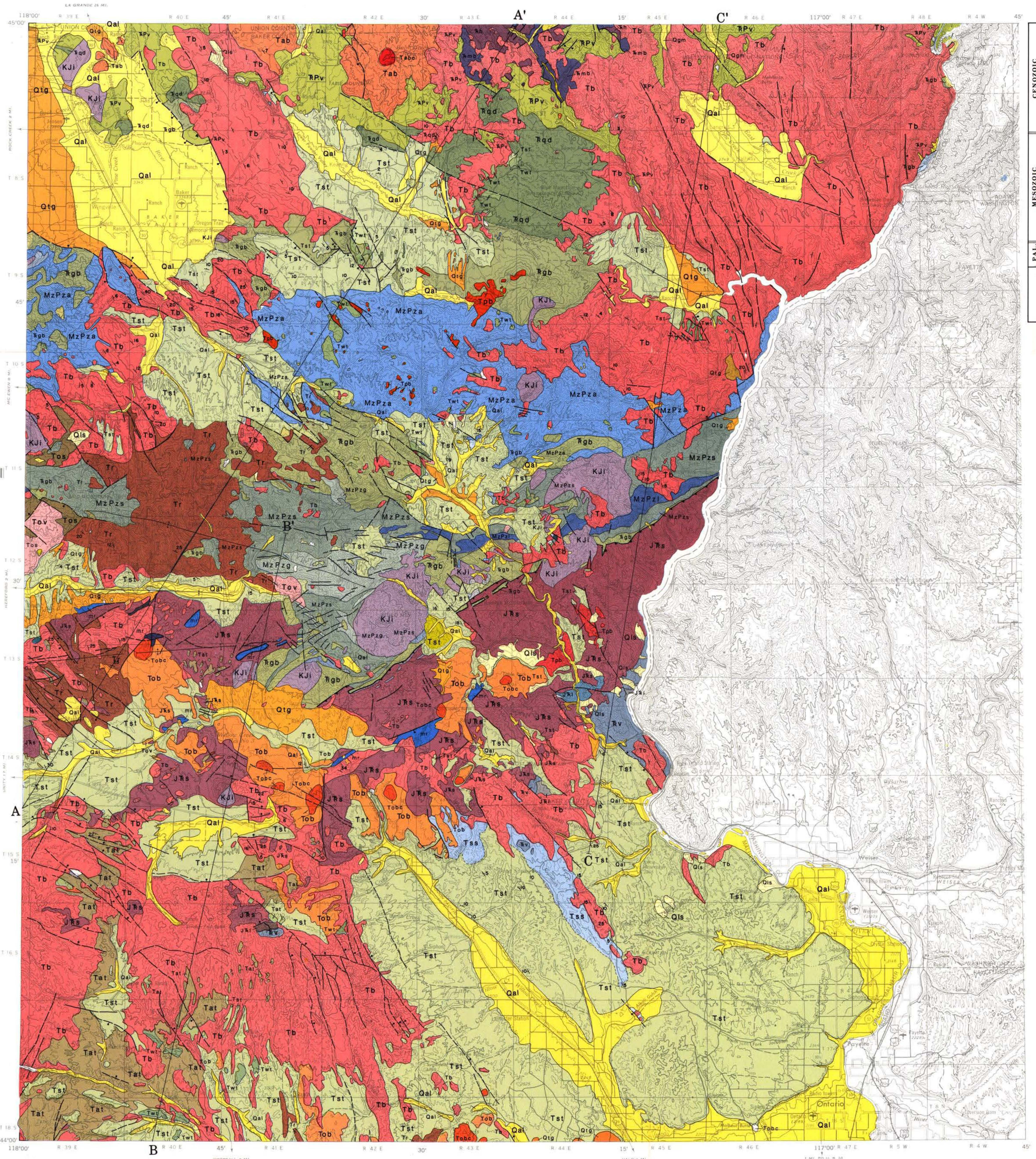
GMS - 7

GEOLOGIC MAP OF THE OREGON PART OF THE BAKER 1° by 2° QUADRANGLE



prepared in cooperation with the U.S. Geological Survey, Menlo Park

Scale 1:250,000

5 0 5 10 15 20 Statute Miles

5 0 5 10 15 20 25 30 Kilometers

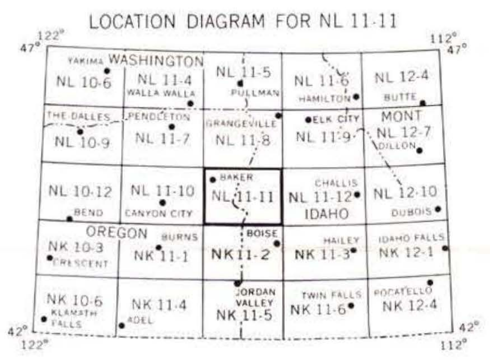
5 0 5 10 15 Nautical Miles

CONTOUR INTERVAL 200 FEET
WITH SUPPLEMENTARY CONTOURS AT 100 FOOT INTERVALS

TRANSVERSE MERCATOR PROJECTION

1960 MAGNETIC DECLINATION FOR THIS SHEET VARIES FROM 19°30′ EASTERLY FOR THE CENTER OF THE WEST EDGE TO 19°00′ EASTERLY FOR THE CENTER OF THE EAST EDGE. MEAN ANNUAL CHANGE IS 0°02′ WESTERLY.

LOCATION DIAGRAM FOR NL 11-11



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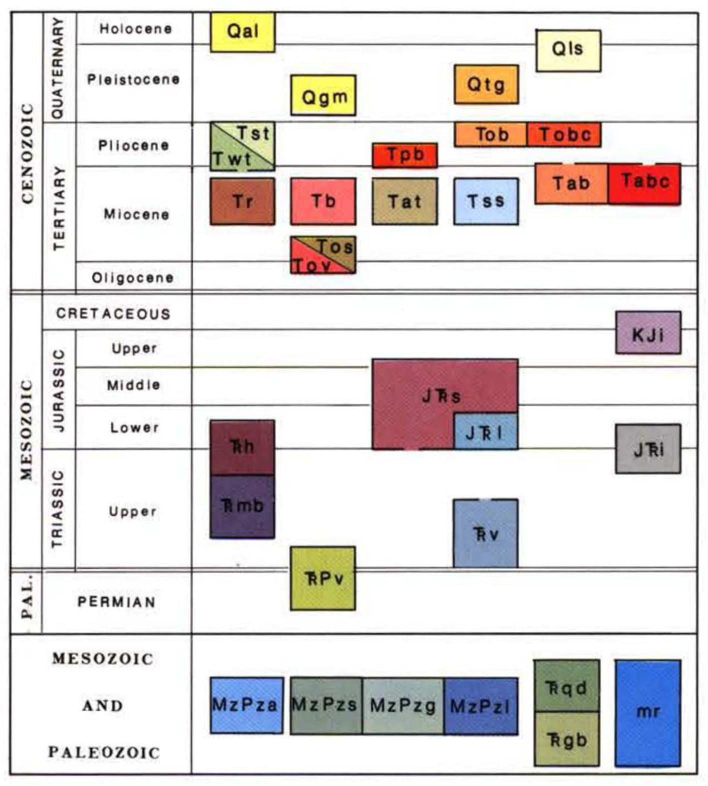
STRATIGRAPHIC TIME CHART



EXPLANATION

- **Qal** — Alluvium: *Mainly valley fill and stream channel deposits consisting of unconsolidated silt, sand, and gravel.*
- **Qls** — Landslide debris
- **Qtg** — Terrace and fan deposits: *Unconsolidated gravel, cobbles, and boulders with intermixed clay, silt, and sand.*
- **Qgm** — Glaciofluvial deposits: *Unsorted bouldery gravel, sand, and silt of terminal and lateral moraines.*
- **Tob** — Basalt: *Mostly thin, gently dipping flows of gray to black olivine-bearing basalt and basaltic andesite.*
- **Tobc** — Small mafic volcanic centers: *probably the source of* (Tob) *flows.*
- **Tst** — Tuffaceous sedimentary rocks: *Poorly consolidated, water-laid silicic volcanic ash, tuffaceous clay, siltstone, sandstone, minor diatomite, mud-flow deposits, air-fall and ash-flow tuffs, and some coarse epiclastic deposits. Chiefly lacustrine except in the northern part of the map area where the upper part of the sequence includes gravelly fluviatile deposits.*
- **Tpb** — Basalt: *Thin basalt flows and small eruptive centers. Locally overlies welded tuff of unit* (Twt) *and some sedimentary rocks of unit* (Tst).
- **Twt** — Silicic welded and non-welded tuff: *Some tuffaceous sedimentary rocks included.*
- **Tab** — Andesite and basalt: *Platy-jointed flows of hypersthene andesite and basalt. The unit is exposed only in the northern part of the map area. Stratigraphic relations are uncertain.*
- **Tabc** — Mafic shield volcano: *probably the source of* (Tab) *flows.*
- **Tss** — Tuffaceous sedimentary rocks: *Semi consolidated to well-consolidated, bedded, fine-grained tuffaceous sediments and water-laid tuff; lesser amounts of arkosic sandstone and siltstone, impure diatomite, pumicite and palagonite tuff.*
- **Tat** — Ash flow tuffs and tuffaceous sedimentary rocks: *Partly to densely welded silicic ash-flow tuff. Includes some non-welded tuff and tuffaceous sedimentary rocks.*
- **Tb** — Basalt and andesite: *Chiefly flow on flow basalt. Includes some andesite flows, basaltic and andesitic flow breccias, palagonite tuff and breccia, and minor silicic tuff and tuffaceous sedimentary rocks. In southwest part of area includes some silicic flows at top of section.*
- **Tr** — Rhyolite and andesite: *Rhyolitic and subordinate andesitic flows, flow breccia, welded and non-welded tuff, tuff breccia and small intrusive masses, commonly flow banded and locally perlitic. Includes part of Dooley Rhyolite Breccia of Gilluly (1937).*
- **Tos** — Volcaniclastic sedimentary rocks: *Poorly sorted andesite and dacite pebble and boulder conglomerate, breccia and water-laid tuff.*
- **Tov** — Andesite and dacite: *Flows, breccia, tuff, and intrusive rocks consisting of porphyritic hornblende andesite and dacite.*
- **JŦl** — Limestone: *Massive and thin-bedded limestone. Minor wacke, siltstone and arkosic sandstone.*
- **JŦs** — Sedimentary rocks: *Volcanic wacke and siltstone. Some conglomeratic wacke and thin limestone lenses.*
- **Ŧh** — Sedimentary rocks: *Graywacke and laminated siltstone; minor chert, thin-bedded limestone and conglomerate. Mapped as Hurwal Formation by Prostka (1962).*
- **Ŧmb** — Limestone: *Massive conglomeratic and coralline limestone interbedded with thin-bedded pyritic and carbonaceous limestone and calcareous shale. Named Martin Bridge Formation by Ross (1938).*
- **Ŧv** — Volcanic and sedimentary rocks: *Lava flows, flow breccia, agglomerate, tuff; volcaniclastic conglomerate, breccia, sandstone, and siltstone. Chiefly andesitic; some basaltic and rhyolitic rocks. Minor limestone.*
- **mr** — Mixed sedimentary, volcanic and intrusive rocks: *Windows and fault slices of older rocks in* (JŦs) *terrain. Includes rocks typical of units* (Ŧgb), (MzPzs) *and* (MzPzg).
- **ŦPv** — Volcanic and sedimentary rocks: *Lava flows, flow breccia, and agglomerate; pyroclastic rocks; subordinate epiclastic conglomerate, sandstone, and argillite; minor chert and limestone. Volcanic rocks include spilite and keratophyre. Includes Clover Creek Greenstone of Gilluly (1937).*
- **MzPzs / MzPzg / MzPzl** — Foliated sedimentary and volcanic rocks and marble: *Includes Burnt River Schist of Gilluly (1937). Phyllitic quartzite, quartz phyllite, pelitic phyllite, minor slate, conglomerate and marble* (M_ZP_Zs). *Mostly greenstone and greenschist* (M_ZP_Zg). *Marble with interlayered phyllite and slate* (M_ZP_Zl); *includes Nelson Marble of Prostka (1967).*
- **MzPza** — Sedimentary and volcanic rocks: *Argillite, chert and tuff; subordinate lava flows, conglomerate, and limestone. Includes Elkhorn Ridge Argillite of Gilluly (1937).*

PLUTONIC ROCKS

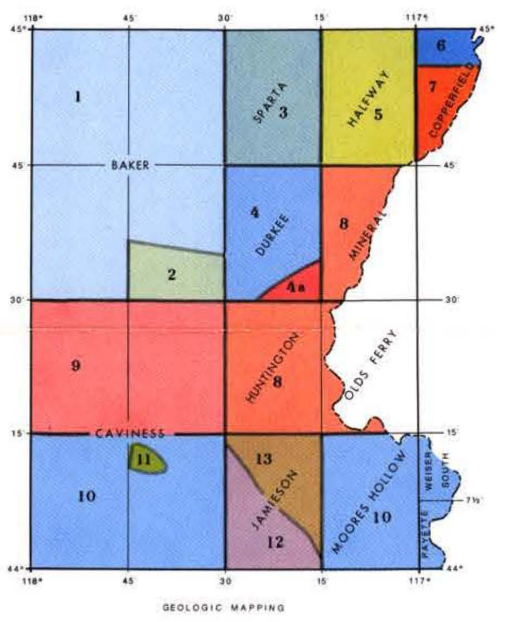
- **KJi** — Upper Jurassic-Lower Cretaceous plutons: *Medium-grained hornblende and biotite quartz diorite and granodiorite. Some trondhjemite and gabbro.*
- **JŦi** — Upper Triassic — Lower Jurassic quartz diorite.
- **Ŧqd / Ŧgb** — Pre-Upper Triassic intrusive complex: *Chiefly quartz diorite and "albite granite"* (Ŧqd); *gabbro and altered gabbro, minor periodtite, pyroxenite, and serpentinite* (Ŧgb)

GEOLOGIC SYMBOLS

- Contact (dashed where gradational or inferred)
- Fault showing downthrown side (dashed where inferred)
- Fault, High-angle reverse
- Anticline (showing trace of axial plane and bearing and plunge of axis. Dashed where approximately located)
- Syncline (showing trace of axial plane and bearing and plunge of axis)
- Strike and dip of beds or flows

SECTIONIZED TOWNSHIP

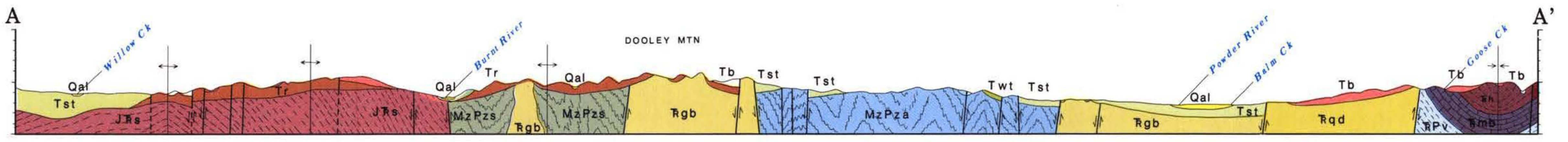
6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

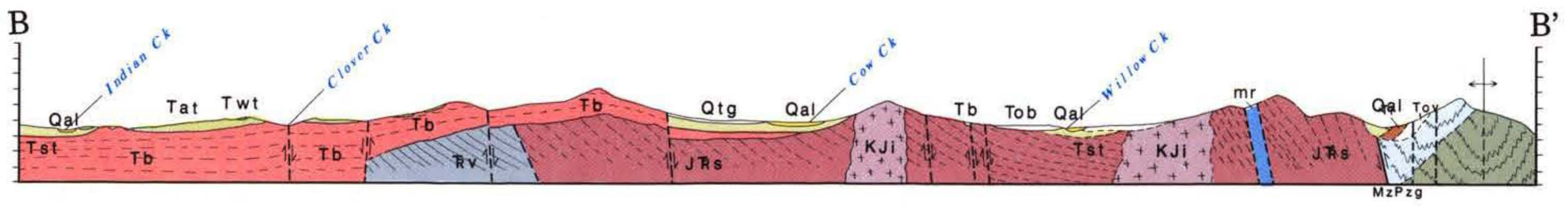


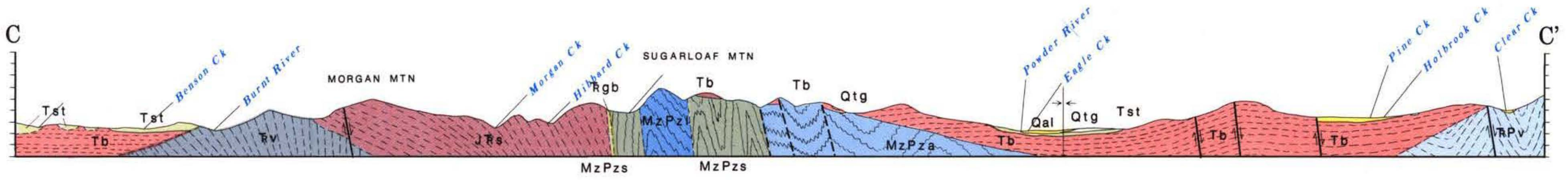
GEOLOGIC MAPPING

1. Unpublished reconnaissance mapping by J.R. McIntyre, 1969-1972 and H.C. Brooks, 1972-1973; modified extensively from Gilluly, James, 1937, Geology and mineral resources of the Baker quadrangle, U.S. Geol. Survey Bull. 879.
2. Modified from Ashley, R.P., 1966, Metamorphic petrology and structure of the Burnt River Canyon area, northeastern Oregon: Stanford Univ. doctoral thesis.
3. Prostka, H.J., and Bateman, R.L., 1962, Geology of the Sparta quadrangle: Oregon Dept. Geol. and Mineral Indus. GMS-1.
4. Prostka, H.J., 1967, Preliminary geologic map of the Durkee quadrangle, Oregon: Oregon Dept. Geol. and Mineral Indus. GMS-3.
4a. Pre-Cenozoic geology reinterpreted by H.C. Brooks.
5. Reconnaissance mapping by J.R. McIntyre, H.C. Brooks, and T.L. Vallier in 1967-1972.
6. Vallier, T.L., 1973, Geologic map of the Snake River Canyon, Oregon and Idaho: Oregon Dept. Geol and Mineral Indus. GMS-6.
7. Mapping by T.L. Vallier in 1967.
8. Mapping by H.C. Brooks in 1962-1973.
9. Modified from Wolff, Ernest, 1965, The geology of the northern half of the Caviness quadrangle, Oregon: Univ. Oregon doctoral thesis.
10. Reconnaissance mapping by G.W. Walker in 1969-1970; some contacts according to reconnaissance mapping by R.E. Corcoran in 1963.
11. Wagner, N.S., Brooks, H.C., and Imlay, R.M., 1963, Marine Jurassic exposures in the Juniper Mountain area of eastern Oregon: Am. Assoc. Petrol. Geologists Bull, v. 47, p. 687-701.
12. Carlat, J.E., 1954, The geology of the southwest portion of the Jamieson quadrangle, Malheur County, Oregon: Univ. Oregon master's thesis.
13. Calkins, J.A., 1954, The geology of the northeastern half of the Jamieson quadrangle, Oregon: Univ. Oregon master's thesis.

Geologic Cross Sections







Geologic compilation by H. C. Brooks, J. R. McIntyre and G. W. Walker.

Cartography by S. R. Renoud, 1976

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GEOLOGICAL MAP SERIES

GMS - 7

GEOLOGY OF THE OREGON PART OF THE BAKER 1° BY 2° QUADRANGLE

by

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Oregon Department of Geology and Mineral Industries

James R. McIntyre
Consulting Geologist

George W. Walker
U. S. Geological Survey

1976

CONTENTS

INTRODUCTION

The Baker quadrangle, lying in both Oregon and Idaho, is bounded by latitudes 45° and 46° and by longitudes 116° and 118°. The area of the accompanying geologic map is the Oregon portion of the Baker quadrangle—that part west of the Snake River, which marks the Oregon-Idaho border. The map scale is 1:250,000. The text describes the geologic units of the area covered by the map and presents interpretations of the tectonic history.

The work of many geologists is represented in the text, and the more important contributions are cited. Sources of map data are shown on the geologic map sheet. Helpful discussions and aid in the field were provided by N. S. Wagner, T. L. Vallier, G. T. Benson, and R. D. Lawrence. André Isotoff assisted with petrographic determinations. Paleontologic age assignments were made by R. W. Imlay, J. A. Shotwell, N. J. Silberling, and J. A. Wolfe. Most of the known Jurassic fossil localities were visited by Dr. Imlay. Student field assistants include D. W. Baggs, R. L. Ozier, G. D. Paul, and D. L. White. Special thanks are extended to editors Margaret Steere and Carol Brookhyser, camera-copy typist Cynthia Drayer, and cartographer Steve Renoud for their efforts in bringing our manuscript and map to publication.

GEOGRAPHY

The map area occupies parts of Baker and Malheur Counties, Oregon (Figure 1). The main population centers are Baker, 9,440; Haines, 320; Richland, 130; Halfway, 300; Huntington, 530; and Ontario, 7,000. Interstate 80N and the Union Pacific Railroad extend southeasterly across the area via Baker, Huntington, and Ontario. Principal industries are cattle ranching and lumbering. The production of cement, limestone, and sand and gravel are important facets of the present economy. Several gold mining districts lie within the area, but there has been little gold production for many years.

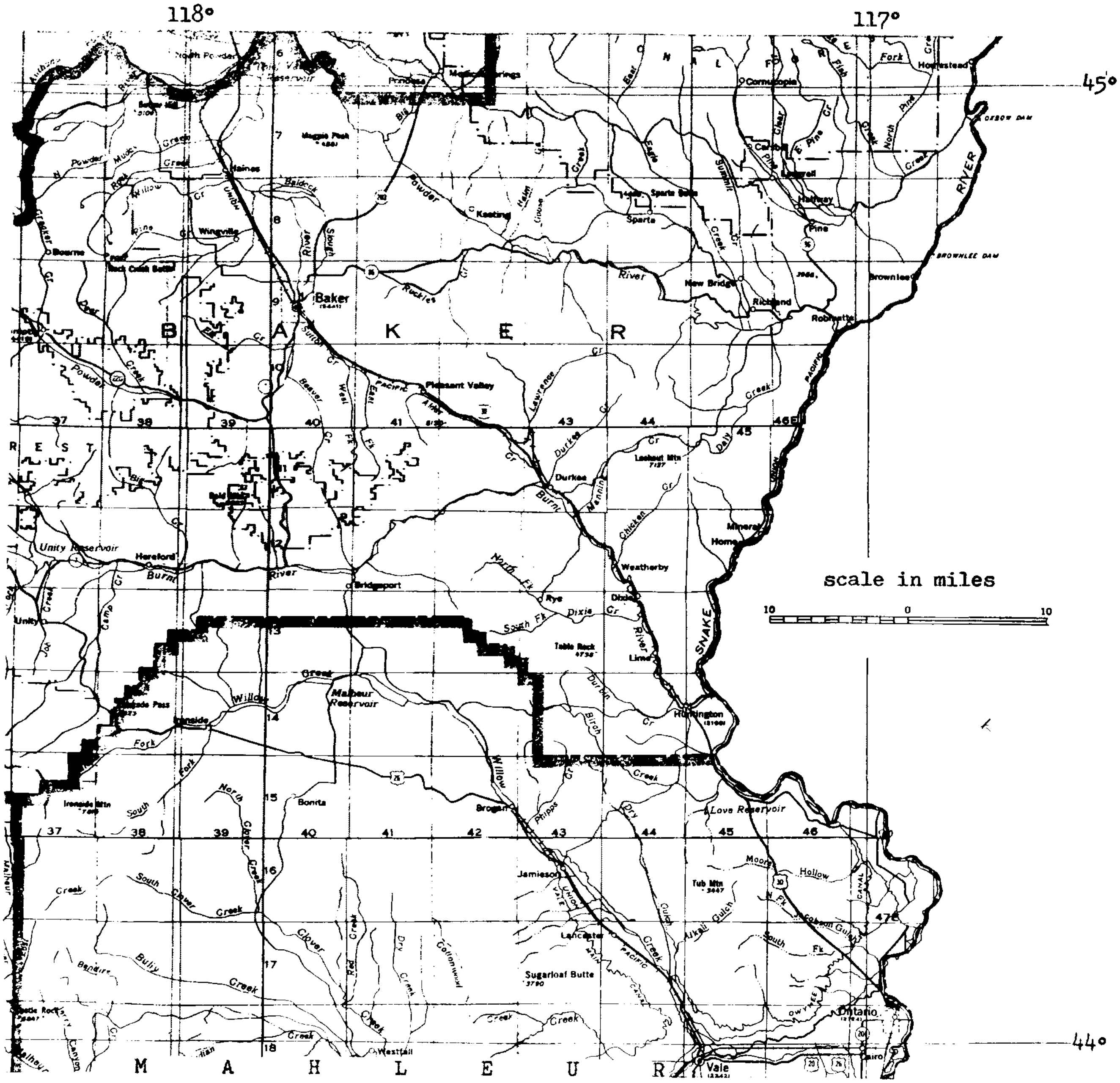
Vegetation consists mainly of sagebrush, dry-land grasses, and scattered juniper trees. Timber is abundant in the northwestern and northern parts of the map area, particularly at high elevations.

Main drainage systems flow generally eastward to the Snake River and include Burnt River, Powder River, and Pine Creek. Tributaries of the Malheur River drain the southern extremities of the area. Elevations range from about 1,700 feet on the Snake River at the northern map boundary to 7,120 feet on Lookout Mountain (sec. 13, T. 11 S., R. 44 E.).

The map area is in the southeastern part of the Blue Mountains geomorphic province, a complex of mountain ranges, incised plateaus, and fertile valleys, which includes most of northeastern Oregon. The Snake River has cut a deep canyon between the Blue Mountains of Oregon and similarly mountainous terrain of western Idaho. The Blue Mountains province is bordered on the north, west, and south by dissected plateaus underlain by continental lavas and sediments of Cenozoic age. Uplift and erosion of the Blue Mountains region have resulted in the patchwork removal of Cenozoic cover from older pre-Tertiary rocks. The southeasternmost "window" of these older rocks in the Blue Mountains is included in the Baker sheet.

GEOLOGIC SETTING

Rocks exposed in the Baker map area are divided by age into two broad groups: pre-Cenozoic and Cenozoic. The pre-Cenozoic rocks include thick sections of eugeosynclinal sedimentary and volcanic strata of Pennsylvanian, Permian, Late Triassic, and Jurassic ages and a wide variety of plutonic rocks of pre-Late Triassic, Late Triassic-Early Jurassic (?), and Late Jurassic-Early Cretaceous ages. The bedded rocks and pre-Late Jurassic intrusives have been deformed extensively and regionally metamorphosed to greenschist facies. Dominant structural trends are east and northeast. Dips of bedding and foliation planes



Index map of the Oregon part of the Baker 1° by 2° quadrangle.

generally are steep. Rocks older than Pennsylvanian (Desmoinsian) have not been recognized, but some of the more highly deformed rocks may be older.

Cenozoic deposits range in age from late Oligocene to Holocene and comprise a heterogeneous assemblage of basaltic to rhyolitic lavas and pyroclastic rocks, tuffaceous lake beds, gravels, and alluvium. Dikes and plugs are common and locally abundant. The rocks are gently warped and relatively unaltered except for diagenetic changes in some of the tuffaceous sediments. The structure is complicated by a multitude of predominantly northwest-trending normal faults. Contacts with pre-Cenozoic rocks are strongly discordant.

PRE-CENOZOIC ROCKS

Rock Units of Undifferentiated Paleozoic and Mesozoic Age

Map units (M_zP_za), (M_zP_zs), (M_zP_zg), and (M_zP_zl) represent lithologic subdivisions of a group of highly deformed sedimentary and volcanic rocks whose age and stratigraphic relationships are poorly known. The assemblage is widely exposed in a broad easterly trending belt crossing the middle portion of the map area and extending eastward into Idaho and westward across the Sumpter quadrangle. The approximate distribution of these rocks was shown by Lindgren (1901) and the rocks were described under the heading "Paleozoic sediments." Exposures in the Sumpter quadrangle comprise the "argillite series" of Pardee and others (1914 and 1941). Representative rocks in the Baker 30-minute quadrangle were divided by Gilluly (1937) into two formations: The Burnt River Schist and the Elkhorn Ridge Argillite. Exposures in the canyon of Burnt River east of Bridgeport were designated as the type locality of the Burnt River Schist. The Elkhorn Ridge Argillite was named for exposures on Elkhorn Ridge in the Sumpter quadrangle.

Rocks interpreted as part of the Burnt River Schist extend southward into the northern part of the Caviness quadrangle and were divided into several subunits by Wolff (1965).

In the Durkee quadrangle, strata representing the eastward extensions of the Elkhorn Ridge Argillite and Burnt River Schist were divided by Prostka (1967) among four units: "greenschist," Elkhorn Ridge Argillite, Nelson Marble, and gray phyllite.

Ashley (1966) remapped the Burnt River Schist in the type locality and tentatively concluded that the rocks in the northern part of the area are lithologically and structurally like the Elkhorn Ridge Argillite and implied that the rocks in the southern part of the area are continuous with strata included in the "greenschist," Nelson Marble, and gray phyllite of Prostka (1976).

(M_zP_za) Sedimentary and volcanic rocks

This unit is characterized by thick sections of poorly bedded fine-grained siliceous rocks which range from argillite through cherty or tuffaceous argillite to nearly pure chert or tuff. Interlayered with these rocks are thin andesitic and basaltic lavas, conglomerate beds, and limestone lenses. The unit represents the Elkhorn Ridge Argillite as mapped by Gilluly (1937) and Prostka (1962, 1967) and the eastward extension of similar rocks.

Siliceous argillite is the prevalent rock type, but chert and pyroclastic beds are important components. Sandstone and conglomerate are rare. Neither the top nor bottom of the formation nor units diagnostic of particular parts of the section have been recognized. The formation has been tightly folded. Metamorphism typically is low-grade greenschist facies. Foliation is well developed locally. The rocks typically have been severely fractured and break into small angular fragments. Outcrops are small and widely separated. Soil development is poor. The best exposures in the map area are along the steep slopes in the Snake River Canyon.

Siliceous argillite beds consist mostly of very fine-grained, angular to subangular quartz, and subordinate feldspar detritus. Minor constituents include calcite, chlorite, sericite, clay minerals, and black carbonaceous material. The rocks usually are gray or black, depending upon the amount of carbonaceous matter. Weathered surfaces commonly are stained by iron oxides. Some recrystallization of quartz is apparent in most thin sections; with advancing quartz growth, the carbonaceous material has segregated in bands and patches, giving the rock a streaked or mottled appearance.

Argillite and tuff are fully gradational. Generally, rocks with a high pyroclastic content are greenish due to the development of chlorite, although in some specimens the color is masked by carbonaceous matter. Tuffaceous rocks examined in thin section are andesitic. Thin andesitic and basaltic flow rocks are present locally. Pillow lavas have been observed in several places, but they are deformed and therefore difficult to recognize. One of the better exposures is along the Snake River road in sec. 32, T. 10 S., R. 46 E. Exposures of "greenschist" were mapped separately by Prostka (1967), and the rocks were described as "metamorphosed basic tuff, lava flows, and sills; but included also are small amounts of highly sheared gabbro which in the field are indistinguishable from altered sills and flows."

Cherts consist of a dense mosaic of micro-crystalline quartz or chalcedony. Colors range from black through red to yellow to nearly white. Radiolarian remains indicate that the siliceous material is partly of organic origin. Badly deformed sequences of banded chert more than 10 feet thick are locally present. More characteristically, the chert layers vary from a fraction of an inch to 3 inches in thickness, and relatively thin chloritic or sericitic argillite layers are lightly bonded to most bedding and fracture surfaces. As the brittle cherts were fractured during folding, the less competent argillaceous material was probably squeezed into incipient fractures and openings. Layers of autoclastic breccia which resemble conglomerate beds are common.

Limestone occurs as scattered lenses and podlike bodies ranging from a few inches to many hundreds of feet in longest dimension. It appears that the limestone beds were discontinuous originally and have been further disrupted tectonically. Most of these detached bodies are elongate parallel to the major foliation, although many have not been noticeably flattened. The limestone is bluish gray to dark gray, highly fractured, and locally recrystallized to marble.

Pardee and Hewett (1914, p. 35) reported the occurrence of Carboniferous Fusulina in a small limestone mass in their "Argillite Series" at a point about 3 miles south of Sumpter, but in consideration of the great thickness of sedimentary beds below the limestone and the presence of limestone cobbles in conglomerate beds above it, they assigned the "Argillite Series" to the "Paleozoic and Mesozoic." Gilluly (1937) assigned the Elkhorn Ridge Argillite in the Baker 30-minute quadrangle to the Pennsylvanian(?) on the basis of the fusulinids collected by Pardee and Hewett. Later, fusulinid specimens obtained from the Sumpter locality were identified as Permian, probably Leonardian, by M. L. Thompson (Taubeneck, 1955). Collections by Bostwick and Koch (1962) support the Leonardian age assignment and indicate that the limestone at the Sumpter locality is correlative with at least part of the Coyote Butte Formation near Suplee in central Oregon. Bostwick and Koch (1962) report the discovery of " Late Permian, probably Ochoan" fusulinids in small limestone pods in exposures of the Elkhorn Ridge Argillite in the Virtue Hills east of Baker, and interpret pentacrinid (?) columnals found in other similar-appearing limestone pods in the same area as evidence that the unit also includes rocks of Late Triassic age. Lithologically and structurally the pentacrinid(?) bearing rocks are similar to the Paleozoic rocks of the assemblage and unlike known Late Triassic or younger rocks elsewhere in the region. More recently Bostwick (written communication, 1974) has found and identified fusulinids of Middle Pennsylvanian (Desmoinsian) age in a limestone pod in sec. 2, T. 10 S., R. 43 E. and hydrozoans (Spongiomorpha (?), Stromatomorpha) and hexacorals of probable Triassic age in limestones in sec. 18, T. 10 S., R. 39 E.

The structure of unit (M_zP_za) has not been studied in detail. Complicated swirling folds indicate intense crumpling of the rocks. Compressional shearing is so pervasive and has affected so large a part of the formation that it probably represents a "penetrative movement" or distributive overthrusting, the cumulative displacement of which must be considerable (Gilluly, 1937, p. 69). Fold features trend generally eastward, and there is evidence of at least two stages of folding, which suggests that the deformational history of these rocks is similar to that of the Burnt River Schist.

(M_zP_zs) - (M_zP_zg) - (M_zP_zl) Foliated sedimentary and volcanic rocks and marble

These three map units collectively represent the Burnt River Schist of Gilluly (1937) and the exposures of similar rocks to the south and east. Individually, the map units represent lithologic subdivisions of the assemblage and were adapted in part from maps by Wolff (1965), Ashley (1966), and Prostka (1967).

Prior to deformation and metamorphism, the rocks probably comprised a thick assemblage of fine-grained quartzitic to argillaceous detrital rocks, chert, tuff, lava flows, and limestone. Some of the detrital rocks apparently were tuffaceous; others were calcareous or carbonaceous. Detailed petrographic and structural study of the Burnt River Schist in the type locality was made by Ashley (1966), and some of his data are paraphrased here.

Subunit (M_zP_zs) represents mainly the metamorphosed clastic sedimentary rocks of the assemblage, but metamorphosed volcanic rocks also are included in some areas, particularly in the Mineral quadrangle and in Tps. 11 and 12 S., Rs. 39 and 40 E., where sufficient data for their separation are not available. The most abundant rock types in the subunit have been described by Ashley (1966) as phyllitic quartzite, quartz phyllite, and pelitic phyllite. These rocks are intergradational. Pure, non-foliated quartzite beds, black carbonaceous slate, and sheared conglomerate that contains clasts of basic and intermediate volcanic rocks, chert, and mudstone are rare. Small, widely distributed marble lenses make up less than one percent of the subunit. The phyllitic quartzite and quartz phyllite are crudely layered rocks in which quartz-rich folia pinch and swell between sericitic partings. The pelitic phyllites show little compositional layering, but a phyllitic parting is well developed because of strong preferred orientation of micaceous minerals. Principal constituents are quartz and muscovite with minor albite, chlorite, biotite, clinozoisite, and carbonaceous matter. All contain relict quartz detritus. Many of the quartzitic rocks are extremely fine grained, suggesting that they may be sheared chert. Some probably are sheared sandstone. The pelitic phyllites probably were derived from rocks that were rich in clay minerals.

Subunit (M_zP_zg) lithologies are mainly greenstone and greenschist which are products of the metamorphism of volcanic and volcaniclastic rocks. The greenschists range from actinolite-rich to chlorite-muscovite-rich varieties. The original rocks probably were fine-grained tuffs. The more massive greenstones are mostly meta-andesite and metabasalt. They are now aggregates of actinolite, albite, pumpellyite or epidote, chlorite, and sphene/leucoxene (Ashley, 1966, p. 95-96). Relict pillows, found locally, indicate submarine deposition of part, if not all, of the lavas. Some of the andesites and basalts are flow breccias and conglomerates. Ashley stated (p. 103), "These rocks are not spilites and keratophyres, but tholeiites, basic andesites, and porphyritic andesites. Some of the greenstones are intrusive with ophitic or sub-ophitic textures."

Subunit (M_zP_zl) is chiefly marbleized massive and thin-bedded limestone with interlayered siliceous and calcareous phyllite and slate. In Burnt River Canyon, the limestone occurs as tectonically scattered lenses and pods, most of which are too small to show on the map and are therefore included in subunit (M_zP_zs). Eastward from Burnt River Canyon to the Snake River and beyond into Idaho, individual limestone masses range from tens of feet to several thousands of feet in length. Cross sections of the unit may be seen in roadcuts at Nelson and at the head of Hibbard Creek. Exposures of the unit in the Durkee quadrangle were informally named the Nelson Marble by Prostka (1967).

The limestone masses usually dip steeply northwest and form cockscomb ridges and steep slopes that are nearly barren of soil. The intervening slate and phyllite are more subdued topographically and are mantled by soil and limestone debris. The limestone typically is light gray in outcrop and dark to light bluish gray on fresh surfaces. Most of the limestone is granular and structurally massive, although schistosity is well developed locally. Chert bands 2 or 3 inches thick are common but are rarely continuous for more than a few tens of feet. Recrystallized quartz and carbonaceous material are common impurities in the massive limestone. Near intrusive contacts with plutonic rocks of unit (KJi), metamorphism has produced small quantities of actinolite-tremolite, epidote, diopside, and garnet.

The tectonic trend of the (M_zP_zs) - (M_zP_zg) - (M_zP_zl) assemblage is northeasterly. Foliation planes generally dip steeply northwest, but some dip southeast. Two sets of lineations which parallel fold axes are visible on many foliation surfaces, particularly in the quartz phyllite. Linear schistosity is so well developed in some of the quartz phyllite that the broken rocks resemble splintered wood. In the Snake River Canyon area, fold axial planes commonly are nearly parallel, but the one set of axes, representing primary, large-scale folds, plunges 30° to 60° southwest. The other, which represents a later deformation, plunges 50° to 70° northeast. The earlier folding produced large, tight folds and is responsible for the gross distribution of lithologic units. The latter produced small folds with amplitudes of a few feet or less.

Age of the assemblage has not been firmly established. A single bryozoan specimen from the Burnt River Schist was assigned a questionable Permian age by Helen Duncan (Ashley, 1966, p. 159). A pentacrinid columnal from a small marble exposure in the SW$\frac{1}{4}$ sec. 10, T. 12 S., R. 41 E. is considered indicative of a Mesozoic, probably Late Triassic, age for part of the assemblage by David Bostwick (written communication, 1974). Subunits (M_zP_zs) and (M_zP_zg) are made up largely of rocks that, except for their higher degree of deformation and metamorphism, are very similar to the principal lithologies included in unit

(M_zP_za). Fold features appear similar but generally are more tightly compressed in (M_zP_zs) - (M_zP_zg) - (M_zP_zl). Gilluly (1937, p. 13) did not equate the Burnt River Schist and Elkhorn Ridge Argillite, stating that, "The Burnt River Schist appears less siliceous than the Elkhorn Ridge Argillite, and its quartzose members appear to be chiefly of clastic origin, whereas those of the argillite are probably chemical deposits." He assumed a greater age for the Burnt River Schist because of its more intense deformation.

Ashley (1966) divided the Burnt River Schist into two units on the basis of subtle differences in gross lithology and structural geometry. The two units are separated by an east-trending high-angle fault that crosses Burnt River in T. 12 S., Rs. 41 and 42 E. Phyllites of the "northern" unit consist mainly of quartz phyllite, quartzo-feldspathic phyllite, and calc-phyllite; phyllites of the "southern" unit are mostly pelitic phyllite with some phyllitic quartzite, quartzo-feldspathic phyllite, and calc-phyllite. Metavolcanic rocks and lenses of marble occur in both units but are much more abundant in the "southern" unit. Ashley stated (1966, p. 14) that, "Although they both show evidence of two deformations, neither deformation was strictly similar between the two units. In each unit the first folding is the major folding, primarily responsible for the distribution of rock subunits. The east-northeast trends and westerly plunges of the first-deformation folds are similar in both units, but the attitudes of second-deformation folds differ greatly between the two units." He equates the "northern" unit with the Elkhorn Ridge Argillite and suggests a pre-Mesozoic age for the southern unit.

Prostka (1967) tentatively correlated his Nelson Marble and "gray phyllite" units with the Upper Triassic Martin Bridge (TRmb) and Hurwal (TRh) formations, respectively, in the Wallowa Mountains. We have included part of his "gray phyllite" in unit (M_zP_zs) and part of it in unit (JTRs).

(TRPv) Volcanic and sedimentary rocks

The unit (TRPv) represents a heterogeneous assemblage of predominantly volcanic and volcaniclastic rocks exposed in the northern part of the map area. Rock types include lava flows; flow breccia and agglomerate; pyroclastic rocks; subordinate epiclastic conglomerate, sandstone, and argillite; chert; and minor limestone. The assemblage is exposed more extensively farther north in the Wallowa Mountains and Snake River Canyon. It predates the Martin Bridge Formation and includes both Permian and Upper Triassic strata.

Exposures of these rocks in the Seven Devils Mountains and adjacent parts of the Snake River Canyon in Idaho were named the Seven Devils Volcanics by Anderson (1930, p. 13). Correlative rocks in the Baker quadrangle are found in the Clover Creek Greenstone of Gilluly (1937), Ross(1938), and Prostka (1962); the "Carboniferous (?) sedimentary rocks" and other informally designated units of Ross(1938); and the "Lower Sedimentary Series" and Gold Creek Greenstone of Prostka (1962). Throughout the assemblage there are marked lithofacies variations, both laterally and vertically, and a similarity in structural geometry and degree of metamorphism. The lack of regionally distinctive lithologies and the scarcity of fossil controls has made subdivision of the assemblage extremely difficult, and over the years a complexity of obscure correlations and conflicting stratigraphic interpretations has developed. Exposures of the assemblage in the Snake River Canyon have been more precisely subdivided and defined by Vallier (1974).

Gilluly (1937, p. 22) stated, "The rocks composing the Clover Creek Greenstone include quartz keratophyre, keratophyre, spilite, albite diabase, quartz keratophyre tuff and breccia, meta-andesite, chert, conglomerate, argillite, and limestone. The most abundant varieties are the quartz keratophyres, probably followed by quartz keratophyre tuffs, keratophyre flows, meta-andesites, and keratophyre tuffs. The other rock varieties are subordinate.... As the formation is exposed over a width of about 4 miles across the strike, it is highly probable that the great apparent thickness is due to close or isoclinal folding. It is thought likely, however, that the thickness of the Clover Creek Greenstone is at least 4,000 feet, and it may be very much more."

Strata included in the Clover Creek Greenstone by Gilluly extend eastward into the Sparta quadrangle, where they were divided by Prostka (1962) among three units: Clover Creek Greenstone, Gold Creek Greenstone, and Lower Sedimentary Series. According to Prostka, the Gold Creek Greenstone grades abruptly upward into the Lower Sedimentary Series, and both grade laterally into the Clover Creek Greenstone. A combined thickness of 5,200 feet was estimated. The name Gold Creek Greenstone was assigned to 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 Sparta quadrangle.

The name Lower Sedimentary Series was first assigned by Smith and Allen (1941) to a group of metamorphosed sedimentary rocks, chiefly mudstone, sandstone, and shale, which they interpreted as lying stratigraphically between the Clover Creek Greenstone and the Martin Bridge Formation in the northern part of the Wallowa Mountains. Prostka (1962) applied the name to a sequence of similar rocks in the Sparta quadrangle and stated that there "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 at most horizons. Graded bedding, load casts, and mud cracks are common sedimentary features. . . . The uppermost part of the formation is fine-grained green calcareous argillite which conformably underlies massive Martin Bridge limestone."

Based on limited fossil evidence, the Clover Creek Greenstone was assigned to the Permian by Gilluly (1937), and the Lower Sedimentary Series was assigned to the Late Triassic (middle Karnic) by Smith and Allen (1941). Subsequent workers, including Wetherell (1960), Bostwick and Koch (1962), Prostka (1962), Nolf (1966), and Vallier (1967), have shown that both of these assemblages as originally defined include Permian and Upper Triassic strata.

Unit (TRPv) includes the exposures near Oxbow in the Snake River Canyon of the middle Permian (Leonardian/Guadalupian) Hunsaker Creek Formation of Vallier (1967; 1974), which is made up mostly of marine volcaniclastic rocks, with minor amounts of spilite and keratophyre flow rocks, argillite and recrystallized limestone.

The relationship between units (TRPv) and (M_ZP_Za) is not clear. The zone of transition from one to the other is covered by Cenozoic deposits. Strata of middle Permian age are included in both units, but in view of their lithologic differences it is questionable whether they represent the same depositional system.

<u>(TRgb) and (TRqd) Pre-Upper Triassic intrusive complex</u>

These units represent mafic and felsic divisions of an igneous complex that ranges from peridotite to albite granite. Gabbro, albite granite, and quartz diorite are the prevalent rock types. Ultramafic rocks, including serpentinite, peridotite, and pyroxenite, are widely distributed but probably constitute less than 2 percent of the total outcrop area. Diabase dikes are abundant locally.

Nearly all of the plutonic rocks are foliated to some degree and some exhibit gneissic banding. Semi-schistose structure is common. Locally, shearing and recrystallization has produced cataclasite, mylonite, and gneissic mylonite. Under the microscope the rocks typically show mild cataclastic textures, and a few are crystalloblastic. The country rocks appear to have exerted little or no influence on the emplacement of the intrusives. External contacts are sharp, generally discordant with foliation of the enclosing rocks, and devoid of contact metamorphic effects. Internal contacts between the various rock types range from broadly gradational to very sharp, and in some areas the rocks are too intermixed for differentiation on the map.

Unit (TRgb) represents mainly altered gabbro, serpentinite, and other ultramafic rocks. Primary minerals of the gabbro typically have been partly or totally replaced by albite, clinozoisite, epidote, chlorite, prehnite, muscovite, and serpentine minerals. Actinolite-tremolite and calcite also are common. Small amounts of secondary quartz are found in many rocks, and some rocks are altered to dense masses of quartz-epidote-chlorite. Albite rims commonly surround more calcic plagioclase, and in many specimens the plagioclase is totally saussuritized. Albite, epidote, and clinozoisite also are localized in veinlets. Prostka (1963) described rodingite alteration of gabbro in the Sparta quadrangle. Rare, small masses of tremolite-talc schist probably are indicative of intense shearing and hydrothermal alteration along faults. Chlorite schist, derived from gabbro, also is common. Some gabbro included in the unit is relatively unaltered, for example in the vicinity of the Flagstaff mine (sec. 5, T. 9 S., R. 41 E.).

Exposures of unit (TRgb) southwest of Mormon Basin (T. 13 S., Rs. 41 and 42 E.) include large undifferentiated serpentinite masses in association with gabbro, peridotite, and talc. Another large mass of serpentinite is associated with peridotite and pyroxenite in the vicinity of Glasgow Butte (T. 9 S., Rs. 43 and 44 E.). A more accessible exposure of serpentinite occurs on the hill half a mile east of Pleasant Valley in sec. 30, T. 10 S., R. 42 E.

Unit (TRqd) is mostly quartz diorite and albite granite. The quartz diorite is composed largely of plagioclase, hornblende, quartz, and minor amounts of biotite and magnetite. The percentage of potash feldspar is very small. Mineral components of the albite granite are chiefly quartz and albite. Much of the quartz is bluish in hand specimen and somewhat larger than the albite. Other minerals typically present are chlorite, epidote, hornblende, clinozoisite, sphene, and magnetite. The albite granite is closely associated with gabbro or quartz diorite.

Evidence for a metasomatic origin of the albite granite near Sparta (T. 8 S., Rs. 43 and 44 E.) is given by Gilluly (1933b) and Prostka (1963). Gradational transition from quartz diorite to albite granite involves an increase in the amount of quartz and albite and a decrease in mafic minerals. A direct relationship was noted between the intensity of crushing and the increase in minerals characteristic of the albite granite. Small bodies of albite granite in the Burnt River Canyon area may have formed directly from residual magmatic fluids (Ashley, 1966, p. 42). Composite swarms of diabase, quartz diorite, and albite granite dikes cut gabbroic rocks in the NW¼ T. 9S., R. 42 E. and in the SW¼ T. 10 S., R. 42 E. The dikes dip steeply, range from a few inches to about 10 feet in width, and have sharp, chilled contacts against the gabbro. The dikes appear to overlap in age, and their origin may correspond to that of the sheeted dike swarms of the Canyon Mountain Complex (Thayer, 1973) and the "multiple dike injections" of the Oxbow Complex (Vallier, 1974).

Unit (₸gb) in T. 7 S., R. 48 E. represents part of the Oxbow Complex, which was described by Vallier (1974) as a mixture of intrusives with metagabbro, amphibolite, meta-quartz diorite, metadiabase, metadiorite, and albite granite plus their mylonitized equivalents as the major rock types. A similar assemblage is exposed along the Snake River in T. 8 S., R. 48 E.

Emplacement history of units (₸gb) and (₸qd) has not been firmly established. The rocks were affected by regional metamorphism which ceased in the Late Jurassic, and they clearly are older and of different overall composition than the unmetamorphosed Late Jurassic-Early Cretaceous plutons in the area. Prostka (1963, p. 112) cited evidence that gabbro of unit (₸gb) in sec. 36, T. 9 S., R. 43 E. is intrusive into chert and argillite presumed to be of Permian age and that rocks of Late Triassic (Karnian) age in the northern part of the Sparta quadrangle are in depositional contact with albite granite. F. G. Poole (written communication, October 8, 1975) reported that a K-Ar age of 213 ± 5 m.y. was determined for biotite from quartz diorite at Bishop Springs in sec. 6, T. 9 S., R. 44 E. (sample collection by F. G. Poole and G. A. Desborough; age determination by R. F. Marvin, H. H. Mehnert, and L. B. Schlocker). Vallier (1974) found gabbro and albite granite clasts in Permian conglomerate beds in the Snake River Canyon a few miles north of the map area.

Units (₸gb) and (₸qd) were identified as part of the Canyon Mountain magma series (Thayer, 1963; Thayer and Brown, 1964). Emplacement of the Canyon Mountain Complex has been dated stratigraphically as post-Middle Permian and pre-Late Triassic (Thayer and Brown, 1964; Thayer, 1973). Radiometric dates of about 210 million years were obtained from samples of quartz diorite on Canyon Mountain (T. P. Thayer, personal communication, September 1975). Rocks of the Canyon Mountain magma series probably do not represent a single magmatic cycle. Generally it appears that the quartz diorite, the albite granite, and the diabase dikes post-date the gabbro and more mafic rocks (Thayer, 1963; Prostka, 1963) and may be considerably younger (Thayer, 1973).

(mr) Mixed sedimentary, volcanic, and intrusive rocks

Exposures designated (mr) within the (J₸s) outcrop belt incorporate rocks having the respective lithologic and deformational characteristics of rocks included in units (₸gb) and (M_ZP_Zs)-(M_ZP_Zg). Unit (mr) consists of a mixture of sedimentary and igneous rocks, including serpentinite, altered gabbro, chert, siliceous phyllite, greenstone, and limestone. The exposures are elongated northeast, roughly paralleling the tectonic grain of unit (J₸s). External contacts are steep and discordant.

Mesozoic Rock Units

(₸v) Triassic volcanic and sedimentary rocks

Unit (₸v) comprises lavas and volcaniclastic rocks, coarse- to fine-grained epiclastic sedimentary rocks, minor limestone, and small intrusive bodies.

This unit is best exposed in roadcuts extending downstream from Huntington to the mouth of Burnt River and from there northward along both sides of the Snake River for about 7 miles. Small exposures also have been found as far west as Juniper Mountain.

Massive agglomerate, tuff, and flows intercalated with coarse volcaniclastic breccia and conglomerate are the dominate rock types. The presence of fossiliferous marine clastic beds in many parts of the section suggests that most of the volcanic ejecta is submarine.

The volcanic rocks range from basalt to rhyolite. Andesites probably are most abundant, although little detailed petrography has been done on these rocks. The assemblage includes dikes, sills, and irregular intrusive masses that commonly are difficult to distinguish from their extrusive counterparts. The rocks range in color from drab greens and grays through black, red, and pale brown.

Detailed stratigraphic and structural relationships of the more massive volcanic and volcaniclastic rocks are bewildering. Some of the complications probably developed during or shortly after deposition of the rocks due in large part to submarine sliding and to the coalescing of materials from different vents. Intercalation of volcanic flows and pyroclastic rocks suggests that the materials were ejected from volcanic vents as alternating quiet flows and explosive eruptions. Many of the rocks are monolithologic volcanic breccia andagglomerate which probably resulted from the phreatic fragmentation of submarine flows. Mixed clast breccia and conglomerate of epiclastic origin also are common. Clasts commonly range from 1 to 6 inches in diameter.

Massive and thin-bedded volcanic wacke, volcanic arenite, water-laid tuff, and volcanic siltstone occur in many parts of the section. Volcanic sandstone and siltstone commonly grade downward into volcanic conglomerate or breccia. In outcrop, tuff is difficult to distinguish from epiclastic sandstone and siltstone. In places, epiclastic and pyroclastic strata are interbedded, are composed of similar materials, and are intergradational. Turbidity currents, generated by subaqueous volcanism and gravity sliding on slopes of volcanic vents, probably were an important transporting and sorting mechanism.

Limestone forms a very small part of the unit. It occurs partly as scattered pods and lenses, many of which have been recrystallized to light-gray marble. Thinly interbedded dark-gray limestone and siltstone also occur in parts of the section. The limestone has a high content of volcanic debris.

Most of the volcanic rocks have been metamorphosed to greenschist facies. Metamorphic minerals are chiefly chlorite and/or epidote. Feldspars commonly are albitized, although there seems to be wide variation in the degree of albitization. Actinolite, leucoxene, and muscovite occur in some rocks.

Structural trends are determinable only where thin-bedded epiclastic strata are present. East of Huntington bedding planes typically dip about 10 degrees to the north. Northward, along the Snake River, dips increase to a maximum of about 70 degrees to the northwest. No evidence for isoclinal folding has been recognized. There has been some repetition of parts of the section due to faulting.

Neither the base nor the top of the unit (₮v) has been recognized in the map area. Early Jurassic strata of the (J₮s) assemblage lie unconformably on an erosion surface across (₮v) strata. Unit (₮v) strata exposed along the Snake River form a section that may be more than 10,000 feet thick

According to fossil assignments by Dr. Norman Silberling (written communication, April 1968), the Tropites dilleri and Tropites welleri zones of the upper Karnian stage of the Upper Triassic are well represented. Two collections were assigned with some question to the upper middle Norian and a third to the lower or middle Norian.

The gross lithology of unit (₮v) is very similar to that of unit (₮Pv) in the northern part of the map area, which includes both Permian and Upper Triassic rocks. The possibility that Permian rocks are included in unit (₮v) appears remote in view of the wide distribution of Late Triassic fauna.

(₮mb) Triassic limestone

This unit represents exposures of the Martin Bridge Formation in the north-central part of the map area. The formation was named by Ross (1938) for limestone exposures at Martin Bridge on Eagle Creek at the mouth of Paddy Creek. The formation is extensively exposed farther north in the Wallowa Mountains (Smith and Allen, 1941) and near Big Bar on the Snake River (Vallier, 1974). Owing to the wide distribution of exposures and consistent lithology, the Martin Bridge is a key stratigraphic horizon.

Interbedded massive and thin-bedded limestone constitutes the bulk of the section. The limestone typically is gray to black on fresh surfaces and weathers light gray to nearly white. In many places, it is highly carbonaceous; pyrite is abundant locally. Variable concentrations of carbonaceous material give the limestone a laminated appearance. Massive limestone-clast breccia and conglomerate are common. The limestone is complexly folded, and its true thickness is difficult to determine. Thickness estimates range from 1,000 to 2,000 feet.

The Martin Bridge Formation is overlain conformably by the Hurwal Formation, and the contact with underlying (ꞦPv) strata has been defined as conformable in the map area (Prostka, 1962). Unconformable relations were ascribed in some areas farther north (Smith and Allen, 1941).

Age of the Martin Bridge Formation is late Karnian and earliest Norian. Silberling states (written communication, December 8, 1965), "As a result of the painstaking work by Bruce Nolf in the Hurricane Creek area of the Wallowas, the contact between the Martin Bridge and type Hurwal can be placed within the *Mojsisovicsites kerri* zone, the lowest of six ammonite zones we now recognize in the Norian of the western U.S. and one of a total of 13 Upper Triassic ammonite zones."

(Ꞧh) Triassic sedimentary rocks

This unit represents exposures of the Hurwal Formation in the northern part of the map area. The formation was named by Smith and Allen (1941) for exposures on Hurwal Divide in the central part of the Wallowa Mountains. Prostka (1962) estimated a maximum thickness of 4,000 feet for the section in the Sparta quadrangle. Throughout the section, thin-bedded argillite and siltstone are the dominant rock types. These rocks typically are carbonaceous and pyritic and are iron-stained on weathered surfaces. Local lithofacies variants include fine-grained quartzite, quartz graywacke, calcareous argillite, and calcareous siltstone. Black and gray limestone intervals, ranging from less than an inch to over 50 feet in thickness, constitute a very small part of the formation. The limestones commonly are marbleized.

The Hurwal Formation is more than 6,500 feet thick in the northern Wallowa Mountains and paleontologic age assignments range from earliest Norian through late Pliensbachian stages of the Upper Triassic and Lower Jurassic (Nolf, 1966). Fossils of latest Norian, Rhaetian, and Hettangian age have not yet been identified, although the section appears to be continuous.

(JꞦi) Upper Triassic-Lower Jurassic plutons

This unit represents two small plutons. One is well exposed by roadcuts along the Snake River in T. 13 S., R. 45 E. The other is near Limestone Butte in the SW¼ T. 14 S., R. 44 E. Thin sections of typical specimens indicate that most rocks approximate quartz diorite or granodiorite in compostion.

The pluton in T. 13 S., R. 45 E. is composed mainly of medium to coarse crystalline quartz and sericitized andesine, oligoclase, and orthoclase. Many specimens also contain a little chloritic hornblende, epidote, clinozoisite, and magnetite. Quartz constitutes about 20 to 25 percent of the rock. Partial analysis of a single sample revealed the following percentages: CaO - 2.5; Na_2O - 4.2; K_2O - 1.33. Locally the coarse-grained quartz diorite is cut by flat or gently dipping, fine-grained olive-green andesitic dikes that range from a few inches to several feet in thickness. The pluton intrudes Upper Triassic volcanic and sedimentary rocks of the (Ꞧv) assemblage. Fragments of very similar appearing quartz diorite have been found in conglomerate beds of Early Jurassic (Pliensbachian) age in the SW¼ sec. 30, T. 13 S., R. 45 E.

Rocks typical of the pluton in the SW¼ T. 14 S., R. 44 E. are pinkish and equigranular to porphyritic. Quartz comprises less than 10 percent of most specimens from this mass, and some phases of the plutons may be monzonitic.

The (JꞦi) intrusives probably are of Late Triassic-Early Jurassic age and may correlate with similar intrusives in the Cuddy Mountain area of Idaho from which K/Ar dates of 190 to 215 m.y. were reported by Field and others (1972).

(JꞦs) Triassic and Jurassic sedimentary rocks; (JꞦl) limestone

Unit (JꞦs) is mostly volcanic wacke, siltstone, and argillite, but includes also phyllite, slate, conglomerate, sandstone, limestone, and minor gypsum. Some of the larger bodies of limestone are mapped separately as unit (JꞦl).

Rocks of unit (JꞦs) are exposed in a broad belt that extends east-northeast across the central part of the map area . Exposures continue eastward into Idaho at least as far as Cuddy Mountain and westward to the vicinity of Ironside Mountain in the Canyon City quadrangle. The exposure belt narrows to the east between converging contacts with older rocks. On the south, (JꞦs) strata unconformably overlie eroded beds of the (Ꞧv) unit. Exposures of the contact form a northeasterly trending arc extending from Juniper Mountain (T. 16 S., R. 41 E.) across Snake River to Cuddy Mountain in Idaho, a distance of over 65 miles.

The contact with older rocks on the north probably is a major fault.

Natural exposures of the formation usually are small and widely separated. Thick soil cover, downhill soil creep, and landsliding are common. Intact strata rarely are traceable for more than a few tens of feet. Poor exposures, similar lithologies, and structural complications throughout the exposure belt prevent confident estimates of thickness. The estimate of 17,000 feet for the thickness of the similar, but less deformed, Jurassic section in the Izee-Suplee area (Dickinson and Vigrass, 1965) does not seem excessive for the (JTRs) section along Snake River.

The unit is made up almost totally of interlayered massive and thin-bedded detrital rocks. Colors typically range through drab shades of green, brown, and gray to black. Common to most of the rocks is angularity of grains, poor sorting, and an abundance of rock fragments, usually including andesite. The sediments comprising these rocks probably were derived by rapid erosion and deposited swiftly; grading is uncommon. Wacke beds typically consist of quartz, plagioclase, and rock fragments embedded in a finely comminuted matrix which includes chlorite and sericite and comprises well above 10 percent of the rock. Carbonate minerals occur in some specimens. The finest grained rocks are composed of quartz grains in an argillaceous matrix. Thin intraformational conglomerates occur in many parts of the section. Most are supported by rounded wacke pebbles. Some contain angular chips of phyllitic argillite. Graded carbonaceous quartz sandstone and siltstone beds are intercalated with greenish tuff beds in roadcuts north of Weatherby.

Initial deposits on the erosion surface across (TRv) strata comprise a shallow marine, partly high-energy facies of unit (JTRs) that is characterized by conglomeratic volcanic wacke beds of distinctive red and green color (Brooks, 1967). Massive limestone pods and thinly interbedded limestone-siltstone sequences are associated with the conglomeratic beds. Gypsum lenses form a small part of the facies in T. 13 S., R. 45 E. Some of the larger bodies have been mined. The separately mapped exposures of massive and thin-bedded limestone (JTRl) at Lime and Juniper Mountain probably are part of this conglomeratic facies, although diagnostic fossils have not been found in the limestone, and stratigraphic relations are obscured by faults and landslides. The conglomeratic facies ranges from a few tens of feet to about 800 feet in thickness and is best exposed between Lime and the Snake River. Clasts included in this "basal" conglomerate are typical of the underlying (TRv) assemblage and commonly are as large as 2 inches in diameter. Sorting generally is poor. Discontinuous graded beds are present in many outcrops.

(JTRs) strata are weakly metamorphosed. Thin sections usually show a little chlorite and sericite. The finest grained rocks commonly are mildly phyllitic. Pervasive, generally poorly developed, axial-plane fracture cleavage usually is oriented northeast and dips steeply northwest. Fold hinges have not been recognized except in small scale.

Roadcuts at the mouth of Connor Creek (sec. 14, T. 12 S., R. 45 E.) expose a section of black, pyritiferous, slaty siltstone more than 800 feet thick that dips steeply northwest. Bedding and cleavage intersect at sharp angles. Similar relationships are seen in steep slopes along Highway 80N near Weatherby. In many other areas, bedding-cleavage relationships indicate broad open folds around northeast-trending axes.

Bedding features usually are disrupted by cleavage. Some specimens have definite foliated or semi-schistose fabric. However, in thin sections there is little evidence of cataclasis and recrystallization. Probably minor folding occurred during deposition of the sediments and cleavage development began before the sediments became lithified. The common occurrence of intra-formational conglomerate beds is further evidence of syndepositional tectonism. Fossil distribution patterns indicate that bedding trends are northeasterly, roughly paralleling the surface trace of the contact between units (JTRs) and (TRv) and that there has been some tectonic repetition of bedding. In the area between Lime and the Snake River, the basal red and green conglomeratic facies of (JTRs) includes fossils of late Early Jurassic (late Pliensbachian) age. These beds are structurally overlain by older beds of Sinemurian age, possibly as a result of southeastward imbricate thrusting. No large-scale thrust faults have been recognized within the unit. Total movement along existing, closely spaced shear planes probably has been very large.

Most of the strata included in (JTRs) probably are of Early and Middle Jurassic age. Ammonite age assignments by Ralph Imlay (written communication, April 25, 1974) range from early Sinemurian to early late Bajocian, although there are lengthy gaps in the fossil record (see also Imlay, 1968). Imlay (1964) has described Late Jurassic (Callovian) ammonites from exposures of the unit at Mineral, Idaho, four miles east of the Snake River. Lowry (1968) reported Triassic corals from (JTRs) strata exposed in the Ironside Mountain quadrangle. Within the Baker map area, fossils have been found in unit (JTRs) strata only in the southern part of the exposure belt. Upper Triassic strata may be incorporated in more northerly non-fossiliferous exposures of the unit.

The range of compositions and textures of the rock fragments suggests that much of the clastic debris was derived from the (TRv) assemblage. Perhaps positive areas of (TRv) marked the margins of the Jurassic basin. The boundary between (TRv) and (TRvs) strata records the development of an erosion surface across northward tilted beds of unit (TRv) and the subsequent overlap of the erosion surface by sediments of unit (JTRs). Continuing tectonism during and after (JTRs) sedimentation increased the northward tilt of (TRv) beds and produced northeast trending folds and pervasive axial-plane cleavage in (JTRs).

The unconformity surface across Triassic strata dips about 30° north where it crosses the Snake River and appears to be broadly undulating, whereas the bedding in the Jurassic section has been more intricately deformed. No evidence of major infolding of (TRv) and (JTRs) strata has been observed.

The arcuate (TRv)-(JTRs) unconformity has been traced northeastward to the vicinity of Cuddy Mountain in Idaho by students of Cyrus W. Field of Oregon State University. These students have shown that (JTRs) strata are continuous, at least in part, with the Lucille Series of W. R. Wagner (1945) and that (TRv) strata interconnect with strata in the Seven Devils Volcanics. In the Cuddy Mountain area, the red and green conglomerate beds of unit (JTRs) are not everywhere present along the contact, but similar beds occur higher in the (JTRs) section.

The contact between units (JTRs) and (M_zP_zs-M_zP_zg) is a major stratigraphic and structural discontinuity. Strata of the two assemblages are everywhere separated by faults or mafic, ultramafic, or granitic rocks. Contrasting sedimentary lithologies and structural geometry on opposite sides of the contact indicate that the assemblages represent different depositional systems and that their deformational histories are different.

(KJi) Upper Jurassic - Lower Cretaceous plutons

The plutons (KJi) are composed of quartz diorite and granodiorite. Typically these rocks are medium grained with hypidiomorphic granular texture. The plagioclase is mostly andesine, and potash feldspar content rarely is as much as 5 percent. Quartz content ranges from 0 to 30 percent but probably averages about 20 percent. Mafic minerals, commonly equal amounts of hornblende and biotite, comprise 15 to 30 percent of typical specimens. Central parts of the Lookout Mountain stock are trondhjemitic (Prostka, 1967). Dikes and small irregular masses of hornblende gabbro occur locally. The (KJi) intrusives postdate regional metamorphism of Jurassic sedimentary rocks (JTRs) and pre-date all adjacent Tertiary units. They are lithologically similar to the Bald Mountain and Wallowa batholiths of Late Jurassic-Early Cretaceous age (Taubeneck, 1955 and 1959).

Exposures of the unit are aligned northeasterly and for several miles lie close to and nearly parallel to the tectonic contact between units (M_zP_zs) and (JTRs). Deflection of country-rock foliation around the southwest margin of the Pedro Mountain stock is attributed by Wolff (1965, p. 56-58) to thrusting of the country rocks coincident with upward and southwestward movement of the intruding mass.

TECTONIC EVOLUTION OF PRE-CENOZOIC ROCKS

The pre-Cenozoic rocks in the map area belong to the eugeosynclinal part of the Cordilleran fold belt (King, 1969, p. 75) and were involved in the climactic Nevadan orogeny as defined by geologic relations in northern California and southwestern Oregon.

The most prominent structural feature is the division of the supracrustal rocks into east- and northeast-trending lithic belts. Pre-Cenozoic fold features and faults are in approximate conformity with the trend of the lithic belts, except in the north-central part of the map area where fold axes trend northwest. In the Sparta quadrangle the rocks of units (TRPv), (TRmb) and (TRh) have been folded into a northwest-trending synclinorium (Prostka, 1962).

According to plate-tectonic models by Hamilton (1969) and many others, the Cordilleran fold belt records the westward growth of North America as island arc, trench, and sea-floor materials were added to the continent while relatively eastward-moving Pacific crust and mantle turned downward beneath the continental margin. Viewed in this context, the pre-Cenozoic rocks exposed in the map area appear to include spatially rearranged fragments of volcanic-plutonic arc and ocean-floor complexes which were mechanically accreted to the Mesozoic continental margin by folding and overthrust faulting.

The volcanogenic assemblages (TRPv) and (TRv) are interpreted as island-arc accumulations. Similarities in rock types and fossil age data and projections of structural trends indicate former continuity of these rocks with the Permian and Upper Triassic metavolcanic rocks of the Seven Devils Mountains of western Idaho, which, according to Hamilton (1963, p. 69), "are chemically so similar to the submarine rocks of the Aleutian Islands that a common origin is likely." The volcanic rocks are chiefly calc-alkaline andesite, dacite, and basalt and their albitized equivalents keratophyre, quartz keratophyre, and spilite. It is commonly assumed that calc-alkaline composition is diagnostic of magmas generated in a subduction zone-volcanic arc system (Dickinson and Hatherton, 1967; Dickinson, 1970). The abundance of explosive eruptions that characterized the volcanism and the compositional variation of the rocks are consistent with a volcanic-arc tectonic environment (McBirney, 1969). Further evidence for an island-arc origin is found in the interlayering of the volcanic rocks with fossiliferous marine sedimentary rocks whose characteristics suggest rapid deposition in basins near rugged volcanic source areas.

Units (M_zP_za), (M_zP_zs), (M_zP_zg), and (TRgb) are interpreted as representing fragmented oceanic crust in which blocks of argillite, chert, greenstone, limestone, gabbro, and other rocks are chaotically juxtaposed. The association of radiolarian chert and pillow lavas and the scarcity of clastic rocks coarser than argillite suggest that most of the sedimentary and volcanic rocks are of abyssal marine origin. The presence of fusulinids in limestone pods may indicate a relatively shallow-water environment for some of the rocks. The occurrence of both Tethyan and North American fusulinid faunas (Bostwick and Nestell, 1967) may indicate that large-scale dislocations have occurred, and that deposits which at one time were widely separated are now juxtaposed (Hamilton, 1969, p. 2412; Jones and others, 1972).

The gabbro and associated rocks of unit (TRgb) probably represent the igneous crust upon which the sedimentary and volcanic rocks were deposited. This interpretation is consistent with the concept of ocean crust "psuedostratigraphy" presented by Dickinson (1972) and the fact that no other base for the sedimentary and volcanic rocks has been recognized. Silicic rocks similar to the quartz diorite and albite granite of unit (TRqd) are also found in many ocean crust sequences (Dickinson, 1972, p. 557).

For many years the belief was generally held that the rocks included in units (TRgb) and (TRqd) were intruded sequentially—gabbro and more mafic rocks first, followed by quartz diorite and albite granite—during Early and Middle Triassic time. However, most of these rock bodies have faulted exterior margins and have shared fully in the deformation and recrystallization of their wall rocks. Thus, from available field evidence, it is not possible to assign an unquestionable time frame for their earliest entry in the tectonic history of the region, nor is it possible to establish firmly their mode of final emplacment. Thayer (1973) suggests that the gabbro-peridotite fraction of the Canyon Mountain Complex was emplaced as a solid tectonic block between mid-Permian and Late Triassic time and that quartz diorite, albite granite, and a swarm of basaltic dikes were intruded soon after the emplacement of the gabbro-peridotite block. Insofar as the rocks included in units (TRgb) and (TRqd) are related to the Canyon Mountain Complex, their age and emplacement history probably are similar.

No Early or Middle Triassic supracrustal rocks have been identified in northeastern Oregon or western Idaho, nor has the nature of the depositional interface between Permian and younger pre-Cenozoic rocks been clearly defined. Dott (1962) reviewed the evidence for complex diastrophism, plutonism, and elevation of lands in much of the western Cordilleran belt in Later Permian-Early Triassic time. Plate tectonic hypotheses suggest that some "missing" strata may have been subducted and magmatically assimilated in the roots of volcanic island arcs.

Radiometric ages of 190 to 215 m.y. for composite plutons that intrude volcanic rocks of units (TRv) and (TRPv) in western Idaho and of about 210 m.y. for quartz diorite of the Canyon Mountain Complex are indicative of deep-seated magmatism coincident with volcanism in eastern Oregon and western Idaho in the Late Triassic.

It appears that arc volcanism within the map area either ceased or waned greatly near the end of the Triassic, although Mesozoic magmatic activity culminated with the intrusion of granitic rocks in Late Jurassic-Early Cretaceous time. Volcanic rocks (TRPv) in the northern part of the map area are overlain by Upper Triassic limestone (TRmb) which, in turn, is overlain by Upper Triassic-Lower Jurassic clastic sedimentary rocks (TRh). Along the southern margin of the pre-Cenozoic exposure belt, volcanic rocks of unit (TRv) are overlain unconformably by Early and Middle Jurassic wacke and siltstone beds (JTRs). The occurrence in the (JTRs) assemblage of windows and fault slices of ocean-floor rocks (mr) indicates that the ocean-floor and island-arc terrains were tectonically juxtaposed prior to (JTRs) deposition and that the (JTRs) sediments were deposited across the active tectonic boundary between the oceanic and island-arc assemblages. Concurrent deformation of the ocean floor with imbricate thrusts verging south and southeast toward the island arc resulted in the emplacement of tectonic slivers of ocean-floor rocks (mr) in the Early and Middle Jurassic sedimentary assemblage.

The north margin of the (JTRs) unit exposure belt is regarded as a major fault along which ocean-floor terrain was further uplifted and driven eastward into overthrust relationship with the (JTRs) assemblage. Thus the rocks of unit (JTRs) were compressed between the ocean-floor block and the island arc, producing southeastward imbrication of the (JTRs) assemblage and closure of the Jurassic basin. The harmony of the fault with the pre-Cenozoic tectonic grain of the region, the juxtapositioning across the fault of different petrotectonic assemblages, the alignment of Jurassic-Cretaceous quartz diorite plutons near the fault, and the northeasterly elongation of the tectonic slivers of sea-floor rocks in (JTRs) terrain are considered collectively as strong evidence that the fault is part of a broad zone of deep-seated structural dislocations.

The youngest pre-Tertiary strata recognized in the map area are beds of Middle Jurassic (Bajocian) age included in the (JTRs) assemblage. Regional metamorphism ceased after deposition of these rocks and prior to intrusion of the Nevadan granitic plutons (KJi) in Late Jurassic-Early Cretaceous time. During Late Jurassic through early Tertiary the pre-Cenozoic rocks were subjected to extensive erosion.

CENOZOIC ROCKS

Upper Oligocene - Lower Miocene Rock Units

(Tov) Andesite and dacite

This unit includes the oldest Cenozoic rocks recognized in the map area. Chief components are porphyritic dacite and andesite flows, breccias, tuffs, and possibly, shallow intrusives related to local eruptive centers. Thick accumulation of these rocks extends from the western map boundary eastward along the south side of the Dooley Mountain uplift as far as Big Creek (NW¼ T. 12 S., R. 39 E.). The rock unit was mapped as "dacite, probably intrusive" by Gilluly (1937) and described as a light gray porphyry with prominent phenocrysts of sodic andesine and hornblende, with quartz present in the groundmass. Additional petrographic work by André Isotoff (written communication, 1971) indicates that some of the rocks are porphyritic hornblende andesite. Thin basalt flows are included locally.

Unit (Tov) extends westward into the Canyon City map in the area north of Hereford, where it was mapped as part of the Clarno Formation by Brown and Thayer (1966). Subsequently a K-Ar age of about 19 m.y. (J. C. Von Essen and E. H. McKee, written communication, 1974) was obtained on both plagioclase and hornblende from a sample of the andesite breccia near Unity Reservoir.

The porphyritic hornblende andesite flow breccias and tuffs near the mouth of Clarks Creek (SW¼ T. 12 S., R. 41 E.) and several small exposures of andesite porphyry in Willow Creek (secs. 3 and 4, T. 14 S., R. 40 E.) are mapped as part of unit (Tov) although correlation has not been proven. The coarse texture of the Clarks Creek flows indicates proximity to a vent area. The flows rest unconformably on pre-Cenozoic rocks and are overlain, at least locally, by rhyolitic tuff that has been dated at 14.3 m. y. (Walker, Dalrymple, and Lanphere, 1974) from outcrops north of Unity Reservoir, a short distance west of the map area boundary.

(Tos) Volcaniclastic sedimentary rocks

This unit consists mainly of conglomerate beds in which angular, poorly sorted porphyritic andesite and dacite pebbles and boulders are embedded in a tuffaceous matrix. Thin-bedded water-laid tuff, tuffaceous sandstone, and siltstone interbeds make up a small part of the section. Basalt is rare as clasts in the conglomerate and as thin flows. The unit includes the "andesite tuff breccia" of Gilluly (1937).

The unit extends into the map area from the adjacent Canyon City sheet along both the north and south sides of the Dooley Mountain uplift, as far east as the headwaters of Big Creek and Lake Creek.

In the map area, unit (Tos) is poorly exposed, thickness of the section is not known, and no fossils other than petrified wood have been found. In the Lake Creek drainage, rocks of unit (Tos) are overlain by Miocene basalt of unit (Tb). Although the relationships are not clear, the unit appears to be overlain by Miocene rhyolite of unit (Tr) east of Big Creek. In the adjacent Canyon City sheet, rocks of the unit (Tos) are more extensively exposed in China and First Creeks, east of the North Fork of the Burnt River (E$\frac{1}{2}$ T. 11 S., R. 37 E.), and in and adjacent to sec. 16, T. 13 S., R. 38 E. Several hundred feet of section are present in these areas. Exposures of the unit in the Canyon City sheet were included in the Clarno Formation by Brown and Thayer (1966). Petrified palm wood near the center of sec. 36, T. 12 S., R. 37 E. and a variety of leaves in tuffaceous sandstone in First Creek (roadcut, sec. 17, T. 11 S., R. 37 E.) and Whipple Gulch (sec. 23, T. 11 S., R. 38 E.) are similar to Clarno flora in central Oregon (Jack A. Wolfe, written communication, 1971). However, the (Tos) unit appears to overlie flows of (Tov) in the SW$\frac{1}{4}$ T. 11 S., R. 39 E., and (Tos) strata contain angular fragments of porphyritic andesite and dacite which probably were derived from eroding (Tov) terrain.

Middle and Upper Miocene Rock Units

Regionally the middle and upper Miocene assemblage consists mainly of flow-on-flow basalt. Local variants include rhyolitic and andesitic lavas and intrusive rocks, silicic and palagonitic tuffs, tuffaceous sedimentary rocks, and small patches of welded tuff. For mapping purposes, the rocks have been divided into five lithologically different units: (Tr), (Tb), (Tat), (Tss), and (Tab). Units (Tb) and (Tab) are mainly basalt, unit (Tr) is mostly rhyolite, and unit (Tat) is mainly silicic ash-flow tuffs. Unit (Tss) is mainly tuffaceous sedimentary rocks. Existing isotope dates indicate a rather restricted age of about 13 to 15 m.y. for the volcanic rocks and demonstrate some overlapping age relationships between the different units.

(Tr) Rhyolite and andesite

Rocks of this unit comprise the base of the middle and upper Miocene section in the Dooley Mountain area. Included in the unit are cream-colored, flow-banded platy rhyolite; gray, glassy rhyolite with white feldspar phenocrysts; both welded and non-welded tuff; small intrusive bodies with associated perlite and obsidian; and dark, purple-to-red, flow-banded andesite vitrophyre. These rocks are well exposed along State Highway 7 in Mill Creek and Stices Gulch and also in adjacent canyons. Most of the rhyolitic rocks can be classed as flow or tuff breccias and appear to represent the coarsely fragmental and subordinate fluid ejecta of a volcanic center (Gilluly, 1937, p. 51). The rocks typically are aphanitic. Volcanic glass is the chief component of most rocks, and some rocks are almost entirely glassy. Unit (Tr) is equivalent to the "Dooley Rhyolite Breccia" as mapped by Gilluly (1937), with two major exceptions. The numerous isolated outcrops of welded and non-welded pumice and obsidian-bearing tuffs near Pleasant Valley and farther north are now believed to be younger than the rhyolite of Dooley Mountain and more appropriately included in the lower Pliocene unit (Twt). The other exception is the banded andesite vitrophyre that locally overlies the rhyolite of Dooley Mountain. These dark, reddish-brown to purple flows were mapped as a separate unit by Gilluly (1937), but for this map project they are included with the rhyolite because the two rock types are difficult to separate consistently in the field. The vitrophyre flows are best exposed on the south flank of the range from Pine Creek, in the central parts of secs. 10 and 15, T. 12 S., R. 39 E., eastward to Mill and Auburn Creeks. Thick-bedded, pinnacle-weathering, white pumiceous tuff is associated with the andesite vitrophyre in Mill Creek in the NW$\frac{1}{4}$ sec. 20, T. 12 S., R. 40 E. and may be correlative with similar deposits in canyons north of Clarks Creek in secs. 28 and 29, T. 12 S., R. 41 E.

A K-Ar age of 14.3 $\pm$ 0.4 m.y. was obtained on intrusive rhyolite from Dooley Mountain (Walker, Dalrymple, and Lanphere, 1974). Unit (Tr) in the Dooley Mountain area is overlain either by basalt of unit (Tb) or by overlapping Pliocene sediments of unit (Tst) and in most places rests unconformably on pre-Cenozoic rocks. A roadcut in the northwestern part of sec. 31, T. 11 S., R. 40 E. exposes a basal unit of a dark-gray sandstone containing angular fragments of white rhyolite. The sandstone unit is about 50 feet thick. It overlies pre-Cenozoic schists with angular unconformity and is overlain by typical flow-banded rhyolite. Farther west, in the Big Creek area, the rhyolite unit appears to overlie the older Cenozoic volcaniclastic rocks of unit (Tos), although the evidence is not conclusive. Along Clarks Creek, unit (Tr) thins to a single flow in which blocks of rhyolite are incorporated in a matrix of pumiceous tuff. In sec. 27, T. 12 S., R. 41 E., the unit overlaps both pre-Cenozoic rocks and andesite of unit (Tov).

In the unnamed hills north of Willow Creek, Wolff (1965) mapped a succession several hundred feet thick consisting of rhyolitic ash-flow tuff and flow-banded vitrophyre resting on pre-Cenozoic rocks. This rhyolitic map unit is well exposed on Long Creek (sec. 34, T. 13 S., R. 39 E.) and adjacent drainages. It is believed to be approximately equivalent in age to unit (Tr) of Dooley Mountain. It is overlain by a moderately thick sequence of vesicular basalt which appears to be correlative with the basalts which overlie rhyolitic rocks on the northern flank of Dooley Mountain. South of the study area, rhyolite and rhyodacite flows, both above and below Miocene basalts, appear to be correlative with unit (Tr).

(Tb) Basalt and andesite

The middle and upper Miocene section in the northern third of the map area is composed mainly of flow-on-flow basalts. The basalt sequence normally rests unconformably on pre-Cenozoic rocks, although locally a prominent light-gray, partly water-laid tuff unit occurs at the base of the section (as in roadside exposures near the center of sec. 33, T. 8 S., R. 43 E. and the SE$\frac{1}{4}$ sec. 20, T. 10 S., R. 46 E.). This tuff ranges in thickness from 0 to about 50 feet.

Basalt flows make up more than 90 percent of the section. Beds of tuff and tuffaceous sedimentary rocks a few inches to several tens of feet thick separate flows in some areas. Individual flows vary greatly in thickness from a few feet to as much as 100 feet. Platy jointing and columnar jointing are prominent features locally. Parts of many flows are vesicular and flow tops commonly are scoriaceous. The basalt weathers rust-brown and is dark gray on fresh surfaces. Prostka (1963, p. 205-208) describes the texture as variable, mostly holocrystalline, diktytaxitic or porphyritic, with plagioclase and olivine phenocrysts.

The total original thickness of the basalt is unknown as all exposures are truncated by erosional surfaces. Preserved sections of 3,000 feet near the mouth of Pine Creek (Vallier, 1967, p. 128) and 2,000 feet at Sheep Mountain in the NE$\frac{1}{4}$ T. 10 S., R. 44 E. (Prostka. 1967, p. 5) have been reported. Sedimentary rocks of unit (Tst) of early Pliocene age rest on basalt of unit (Tb) or directly on pre-Cenozoic rocks, indicating that the basalt was either not deposited in some areas or was eroded prior to the Pliocene.

Along the Snake River, the basalt unit (Tb) has been correlated with the Picture Gorge Basalt of the Columbia River Group (Waters, 1961). The relatively isolated basalt outcrop area along the Powder River in T. 10 S., R. 39 E. is continuous with the Strawberry Volcanics of Brown and Thayer (1966). Flora of middle or late Miocene age occur in a tuff bed in the lower part of the thick basalt section in the SW$\frac{1}{4}$ sec. 1, T. 7 S., R. 43 E. (Hoxie, 1965). Basalt of the (Tb) unit is unconformably overlain by lower Pliocene (Clarendonian) vertebrate fossil-bearing lacustrine sedimentary rocks (Tst) near Richmond in sec. 34, T. 9 S., R. 45 E. (J.A. Shotwell, written communication, 1969).

Flow-on-flow basalts extend onto the north flank of Dooley Mountain, where they overlie unit (Tr) of late Miocene age. Isolated patches of basalt tentatively assigned to unit (Tb) occur in many places on the uplift either overlying unit (Tr) or resting directly on pre-Cenozoic rocks, such as at Little Bald Mountain (NW$\frac{1}{4}$ sec. 28, T. 11 S., R. 39 E.). Along the south flank of the uplift, a thin sequence of southward-dipping basalt flows occurs in a small area between Mill Creek and Big Creek. These flows rest on rhyolitic rocks of unit (Tr) and are unconformably overlain by tuffaceous sediments of unit (Tst). It is not clear whether these small outcrops are parts of flows which once extended across the range or if they came from unidentified local sources.

South of Willow Creek, in parts of the Clover Creek Ranch and Brogan quadrangles, unit (Tb) is composed of basalt and andesite flows and flow breccias, thick sections of interbedded flow breccia and palagonite tuff and breccia, and a few small areas of rhyodacite flows. The proportion of basalt and andesite flows and flow breccias to the corresponding deposits of palagonite tuffs and breccia decreases from the area southeast of Juniper Mountain westward toward the Cow Creek-Clover Creek drainage.

Some of the basalt in the Cow Creek-Clover Creek area is dark gray to black, locally vesicular, and aphanitic, with occasional phenocrysts of plagioclase; olivine is a rare constituent. A few flows low in the section have intergranular and partly subophitic textures and are composed of clinopyroxene, plagioclase microlites, and an unidentified green mineral or mineraloid, probably derived from the alteration of chlorophaeite. A few flows higher in the section are dark-gray to black andesite or basaltic andesite characterized by pilotaxitic texture and a well-defined conchoidal fracture. Most fractures in these dense flows are coated with mottled yellowish-gray and grayish-orange iron-bearing montmorillonite clay.

The palagonite tuffs and breccias are light gray and yellowish gray, poorly sorted, and contain widely varying amounts of basalt and andesite fragments. Perhaps most of these tuffs and breccias are water laid. Good exposures of the clastic basaltic and andesitic rocks occur in sec. 10, T. 16 S., R. 40 E. Fouch (1968, p. 29) estimated that beds of palagonite tuff and breccia are about 1,700 feet thick in the northwest part of the Brogan quadrangle.

The basalt and andesite sequence in the southern part of the map area is overlain by silicic tuff of unit (Tat) and locally by silicic flows, which we regard as correlative with the flows of unit (Tr); both conformable and unconformable relations appear to be present. Age relation of this dominantly basaltic and andesitic assemblage to the flow-on-flow sequence of basalts in unit (Tb) farther north has not been established. All of the different basalt flows included in unit (Tb) may be parts of sheets of approximately the same age which erupted from different vents.

Basalt of unit (Tb) in the southern part of the map area is in part correlative with the Tims Peak Basalt, Hunter Creek Basalt, "unnamed igneous complex" of Kittleman and others (1965), and the Owyhee Basalt of Corcoran and others (1962).

(Tat) Ash-flow tuff and tuffaceous sedimentary rocks

The Miocene section in the southwestern part of the map area includes an extensive unit of welded and non-welded ash-flow tuff and associated thin pumiceous sediments. This unit appears to be the northeastern extension of the widespread and prominently exposed Dinner Creek Welded Tuff described by Haddock (1967) and may be equivalent to similar unnamed ash-flow units of essentially the same age. In several places, the Dinner Creek Welded Tuff has been dated by K-Ar as about 14 m.y. (Walker, Dalrymple, and Lanphere, 1974). Exposures typically consist of fine-grained, partly to densely welded tuff composed of glass and devitrified glass shards with a few plagioclase phenocrysts. The unit also includes coarse vitric breccia, non-welded pumice-lapilli tuff containing flattened obsidian inclusions, and some pumiceous sedimentary rocks. In places, the unit exhibits the characteristic vertical zonation of ash flows. The tuff is stained dark red-brown to nearly black on weathered surfaces. Thicknesses up to 200 feet have been noted in the map area.

Rocks believed to be part of this unit have been mapped (Wolff, 1965) as far north as T. 13 S., R. 40 E., where small patches of ash-flow tuff rest on pre-Cenozoic rocks. In the NW$\frac{1}{4}$ T. 15 S., R. 39 E., it overlies basalt of unit (Tb). Stratigraphic relationship of unit (Tat) to the upper Miocene rhyolitic rocks of unit (Tr) is not clear, although K-Ar dates indicate they are about the same age.

(Tss) Tuffaceous sedimentary rocks

Mapped exposures of unit (Tss) are restricted to the southern part of the Baker quadrangle. The unit consists mainly of tan, pale-orange and white, platy, fine-grained, tuffaceous siltstones. Siliceous shale, impure diatomite, and medium- to thick-bedded, coarse-grained sandstones make up part of the section. The sandstone beds typically are several feet thick and are composed mainly of moderately-to well-rounded grains of quartz, decayed feldspar, and siliceous volcanic rock fragments; the cementing material is opaline or chalcedonic silica commonly deposited as rims around the sand grains. The sandstone weathers to dark brown and is "case-hardened" by surface silicification.

Plant fossils collected from sec. 28, T. 15 S., R. 44 E. suggest an upper Miocene age for these beds (J. A. Wolfe, oral communication, 1971). The general lithologic appearance of this assemblage and the probable upper Miocene age of its flora indicate that the (Tss) unit is correlative with the Deer Butte Formation of the adjacent Mitchell Butte quadrangle (Corcoran and others, 1962). Unit (Tss) strata overlie basalt flows (Tb) and may interfinger with them locally. Most (Tss) exposures are wholly or partly surrounded by (Tst) strata. Unconformable relationships have been observed locally, but since (Tss) and (Tst) include similar lithologies and since bedding attitudes are not greatly different, separation of the two units is difficult in some areas. The Miocene (Tss) exposures may be relatively recently uplifted fault blocks from which the Pliocene (Tst) has been stripped, or they may represent old fault-block ridges surrounded by onlapping Pliocene rocks, as has been suggested by R. E. Corcoran (oral communication, 1971), relative to Miocene exposures at Deer Butte in the Mitchell Butte quadrangle. Also, the (Tss) and (Tst) exposures may represent older and younger parts of an essentially continuous sequence.

(Tab) Andesite and basalt; (Tabc) mafic shield volcano

Platy andesite flows (Tab) are associated with one or more eruptive centers (Tabc) in and north of T. 7 S., Rs. 41, 42, and 43 E. The andesite typically is gray (locally dark red or pink), fine grained, non-vesicular and slightly porphyritic with scattered phenocrysts of andesine, augite, and hypersthene in a pilotaxitic groundmass of flow-aligned plagioclase microlites. Most of the rock breaks readily into thin slabs. Some flows are dark-gray to black aphanitic andesite or basalt which fractures conchoidally. Sawtooth Ridge Crater (Tabc), which has been described by Patterson (1969), is the vent area of a large, low-relief shield volcano with andesite flows dipping gently away from the source. Dikes, flow breccias, and pyroclastic rocks comprise part of the vent area.

Gilluly (1937) and Prostka (1962) believed that the (Tab) flows are part of the middle and upper Miocene volcanic section. Field relationships observed in the present study indicate that unit (Tab) flows are unconformable on some flows of unit (Tb) and that erosion and tilting of the Sawtooth Ridge volcano, if any, has been less than is typical of the erosion and deformation of the basalts included in unit (Tb). Also, unmapped thin remnants of a tuffaceous lacustrine sedimentary unit are exposed at the base of the unit (Tab) section in several places along the Big Creek Ditch in secs. 5 and 8, T. 7 S., R. 42 E. The lacustrine rocks, which include rhyolitic flow rocks in the NW$\frac{1}{4}$ sec. 5, T. 7 S., R. 42 E., are lithologically indistinguishable from strata mapped as part of the Pliocene unit (Tst) in the Lower Powder River Valley area 5 miles to the south. Therefore, if unit (Tab) flows are of Miocene age equivalent to unit (Tb), as postulated by Gilluly (1937) and Prostka (1962), unit (Tst) in the Lower Powder River Valley probably includes both pre-basalt Miocene and post-basalt Pliocene strata.

Platy andesite and basalt lavas (Tab) occur in several isolated localities in the northwestern part of the map. These have been tentatively separated from underlying basalts (Tb) because of their lithologic similarity to the lavas of Sawtooth Ridge, and an angular unconformity separates the two lava sequences in the area between Medical Springs and Thief Valley Reservoir, immediately north of the map area.

Upper Miocene(?) and Pliocene Rock Units

In contrast to the lava-flow-dominated Miocene section, the Pliocene rocks exposed in the map area are mainly volcaniclastic sedimentary rocks of lacustrine and fluvial origin and minor amounts of ash-flow tuff. The chief characteristic of the section is the vast amount of light-colored, fresh or altered, fine-grained, water-laid volcanic ash in all of the areas of Pliocene deposition. The source of the ash is not known, although it may relate to the eruption of large volumes of silicic ash from vents in Harney Basin during Pliocene time. Chemical analysis of two tuff samples from this sequence indicate that the ash is rhyolitic.

Although Pliocene rocks throughout the area show many similarities, there are significant differences between the sections preserved in the large Snake River Basin in the southern part of the map area and the smaller isolated outcrop areas to the north.

(Twt) Silicic welded and non-welded tuff

The tuff of unit (Twt) is firmly to moderately welded in most outcrops but locally grades through non-welded varieties of ash-flow and air-fall tuff, some of which is water laid. Typical colors are light gray or pale brown. Much of the tuff contains angular fragments of white pumice. Black obsidian blebs are abundant locally. Thickness of individual ash flows ranges from a few inches to 20 feet, and more than one flow is present in most outcrops. The thickest single flow observed is in a quarry south of Pleasant Valley (NE$\frac{1}{4}$ sec. 25, T. 10 S., R. 41 E.). Exposures in the Sparta quadrangle (T. 8 S., R. 43 E.) average about 8 feet in thickness (Prostka, 1962). In places, flow-banded rhyolite (sec. 11, T. 9 S., R. 42 E.) and tuffaceous and diatomaceous sediments (sec. 18, T. 8 S., R. 44 E.) are interlayered with the tuff. Other exposures typical of the unit are found south of Richland in secs. 1 and 2, T. 10 S., R. 45 E.; in the Durkee Basin in the NE corner of sec. 9, T. 11 S., R. 43 E.; in Pine Creek in the SE$\frac{1}{4}$ sec. 22, T. 12 S., R. 39 E.; and in many other isolated outcrop areas.

The distribution of unit (Twt) indicates that several of the Pliocene basins were contemporaneous. The tuff is preserved in discontinuous patches at the base of the Pliocene section in the Durkee, Lower Powder River Valley, and Richland basins. It also occurs in isolated areas between the present-day basins where no younger Pliocene sediments are preserved, such as in the hills north of Alder Creek in Tps. 9 and 10 S., R. 41 E.; in the N$\frac{1}{4}$ sec. 22, T. 10 S., R. 43 E.; and in the N$\frac{1}{2}$ sec. 26, T. 8 S., R. 43 E. The distribution of the (Twt) exposures indicates that the regional topography in the early part of the Pliocene differed considerably from that of today, and it appears that some of the Pliocene depositional basins may have been much larger than the present topographic basins in which the sections are best preserved.

In the Durkee and Richland areas, rocks of unit (Twt) are overlain gradationally by sedimentary rocks of unit (Tst) which contain vertebrate fossils of early Pliocene (Clarendonian) age. Small residual patches of vitric welded tuff mapped as unit (Twt) in the Bully Creek and Clover Creek drainages in the southwestern part of the map area appear to be stratigraphically equivalent with and lithologically similar to ash-flow tuffs in the Harney Basin which are middle Pliocene in age.

(Tst) Tuffaceous sedimentary rocks

Unit (Tst) in the northern part of the map area involves a lower lacustrine facies and an upper fluviatile facies. The "lake beds" consist mainly of thinly bedded light-gray to yellowish tuffaceous clay, siltstone, and sandstone; diatomite; and glass-shard tuff. The sediments appear to represent a low-energy depositional environment. Typically, they are made up of light-colored silicic volcanic ash or its alteration product. In some areas, such as the section exposed along the north side of Rye Valley, large amounts of clastic material eroded from pre-Cenozoic granitic and metamorphic rocks are mixed with tuffaceous debris. Near the mouth of Ritter Creek (center N$\frac{1}{2}$ sec. 36, T. 8 S., R. 42 E.), a tuffaceous mudflow containing large basaltic clasts is present. In places the vitroclastic material of the tuffaceous rocks has been altered extensively to zeolites.

The lacustrine sediments are well exposed in the Durkee area (T. 11 S., R. 43 E.), where the section is at least 500 feet thick. Sections of similar thickness are either exposed or have been penetrated by water wells in the Richland, Lower Powder River, Beaver Creek-Sutton Creek, Baker Valley, Rye Valley, Durbin Creek, Burnt River, and Willow Creek areas.

Data from surface mapping and water wells indicate that although the (Tst) sediments locally contain thin basaltic eruptive material, in most areas they are not contemporaneous with or interbedded with basalts of the unit (Tb), as Gilluly (1937, p. 59–60) contended, but are younger than these basalts. A water well in sec. 14, T. 8 S., R. 41 E., near the contact between thick basalt flows and thick lacustrine sediments, cut 685 feet of basalt without encountering any significant thickness of lacustrine sediments. Other deep water wells near Baker Valley show a clear separation of tuffaceous lacustrine sediments over a basalt section containing only a few thin scoria and tuff interbeds.

The lacustrine sediments, as well as the (Twt) ash-flow tuff unit, were deposited in basins that were larger than the present valleys in which these sediments are now mainly confined. Isolated outcrops of unit (Tst) are preserved in fault blocks well above the present valleys.

In many areas, the upper part of the unit (Tst) section consists of pebble and cobble conglomerate interbedded with fine-grained, light reddish-brown, tuffaceous sandstones and siltstones. The conglomerate beds are made up mainly of clasts of pre-Cenozoic igneous and metamorphic rocks and of minor basalt and rhyolite. The reddish-brown color of the tuffaceous interbeds suggests deposition in an oxygenated environment. Together, the color and coarse texture indicate that topographic gradient had increased and that streams had drained earlier lakes. The influx of clasts of pre-Cenozoic rocks probably indicates accelerated uplift of nearby areas, perhaps defining the present topographic basins for the first time. The gradational contact between the lacustrine and fluvial parts of the section is well exposed in the Durkee area (sec. 14, 15, and 23, T. 11 S., R. 43 E.) and Lower Powder River Valley (NE$\frac{1}{4}$ T. 9 S., R. 42 E.). The upper fluvial section in some places also rests directly on pre-Pliocene rocks (as in sec. 5, T. 9 S., R. 45 E.).

Small collections of vertebrate fossils found in several widely scattered localities near the top of the lacustrine section have been identified as most likely of early Pliocene age (J. A. Shotwell, written communication, 1969). Collections of fossil leaves dated as Miocene have been reported from this unit (Gilluly, 1937, p. 61–62). However, an early Pliocene vertebrate locality has been found less than 100 feet stratigraphically above one leaf locality in what appears to be a continuous section.

Exposures of unit (Tst) in the southern part of the map area are part of the thick and extensive sedimentary section of the Snake River Basin. Correlative rocks to the south include the Chalk Butte Formation of the Idaho Group of Corcoran and others (1962) and the Bully Creek Formation of Kittleman and others (1967). Vertebrate fossils of middle Pliocene (Hemphillian) age were reported from a single locality in the Chalk Butte Formation. According to Kittleman and others (1967), the Bully Creek Formation overlies rocks of late Miocene age and underlies rocks of early or middle Pliocene age. At the top of Lone Pine Ridge (NW$\frac{1}{4}$ sec. 1, T. 16 S., R. 45 E.) a thin, ferruginous round-pebble conglomerate unit contains fish and other vetebrate fossils reported to be of upper Pliocene or slightly younger age (J. A. Shotwell, written communication, 1969). Fossils of similar age were found near Tubb Mountain in the SW$\frac{1}{4}$ sec. 20, T. 16 S., R. 45 E. (J. A. Shotwell, oral communication, 1969). Thus it appears that deposition may have continued longer in the Snake River Basin than in the smaller, more isolated basins to the north. The northern limit of the Snake River Basin in this area may have extended from the vicinity of Huntington westward to the canyon of Willow Creek and the hills north of Brogan. Dip of the strata is low, generally in a southerly direction.

(Tpb) Basalt

Basalt flows are common in the Idaho Group of the Snake River Basin, but only a few isolated exposures of basalt in the northern part of the map area can be assigned with any certainty to volcanism contemporaneous with Pliocene lacustrine sedimentation. The symbol (Tpb) has been assigned to basalt flows which appear to be younger than unit (Twt). These flows are thin, black, dense, glassy, and vesicular. A few scattered outcrops of basalt, occurring in the same general areas as those in which (Tpb) overlies (Twt) but resting directly on pre-Cenozoic rocks, have also tentatively been included in (Tpb). Some small isolated exposures of basalt that are mapped as (Tb) may also be correlative with this unit.

Relationship of these basalts to the (Tob) unit is not clear, but they are assumed to be older. They are recognized as scattered erosional remnants, commonly associated with welded tuff of (Twt), and they appear to be more intensely weathered and tectonically deformed than the (Tob) flows. All of the (Tpb) basalts may be genetically related to the (Tb) unit of Miocene age, as indicated by Gilluly (1937) and Prostka (1967). However, the fact that welded tuff of unit (Twt) underlies the basalt in a few places seems to make the correlation used in the present mapping more likely. Contrary to Prostka (1967), Iron Mountain (sec. 9, T. 11 S., R. 43 E.) is here interpreted as a pile of flows near a buried vent. The basalt accumulation probably has been exposed by the erosion of the surrounding softer rocks of unit (Tst), in which the basalt was in part intruded and in part interbedded.

(Tob) Olivine basalt; (Tobc) small mafic volcanic centers

The unit (Tob) consists mainly of one or more thin flows of open-textured, subophitic to intergranular olivine basalt and basaltic andesite. Most of the flows dip gently away from small, well-defined mafic volcanic centers (Tobc) and typically form cliff-rimmed mesas and benches.

Age of the flows is not clear. They rest on deformed sedimentary rocks of early Pliocene age included in (Tst), and locally they overlap the margin between tilted (Tst) and pre-Cenozoic rocks. The flows appear to have been controlled by the early stages of development of the present drainage slopes but have later been dissected by the streams in these drainages, such as Willow Creek and its tributaries. Because some of the drainage deposits contain Pleistocene mammal remains, the age of the basalt falls in the interval between post-early Pliocene and Pleistocene.

Pleistocene-Holocene Rock Units

(Qgm) Glaciofluvial deposits

Alluvial deposits of glacial origin have been mapped in only two places in the quadrangle, although some deposits interpreted as terrace or flood-plain gravels may be attributable to glaciation. Extensive deposits of gravel along the slopes of Pine Creek in Tps. 6 and 7 S., R. 45 E. and along Clear Creek in Tps. 6 and 7 S., R. 46 E. are clearly morainal. In places these gravels extend several hundred feet above the present stream bed. The deposits involve a great variety of rock types and are composed largely of unsorted material ranging in size from silt up to boulders the size of a small house.

(Qtg) Terrace and fan deposits

This unit includes the large coalescing alluvial fans along the southwest margin of Baker Valley; terrace gravels in Durkee Valley (T. 11 S., R. 43 E.) and Eagle Valley (T. 9 S., R. 45 E.) which mark former levels of Burnt River and Eagle Creek, respectively; the gravel-covered slopes of Burnt River in T. 12 S., R. 39 E.; and the thick veneer of gravel in the Malheur City-Basin Creek area (Tps. 13 and 14 S., Rs. 40, 41, and 42 E.).

Many Pleistocene gravel deposits are too small to show on the map. Differentiation of (Qtg), (Qal), and the fluvial facies of (Tst) is difficult or impossible locally due to the similar surface expression of these units. In several areas, notably the southwestern part of Baker Valley, contacts between these units are only approximately located. Unit (Tst) on the west side of Rye Valley (Tps. 12 and 13 S., R. 43 E.) includes auriferous gravel deposits which occupy a series of fluvial terraces carved in the lakebeds (Lindgren, 1901, p. 769). Some areas mapped by Gilluly (1937) as terrace gravels in Lower Powder River Valley and Virtue Flat (Tps. 8 and 9 S., Rs. 41 and 42 E.) are now known to contain Pliocene fossils and therefore are included in unit (Tst).

(Qls) Landslide debris

Landslides are common in many parts of the map area. Relatively few are large enough to show on the map. Landslide and rockfall debris typically is abundant on slopes where basalt flows of unit (Tob) overlie sedimentary strata of unit (Tst). The relatively poor resistance to erosion of the sedimentary strata results in oversteepening and failure of slopes beneath the basalt. Individual slope failures of this type usually are small. In the large area mapped as landslide on the north and west flanks of Table Rock (T. 13 S., Rs. 43 and 44 E.), an aggregate of many small slides is represented by a chaotic arrangement of large and small blocks of basalt in a clayey tuffaceous matrix.

Several large landslides on the steep slopes of Snake River and Burnt River in T. 13 S., Rs. 44 and 45 E. involve the basal red and green conglomeratic facies of the Jurassic sedimentary unit (J̄Rs). The conglomeratic unit is locally gypsiferous, which may account for part of its instability.

(Qal) Alluvium

Mapping of alluvium has been restricted to large stream valleys and a few other areas where soil cover and recent stream deposits are sufficiently thick and extensive to mask the underlying rocks. This alluvium is essentially a deposit related to the present topographic framework and climatic cycle, although locally these sediments are now being actively dissected by downcutting in the beds of present streams. One notable feature in the (Qal) profile in the stream banks north of Bald Mountain (NE$\frac{1}{4}$ T. 11 S., R. 39 E.) is a persistent layer of fine white volcanic ash a few inches thick, at a depth of from a few inches to 2 feet below the present ground surface. This ash was also noted by Gilluly (1937, p. 66).

STRUCTURAL HISTORY OF CENOZOIC ROCKS

Rocks of the Cenozoic assemblage are regionally unconformable on rocks of all of the major pre-Cenozoic units. The unconformity represents change in environment, from marine to continental, followed by an episode of widespread and long-continued erosion. Emergence of the pre-Cenozoic marine assemblage marks an important phase in the westward advance of the continental margin as oceanic terrain was cratonized. When erosion of the pre-Cenozoic rocks began is not known exactly. The youngest marine strata in the map area are of middle Jurassic age. The oldest continental unit is of late Oligocene-early Miocene age. The presence of the Cretaceous *Tempskya* fern in gravels near Greenhorn in the Sumpter quadrangle (Read and Brown, 1937) indicates that area was emergent in Cretaceous time. Final emergence of the western part of the Blue Mountains is bracketed in time between Cretaceous (Albian-Cenomanian) marine deposits and upper Eocene continental deposits.

All of the Tertiary map units are separated by erosional unconformities. Folding, faulting, and deep erosion were concomitantly altering the configuration of the land surface during all of the depositional cycles, so that rocks of each of the map units form the base of the Tertiary section at one place or another. In few places are more than two rock units preserved in vertical succession.

In contrast to the intense compressional tectonism which affected all of the pre-Late Jurassic rocks, the Cenozoic has been dominated by gentle regional arching, warping, and normal faulting which, at least locally, represents extension. The predominant northwest trend of the Tertiary structural features indicates that development of the east-northeast grain of the underlying pre-Cenozoic rocks had ceased prior to recorded Tertiary deposition. The oldest rocks recognized are unit (Tos) and (Tov), which are here assigned to the late Oligocene or early Miocene. The largest exposures of these rocks are in the western part of the Dooley Mountain uplift. Small, widely separated remnants of unit (Tov) are also found in the Willow Creek and Clarks Creek drainages. The rather abrupt termination of the exposures in the Dooley Mountain uplift may be the result of post-depositional faulting rather than thinning against a positive element.

The rock record indicates that the major depositional events of the Cenozoic occurred in the middle Miocene-late Pliocene time interval. Middle and late Miocene deposition was dominated by the construction of a thick blanket of lava, mainly basalt with some rhyolite locally, over most and perhaps all of the map area. Pliocene deposition was dominated by the filling of large and small structural basins with tuffaceous lake and stream sediments. The volcanism and basin filling were not exclusive events. The Miocene section includes sedimentary units and the Pliocene section includes thin basalt flows and rhyolitic tuff. The scarcity of older Cenozoic rocks indicates that most of the map area was positive and undergoing erosion when the basaltic volcanism began.

The middle and upper Miocene basalts are thickest in the northeastern and southwestern portions of the map area. Basalt dike swarms in these areas have a regional northerly trend and probably represent a period of crustal extension and normal faulting.

During the Pliocene a number of large and small structural basins developed and became the sites of fresh-water lakes in which tuffaceous sediments were deposited. The thick Pliocene sedimentary section (Tst) in the southern part of the map represents a northern extension of the Snake River Basin. The central and northern parts of the map area were higher topographically and underwent fragmentation into a number of basins that were more restricted in size and depth than the Snake River Basin. The Snake River Basin is a major flexural downwarp whose development was accompanied by block faulting. The smaller basins to the north also were formed partly by faulting and partly by folding, but on a smaller scale.

Most of the faults outlining the present uplifts and basins in the northern third of the map area have a characteristic strike which averages about N. 45° W., although minor faults trending in a northerly and northeasterly direction are not uncommon. The Farley Hills and the hills immediately east of Haines, which border the Baker Valley on the northeast side, probably are bounded by buried faults of northwest trend. The west side of the Baker Valley also is fault bounded for its entire length, as indicated by the straight front and faceted spurs along the base of Elkhorn Ridge. Faulting in this same trend appears, at least in part, to be responsible for the development of the Eagle Creek (Richland) and Pine Creek (Halfway) Valleys and the basalt ridges between them. The southwest side of the Durkee basin is similarly bordered by hills with faceted spurs.

Folding of Cenozoic age is difficult to discern owing to the prominent tilt of strata that is clearly related to faulting. In spite of this, the widespread opposed dips on the flanks of the Dooley Mountain uplift suggest that an east-west trending anticline (or antiform) is present there. The age of the folding appears to be post-lower Pliocene because of the involvement of the (Twt) unit on the south flank.

Prostka (1963, p. 224-225) and Gilluly (1937, p. 71-77) favored folding as the major mode of deformation of Cenozoic rocks. They interpreted the major present-day northwest-trending drainage basins such as Eagle Creek, Lower Powder Valley, Virtue Flat, and the Alder Creek-Sutton Creek trough as essentially downwarps and the intervening ridges as anticlines or upwarps, both much faulted. Folding has also been reported by Wolff (1965, p. 71) in the Johnson Creek-Boulder Creek area (T. 13 S., R. 39 E.) where the fold trend is in a northwesterly direction and is complicated by normal faults trending in the same direction. The large-scale uparching of the Wallowa Mountains area and downwarping of the Snake River Basin are not disputed here, but the degree to which the smaller drainage basins and separating ridges have been caused by folding is certainly questionable.

Regional uplift in post-Pliocene time has been sufficient to provoke deep erosion of the Pliocene sediments and the entrenchment of rivers in Cenozoic volcanics and older rocks.

In summary, the area, in late Cenozic time, has been in a transitional environment between Basin and Range and Columbia Plateau. The typical Basin and Range fault trends are present, but the average displacement and length of faults appears to be less than that found in the Basin and Range province of southeastern Oregon and Nevada.

Trends of Cenozoic faults in the Dooley Mountain-Burnt River Canyon area are variable, although the largest faults strike approximately due west and most are downthrown to the south (Ashley, 1966, p. 18). These faults appear to be post-lower Pliocene in age, because lower Pliocene rocks have been disrupted. That a large amount of displacement has occurred locally is indicated by the steep westward dip of Cenozoic rocks on the eastern wall of Rye Valley and the preservation of Pliocene(?) fluvial and lacustrine rocks at high elevations.

In the south-central portion of the map area, the northwest trend of several topographic features, such as Willow Creek, Dry Gulch, and the basalt-supported ridges northeast of Dry Gulch, may be due to vertical displacements along northwest-trending faults. Faulting in the southeastern part of the map area is generally less prominent than elsewhere, although many faults may be unrecognized due to the lithologic homogeneity of the rocks. Farther west, faults of N. 70° W. trend predominate, but minor faults of northerly, westerly, and northeasterly trends are common (Wolff, 1965, p. 70-73).

All faults of Cenozoic age appear to be of normal dip-slip movement, but the amount of movement for most is not determinable. Displacement along the east front of the Elkhorn Ridge may be more than 6,000 feet. Uplift of the Wallowa Mountains was accomplished in part by large vertical displacement along several northwest-trending faults.

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