BULLETIN 73

GEOLOGIC FORMATIONS OF EASTERN OREGON

EAST OF LONGITUDE 121° 30'

STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES

1972

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By

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INTRODUCTION

It is the purpose of this publication to fulfill the need for a complete and comprehensive discussion of the formations of Oregon east of longitude 121° 30'. Together with Bulletin 70 dealing with the geologic formations of Oregon west of longitude 121° 30' it provides a ready geologic reference for those doing research in the state.

The distribution, lithology, age, and stratigraphic relationships of approximately 100 formations are discussed. In addition, a list of references accompanies the discussion of each of the geologic units. Owing to the localized occurrences and poorly understood character of the numerous informal rock units in eastern Oregon, however, only a few of the more significant ones are treated in detail.

It is evident that most of central and eastern Oregon is in need of more detailed mapping. Specifically, the late Miocene and Pliocene rocks of southern and eastern Oregon, the Paleozoic rocks of central and northeastern Oregon, and the Triassic rocks of northeastern Oregon are poorly understood. Nevertheless, mapping in recent years, especially in northeastern Oregon, is beginning to clarify some of the regional stratigraphic relationships.

Three correlation charts based on 16 localities (indicated on an accompanying index map) are included. In addition, a fairly complete bibliography of the more recent published and unpublished geologic literature of eastern Oregon is provided. A series of index maps keys many of the references containing geologic maps to their geographic localities.

It is hoped that this publication will serve to consolidate and clarify present thought regarding the stratigraphy of central and eastern Oregon. It is further hoped that it will promote much research, critical thought and discussion, which in turn will lead to greater understanding of the geology in the future.

ACKNOWLEDGMENTS

In the preparation of this bulletin the writer received help from many individuals, for which he is grateful. Office and field discussions with Dr. Keith Oles and Dr. Harold Enlows, both of Oregon State University, were invaluable to the interpretation of many of the Tertiary units of eastern Oregon. Likewise, the comments of George Walker were invaluable in developing an understanding of the overall geology of the area.

Dr. Tracy Vallier of Indiana State University provided much of the information on the Pre-Tertiary geology of the Snake River Canyon. Discussions with Howard Brooks and Norman Wagner of the Baker Office of the State of Oregon Department of Geology and Mineral Industries added much to the author's understanding of the geology of northeastern Oregon. Extensive communications with Howard Brooks, in particular, contributed a great deal to the author's understanding of the Pre-Tertiary units in that area.

Also appreciated are the comments and suggestions of numerous other geologists with experience in eastern Oregon, including Dr. Harold Prostka of the United States Geological Survey, Dr. Ewart Baldwin of the University of Oregon, and Raymond Corcoran, State Geologist and head of the State of Oregon Department of Geology and Mineral Industries.

GEOLOGIC FORMATIONS OF EASTERN OREGON

ALDRICH MOUNTAIN GROUP

Discussion: The Aldrich Mountain Group was erected by Thayer and Brown (1966a) and consists of a conformable sequence of Late Triassic and Early Jurassic sedimentary rocks exposed on the south limb of the Aldrich Mountain anticline. In ascending order the included formations are the: Fields Creek Formation, Laycock Graywacke, Murderers Creek Graywacke, and Kellers Creek Shale. More complete discussion is provided under those terms.

The relationship of the Aldrich Mountain Group to the Mesozoic section of Dickinson and Vigrass (1965) to the south in the Suplee-Izee area is unclear, but most certainly complex. The Aldrich Mountain Group predates the Mowich Group and correlates roughly with the Graylock Formation. It probably is situated stratigraphically above the Brisbois and Begg Formations.

ALVORD CREEK BEDS (FORMATION)

Original description: The term Alvord Creek Formation was originally applied by Fuller (1931) to exposures of light-colored tuffaceous sediments along the east base of Steens Mountain between Cottonwood and Toughney Creeks. In view of the uncertain stratigraphic relationships of the exposures, use of the informal term Alvord Creek beds is recommended here.

Lithology: The Alvord Creek beds are poorly exposed and consist of light-colored tuffaceous mudstone and shale with subordinate conglomerate locally. Bedding is well defined and the strata dip westward at low angles. According to Baldwin (oral communication, 1971) rocks belonging to the Alvord Creek beds are fractured and more deformed than some of the younger deposits with which they are sometimes confused.

Contacts: The stratigraphic boundaries of the Alvord Creek beds are concealed by talus and the relationship of the unit to other units is unclear. According to Walker (oral communication, 1971) the beds rest upon beveled eastern portions of the fault block which makes up Steens Mountain. As such the strata represent upfaulted valley deposits that originally were deposited against the east face of Steens Mountain.

An alternative interpretation is presented by Baldwin (1964), who feels that the Alvord Creek beds dip beneath the Steens Mountain Volcanic Series and interfinger with the Pike Creek Formation.

Age: Leaves recovered from beds assigned to the Alvord Creek beds have been variously dated as Miocene (Fuller, 1931), early Pliocene or younger (Axelrod, 1957), and middle Pliocene (Wolfe, in Wilkerson, 1958). Walker (oral communication, 1971) maintains that rocks assigned a radiometric age of 21.3 million years by Evernden and James (1964) should not be assigned to the Alvord Creek beds, but rather should be viewed as a flow in the lower part of the Steens Mountain Volcanic Series.

References:
Avent, 1969
Baldwin, 1964
Evernden and James, 1964
Fryberger, 1959
Fuller, 1931
Walker and Repenning, 1965
Wilkerson, 1958
Williams and Compton, 1953

ANTELOPE FLAT BASALT

Original description: Kittleman and others (1965) defined the Antelope Flat Basalt and designated exposures located southeast of the Owyhee Reservoir in central Malheur County (SE$\frac{1}{4}$ SW$\frac{1}{4}$ sec. 12, T. 25 S., R. 41 E.) as the type locality.

Distribution: The Antelope Flat Basalt is widely exposed in the Western Crowley and eastern Owyhee Reservoir districts.

Lithology: The unit consists of a maximum of 300 feet of pyroxene basalt and subordinate interbedded volcanic sandstone. The basalts are microporphyritic, intergranular, and olivine poor. Four distinct flows are present.

Contacts: The Antelope Flat Basalt rests on Miocene rocks and is stratigraphically equivalent to the Grassy Mountain Formation, from which it is separated on the basis of its geographic location and differing petrography.

Age: Hemphillian (early Pliocene) vertebrates are reported at the base of the unit.

References: Kittleman and others, 1965, 1967.

BASEY MEMBER (OF SNOWSHOE FORMATION)

Original description: The Basey member was first described by Dickinson and Vigrass (1965), who designated the type locality as secs. 1, 12, 13, T. 18 S., R. 25 E. in the vicinity of Basey Ranch at the head of Camp Creek in the Suplee-Izee district of central Oregon. According to them, rocks assigned to the Basey member were originally assigned to the Hyde Formation by Lupher (1941) on the basis of their lithologic similarity to the type Hyde Formation located to the east. (See Mowich Group and Hyde Formation.)

Distribution: The Basey member is widespread in the Pine Creek downwarp situated northwest of the western part of the Mowich anticline and also in the adjoining structural lows west and southwest of the Mowich anticline.

Lithology: The unit consists of up to 2,500 feet of hard, massive marine volcaniclastic rocks interbedded with andesitic lava. The volcaniclastics consist primarily of dark-gray to blue-gray sandstone composed of 30 to 50 percent plagioclase and 40 to 70 percent zeolitized rock fragments with minor amounts of augite, calcite and quartz. Texturally the volcaniclastics range from slightly reworked marine tuffs to stratified sandstones, mudstones, and siltstones.

Two porphyritic to aphanitic flows of andesite with an aggregate thickness of 300 feet are widespread in the western part of the Suplee area and grade laterally into flow breccias locally. Flinty, aphanitic tuffs also occur sporadically in the Basey member.

The lithology of the coarse volcaniclastics is remarkably similar to that of the type Hyde Formation, but the presence of small amounts of bright red or orange shards is diagnostic. Also, the lithic fragments of the Basey member tend to be brownish in thin section, whereas those of the Hyde Formation are more green in color.

Contacts: The Basey member is conformable with the underlying Warm Spring member and the underlying Shaw member of the Snowshoe Formation. It passes laterally to the east into the middle member of the type Snowshoe from which it is separated by an arbitrary cutoff.

Age: A middle Bajocian age (middle Jurassic) is assigned to the unit on the basis of scattered ammonites.

Reference: Dickinson and Vigrass, 1965

"BASALTS AT COW CREEK LAKES"

Discussion: This is an informal term applied by Kittleman and others (1965) to six to eight flows of

olivine basalt which overlie the eroded Sucker Creek Formation and Jump Creek Rhyolite in the vicinity of Cow Creek Lakes directly south of the Owyhee Reservoir in central Malheur County. The flows are 20 to 50 feet thick and are composed of 35 to 40 percent labradorite, 25 to 30 percent clinopyroxene, 15 percent olivine, 10 percent opaques, and 10 percent glass. A middle or late Pliocene to subhistoric age is assigned to the flows, some of which are remarkably fresh.

References: Kittleman, 1962
Kittleman and others, 1965, 1967
Millholen, 1965

BEGG FORMATION

Original description: The Begg Formation was defined by Dickinson and Vigrass (1965), who designated as the type locality the nose and southeast limb of the Little Bear anticline in the northwestern part of the Suplee-Izee district, in secs. 7, 8, 17, 18, and 20, T. 17 S., R. 26 E., and sec. 24, T. 17 S., R. 25 E.

Distribution: The unit is fairly widespread in the western and north-central part of the Suplee-Izee district of central Oregon. It is equivalent to the lower part of the Vester Formation located in the Aldrich Mountains to the north.

Lithology: The Begg Formation consists of a maximum of 7,500 feet of resistant sandstone, conglomerate, and sedimentary breccia interbedded with less resistant mudstone and siltstone. Soft, carbonaceous, poorly sorted, noncalcareous, dark-gray to dark-green, fine-grained sandstone, siltstone and mudstone compose 50 to 70 percent of the unit. Cross-bedded, locally graded subfeldspathic lithic arenites, chert sandstones, and chert pebble conglomerates make up 25 percent of the unit and marine tuffs which become increasingly finer grained upsection make up 10 percent of the unit. Thin flows of pyroxene keratophyre, minor polymictic conglomerates of chert, greenstone, and limestone, and sporadic lenses of limestone crop out locally.

Contacts: The Begg Formation rests unconformably on Paleozoic strata and grades upsection into the Brisbois Formation.

Age: A poorly substantiated Karnian (Upper Triassic) age is assigned to the unit. It is older than the Karnian Brisbois Formation which overlies it, however, and the lower part of the unit may extend downsection into the Middle Triassic.

Reference: Dickinson and Vigrass, 1965

BERNARD FORMATION

Original description: The Bernard Formation was originally described by Dickinson and Vigrass (1965), who derived the name from Bernard Ranch on the South Fork of Beaver Creek in the Suplee area of central Oregon ($SE\frac{1}{4}$ sec. 11, T. 17 S., R. 25 E.).

Distribution: The unit is exposed in the northwestern part of the Suplee-Izee district and is contiguous with the Gable Creek and Hudspeth Formations described by Wilkinson and Oles (1968) and Oles and Enlows (1971) in the Mitchell quadrangle.

Lithology: The unit consists of approximately 1,500 feet of massive yellow-brown, calcareous and limonitic pebbly sandstone and subordinate interbedded clayey sandstone, poorly consolidated gravel, gray mudstone, and brown shale. The sandstone grades locally into sandy roundstone conglomerate in

which the coarser fragments consist of aphanitic porphyry of intermediate composition, chert, granitic clasts, and metaquartzite.

Contacts: The Bernard Formation rests upon the older Mesozoic units with angular unconformity.

Age: Cenomanian (lowermost Upper Cretaceous) fossils have been recovered from the lowest 500 to 600 feet of the unit.

Reference: Dickinson and Vigrass, 1965

BRISBOIS FORMATION

Original description: The Brisbois Formation was originally defined by Dickinson and Vigrass (1965) after exposures along the South Fork of the John Day River between the mouths of Morgan and Dry Soda Creeks (a distance of three miles).

Distribution: The unit is fairly widespread in the central Suplee area of central Oregon surrounding the type locality.

Lithology: The Brisbois Formation consists of 5,000 feet of black, gray, and green mudstone intercalated with minor amounts of sandy limestone and limy sandstone. It differs from the Begg Formation in its greater abundance of fine-grained clastics and the limy composition of the more resistant intercalated interbeds. The contact between the two units in the field is arbitrary, but is generally placed where a decrease in the abundance of resistant interbeds of variable composition (Begg Formation) is noticeable.

The limestone consists of gray, calcareous interbeds of bioclastic debris which includes fragments of brachiopods, pelecypods, gastropods, and crinoids. Locally the bioclastic debris grades laterally into relatively undisturbed reefoid limestones.

The middle 2,000 feet of the unit contains a total of 600 feet of interbedded spilites and sills of felsic keratophyre and granophyre.

Contacts: The Brisbois Formation is conformable over the Begg Formation (see lithology) and unconformable under younger Mesozoic units.

Age: An uppermost Karnian (Tropites subbullatus zone) age is assigned to the unit.

Reference: Dickinson and Vigrass, 1965

BULLY CREEK FORMATION

Original description: The unit was originally described by Kittleman and others (1965), who designated a two-part type section which included exposures in the SW$\frac{1}{4}$ sec. 7,T. 19 S., R. 41 E., and the NW$\frac{1}{4}$ sec. 11, T. 19 S., R. 41 E. in the Harper district of northern Malheur County.

Distribution: The unit is limited primarily to the Harper Basin district northwest of Harper in northern Malheur County. One additional small exposure crops out southwest of Harper along the boundary between T. 21 S., R. 40 E., and T. 21 S., R. 41 E.

Lithology: The unit consists of a series of interbedded lacustrine diatomites and volcanic sandstones with a total thickness of approximately 440 feet. Indurated vitric tuffs intercalated with sandstones predominate near the base; friable, nearly pure diatomite dominates the middle of the section; and volcanic conglomerates occur near the top. The unit is lithologically similar to the Juntura Formation of similar age exposed to the west.

Contacts: The Bully Creek Formation is unconformable over the Littlefield Rhyolite, Drip Spring Formation, and Hunter Creek Basalt. It underlies the Grassy Mountain Formation.

Age: An early Pliocene age is assigned to the unit on the basis of stratigraphic position. It correlates with the Kern Basin Formation of Corcoran and others (1962) and the Juntura Formation to the west.

References: Haddock, 1967
Kittleman and others, 1965, 1967
Weeden, 1963

BURNT RIVER SCHIST

Original description: The Burnt River Schist was defined by Gilluly (1937), who designated exposures in the Burnt River canyon in the southern part of the Baker 30' quadrangle (Tps. 11 and 12 S., R. 41 E.) as the type locality.

Distribution: Strata continuous with The Burnt River Schist are fairly widespread in the southern part of Baker County, but the precise nature and distribution of the unit is poorly understood. Parts of the Burnt River Schist are correlative with part of the "argillite series" of Pardee (1941) in the Sumpter quadrangle and part of the Pre-Tertiary "greenschist," Nelson marble and "gray phyllite," of Prostka (1967) in the Durkee quadrangle. Wolff (1965) reports the unit to the south in the Ironside Mountain quadrangle.

Lithology: The unit consists of a minimum of several thousand feet of quartzitic and pelitic phyllitic rocks, metavolcaniclastic rocks, greenstones, and minor marble. The parent rocks are interpreted to have been flows and tuffs of basalt and andesite, beds of volcanic sandstone, chert, shale, and limestone. Collectively the rocks correspond to those making up the present-day deep-sea floor.

According to Ashley (1966) the northern half of the exposure of Burnt River Schist along the Burnt River consists primarily of phyllitic rocks which include quartz phyllites, phyllitic quartzites, and minor pelitic phyllite. Other rock types include andesitic and dacitic pyroclastic material, minor flows of greenstone, and some marble. To the south the major rock types include metabasalts, meta-andesites, pelitic phyllites, and marble. An east-west fault separates the northern exposures from the southern exposures and straddles the east-flowing segment of the Burnt River, approximately midway between Bridgeport and the Durkee Valley.

Two sets of steeply dipping shear planes impart a prominent east-west lineation to the unit. The structural geometry in the type area has been studied in detail by Ashley (1966), and Wolff (1965) discusses possible isoclinal folding and repetition of the section in the Ironside Mountain quadrangle to the south. In view of the plate tectonics model, the Burnt River Schist may represent several inclined slabs of sea floor structurally stacked one atop the other in a late Paleozoic subduction zone.

Contacts: The relationship of the Burnt River Schist to other units of similar age is poorly understood owing to the similar lithologies, complex structures, and varying degrees of deformation involved. The widespread relatively high degree of deformation in the Burnt River Schist suggests to some that it predates the Elkhorn Ridge Argillite. Alternatively, the two units may have been deposited contemporaneously and subsequently may have occupied different positions in a regionally variable tectonic setting.

Age: No diagnostic fossils have been recovered from the Burnt River Schist and a late Paleozoic, possibly Permian, age is assigned to the unit on the basis of metamorphic grade.

References: Ashley, 1966
Gilluly, 1937
Pardee, 1941
Prostka, 1963, 1967
Wolff, 1965

BUTTE CREEK VOLCANIC SANDSTONE

Original description: The Butte Creek Volcanic Sandstone was originally described by Kittleman and others (1965), who designated as the type locality exposures in SW$\frac{1}{4}$ sec. 23, T. 24 S., R. 40 E., west of the Owyhee Reservoir in central Malheur County.

Distribution: The unit mantles the Littlefield Rhyolite in the northern Crowley district. Exposures generally crop out as narrow bands in canyons which cut through the overlying units.

Lithology: The unit is flat lying and poorly exposed except in gulleys. It consists of approximately 50 feet of thin- to thick-bedded, pale, yellowish-gray, altered vitric volcanic sandstone, pebble conglomerate and laharic breccia. Silicic glass shards set in a matrix of clayey alteration products are abundant.

Contacts: The unit overlies the Littlefield Rhyolite and underlies the Wildcat Creek Welded Ash-Flow Tuff.

Age: A Barstovian (late Miocene) age is assigned to the unit. A radiometric age of 15.1 million years for a sample of contained sanidine indicates that the maximum possible age for the unit is late Miocene.

References: Kittleman and others, 1965, 1967.

"CAPS CREEK BEDS"

Definition: "Caps Creek beds" is an informal term applied to exposures of Early Jurassic strata covering five square miles along Poison and Caps Creeks and in the headwaters of Rosebud Creek in the Suplee-Izee district of central Oregon. Exposures are poor and stratigraphic relationships are uncertain. Dickinson and Vigrass (1965) recommend that formal definition of the unit be deferred until exposures to the north in the Wickiup-Keller Creek area are studied in more detail.

Lithology: The unit consists of a series of intercalated thin-bedded calcareous sandstone, mudstone, and siltstone. Discontinuous lenses of calcirudite derived from the underlying Triassic and Paleozoic units are locally developed. The unit differs from the Graylock Formation in its higher content of lime and the presence of calcirudite interbeds.

Contacts: The unit is in fault contact with the Begg and Brisbois Formations and it is overlain by the Suplee Formation with angular unconformity.

Age: The "Caps Creek beds" contain reworked Karnian (Late Triassic) fossils and are associated with Sinemurian (Early Jurassic) ammonites. It correlates roughly with the Graylock Formation, but differs from it somewhat in lithology.

Reference: Dickinson and Vigrass, 1965

CHALK BUTTE FORMATION

Original description: The Chalk Butte Formation was originally described by Corcoran and others (1962), who designated the type locality as Chalk Butte in the SE$\frac{1}{4}$ of sec. 22, T. 20 S., R. 45 E. in northeastern Malheur County.

Distribution: The unit is fairly widespread in the northern half of the Mitchell Butte 30' quadrangle. It corresponds to the uppermost part of the Idaho Group.

Lithology: The unit consists of loosely consolidated tuffaceous conglomerate, sandstone, and siltstone with lesser amounts of ash, fresh water limestone, and diatomite. Deltaic features, scour channeling, and plant debris indicative of a fluviatile origin are dominant low in the section; and fluvial deposits with patchy diatomites and limestones indicative of lacustrine conditions are present high in the section. Minor flows of basalt less than 30 feet in thickness are developed in the vicinity of Brown Butte.

Contacts: The Chalk Butte Formation is unconformable over the Grassy Mountain Formation, the Sucker Creek Formation, and the Owyhee Basalt.

Age: A Hemphillian (middle Pliocene) age is assigned to the unit on the basis of contained vertebrates.

References: Corcoran and others, 1962
Corcoran, 1965

CLARNO FORMATION

Original description: The Clarno Formation was originally described by Merriam (1901), who designated exposures at Clarnos Ferry on the John Day River as the type locality.

Distribution: The Clarno Formation is fairly widespread in north-central Oregon along the western, southern, and eastern edges of the John Day Formation. To the north it is buried beneath the John Day Formation and the Columbia River Group, and according to Brown and Thayer (1966a) it is continuous to the east with the "andesitic flows and tuff breccias" of Pardee (1941) in west Baker County.

Lithology: The Clarno Formation consists of a wide variety of volcanic and related terrestrial rocks having an aggregate thickness of at least several thousand feet. The unit includes mafic flows, coarse unsorted breccias, mudflows, tuffaceous terrestrial sediments, and scattered silicic domes. The volcanic rocks are primarily andesitic, but range in composition from basalts through dacites. In contrast to the flows of the Columbia River Group, the volcanic rocks display phenocrysts of ferromagnesian minerals and irregular jointing.

Volcaniclastic units in the Clarno Formation display a wide range of grain size and sorting and consist of coarse tuff, lapilli tuff, pyroclastic breccia, volcanic siltstone, sandstone, and conglomerate. The volcaniclastic sediments collectively represent subtropical fan deposits of composite fluvial, mudflow, sheetwash, lacustrine, and airfall origin.

Lateral variations characterize the Clarno Formation. The regional stratigraphic order of the unit is unclear, although local stratigraphic successions are commonly presented in the literature. According to Oles and Enlows (1971), a regional unconformity separates the Clarno Formation into two units: their Lower Clarno Formation and Upper Clarno Formation. The Lower Clarno Formation consists of volcanic breccias composed of porphyritic andesite blocks set in a pebbly matrix of volcanic wacke, and interbedded andesite flows, and tuffaceous sediments. It is best exposed north of the Mitchell Fault and displays deformation comparable to that of the underlying Cretaceous strata.

The Upper Clarno Formation of Oles and Enlows (1971) consists of light green-gray mudflows that grade laterally into fluvial and lacustrine pediplane deposits at their distal ends. Intercalated darker brown, platy to irregularly jointed andesite flows are clustered about ancient volcanic centers and are most abundant on the flanks of Keyes Mountain, an exhumed Eocene volcano.

Similar flows of basaltic andesite unconformable over definite Clarno rocks in the Horse Heaven mining district are described as "Post-Clarno" by Waters and others (1951), but are regarded as Clarno Formation by Swanson and Robinson (1968) and Swanson (1969a). Supporting evidence for their interpretation include the radiometric age of the flows, their stratigraphic position beneath the John Day Formation, and the presence of numerous saprolitic weathering horizons characteristic of the Clarno Formation.

Contacts: The Clarno Formation is unconformable over pre-Tertiary strata and is unconformable beneath the John Day Formation along a contact that is commonly marked by a saprolitic weathering horizon.

Numerous other discontinuous saprolitic weathering horizons occur within the unit and are to be expected in a terrestrial volcanic and sedimentary unit.

Possibly the angular unconformity which underlies the mudflows and andesite flows of the Upper Clarno Formation in the Mitchell area is the same one that underlies the "Post-Clarno" andesite flows of Waters and others (1951) in the Horse Heaven mining district.

Age: Vertebrate, floral, and radiometric age data indicate a late Eocene through earliest Oligocene age for the bulk of the dated Clarno Formation. Radiometric age determinations high in the section at the Clarno nutbed locality one mile east of Clarno indicate an age of 34.2 million years, and determinations lower in the section reveal ages as old as 41 million years in the "Post-Clarno" rocks of Waters and others (1951). Dates beneath the unconformity noted above are not available and extension of the unit into the lower Eocene is possible.

According to Walker (oral communication, 1971), radiometric dating reveals that some of the rocks mapped as Clarno by Brown and Thayer (1966a) in Baker County are actually equivalent in age to the John Day Formation. These and similar occurrences in which the age of the Clarno Formation is younger than 36 million years (an age assigned to the basal John Day Formation in the Horse Heaven mining district by Swanson, written communication, 1971) suggest that the stratigraphic relationship between the two units is complex (see John Day Formation). Alternatively, weathering of the Clarno rocks prior to the deposition of the John Day Formation may have resulted in the anomalously low radiometric age dates.

Equivalents of the Clarno Formation may extend westward under the High Cascades to emerge in western Oregon as the Colestin Formation and the lower Fisher Formation of the southern and central Western Cascades. It correlates in part with the Spencer and Nestucca Formations.

References:
Bedford, 1954
Bowers, 1953
Brown and Thayer, 1966a
Cavender, 1968
Dale, 1957
Dawson, 1951
Dickinson and Vigrass, 1965
Dobell, 1949
Evernden and James, 1964
Forth, 1965
Hogenson, 1964
Howard, 1955
Humphrey, 1956
Irish, 1954
Jolly, 1957
Lukanuski, 1963
McIntyre, 1953
McKee, 1970
Napper, 1958
Ojala, 1964
Patterson, 1965
Peck, 1964
Pigg, 1961
Snook, 1957
Stensland, 1970
Swanson, 1969a
Swanson and Robinson, 1968
Swarbrick, 1953
Swinney, Waters and Miller, 1968
Taubeneck, 1950
Taylor, 1960
Walker, Peterson, and Greene, 1967
Waters, 1968 a, b, c
Waters and Vaughan, 1968 a, b
Waters and others, 1951
White, 1964
Wilcox and Fisher, 1966

CLOVER CREEK GREENSTONE

Original description: The Clover Creek Greenstone was defined by Gilluly (1937), who designated exposures along Clover Creek in the Baker quadrangle as the type locality (secs. 24, 25, and 26, T. 7 S., R. 42 E.).

Introduction: The Clover Creek Greenstone is part of a heterogeneous assemblage of metamorphosed volcanic and sedimentary rocks of Permian and Late Triassic age which underlies the Martin Bridge Formation in the Wallowa Mountains and adjacent areas. Marked facies variations, both laterally and vertically, the scarcity of fossils, and regional similarities in structural geometry and degree of metamorphism have made subdivision of the section extremely difficult. As discussed below, a complexity of obscure correlations and stratigraphic interpretations has developed so that the nomenclature of the rocks is now highly confused.

Historical treatment: In describing the Clover Creek Greenstone, Gilluly (1937) assigned a provisional Permian age to the unit on the basis of fossils found 6 miles northwest of the type locality. In addition,

he suggested that the unit extended eastward from the type locality to the vicinity of Homestead. Thereafter a trend was established in which many greenstones of similar appearance in the Wallowa Mountains were assigned to the Clover Creek Greenstone.

Ross (1938) found strata characteristic of the Clover Creek Greenstone of Gilluly to be widely exposed in the southeastern part of the Wallowa Mountains. He mapped sequences consisting mostly of andesitic and dacitic volcanic rocks as part of the Clover Creek Greenstone; however, the predominantly sedimentary sequences were called "Carboniferous (?) sedimentary rocks." The close, partly equivalent, relationship of these two units was noted.

Smith and Allen (1941) partly overlapped the work of Ross and extended the mapping of correlative greenstone into the northern Wallowa Mountains. They found Late Triassic fossils in a sedimentary sequence conformably overlying a series of greenstones on the north escarpment of Point Joseph. Assuming the greenstones to be Permian in age and therefore stratigraphically distinct, they assigned the name "Lower Sedimentary Series" to the Late Triassic sedimentary sequence. Because of their lithologic similarity, most of the "Carboniferous (?) sedimentary rocks" of Ross in the Wallowa Lake quadrangle were included in the "Lower Sedimentary Series."

In parts of the Cornucopia and Eagle Cap quadrangles Wetherell (1960) discovered Late Triassic fossils in rocks assigned to the Clover Creek Greenstone and Lower Sedimentary Series by Smith and Allen (1941) and Permian fossils in other strata also assigned to the Lower Sedimentary Series by Smith and Allen (1941). On the basis of age and lithology he established two new units which he informally named the "Imnaha Formation" (Late Triassic) and the "Trinity Creek Formation" (Permian).

Bostwick and Koch (1962) reported both Permian and Triassic fossils in rocks assigned to the Clover Creek Greenstone by Gilluly (1937). Fossil localities nearest the type locality yielded Triassic fossils (Bostwick and Koch, 1962; Koch and Bowen, unpublished report). Although the Permian fossils of Gilluly (1937) and Bostwick and Koch (1962) were collected from a different stratigraphic entity than the Late Triassic rocks, attempts to map the two units has thus far proven only partially successful. Exposures at the type locality are believed to be Late Triassic in age.

In the northwestern part of the Sparta quadrangle, Prostka (1963) divides exposures contiguous with the type Clover Creek Greenstone of Gilluly (1937) into five vertically arranged conformable units. More recently (written communication, 1971), however, he interprets the uppermost unit (unit "A") to disconformably overlie the other four units, and he correlates it with his "Gold Creek Greenstone" and Lower Sedimentary Series in the northeast part of the quadrangle and the "Imnaha Formation" of Wetherell (1960). Vallier, however, considers the "Imnaha Formation" and the "Gold Creek Greenstone" to be lateral equivalents of the Late Triassic part of the Clover Creek Greenstone of Gilluly (1937) (oral communication, 1971).

Nolf (1966) remapped much of the area previously mapped by Smith and Allen (1941) in the northern Wallowa Mountains. According to Vallier (1967, p. 20) Nolf divided the Clover Creek Formation into three members; in decreasing age these are the Mount Howard member, Chief Joseph member, and the Dunn Creek conglomerate. Also, according to Vallier (p. 20) Nolf reported that Smith and Allen included in the "Lower Sedimentary Series" approximately the same beds on Chief Joseph Mountain as those of the Chief Joseph Member and Dunn Creek Conglomerate of the Clover Creek Formation of Nolf (1966).

Vallier (1967) discovered Ladinian (Upper Middle Triassic) and Karnian (Late Triassic) fossils in his "Grassy Ridge Formation," a unit which he equated with parts of the Clover Creek Greenstone and "Imnaha Formation." Permian strata in the Snake River Canyon assigned to the "Hunsaker Creek Formation" by Vallier (1967) are equivalent in part to the "Trinity Creek Formation" of Wetherell (1960) and possibly the Permian rocks included in the Clover Creek Greenstone by Gilluly (1937) farther to the west.

Lithology: As originally described by Gilluly (1937) the Clover Creek Greenstone consists of a minimum of 4,000 feet of altered volcanic flows and pyroclastic rocks with subordinate amounts of conglomerate, limestone, and shale. The volcanic rocks consist of chloritized and locally silicified and sheared keratophyre, quartz keratophyre, and very minor spilite.

Directly to the east in the Sparta quadrangle exposures of Clover Creek Greenstone contiguous with those of the type locality were described in detail by Prostka (1963). He presents a generalized composite section which in ascending order consists of 300 feet of fine-grained volcanic sandstone and keratophyre tuff underlain by coarse sandstone and breccia, 300 feet of spilite flows, 1,000 feet of

keratophyre and quartz keratophyre flows, tuffs, and breccias, 1,900 feet of fine-grained volcaniclastic sediments, and 400 feet of spilite and meta-andesite.

Contacts: In the Sparta quadrangle the Clover Creek Greenstone of Prostka (1963) rests depositionally upon granites interpreted to be Early Triassic in age by Prostka (1963). As mapped by Gilluly (1937), contacts of the Clover Creek Greenstone with other Pre-Tertiary bedded units are not exposed. Permian rocks included in the Clover Creek Greenstone by Gilluly (1937) appear to be separated from the Triassic volcanic rocks of the Clover Creek Greenstone by a considerable time gap spanning the Early and Middle Triassic. The precise nature of this contact is unknown.

Throughout the Wallowa Mountains pre-Martin Bridge (Triassic and Permian) greenstones and associated sediments form a heterogeneous assemblage of rocks characterized by poor exposures and complex facies relationships over large areas. Because the present state of knowledge concerning the rocks is highly confused, definitive statements regarding the contact relationships of the various units are not possible. It appears advisable, therefore, not to carry particular interpretations beyond the boundaries of the areas in which supporting data were collected.

Age: A provisional Permian age was assigned to the Clover Creek Greenstone by Gilluly (1937) on the basis of abundant Permian productids discovered in his Clover Creek Greenstone six miles northwest of the type locality. However, more recent discoveries of Late Triassic fossils, notably Pentacrinus and Halobia throughout much of the unit have established that a large part of the Clover Creek Greenstone is of Late Triassic Age. Fossil localities nearest the type locality have yielded Late Triassic fossils (Bostwick and Koch, 1962; Koch and Bowen, unpublished report). In view of the large time gap separating the fossils of Permian age from those of Late Triassic age, it is apparent that two distinct stratigraphic units are included in the Clover Creek Greenstone of Gilluly (1937).

References: Bostwick and Koch, 1962
Gilluly, 1937
Nolf, 1966
Prostka, 1962, 1963, 1967
Smedes, 1959
Smith and Allen, 1941
Vallier, 1967
Wetherell, 1960

COFFEE CREEK FORMATION

Original description: The Coffee Creek Formation was first described by Merriam and Berthiaume (1943), who designated exposures along Coffee Creek in sec. 30, T. 18 S., R. 25 E. as the type locality. Coffee Creek drains into Grindstone Creek south of Wade Butte in central Oregon.

Distribution: Exposures of the unit are limited to the southeast corner of Crook County in the immediate vicinity of the type locality.

Lithology: The Coffee Creek Formation consists of approximately 1,000 feet of argillaceous and sandy limestone which passes downsection into limy sandstone and dull-green pebbly sandstone. Definitive exposures are developed only in the more resistant calcareous portions of the upper half of the unit. There bioclastic and oölitic textures indicate a shallow water environment of deposition.

Contacts: The base and top of the unit are not exposed. Presumably the Spotted Ridge Formation overlies it unconformably.

Age: Rugose corals, brachiopods, and crinoids are indicative of a Mississippian (probably Lower Mississippian) age for the Spotted Ridge Formation. The most common fossils are Striatifera and Gigantella.

References: Mamay and Read, 1956
Merriam and Berthiaume, 1943
Ogren, 1958

COLPITTS GROUP

Original definition: The Colpitts Group was originally defined by Lupher (1941), who included in it the Middle Jurassic Weberg Formation and Warm Springs Formation exposed in the Suplee area of central Oregon.

Present status: Dickinson and Vigrass (1965) included the Weberg and Warm Springs Formations in the Snowshoe Formation and discontinued the use of the term Colpitts Group. (See Weberg member and Warm Springs member of the Snowshoe Formation.)

COLUMBIA RIVER GROUP

Original description: Russell (1893) proposed the term Columbia lava for the Eocene through Pliocene(?) basalts of the Columbia Plateau in Washington and Oregon. Subsequently the term was changed to Columbia River lava by Russell (1901) and was restricted to lavas of post-John Day and pre-Mascall age by Merriam (1901).

Smith (1901) introduced the term Yakima basalt for exposures high in the section in Washington, and Waters (1961) extended the unit into Oregon, where he applied the term Picture Gorge Basalt to basalts lower in the section. Brown and Thayer (1966a) erected the Columbia River Group and included in it the Picture Gorge Basalt, the Yakima Basalt, the Mascall Formation, and the "rhyolitic marginal facies," a unit transitional with the Strawberry Volcanics.

The broad term Columbia River Basalt is commonly used where lithologic affinities and stratigraphic relationships to the individual formations nearer the type areas are unclear.

Distribution: The Columbia River Group is the most widespread geologic unit in the northwest, covering the southeastern third of the state of Washington, much of north-central and northeastern Oregon, and parts of adjacent Idaho. It forms the walls of the Columbia River Gorge and also is widespread in the Willamette Valley of western Oregon.

Lithology: The Columbia River Group consists of a maximum of 8,000 feet (average 2,000 to 3,000 feet) of hard, dark basalt and subordinate tuffaceous sediments (Mascall Formation and "rhyolitic marginal facies"). Dense, black, aphanitic to locally porphyritic, olivine-bearing to tholeiitic flow-on-flow basalt is the dominant rock type. Superficially the lavas appear to be very uniform, but in a regional sense the development of several geographically distinct source areas has no doubt resulted in subtle variations of the lithology, stratigraphy and age of the unit.

The basalts of the Columbia River Group are divided into two types: the Picture Gorge Basalt and the Yakima Basalt. The Picture Gorge Basalt is apparently the older of the two units and is the most widespread in Oregon, being reported in the east Crescent and east Bend AMS sheets to the west and in the Durkee quadrangle to the east. It forms the bulk of the Columbia River Group in the Aldrich Mountains and the Ochoco Mountains, and it comprises much of the Columbia River Group north of Picture Gorge, the type locality.

Chemically the Picture Gorge Basalt is composed of 47 to 50 percent silica and it is high in Al_2O_3, MgO, and CaO. It averages 5 percent olivine, is porphyritic, and displays blocky jointing. The relatively high content of chlorophaeite in the lavas gives the weathered rock a waxy appearance.

The Yakima Basalt is interpreted to overlie the Picture Gorge Basalt by Brown and Thayer (1966a), but it is thought also to intertongue with the Picture Gorge Basalt by Walker, oral communication (1971). Chemically it is composed of 53-54 percent silica, and opaline pods of late origin are developed locally. The rock is high in K_2O and TiO_2. The unit displays columnar jointing and is olivine poor with the exception of some late, basic, iron-rich, diktytaxitic variants in parts of Washington.

The Mascall Formation (see Mascall Formation) consists of a series of cream-colored, waterlaid tuffs and ash which thickens to the south to an estimated thickness of approximately 2,000 feet in the John Day River valley near Dayville. There, intertonguing flows of basalt are tentatively assigned to the Yakima Basalt by Thayer and Brown (1966b).

Farther to the south the fluvial Mascall Formation is interpreted to pass laterally into fan deposits and flow rocks assigned to the "rhyolitic marginal facies" of Brown and Thayer (1966a), and Thayer and Brown (1966 b, c). The "rhyolitic marginal facies" consists of basaltic and andesitic flow rocks interbedded with waterlaid debris, welded tuffs, and lenticular rhyolite flows of local extent. It is interpreted to be conformable with the basalts of the Columbia River Group and is believed to pass laterally to the south into the Strawberry Volcanics (see Strawberry Volcanics).

Source areas: Source areas for the basalts of the Columbia River Group are concentrated into three northwest trending dike swarms: the Grande Rhonde dike swarm along the Snake River, the Cornucopia dike swarm in the southern Wallowa Mountains, and the Monument dike swarm along the John Day River in central Oregon. Various aspects of the swarms are discussed by Waters (1961), Gibson (1966), Shaw (1967), and Taubeneck (1969 a, b).

Other more distant source areas include the Tieton dike swarm in central Washington, possible feeder dikes in the Willamette Valley (Osawa and Goles 1969), dikes along the coast (Snavely and MacLeod, 1969), and source dikes for the Roza flow in southeastern Washington (Bingham, 1969). That other source areas underlie the Columbia River Group in the more central parts of the Columbia River Plateau is suggested by geophysical data (Hill, written communication, 1971).

Contacts: The Columbia River Group is unconformable over older units including the Clarno and John Day Formations. It is unconformable beneath the Dalles, Deschutes and Rattlesnake Formations.

The Mascall Formation is interpreted to interfinger with basalts tentatively assigned to the Yakima Basalt (Thayer and Brown, 1966 b,c) in the vicinity of John Day and to pass laterally to the south into the "rhyolitic marginal facies" and ultimately into the Strawberry Volcanics. A picture emerges in which a debris fan spreading north from Strawberry Mountain interfingers with the basalts of the Columbia River Group to give a Miocene landscape similar to that of south-central Oregon today, where flows and debris from Mt. Mazama spread northward and northeastward over the flows of the High Cascades.

Age: Recent faunal data and radiometric age determinations restrict most of the Columbia River Group to the late Miocene and possibly the early Pliocene. In Washington, radiometric age dates ranging from 12.3 to 16.9 million years have been obtained for the Yakima Basalt (Holmgren, 1969 a, b: Waters, 1961). The wide scatter is attributed to inaccuracies inherent in the dating techniques (Holmgren, 1969,b). An age of 11.9 to 13.3 million years is reported for the Pomona flow by Holmgren (1969a,b). In Oregon the Elephant Mountain flow overlies the Ellensburg Formation of latest Miocene or early Pliocene age near Arlington (Newcomb, 1971).

Basalts believed to occur high in the Picture Gorge Basalt in the John Day River have yielded an age date of 15.4 million years (Gray and Kittleman, 1967). Similarly, Avent (1969) reports an age of 15.0 million years for flows assigned to the Picture Gorge Basalt.

References:

Avent, 1969
Bedford, 1954
Bingham, 1969
Bowers, 1953
Brown and Thayer, 1966 a,b,c
Carnahan, 1962
Dale, 1957
Dawson, 1951
Dickinson and Vigrass, 1965
Dobell, 1949
Forth, 1965
Gibson, 1966
Goebel, 1963
Gray and Kittleman, 1967
Hampton and Brown, 1964
Hogenson, 1964
Holmgren, 1969 a,b
Humphrey, 1956
Irish, 1954
Jolly, 1957
McIntyre, 1953
Mobley, 1956
Napper, 1958
Newcomb, 1971
Ogren, 1958
Osawa and Goles, 1969
Patterson, 1965
Peck, 1964

References: (continued)
Pigg, 1961
Prostka, 1963, 1967
Shaw, 1967
Smedes, 1959
Smith and Allen, 1941
Snavely and MacLeod, 1969
Snavely and Vokes, 1969
Snook, 1957
Swanson, 1969 a
Swinney and others, 1968
Taubeneck, 1950, 1969a, b
Taylor, 1960
Thayer and Brown, 1966 b, c
Thomas, 1956
Vallier, 1967
Walker and others, 1967
Waters, 1961, 1968 a, b
Waters and Vaughan, 1968 a, b
Wetherell, 1960
White, 1964
Wilcox and Fisher, 1966
Williams, 1957

COON HOLLOW MUDSTONE

Original description: Morrison (1964) described the Coon Hollow Mudstone and designated exposures in Coon Hollow as the type locality. Coon Hollow is a small canyon leading into the Snake River in the extreme northeastern corner of Oregon.

Distribution: The unit is exposed in a rectangular area covering 12 square miles in the extreme northeastern corner of the state and extending for short distances into adjacent Idaho and Washington.

Lithology: As exposed at the type section the Coon Hollow Mudstone consists of 1,250 feet of mudstone and subordinate interbedded pebble conglomerate and lithic graywacke. The total thickness of the unit including exposures outside the type area is approximately 2,000 feet.

The base of the unit is marked by a basal conglomerate consisting of boulders of chert, volcanic rocks, and silicified siltstone. The mudstone is thin-bedded, black, hard, splintery, and noncalcareous. Minor amounts of interbedded pebble conglomerate occur sporadically in the section.

Contacts: The unit is unconformable over Triassic rocks.

Age: An early Oxfordian (Late Jurassic) age is assigned to the unit on the basis of a few ammonites collected on the Idaho side of the Snake River.

References: Imlay, 1964a
Morrison, 1964

COYOTE BUTTE FORMATION

Original description: Merriam (1942) defined the Coyote Butte Formation and designated the steeply dipping strata that form the crest of Coyote Butte southeast of Paulina as the type locality.

Distribution: The unit is restricted to exposures immediately surrounding the type locality in southeastern Crook County in central Oregon.

Lithology: The Coyote Butte Formation consists of approximately 900 feet of massive to distinctly bedded limestones and feldspathic sandstone. Locally conglomeratic, olive-gray sandstones with interbedded crinoidal limestones rich in fusulinids characterize the lower part of the section.

Higher in the section purer, finer-grained, more distinctly bedded, deeper-gray limestones with abundant brachiopods and sparse fusulinids are abundant. Also present are zones of dolomitization and silicification and occasional chert interbeds of uncertain origin.

Although the unit is commonly thought of as being dominantly a limestone, this is probably a misconception arising from the greater resistance of the limestone as compared to the sandstone. Low in the

section the limestone probably occurs as subordinate lenses within a dominantly sandstone lithology.

Contacts: The Coyote Butte Formation is probably unconformable over the Spotted Ridge Formation as suggested by the pinchout of the underlying strata in sec. 5, T. 19 S., R. 25 E., the coarse basal beds and the relative ages of the two units. Ogren (1958), however, includes it as a member within his Spotted Ridge Formation.

Age: Middle Permian Leonardian fusulinids recovered from the unit suggest correlation with exposures of the Elkhorn Ridge Argillite 3 miles south of Sumpter in Baker County (Bostwick and Koch, 1962).

References: Bostwick and Koch, 1962
Mamay and Read, 1956
Merriam, 1942
Merriam and Berthiaume, 1943
Ogren, 1958

DALLES FORMATION

Original description: Cope (1880) applied the term Dalles Formation to semi-consolidated fluviatile sediments exposed in the vicinity of The Dalles in north-central Oregon.

Distribution: The Pliocene fluvial sediments overlying the Columbia River Group, here assigned to the Dalles Formation, extend approximately 15 miles south of The Dalles in an exposure which is approximately 10 to 15 miles wide. Exposures previously included in the Shutler Formation and which extend eastward through much of the Umatilla Basin are included in the Dalles Formation by Newcomb (1966, 1971).

Similar beds farther south in the Bend and Madras areas are sometimes assigned to the Dalles Formation (Waters, 1968b; Peck, 1964; Peterson and Groh, 1970), but are here excluded from the unit on the basis of their geographic separation from the type Dalles. For these beds the term Deschutes Formation is probably more appropriate. (See Deschutes Formation.)

Lithology: The Dalles Formation consists of up to 1,500 feet of andesitic agglomerates of mudflow origin that grade upsection and laterally to the east and north into fluvial sediments composed of conglomerate, fine-grained tuffaceous sandstone, and siltstone. The agglomerates consist of andesite blocks set in an unbedded matrix of shards, pumice, scoria, mineral grains, and clay. The unit probably represents a debris fan that spread to the north and east of the northern High Cascades.

Contacts: The Dalles Formation is unconformable over the Columbia River Group and is overlain by Plio-Pleistocene basalts.

Age: An early Pliocene age is assigned to the Dalles Formation on the basis of fossil leaves and vertebrates of that age recovered from the unit. In addition, radiometric ages of 10.6 and 15.2 million years have been determined for a flow within the sedimentary facies. The unit correlates with the lower Deschutes Formation to the south. The precise stratigraphic relationship of the Dalles Formation to the middle Pliocene Shutler Formation and the middle Pliocene beds at McKay Reservoir to the east is unclear, although Newcomb (1966, 1971) considers both may be extensions of the Dalles Formation.

References: Baldwin, 1964
Newcomb, 1966, 1971
Peck, 1964
Peterson and Groh, 1970
Piper, 1932
Waters, 1968a,b
Williams, 1957

DANFORTH FORMATION

Original description: The Danforth Formation was originally described by Piper (1936) and subsequently by Piper, Robinson and Park (1939). Exposures along Cow Creek on the Danforth Ranch in T. 22 S., R. 32½ E. are designated as the type locality.

Distribution: The Danforth Formation is well-developed in the Harney Basin and is widespread in northern and central Harney County.

Lithology: The Danforth Formation consists of a highly variable sequence of tuffaceous sedimentary rocks, interstratified ash-flow tuffs, thin basalt flows and basaltic breccias. According to Piper, Robinson and Park (1939) extrusives are dominant low in the section and sediments dominate high in the section. In this sense the Danforth Formation is grossly similar to the Juntura Formation in northern Malheur County.

Three rhyolitic to rhyodacitic ash-flow tuffs occur within the unit and are traceable regionally on the basis of their respective characteristics of chemistry, petrology, lithology, and stratigraphy. For example, the lower ignimbrite is crystal rich and lacking in pumiceous fragments; the upper two tuffs are vitric and welded. The basinal depression southeast of Burns may represent a collapsed source area for the upper vitric tuff.

The Danforth Formation exhibits a maximum thickness of 700 feet in the central parts of the Harney Basin and tapers to a feather edge of rhyolite ash-flow tuff on the slopes of the surrounding topographic highs such as the west slope of Steens Mountain.

Contacts: The Danforth Formation is disconformable over the Steens Basalt and unconformable under younger units including the Harney tuff.

Age: Hemphillian vertebrates and radiometric age determinations indicate a middle Pliocene age for the unit. An age of 9.2 million years has been obtained for the lower welded tuff and an age of 6.1 million years has been determined for the upper welded tuff. The upper tuff is thought to be the same unit as the middle tuff of the Rattlesnake Formation and is termed the "Rattlesnake ignimbrite" by Davenport (1970).

References:
Bateman, 1961
Beeson, M. H., 1962, 1969
Campbell and others, 1958
Crowley, 1960
Davenport, 1970
Lund, 1966
Piper, 1936
Piper and others, 1939
Walker, 1969c, 1970
Walker and Swanson, 1968 a, b

DEER BUTTE FORMATION

Original description: Corcoran and others (1962) proposed the term Deer Butte Formation for strata typically exposed at Deer Butte north of the Owyhee Reservoir in the Mitchell quadrangle. It has subsequently been described by Kittleman and others (1965).

Distribution: The Deer Butte Formation is widespread north and northeast of the Owyhee Reservoir in east-central Malheur County and as steptoes poking through younger Pliocene strata in the northern part of the Mitchell Butte quadrangle (Corcoran and others, 1962). It is included in the Idaho Group by Kittleman and others (1965), but it is excluded from the Idaho Group by Corcoran (1965) on the basis of a pronounced overlying unconformity.

Lithology: The Deer Butte Formation is 950 feet thick at the type locality and may be present in thicknesses of greater than 2,000 feet locally. It consists of a series of buff, soft tuffaceous siltstones, volcanic carbonaceous shales, and altered tuffaceous vitric and crystal sandstones of fluvial and lacustrine origin grading upsection into massive arkosic sandstones and well-cemented rhyolite-granite conglomerate high in the section. The arkosic sandstones and conglomerates probably were derived from the vicinity of Silver City, Idaho, located 50 miles to the southeast.

Thin olivine basalt flows and laharic breccias are locally developed in the middle of the section.

Contacts: The Deer Butte Formation is disconformable over the Owyhee Basalt and unconformable beneath the Kern Basin Formation of Corcoran and others (1962) and the lower Grassy Mountain Formation of Kittleman and others (1965).

Age: The Deer Butte Formation is Barstovian (late Miocene) in age and correlates with the Drip Spring Formation to the north.

References: Corcoran, 1953, 1965
Corcoran and others, 1962
Kittleman, 1962
Kittleman and others, 1965, 1967
Newton and Corcoran, 1963
Weeden, 1963

DESCHUTES FORMATION

Original description: Russell (1905) applied the term Deschutes Formation to lacustrine and fluvial Pliocene sediments in the Bend and Madras areas.

Distribution: The unit is fairly widespread in the middle reaches of the Deschutes River in the area surrounding Bend and Madras. It is geographically isolated from the Dalles Formation to the north. Included in the unit are exposures referred to as Deschutes by Stearns (1931), Madras Formation by Hodge (1941) and Williams (1957), and Dalles Formation by Hodge (1942), Peck (1964), Waters (1968b) and Peterson and Groh (1970). The term Deschutes Formation has historical priority (Baldwin, 1964) and the unit differs from the Dalles Formation in terms of lithology and possibly age.

Lithology: The Deschutes Formation is a flat-lying heterogeneous sequence of sediments, tuffs, and lavas having a total thickness of approximately 600 feet. The sediments include diatomites, fluvial sandstones, mudflow breccias,and conglomerates. The tuffs include vitric ash, cindery ash, lapilli tuff, pumice lapilli tuff, and several welded ash-flow tuffs. The flows are composed of both andesite and basalt, are most abundant in the west, and are contiguous with the Cascades Formation.

The lower 200 feet of the unit consists of interbedded basalts, ash-flow tuffs and volcanic sediments; the middle 200 feet of the unit consists of volcanic sediments, pyroclastic deposits, and some basalt; the upper 200 feet of the unit consists of cones, cinders, volcanic sediments, diatomite beds, and ash-flow tuffs. Although the lower 400 feet of the unit is very similar to the Dalles Formation, it differs from that unit in its lesser abundance of mudflow deposits and in its greater abundance of ash-flow tuffs and diatomite.

Contacts: The Deschutes Formation is unconformable over the Columbia River Group and locally unconformable over beds assigned to the Ellensberg Formation. It wedges out against the John Day Formation to the east.

The Deschutes Formation is unconformable beneath younger flows of basalt and grades laterally to the west into the Cascades Formation.

Age: An early Pliocene through late Pliocene age is assigned to the unit by Stensland (1970) on the basis of radiometric age determinations, stratigraphic position, and fossil content.

References: Baldwin, 1964
Hodge, 1940, 1941, 1942
Peck, 1964
Peterson and Groh, 1970
Russell, 1905
Stearns, 1931
Stensland, 1970
Waters, 1968b
Williams, 1957

DEVONIAN STRATA OF CENTRAL OREGON

Original description: Devonian strata in central Oregon are described by Kleweno and Jeffords (1961,1962).

Location: The Devonian strata are exposed in the Suplee area a mile north of the area mapped by Merriam and Berthiaume (1943) in the south fork of Trout Creek T. 18 S., R. 25 E. Small exposures are also present in the southwest corner of T. 19 S., R. 25 E.

Lithology: The exposures in Trout Creek consist of 200 feet of massive, green chert grit and sandstone overlain by 100 feet of highly folded, massive, cherty, light-to medium-brown stromatoporoidal limestone, which in turn is overlain by an undetermined thickness of chert and argillite.

The small southerly exposures consist of fossiliferous limestone.

Contacts: Contacts with other units are not visible.

Age: A middle Devonian age is assigned to the rocks on the basis of stromatoporoids, brachiopods, and corals.

References: Brown and Thayer, 1966a
Kleweno and Jeffords, 1961, 1962
Thayer and Brown, 1964

DINNER CREEK WELDED ASH-FLOW TUFF

Original description: The unit was first described by Kittleman and others (1965), who designated as the type locality exposures in Conroy Creek in the NW$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 30, T. 21 S., R. 39 E. in the Monument Peak district of northern Malheur County.

Distribution: Exposures of the Dinner Creek Welded Ash-Flow Tuff are fairly widespread in the Monument Peak and Malheur Gorge districts surrounding the type locality. The "welded tuff of Owyhee Basalt" of Bowen (1956) and Gray (1956) may also belong to the unit as may similar rocks to the north in the Caviness (Ironside) quadrangle and to the south beyond Warm Springs.

Lithology: The unit is a pale-brown to grayish-red, ledge-forming, rhyolitic ash-flow tuff which generally exhibits vertical zonation and textures characteristic of welded ash flows. Locally, however, a welded zone overlies the upper partially welded zone, suggesting that two ash flows are included in the unit in places. The unit varies from 20 to 200 feet in thickness.

Contacts: The Dinner Creek Welded Ash-Flow Tuff is overlain by the Butte Creek Volcanic Sandstone of Barstovian age according to Kittleman and others (1965).

Age: A late Miocene age is assigned to the unit on the basis of stratigraphic position.

References:
Bowen, 1956
Fouch, 1968
Gray, 1956
Haddock, 1967
Hagood, 1963
Kittleman and others, 1965, 1967
Wolff, 1965

DONOVAN FORMATION

Original description: Lupher (1941) applied the term Donovan Formation to an isolated exposure of sediments cropping out from beneath Tertiary volcanics in the canyon of the Silvies River 19 miles north of Burns.

Lithology: The unit consists of 2,500 feet of hard, green and gray, noncalcareous sandstone with subordinate amounts of sandy shale, red sandstone, and yellowish, calcareous sandstone. Very minor amounts of limestone and conglomerate are also present. The red sandstone is rich in marine mollusks and according to Lupher (1941) was referred to as the "Hardgrave Sandstone" in the older literature.

Contacts: Contacts with other units are concealed.

Age: An uppermost Sinemurian (Early Jurassic) age is assigned to the uppermost parts of the Donovan Formation where diagnostic fossils have been found (Imlay to Corcoran, written communication, 1968). Possibly an unconformity separates the upper 1,800 feet of the unit from the lower 700 feet; hence the lower part of the unit may be significantly older.

Reference: Lupher, 1941

DOOLEY RHYOLITE BRECCIA

Original description: The Dooley Rhyolite Breccia was originally described by Gilluly (1937), who designated the type locality as Dooley Mountain in south central Baker County.

Distribution: The Dooley Rhyolite Breccia is restricted to exposures at Dooley Mountain. More widespread ash-flow tuffs of apparent Pliocene age included in the unit by Gilluly (1937) should probably be excluded from the unit (McIntyre, written communication to Brooks, 1971).

Lithology: The Dooley Rhyolite Breccia forms a centralized accumulation of up to 2,000 feet of rhyolite breccias and subordinate flows and breccias of andesite. The breccias include light-colored glassy rocks set in a white matrix, light-gray pumiceous flow breccias, and finely banded light-gray to green obsidian. Also present are minor amounts of spherulitic rhyolite flows, pumice, and glassy flow breccias. The unit grades upsection into several hundred feet of red, ledge-forming, flow-banded andesite.

Contacts: As described by Gilluly (1937) the unit exhibits highly ambiguous stratigraphic relationships suggestive of a middle Tertiary age. Restriction of the unit to exposures in the immediate vicinity of Dooley Mountain removed much of the ambiguity, however, and a late Miocene age seems most likely. Most of the unit rests with angular unconformity over pre-Tertiary strata.

Age: The Dooley Rhyolite Breccia has been assigned to the late Miocene on the basis of one radiometric age determination (Walker, written communication, 1971). It post-dates parts of the Columbia River Group and predates other parts of the Columbia River Group. Apparently the two units are contemporaneous and the Dooley Rhyolite Breccia may represent an eastern Oregon analog of the Strawberry Volcanics of Central Oregon.

Reference: Gilluly, 1937

"DOYLE CREEK FORMATION"

Original description: "Doyle Creek Formation" is a term informally used by Vallier (1967) in reference to Triassic exposures in the Snake River Canyon and characteristically exposed on the north side of Doyle Creek. Although part of the unit is regarded as equivalent to the Lower Sedimentary Series, it is geographically isolated from that unit.

Lithology: The "Doyle Creek Formation" consists of 3,000 to 5,000 feet of spilite, volcaniclastic rock, minor keratophyre, and minimal limestone. The lower member (the Piedmont Point member) is composed of pyroclastic rocks and volcanic flows. The flows are dusky-red, glomeroporphyritic, and spilitic; they resemble part of the Russell member of the "Imnaha Formation" of Wetherell (1960) to the west and are equated with that unit. Vallier (1967) proposes a northerly source.

The overlying Ashby Creek conglomerate member is composed of volcanic conglomerate, volcanic breccia, fine-grained volcaniclastic rocks, and locally intercalated greenish-black to red flow rocks. Plutonic clasts are reported in the conglomerate.

The rugged outcrops and red color of the flows within the "Doyle Creek Formation" are considered to be diagnostic of the unit.

Contacts: The "Doyle Creek Formation" is conformable over the "Grassy Ridge Formation" and conformable under the Martin Bridge Formation.

Age: A Karnian (Late Triassic) age is assigned to the unit on the basis of stratigraphic position. The lower member correlates with part of the "Imnaha Formation" of Wetherell (1960) and the upper member correlates with the Lower Sedimentary Series (Vallier, oral communication, 1971).

Reference: Vallier, 1967

DREWSEY FORMATION

Original description: The Drewsey Formation was first described by Bowen and others (1963), who designated exposures near Table Mountain north of the town of Drewsey on the banks of the Malheur River as the type locality.

Distribution: Exposures of the Drewsey Formation are limited to the western part of the Malheur Gorge district of northern Malheur County.

Lithology: The lower part of the Drewsey Formation consists of 15 to 35 feet of rhyolitic ash-flow tuff overlain by 75 to 100 feet of basaltic tuff agglomerate, tuff, and diatomite. The uppermost 700 feet of the formation consists of coarse, brown tuffaceous sediments, cream to gray tuffs, thick brown sandstones, and thin diatomite beds.

Contacts: The Drewsey Formation is unconformable over the Juntura Formation and is essentially conformable beneath the overlying basalts.

Age: The basal rhyolite has been radiometrically dated at 8.9 million years. Hemphillian (middle Pliocene) vertebrates have been recovered from the formation.

References:
Bowen, 1956
Bowen and others, 1963
Gray, 1956
Gregory, 1962
Hagood, 1963
Kittleman and others, 1965

DRIP SPRING FORMATION

Original description: The Drip Spring Formation was named by Kittleman and others (1965) for exposures near Drip Spring in the SW$\frac{1}{4}$ NE$\frac{1}{4}$ sec. 3, T. 22 S., R. 41 E. The type section is located in the SE$\frac{1}{4}$ sec. 20, T. 20 S., R. 42 E.

Distribution: The Drip Spring Formation consists of those sediments in the Harper Basin which overlie the Littlefield Rhyolite. It extends from a point immediately south of the Malheur River in the Harper area south southwest approximately 15 miles to the vicinity of Drip Spring.

Lithology: The Drip Spring Formation is 260 feet thick at the type locality, 700 feet thick in Cottonwood Creek and possibly 1,500 feet thick overall. It consists of yellow-brown and yellow-gray, fluvial, altered volcanic sandstone and arkosic sandstone with subordinate interbeds of carbonaceous shale and diatomite. The unit is silicified and fairly resistant to erosion high in the section. Lithologically it is similar to the Deer Butte Formation to the south, which occupies the same stratigraphic position and is of the same age.

Contacts: The Drip Spring Formation overlies the late Miocene Littlefield Rhyolite and underlies the early and middle Pliocene Grassy Mountain Formation of Kittleman and others (1965, 1967).

Age: A late Miocene to early Pliocene age is inferred for the unit on the basis of stratigraphic position. The Drip Spring Formation correlates roughly with the Deer Butte Formation.

References:
Kittleman and others, 1965, 1967
McMurray, 1962
Weeden, 1963

"EARLY TERTIARY CONGLOMERATES"

Definition: Included in this informal unit are all the early Tertiary fluvial conglomerates in the Sumpter and Baker 30' quadrangles and the Susanville and Bates 15' quadrangles to the west.

Lithology: The conglomerates form linear exposures and average a few tens of feet in thickness. They are composed of clasts of granodiorite, gabbro, chert, dense fine-grained porphyries, and quartzite set in a matrix of reddish-gray to blue-gray sandy clay. In the Sumpter quadrangle the conglomerates yielded much gold in the gold rush days. To the east similar conglomerates are described by Goebel (1963) in Wallowa County and by Ozier (1971) in the Snake River Canyon.

Contacts: The conglomerates are unconformable beneath Miocene volcanic rocks and andesite breccias of Clarno lithology, but John Day age (Walker, oral communication, 1971).

Age: The conglomerates are pre-John Day in age and are probably post-Cretaceous. Some of the clasts contain the lower Upper Cretaceous fern, Tempskya.

References:
Baldwin, 1964
Gilluly, 1937
Goebel, 1963
Mobley, 1956
Nelson, 1956
Ozier, 1971
Pardee, 1941
Pigg, 1961
Taubeneck, 1955
Thompson, 1956

ELKHORN RIDGE ARGILLITE

Original description: The Elkhorn Ridge Argillite was named by Gilluly (1937) for exposures on Elkhorn Ridge in the Sumpter quadrangle.

Distribution: The Elkhorn Ridge Argillite can be traced for 70 miles from the Snake River in eastern Baker County westward to the Greenhorn Mountains in eastern Grant County. In addition, it may extend farther to the west into isolated exposures of undifferentiated Paleozoic rocks.

Lithology: The Elkhorn Ridge Argillite consists of approximately 5,000 feet (Gilluly, 1937) of silicified, highly contorted argillite, tuff, and varicolored chert with subordinate amounts of limestone and greenstone. The argillite dominates and is dark-gray, fine-grained, and indistinctly bedded. It is composed of quartz, andesine, muscovite, chlorite, and considerable black carbonaceous material. With increasing content of coarser igneous material the argillite grades into tuffs.

Greenstone interbeds crop out in the headwaters of Manning Creek and west of Lookout Mountain in areas interpreted to be near the base of the Elkhorn Ridge Argillite by Prostka (1967). In addition, Prostka (1967) suggests that the argillite grades downsection into a dominantly greenschist unit in the Durkee quadrangle which he terms "greenschist" of Paleozoic age.

Limestone in podlike lenses makes up a small percentage of the unit. Some of these bodies may be downfaulted blocks of younger strata such as the Martin Bridge Formation. In the Sumpter area the Elkhorn Ridge Argillite forms a south dipping, possibly isoclinally folded, homocline upon which has been

imposed a north-south axial plane cleavage of Jurassic or Cretaceous age according to Switeck (1967). Post-Miocene block faulting further complicates the structure.

Contacts: Neither the top nor bottom of the Elkhorn Ridge Argillite has been recognized; stratigraphic relationships with the Burnt River Schist and the Permian part of the Clover Creek Greenstone of Gilluly (1937) are unclear. The units may represent fault-bounded structural slices in a plate tectonic terrain.

Age: Leonardian (middle Permian) fusulinids have been recovered from outcrops three miles south of Sumpter, and Ochocoan (late Permian) fusulinids have been recovered from the Virtue Hills southeast of Baker.

Post-Permian Pentacrinus columnals have been reported in limestone pods in the east central Baker quadrangle in strata with lithologies similar to that of the Martin Bridge Formation. In view of the complex structure in the area, infolding or downfaulting of younger limestone units such as the Martin Bridge Formation seems likely in these exposures.

References:
Berry, 1956
Bostwick and Koch, 1962
Dale, 1957
Gilluly, 1937
Kennedy, 1956
Mobley, 1956
Nelson, 1956
Pardee, 1941
Prostka, 1963, 1967
Thomas, 1956
Thompson, 1956

ELLENSBURG FORMATION

Original description: The term Ellensburg Formation was first proposed by Russell (1900) for lower Pliocene sediments underlying the Kittitas Valley in central Washington. The formation was extended into the Dufur quadrangle of north central Oregon by Waters (1968c).

Lithology: In the Dufur quadrangle the Ellensburg Formation consists of thin-bedded volcaniclastic sedimentary rocks.

Contacts: The unit conformably overlies the Yakima Basalt of the Columbia River Group and unconformably underlies the Dalles Formation. In Washington it interfingers with some of the later flows assigned to the Columbia River Group (Pomona flow and Elephant Mountain flow) and possibly it should be included in the Columbia River Group.

Age: On the basis of stratigraphic relationships an uppermost Miocene or lowermost Pliocene age is inferred for the unit.

References:
Newcomb, 1971
Russell, 1900
Waters, 1968c

FIELDS CREEK FORMATION

Original description: The Fields Creek Formation was described by Brown and Thayer (1966a) who designated the type locality as exposures in Fields Creek on the eastern side of the Aldrich Mountain quadrangle in the Aldrich Mountains of central Oregon.

Distribution: The unit is included in the Aldrich Mountain Group and forms a north-trending band in the Aldrich Mountains which fans out into a wide exposure immediately south of the John Day River along the Aldrich Mountain Anticline.

Lithology: The unit is approximately 15,000 feet thick at the type locality. The lower 10,000 to 11,000 feet of the unit is dominated by black shales and siliceous mudstones. In addition the lowermost 4,000 feet contains andesite flows and breccias, dacite breccias, rubbly conglomerates of reworked Triassic rocks, banded cherts, and waterlaid ash. The uppermost 3,500 feet of the unit is rich in pumiceous andesitic tuff. To the north the tuff is 8,500 feet thick.

Contacts: The Fields Creek Formation is unconformable over Paleozoic rocks and the Vester Formation. The unit is conformable with the overlying Laycock Graywacke in some places and unconformable in others.

Age: Numerous clasts in the limestone conglomerate contain fossils of late Karnian and middle and early Norian age; therefore an age no older than latest Triassic is inferred for the unit.

References: Brown and Thayer, 1966a,c

FORT ROCK FORMATION

Original description: Hampton (1964) defined the Fort Rock Formation and described several reference sections. The unit is included in the "Pliocene sedimentary and volcanic rocks" of Walker, Peterson, and Greene (1967).

Distribution: The unit forms extensive exposures in the southern part of the Fort Rock Basin in northern Lake County.

Lithology: The Fort Rock Formation generally is 10 to 200 feet thick, but thicknesses as great as 1,000 feet are developed in early Pliocene topographic depressions. In order of decreasing abundance the constituent rock types are tuff, diatomite, basaltic agglomerate, and basaltic lava. The tuff consists of basaltic lapilli tuffs and brown mudflows which grade into finer-grained deposits farther from the eruptive centers, which are represented by basaltic agglomerates and flows. The diatomite varies from massive, friable pure varieties to bedded and ashy deposits.

Contacts: The Fort Rock Formation is unconformable over the Picture Rock Basalt.

Age: A middle or late Pliocene age is inferred for the unit on the basis of stratigraphic position and fossil evidence.

References: Hampton, 1964
Walker, Peterson, and Greene, 1967

GABLE CREEK FORMATION

Original description: The Gable Creek Formation was defined by Wilkinson and Oles (1968). They present no type section owing to the complex intertonguing of the unit with the Hudspeth Formation. Instead they designate a series of three reference sections located in the south central part of the Mitchell 15' quadrangle.

Distribution: The Gable Creek Formation and the intertonguing Hudspeth Formation constitute all of the Cretaceous exposures in the Mitchell 30' quadrangle. The strata were treated in several master's theses including McIntyre (1953), Bowers (1953), Swarbrick (1953), Bedford (1954), Howard (1955), Taylor (1960), and McKnight (1964). Although Cretaceous strata studied by Taubeneck (1950), Snook (1957), and White (1964) lie short distances out of the Mitchell quadrangle, they undoubtedly belong to the same unit. The variety of localized terms employed by the above workers are considered provincial and the correlations between them are probably inaccurate (Oles, oral communication, 1971).

Lithology: The Gable Creek Formation and the Hudspeth Formation together are present in thicknesses of up to 9,000 feet. The Gable Creek Formation consists of a series of interbeds of conglomerate and lithic arenite which wedge out to the south into the finer-grained marine Hudspeth Formation. In order of abundance the clasts consist of chert, quartzite, and granite. Minor amounts of phyllite, greenstone, rhyolite, andesite, mudstone, and calcareous sandstone are also present.

Channel structures and graded bedding probably reflecting continuously shifting stream regimen are widespread. Cross bedding, grain size distribution, imbrication and channel orientations indicate a southerly direction of transport within the Mitchell quadrangle.

Contacts: The unit overlies the lower part of the Hudspeth Formation and intertongues with the middle and upper Hudspeth Formation to the south.

Age: An Albian and Cenomanian age is assigned to the unit.

References: Oles and Enlows, 1971
Wilkinson and Oles, 1968

"GOLD CREEK GREENSTONE"

Original description: "Gold Creek Greenstone" is an informal term proposed by Prostka (1962) for small exposures of Late Triassic greenstone that underlie the Lower Sedimentary Series of Prostka in the northeast corner of the Sparta quadrangle. The unit is equivalent to the "Imnaha Formation" of Wetherell (1960) according to Prostka (1963) and Vallier (oral communication, 1971). According to Prostka it also is equivalent to part of unit "A " of the Clover Creek Greenstone in the western Sparta quadrangle, (written communication, 1971).

Lithology: The "Gold Creek Greenstone" consists of approximately 2,000 feet of spilitic and minor keratophyric flows interbedded with subordinate amounts of graywacke, mudstone, and breccia. The unit thickens to the northeast where it can practically be walked into the "Imnaha Formation" according to Prostka (written communication, 1971).

Contacts: Although the base of the "Gold Creek Greenstone" is not exposed, Prostka (written communication, 1971) interprets an unconformity with the underlying Permian rocks on the basis of the unconformable relationship between the laterally equivalent "Imnaha Formation" and the Permian strata farther to the northeast.

The "Gold Creek Greenstone" is conformably overlain by the Lower Sedimentary Series in the northeast part of the Sparta quadrangle.

Age: A Late Triassic age is assigned to the unit on the basis of lithology and stratigraphic position. Prostka, (written communication, 1971) believes that the "Gold Creek Greenstone" and unit "A" of his Clover Creek Greenstone lie unconformably above the Clover Creek Greenstone of Gilluly (1937). To the east, however, Vallier (oral communication, 1971) believes the laterally equivalent "Imnaha Formation" is a correlative of the Clover Creek Greenstone.

References: Prostka, 1962, 1963

GRASSY MOUNTAIN FORMATION

Original description: Bryan (1929) named the Grassy Mountain Basalt after exposures capping Grassy Mountain in Malheur County immediately north of the present day Owyhee Reservoir. The name has subsequently been modified to Grassy Mountain Formation in recognition of the tuffaceous interbeds. As mapped by Kittleman and others (1967) the unit includes all the post-Deer Butte sediments underlying the

basalt. Corcoran and others (1962) assign much of the underlying sediments to the Kern Basin Formation.

Distribution: The unit is widespread in northern Malheur County northwest of the Owyhee Reservoir in a series of exposures extending northward beyond the Malheur River to the area northwest of Harper.

Lithology: The Grassy Mountain Formation consists of numerous flows of brown-gray to olive-black aphanitic to porphyritic olivine basalt of local extent interbedded with a variety of friable tuffaceous sediments of fluvial and lacustrine origin. The flows vary from 10 to 100 feet in thickness and the unit as a whole is 500 to 1,000 feet thick. The basalt is coarser and contains more olivine than Miocene flows in the same general area which are assigned to the Antelope Flat Basalt.

The interbedded volcanic sediments consist primarily of vitric sandstone. Below the lowermost basalt flow are sediments assigned to the Kern Basin Formation by Corcoran and others (1962), but included in the Grassy Mountain Formation by Kittleman and others (1965, 1967). They consist of light-gray pumice lapilli tuff, yellow-gray friable arkosic sandstone, and ash, with very minor amounts of arkosic granite conglomerate and volcanic conglomerate (see Kern Basin Formation).

Contacts: According to Corcoran and others (1962) the Grassy Mountain Formation is unconformable beneath the Chalk Butte Formation and unconformable over the Kern Basin Formation. As described by Kittleman and others (1965, 1967) the Grassy Mountain Formation is unconformable over the Deer Butte Formation.

Age: Clarendonian and Hemphillian vertebrates indicate an early to middle Pliocene age for the unit.

References:
Baldwin, 1964
Bryan, 1929
Carlat, 1954
Corcoran, 1965
Corcoran and others, 1962
Kittleman, 1962
Kittleman and others, 1965, 1967
McMurray, 1962
Privrasky, 1953
Renick, 1930
Russell, 1961
Weeden, 1963

"GRASSY RIDGE FORMATION"

Original description: The "Grassy Ridge Formation" is an informal term introduced by Vallier (1967) in reference to exposures of Late Triassic spilite on the west side of Grassy Ridge in the Snake River Canyon. Apparently the unit predates other Triassic units in the area.

Lithology: The unit consists of up to 4,000 feet of primarily spilitic pyroclastic rocks including tuffs and tuff breccias interbedded with lesser amounts of porphyritic to aphanitic flow rock, also of spilitic composition. Keratophyric rocks are very minor.

Interbedded with the volcanics are localized deposits of epiclastics which include conglomerates in the west and sandstones and siltstones in the south.

According to Vallier (1967) the spilitic composition, abundant volcanic breccia, local carbonaceous limestone, and only minor development of conglomerate serve to distinguish the unit from the "Hunsaker Creek Formation."

The unit differs from the "Doyle Creek Formation" in its lesser abundance of flow rock, its greenish rather than red hue, and its more subdued topographic relief.

A topographic high to the west during deposition of the unit is suggested by the abundance of conglomerate to the west and the predominance of volcanic marine flow rock to the northeast. Vallier (1967) postulates deposition in a localized tectonic basin with sediments being derived primarily from a volcanically active western landmass of undefined extent.

Contacts: The "Grassy Ridge Formation" predates the "Doyle Creek Formation" and is unconformable over Permian strata.

Age: A Ladinian (late Middle Triassic) age is assigned to the unit on the basis of pelecypods and a lowermost Karnian age is suggested for the unit on the basis of ammonites. It correlates in part with the "Imnaha Formation" (Vallier, oral communication, 1971).

Reference: Vallier, 1967

GRAYLOCK FORMATION

Original description: Dickinson and Vigrass (1965) defined the Graylock Formation and designated as the type locality exposures on the Elkhorn Creek-Morgan Creek divide in sec. 12, T. 17 S., R. 27 E.

Distribution: The Graylock Formation is limited in distribution to an area of less than one square mile in the area immediately surrounding the type locality.

Lithology: The unit consists of thin-bedded, dark-gray to black siltstone with thin interbeds of black argillaceous limestone low in the section. The siltstone is laminated and firm, although not as hard as the Rail Cabin Argillite. Also, it displays hackly fracture rather than subconchoidal fracture such as that displayed in the Rail Cabin Argillite.

The siltstones coarsen locally to fine-grained volcanic graywacke having a composition of 50 percent keratophyre clasts, 20 percent albite, and 5 percent quartz with matrix constituting the remainder. The limestone is a thin-bedded argillaceous calcilutite similar to that present in the upper part of the Rail Cabin Argillite. Dickinson and Vigrass (1965) interpret a shallow water, brackish environment of deposition, possibly transitional to an estuarine embayment.

Contacts: The Graylock Formation is probably unconformable over the Rail Cabin Argillite and it is unconformable under the Mowich Group.

Age: The Graylock Formation contains Hettangian (lowermost Early Jurassic) ammonites. In addition, a Sinemurian age is possible for the upper part of the section. The unit correlates with gray, silty strata and nodular limestone exposed southeast of the Williams Reservoir (T. 19 S., R. 25 E.).

Reference: Dickinson and Vigrass, 1965

HARNEY FORMATION

Original description: The Harney Formation was defined by Piper, (1936) and subsequently by Piper, Robinson, and Park (1939). Exposures on the east face of Dog Mountain along the boundary between secs. 20 and 28, T. 25 S., R. 30 E., in central Harney County are designated as the type locality.

Distribution: The Harney Formation crops out as an erosion plane of intermediate elevation which borders the western edge of the lower lying central alluvial plane of the Harney Basin.

Lithology: At the type section the Harney Formation consists of interbedded massive basaltic tuff, light-tan to gray sandstone, tuffaceous shale, and basaltic conglomerate. Basaltic scoria is present in minor quantities. Elsewhere cross-bedded gravel and fine-grained stratified volcanic ash are also present. The unit is up to 750 feet thick.

Contacts: The Harney Formation is unconformable over the Danforth Formation.

Age: A tentative late Pliocene age is assigned to the unit on the basis of stratigraphic position.

References: Ogren, 1958 Piper, 1936 Piper and others, 1939

HAYES BUTTE BASALT

Original description: The Hayes Butte Basalt was defined by Hampton (1964) who designated Hayes Butte and its lava shield in T. 27 S., R. 15 E. and northern T. 28 S., R. 15 E. as the type locality.

Distribution: The unit forms extensive exposures in Fort Rock Basin in northern Lake County.

Lithology: The Hayes Butte Basalt consists of up to 1,300 feet, but more commonly 100 feet, of light- to dark-gray basalt with textures that range from frothy and scoriaceous to diktytaxitic. Flows average 10 to 30 feet in thickness and are dense and jointed in the interiors. Thickness patterns and detailed stratigraphy indicate derivation from local vents aligned along northwest-trending faults within the basin.

Contacts: The unit is unconformable over the Fort Rock Formation and unconformable under the Peyerl Tuff and the Paulina Basalt.

Age: On the basis of stratigraphic position a late Pliocene and possible early Pleistocene age is assigned to the unit.

Reference: Hampton, 1964

HUDSPETH FORMATION

Original description: The Hudspeth Formation was defined by Wilkinson and Oles (1968). Owing to complex intertonguing with the Gable Creek Formation, they do not designate a type section. Instead three reference sections in the south central Mitchell 15' quadrangle are designated.

Distribution: The Hudspeth Formation and Gable Creek Formation constitute all the Cretaceous exposures in the Mitchell 30' quadrangle and are extensively exposed in the area surrounding the Mitchell Fault in the southern part of the quadrangle. (See Gable Creek Formation.)

Lithology: The unit consists of a series of olive-gray to dark-gray, friable mudstones with subordinate amounts of siltstone and sandstone. It wedges out to the north into the nonmarine Gable Creek Formation through a series of intertongues and, together with the Gable Creek Formation, has a total thickness greater than 9,000 feet.

A shallow-water, sheltered marine environment is interpreted on the basis of fossil content, lithology, and primary structures such as laminations, cross laminations, cross bedding, mudcracks, and load casts.

Contacts: The Hudspeth Formation is unconformable over Permian strata and it grades laterally to the north into the Gable Creek Formation. The lowermost part of the unit is conformable beneath the lower part of the Gable Creek Formation.

Age: The Hudspeth Formation is Albian and Cenomanian in age.

References: Oles and Enlows, 1971
Wilkinson and Oles, 1968

"HUNSAKER CREEK FORMATION"

Original description: The unit was informally proposed by Vallier (1967) for exposures on the north side of Hunsaker Creek in the Snake River Canyon. The "Hunsaker Creek Formation" is roughly equivalent to the "Trinity Creek Formation" of Wetherell (1960) and possibly the Permian part of the Clover Creek Greenstone.

Lithology: The "Hunsaker Creek Formation" consists of approximately 8,000 to 10,000 feet of volcaniclastic rock and subordinate keratophyre, conglomerate, nonpillowed spilite, mudstone, and bioclastic limestone. The volcaniclastic rocks consist largely of breccias, volcanic graywacke, arenites, and volcanic siltstones.

The unit contains less spilite and more volcaniclastic debris than the overlying "Grassy Ridge Formation." Also, as a result of its keratophyric rather than spilitic composition, it weathers to give gray and light-brown colors rather than the reddish colors characteristic of the "Grassy Ridge Formation." According to Vallier (1967) current and provenance indicators suggest a source to the west or the southwest.

Contacts: The unit is unconformable over the "Windy Ridge Formation" and unconformable under the Triassic "Grassy Ridge Formation." The "Hunsaker Creek Formation" is unconformable beneath the "Imnaha Formation" of Wetherell (1960) in the vicinity of Fish Lake where Wetherell (1960) incorrectly interpreted a conformable relationship.

Age: The "Hunsaker Creek Formation" is probably of Leonardian and Wordian (middle Permian) age.

Reference: Vallier, 1967

HUNTER CREEK BASALT

Original description: Kittleman and others (1965) defined the Hunter Creek Basalt and designated as the type locality exposures at Hunter Creek in the SW$\frac{1}{4}$ SW$\frac{1}{4}$ NW$\frac{1}{4}$ sec. 26, T. 21 S., R. 39 E., in east-central Oregon.

Distribution: The unit is exposed in the Monument Peak, Malheur Gorge, and Harper Basin areas of northern Malheur County. It extends southwest to the vicinity of Warm Springs Reservoir.

Lithology: The unit consists of several flows of felty, aphanitic, dense, nonvesicular, black basalt. It is closely jointed and is up to 400 feet thick.

Contacts: The Hunter Creek Basalt overlies the Dinner Creek Welded Ash-Flow Tuff and underlies the Littlefield Rhyolite. It is postdated by the Butte Creek Volcanic Sandstone and according to Haddock (1967) it is locally unconformable under the Juntura and Bully Creek Formations.

Age: On the basis of stratigraphic position a late Miocene age is assigned to the unit.

References: Haddock, 1967
Kittleman and others, 1965, 1967

HURWAL FORMATION

Original description: The Hurwal Formation was named by Smith and Allen (1941) for exposures on Hurwal Divide in the center of the Wallowa Lake quadrangle in Wallowa County.

Distribution: The unit is present as a series of fairly extensive exposures which form a band around the northern and eastern parts of the Wallowa Mountains from the vicinity of Enterprise on the north to Cornucopia to the south. Prostka (1967) suggests that the "gray phyllite" in the Durkee quadrangle to the south may be equivalent to this unit.

Lithology: The Hurwal Formation consists of minor dark-gray, fossiliferous, calcareous, shaly limestone grading upsection into a thick series of clastic sediments which include argillite, black shale, delicately cross-bedded and graded siltstone with load casts, tuffaceous lithic sandstone and conglomerate. Total thickness for the unit is at least several thousand feet. Throughout the section argillite and siltstone are the dominant rock types. A 238-foot bed of well-rounded limestone conglomerate and a conglomerate of chert pebbles and volcanic rock fragments are reported high in the section in the Sparta quadrangle (Prostka, 1963). Locally, varying degrees of metamorphism have altered the Hurwal Formation to varieties of hornfels and phyllite in addition to argillite.

Contacts: The Hurwal Formation is generally interpreted to be conformable over the Martin Bridge Formation. It is overlain unconformably by Tertiary strata.

Age: An upper Karnian and lower to middle Norian age (Late Triassic) is interpreted for most of the Hurwal Formation (Silberling and Tozar, 1968) on the basis of a fairly diagnostic ammonite fauna.

In addition, beds situated 5½ miles southwest of Enterprise are designated as Hurwal Formation by Nolf (1966) and are dated as late Sinemurian through late Pleinsbachian (Early Jurassic) by Imlay (1968). The upper 620 feet of these beds correlate with the upper third of the Suplee Formation and the lower third of the Nicely Formation in central Oregon (Imlay, 1968).

Although the specific stratigraphic relationships of the Early Jurassic rocks is uncertain, similar rocks nearby grade downsection into the Triassic and they are regarded as being part of the Hurwal Formation (Imlay, 1968).

References: Goebel, 1963; Imlay, 1968; Nolf, 1966; Palen, 1955; Prostka, 1963, 1967; Silberling and Tozar, 1968; Smedes, 1959; Smith and Allen, 1941

HYDE FORMATION

Original description: Lupher (1941) defined the Hyde Formation and designated as the type locality exposures at South Fork Bridge on the South Fork of the John Day River in sec. 30, T. 17 S., R. 28 E., in the Suplee-Izee district of central Oregon.

Distribution: The Hyde Formation crops out as a narrow band which extends for 20 miles in a northeasterly direction through the center of the Suplee-Izee district of central Oregon.

The present distribution near the junction of Freeman Creek and the South Fork of Beaver Creek (12 miles southwest of the type locality) differs somewhat from that originally designated by Lupher (1941). There his Hyde Formation is mapped as part of the Snowshoe Formation by Dickinson and Vigrass (1965), who choose to map the "incertae sedis" of Lupher (1941) as Hyde Formation. (See Mowich Group for a more complete explanation.)

Lithology: The Hyde Formation consists of 700 to 1,500 feet of resistant, massive, blue-gray andesitic marine tuff and tuffaceous volcanic graywacke intercalated with subordinate dark, laminated, volcanic siltstone and mudstone. The sandstone is moderately sorted, medium-grained, and shardy. In order of abundance it consists of clastic andesitic debris, nonvolcanic quartz, chert, and argillite. Mudstone is most abundant in the western part of the Suplee area and in the eastern part of the Izee area.

Contacts: The unit is conformable over the Nicely Shale and is conformable under the Snowshoe Formation in the Izee area. Near the juncture of Freeman Creek and the South Fork of Beaver Creek in the Suplee area, however, the Hyde Formation is unconformable beneath the Snowshoe Formation.

Age: The age of the Hyde Formation is designated as late Toarcian (Middle Jurassic) by Dickinson and Vigrass (1965) and as early Toarcian by Imlay (1968).

References: Dickinson and Vigrass, 1965
Imlay, 1968
Lupher, 1941

IDAHO GROUP (FORMATION)

Definition: The Idaho Formation was first mentioned by Cope (1883) in reference to sediments of Pliocene age in eastern Oregon which were thought to have been deposited in ancient Lake Idaho.

Historical treatment: The term Idaho Formation was applied to sediments of post-Grassy Mountain Basalt age in the Owyhee region by Bryan (1929) and Renick (1930). As such it was equivalent to the Chalk Butte Formation of Corcoran and others (1962).

Subsequently it was expanded by Kirkham (1931) to include sediments of pre-Grassy Mountain Basalt age which overlay the Owyhee Basalt. As such it included the Idaho Formation, Grassy Mountain Basalt, and Payette Formation of Bryan (1929) and Renick (1930). The sediments beneath the Grassy Mountain Basalt are referred to as Deer Butte Formation and lower Grassy Mountain Formation by Kittleman and others (1965) and as Deer Butte Formation and Kern Basin Formation by Corcoran and others (1962).

In recognition of the numerous distinct and mappable lithologic units within the formation, it was elevated to group status by Baldwin (1959, in Baldwin,1964), Malde and Powers (1962) and Corcoran and others (1962).

Lithology: The Idaho Group consists of a broad, almost flat-lying blanket of sedimentary rocks with some intercalated basalt flows in the middle of the section. A total thickness of 5,000 feet is developed and the aggregate thickness of the unit approaches 10,000 feet. The sediments include fluvial and lacustrine semi-consolidated claystones, shales, sandstones, tuffs, diatomites, and conglomerates.

Contacts and age: The Idaho Group of Kittleman and others (1965) includes the Deer Butte Formation, and the Grassy Mountain Formation. The Idaho Group of Corcoran and others (1962) includes the Kern Basin Formation (lower Grassy Mountain Formation of Kittleman and others, 1965), the Grassy Mountain Formation, and the Chalk Butte Formation. They exclude the Deer Butte Formation from the unit in recognition of the marked unconformity that separates the two units.

Unconformities within the Idaho Group probably feather out eastward toward the center of the basin where deposition was probably more continuous. Also, the basalts of the Grassy Mountain Formation are of local extent only and may not be present far to the east in the subsurface. Hence, individual units within the Idaho Group lose much of their identity towards the east beneath the younger volcanics, and direct correlations with exposures in Idaho are tenuous.

Remarks: For further discussion see Deer Butte Formation, Kern Basin Formation, Grassy Mountain Formation and Chalk Butte Formation.

References:
Baldwin, 1959, 1964
Bryan, 1929
Cope, 1883
Corcoran and others, 1962
Kirkham, 1931
Kittleman and others, 1965
Malde and Powers, 1962
Renick, 1930

"IMNAHA FORMATION"

Original description: "Imnaha Formation" is an informal term introduced by Wetherell (1960) for a series of volcanic rocks and related breccias and sediments of Late Triassic age in the Cornucopia quadrangle of the southern Wallowa Mountains. The strata were originally mapped as Clover Creek Greenstone in a small-scale map by Smith and Allen (1941).

Lithology: The "Imnaha Formation" of the Snake River Canyon consists of porphyritic and glomeroporphyritic flows of spilite, metabasalt, and meta-andesite (Vallier, 1967). In the Cornucopia quadrangle to the west equivalent flows are termed the Russell member by Wetherell (1960). The thickness of the unit exceeds 10,000 feet.

Overlying the volcanic flows in the Cornucopia quadrangle are up to 8,000 feet of marine clastic sediments, pillow lavas, and pillow breccias intercalated with feldspathic siltstones which Wetherell (1960) assigns to the "Norway member."

Contacts: The "Imnaha Formation" is unconformable over Permian strata including the "Hunsaker Creek Formation" of Vallier (1967). Although Wetherell (1960) interprets conformity with his Permian "Trinity Creek Formation" south of Fish Lake, remapping conducted by Vallier (1967) indicates a pronounced unconformity in that area. The lithology and stratigraphic position of the unit at the base of the Late Triassic section suggest rough equivalence to the other Late Triassic greenstones in the Wallowa Mountains, including part of the Clover Creek Greenstone of Gilluly (1937), the "Gold Creek Greenstone," and part of the "Doyle Creek Formation."

Age: A Late Triassic, post-Clover Creek and pre-Lower Sedimentary Series age is interpreted for the "Imnaha Formation." As such it is probably Karnian.

References: Gilluly, 1937
Prostka, 1963
Smith and Allen, 1941
Vallier, 1967
Wetherell, 1960

IZEE GROUP

Original definition: The Izee Group was originally defined by Lupher (1941) for exposures along the Ochoco anticline that extend from the western end of the Jurassic exposures northeastward across the South Fork Valley into western Bear Valley in central Oregon. He included in the unit the Hyde Formation and the Snowshoe Formation.

Present status: On the basis of more recent mapping, beds assigned to the Hyde Formation by Lupher (1941) are variously assigned to the Snowshoe Formation and the underlying Mowich Group by Dickinson and Vigrass (1965). Consequently the concept of Izee Group is no longer required.

References: Dickinson and Vigrass, 1965
Lupher, 1941

JOHN DAY FORMATION

Original description: The John Day Formation was defined by Marsh (1875) who designated exposures along the John Day River as the type locality.

Distribution: The John Day Formation crops out beneath the protective cover of the Columbia River Group at a variety of widespread localities in north-central Oregon including the Antelope-Ashwood area, Sutton Mountain, and the John Day Valley north of Picture Gorge. The unit is probably extensive to the north beneath the basalts of the Columbia River Group and it forms isolated outcrops of limited extent in Clarno terrain where the Columbia River Group is absent.

Lithology: In the Sutton Mountain area the John Day Formation consists of 3,000 feet of varicolored siltstones, claystones, and vitric tuffs which are dominated by reddish trachytic beds low in the section, greenish celadonitic beds in the middle of the section, and buff deposits high in the section. Alteration to heulandite, clinoptilolite, montmorillonite, celadonite, opal, and orthoclase is widespread.

In the Antelope-Ashwood area the development of numerous flows and domes of rhyolitic and dacitic composition in conjunction with the intercalation of lapilli tuffs, coarse-grained sedimentary rocks, and numerous ash-flow tuffs is indicative of a source area to the west. Of the possible vents Smith Rock, Grizzly Mountain, Gray Butte, Juniper Butte, and Powell Butte are the most prominent. Many of the smaller domes of rhyolitic composition which intrude the Clarno Formation may also have functioned as source areas in John Day times.

Contacts: The John Day Formation is unconformable beneath the Columbia River Group and overlies the Clarno Formation along a poorly defined contact. In the Antelope-Ashwood area and the Horse Heaven mining district the mafic lower parts of the John Day Formation are distinguished from the Clarno Formation primarily on the basis of their stratigraphic position above a distinctive ash-flow tuff interpreted to represent the base of the John Day Formation by Robinson (1968) and Swanson and Robinson (1968).

Taylor (1960), however, states that the structural deformation of the ash-flow tuff is more akin to that of the Clarno Formation in that area and, consequently, that it should be included in the Clarno Formation.

To the southeast in the Sutton Mountain area the contact is better defined and an unconformable relationship is interpreted. Farther to the east in Baker County, exposures mapped as Clarno Formation by Brown and Thayer (1966a) have yielded radiometric age dates equivalent to the John Day Formation (Walker, oral communication, 1971). The stratigraphic relationships of the two units are apparently complex and it is possible that additional stratigraphic units will be recognized in the future.

Age: An early Oligocene through early Miocene age is assigned to the John Day Formation on the basis of radiometric age data and fossil evidence. An age of 24.9 million years for the top of the section is reported by Evernden and James (1964) and an age of 36.4 million years is well established for the ash-flow tuff interpreted by some to be the base of the unit in the Horse Heaven mining district (Swanson, written communication, 1971). As discussed above, however, the stratigraphic position of the ash-flow tuff is open to debate.

Late Oligocene and early Miocene vertebrates and flora are reported by Walker, Peterson, and Greene (1967); Rensberger (1965) interprets a middle Oligocene age for some of the vertebrates in the unit. Strata in the Antelope-Ashwood area are dated as late Oligocene by Peck (1964) on the basis of floral content.

References:

Bedford, 1954
Bowers, 1953
Brown and Thayer, 1966a
Coleman, 1949
Cummings, 1958
Dawson, 1951
Dobell, 1948
Evernden and James, 1964
Fisher, 1966 a,b
Hay, 1963
Hodge, 1932a
Irish, 1954
Jolly, 1957
Lukanuski, 1963
Napper, 1958
Ojala, 1964
Patterson, 1965
Peck, 1964
Rensberger, 1965
Robinson, 1968
Snook, 1957
Stensland, 1970
Swanson, 1969a
Swanson and Robinson, 1968
Swarbrick, 1953
Swinney and others, 1968
Taubeneck, 1950
Taylor, 1960
Thomas, 1956
Walker, Peterson and Greene, 1967
Waters, 1968a, b, c
Waters and Vaughan, 1968 a, b
White, 1964
Wilcox and Fisher, 1966
Williams, 1957

JUMP CREEK RHYOLITE

Original description: The Jump Creek Rhyolite was formally defined by Kittleman and others (1965),

who designated exposures in the headwaters of Jump Creek east of the Owyhee Reservoir in adjacent Idaho as the type locality.

Distribution: As mapped by Kittleman and others (1967) the unit crops out east and south of the Owyhee Reservoir in southeastern Oregon. Rocks assigned to the unit are included in the Sucker Creek Formation by Corcoran and others (1962). Exposures at Owyhee dam mapped as Owyhee Rhyolite by Kirkham (1931) are not included in the unit.

Lithology and contacts: The Jump Creek Rhyolite is a mesa-forming unit which consists of 100 to 800 feet of grayish-red to gray porphyritic andesine rhyolite. It is highly probable that more than one vent expelled rhyolitic flows in southeastern Oregon during Mio-Pliocene times and it is recommended that the term Jump Creek Rhyolite be restricted to exposures directly traceable to the type locality. The unit overlies the Sucker Creek Formation of Kittleman and others (1965) and is unconformable under the late Pliocene basalt at Cow Creek Lakes.

Age: A late Miocene age is tentatively assigned to the unit on the basis of stratigraphic position.

References: Kittleman, 1962
Kittleman and others, 1965, 1967

JUNTURA FORMATION

Original description: Bowen and others (1963) defined the Juntura Formation and designated a type section having three segments including an upper section at the quarry three miles south of Pete Mountain, a middle segment at Juniper Hill, and a lower segment north of Scab Mountain.

Distribution: Exposures of the Juntura Formation are centered in the Juntura Basin in northern Malheur County and crop out in a series of connected basins which extend a distance of 20 miles north and west of the community of Juntura. It is also present in the Drewsey area in northeastern Harney County.

Lithology: The Juntura Formation consists of 1,250 feet of tuffaceous fluvial and lacustrine sediments intercalated locally with subordinate flows of basalt. The lower part of the unit consists of 400 feet of tuffaceous sandstones and volcanic ash capped by agglomerates and a thin flow of palagonitic basalt. Basaltic flow rocks crop out locally and lignitic deposits are developed near Drewsey.

The middle part of the unit consists of 450 feet of diatomite with minor amounts of lignitic material, ash, tuff, and basalt. The upper member is composed of 400 feet of tuffaceous sandstone, clay sandstone, pumice, and ash.

Contacts: The Juntura Formation is unconformable over the Tims Peak Basalt in the Malheur Gorge area and it is disconformable over the Owyhee Basalt in the Drinkwater Pass area. It is unconformably overlain by the Drewsey Formation and younger basalts.

Age: A Clarendonian (early Pliocene) age is assigned to the unit on the basis of vertebrate fossils.

References: Bowen, 1956
Bowen and others, 1963
Gray, 1956
Gregory, 1962
Haddock, 1967
Kittleman and others, 1965, 1967

KELLER CREEK SHALE

Original description: The Keller Creek Shale was defined by Brown and Thayer (1966a), who designated exposures in Keller Creek in the northwest corner of the Logdell quadrangle in the Aldrich Mountains as the type locality. (See Aldrich Mountain Group.)

Distribution: The Keller Creek Shale forms an east-west trending exposure 25 miles long and generally less than 5 miles wide and occupies part of the south limb of the Aldrich Mountain Anticline. It is partly overlain by the younger sediments of Bear Valley to the south.

Lithology: The Keller Creek Shale consists of up to 5,000 feet of graywacke and black shale. The lower 2,000 to 2,500 feet of the section are dominated by thick-bedded, coarse- to fine-grained tuffaceous graywacke with lenses of pebbly conglomerate, shale, and ash. The upper half of the unit consists predominately of gray to black shale with subordinate amounts of graywacke and siltstone. Massive coarse- to fine-grained sandstone is common high in the section.

Contacts: The unit is conformable over the Murderers Creek Graywacke and unconformable under Lower Jurassic volcanic and sedimentary rocks.

Age: An early to middle Sinemurian (early Early Jurassic) age is interpreted for the unit on the basis of megafossils.

Reference: Brown and Thayer, 1966a

KERN BASIN FORMATION

Original description: The Kern Basin Formation was defined by Corcoran and others (1962), who designated exposures in Kern Basin (sec. 1, T. 22 S., R. 44 E.) near the Owyhee Reservoir as the type locality.

Distribution: The Kern Basin Formation crops out extensively northwest of the Owyhee Reservoir in the central part of the Mitchell Butte 30' quadrangle. It is included in the lower part of the Grassy Mountain Formation by Kittleman and others (1965) and constitutes part of the Idaho Group.

Lithology: The unit consists of loosely consolidated fluvial and lacustrine, tuffaceous, arkosic sandstone and siltstone with subordinate amounts of bedded tuff, ash, and massive tuff breccia. Conglomerate derived from the underlying Deer Butte Formation and pumice lapilli tuff are common low in the section. Arkosic sandstone is more common higher in the section.

Contacts: The contact between the Kern Basin Formation and the overlying Grassy Mountain Formation of Corcoran and others (1962) is designated as a disconformity by Corcoran and others (1962). Kittleman and others (1965), who incorporate the Kern Basin Formation into the Grassy Mountain Formation, believe the contact to be conformable. The unit is unconformable over the Deer Butte Formation.

Age: A Clarendonian (early Pliocene) age is assigned to the unit on the basis of vertebrate remains.

References: Corcoran, 1965
Corcoran and others, 1962
Kittleman and others, 1965

LAYCOCK GRAYWACKE

Original description: Brown and Thayer (1966a) defined the Laycock Graywacke and designated exposures in upper Laycock Creek in the Aldrich Mountains as the type locality.

Distribution: The Laycock Graywacke forms an east-west trending exposure which covers approximately 30 square miles on the south flank of the Aldrich Mountain anticline midway between the John Day River on the north and Bear Valley on the south. (See Aldrich Mountain Group.)

Lithology: The unit consists of a maximum of 11,000 feet of coarse- to medium-grained graywacke and black shale which becomes increasingly finer grained upsection. High in the section the unit grades westward into tuff and feldspathic graywacke.

Contacts: The contact between the Laycock Graywacke and the underlying Fields Creek Formation is conformable in some places and unconformable in others. The unit is conformably overlain by the Murderers Creek Graywacke.

Age: The Laycock Graywacke is assigned a Late Triassic Age. It has yielded fossils questionably assigned to the genus Monotis (Silberling, written communication, 1971).

References: Brown and Thayer, 1966a, c

LITTLEFIELD RHYOLITE

Original description: Kittleman and others (1965) defined the Littlefield Rhyolite and designated exposures at Littlefield Ranch (sec. 35, T. 23 S., R. 40 E.) in the Crowley district of central Malheur County as the type locality.

Distribution: The Littlefield Rhyolite crops out in the Crowley, Monument Peak, Harper Basin, and Malheur Gorge districts of northern and central Malheur County.

Lithology: The Littlefield Rhyolite consists of up to 500 feet of flaggy, grayish-red to dark-gray porphyritic rhyolite. The unit is irregularly devitrified and displays spherulitic and pilotaxitic structures. It is conspicuously flow-banded and shows no evidence for an ash-flow origin in spite of its extent. The unit is interpreted to be a series of rhyolite flows.

Contacts: The Littlefield Rhyolite is unconformable over the Hunter Creek Basalt and the "Unnamed igneous complex." It is unconformable beneath the Bully Creek Formation and the Butte Creek Volcanic Sandstone.

Age: A Barstovian (late Miocene) age is assigned to the unit on the basis of stratigraphic position. The age of the unit relative to the Jump Creek Rhyolite is unclear, although it probably is somewhat younger.

References: Haddock, 1967
Kittleman and others, 1965, 1967

LONESOME FORMATION

Original description: Lupher (1941) defined the Lonesome Formation. The type area extends from the vicinity of Spoon Creek on Snow Mountain northeastward across the valley of the South Fork of the John Day River.

Distribution: The Lonesome Formation is exposed over an area covering 20 square miles in the Lonesome Syncline in the southeast corner of the Suplee district in central Oregon.

Lithology: The Lonesome Formation exhibits a maximum thickness of 4,000 feet according to Lupher (1941) and may be as thick as 10,000 feet according to Dickinson and Vigrass (1965). It consists of a monotonous repetition of moderately sorted, graded interbeds of volcanic graywacke and dark interbeds of mudstone. Individual beds vary in thickness from one inch to ten feet. Graded pebble-bearing graywackes and pebble conglomerates crop out high in the section.

Contacts: The Lonesome Formation is gradational over the Trowbridge Formation. The thick sandstone and conglomerate basal unit of Lupher (1941) is interpreted as one of several coarse-grained interbeds within the unit by Dickinson and Vigrass (1965).

Age: Although the Lonesome Formation lies physically above the early to middle Callovian Trowbridge Formation, it is assigned an early Callovian age. Rapid deposition in the late Middle Jurassic is indicated

References: Dickinson and Vigrass, 1965
Imlay, 1964a
Lupher, 1941

LOWER SEDIMENTARY SERIES

Original description: This informal term was first applied by Smith and Allen (1941) to a series of Late Triassic metamorphosed sedimentary rocks in the northern Wallowa Mountains. Rocks included in the unit are part of the complex assemblage of volcanic and sedimentary strata which underlies the Martin Bridge Formation. (See Clover Creek Greenstone.)

Historical treatment: Complex facies changes and poor fossil control have resulted in an inconsistent treatment of the Lower Sedimentary Series throughout the Wallowa Mountains. The boundaries of the unit as mapped by Smith and Allen (1941) were redefined in part by Laudon (1956), Wetherell (1960), and Carnahan (1962) in their respective study areas on the basis of local evidence. Prostka (1963) correlated the Lower Sedimentary Series and his "Gold Creek Greenstone" with the upper part of the Clover Creek Greenstone (unit "A") in the Sparta Quadrangle. In a later interpretation he considers the three units to be unconformable over the remainder of the Clover Creek Greenstone (written communication, 1971).

Vallier (oral communication, 1971), regards the Pittsburg Formation of Wagner (1945) and the upper part of the "Doyle Creek Formation" of Vallier (1967) to be stratigraphically equivalent to the Lower Sedimentary Series. The Lower Sedimentary Series is equivalent to part of the "Carboniferous (?) sedimentary rocks" of Ross (1938).

Lithology: Smith and Allen (1941) described the unit as consisting of a series of shale, sandstone, and limestone variably altered to pyritized hornfels, schist, quartzite, and crystalline limestone. They report a maximum thickness of approximately 2,000 feet at Point Joseph. Although argillites are the most common rock type, conglomerates and breccias compose up to half of the section locally (Laudon, 1956), and complex facies changes characterize the unit.

Wetherell (1960) used the term Lower Sedimentary Series for a sedimentary sequence dominated by thin repetitious beds of fine-grained pyritiferous sandstone in the Cliff River-Red Mountain area in the eastern Wallowa Mountains. The exposures were mapped as Hurwal Formation and Lower Sedimentary Series by Smith and Allen (1941).

Prostka (1963) correlated approximately 3,000 feet of the section in the northeastern Sparta quadrangle with the Lower Sedimentary Series and stated that the lower two-thirds of the section consisted of submarine andesitic and dacitic breccia intercalated with minor amounts of volcaniclastic rocks. According to Prostka (1963) the upper one-third of the unit consists of fine-grained sandstone, siltstone, and argillite.

Contacts: The Lower Sedimentary Series is overlain stratigraphically by the Martin Bridge Formation and is underlain by, and locally grades laterally into, strata regarded as continuous with or equivalent to the Triassic part of the Clover Creek Greenstone of Gilluly (1937). Contact relationships with the Martin Bridge Formation were interpreted to be strongly unconformable by Smith and Allen (1941), who noted that the limestone of the Martin Bridge Formation lies directly upon the Clover Creek Greenstone on Hurricane Ridge and on the Middle Fork of the Imnaha River. Subsequent mapping by numerous workers in surrounding areas indicate a regionally conformable relationship (Prostka, 1963; Vallier, oral communication, 1971).

Age: A Karnian (Late Triassic) age is indicated for the Lower Sedimentary Series by fossils collected by Smith and Allen (1941) and Laudon (1956). These collections were taken from the northern Wallowa Mountains, however, and exposures in the southern Wallowas were assigned a similar age on the basis of stratigraphic position and lithology. Wetherell (1960) found Permian fossils in part of the Lower Sedimentary rocks of Smith and Allen (1941) and mapped those exposures as "Trinity Creek Formation."

References:
Carnahan, 1962
Gilluly, 1937
Goebel, 1963
Laudon, 1956
Palen, 1955
Prostka, 1962, 1963, 1967
Ross, 1938
Smedes, 1959
Smith and Allen, 1941
Vallier, 1967
Wagner, 1945
Wetherell, 1960

MADRAS FORMATION

Discussion: Madras Formation is a term proposed by Hodge (1941) and used by Williams (1957) for Pliocene strata in the vicinity of Madras.. The term Deschutes Formation is recommended here in recognition of the historical priority of that erm (Russell, 1905). Although the exposures are sometimes included in the Dalles Formation (Hodge, 1942; Waters, 1968b; Peck, 1964), treatment as a distinct unit is recommended. The Deschutes Formation contains more ash than the Dalles Formation and may have wider age range. It also is geographically isolated from the type Dalles Formation. (See Deschutes Formation.)

MARTIN BRIDGE FORMATION

Original description: The Martin Bridge Formation was defined by Ross (1938). The type locality is located at the bridge which crosses Eagle Creek in the center of T. 7 S., R. 44 E., in Baker County.

Distribution: The Martin Bridge Formation is widely distributed throughout much of northeastern Oregon and is exposed in the Sparta, Durkee, Enterprise, Eagle Cap, and Mineral quadrangles. Particularly good exposures are developed in the central Wallowa Mountains.

Because more than one Mesozoic limestone unit may be present in the area, exposures of limestone with uncertain stratigraphic relationships should not be automatically equated with the Martin Bridge Formation. The limestone at Lime is probably younger than the Martin Bridge Formation, and the "Nelson Marble" of Prostka (1967) also is probably a distinct stratigraphic unit.

Lithology: The Martin Bridge Formation consists of a maximum of 3,000 to 5,000 feet of light to dark-gray and bluish, fine-grained marble and subordinate gray calcareous phyllite. Intercalations of argillaceous, tuffaceous, arenaceous, and carbonaceous material increase upsection.

The limestones are dominated by relatively shallow water coral limestones and calcilutites low in the section, by limestone breccias in the middle of the section, and by relatively deep-water carbonaceous limestones high in the section.

Contacts: The Martin Bridge Formation grades upsection into the Hurwal Formation through a series of shaly interbeds. The unit is generally conformable over the Lower Sedimentary Series and its lateral equivalents, including the Pittsburg Formation in the middle reaches of the Snake River Canyon (Vallier, oral communication, 1971).

Age: An upper Karnian (Late Triassic) age is well-established for the Martin Bridge Formation on the basis of fossil coral, gastropods, pelecypods, and crinoids. Ammonites described by Vallier (1967) indicate an uppermost Karnian through early Norian age for the unit.

References: Carnahan, 1962
Goebel, 1963
Laudon, 1956
Prostka, 1963, 1967
Ross, 1938
Smedes, 1959
Smith and Allen, 1941
Vallier, 1967
Wagner, 1958a
Wetherell, 1960

MASCALL FORMATION

Original description: The Mascall Formation was named by Merriam (1901a) after exposures near the Mascall Ranch 4 miles south of Dayville in central Oregon.

Distribution: The Mascall Formation is best developed in the John Day Valley between Picture Gorge and the community of John Day. It is also preserved in Fox Basin 15 miles to the northeast and in Beech Creek Basin five miles east of Fox Basin.

The Mascall Formation is included in the Columbia River Group by Brown and Thayer (1966a) who interpret it to be a preserved remnant of a late Miocene alluvial fan which extended northward and westward from a volcanic high centered around Strawberry and Lookout Mountains.

Lithology: The Mascall Formation consists of a maximum of 2,000 feet of fluvial sandstone, ash, light-colored water-laid tuff, and well-rounded conglomerate. The conglomerate is increasingly coarse-grained towards the east and is composed of clasts of chert, metavolcanics, and rhyolite.

Within the Mascall Formation is a widespread ignimbrite unit which consists of 97 to 99 percent glass shards and minor amounts of anorthoclase, quartz, magnetite, zircon, and clinopyroxene. That 10 percent of the anorthoclase consists of orthoclase is considered to be a unique feature of the unit by Davenport (1970).

Contacts: The Mascall Formation is interpreted to interfinger with basalts of the Columbia River Group assigned to the Yakima Basalt by Thayer and Brown (1966b,c). East of Mt. Vernon it is also thought to grade laterally into the rhyolitic marginal facies of the Columbia River Group. The Mascall Formation is unconformable beneath the Rattlesnake Formation.

Age: A late Miocene age is established for the Mascall Formation by Barstovian vertebrates recovered from the unit and by radiometric dating techniques which have yielded an age of 13 million years for the interbedded ignimbrite unit.

The stratigraphic relationships of fluvial deposits that have yielded early Pliocene vertebrates in the Unity Basin (Brown and Thayer, 1966a) are unclear and the involved beds may not be correlative to the Mascall Formation.

References: Brown and Thayer, 1966a
Coleman, 1949
Cummings, 1958
Davenport, 1970
Dawson, 1951
Dobell, 1948
Forth, 1965
Irish, 1954
Merriam, 1901a
Taubeneck, 1950
Thayer and Brown, 1966b, c
White, 1964

MOWICH GROUP

Original definition: The Mowich Group was defined by Lupher (1941) after exposures on the limbs of the Mowich anticline in the Suplee-Izee district of central Oregon. He designated exposures in the headwaters of the South Fork of Beaver Creek 7 miles southeast of the Suplee post office (secs. 26, 27, 28, 29, T. 18 S., R. 26 E.) as the type locality. As defined the unit included in ascending order the Robertson Formation, Suplee Formation, and the Nicely Shale.

Revised definition: The Mowich Group of Dickinson and Vigrass (1965) is essentially equivalent to that of Lupher (1941) with the exception that it also includes the Hyde Formation as discussed below.

Along Freeman Creek 12 miles southwest of the type locality of the Hyde Formation (Lupher (1941) assigned fossiliferous strata to the Hyde Formation on the basis of lithology. The fossils and stratigraphic position of the exposures indicated a post-Mowich age and Lupher included them in the Izee Group along with the Snowshoe Formation.

Recent more detailed mapping by Dickinson and Vigrass reveals that beds unconformable beneath the Hyde Formation of Lupher in the Freeman Creek area are laterally continuous with the type Hyde Formation. Because the beds are conformable with the underlying Nicely Shale, they included them with the Nicely Shale in the Mowich Group. The involved strata were termed "incertae sedis" by Lupher (1941).

Strata unconformable over the Hyde Formation of Dickinson and Vigrass (1965) and originally assigned to the Hyde Formation by Lupher (1941) are included in the Snowshoe Formation by Dickinson and Vigrass (1965). (See also Izee Group, Hyde Formation.)

References: Dickinson and Vigrass, 1965
Lupher, 1941

MURDERERS CREEK GRAYWACKE

Original description: The Murderers Creek Graywacke was defined by Brown and Thayer (1966a), who designated exposures in upper Murderers Creek in the Aldrich Mountains as the type locality.

Distribution: The unit forms thin exposures generally less than one mile wide and is bounded on the east and south by the Quaternary sediments of Bear Valley. The unit occupies part of the south limb of the Aldrich Mountain anticline and is part of the Aldrich Mountain Group.

Lithology: The Murderers Creek Graywacke consists of up to 1,500 feet of medium- to coarse-grained calcareous graywacke and subordinate lenses of limestone breccia and conglomerate which occur low in the section and are up to 1,500 feet in length. Blocks in the breccia vary from two inches to 20 feet in their greatest dimension.

Contacts: Although some channeling into the underlying Laycock Graywacke is associated with the breccias, the contact between the Murderers Creek Graywacke and the Laycock Graywacke is interpreted to be conformable. Locally intertonguing with the tuffs of the Laycock Graywacke is noted, but in general a sharp lithologic break marks the contact. The unit is conformably overlain by the Kellers Creek Shale.

Age: Diagnostic Norian ammonites have been recovered from the limestone blocks in the breccia lenses. Hence the unit is no older than Norian and it is placed in the Late Triassic.

References: Brown and Thayer, 1966 a, c

"NELSON MARBLE"

Definition and distribution: "Nelson Marble" is an informal term introduced by Prostka (1967) for exposures of marble at Nelson where the Burnt River has cut a deep gorge between Gold Hill and Gold Ridge in the Durkee quadrangle. The unit is also exposed in Sisley Creek and it can be traced eastward to Conner Creek and across the Snake River into Idaho. To the west it is continuous with the thick discontinuous marble beds of the Burnt River Schist.

Lithology: The "Nelson Marble" consists of light-gray, fine-grained marble and dark gray calcareous

phyllite. It is 1500 feet thick at Nelson. The "Nelson Marble" displays a significantly higher degree of metamorphism than the Martin Bridge Formation, a feature which is subject to several interpretations, as discussed below.

Contacts: The "Nelson Marble" is included in strata which are continuous with the Burnt River Schist, the stratigraphic relationships of which are poorly understood. Rocks in contact with the "Nelson Marble" in the Durkee quadrangle vary from place to place suggesting either faulting or unconformity.

Age: A tentative Late Triassic age has been assigned to the "Nelson Marble" by Prostka (1967) on the basis of lithologic similarities to the Martin Bridge Formation. He feels that the higher metamorphic grade is a result of local intrusion in the southern Durkee quadrangle. Brooks (oral communication, 1971) points out that regional map patterns in addition to metamorphic and structural geometry suggest that the "Nelson Marble" is equivalent to parts of the Burnt River Schist in the Baker quadrangle, and that the structural style of the Burnt River Schist is unlike that of the known Mesozoic strata in the region.

Reference: Prostka, 1967

NICELY SHALE (FORMATION)

Original description: The Nicely Shale was first defined by Lupher (1941), who designated exposures along the headwaters of the South Fork of Beaver Creek seven miles southeast of the Suplee post office (secs. 26, 27, 28, 29, T. 18 S., R. 26 E.) as the type locality.

Distribution: The Nicely Shale is limited to exposures in the immediate vicinity of the type area in the Suplee-Izee district of central Oregon. The unit is included in the Mowich Group.

Lithology: The Nicely Shale consists of 75 to 350 feet of black, flaky shale with subordinate amounts of mudstone. Thin interbeds of calcareous siltstone and sandstone are increasingly abundant to the east.

The unit contains a 50-foot thick flow of porphyritic labradorite-augite lava which apparently grades laterally into a sandstone interbed.

Contacts: The Nicely Shale is conformable over the Suplee Formation and grades upsection into the Hyde Formation of Dickinson and Vigrass (1965).

Age: A late Pleinsbachian (middle Early Jurassic) age is interpreted for the unit (Imlay, 1968). Earlier designations of a Toarcian age are erroneous owing to a misinterpretation of the genus Dactylioceras in relation to the European time scale (Imlay, 1968).

References: Dickinson and Vigrass, 1965; Imlay, 1968; Lupher, 1941; Waisgerber, 1956

OCHOCO LAVAS

Original description: The Ochoco Lavas were defined by Wilkinson (1939). He designates no type locality, but notes that the lavas are widespread in the eastern and northeastern parts of the Round Mountain 30' quadrangle of central Oregon.

Distribution: The Ochoco Lavas are widespread in the northern half of the Round Mountain quadrangle and extend short distances into the southern Mitchell quadrangle and the western Dayville quadrangle. The unit is equivalent to the Ochoco Formation of Hodge (1942) and the "Ochoco Basalts" of Forth (1965) and Howard (1955).

Lithology: The Ochoco Lavas consist of a series of flows of platy, porphyritic, olivine basalt flows that are traceable to several local vents including Arrowhead Point in the Round Mountain quadrangle and Maupin Butte and Twelve Mile Table Mountain in the Dayville quadrangle. Thicknesses of up to 700 feet are developed near the source areas and the unit tapers to thicknesses of about 15 feet at its distal edges. Characteristically the basalt is a ridge-former and an inverted topography is developed beneath it in the southern Mitchell quadrangle.

Contacts: The Ochoco Lavas are unconformable over the Rattlesnake Formation and older units.

Age: A late Pliocene or early Pleistocene age is interpreted for the unit on the basis of stratigraphic position and topographic expression.

References: Forth, 1965
Hodge, 1942
Howard, 1955
Wilkinson, 1939

OWYHEE BASALT

Original description: The Owyhee Basalt was defined by Bryan (1929) after exposures along the lower Owyhee River in Malheur County. The type section was designated by Kittleman and Others (1965) to include exposures in the S.E.$\frac{1}{4}$ of sec. 20, T. 22 S., R. 45 E.

Distribution: The Owyhee Basalt forms fairly extensive exposures that are centered at the northern end of the Owyhee Reservoir in east central Malheur County.

Lithology: The Owyhee Basalt consists of up to 1,300 feet of flow-on-flow, dense to scoriaceous, olivine-free basalt. Colors range from dark gray and black to dusky red and scattered interbeds of tuff and ash are indicative of contemporaneous explosive volcanism in the area.

Contacts: The unit is unconformably overlain by the Deer Butte Formation and the Grassy Mountain Formation. It unconformably overlies the Sucker Creek Formation.

Age: On the basis of stratigraphic position the Owyhee Basalt is assigned a late Miocene age and it is correlated with the Steens Basalt.

References: Bryan, 1929
Carlat, 1954
Corcoran, 1965
Corcoran and others, 1962
Kittleman, 1962
Kittleman and others, 1965, 1967
Porter, 1953
Privrasky, 1953
Renick, 1930

PAULINA BASALT

Original description: The Paulina Basalt was defined by Hampton (1964), who designated exposures in secs. 1, 2, 11, and 12, T. 26 S., R. 16 E., as the type locality.

Distribution: The unit is exposed over an area of 370 square miles in northern Fort Rock Basin in northern Lake County.

Lithology: The Paulina Basalt consists of a series of flows of dark-gray, diktytaxitic basalt which are traceable to several shield volcanoes in the Paulina Mountains to the north. The flows average 5 to 20 feet in thickness and a total thickness of 1,000 feet for the unit is developed near the source area.

Contacts: The Paulina Basalt is unconformable over the Peyerl Tuff and the Hayes Butte Basalt.

Age: A late Pliocene or early Pleistocene age is interpreted for the Paulina Basalt. It is approximately the same age as the Ochoco Lavas, although precise age equivalence has not been demonstrated.

Reference: Hampton, 1964

PEYERL TUFF

Original description: The Peyerl Tuff was defined by Hampton (1964), who designated exposures in a roadcut along Highway 31 in Fort Rock Basin (sec. 31, T. 25 S., R. 13 E.) as the type locality.

Distribution: The Peyerl Tuff is exposed over an area of 10 square miles near the Peyerl Ranch (sec. 10, T. 26 S., R. 13 E.) in the northwestern corner of the Fort Rock Basin.

Lithology: The unit consists of a maximum of 400 feet of tuffaceous sediments which include volcanic sandstones and conglomerates rich in pumiceous debris. A welded tuff interbed is present high in the section.

Contacts: The Peyerl Tuff is unconformable over the Hayes Butte Basalt.

Age: Hampton assigns a latest Pliocene or early Pleistocene age to the unit.

Reference: Hampton, 1964

PICTURE GORGE BASALT

(See Columbia River Group.)

PICTURE ROCK BASALT

Original description: The Picture Rock Basalt was defined by Hampton (1964). He designated exposures in sec. 14, and 15, T. 29 S., R. 16 E. in Fort Rock Basin as the type locality.

Distribution: The unit crops out as gentle slopes and escarpments over an area of 150 square miles in southern Fort Rock Basin south and east of Silver Lake.

Lithology: The unit consists of a series of flows of olivine basalt which average 10 to 50 feet in thickness and which have a total thickness of approximately 1,000 feet. The basalts are dark blue gray or green gray in color and are scoriaceous, brecciated, and glassy near the base of individual flows. Sedimentary interbeds composed of waterlain pumiceous debris and fragments of basaltic scoria are developed locally to thicknesses of up to 250 feet.

Contacts: The Picture Rock Basalt is unconformable beneath the Fort Rock Formation.

Age: A tentative early Pliocene age is assigned to the unit on the basis of stratigraphic position and degree of deformation.

Reference: Hampton, 1964

PIKE CREEK FORMATION

Original description: Fuller (1931) applied the term Pike Creek Volcanic Series to exposures underlying the Steens Mountain Volcanic Series between Little Alvord Creek and Indian Creek on the east face of Steens Mountain. Walker and Repenning (1965) revised the name to Pike Creek Formation.

Distribution: The unit is exposed as a north-trending series of small outcrops along the southeast base of Steens Mountain in southern Harney County.

Lithology: The Pike Creek Formation consists of a lower series of lenticular silicic flows and associated tuffs overlain by a more extensive and laterally more uniform series of flows of biotite dacite and trachyandesite. As described by Fuller (1931) the lower unit consists of 200 feet of greenish stratified acidic tuffs overlain successively by 200 feet of laminated, reddish, felsitic rhyolite, 300 feet of well-bedded shardy tuffaceous sediments, and 200 to 500 feet of banded, felsitic rhyolite lava. The lower unit displays a wide range of lateral variability and is interpreted to be a series of flows and sediments derived from local vents.

The upper unit consists of a 200-foot thick flow of biotite dacite overlain by a second flow of similar composition which varies in thickness from 200 feet at Little Alvord Creek to 500 feet between Pike and Alvord Creeks. The upper unit is more widespread than the lower unit and locally contains thin lenses of stratified tuff and perlite.

Contacts: The Pike Creek Formation is unconformable beneath the Steens Mountain Volcanic Series. The base of the unit is not exposed. The talus-covered contact with the Alvord Creek Formation is interpreted to be an unconformity by Wilkerson (1958), and a lateral gradation by Baldwin (1964). According to Walker (oral communication, 1971), the Alvord Creek Formation post-dates the Pike Creek Formation.

Age: On the basis of stratigraphic position the Pike Creek Formation is late Miocene or older.

References: Baldwin, 1964
Fuller, 1931
Walker and Repenning, 1965
Wilkerson, 1958
Williams and Compton, 1953

PITTSBURG FORMATION

Original description: The Pittsburg Formation was defined by Wagner (1945) in reference to exposures in the immediate vicinity of Pittsburg Landing on the Idaho side of the Snake River near the easternmost extremity of Oregon.

Distribution: The unit is exposed over an area of approximately 3 square miles and is equally distributed between the states of Idaho and Oregon in the immediate vicinity of the type locality. It is correlated with the Lower Sedimentary Series by Vallier (oral communication, 1971).

Lithology: The unit consists of approximately 2,000 feet of conglomerate, sandstone, and subordinate argillaceous strata. Greenish hues predominate and the unit was presumably derived from the underlying Permian rocks.

Contacts: The Pittsburg Formation conformably overlies volcaniclastic rocks and spilites of Late Triassic age which Vallier correlates with the "Imnaha Formation" (oral communication, 1971). The unit is interpreted to interfinger with the upper "Doyle Creek Formation" and is believed to conformably underlie the Martin Bridge Formation.

Age: Wagner applied a tentative Carboniferous age to the Pittsburg Formation, but the recent discovery of Karnian ammonites and the pelecypod genus Halobia establishes a Late Triassic age for the unit.

References: Vallier, 1968
Wagner, 1945

RAIL CABIN ARGILLITE

Original description: Dickinson and Vigrass (1965) defined the Rail Cabin Argillite and designated as the type locality exposures on the upper slopes of Morgan Mountain in the Izee district of central Oregon.

Distribution: The unit is restricted to exposures immediately surrounding the type locality.

Lithology: The Rail Cabin Argillite consists of thin-bedded, green and black, hard siliceous argillite interbedded with pale-green argillaceous quartz keratophyre tuff and tuff argillite, which is distinguished by its greater hardness and conchoidal fracture. Minor massive beds of gray bioclastic limestone and dense black calcilutite are developed locally suggesting a shallow-water environment of deposition.

Contacts: The contact with the overlying Graylock Formation is interpreted to be a disconformity by Silberling (written communication, 1971) and possibly a conformity by Dickinson and Vigrass (1965). The unit is unconformable over the softer Brisbois Formation.

Age: The unit has yielded middle Norian (Late Triassic) ammonites in the lower part of the section and it may range upwards into the upper Norian. The possibility that the unit includes Rhaetian strata as suggested by Dickinson and Vigrass (1965) is regarded as unlikely by Silberling (written communication, 1971).

Reference: Dickinson and Vigrass, 1965

RATTLESNAKE FORMATION

Original description: The Rattlesnake Formation was defined by Merriam (1901a) and is typically exposed along Rattlesnake Creek approximately one mile west of Cottonwood in Malheur County.

Distribution: The Rattlesnake Formation is best developed in the John Day Valley and subsidiary lowlands. The ignimbrite member is widespread throughout central Oregon and is believed to be the same unit as the upper ash-flow welded tuff of the Danforth Formation in the Harney Basin (see Danforth Formation).

Lithology: The unit is composed of up to 700 feet of fanglomerate and finer terrestrial sediments and a 40-foot thick ignimbrite unit which crops out in the middle of the section. The gravel is well rounded and consists of pebbles of basalt, chert, siltstone, diorite, rhyolite, and chert set in a medium-grained matrix of poorly indurated volcanic sandstone. The ignimbrite displays zonation typical of welded ash-flow tuffs and is a prominent ridge former.

Contacts: The Rattlesnake Formation is unconformable over the Mascall Formation and the basalts of the Columbia River Group.

Age: A radiometric age of 6.4 million years was determined for the ignimbrite unit by Evernden and James (1964). On the basis of trace elements the tuff is correlated with the upper ash-flow tuff of the Danforth Formation (Beeson, 1969) for which Davenport (1970) reports an age of 6.1 million years.

Middle and late Pliocene mammals have been recovered from the gravels beneath the ignimbrite. The upper part of the formation may extend into early Pleistocene.

References: Beeson, 1969
Brown and Thayer, 1966a
Campbell and others, 1958
Coleman, 1949

References: (continued)
Cummings, 1958
Davenport, 1970
Dawson, 1951
Dobell, 1948
Evernden and James, 1964
Irish, 1954
McIntyre, 1953
Merriam, 1901a
Napper, 1958
Taubeneck, 1950
White, 1964

ROBERTSON FORMATION

Original description: The Robertson Formation was defined by Lupher (1941) and is typically exposed in the headwaters of the South Fork of Beaver Creek 7 miles south of the Suplee post office in secs. 26, 27, 28, and 29, T. 18 S., R. 26 E.

Distribution: The Robertson Formation is exposed on the nose of the southwest-plunging Mowich upwarp in the area surrounding the type locality in the Suplee-Izee district of central Oregon.

Lithology: The Robertson Formation has a maximum thickness of 335 feet according to Dickinson and Vigrass (1965) and is composed of a lower clastic unit and an upper unit of biostromal limestone. The basal clastic unit consists of locally cross-bedded volcanic arenite and conglomerate with clasts of chert, felsophyre, and argillite. Distribution and composition of the basal unit suggests derivation from the underlying Begg Formation.

The overlying limestone consists of lenses of gray, biostromal limestone and massive bioclastic limestone up to 30 feet in thickness which grade laterally into calcilutite. The biostromes are composed almost entirely of the aberrant sessile pelecypod, Plicatostylus gregarius.

Contacts: The unit is unconformable over the Begg and Brisbois Formations and it is conformable under the Suplee Formation.

Age: A provisional Pleinsbachian (middle Early Jurassic) age is assigned to the Robertson Formation.

References: Dickinson and Vigrass, 1965
Lupher, 1941

SHAW MEMBER (OF SNOWSHOE FORMATION)

Original description: Rocks assigned to the Shaw member by Dickinson and Vigrass (1965) were originally assigned to the Snowshoe Formation by Lupher (1941). Characteristic exposures are located in sec. 24, T. 17 S., R. 26 E.

Distribution: Several small exposures of the Shaw member are present in the central parts of the Pine Creek downwarp in the western part of the Suplee-Izee district of central Oregon. According to Buddenhagen (written communication to Imlay, 1968) rocks designated as Shaw member by Dickinson and Vigrass (1965) situated north of Pine Creek are more appropriately assigned to stratigraphically lower parts of the Snowshoe Formation.

Lithology: The unit consists of approximately 1,000 feet of gray to dark brownish-gray platy to fissile shale and subordinate interbedded fissile green shale, hard gray calcareous mudstone, siltstone and sandstone. Locally, horizons of ellipsoidal calcareous concretions and beds of gray sandy calcarenite and microcrystalline limestone are developed.

Contacts: The Shaw member is interpreted as a lateral equivalent of the upper part of the Basey member of the Snowshoe Formation from which it is distinguished primarily on the basis of its finer grain size.

Age: A middle Bajocian (Middle Jurassic) age is suggested for the unit by fossils recovered from the north side of Pine Creek. However, Buddenhagen (see preceding page) favors a Callovian (late Middle Jurassic) age based on fossils taken from a structurally less complex area.

References: Dickinson and Vigrass, 1965
Lupher, 1941

SHUMURAY RANCH BASALT

Original description: The Shumuray Ranch Basalt was defined by Kittleman and others (1965) and is typically exposed near the Shumuray Ranch (S½ sec. 30, T. 23 S., R. 39 E.) in the Monument Peak district of northern Malheur County.

Lithology: The unit consists of 50 to 150 feet of microporphyritic, trachytic to pilotaxitic multiflow basalt. It is a prominent mesa former and is limited in distribution to exposures in the immediate vicinity of the type locality.

Contacts: The Shumuray Ranch Basalt is underlain by unnamed volcaniclastic strata which in turn are underlain by the Wildcat Creek Welded Ash-Flow Tuff and the Grassy Mountain Formation.

Age: The unit is assigned a late Pliocene age on the basis of stratigraphic position.

Reference: Kittleman and others, 1965, 1967

SHUTLER FORMATION

Definition: The term Shutler Formation was introduced by Hodge (1932b) to replace the poorly defined "Arlington Formation," a term previously applied to the Pliocene sediments exposed in the vicinity of Shutler, Oregon. In recent years the term Shutler Formation has been largely discarded. Newcomb (1971) suggests that the unit is equivalent to the upper Dalles Formation and possibly part of the lower Ellensburg Formation.

Lithology: Included in the Shutler Formation by Hodge (1932b, 1938, 1942) were fluvial deposits of caliche-coated gravels crudely interbedded with layers of sand and silt. Also included in the unit were more evenly bedded deposits of sand, silt, and diatomaceous ash which overlie the fluvial deposits south of Arlington and between the Deschutes River and Willow Creek.

Contacts: According to Hodge (1938) the Shutler Formation interfingers with the upper part of the Dalles Formation to the west. In extending the Dalles Formation eastward to include the Shutler Formation, Newcomb (1971) also describes this relationship.

According to Newcomb (1971) the Dalles Formation unconformably overlies the Selah and Rattlesnake Ridge members of the Ellensburg Formation and the Pomona flow of the Yakima Basalt in the vicinity of Shutler, Oregon.

Age: Middle Pliocene vertebrates have been recovered from the "Dalles Formation extended" of Newcomb (1966, 1971) in the Shutler area. This compares with faunal and radiometric age data which suggest an early Pliocene age for the type Dalles Formation and a late Miocene-early Pliocene age for the Selah member of the Ellensburg Formation. Although Hodge (1938) postulated a Pleistocene age for the Shutler

Formation on the basis of vertebrates recovered near Umatilla, Oregon, this age should be discarded on the basis of the geographic separation of this fauna from the type Shutler Formation.

References: Baldwin, 1964
Hodge, 1932b, 1938, 1942
Hogenson, 1964
Lowry and Baldwin, 1952
Newcomb, 1966, 1971
Shotwell, 1956

SILVIES MEMBER (OF SNOWSHOE FORMATION)

Original description: The Silvies member was defined by Dickinson and Vigrass (1965) and is characteristically exposed in the canyon of upper Silvies Creek at the juncture of sections 21,22,27 and 28,T.16 S., R. 29 E.

Distribution: The Silvies member forms an extensive northeast-trending exposure in the southeast part of the Suplee-Izee district mapped by Dickinson and Vigrass (1965). To the west it grades into the middle part of the type Snowshoe Formation and to the east its extent is undefined although Dickinson and Vigrass (1965) suggest possible equivalence to flows and breccias exposed south of Seneca.

Lithology: The member consists of 1,500 feet of volcaniclastic strata which include abundant blue, hard, coarse-grained andesitic sandstone and conglomerate. Sandstone interbeds are graded, vary in thickness from 1 to 12 feet, and alternate with finer-grained interbeds of siltstone and mudstone. The lutites are very similar to the middle part of the Snowshoe Formation of Lupher (1941) to the west. The Silvies member differs from the equivalent Basey member on the basis of the presence of conglomerate, the prevalence of graded bedding, and several other more subtle features of texture and composition.

Contacts: The Silvies member is conformable within the overlying and underlying parts of the Snowshoe Formation. Facies relationships suggest derivation from a volcanic pile located 25 miles east of Izee beyond Seneca. To the west the infrequent graded beds in the middle Snowshoe Formation mark the distal ends of the turbidity current deposits in the Izee Basin.

Age: A middle Bajocian (Middle Jurassic) age is assigned to the Silvies member.

Reference: Dickinson and Vigrass, 1965

SNOWSHOE FORMATION

Original description: Lupher (1941) defined the Snowshoe Formation and designated as the type locality a band of exposures extending northeastward from Snow Mountain across South Fork Valley on the southeast limb of the Mowich anticline.

Distribution: The Snowshoe Formation is widespread in the Suplee-Izee district of central Oregon. West of the type locality Dickinson and Vigrass (1965) included the Weberg member (Weberg Formation of Lupher, 1941), the Warm Springs member (Warm Springs Formation of Lupher, 1941), the Basey member (Hyde Formation of Lupher, 1941) and the Shaw member in the unit. To the east they incorporated the Silvies member into the Snowshoe Formation.

Lithology: In the vicinity of the type locality the Snowshoe Formation consists of 2,750 feet of dark lutites with intercalations of fine-grained sandstone and thick-bedded calcareous sandstone in the middle and top of the section respectively. It is subdivided into the lower member, middle member, and upper member by Dickinson and Vigrass (1965).

The lower member consists of 600 feet of soft, dark-gray to black, thin-bedded mudstone, siltstone

and shale. It is locally calcareous and displays a characteristic platy parting. Radiolarians are abundant.

The middle member consists of 1,000 feet of dark-gray to black lutite interlaminated with coarser beds of graded volcaniclastics. The middle member lacks radiolarians. It grades westward into the Basey member of the Snowshoe Formation and eastward into the Silvies member of the Snowshoe Formation.

The upper member consists of 1,250 feet of thin-bedded dark mudstone and siltstone with thick interbeds of gray calcareous sandstone. It increases in thickness to 1,500 or 2,000 feet east of Rosebud and Lewis Creeks and wedges out to the west under the Trowbridge Formation.

For further information regarding the Snowshoe Formation east and west of the type locality consult the discussion of the members referred to in "Distribution" above.

Contacts: The Snowshoe Formation is gradational over the Hyde Formation in the eastern part of the Suplee-Izee district and it is interpreted to be unconformable beneath the Trowbridge Formation on the basis of map relationships. The Snowshoe Formation is unconformable over the Mowich Group in the western part of the Suplee-Izee district.

Age: A lower Toarcian through lower Callovian age (middle Jurassic) is interpreted for the unit in the eastern part of the Suplee-Izee district. The base is somewhat younger in the west where the Weberg member is assigned a lower middle Bajocian age.

References: Dickinson and Vigrass, 1965
Imlay, 1964b, 1968
Lupher, 1941

SPOTTED RIDGE FORMATION

Original description: The Spotted Ridge Formation was defined by Merriam (1942), who designated exposures on the west flank of Spotted Ridge in central Oregon as the type locality.

Distribution: The Spotted Ridge Formation forms isolated exposures in the pre-Tertiary terrain surrounding the type locality 15 miles south of Paulina in southeastern Crook County.

Lithology: The Spotted Ridge Formation consists of 1,000 to 1,500 feet of highly variable deltaic sediments, which include sandstone, conglomerate, chert, and mudstone. Marine sediments are most abundant in the middle of the section.

Lenticular beds of feldspathic, medium-grained graywacke of marine and nonmarine origin occur throughout the section. Cross-bedding and plant debris are locally present. The conglomerate is poorly sorted and consists of boulders of diorite, andesite, dacite, and chert.

Marine, greenish, pebbly sandstone and mudstone occupy the middle of the section and contain fairly abundant calcite cement and crinoidal debris. Also present are thin-bedded greenish radiolarian cherts which exhibit a clustered distribution about plutons; in part they may represent silicified fissile mudstones.

Contacts: The Spotted Ridge Formation is unconformable beneath the Coyote Butte Formation and it is probably disconformable or unconformable over the Coffee Creek Formation.

Age: The age range of the unit is uncertain, but it is probably lower Pennsylvanian based upon a fairly diagnostic flora present in the nonmarine interbeds.

References: Brogan, 1952
Mamay and Read, 1956
Merriam, 1942
Merriam and Berthiaume, 1943
Ogren, 1958

STEENS BASALT

Original description: The Steens Basalt was first described by Fuller (1931), who designated as the type locality exposures along the highest part of Steens Mountain about 20 miles east of the head of Donner and Blitzen Valleys, Harney County.

Distribution: The Steens Basalt forms faulted and surficial exposures along the crest of Steens Mountain and it is presumably widespread in the subsurface. Equivalent basalts are possibly represented by the Miocene basalts of the Pueblo Mountains to the south and the "Unnamed igneous complex" of Kittleman and others (1965) to the north in northern Malheur County.

Lithology: The Steens Basalt consists of approximately 3,000 feet of olivine-bearing basalts which collectively are intermediate in composition between olivine tholeiite and high-alumina basalt. At least 70 flows are present and jointing is poor. Flow contacts are discontinuous suggesting that the flows were extruded in rapid succession.

Porphyritic textures are most common low in the section and platiness is most abundant high in the section. True diktytaxitic texture, although present, is notably rarer than suggested by Fuller (1931) in his type description. Geochemical trends are discussed in detail by Gunn and Watkins (1970). The basalts emerged from dikes concentrated in swarms along the margins of tilted fault blocks, the east face of Steens Mountain being the most notable.

Contacts: The Steens Basalt overlies the Steens Mountain Volcanic Complex and underlies a variety of Pliocene units including welded tuffs assigned to the Danforth Formation on the west slope of Steens Mountain.

Age: The unit is regarded as late Miocene and has yielded radiometric age dates of 15.1 million years. Lithologic data suggest rapid extrusion of the unit and geomagnetic data suggest that all the flows were extruded in less than 50,000 years.

References:
Avent, 1969
Baksi and others, 1967
Doak, 1953
Evernden and James, 1964
Fryberger, 1959
Fuller, 1931
Gunn and Watkins, 1970
Johnson, G. D., 1960
Piper and others, 1939
Porter, 1953
Walker and Peterson, 1969
Wilkerson, 1958
Williams and Compton, 1953

STEENS MOUNTAIN VOLCANIC SERIES

Original description: Fuller (1931) was the first to describe the Steens Mountain Volcanic Series. He did not describe a type section, but he discussed the exposures between Alvord Creek and Cottonwood Creek in detail and they are generally regarded as being representative.

Distribution: The Steens Mountain Volcanic Series is restricted to the east face of Steens Mountain, but is presumably more widespread in the subsurface.

Lithology: The unit consists of several thousand feet of heterogeneous vesicular andesitic breccias alternating with platy lavas of andesite and basalt. Flows vary from 10 to 200 feet in thickness, and flow contacts are poorly defined. Cinder cones and pyroclastic accumulations are locally abundant within the sequence. Vent areas are also recognized on the basis of steeply inclined platy jointing.

One unit termed the "Great Flow" by Fuller (1931) consists of 500 to 900 feet of coarsely columnar aphanitic basaltic andesite. Nearby structures and the extreme thickness of the unit are consistent with a sill-like origin, although the fine grain size is suggestive of extrusion.

Sedimentary rocks are restricted to rare exposures of fresh water limestone, arkose and shale low in the section to the south. Also present are conglomerates composed of metamorphic and plutonic rocks. Pillow lavas directly overlie the sediments.

Contacts: The Steens Mountain Volcanic Series is unconformable beneath the Steens Basalt and shares an uncertain relationship with the Alvord Creek beds (see Alvord Creek beds).

Age: The Steens Mountain Volcanic Series is late Miocene in age. Walker (oral communication, 1971) believes that a radiometric age of 21 million years assigned to the Alvord Creek beds by Evernden and James (1964) is more appropriately applied to the lower part of the Steens Mountain Volcanic Series.

References: Evernden and James, 1964
Fuller, 1931
Wilkerson, 1958
Williams and Compton, 1953

STRAWBERRY VOLCANICS

Definition: Strawberry Volcanics is a term first proposed by Thayer (1957) for the Miocene accumulation of mafic to silicic volcanic rocks which make up Strawberry Mountain and parts of the surrounding area near John Day in central Oregon.

Distribution: As mapped by Brown and Thayer (1966a) the Strawberry Volcanics are exposed over large areas between Bear Valley and Unity Basin in southeastern Grant County and southwestern Baker County.

Lithology: The unit consists of a maximum of several thousand feet of flow rock varying from medium-gray basaltic andesite and olivine basalt similar to the Picture Gorge Basalt low in the section to dacite and rhyolite near the top of the section. The flows erupted from a series of vents and shield volcanoes represented by the present-day Strawberry Mountain and Lookout Mountain.

Contacts: The Strawberry Volcanics may interfinger with the Picture Gorge Basalt low in the section and are intertongued high in the section with the rhyolitic marginal facies and presumably the Mascall Formation, both of the Columbia River Group.

The Strawberry Volcanics are interpreted to interfinger with early Pliocene lacustrine deposits in the Unity Basin by Brown and Thayer (1966a), but this relationship is questioned by other workers in the area (McIntyre, written communication to Corcoran, 1971). The unit is unconformable over rocks similar in lithology to the Clarno Formation farther to the west.

Age: The Strawberry Volcanics are late Miocene in age and correlate with the Columbia River Group. The silicic younger parts of the unit near the type locality interfinger with the late Miocene Mascall Formation. Consequently the basalts in the Unity Basin which reportedly interfinger with Pliocene sediments, probably belong to a younger as yet undefined stratigraphic unit.

References: Brown and Thayer, 1966a
Thayer, 1957
Thayer and Brown, 1966b

SUCKER CREEK FORMATION

Original description: The Sucker Creek Formation was first proposed in a thesis by Kittleman (1962) and first introduced into the literature by Corcoran and others (1962), who list exposures along Sucker Creek in the Mitchell Butte 30' quadrangle as the type locality. A more accurate definition of the type locality is provided by Kittleman and others (1965), who designate exposures in secs. 28 and 33, T. 24 S., R. 46 E. as being typical.

Distribution: The Sucker Creek Formation is exposed at the north end of the Owyhee Reservoir and is presumably widespread in the subsurface of the surrounding area. It supplants the Payette Formation of Kirkham (1931) in that area as explained by Newton and Corcoran (1963) and Corcoran (1965).

Lithology: The Sucker Creek Formation consists of approximately 2,000 feet of fine-grained, lacustrine and fluvial, thin-bedded, light-colored, tuffaceous sediments with a local rhyolite flow (Owyhee Rhyolite of Kirkham, 1931; Rhyolite at Owyhee Dam of Corcoran, 1965) and an extensive ash-flow tuff (Leslie Gulch ash-flow tuff member of Kittleman and others, 1965) high in the section and an olivine-poor aphanitic basalt flow low in the section.

The sediments include brown to yellowish-green tuffaceous volcanic and arkosic sandstones, water-laid tuffs, locally carbonaceous buff shales, massive siltstones, and very minor conglomerates. Tuffaceous claystone is increasingly more dominant high in the section. The abundance of ash, lack of induration, and scarcity of conglomerate are distinctive features of the unit.

Contacts: The Sucker Creek Formation is unconformable beneath the Owyhee Basalt, and south of Owyhee Reservoir it underlies the Jump Creek Rhyolite. The base of the unit is not exposed.

Age: Vertebrate remains indicate a Barstovian (late Miocene) age for the unit. The basalt flow low in the section has been radiometrically dated at 16.7 million years.

References:
Corcoran, 1965
Corcoran and others, 1962
Eubanks, 1966
Graham, 1962
Kirkham, 1931
Kittleman, 1962
Kittleman and others, 1965, 1967
Newton and Corcoran, 1963

SUPLEE FORMATION

Original description: Lupher (1941) defined the Suplee Formation and designated exposures in the headwaters of the South Fork of Beaver Creek 7 miles southeast of the Suplee post office (secs. 26, 27, 28 and 29, T. 29 S., R. 26 E.) as the type locality.

Distribution: The Suplee Formation is restricted to exposures in the pre-Tertiary window in the Suplee-Izee district of central Oregon.

Lithology: The Suplee Formation consists of indistinctly bedded, fossiliferous, gray calcareous sandstone and sandy limestone. Intercalations of green volcanic sandstone similar in lithology to the underlying Robertson Formation suggest lateral intergradation of the two units. Thicknesses vary from 30 to 35 feet in the west to 75 feet farther east.

Contacts: The Suplee Formation is conformable over the Robertson Formation at the type locality and along the north side of Bear Valley north of Seneca. Elsewhere the unit is unconformable over older Mesozoic rocks.

Age: The Suplee Formation is assigned a Pleinsbachian age (Early Jurassic) on the basis of abundant pelecypods and ammonites. Imlay (1968) correlates it with the upper 620 feet of the Hurwal Formation of Nolf in the Wallowa Mountains (see Hurwal Formation).

References:
Dickinson and Vigrass, 1965
Imlay, 1968
Lupher, 1941

TIMS PEAK BASALT

Original description: Kittleman and others (1965) defined the Tims Peak Basalt and designated exposures near Tims Peak (SE $\frac{1}{4}$ sec. 34, T. 21 S., R. 40 E.) in northern Malheur County as the type locality. Tims Peak, however, is underlain by the "Unnamed igneous complex."

Distribution: The Tims Peak Basalt is exposed in the Monument Peak and Malheur Gorge districts in the immediate vicinity of the type area.

Lithology: The Tims Peak Basalt consists of 10 to 250 feet of gray, micro-diktytaxitic, olivine basalt. Subophitic textures are characteristic and the flows are locally porphyritic. In the northwesternmost exposures the unit includes subordinate amounts of tuffaceous sandstone and pumiceous diatomite which are interbedded with the flows of basalt.

Contacts: The unit is unconformable over the Littlefield Rhyolite and the Hunter Creek Basalt. It also overlies the Butte Creek Volcanic Sandstone of Barstovian age and underlies the Wildcat Creek Welded Ash-Flow Tuff and Juntura Formation, both of Clarendonian age.

Age: A late Miocene to early Pliocene age is assigned to the unit on the basis of stratigraphic position.

References: Haddock, 1967
Kittleman and others, 1965, 1967

"TRINITY CREEK FORMATION"

Original description: This is an informal term proposed in a thesis by Wetherell (1960) for representative exposures along Trinity Creek in the southeastern Wallowa Mountains (secs. 16, 21, and 27, T. 6 S., R. 46 E.).

Distribution: The "Trinity Creek Formation" is exposed south of Fish Lake in the southern part of the Cornucopia quadrangle. The unit is equivalent to the "Hunsaker Creek Formation" of Vallier (1967) and possibly the Permian part of the Clover Creek Greenstone of Gilluly (1937) in the northeastern part of the Baker quadrangle. Exposures included in the unit were mapped as Lower Sedimentary Series by Smith and Allen (1941).

Lithology: The "Trinity Creek Formation" consists of a sequence of interbedded gray to green, medium- to coarse-grained, lithic and feldspathic graywacke, discontinuous conglomerate with cobbles of fine-grained porphyritic volcanic rocks, and bedded green to buff mudstone and siltstone. A total thickness of 7,000 to 10,000 feet is estimated by Wetherell (1960). Cross-bedding, graded bedding, and load casts are reported locally.

Contacts: Although Wetherell (1960) interpreted conformity with the overlying Imnaha Formation, an unconformity is interpreted by Vallier (1967) on the basis of subsequent remapping.

Age: Permian brachiopods have been recovered from the unit (Wetherell, 1960).

References: Gilluly, 1937
Smith and Allen, 1941
Vallier, 1967
Wetherell, 1960

TROUT CREEK FORMATION

Original description: Smith (1926) defined the Trout Creek Formation and designated as the type locality exposures at Trout Creek on the east side of Alvord Valley in the southeastern part of Harney County.

Distribution: The Trout Creek Formation is exposed on the northern edge of the Trout Creek Mountains near Flagstaff Butte and Trout Creek. It is included in the "Miocene tuffaceous sedimentary rocks, tuffs, and silicic flows" of Walker and Repenning (1965).

Lithology: The unit consists of a series of fine-grained tuffaceous sediments and diatomaceous leaf-bearing beds of flood plain and shallow lacustrine origin.

Contacts: The unit underlies varicolored flows of rhyolitic composition.

Age: The Trout Creek Formation contains a late Miocene flora and has yielded a radiometric age of 13.1 million years. The unit post-dates the Steens Basalt and may be equivalent to the Alvord Creek beds on the western side of the Alvord Valley.

References: Carlton, 1969
Graham, 1962
Smith, 1926
Walker and Repenning, 1965

TROWBRIDGE FORMATION

Original description: Lupher (1941) defined the Trowbridge Formation and designated northeast-trending exposures along the Mowich anticline in South Fork Valley as the type locality.

Distribution: The Trowbridge Formation is extensively exposed on the southeast limb of the Mowich anticline in the southeast part of the Suplee-Izee district of central Oregon.

Lithology: The Trowbridge Formation consists of 2750 to 3250 feet of dark pencil lutites with subordinate amounts of arenaceous material and calcareous concretions. The unit becomes progressively more arenaceous upsection, and it thickens toward the northeast.

The Trowbridge Formation is subdivided into three members by Dickinson and Vigrass (1965). The lowermost member, the Rosebud member, consists of pencil mudstone and volcaniclastic siltstone with a thickness of 400 to 500 feet. The overlying Officer member consists of hard black and green pencil lutite interbedded with a subequal amount of volcanic sandstone and felsic tuff. The Magill member, the uppermost member, consists of black mudstone similar to that of the Rosebud member and intercalated beds of graded sandstone.

Contacts: The Trowbridge Formation is conformable over the Lonesome Formation. On the basis of regional stratigraphic relationships Dickinson and Vigrass (1965) interpret an unconformity between the Trowbridge Formation and the underlying Snowshoe Formation.

Age: An early to early-middle Callovian age (upper Middle Jurassic) is interpreted for the middle and lower parts of the Trowbridge Formation. It is very similar in age to the overlying Lonesome Formation.

References: Dickinson and Vigrass, 1965
Imlay, 1964a
Lupher, 1941

"UNNAMED IGNEOUS COMPLEX"

Definition: "Unnamed igneous complex" is an informal term applied by Kittleman and other (1965) to the undifferentiated igneous assemblage that forms the basement in northern Malheur County. The unit is not a formation and there is no type section. Particularly good exposures crop out in Malheur Gorge west of Namorf.

Lithology: The "Unnamed igneous complex" consists of a heterogeneous assemblage of flows and autoclastic breccias of basalt and andesite which have a total aggregate thickness of several thousand feet. Up to 1,000 feet of intercalated autoclastic breccias and dense aphanitic basalts are exposed in the Crowley district and presumably represent the lower part of the section.

Up to 600 feet of multiple-flow porphyritic, olivine basalt overlain by 700 feet of folicated aphanitic andesite and andesitic basalt are exposed in the Monument Peak district and probably represent the middle of the section.

In the central Monument Peak district approximately 2,000 feet of alternating aphanitic and porphyritic basalt flows and flow breccias of uncertain stratigraphic position are exposed.

Contacts: The "Unnamed igneous complex" is unconformable beneath the Littlefield Rhyolite and the Wildcat Creek Welded Ash-Flow Tuff along a contact that locally exhibits several hundred feet of relief. The base of the unit is not exposed.

Age: The "Unnamed igneous complex" is post-dated by sediments containing Barstovian (late Miocene) vertebrates. A late Miocene age is assigned to the unit and it may be equivalent in age to the Steens Basalt, the Owyhee Basalt, or the Steens Mountain Volcanic Series.

References: Hagood, 1963
Kittleman and others 1965, 1967
McMurray, 1962

VESTER FORMATION

Original description: The Vester Formation was defined by Brown and Thayer (1966a). Exposures in lower Vester Creek in the north central part of the Izee quadrangle in central Oregon are designated as the type locality.

Distribution: The Vester Formation forms rather extensive northwest-trending exposures between Paulina Basin and Bear Valley Basin in the pre-Tertiary uplands northeast of Izee in central Oregon.

Lithology: In ascending order the unit consists of 6,000 feet of pebbly conglomerate and interbedded black shale, 1,000 feet of water-laid andesitic tuff, and 1,000 feet of black shale. Two miles north of the type locality 1,000 feet of interlayered black shale, ophitic basalts, and breccias are included in the formation and are believed to represent the lower part of the section.

Contacts: The Vester Formation is unconformable over Paleozoic rocks and unconformable beneath the Aldrich Mountain Group. It is probably the northward lateral equivalent of the Begg and Brisbois Formations of Dickinson and Vigrass (1965) in the Suplee-Izee district to the south.

Age: Fossils recovered from a small lens of limestone breccia indicate that the unit is no older than late Karnian (middle Late Triassic).

References: Brown and Thayer, 1966a
Thayer and Brown, 1966a, b

WARM SPRINGS MEMBER (OF SNOWSHOE FORMATION)

Original description: The Warm Springs Formation was defined by Lupher (1941), who designated exposures on the east side of Warm Spring Creek Valley (secs. 19, 20, 29, and 30, T. 18 S., R. 26 E.) as the type area.

In recognition of the lateral equivalence of the unit to part of the lower Snowshoe Formation to the east Dickinson and Vigrass (1965) described the unit as the Warm Springs member of the Snowshoe Formation.

Distribution: The unit is exposed as narrow bands along the limbs of the major structures in the Suplee district including the nose of the Mowich anticline and the limbs of the Pine Creek downwarp situated immediately to the northwest.

Lithology: The unit consists of 200 to 300 feet of dark silty calcareous shale and mudstone with subordinate amounts of intercalated gray calcareous siltstone and fine-grained limestone. With the exception of fine laminations in the type area, the unit is indistinctly bedded. It is distinguished from the underlying Weberg Formation on the basis of finer grain size and the lower lime content.

Contacts: The Warm Springs member is conformable over the Weberg member and unconformable over older units where the Weberg member is not present. The Warm Springs member is conformable beneath the Basey member of the Snowshoe Formation.

Age: The unit is lower middle Bajocian (Middle Jurassic) in age.

References: Dickinson and Vigrass, 1965
Lupher, 1941

WEBERG MEMBER (OF SNOWSHOE FORMATION)

Original description: The Weberg Formation was first described by Lupher (1941), who designated the type locality as the east side of Warm Springs Creek Valley (sec. 19, 20, 29, and 30, T. 18 S., R. 26 E.).

The unit was redefined as a member of the Snowshoe Formation by Dickinson and Vigrass (1965), who interpreted it to be a westward lateral equivalent of part of the type Snowshoe Formation. They limited the type locality to exposures on the north side of a gully emptying into Warm Springs Creek in the SW$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 19, T. 18 S., R. 26 E.

Distribution: The Weberg member of the Snowshoe Formation is exposed along the western nose of the Mowich anticline and on the limbs of the adjacent Pine Creek downwarp and smaller structures within the western part of the Suplee district of central Oregon.

Lithology: The Weberg member consists of 50 to 200 feet of basal limy sandstone and sandy limestone. The lower part of the section consists of gray, resistant, calcareous sandstone and pebble conglomerate composed of chert, felsite, quartz, albite, and biogenic calcite. Fragments of Ostrea and Pinna are recognizable locally. The upper part of the unit consists of fossiliferous silty and sandy limestone composed of bivalve plates and echinoid plates and spines set in a matrix of limy mud.

Contacts: The unit grades upward into the Warm Springs member of the Snowshoe Formation and is unconformable over the Mowich Group and Upper Triassic rocks.

Age: A lower middle Bajocian age (Middle Jurassic) is indicated by a variety of fossil remains which include rhynchonellids, belemnites, terebratulids, ammonites and reptilian vertebrae.

References: Dickinson and Vigrass, 1965
Lupher, 1941

WILDCAT CREEK WELDED ASH-FLOW TUFF

Original description: Kittleman and others (1965) defined the Wildcat Creek Welded Ash-Flow Tuff and

designated exposures at the head of Wildcat Creek ($SW\frac{1}{4}NW\frac{1}{4}$ sec. 29, T. 24 S., R. 40 E.) in northern Malheur County as the type locality.

Distribution: The unit is a discontinuous mesa-former in the Monument Peak and Crowley districts in the vicinity of the type locality.

Lithology: The Wildcat Creek Welded Ash-Flow Tuff is composed of light-gray to black and pale reddish-brown pumiceous vitric tuff which displays vertical zonation characteristic of ash flows. The nonwelded upper zone has been removed by erosion over wide areas. Thicknesses average a few tens of feet, although local thicknesses of 200 feet are developed.

Contacts: The unit overlies the Butte Creek Volcanic Sandstone and the Tims Peak Basalt.

Age: A tentative late Miocene or early Pliocene age is assigned to the unit.

References: Hagood, 1963
Kittleman and others, 1965, 1967

"WINDY RIDGE FORMATION"

Original description: The "Windy Ridge Formation" is an informal unit proposed by Vallier (1967) in his doctoral dissertation at Oregon State University. He applies the term to early or middle Permian exposures near the Oxbow of the Snake River Canyon in northeastern Oregon.

Lithology: The unit consists of 2,000 to 3,000 feet of flows and breccias of both keratophyric and porphyritic quartz keratophyric composition. Colors vary from green to pale yellow-brown, and the unit is difficult to distinguish in the field. Fairly diagnostic characteristics include the presence of dark mafic dikes, euhedral fedlspars, quartz phenocrysts, and indistinct bedding, and the absence of mafic flow rocks, conglomerates, and fossils.

Contacts: The "Windy Ridge Formation" is overlain unconformably by the flows and conglomerates of the "Hunsaker Creek Formation." The base of the unit is not exposed.

Age: An early to middle Permian age is assigned to the unit on the basis of stratigraphic position. It is possibly correlative with the Burnt River Schist.

Reference: Vallier, 1967

YAKIMA BASALT

(See Columbia River Group.)

YONNA FORMATION

Original description: Newcomb (1958) defined the Yonna Formation and designated exposures in Yonna Valley east of Upper Klamath Lake as the type locality.

Distribution: The Yonna Formation is widely distributed in the larger river valleys of southern Klamath County, Oregon.

Lithology: At the type section the Yonna Formation consists of a lower lacustrine unit composed of ashy diatomite, sandstone, laminated siltstone, water-laid volcanic ash, pumice, and gravel and an upper unit of lapilli tuff of basaltic composition. Away from the type section complex facies changes are evident and subdivision into an upper and lower unit is not possible. Surface exposures of the formation indicate thicknesses of 100 to 900 feet and well data suggest a total thickness of 1,500 feet.

Contacts: The Yonna Formation is unconformable over older basalts and slightly unconformable beneath younger basalts.

Age: A tentative middle Pliocene age is assigned to the unit on the basis of lithology and stratigraphic position. Consistent with this determination are sparse undiagnostic remains of diatoms, gastropods, and vertebrates.

References:
Newcomb, 1958
Peterson and McIntyre, 1970

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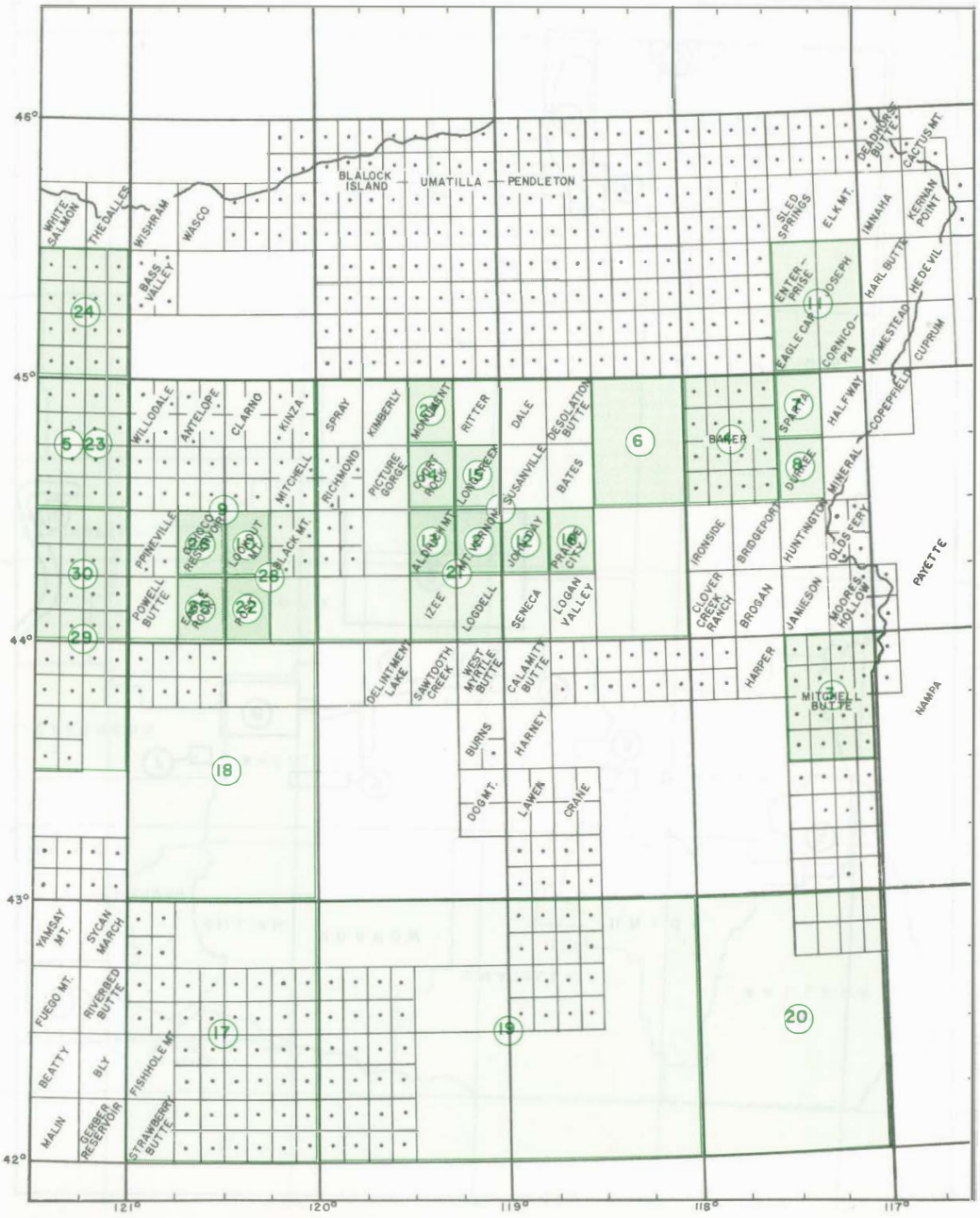

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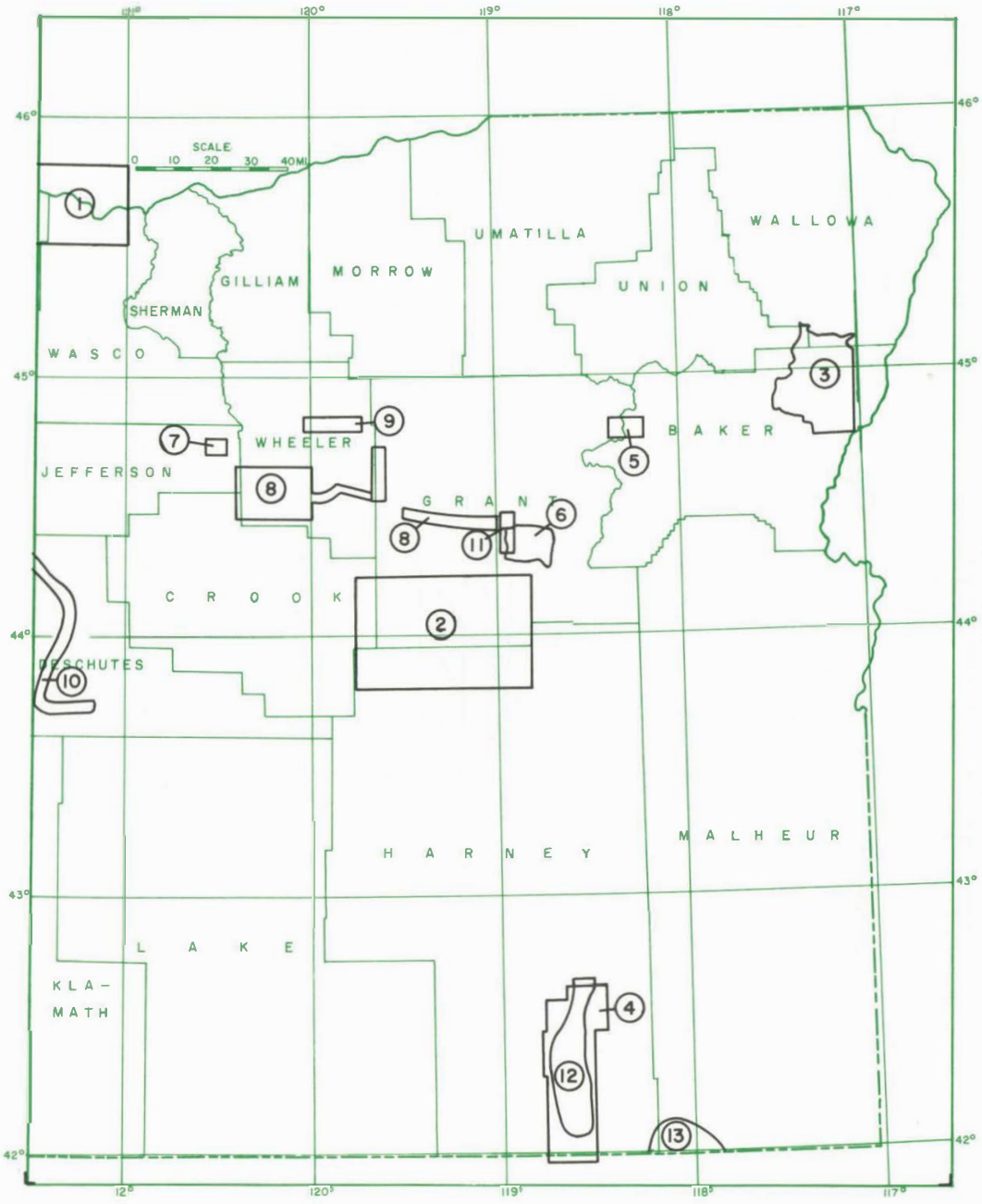

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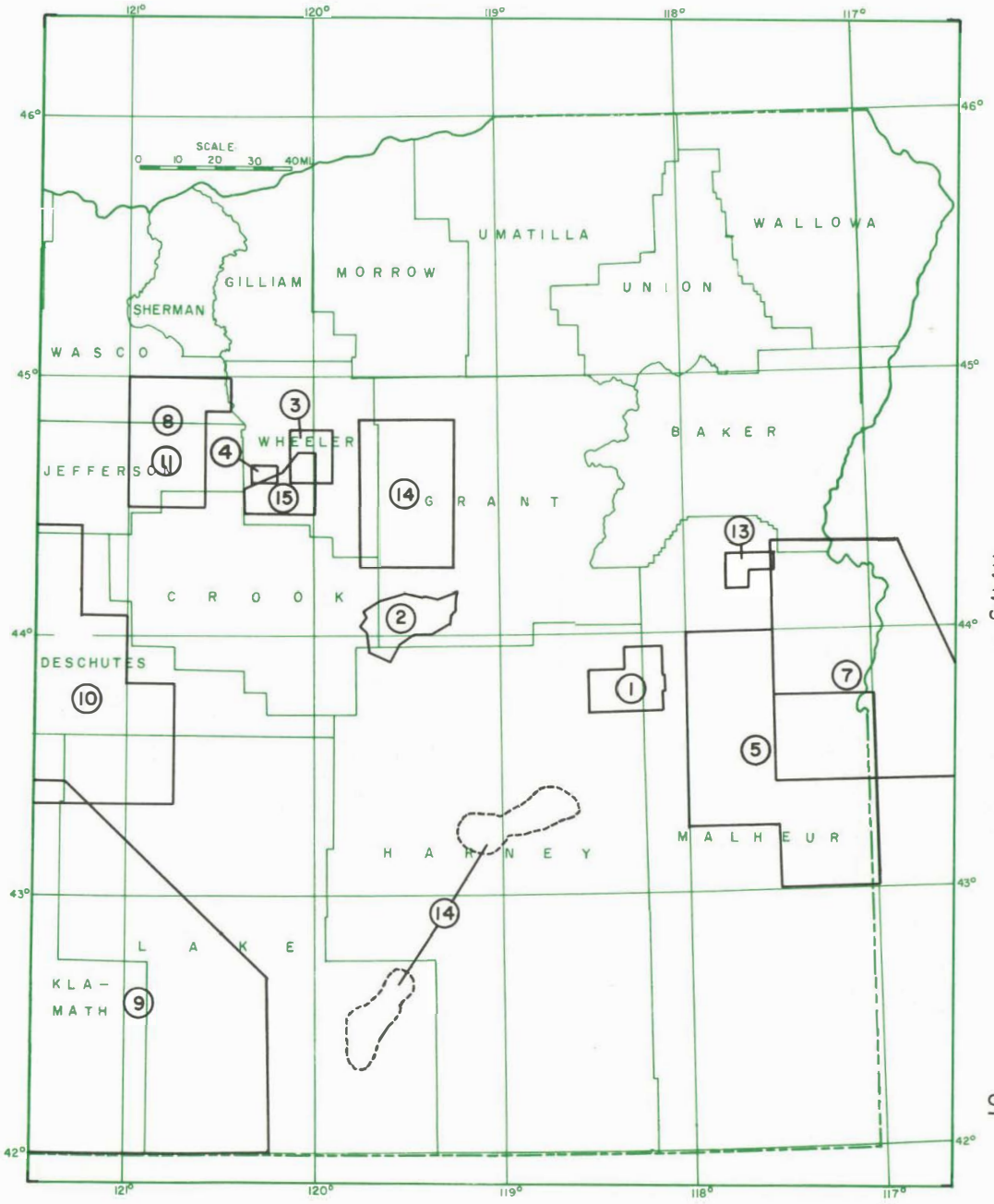

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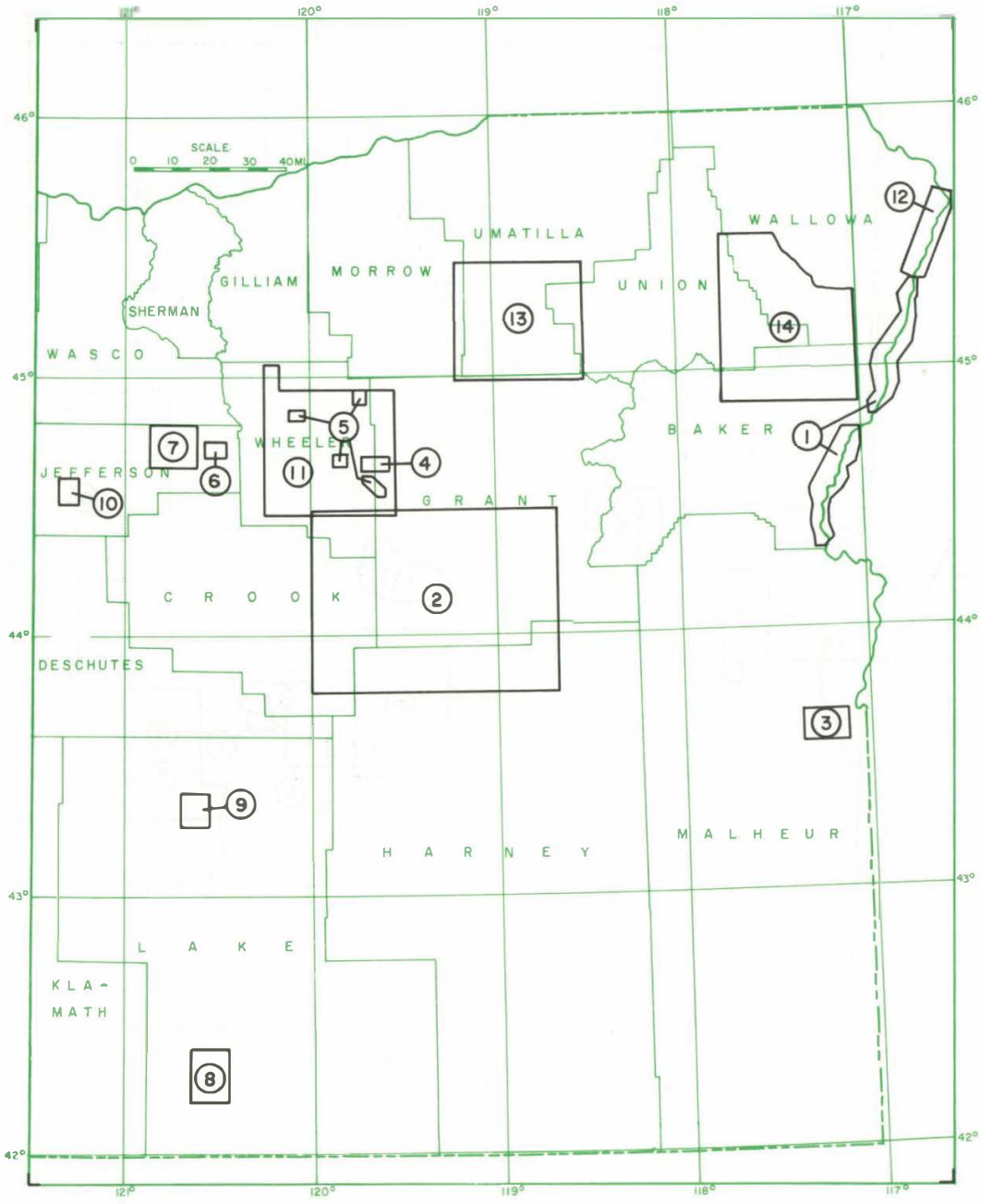

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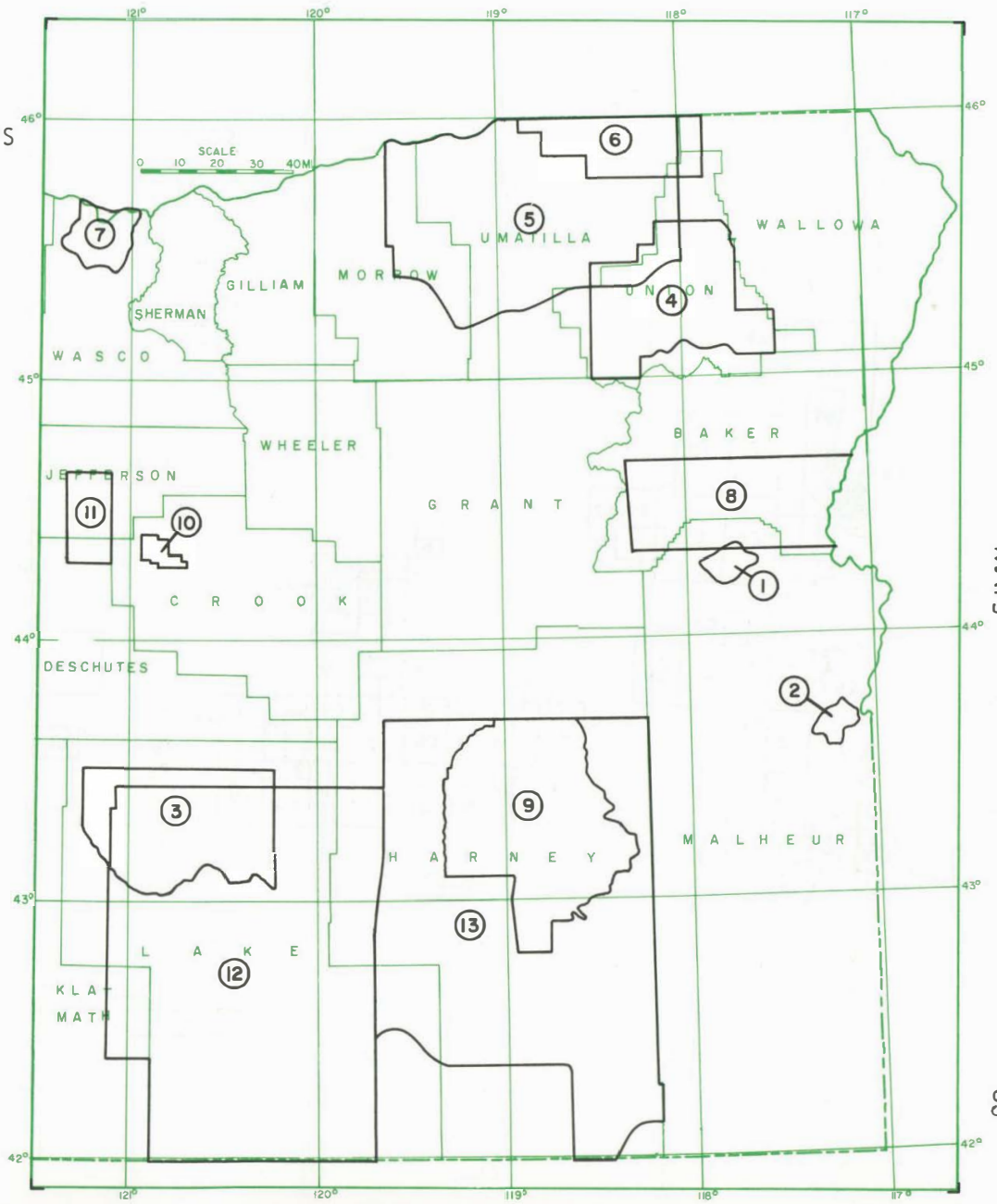

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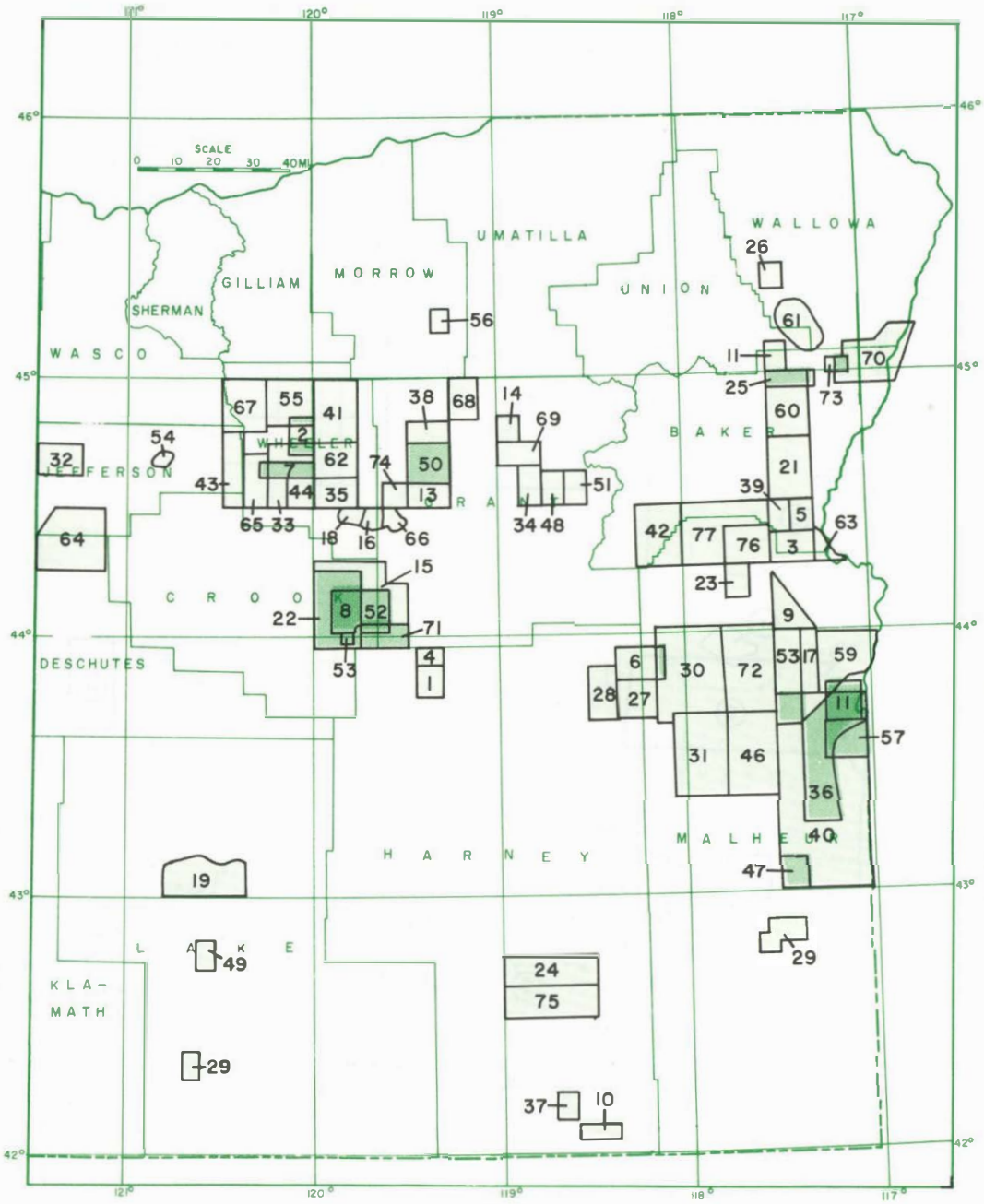
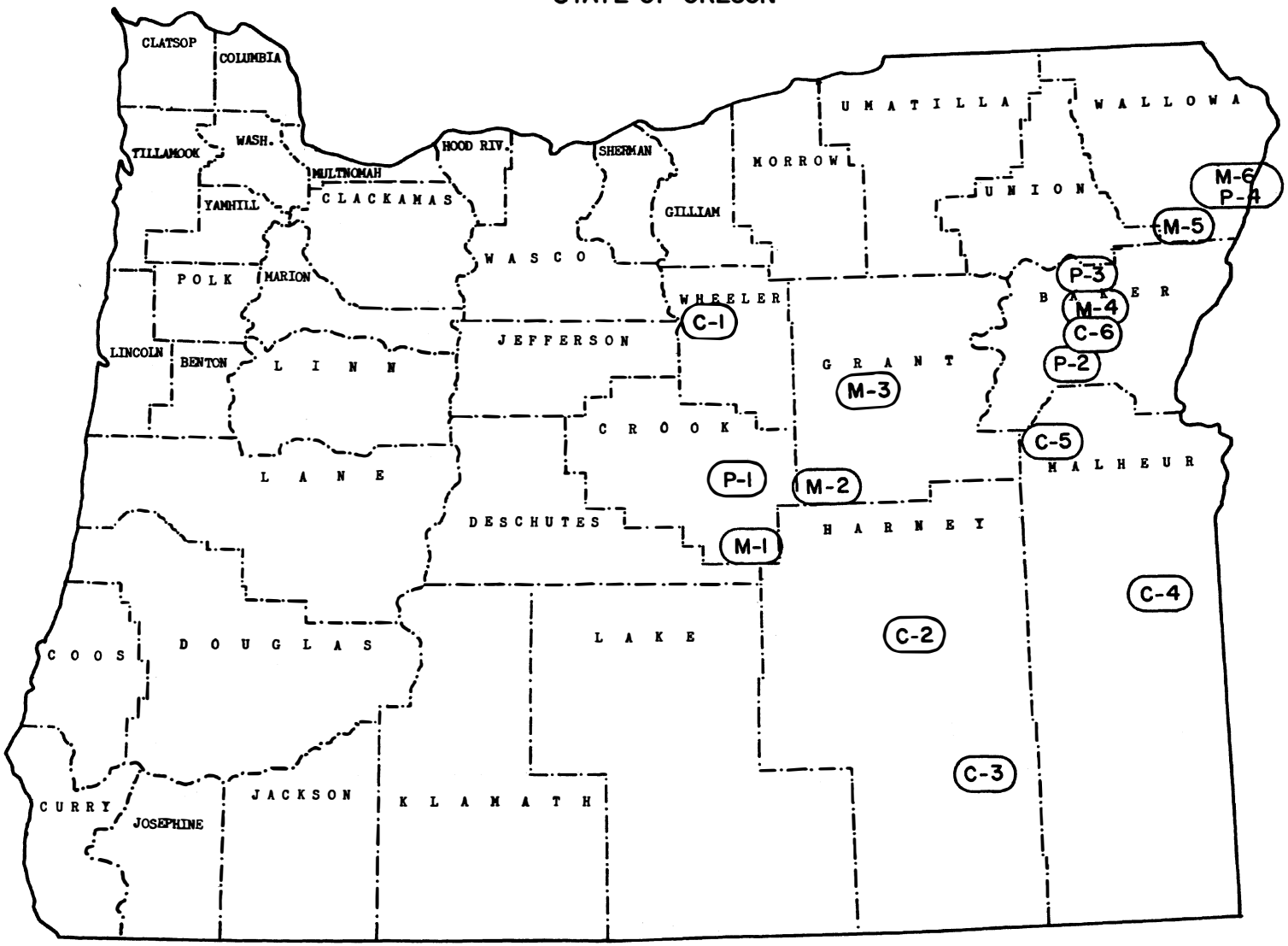
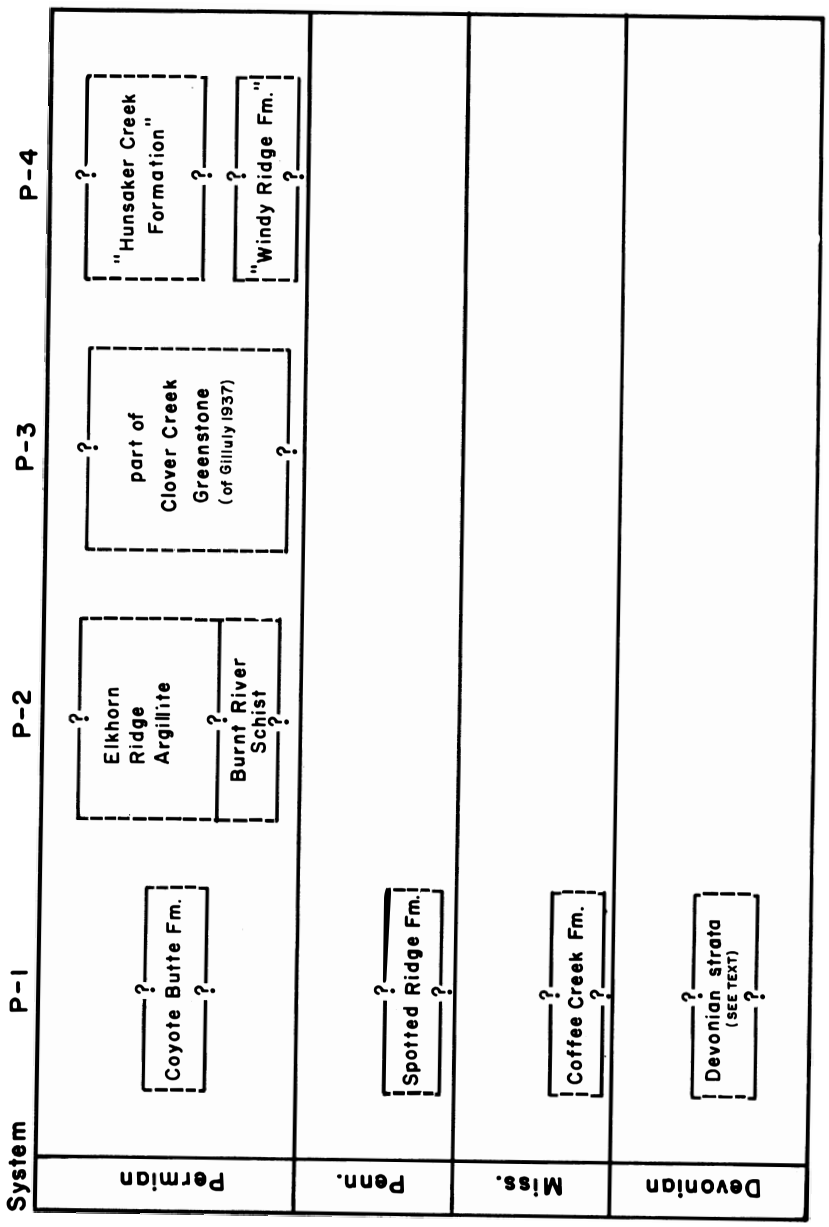


STATE OF OREGON

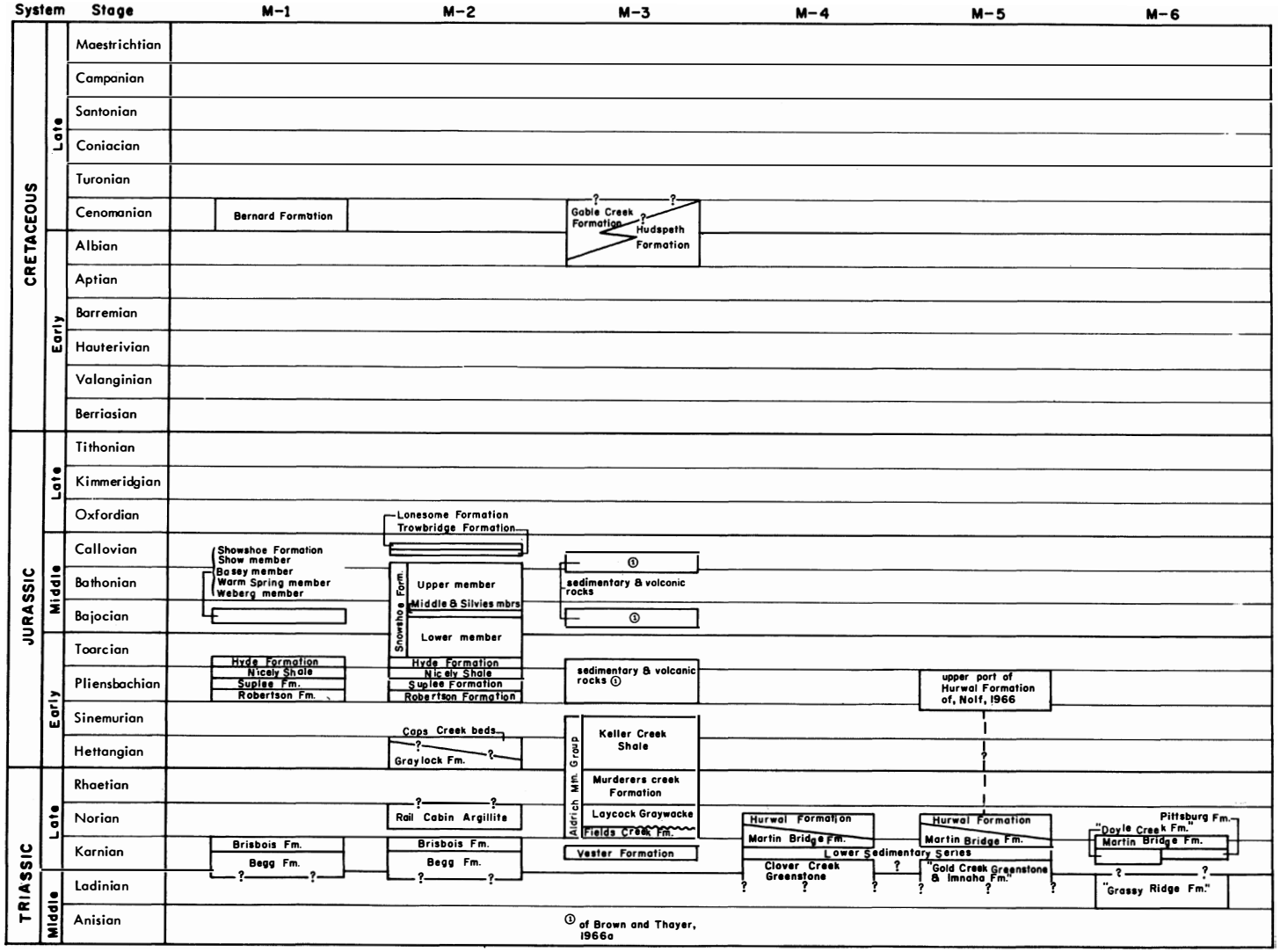


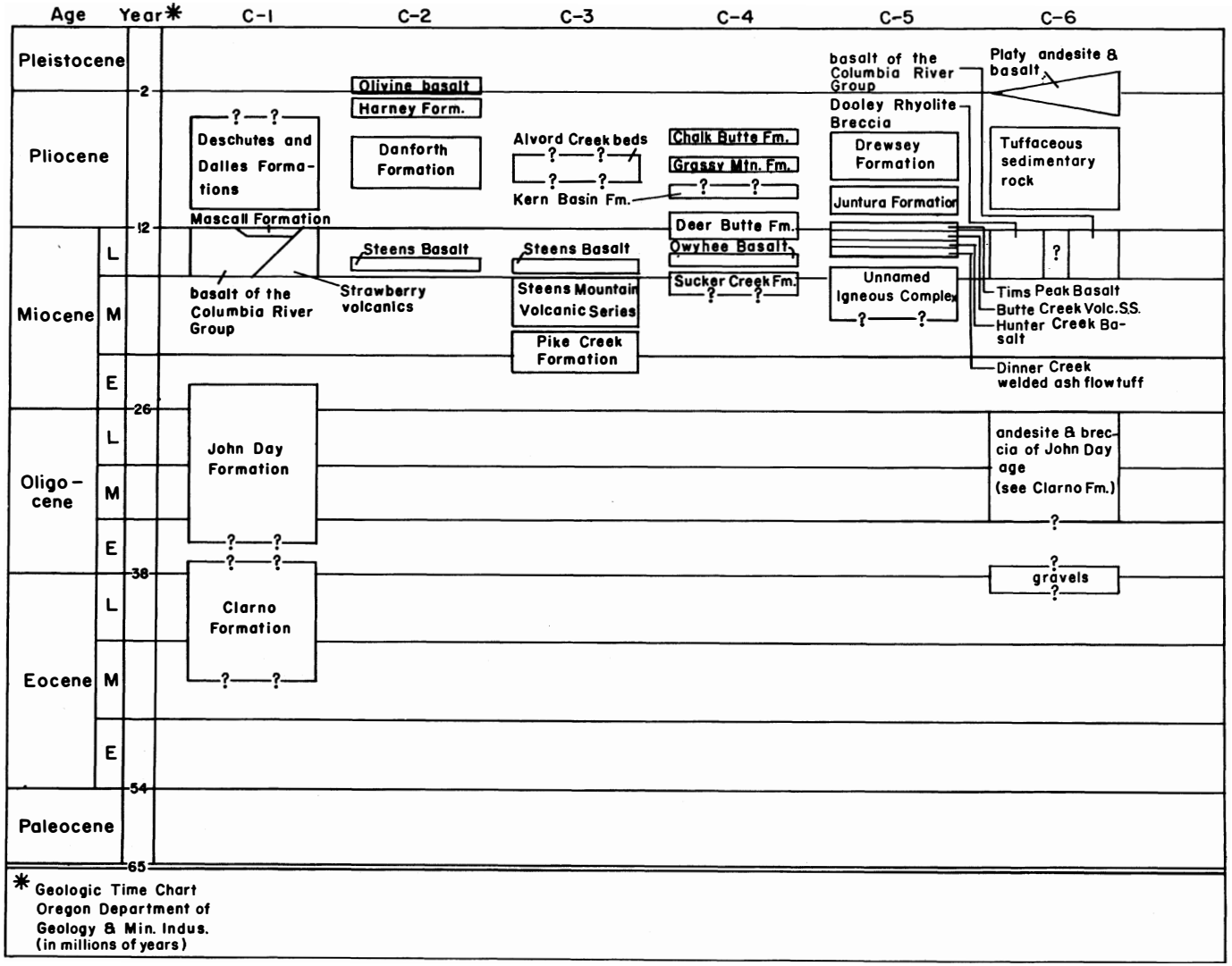
LOCALITIES SHOWN ON CORRELATION CHARTS

PALEOZOIC ROCKS



MESOZOIC ROCKS




Age
Year*
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C-2
C-3
C-4
C-5
C-6
Pleistocene
Pliocene
Miocene
Oligo-cene
Eocene
Paleocene
L
M
E
2
12
26
38
54
65
Olivine basalt
Harney Form.
Danforth Formation
Deschutes and Dalles Formations
Mascall Formation
basalt of the Columbia River Group
Strawberry volcanics
Steens Basalt
Alvord Creek beds
Kern Basin Fm.
Steens Basalt
Steens Mountain Volcanic Series
Pike Creek Formation
Chalk Butte Fm.
Grassy Mtn. Fm.
Deer Butte Fm.
Owyhee Basalt
Sucker Creek Fm.
basalt of the Columbia River Group
Dooley Rhyolite Breccia
Drewsey Formation
Juntura Formation
Unnamed Igneous Complex
Platy andesite & basalt
Tuffaceous sedimentary rock
Tims Peak Basalt
Butte Creek Volc. SS.
Hunter Creek Basalt
Dinner Creek welded ash flowtuff
John Day Formation
Clarno Formation
andesite & breccia of John Day age (see Clarno Fm.)
gravels
* Geologic Time Chart Oregon Department of Geology & Min. Indus. (in millions of years)

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