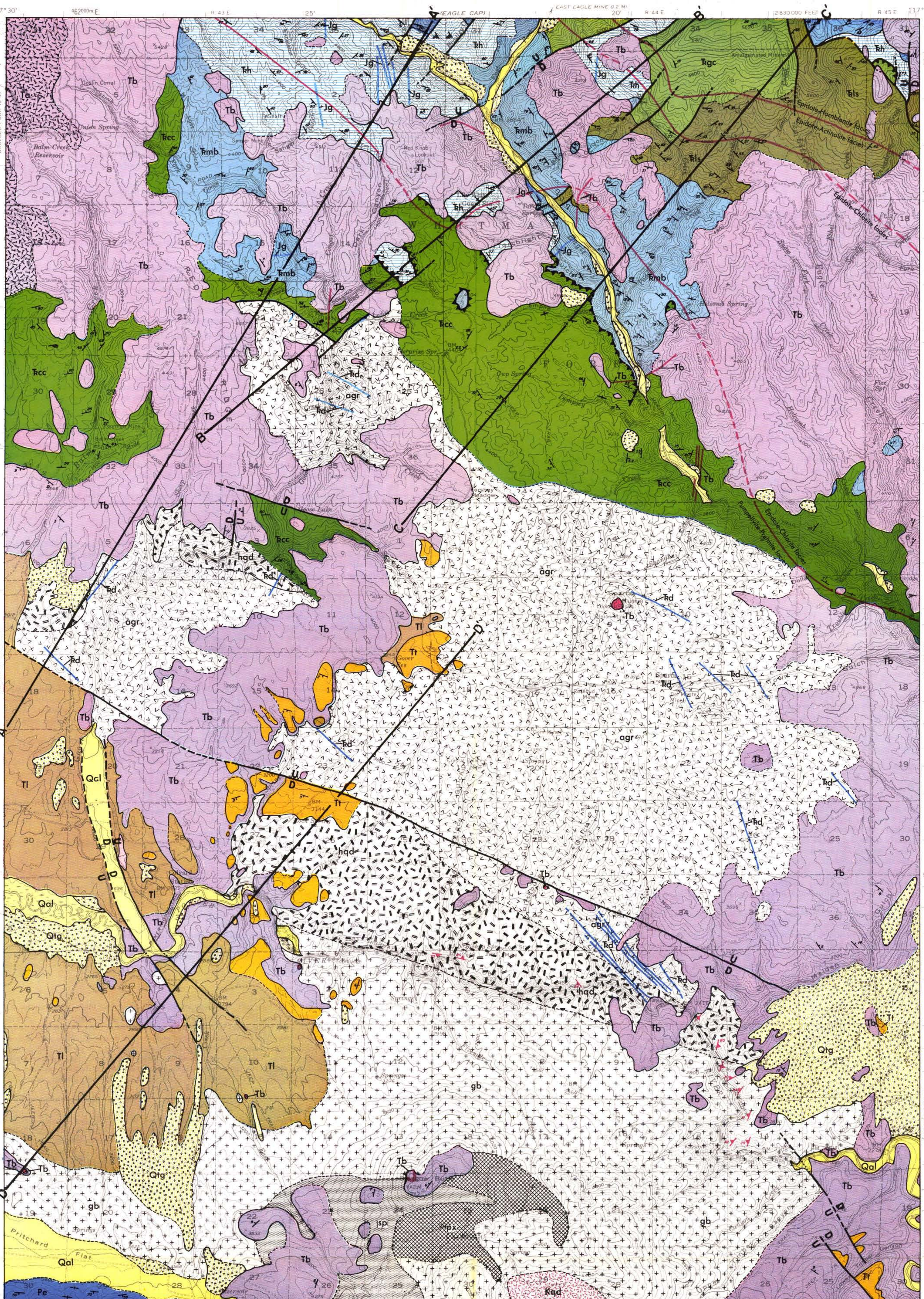
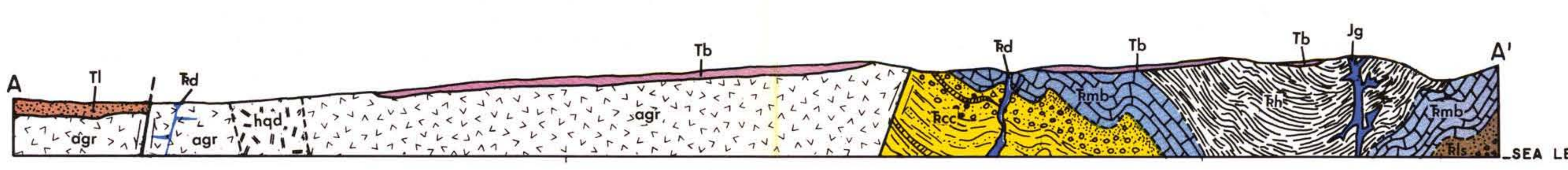
GEOLOGIC MAP
of the
SPARTA QUADRANGLE
OREGON

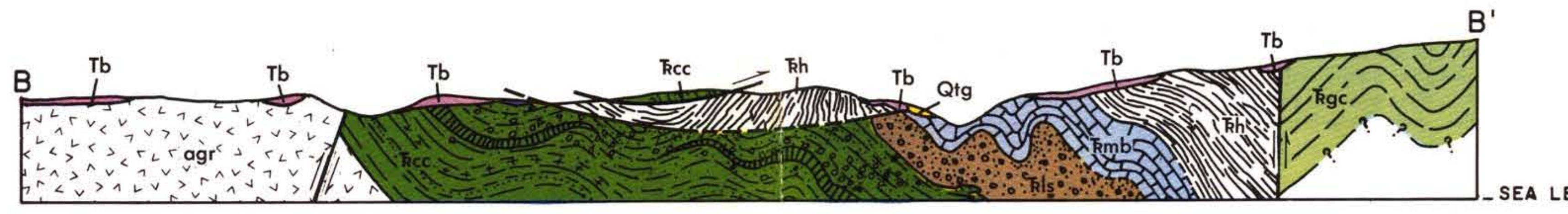


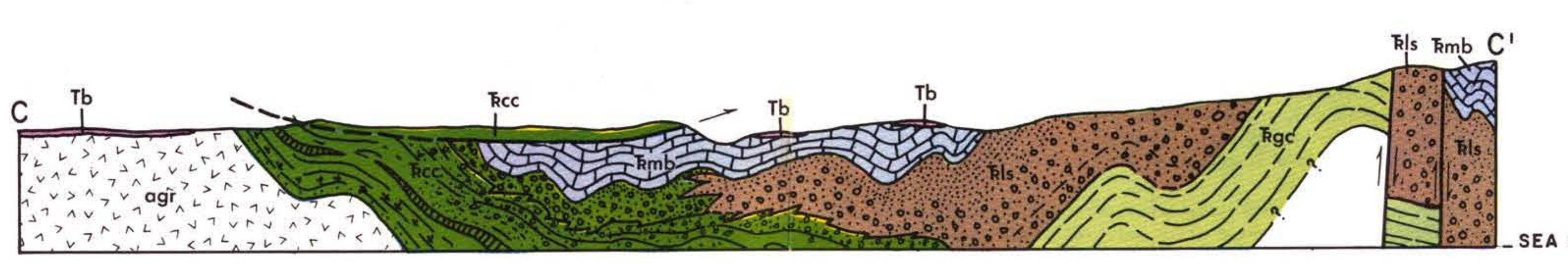
Based upon the Sparta Quadrangle topographic map issued by the U.S. Geologic Survey, 1957

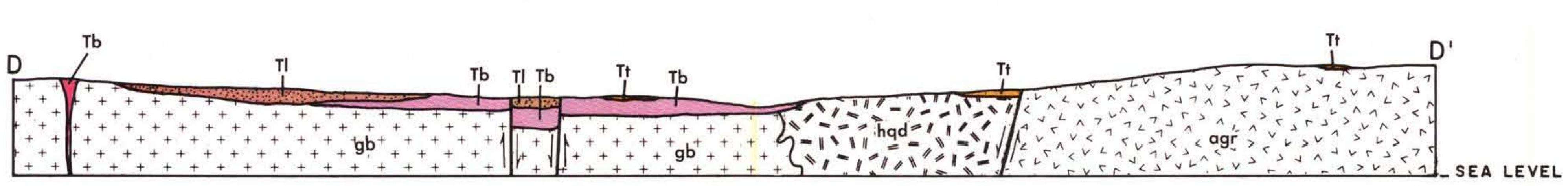
Geology by
Harold J. Prostka and Richard L. Bateman

GENERALIZED GEOLOGIC SECTIONS









EXPLANATION

BEDDED ROCKS

PLEISTOCENE AND RECENT

Qal
Recent alluvium
Sand, silt, and gravel in present day stream beds and flood plains.

Qtg
Terrace and bench gravels
Includes the following: (1) Banks of coarse bouldery gravel along Eagle Creek, probably of fluvial-glacial origin. (2) Unconsolidated stream deposits near the eastern border of the quadrangle, mostly sand and silt with no pyroclastic material. (3) Very well-sorted and rounded quartzite pebbles and cobbles in the southwest near Pritchard Flat. (4) Terraces of sand and fine gravel along Powder River.

UNCONFORMITY

UPPER MIOCENE–LOWER PLIOCENE

Tl
Lake and stream sediments
Light colored, fine-grained tuffaceous lake and stream deposits composed predominantly of well-bedded rhyolitic ash, pumice and diatomite with local coarse mudflow agglomerate. These sediments overlie the basalt with slight unconformity.

Tt
Welded tuff
A thin but prominent welded tuff flow with widely spaced columnar joints. It is interbedded with the lake sediments but in places it rests directly on basalt or older rocks.

UPPER MIOCENE

Ta
Andesite
Platy-jointed hypersthene andesite. Restricted to the northwestern corner of the quadrangle where it interfingers with the olivine basalt.

Tb — dike — neck
Olivine basalt
Vesicular, columnar-jointed olivine basalt flows. Many are diktytaxitic and porphyritic. Contain olivine, zoned titanaugite and abundant opaque minerals. Most of the flows are fissure eruptions but in the southern half of the quadrangle there are several small volcanic necks of platy basalt with associated scoria, flow remnants.
Olivine basalt feeder dikes and necks shown in darker red.

UNCONFORMITY

UPPER TRIASSIC

Trh
Hurwal Formation
Dark gray and purple graywacke and laminated siltstone with minor chert and thin-bedded limestones. More than 200' of limestone cobble conglomerate occurs at the top of the section.

Trmb
Martin Bridge Formation
Massive conglomeratic and coralline limestone interbedded with thin-bedded pyritic and carbonaceous limestones and calcareous shale.

Trls
"Lower Sedimentary Series"
Predominantly massive, well-sorted conglomerates and breccias containing clasts of albite granite and quartz diorite, grading upward into purple and green volcanic sandstones and siltstones.

Trgc
Gold Creek Greenstone
Mostly spilite and keratophyre flows with minor volcanic wackes and breccias containing a few fragments of albite granite.

Trcc
Clover Creek Greenstone
Spilite and keratophyre flows, coarse to fine-grained volcanic wackes, sandstones, tuffs and subordinate amounts of chert, conglomerate and limestone. Eastward the sediments coarsen and there are fewer interbedded volcanic flows.

UNCONFORMITY

PERMIAN (?)

Pe
Elkhorn Ridge Argillite
Highly contorted and fractured chert, argillite, tuff, and conglomerate with minor lenses of limestone.

INTRUSIVE ROCKS

UPPER JURASSIC–LOWER CRETACEOUS

Kqd
Quartz diorite
Fresh, coarse-grained quartz diorite and granodiorite stocks. Near the contacts aplite dikes and xenoliths are common.

Jg
Gabbro dikes and sills
Dikes and sills up to 150' thick of medium to coarse-grained hornblende-bearing gabbro.

UPPER TRIASSIC

Trd
Greenstone dikes
Dikes of porphyritic and non-porphyritic greenstone closely resembling spilite flows in the Clover Creek Greenstone which they probably fed.

LOWER TRIASSIC (?)

agr
Albite Granite
Coarse- to fine-grained granitic rock showing all degrees of shearing, composed primarily of quartz and albite with lesser amounts of biotite, hornblende, chlorite and epidote. In places, veins of quartz, albite and prehnite are numerous.

hqd
Hornblende quartz diorite
Coarse-grained quartz diorite containing hornblende and biotite; inclusions of gabbro and amphibolite are present locally.

gb
Gabbro
Dark coarse-grained gabbro containing ortho and clinopyroxene and, less commonly, hornblende. It is locally banded and has schlieren of coarse peridotite. Chlorite schist is developed along shear zones, and near the late Mesozoic stock (Kqd) is metamorphosed to amphibolite.

sp
Serpentine
Strongly sheared, bluish-black serpentine schist. Contains remnants of fresh peridotite and large metamorphosed inclusions of keratophyre and chert.

px
Pyroxenite and peridotite
Dark gray to greenish, coarse-grained peridotite and pyroxenite composed of ortho and clinopyroxene, olivine, and some chromite and magnetite. Locally it is cut by serpentinized shear zones.

Contact
Dashed where approximately located, dotted where concealed.

U / D
High Angle Fault
Dashed where approximately located, dotted where concealed; U, upthrown side; D, downthrown side.

Epidote-Chlorite facies
Epidote-Hornblende facies
Isograds showing approximate boundaries of metamorphic facies.

Thrust Fault
Teeth on side of upper plate.

Strike and dip of beds

Strike of vertical beds

Strike and dip of foliation

Strike of vertical foliation

CONTOUR INTERVAL 80 FEET
DATUM IS MEAN SEA LEVEL

SCALE 1:62500
1 ½ 0 1 2 3 4 MILES

TRUE NORTH — MAGNETIC NORTH — 20°
APPROXIMATE MEAN DECLINATION, 1957

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

GMS 1

GEOLOGY OF THE SPARTA QUADRANGLE, OREGON

by

Harold J. Prostka

1962

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GEOLOGY OF THE SPARTA QUADRANGLE

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 Sparta 15-minute quadrangle to determine the structure and extent of the mineralized rocks. The quadrangle is directly south of the Wallowa Mountains and is named from the former mining town of Sparta, which is 25 miles east of the city of Baker. This preliminary report is based primarily on six months of field work done in the summers of 1959 and 1960. Subsequent laboratory work and field mapping in adjacent areas may modify the conclusions of this report.

In the Sparta quadrangle the copper-bearing rocks are a sequence of complexly folded volcanic and sedimentary rocks of probable Triassic age. These rocks are extensively exposed across the northern part of the quadrangle and are a continuation of the Clover Creek Greenstone belt of the Keating quadrangle adjoining it to the west. Younger rocks in the Sparta quadrangle consist of basalt flows, tuffs, and lake beds of Tertiary age which in many places conceal the underlying Triassic rocks.

Acknowledgments

Thanks are due Richard L. Bateman who ably assisted the writer during the second field season. Norman J. Silberling of the U. S. Geological Survey and David A. Bostwick of Oregon State University provided fossil identifications and age assignments for the Triassic fossils, and J. A. Shotwell of the University of Oregon identified and dated a collection of vertebrate bones found by James Haight of Baker, Oregon. L. R. Hoxie of La Grande, Oregon, furnished a list of Miocene fossil leaves collected from one of the writer's localities.

Much valuable advice concerning geologic problems was given by George S. Koch, Jr., of Oregon State University and Norman S. Wagner, Howard C. Brooks, and Richard G. Bowen of the State of Oregon Department of Geology and Mineral Industries. Thanks are also due to Richard Q. Lewis of the U.S. Geological Survey for making available a list of fossils he collected in the area.

Previous work

The earliest geologic work in northeast Oregon was done by Lindgren (1902) who prepared a reconnaissance geologic map of northeast Oregon.

In 1912, J. P. Smith published a description of a partial section of the Martin Bridge Formation along Eagle Creek, and in 1921 Ross (1938) mapped the northeast part of the quadrangle in a reconnaissance of the southern portion of the Wallowa Mountains. Gilluly (1933-b) made a petrographic study of the albite granite near Sparta, and his report on the copper deposits in the Keating district (1933-a) includes a geologic map which covers about 31 square miles of the western part of the quadrangle. Recently, Greene (1960) has written a master's thesis on the northeastern portion of the quadrangle.

GENERAL GEOLOGY OF THE AREA

The rocks of the Sparta quadrangle fall into two groups separated by a profound unconformity, the pre-Tertiary rocks and those of Tertiary and later age. The pre-Tertiary rocks consist of Permian (?) sediments intruded by a plutonic complex of albite granite, quartz diorite, peridotite, serpentine, and gabbro overlain by a bedded sequence of upper-Triassic sedimentary and volcanic rocks. These stratified rocks have been folded into a northwest-trending synclinorium which plunges to the northwest and is cut by numerous cross faults. Marked lithologic differences between the northeast and southwest limbs of the fold are strikingly apparent in the lowermost rocks of the sequence; these are due to facies changes which can be traced around the nose of the synclinorium. Jurassic-Cretaceous gabbroic dikes and a quartz-diorite stock were intruded discordantly after the folding. The Tertiary rocks consist in the north of thick olivine basalt and platy andesite, and in the south of minor flows of olivine basalt overlain by tuffaceous lake sediments, diatomite and welded tuff. They have been gently warped and tilted and are cut by northwest-trending normal faults. The Quaternary deposits consist of terrace and old stream gravels, slide rock, and younger alluvium occupying present-day valleys.

PRE-TERTIARY GEOLOGY

Elkhorn Ridge Argillite (Pe)

The oldest rocks in the quadrangle are highly contorted and fractured cherts, argillites, tuffs and conglomerates. They occur in the southwestern corner of the quadrangle in the ridge south of Pritchard flat. Contact relations are not exposed here, but in the adjoining Durkee quadrangle gabbro of probable lower Triassic age has intruded and locally metamorphosed the chert and argillite. No fossils were found in the area; however, the Elkhorn Ridge Argillite a few miles to the southwest in the Baker quadrangle contains numerous limestone lenses, some of which have yielded Permian fusulinids, while others adjacent to them contain Triassic crinoids. Although these relationships remain to be worked out, the writer believes that the Elkhorn Ridge Argillite exposed in the Sparta quadrangle is of the older, or Permian age.

Early Triassic intrusive rocks

General: Intruded into the Elkhorn Ridge Argillite is a plutonic complex consisting of albite granite, quartz diorite, peridotite, serpentine, and gabbro. Contacts between these rock types are transitional, and knots and schlieren of adjacent lithologies are found in all of the units, especially near their borders. The plutonic complex is probably lower Triassic in age since it intrudes upper Permian rocks and is overlain by upper Triassic conglomerates containing pebbles of albite granite and quartz diorite.

Gabbro (gb): Much of the area south of the Powder River is underlain by gabbro. West of Love Creek a thin veneer of Tertiary lake sediments covers a large area of gabbro but numerous small unmapped exposures of gabbro can be found on the steeper hillsides and in the bottoms of draws. The gabbro is dark gray and coarse-grained, and consists of labradorite or bytownite, augite, hypersthene, and accessory opaque minerals. Less commonly, hornblende and biotite are present. The rock is locally banded and near the peridotite contact contains large inclusions of coarse peridotite. In many places the gabbro has been hydrothermally altered and sheared with serpentine and chlorite schist developed along the shear zones.

Peridotite (px) and serpentine (sp): Southward the gabbro becomes darker and encloses several large masses of peridotite and serpentine. Locally the peridotite is gabbroic; in other places, especially along shears, it has been converted to serpentine schist. The peridotite is a dark-gray to greenish coarse-grained rock composed of augite, hypersthene, olivine and a little chromite and magnetite. Westward the peridotite grades into dark bluish-black serpentinite. Unsheared but completely serpentinized peridotite occurs on the south slope of Glasgow Butte. It is made up of large bastite pseudomorphs after augite and magnetite-antigorite replacements of olivine.

Quartz diorite (hqd): The best exposures of the quartz diorite are along the Powder River in the central part of the quadrangle, particularly at J. N. Bishop Spring. Three smaller masses occur along lower Goose Creek. The rock is light gray, coarse-grained, and generally foliated. Locally it contains dark inclusions and coarse pegmatitic areas. Its texture is hypidiomorphic granular and it consists largely of andesine-oligoclase, green hornblende, biotite, a little magnetite, and quartz. Potash feldspar occurs interstitially in minor amounts. The effects of mild crushing and hydrothermal alteration are seen in thin sections. The quartz is strained, mica flakes are bent and slightly chloritized, sericite has replaced plagioclase along fractures, and fine veinlets of prehnite are present.

Albite granite (agr): The albite granite is exposed over a considerable area in the central part of the quadrangle. Exposures are best in the canyon of Goose Creek and in the hills south of Sparta. Much of the granite in upper Goose Creek is strongly sheared and in places cut by quartz-albite veins. The gradational contact with the quartz diorite is best seen along Phillips Ditch in Lower Goose Creek Canyon. The unsheared granite is light gray and coarse grained. It consists of albite, quartz, and small amounts of actinolite, epidote, magnetite, and biotite which is largely replaced by chlorite. Relics of more calcic plagioclase are strongly sericitized and rimmed by clear albite. The granite shows a variety of textures ranging from granitic to crystalloblastic, cataclastic, mylonitic, and micrographic. The quartz and albite show replacement textures and the contact between the albite granite and quartz diorite is transitional. A detailed description and argument for its metasomatic origin is given by Gilluly (1933-b).

Greenstone dikes (TRd)

Numerous greenstone dikes cut the albite granite and quartz diorite. Many are lithologically similar to spilite flows in the overlying Clover Creek Greenstone and were probably feeders. Nodules of magnetite occur in the altered granitic rock adjacent to many of these dikes, and at the northwestern termination of the swarm along the Powder River there are magnetite bodies weighing several tons.

Pre-Martin Bridge Triassic Formations

Clover Creek Greenstone (TRcc): The Clover Creek Greenstone was named by Gilluly (1937, p. 21) for a sequence of altered volcanic flows and pyroclastic rocks exposed along Clover Creek in the Baker quadrangle. These rocks were considered to be Permian on the basis of fossils collected some 6 miles to the northwest. Recent work, however, has shown that the formation contains Upper Triassic as well as Permian fossils, and that the rocks at the type locality are Triassic (Bostwick and Koch, 1962).

At the time of writing, the Clover Creek Greenstone was in the process of being elevated to group rank and subdivided into two new formations, the Harsin Ranch and the Tucker Creek Formations of Permian and upper Triassic ages respectively (Koch and Bowen, 1962, written communication). Inasmuch as all the rocks mapped as Clover Creek Greenstone in the Sparta quadrangle are believed to be Triassic, they would be equivalent to the Tucker Creek Formation and may be referred to by that name.

The Clover Creek Greenstone can be traced eastward 2 miles from the type locality into the Sparta quadrangle, where all of the greenstone is believed to be of Triassic age. This is indicated by: (1) Triassic fossils collected from limestone lenses in the greenstone at both the eastern and western borders of the quadrangle, (2) the presence of granitic rock fragments in the conglomeratic beds, and (3) the absence of contact metamorphic effects by the albite granite.

In the Sparta quadrangle, the formation consists of basaltic to rhyolitic volcanic flows, coarse- to fine-grained volcanic wackes, sandstones, tuff, and subordinate amounts of chert, conglomerate, and limestone. It is exposed along Balm Creek, Larkspur Creek, and Goose Creek, at the head of Red Gulch and in the canyons of Dempsey and Eagle Creeks. In the western part of the quadrangle the sediments tend to be fine grained, and volcanic flows make up about half of the formation. Eastward, the sediments coarsen to wackes and conglomerates, and volcanic flows are less abundant.

Spilites and keratophyres are the most common volcanic rocks. The spilites are dark green, massive, amygdaloidal rocks which occur as flows from 30 feet to more than 100 feet thick. Pillow structures were not found.

Keratophyres and quartz keratophyres, which are albitic, dacitic, and rhyolitic volcanic rocks, are less abundant. They are light greenish-gray and porphyritic with phenocrysts of albite, quartz, and less commonly, hornblende set in a microcrystalline groundmass of quartz, albite, and a little magnetite and chlorite.

Andesitic keratophyres are more basic; they consist of abundant phenocrysts of pyroxene, hornblende, and albite set in a grayish-green microcrystalline groundmass commonly exhibiting flow structure. The siliceous tuffs or keratophyre tuffs are dense, brittle rocks which break with a conchoidal fracture. They are gray, tan, olive, and greenish in color, and some are finely laminated. These tuffs are composed of broken albite and quartz crystals in a fine groundmass of microcrystalline quartz and albite with traces of sericite, chlorite, and iron oxides. They are generally textureless but in rare cases shadowy, shard-like forms may be distinguished.

The sediments consist almost entirely of fragmental volcanic material. Lithic fragments in the conglomerates and coarse wackes and tuffs are predominantly andesitic and dacitic. The fragments are poorly rounded or angular and sorting is poor.

Tuffs consist entirely of angular pyroclastic debris, pumice, and very fine-grained vesicular lithic fragments many of which have chilled or oxidized margins. Crystal fragments and matrix material are minor in amount. Volcanic wackes contain a greater proportion of crystal fragments and the clasts are embedded in a very fine-grained chloritic matrix. Volcanic sandstones consist of essentially the same materials as the wackes but are better rounded and sorted. Many are cemented by calcite and a few are contaminated by unreworked tuffaceous fragments.

The finest products of attrition are the shales and argillites. Many are finely laminated and their predominant olive-gray color is due to an abundance of finely divided chlorite.

A few thin beds of grayish chert are present. Traces of radiolarians were not found and the cherts were probably chemically precipitated from sea water rich in silica because of contemporaneous vulcanism.

The only limestone occurs near the eastern border of the quadrangle in a bed about 30 feet thick that is traceable for more than 2 miles. It consists of rounded, fine-grained calcite clasts, fossil debris, and locally volcanic fragments in a coarse calcite matrix.

All of the rocks of this formation are mildly metamorphosed and contain albite, chlorite, prehnite, pumpellyite, epidote and minor zeolites. The volcanic flows in general are more highly altered than the interbedded sediments, suggesting that the alteration may have been in part a consequence of submarine eruption (Gilluly, 1935; Battey, 1956; Donnelly, 1959).

In the Sparta quadrangle the Clover Creek Greenstone has been deposited directly on albite granite and quartz diorite. The base of the formation consists of poorly exposed siltstone and argillite with intercalated volcanic flows. Conglomeratic beds higher in the sequence contain pebbles of albite granite and quartz diorite. The upper boundary of the formation is marked by fine purple and green argillite which underlies the Martin Bridge Formation with apparent conformity.

Gold Creek Greenstone (TRgc): The name "Gold Creek Greenstone" is used in this report to designate a sequence of spilite and keratophyre flows with minor beds of mudstone, graywacke, and breccia which is exposed in an area of about 3 square miles in the northeastern part of the quadrangle. This unit is correlative with what has been called Clover Creek Greenstone in earlier papers (Ross, 1938; Smith and Allen, 1941). In the Sparta quadrangle it is distinguished from the Clover Creek Greenstone because it occupies a different stratigraphic position; the Gold Creek Greenstone underlies the "Lower Sedimentary Series" whereas the Clover Creek rocks nearer to their type locality underlie the Martin Bridge Formation. This corresponds to a stratigraphic difference of about 3,000 feet. Because of the small extent of the Gold Creek Greenstone in this quadrangle a formal formational name is not proposed. The base of the sequence is not exposed but the section must be at least 2,000 feet thick. The top of the unit is marked by a massive porphyritic keratophyre flow overlain by about 100 feet of volcanic breccia.

The Gold Creek Greenstones underlie strata of the "Lower Sedimentary Series" with apparent conformity. Although no fossils have been found in the Gold Creek Greenstone, it is probably of Triassic age because of its conformable relationship with the "Lower Sedimentary Series" and because the interbedded breccias contain rare fragments of albite granite.

"Lower Sedimentary Series" (TRls): The name "Lower Sedimentary Series" was first used by Smith and Allen (1941) to designate a sequence of mudstones, sandstone, and shale lying conformably below the Martin Bridge Formation in the Wallowa Mountains. In the Sparta quadrangle the formation is somewhat coarser; conglomerate and breccia make up the lower two-thirds of the sequence, and finer grained clastics occur at the top. The conglomerates are not well sorted, the pebbles are poorly rounded and are dominantly of fine-grained purple, green, and gray volcanics. Pebbles of chert, mudstone, and diorite and albite granite are present in most horizons. Graded bedding, load casts, and mud cracks are common sedimentary structures. The base of the formation is taken at the horizon where the volcanic breccia of the Gold Creek Greenstone grades rapidly into breccia containing abundant granitic and sedimentary rock fragments. The uppermost part of the formation is fine-grained green calcareous argillite which conformably underlies massive Martin Bridge limestone.

The "Lower Sedimentary Series" is Karnic (mid-Upper Triassic) as determined from fossils collected in the Wallowa Mountains (Smith and Allen, 1941; Laudon, 1956). No fossils were found within the Sparta quadrangle but the conformable relation to the Martin Bridge Formation is well exposed along East Eagle Creek.

Correlation: Both the "Lower Sedimentary Series" and the Clover Creek Greenstone conformably underlie the Martin Bridge Formation and contain Triassic fossils, but they are situated on opposite limbs of a synclinorium. Hence, they must be facies equivalents of each other. The coarse clastics of the "Lower Sedimentary Series" in the northeast limb become finer grained to the southwest and interfinger with the finer clastics, marine limestones, and submarine volcanics of the Clover Creek Greenstone. At the type locality on Clover Creek the greenstone is estimated to be 4,000 feet thick (Gilluly, 1937). The coarse sediments of the "Lower Sedimentary Series" were undoubtedly deposited much more rapidly, and the 3,200 foot thickness of this formation must be equivalent to a correspondingly lesser thickness of Clover Creek rocks. Since the combined thickness of the "Lower Sedimentary Series" and the Gold Creek Greenstone is about 5,200 feet, it is entirely conceivable that both these formations are correlative with the Clover Creek Greenstone.

Origin and history: The sediments in the Clover Creek Greenstone, "Lower Sedimentary Series," and Gold Creek Greenstone coarsen rapidly to the northeast, thus indicating that the source area was in that direction. Abundant pebbles of Lower Triassic (?) granitic rocks mixed with volcanics suggest that the source may have been an uparched area of volcanic flows deposited on the earlier granitic rocks. As the source area was rapidly uplifted, the volcanics were first stripped then deposited to the southwest as coarse volcanic conglomerates and breccias. Eventually the granitic rocks were exposed and plutonic debris was added to the sediments. To the southwest contemporaneous submarine volcanic centers poured out spilites and keratophyres which became interlayered with sediments. At the cessation of this activity, uplift and vulcanism apparently ended simultaneously. The ensuing period of quiescence was marked by widespread deposition of the Martin Bridge limestones.

Martin Bridge Formation (TRmb)

The name "Martin Bridge Formation" was first used by Ross (1938) for a sequence of limestones and calcareous shales exposed at Martin Bridge, which is located on Eagle Creek at the mouth of Paddy Creek. Previously, J.P. Smith (1912) had collected Upper Triassic (Karnic) fossils and described a partial section at this locality. The formation is well exposed along Eagle, East Eagle, and Paddy Creeks, and also along upper Goose Creek.

Interbedded massive and thin-bedded limestones and calcareous shales constitute the bulk of the section. While massive limestones occur throughout the formation, the thickest and most persistent one is at the base and provides a good marker horizon.

The massive limestones show a variety of textures; some are breccias and conglomerates, others are coral limestones, a few are dark and pyritic and show fine laminations on a freshly broken surface. The shaly limestones are

locally very carbonaceous and ferruginous indicating euxinic conditions. Fossils are abundant throughout the formation: corals, gastropods and Pentacrinus columnals in the massive limestones and pelecypods (Halobia) in the shales.

The Martin Bridge Formation is about 1,500 feet thick and is the best dated of the pre-Tertiary rocks, fossils from several localities indicating a Karnic (mid late Triassic) age.

Hurwal Formation (TRh)

The Hurwal Formation was named by Smith and Allen (1941) from exposures along the Hurwal Divide in the Enterprise quadrangle. In the Sparta quadrangle the formation consists predominantly of gray and purple mudstone, laminated argillite, and graywacke with minor chert, limestone, and conglomerate. Extensive exposures of the Hurwal Formation are found in the north-central part of the Sparta quadrangle, especially near the Sanger mine and along Eagle Creek in the vicinity of Excelsior Gulch.

The base of the formation is taken at the horizon where massive limestone of the Martin Bridge Formation grades rapidly into calcareous Hurwal sandstone and mudstone. In the Sparta quadrangle the highest unit in the section is a coarse massive conglomerate more than 200 feet thick composed of rounded pebbles and boulders of chert, volcanic rocks, and limestone. The limestone pebbles are fossiliferous and appear to be of Martin Bridge limestone. The upper conglomerate unit crops out at the head of Red Gulch and caps many of the hills north of the Sanger mine.

The maximum thickness of the Hurwal Formation in the Sparta quadrangle is about 4,000 feet. Abundant ammonites and pelecypods in the limy beds date the formation as Karnic (Smith and Allen, 1941; Palen, 1955).

The sediments of the Hurwal Formation record the beginnings of deformation and uplift which marked the end of the region as a depositional basin. The reappearance of clastic sediments, especially the coarse conglomerates composed of materials derived from formations immediately below, was probably caused by local upwarpings of the basin. Detritus derived from the upwarped areas was rapidly dumped in the intervening troughs, which persisted only a short time before the area as a whole was uplifted and deformed.

Jurassic-Cretaceous intrusive rocks

Gabbro dikes and sills (Jg) and a small quartz-diorite stock (Kqd) were emplaced discordantly in the folded Triassic sedimentary and volcanic rocks. The gabbro dikes are from a few feet to more than 200 feet thick and are most numerous along the northern border of the quadrangle near the Wallowa batholith. The gabbro is medium to coarse grained and contains hornblende as well as pyroxene.

In the southern part of the quadrangle a small stock of quartz diorite (Kqd) has intruded older plutonic rocks and Elkhorn Ridge Argillite. The quartz diorite is coarse grained and consists of andesine, hornblende, biotite, quartz, and interstitial potash feldspar. Dark amphibolite inclusions are locally abundant and in places aplite dikes transect the quartz diorite and country rocks.

Structure of the pre-Tertiary rocks

The stratified Triassic rocks of the northern half of the quadrangle have been folded into a northwest-trending synclinorium which plunges to the northwest. The axis of this great fold is not straight but bent into an S-shape. At its northwestern end the axis is parallel to Eagle Creek and lies about a mile southwest of it. In the Dark Canyon-Lily White area it bends around to an east-west line, then turns southeast near Torchlight Gulch to parallel Eagle Creek once more. Within the synclinorium smaller folds strike in various directions but, in general, trend northwest. The intensity of folding is likewise variable. In places tight, overturned folds pass abruptly into zones of gently warped strata. In the field this is best seen in the limestones on the northwest side of East Eagle Creek canyon. Most of the folds are open and symmetrical but in the more intensely deformed zones they are strongly asymmetric and overturned to the northeast.

Cleavage is best developed in the limestones, shales, and argillites. Other rock types are jointed in several directions but do not possess a true cleavage.

Thrusting has occurred on the southwest limb of the synclinorium; a sheet of tightly folded Clover Creek Greenstone has been thrust over Hurwal, Martin Bridge, and Clover Creek rocks. The best exposures of the thrust contact are in the southwest wall of Torchlight Gulch and just east of Dark Canyon. At Red Gulch there is a smaller thrust of Hurwal conglomerate over Clover Creek and Martin Bridge strata. A klippe of greenstone forms the crest of a small knob near Basin Creek, and along Collins Road at a road intersection (B.M. 4504) a window in the thrust exposes the underlying Martin Bridge limestone.

Another thrust of greenstone over Hurwal is exposed in the northeast corner of the quadrangle in sec. 6, T.7 S., R. 45 E. The fault plane dips 30° southeast and is marked by a zone of breccia several feet thick. In addition to the thrusts, high angle northeast-trending cross faults transect the pre-Tertiary rocks and displace them as much as a mile laterally.

The sequence of events in the deformation of the Triassic rocks was: (1) folding, (2) thrust faulting, and (3) normal faulting. The thrusts truncate the folds, and the cross faults offset both the folds and thrust contacts.

Metamorphism of the pre-Tertiary rocks

All of the rocks of the Sparta quadrangle have been metamorphosed and contain a number of secondary minerals: albite, chlorite, prehnite, pumpellyite, epidote, blue-green hornblende, actinolite, and calcite. In nearly all cases metamorphism has been a low grade static recrystallization in which original textures are well preserved. Exceptions to this are the foliated chlorite schists which are restricted to shear zones and constitute a minor part of the rocks. Locally, metasomatism has produced rocks enriched in sodium, silica, or calcium. The rocks in the northern part of the quadrangle are in the contact metamorphic aureole of the Cornucopia stock which lies less than a mile north of the northern quadrangle boundary. Four metamorphic facies have been recognized: the pumpellyite-prehnite, epidote-chlorite, epidote-actinolite, and the epidote-hornblende facies. In the highest grades of metamorphism the Gold Creek Greenstone is baked to hornblende hornfels. In the southern part of the quadrangle adjacent to the quartz diorite stock, the gabbro has been converted to coarse amphibolite, and chert in the Elkhorn Ridge Argillite has recrystallized to quartzite.

Northwest-trending zones of shearing and hydrothermal alteration transect the early Triassic intrusive rocks and parts of the Clover Creek Greenstone. Much of the albite granite along Goose Creek between Ledge and Forshey Creeks is mylonitized and riddled with quartz-albite veinlets. The gabbro and quartz diorite along the Powder River is locally sheared and chloritized and cut by veinlets of prehnite. The gabbro and peridotite south of the Powder River is transected by narrow serpentinized zones. Zones of most intense shearing and alteration in the Clover Creek Greenstone occur between Larkspur Creek and Surprise Spring and near the Poorman mine. The rocks are fractured and veined by chlorite, epidote, prehnite, and stilpnomelane.

TERTIARY GEOLOGY

The Tertiary rocks consist of mildly deformed olivine basalts, platy andesite, and tuffaceous stream and lake sediments that contain an interbedded welded tuff member.

Olivine basalt (Tb)

The olivine basalts in the Sparta quadrangle fall into two groups: (1) thick, widespread fissure eruptions that form a basaltic plateau, and (2) small local outpourings from isolated vents.

The thick plateau-forming basalts are restricted to the northern half of the quadrangle where they occur as flows 20 to 80 feet thick deposited one over the other and separated by red baked zones as much as three feet thick. These basalts are best exposed east of Red Knob, at Maiden Gulch, near the mouth of Town Gulch, and on Red Mountain between Holcomb and Basin Creeks. The basalt is generally grayish-brown, vesicular and has prominent columnar joints. Most of the flows are porphyritic and contain phenocrysts of oscillatory-zoned plagioclase, zoned titanaugite, and olivine partially altered to iddingsite in a fine-grained intersertal groundmass rich in iron ore.

These basalts are late Miocene in age as indicated by a collection of fossil leaves from a tuffaceous interbed north of Red Knob (Hoxie; oral communication, 1961).

Isolated volcanic necks with associated scoria and thin flows occur at the following places: Sparta Butte; Pittsburgh Gulch 1½ miles north of the Powder River; south side of the Powder River between BM 2578 and BM 2583; East Fork of Love Creek; Glasgow Butte; and north of Pritchard Flat near the western border of the quadrangle. These basalts are finer grained than the plateau-forming basalts and many have a crude platy jointing which is vertical in the necks but is nearly horizontal in the flows. These necks are probably late Miocene in age but this is not definitely known.

Andesite (Ta)

Andesite is restricted to the northwestern corner of the quadrangle, where it forms the dissected edge of a shield volcano complex lying farther to the northwest. The andesite is dark gray, very fine grained, and breaks readily into thin slabs or plates. It is a hypersthene andesite consisting of scattered phenocrysts of andesine, augite, and hypersthene in an extremely fine-grained, flow-banded groundmass. Because the andesite interfingers with the thick olivine basalts in the Baker and Telocaset quadrangles to the northwest, it is also assigned to the late Miocene.

Tuffaceous lake and stream deposits (Tl)

Tuffaceous lake and stream deposits fill a Tertiary structural depression in the southwestern part of the quadrangle. These sediments consist predominantly of well bedded rhyolitic ash and pumice. Pre-Tertiary rock fragments are com-

mon in the coarser beds, and locally there are coarse mudflow agglomerates, diatomite beds, and a thin welded tuff member. Because the welded tuff is a prominent marker horizon it is mapped separately. The greatest thickness of these deposits is at the western border of the quadrangle, where they are estimated to be several hundred feet thick. The deposits rapidly thin outward from the basin and overlap what was evidently a Tertiary highland. There must have been several hundred feet of relief on the Tertiary surface, for the welded tuff lies unconformably on pre-Tertiary rocks, olivine basalt, and as much as 100 feet of lake beds overlying the basalt. The unconformity between the welded tuff and the underlying basalt is well exposed along lower Goose Creek, where on the west side of the valley the welded tuff rests directly on basalt, whereas on the east side about 100 feet of lake beds separate the two.

Welded tuff (Tt)

The welded tuff member is a resistant unit which forms bold columnar-jointed ledges. It thickens and thins from 25 to 0 feet and averages about 8 feet in thickness. The best exposures are along Spring Creek, at Rock Spring and along the road west of Sparta near BM 3963.

Although datable fossils have not been found in lake beds in the Sparta quadrangle, vertebrate bones from similar deposits 12 miles south in the Durkee basin have been dated as Clarendonian (latest Miocene - earliest Pliocene) by Shotwell (1961, written communication), hence the Sparta beds are believed to be of this age.

Structure of the Tertiary rocks

The Tertiary rocks have been gently warped and displaced by northwest-trending flexures and high-angle normal faults. The pattern of Tertiary deformation in the Sparta quadrangle is simply that of a series of uplifts separated by broad intervening basins filled with Tertiary and Quaternary lake and stream sediments. Outward from these basins, gently tilted fault blocks rise in a series of steps toward the topographically high areas. The regions of greatest uplift center on the Jurassic-Cretaceous plutons. The movements responsible for the formation of the basins must have continued after they were filled, for the lake sediments are also deformed. In the Sparta quadrangle the principal downwarps are along the Powder River at the eastern and western borders of the quadrangle. North and south of the river the rocks have been raised toward the Wallowa Mountains and Lookout Mountain. The gradual step-like uplift to the north is clearly shown along Spring Creek where the welded tuff is raised to successively higher levels by several faults, most of which are too small to indicate on the map.

QUATERNARY GEOLOGY

The Quaternary deposits consist of terrace and old stream gravels (Qtg), slide rock, and younger alluvium (Qal) occupying present-day valleys.

Extensive banks of coarse bouldery gravel occur along Eagle and East Eagle Creeks and on adjacent benches at elevations of more than a thousand feet above the present stream level. The largest and thickest accumulation is in the southeastern part of the quadrangle near the mouth of Eagle Creek, where the gravel is nearly 1,000 feet thick in places. Here the gravel is finer and much better sorted than farther upstream. The lithologies of the pebbles indicate that they were derived from the Wallowa Mountains. This gravel is probably of fluvial-glacial origin deposited at the end of the last glaciation.

Terraces along the Powder River are composed of sand and finer, better sorted gravel reflecting the greater maturity of this stream as compared with Eagle Creek. Most of the pebbles are of chert, argillite, greenstone, basalt, and granodiorite which were probably derived from the Elkhorn Mountains to the west.

Coarse, well-rounded, and well-sorted gravel composed largely of white quartzite pebbles and cobbles cap many of the ridges in the southwestern part of the quadrangle. These deposits are the remnants of a widespread apron of gravel which extended outward from a high east-west trending ridge of Elkhorn Ridge Argillite directly south of the Sparta quadrangle. Locally the gravel is as much as 80 feet thick. Where less than 5 feet thick it has not been mapped. The pebbles were derived from thick beds of metamorphosed chert in the Elkhorn Ridge Argillite. A long period of reworking in a humid climate is suggested by the textural and compositional maturity of the gravel. While most of this reworking probably took place during the Tertiary, the present distribution of the gravel is a result of re-deposition during Quaternary time.

Alluvium in the present-day valleys consists of sand, silt, and fine gravel. The largest accumulations are in parts of the Powder River, lower Goose Creek Valley, and in Pritchard Flat.

Slide rock mantles many of the slopes in the Sparta quadrangle. Thick accumulations occur along upper Balm Creek, on the north slope of Glasgow Butte, southeast of Upper Timber Canyon, and along Goose Creek.

MINERAL DEPOSITS

Copper: Copper minerals are found throughout the Clover Creek Greenstone. The mineralized bodies are irregular replacements along fractures and shear zones. Chalcopyrite is the principal ore mineral. Near the surface it has been oxidized to malachite, azurite, native copper, and other secondary minerals. The gangue minerals are quartz, sericite, chlorite, calcite, and iron oxides. The most extensive mine workings are along Balm and Slide Creeks and west of Lily White Guard Station. The mines and prospects were not examined in detail by the writer. They were described by Gilluly (1933-a), who studied the area when more workings were open than at present.

Gold: Little gold is presently being mined in the quadrangle, though some has been mined in the past. The Sparta and Sanger districts have been the most productive areas (Gilluly and others, 1933-a). The lode deposits in the Sparta district are gold quartz veins in the albite granite and quartz diorite. Native gold, pyrite, sphalerite, and arsenopyrite occur in a gangue of quartz, limonite, sericite, and clay minerals. Locally, the deeply weathered granite was worked in placers. In the Sanger district gold quartz veins are associated with late Mesozoic gabbroic dikes that cut the Hurwal Formation. The ore consists of native gold, pyrite, chalcopyrite, sphalerite, and galena in a gangue of coarse quartz and calcite. The gold-bearing quartz veins transect both the dikes and country rocks. The gravel along Eagle Creek has been worked for gold, particularly just above the confluence with East Eagle Creek and at the mouths of Torchlight and Empire Gulches. Also, gravels on Paddy Creek have been worked near Packsaddle Creek.

Iron: Nodules of magnetite and specular hematite are found in sheared albite granite next to many of the greenstone dikes. At the northwest termination of the dike swarm along the Powder River between BM 2467 and BM 2416 there are pods of ore weighing several tons. These deposits are too small to mine profitably.

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