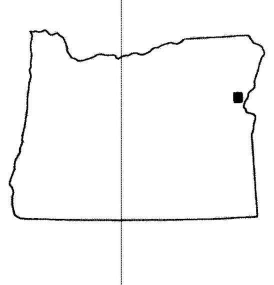
GMS 3

GEOLOGICAL MAP SERIES
GMS 3

PRELIMINARY GEOLOGIC MAP OF THE DURKEE QUADRANGLE, OREGON

by
Harold J. Prostka



1967

Issued by
State of Oregon
Department of Geology and Mineral Industries
Portland, Oregon
Hollis M. Dole, State Geologist

PRELIMINARY GEOLOGIC MAP OF THE DURKEE QUADRANGLE, OREGON

By
Harold J. Prostka

INTRODUCTION

For several years the State of Oregon Department of Geology and Mineral Industries has been investigating copper mineralization in northeastern Oregon. As a part of this work the writer has mapped geologically the Durkee 15-minute quadrangle to determine the structure and relations of the pre-Tertiary rocks to mineralized rocks of similar age which occur farther north.

The Durkee quadrangle lies in northeastern Oregon a few miles west of the Snake River. It is named for the town of Durkee, situated about 25 miles southeast of the city of Baker on U.S. Highway 30, which diagonally crosses the southwestern part of the area.

This preliminary report is based primarily on 5 months of detailed reconnaissance mapping done in the summers of 1961 and 1962. Subsequent laboratory work and field mapping in adjacent areas may modify the conclusions here presented.

Acknowledgments

The writer wishes to thank George S. Koch, Jr., of the U.S. Bureau of Mines; Richard G. Bowen, Norman S. Wagner, and Howard C. Brooks, all of the Oregon Department of Geology and Mineral Industries; and David A. Bostwick of Oregon State University for helpful discussions during the course of the work. J. A. Shotwell of the University of Oregon identified and dated a collection of Tertiary vertebrate bones found by James Haight of Baker, Oregon.

Previous work

The earliest work in the present area was done by Lindgren (1901), who prepared a small-scale reconnaissance geologic map of northeastern Oregon that includes the area now within the Durkee quadrangle. This was followed by a number of reports concerned chiefly with the economic deposits in the area: Swartley (1914), Moore (1937), Gilluly, Reed, and Park (1933), and an unpublished map and report by N. S. Wagner of the Oregon Department of Geology and Mineral Industries on the travertine deposit at Nelson. A map and report by Gilluly on the geology of the Baker quadrangle, which adjoins the Durkee quadrangle on the west, was, in 1937, the first detailed description of the rocks in this general region. Fitzsimmons wrote a doctoral dissertation (University of Washington, 1949) on the petrology of the rocks in the Durkee quadrangle, which included a generalized map. His petrographic descriptions were especially helpful in the preparation of the present report.

GENERAL GEOLOGY OF THE AREA

The rocks of the Durkee quadrangle fall into two groups, the pre-Tertiary rocks and those of Tertiary and Quaternary age, separated by a profound unconformity. The pre-Tertiary rocks include a highly sheared and contorted sequence of Permian(?) chert, argillite, and greenschist intruded by alpine-type gabbro and ultramafic rocks, which are overlain by and faulted against marble and phyllite of probable Upper Triassic age. All of these rocks are complexly folded along generally east- to northeast-trending axes and are cut by numerous faults. The Permian rocks, having been deformed at least twice, are prominently lineated, whereas the structures in the less-deformed Triassic rocks are dominantly planar. Several small quartz diorite stocks of Jurassic-Cretaceous age intrude the earlier rocks. Much of the southeastern part of the area is underlain by intricately faulted hornfels and marble invaded by numerous irregular masses of quartz diorite and aplite.

Tertiary rocks cover about one-third of the Durkee quadrangle. They include irregular patches of basalt, welded tuff, and Pliocene lake and stream sediments. The Tertiary rocks are gently folded and are cut by northwest-trending faults.

Quaternary deposits include travertine and several kinds of alluvium.

PRE-TERTIARY ROCKS

"Greenschist" (Pg)

This unit, which includes probably the oldest rocks in the quadrangle, consists mainly of fine-grained, lineated greenschist with minor talc schist, phyllite, chert, and limestone. The "greenschist" is metamorphosed basic tuff, lava flows, and sills but included also are small amounts of highly sheared gabbros which, in the field, are indistinguishable from altered sills and flows. The limestone in this unit occurs as sheared pods ranging from less than a foot long to larger masses tens of feet across, and in beds up to 50 feet thick, which are traceable for as much as a mile. The larger bodies of limestone are mapped separately. Rocks of the "greenschist" unit are well exposed along U. S. Highway 30 southeast of Nelson, and along Swayze and Manning Creeks. In the adjoining Baker quadrangle rocks similar to these are included in the "Burnt River Schist" (Gilluly, 1937). The base of the "greenschist" is not recognized; about 3,000 feet of the unit is exposed in the section at Nelson.

The "greenschist" is similar to the Elkhorn Ridge Argillite in that it locally contains bedded cherts and discontinuous limestone beds, and appears to have undergone about the same intensity and style of deformation. Both units probably are very nearly the same age and may even be facies equivalents. Datable fossils have not been found in the "greenschist" as yet.

Elkhorn Ridge Argillite (Pe)

This formation is a thick sequence of highly contorted argillite and bedded chert with lesser amounts of tuff, conglomerate, and limestone. The limestone typically occurs as pod-like bodies rarely more than half a mile long. The formation was named by Gilluly (1937, p. 14) from exposures on Elkhorn Ridge in the Sumpter quadrangle. From there it can be traced eastward through the Virtue Hills and into the Durkee quadrangle, where it underlies much of the northern half of the area.

Intense deformation and poor exposures preclude accurate measurement of its total thickness; however, Gilluly (1937, p. 14) suggested 5,000 feet as a reasonable estimate. Neither top nor bottom of the Elkhorn Ridge Argillite has been recognized. At the head of Manning Creek the formation seems to grade downward and laterally into "greenschist" (Pg), which suggests that the latter may be a volcanic-rich basal facies of the Elkhorn Ridge Argillite.

Similar gradational relations can be seen west of Little Lookout Mountain near Black Springs Creek.

Fusulinids of Upper Permian age occur in limestone pods in the Elkhorn Ridge Argillite farther to the west (Taubeneck, 1955a; Bostwick and Koch, 1962). However, some of the pods contain Triassic Pentacrinus columnals and may be infolded masses of Martin Bridge Formation. The only pre-Tertiary fossils found within the Durkee quadrangle were a few poorly preserved corals north of Lawrence Creek in sec. 10, T. 10 S., R. 43 E.

Basic and ultrabasic intrusive rocks (gb, pd, sp)

Masses of partially sheared and metamorphosed gabbro, peridotite, and serpentine have been emplaced in the Elkhorn Ridge Argillite and "greenschist." These alpine-type intrusives, common throughout northeastern Oregon, are probably of Lower Triassic age, for they intrude rocks of upper Permian age and are overlain by Upper Triassic sediments (Prostka, 1963, p. 112).

The fresh gabbro consists of calcic labradorite or bytownite and about equal amounts of hypersthene and augite. Minor accessories include hornblende, magnetite, and epidote. Much of the gabbro is highly sheared and recrystallized to chlorite schist. Small bodies of peridotite and serpentinite occur in the gabbro and Elkhorn Ridge Argillite; the largest masses are near the northern border of the quadrangle.

Most of the plutonic masses have sheared margins, due either to tectonic emplacement or to shearing of the sediments against the more competent crystalline rocks. The large bodies of gabbro in the southern part of the quadrangle are apparently in fault contact with younger marble and phyllite.

Gabbros near the Jurassic-Cretaceous quartz diorite stocks are recrystallized to coarse-grained hornblende hornfels and fine-grained amphibolite. Blocks of amphibolite carried up by the rising magma are common at the margins of the larger stocks. These blocks, which are as much as half a mile long, can be seen at the heads of Swayze and Sisley Creeks and in Drindary Gulch. Gabbro and peridotite hydrothermally altered to tremolite-talc schist occur above the mouth of Gold Cliff Gulch (sec. 20, T. 12 S., R. 44 E.), and in the western part of sec. 12, T. 12 S., R. 44 E.

Nelson marble (TRn)

This formation, consisting of light-gray, fine-grained marble and medium- to dark-gray calcareous phyllite, is here informally named for exposures at Nelson, where the Burnt River has cut a deep canyon between Gold Hill and Gold Ridge, exposing a complete section of the formation. The marble is well exposed along Sisley Creek and at the head of Hibbard Creek, and can be traced eastward to Connor Creek and the Snake River. To the west the unit is continuous with the thick marble beds in the Burnt River Schist (Gilluly, 1937).

The Nelson marble is about 1,500 feet thick. It rests unconformably on "greenschist" at Gold Hill and on gabbro at Gold Ridge. It is conformably overlain by a thick sequence of dark gray, mostly non-calcareous, phyllite. No fossils were found in the Nelson marble but the formation is almost certainly correlative with the Martin Bridge Formation (Ross, 1938) of Upper Triassic age, and with the limestone at Lime, as was originally suggested by Lindgren (1901). All three formations are approximately the same thickness; they consist dominantly of massive limestone and calcareous shale or their metamorphic equivalents, marble, and calcareous phyllite; and they are conformably overlain by a thick argillaceous sequence (Hurwal Formation of gray phyllite).

The higher degree of metamorphism of the Nelson marble as compared with the other two limestone formations is due to contact metamorphism by quartz diorite which has extensively invaded the southern part of the Durkee quadrangle. Similar recrystallization of Martin Bridge limestone to coarse-grained marble has occurred near the Wallowa batholith.

Gray phyllite (TRg)

A thick sequence of gray phyllite with lesser amounts of limestone, sandstone, and black carbonaceous slate conformably overlies the Nelson marble at Nelson, along Sisley Creek, and at the head of Hibbard Creek. In the southeastern corner of the quadrangle, more than 5,000 feet and perhaps as much as 10,000 feet thickness of this unit is exposed.

To the west in the Baker quadrangle, small thicknesses of the phyllite unit are included in the Burnt River Schist. Eastward, the gray phyllite can be traced across the Snake River into Idaho.

The gray phyllite is probably correlative with the Hurwal Formation of Upper Triassic age (Smith and Allen, 1941). Both formations are more than 5,000 feet thick; they consist of rather monotonous sequences of carbonaceous argillite and siltstone, sandstone, and minor limestone; they conformably overlie very massive limestone formations; and both contain thinner interbedded limestones in their upper part (Laudon, 1956; Palen, 1955). In the Durkee quadrangle these limestones may be seen in secs. 26, 27, and 33, T. 11 S., R. 44 E.

The absence of fossils and the more intense alteration of the gray phyllite compared with the Hurwal Formation are believed to have been caused by contact metamorphism by quartz diorite which has extensively invaded the southern part of the Durkee quadrangle.

Quartz diorite and granodiorite (Kqd)

Several small stocks of quartz diorite and granodiorite were intruded into the Permian and Triassic rocks after the main period of folding. These stocks, which are Late Jurassic or Early Cretaceous in age (Taubeneck, 1955b, 1959), are lithologically similar to other large granitic plutons in northeastern Oregon, the Bald Mountain batholith and the Wallowa batholith.

Most of the intrusive rock is coarse- to medium-grained quartz diorite consisting of andesine, about equal amounts of hornblende and biotite, quartz, magnetite, and less than 5 percent potash feldspar. The stocks show systematic variations in mineralogy; the smaller stocks and the margins of the larger ones have a higher total mafic mineral content and higher hornblende to biotite ratio. The center of the large stock which underlies Big Lookout Mountain is trondhjemitic and contains a little biotite as the only mafic mineral.

The two smaller stocks in the northern half of the area are discrete plutons having sharp, nearly vertical contacts. Contact metamorphism of the country rocks around these stocks is much less pronounced than around the granitic masses to the south. The latter are probably parts of a large, partially de-roofed stock that underlies, at depth, much of the southeastern part of the area. Here, contacts with the wall rocks are commonly shallow, for example in sec. 26, T. 11 S., R. 44 E. The contacts are intricate in detail with much diking, and engulfment of inclusions (for example, along Swayze Creek and Hogback Creek). In places there are zones of highly fractured roof-rocks intimately invaded by dikes and veins of quartz diorite and aplite (secs. 32, 33, and 34, T. 11 S., R. 44 E.).

The quartz diorite is for the most part unfoliated, but northwest of Big Lookout Mountain the margin of the stock shows a prominent alignment of hornblende parallel to the contact. Here, there are also abundant mafic-rich schlieren which indicate marginal contamination of the magma by local assimilation of basic wall rocks. Large mappable blocks of country rock engulfed by the magma and carried up along the contacts include pieces of amphibolite and meta-gabbro (along Sisley Creek, Drindary Gulch, and Summit Creek), and marble (NW¼ sec. 11, T. 12 S., R. 44 E.).

Chilled marginal phases of the quartz diorite occur locally; in the NW¼ sec. 13, T. 12 S., R. 44 E. medium-grained quartz diorite grades into hornblende andesite within 100 feet from the contact. A similar body of chilled diorite occurs in sec. 19, T. 12 S., R. 44 E. Dikes of quartz and aplite, some of them more than 20 feet thick, occur in the quartz diorite and nearby country rocks. They are especially abundant in sec. 21, T. 12 S., R. 44 E.

Metamorphism of the pre-Tertiary rocks

All of the rocks older than the Jurassic-Cretaceous intrusives are metamorphosed to some degree. Regional metamorphism of the Elkhorn Ridge Argillite, "greenschist," and sheared gabbro to the greenschist facies probably occurred during folding in Lower or Middle Triassic time. These rocks contain abundant low-grade metamorphic minerals: epidote, albite, chlorite, actinolite, and blue-green hornblende. The sedimentary and tuffaceous rocks have been more thoroughly recrystallized than the relatively massive gabbros. Superimposed on this low-grade regional metamorphism is contact metamorphism near the Jurassic-Cretaceous stocks. In the metamorphic aureole, argillaceous rocks are recrystallized to quartz-muscovite-biotite hornfels, basic rocks to amphibolites or epidote-amphibolite hornfels, and limestone to coarse-grained marble. Locally there is development of skarn in marbles right at the contact (SE¼ sec. 2, T. 12 S., R. 44 E.). Maximum metamorphic grade within the quadrangle is obtained in the southeastern part of the area. From there, metamorphic grade decreases markedly to the northwest, away from the center of most intense intrusion.

Structure of the pre-Tertiary rocks

The bedded rocks are folded along generally east- to northeast-trending axes. Departures from this trend occur mainly near the forcefully emplaced quartz-diorite stocks.

The "greenschist," some of the gabbro, and Elkhorn Ridge Argillite have been strongly folded and deformed at least twice and now possess a characteristic westward-plunging lineation defined by the intersection of two foliations or by bedding and foliation. Axes of small folds and sheared chert beds are elongated parallel to this lineation. The limestone pods are probably sheared-out pieces of once continuous beds.

The Nelson marble and gray phyllite were folded only once and their structures are dominantly planar. Foliation in most cases is parallel to bedding.

The Nelson marble and gray phyllite occur as an east-trending band across the southern part of the quadrangle and comprise a generally northward-dipping sequence that is somewhat complicated by small folds and faults, and interrupted by quartz diorite intrusives. Near the eastern border of the quadrangle these formations terminate abruptly against granitic rocks, but half a mile to the southeast the marble and phyllite continue eastward as a south-dipping sequence. These relations suggest that the two formations once defined a large east-trending anticlinal fold which has been invaded and partially stoped by the quartz diorite.

Two major northeast-trending fault zones in the southern part of the quadrangle have guided the emplacement of the quartz-diorite bodies. The fault north of Gold Ridge, exposed in sec. 3, T. 12 S., R. 43 E., brings greenschist against gray phyllite. To the west this fault is covered by Cenozoic deposits. It probably continues northeastward beneath Tertiary sediments along Swayze Creek to Mud Springs, where the sheared contact of gabbro and greenschist with gray phyllite is invaded by quartz diorite.

Another major fault zone crosses Burnt River near the mouth of Sisley Creek and strikes across sec. 7, T. 12 S., R. 45 E. It brings slices of gabbro against strongly sheared gray phyllite. The quartz-diorite stock between Sisley Creek and Jordan Creek is intruded along this zone.

TERTIARY ROCKS

Tertiary rocks cover about one-third of the area and include olivine basalt erupted from fissures, volcanic necks of platy basalt with attached remnants of flows, and basaltic agglomerate. Overlying these are tuffaceous lake and stream sediments with a thin flow of welded tuff at the base of the unit. These sediments are thickest in the west-central part of the quadrangle, which was the site of a large Tertiary lake.

Columbia River Basalt (Tcr)

Flows of olivine basalt erupted from fissures comprise a 2,000-foot-thick northeastward-dipping sequence on Sheep Mountain and on Little Lookout Mountain. Elsewhere within the area the basalt occurs as relatively thin patches preserved in former depressions or in down-faulted blocks. The basalt overlies the pre-Tertiary rocks with profound unconformity.

Basaltic agglomerate, which locally underlies the basalt, consists of basaltic and pre-Tertiary rock fragments, lapilli, bombs, and pieces of dark glass in a brown, ashy matrix. The agglomerate is irregularly distributed because of the uneven surface on which it was deposited.

The olivine basalt flows are Picture Gorge-type Columbia River Basalt of middle to upper Miocene age (Waters, 1961; Prostka, 1963). The flows are typically holocrystalline and consist of about 50 percent labradorite, 20 percent titanaugite, 6 percent olivine partly altered to iddingsite, and the remainder opaque minerals, chlorophaeite, and montmorillonoids. The flows generally are less than 50 feet thick.

Basalt dikes which are mineralogically and texturally similar to the flows are plentiful in the eastern half of the quadrangle. The dikes strike generally north and are probably a southward continuation of the Cornucopia dike swarm (Waters, 1961) some 25 miles to the north.

Platy basalt (Tp)

Platy olivine basalt erupted from central vents is minor in the Durkee quadrangle, but similar lavas are voluminous a few miles to the north where they interfinger with Columbia River Basalt (Prostka, 1963). Within the Durkee quadrangle there are two vents: Iron Mountain in the west-central part of the area, and a surveyed peak, 4,935 feet high (NW¼ sec. 3, T. 10 S., R. 43 E.).

Iron Mountain is situated in the northern part of the Durkee Basin and is easily seen east of U.S. Highway 30 a few miles north of the town of Durkee. It is a jagged peak composed of platy basalt, pumice, and scoria much of which is encrusted with hematite, hence the name Iron Mountain. On the east side of the vent is a well-indurated agglomerate flow.

The other vent, situated in the northwestern corner of the quadrangle, is composed of vertically jointed, platy olivine basalt. Extending northward from this vent for nearly three miles is a flow of dark, platy, fine-grained basalt containing about 35 percent olivine which is almost completely altered to iddingsite. The characteristic platyness of this flow is due to the subparallel alignment of plagioclase microlites.

Welded tuff (Tt)

Small, isolated patches of welded tuff are preserved in many places throughout the quadrangle. The tuff is a resistant unit, but, because it is less than 20 feet thick, much of it has been eroded away. Best exposures of the tuff are on the west side of U.S. Highway 30 near the western border of the area. Here, the tuff and underlying basalt form resistant hogbacks which dip steeply to the northeast. At most localities the welded tuff overlies basalt or pre-Tertiary rocks but in places (for example, SE¼ sec. 26, T. 11 S., R. 43 E.) basalt overlies welded tuff. The tuff locally is conformably overlain by lake and stream sediments of lower Pliocene age.

Tuffaceous lake and stream deposits (Tl)

Tuffaceous lake and stream deposits fill the nearly circular Durkee Basin in the west-central part of the quadrangle. A smaller basin lies northeast of Gold Hill between Swayze Creek and Pearce Gulch. The sediments are mainly fine- to medium-grained, well-bedded, poorly consolidated sand and silt containing variable amounts of rhyolitic ash and pumice. Beds of nearly pure ash as much as 6 inches thick are locally present and are particularly well exposed about a mile northwest of Iron Mountain. In places there are beds of diatomite (Moore, 1937). The sediments show a general coarsening toward the margins of the basin, where conglomeratic beds are locally present. The deposits are locally derived; for example, sands adjacent to the Jurassic-Cretaceous granitic rocks are arkosic.

Vertebrate bones collected from the Durkee Basin have been dated as Clarendonian (latest Miocene to early Pliocene) by J. A. Shotwell of the University of Oregon (written communication, 1961).

Structure of the Tertiary rocks

The Tertiary rocks in general are gently warped into northwest-trending flexures and are cut by high-angle faults. Over much of the area, however, the details of the Tertiary structure are unknown because post-Miocene uplift and erosion have removed the Tertiary rocks.

The basalt flows on Sheep Mountain comprise a northeastward-dipping monocline that forms the southwestern limb of the Eagle Valley syncline. The steep southwestern slopes of Sheep Mountain and Little Lookout Mountain are probably fault scarps. Several smaller faults southwest of Little Lookout Mountain also trend northwest and consistently have the southwest side downthrown.

Faults in part determine the northern and southern boundaries of the Durkee Basin. The scarp on the north side of Gold Ridge is very abrupt and is marked by several springs which have deposited travertine within historic times. At the north end of the basin, near the railroad, the lake beds vary considerably in strike and dip, probably because of drag along the boundary fault.

In the southeastern corner of the quadrangle there are many faults of late Tertiary to Quaternary age which are probably related to relatively recent uplift of areas underlain by granitic rocks.

QUATERNARY GEOLOGY

Quaternary deposits include sand and gravel deposited on old erosion surfaces, colluvium, terrace gravels along the Burnt River, alluvium in present valleys, and travertine.

Erosional benches partially mantled with older alluvium occur in many parts of the quadrangle. Benches such as these can be seen from U.S. Highway 30 in the southern part of the area on both sides of Shirttail Creek. The alluvium is thin and patchy on this gently northward-sloping surface.

More extensive alluvium-covered surfaces are preserved around the northern edge of the Durkee Basin. This alluvium is not mapped except where it is sufficiently thick to conceal effectively the underlying bedrock.

Fans of colluvium or slope wash occur along the fault scarp on the north side of Gold Ridge.

Terrace gravels are found on both sides of Burnt River where it flows through the Durkee Basin. The town of Durkee is built on such a terrace.

Thin deposits of travertine are found along the foot of Gold Ridge on its north side, and at Nelson. The travertine is interbedded with alluvium and is at most 20 to 30 feet thick. All of the springs from which travertine was deposited are dry except one at Nelson which continues to trickle warm, lime-saturated water (Fitzsimmons, 1949).

Most of the streams in the quadrangle are actively downcutting and contain little or no alluvium. Burnt River flows in steep-sided canyons along most of its course, but where it crosses deposits of soft rocks such as the Tertiary sediments in the Durkee Basin it has built a wide flood plain.

MINERAL DEPOSITS

Gold: In the past gold was mined on Gold Hill and Gold Ridge and around Chicken Creek, but there is virtually no mining activity at present. The lode deposits in the area are gold-quartz veins which cut Jurassic-Cretaceous quartz diorite and nearby country rocks. The gravels in the canyon of Burnt River have been placered for gold. Compared with other mining districts in northeastern Oregon, this has been one of the less productive.

Limestone: Limestone is being quarried at Nelson. It has a low MgO content and very little argillaceous material. Most of it is shipped for use in sugar refining.

SELECTED BIBLIOGRAPHY

Beeson, J., 1955, Geology of the southern half of the Huntington quadrangle, Oregon: Univ. Oregon master's thesis, 79p.

Bostwick, D. A., and Koch, G. S., Jr., 1962, Permian and Triassic rocks of northeastern Oregon: Geol. Soc. America Bull., v. 73, no. 3, p. 419-421, March 1962.

Fitzsimmons, J. P., 1949, Petrology of the southwest quarter of the Pine quadrangle, Oregon: Univ. Washington doctoral dissertation, 145 p.

Gilluly, J., 1937, Geology and mineral resources of the Baker quadrangle, Oregon: U.S. Geol. Survey Bull. 879, 119 p.

Gilluly, J., Reed, J. C., and Park, C. F., Jr., 1933, Some mining districts of eastern Oregon: U.S. Geol. Survey Bull. 846-A, p. 24-31.

Laudon, T. S., 1956, The stratigraphy of the Upper Triassic Martin Bridge Formation and "Lower Sedimentary Series" of the northern Wallowa Mts., Oregon: Univ. Wisconsin master's thesis, 100 p.

Lindgren, W., 1901, The gold belt of the Blue Mts. of eastern Oregon: U.S. Geol. Survey 22nd Ann. Rept., pt. 2, p. 551-776.

Moore, B. N., 1937, Non-metallic mineral resources of eastern Oregon: U.S. Geol. Survey Bull. 875, 180 p.

Palen, F. S., 1955, The stratigraphy of the Hurwal Formation of the northern Wallowa Mts., Oregon: Univ. Wisconsin master's thesis, 58 p.

Prostka, H. J., 1962, Geology of the Sparta quadrangle, Oregon: Oregon Dept. Geology and Mineral Industries Map GMS-1, text 8 p.

________, 1963, Geology of the Sparta quadrangle, Oregon: Johns Hopkins Univ. doctoral dissertation, 245 p.

Ross, C. P., 1938, The geology of part of the Wallowa Mts., Oregon: Oregon Dept. Geology and Mineral Industries, Bull. 3, 172 p.

Smith, W. D., and Allen, J. E., 1941, Geology and physiography of the northern Wallowa Mts., Oregon: Oregon Dept. Geology and Mineral Industries, Bull. 12, 64 p.

Spiller, J., 1958, Geology of part of the Olds Ferry quadrangle, Oregon: Univ. Oregon master's thesis, 84 p.

Swartley, A. M., 1914, Ore deposits of northeastern Oregon: Oregon Bureau Mines and Geology, Mineral Resources of Oregon, vol. 1, no. 8, p. 1-229.

Taubeneck, W. H., 1955a, Age of the Elkhorn Ridge Argillite, northeastern Oregon: Northwest Sci., vol. 29, no. 3, p. 97-100, August 1955.

________, 1955b, Age of the Bald Mountain batholith, northeastern Oregon: Northwest Sci., vol. 29, no. 3, p. 93-96, August 1955.

________, 1959, Age of granitic plutons in northeastern Oregon (abs.): Geol. Soc. America Bull., vol. 70, no. 12, pt. 2, p. 1685, December 1959.

Wagner, N. S., 1958, Important rock units of northeastern Oregon: The ORE BIN, vol. 20, p. 63-68.

Wagner, W. R., 1945, A geological reconnaissance between the Snake and Salmon Rivers north of Riggins, Idaho: Idaho Bur. Mines and Geology Pamph. 74, 16 p.

Waters, A. C., 1961, Stratigraphic and lithologic variations in the Columbia River Basalt: Am. Jour. Sci., vol. 259, p. 583-611.

* * * * *