Peak, and Almeda sulfide deposits. These deposits in southwestern Oregon are believed to have been formed by submarine volcanogenic processes operating in distinct tectonic environments. The copper deposits near Takilma, Oregon, are components of a tectonic mélange and lack clearly defined stockwork zones; their spatial relation to volcanic centers is uncertain. However, the Fe-rich Fe-Cu-Zn sulfide assemblage, preservation of layered or fragmental massive-sulfide textures, and an ophiolitic wall rock environment all suggest an analogy with Cyprus-type cupreous-pyrite deposits. The sulfide-bearing ophiolitic rocks may have formed within a near-arc basin or at a subvolcanic level within a primitive island-arc environment. The zone of sulfide mineralization has been disrupted by later faulting and diapiric emplacement of serpentinite.

The geologic setting, stratigraphy, and composition of the Turner-Albright deposit strongly resemble those of Cyprus-type deposits. The stratiform zone of pyritic massive sulfide breccia and the associated stockwork veining and quartz-chlorite alteration occur in mafic volcanic rocks that stratigraphically overlie an extensive sheeted-dike complex in the Josephine ophiolite. Volcanism and sulfide deposition were contemporaneous at a site of sea-floor spreading in a Mesozoic marginal-basin environment.

The polymetallic Silver Peak and Almeda deposits, which have numerous Kuroko-type characteristics, occur in fragmental calc-alkaline volcanic rocks at separate stratigraphic intervals within the island-arc assemblage that include the Rogue and Galice Formations. Extensive quartz-sericite-pyrite mineralization in subjacent pyroclastic rocks at the Almeda Mine may represent a hydrothermal feeder system in the Rogue section. Massive sulfide and barite deposition are proximal with respect to the central vent. At Silver Peak, a thin but laterally extensive horizon of sulfide-bearing sericitic tuff underlies zoned massive sulfide and barite, but no deep stockwork zone has been located. Disrupted sulfide layers, fragments of massive barite in black ore, detrital sulfide, load structures, and graded bedding all indicate that the sulfides may have been transported downslope from a central vent by slumping and debris flow.

Albers (1981) discusses the syngenetic relation between certain mineral-deposit types and accreted "tectono-stratigraphic" belts. Deposits like those described in this report may occur elsewhere in the northern Klamath Mountains and offer a potential source for copper, gold, silver, zinc, cobalt, nickel, and barite. The recognition and interpretation of oceanic-crust and island-arc terranes in the Klamath province are key factors in exploring for base- and precious-metal deposits in southwestern Oregon.

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Oil and gas developments

State and county lease sales held during summer

An Oregon State Lands Division lease sale held July 8 and 9, 1981, offered over 107,000 acres in several counties and brought bonus bids totaling $1.6 million. The auction, which took place in Salem, offered property in the counties of Clatsop, Columbia, Coos, Crook, Deschutes, Douglas, Harney, and Malheur. High total bonus bids were made by Gulf Oil Corporation, Phillip Brock, A.G. Andrikopoulos, Marathon Oil Company, and Nahama and Weagant Energy Company. The high bid of $230 per acre bonus was made by Nahama and Weagant for a parcel of 640 acres in sec. 13, T. 7 N., R. 6 W.

Terms of State leases are as follows: 10-year duration, $1.00 per acre per year, and one-eighth (⅛) royalty. A drilling commitment within seven (7) years is also a stipulation of the leases.

An auction of mineral rights of Columbia County lands was held August 13, 1981, at the County Courthouse in St. Helens near Mist. Of a total of 65,330 acres offered, 50,025 acres were sold for a total of $1,528,504.00 cash bonus bids. Bids ranged from $0.25 to $93.00 per acre. Nahama and Weagant of Bakersfield, Calif., were successful bidders for the highest priced parcel, 600 acres at $93.00 per acre.

Diamond Shamrock completes drilling in Clatsop County

Diamond Shamrock Corporation has completed a three-well program in Clatsop County. The wells, drilled to depths of 7,864, 5,700, and 6,095 ft, are located near Knappa, Necanicum, and Saddle Mountain. All were abandoned as dry holes before reaching their projected depths. No further drilling plans for Clatsop County have been announced by Diamond Shamrock. The company, however, continues to remain active in the Mist field as partners with Reichhold Energy Corporation and Northwest Natural Gas Company.

Eighth producer completed at Mist

Reichhold Energy Corporation, in partnership with Diamond Shamrock Corporation and Oregon Natural Gas Development, has completed its eighth producing gas well in the Mist Gas Field. Located in sec. 1, T. 6 N., R. 5 W., approximately 2 mi north of the town of Mist, Columbia County 13-1 was completed August 17, 1981, flowing 2.6 million cubic feet of gas per day.

Plans are to connect this well to the Northwest Natural Gas pipeline that carries gas from the Mist field to Clatskanie. An offset well will also be drilled.

Exploration continues in Willamette Valley

American Quasar Petroleum Company's Kenneth Wetgen 26-32, NE ¼ sec. 26, T. 13 S., R. 4 W., Linn County, was spudded August 14, 1981. Proposed depth is 5,000 ft; the contractor is Paul Graham Drilling Company.

Quintana Petroleum Corporation's Gath 1, SE ¼ sec. 16, T. 8 S., R. 2 W., Marion County, was also spudded August 14, 1981. Proposed depth is 6,000 ft; the contractor is John Taylor Drilling Company. □

Newberry well is hottest geothermal prospect yet reported in Oregon

The hottest temperatures measured so far in a geothermal energy prospect in Oregon were reported July 23, 1981, by the U.S. Geological Survey (USGS), Department of the Interior.

USGS scientists said that a geothermal test hole being drilled in the summit crater of Newberry Volcano, about 25 mi southeast of Bend, Oreg., produced temperatures of 190°C (375°F) at a depth of 2,656 ft. A temperature of at least 150°C (300°F) is generally considered the minimum necessary for commercial consideration in using a geothermal resource to produce electricity.

Robert Tilling, chief, USGS Office of Geophysics and Geochemistry, emphasized that "the Newberry report is not yet a proven commercial discovery, but it is the most encouraging geothermal find in Oregon and could spur a re-evaluation of the nearby Cascade geothermal-energy potential. Finding a prospect as hot as the Newberry well provides at least the first step necessary to prove the feasibility of a geothermal resource—high temperatures. The next step would be to determine if there is enough flow to produce the volume and rate of the hot geothermal fluids that could be used in a power generation plant for conversion of the geothermal energy to electricity."

Edward Sammel, USGS hydrologist who is supervising the geothermal drilling at Newberry, said that plans are to drill the 3-in. hole to as deep as 3,000 ft and then run tests at that depth to determine temperature and rate of flow. The well is part of the USGS geothermal-research program that, in addition to other related efforts, is conducting a comprehensive regional evaluation of the geothermal potential of the Cascade Range in Washington, Oregon, and California.

The Newberry crater is in the Deschutes National Forest and is part of the "Newberry Caldera Known Geothermal Resource Area" (KGRA) previously outlined by the USGS. The U.S. Forest Service has been conducting an environmental impact study should any part of this KGRA ever be offered by the federal government for leasing for geothermal exploration.

Newberry Volcano is one of the largest volcanoes that formed in the conterminous 48 states during the geologically recent period of the last 2 million years (Quaternary Period). The last known eruption from the present Newberry Crater occurred about 1,400 years ago, and there is a high probability that extremely hot rock, perhaps even molten rock (magma), may still underlie the crater at fairly shallow depths.

The summit of Newberry Volcano has collapsed to form a caldera or crater about 5 mi in diameter. The collapse followed the eruption of vast volumes of volcanic ash and lava from the volcano's underlying magma chamber. Newberry Crater is similar in its origin to the crater formed by the violent eruption and associated collapse of nearby Mount Mazama about 6,700 years ago, whose caldera now contains scenic Crater Lake. Newberry Crater contains two small lakes, Paulina and East lakes.

Temperature measurements in the test hole were made by David Blackwell, Department of Geological Sciences, Southern Methodist University. USGS scientists said that in the lower 450 ft of the test hole, the temperature gradient became extremely high—about 600°C per kilometer, compared to a worldwide continental average of about 30°C per kilometer.

"This high gradient is extremely encouraging for two reasons," Tilling said. "First, it suggests an increased potential for development, should the high gradient continue at deeper depths. Second, and perhaps more important, the high gradient tends to confirm a theory that the low temperatures at shallow depths that have discouraged previous geothermal exploration in the nearby Cascade Range may reflect more the effects of shallow lateral flow of cool ground water rather than the real geothermal-energy potential. We think the high precipitation and generally high rate of ground-water recharge in the Pacific Northwest have combined to dilute and cool its geothermally heated water and to lower its rock temperatures at shallow depths during the past thousand years or so. As a result, temperature data from shallow drill holes in the past have tended to discourage additional geothermal development in the region. If temperatures remain high in the Newberry well, it could spur a re-evaluation of the geothermal energy potential in the Cascades."

Similar encouraging results were recently reported in the Canadian Cascades where a geothermal exploration project measured a temperature of more than 200°C in the Meagher Creek area of British Columbia. The recent eruptions of Mount St. Helens remain the most obvious manifestations of the internal heat and geothermal activity in the Cascade Range. □

Oregon fossils subject of new book

William N. Orr, professor of paleontology and geology at the University of Oregon, and Elizabeth L. Orr, catalog librarian, are the authors of a new 284-page paperback book, *Handbook of Oregon Plant and Animal Fossils.*

The book, which covers all aspects of Oregon plant and animal fossils, is divided into chapters on fossil plants, pollen, invertebrates, trace fossils, arthropods, freshwater fish, birds, marine vertebrates, and mammals and other land vertebrates. It contains drawings of fossils, lists of animal ranges, fossil-locality lists and maps, correlation charts, a 400-entry bibliography, and an index. The text reviews the literature on various fossils and discusses such paleontological subjects as ancient environments and settings, the forms in which fossils were preserved, and the ways fossils are used by geologists. The book is written for the knowledgeable layman but is also a useful reference for the professional geologist.

Price of *Handbook of Oregon Plant and Animal Fossils* is $10.95. It is available by mail from William N. or Elizabeth Orr, P.O. Box 5286, Eugene, OR 97405. □

(**New DOGAMI publications,** *from page 118)*
geologic mapping in Oregon, costs $7.00.

Open-File Reports 0-81-5, *Preliminary Geologic Map of the Amity and Mission Bottom Quadrangles, Oregon*, and 0-81-6, *Preliminary Geologic Map of the McMinnville and Dayton Quadrangles, Oregon*, begun in 1979 by H.G. Schlicker and completed in 1980 and 1981 by M.E. Brownfield, Oregon Department of Geology and Mineral Industries. These blackline preliminary geologic maps (scale 1:24,000) cover areas north and northwest of Salem in the northern Willamette Valley and represent DOGAMI's ongoing program to map strategic quadrangles in western Oregon that are, as in this case, experiencing rapid population growth. The maps delineate the geologic units and structure of the area and identify fossil and microfossil localities and abandoned oil and gas exploratory wells. Cost of each of these open-file reports is $4.00.

All of these new releases are available for inspection or purchase at the Oregon Department of Geology and Mineral Industries, 1005 State Office Building, Portland, OR 97201. Payment must accompany orders of less than $20.00 □

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