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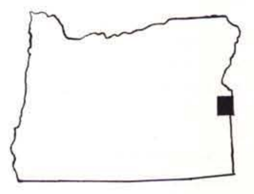
GEOLOGICAL MAP SERIES

GEOLOGY OF THE MITCHELL BUTTE QUADRANGLE, OREGON

by
R. E. Corcoran, R. A. Doak, P. W. Porter
F. I. Pritchett, and N. C. Privrasky



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INTRODUCTION

History of the study

The Mitchell Butte 30-minute quadrangle is situated in eastern Oregon along the Idaho boundary. It lies on the western edge of a much larger region which centers in the broad valley of the Snake River in Idaho and which is occupied by a thick series of late Tertiary lake beds, stream deposits, pyroclastic rocks, and lava flows. These deposits were first visited by Clarence King in 1869 during the exploration of the 40th parallel (1878), and since then have been studied by many geologists. The relative stratigraphic positions of the sedimentary rocks and lava flows were generally established before 1900, but problems later arose when it was discovered that the sedimentary rocks could be divided into at least two separate formations. That these formations were laid down during different time intervals is now well documented by considerable fossil evidence. The younger sediments were called the "Idaho formation" and the older the "Payette formation."

Around the turn of the century, such early geologists as Lindgren, Russell, and Washburn recognized that the Payette and Idaho Formations were separate entities; however, they failed to differentiate them on geologic maps because of their apparent similarity in lithology. Bryan (1929) was the first to attempt to map them as separate units. Later, Kirkham (1931a) summarized all previous work on the Payette and Idaho Formations and concluded that in the Snake River downwarp they were separated by 600 feet of Columbia River Basalt of Miocene age.

Since Kirkham's work in 1931, very little information has been published concerning the Payette and Idaho Formations. The fact that practically no geologic mapping of these sedimentary rocks and associated volcanics had been done in Oregon prompted the mapping of the Mitchell Butte quadrangle. This region was chosen primarily because there appeared to be excellent exposures of both the Idaho and Payette Formations within the boundaries of the quadrangle. The authors, graduate students in geology at the University of Oregon, divided the quadrangle into five portions, one to be studied by each for a master's thesis problem. It was hoped that by thus completing a geologic map of the Mitchell Butte quadrangle, a starting point would be provided for further geologic work in this eastern Oregon region. Also, an effort has been made to clarify the stratigraphic positions of the Payette and Idaho Formations.

As a result of this study, the term "Payette formation," given to the upper Miocene sediments in Oregon by earlier geologists, has been discarded for the map area because of the confusion regarding its supposed type locality in Idaho, and the impossibility of tracing Miocene stratigraphic units across the Snake River Plains into Oregon. Instead, the names "Deer Butte Formation" and "Sucker Creek Formation" are proposed for the upper Miocene sedimentary rocks in this part of Oregon.

The Idaho Formation has been raised to group status to conform with the studies of workers farther east in the Snake River Plains of Idaho, and the rocks within this group in the Mitchell Butte quadrangle are broken down into three units: the Chalk Butte Formation, the Grassy Mountain Basalt, and the Kern Basin Formation.

Location and accessibility

The Mitchell Butte quadrangle lies within the northeast portion of Malheur County, Oregon, with the exception of a narrow strip in Canyon and Owyhee Counties, Idaho. It is bounded by meridians 117°00' and 117°30' west longitude, and by parallels 43°30' and 44°00' north latitude. Vale, the county seat of Malheur County, near the northern edge, and Nyssa, near the eastern edge, are the major towns within the map area. Ontario, Oregon, lies just outside the northeast corner of the map. U. S. Highway 20, the main route between Bend, Oregon, and Boise, Idaho, crosses the northern part and passes through Nyssa and Ontario. Oregon Highway 201 runs south from Ontario along the eastern side of the quadrangle. Secondary roads and unimproved dirt roads, the latter usable only during the summer months, make most of the region fairly accessible.

Physiography

The mapped area lies just within the Columbia River Plateau Province. The more prominent topographic forms in the region are largely the result of the westward tilt of the resistant lava flows which form cuestalike escarpments. The softer sedimentary deposits that are associated with the lavas show a more subdued topography because of their nonresistant character.

The maximum relief for the quadrangle is 2,778 feet; the lowest elevation, 2,182 feet, is in the northeast corner of the area in the Snake River floodplain, and the maximum elevation, 4,960 feet, is at the crest of Owyhee Ridge in the south-central portion of the map. Mitchell Butte, a prominent topographic feature at 3,495 feet elevation, lies near the center of the quadrangle.

Topographically the quadrangle falls into two units. The northern half is an area of low relief with the drainage controlled by the Malheur River, which flows eastward across the northern part of the quadrangle. The north-flowing Snake River drains a strip along the eastern border of the map and is the major controlling stream in the region. The southern half is a rugged upland area that has been deeply dissected by the northeastward-flowing Owyhee River. The Owyhee joins the Snake River near the town of Adrian on the eastern border.

Field work and acknowledgments

The area was first visited on a reconnaissance basis in the spring of 1952 by the authors and Dr. E. M. Baldwin and Dr. J. E. Gair from the University of Oregon Department of Geography and Geology. Most of the quadrangle was mapped during the following summer with the exception of approximately 75 square miles in the relatively inaccessible southwestern corner. Mapping of the unfinished portion was completed by the senior author during succeeding field seasons from 1953 through 1956 while a member of the State of Oregon Department of Geology and Mineral Industries.

During the mapping of the Mitchell Butte quadrangle, many persons gave valuable assistance and information. Particular thanks are given to Dr. Baldwin, who initiated this study and later spent several weeks with the senior author in the Mitchell Butte area helping to clarify the stratigraphy of the region. Additional thanks go to the following paleontologists for identifying and making age determinations on the fossil material collected from the Mitchell Butte quadrangle: Drs. Ralph W. Chaney and the late Roland W. Brown (fossil flora), J. Arnold Shotwell (vertebrates), and Dwight W. Taylor (fresh water mollusca). To the professors and graduate students of the Department of Geography and Geology at the University of Oregon and members of the State of Oregon Department of Geology and Mineral Industries the authors are indebted for their constructive comments and criticism on the manuscript.

STRATIGRAPHIC GEOLOGY

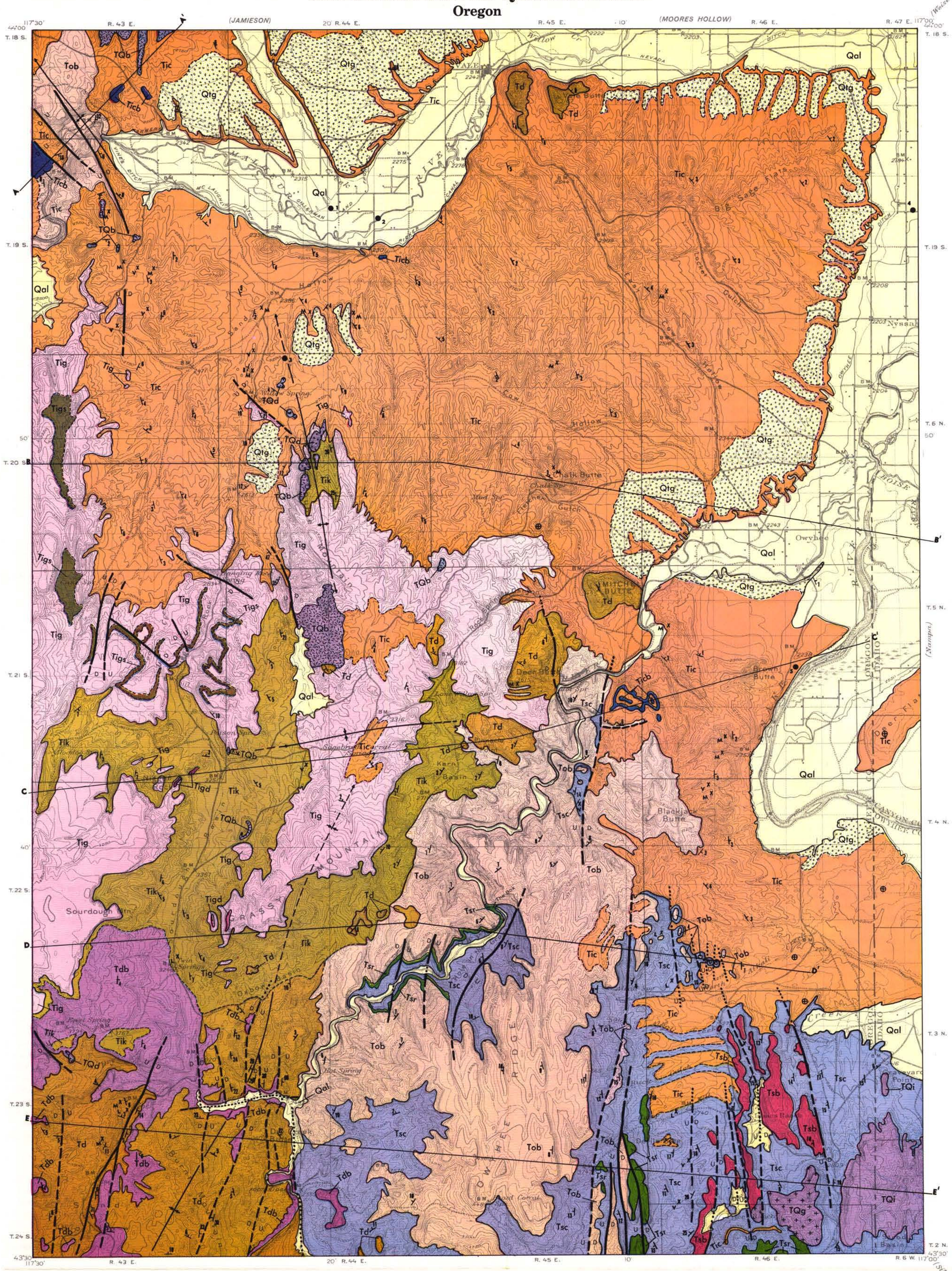
Sucker Creek Formation (Tsc)

General description: The Sucker Creek Formation of upper Miocene age is named from exposures along Sucker Creek in the southeastern part of the quadrangle. The sediments are drab-colored, nonindurated vitric tuffs and tuffaceous lakebed deposits having a pale yellowish- to greenish-orange and dark yellowish-orange color. Greenish-brown, reddish-brown, and grayish-white beds are also relatively common. In the lower part of the formation occur a series of lava flows of basaltic composition which are exposed in the southeastern quarter of the quadrangle in the vicinity of Sucker Creek. Interbedded with the upper part of the formation are several acidic flows and associated intrusives.

Distribution and thickness: The Sucker Creek Formation crops out in three separate areas of the quadrangle: (1) the southern and eastern flanks of the Owyhee Ridge, (2) along the Owyhee Reservoir in the vicinity of the Hole-in-the-Ground, and (3) as a small window in the overlying Owyhee basalts northwest of Blackjack Butte.

The formation is best exposed in the southeastern part of the quadrangle where Sucker Creek and its tributaries have cut through the overlying Owyhee Basalt. Attitudes taken on beds in this region show a fairly consistent northerly strike and a dip to the west of 10° to 25°. In general, the dips steepen westward along the base of the Owyhee Ridge and probably reflect local flexures along sub-parallel fault zones. A section measured in the southwest corner of T. 23 S., R. 46 E. using a plane table and alidade showed a formational thickness of 2,250 feet. Repetition of beds by normal faulting is quite common in this vicinity, however, and it is possible that this figure is somewhat greater than the true thickness.

Geologic Map of the MITCHELL BUTTE QUADRANGLE Oregon



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Based upon the Mitchell Butte
topographic map issued by the
U. S. Geological Survey, 1906

EXPLANATION

QUATERNARY

RECENT

Qal

Alluvium
Predominantly sand and silt of recent age deposited in flood plains of the Snake and Malheur Rivers and their tributaries. Considerable bar and channel gravel in the Owyhee River below the dam.

PLEISTOCENE

Qtg

Terrace gravels
Eroded and terraced deposits of unconsolidated gravel, sand, silt, and clay. Mostly on benches above the present flood plains of the Snake and Malheur Rivers at altitudes from 2250 feet along the Snake to as high as 2500 feet farther west along the Malheur.

UNCONFORMITY

PLIOCENE (?)

TQb TQd TQg TQi

Basic and acidic igneous rocks
Undifferentiated basic and acidic intrusives and flows scattered throughout various parts of the quadrangle, TQi; basalt vitrophyre, TQb; dacite vitrophyre, TQd; gabbro, TQg.

UNCONFORMITY

TERTIARY

PLIOCENE

IDAHO GROUP

Tic Ticb

Chalk Butte Formation
Loosely consolidated tuffaceous conglomerate, sandstone and siltstone of lacustrine or fluviatile origin with lesser amounts of ash and fresh-water limestone, Tic; occasional interbedded basalt flows, Ticb.

UNCONFORMITY

Tig Tigs Tigd

Grassy Mountain Basalt
Thin flows of normal olivine basalt, Tig; includes interflow sediments, Tigs, and feeder dikes, Tigd.

DISCONFORMITY

Tik

Kern Basin Formation
Tuffaceous sandstone and siltstone with bedded tuffs, ash deposits and massive tuff breccias. Conglomerate beds common in basal part of section.

UNCONFORMITY

MIOCENE

Tdb Td

Deer Butte Formation
Soft tuffaceous siltstones and shales grading upward into interbedded tuffaceous siltstones, massive silicified arkosic sandstones and rhyolite-granite conglomerates, Td; few intercalated basalt flows in lower tuffaceous part of section, Tdb.

UNCONFORMITY

Tob

Owyhee Basalt
Massive and scoriaceous basalt flows with tuffs and ash deposits.

UNCONFORMITY

Tsr Tsc Tsb

Sucker Creek Formation
Predominantly bedded and massive varicolored tuffs and tuffaceous shales with minor siltstone and sandstone, Tsc; includes massive flows and intrusions of rhyolite, in upper part, Tsr; also massive to thin-layered flows of basalt in lower part, Tsb.

Contact
Dashed where approximately located or indefinite.

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

Anticlinal axis
Showing trace of axial plane and bearing and plunge of axis; dashed where approximately located.

Synclinal axis
Showing trace of axial plane and bearing and plunge of axis; dashed where approximately located.

Approximate strike and dip of beds or flows.

Horizontal beds or lava flows.

FOSSIL LOCALITIES

Mollusks x_M

Vertebrates x_V

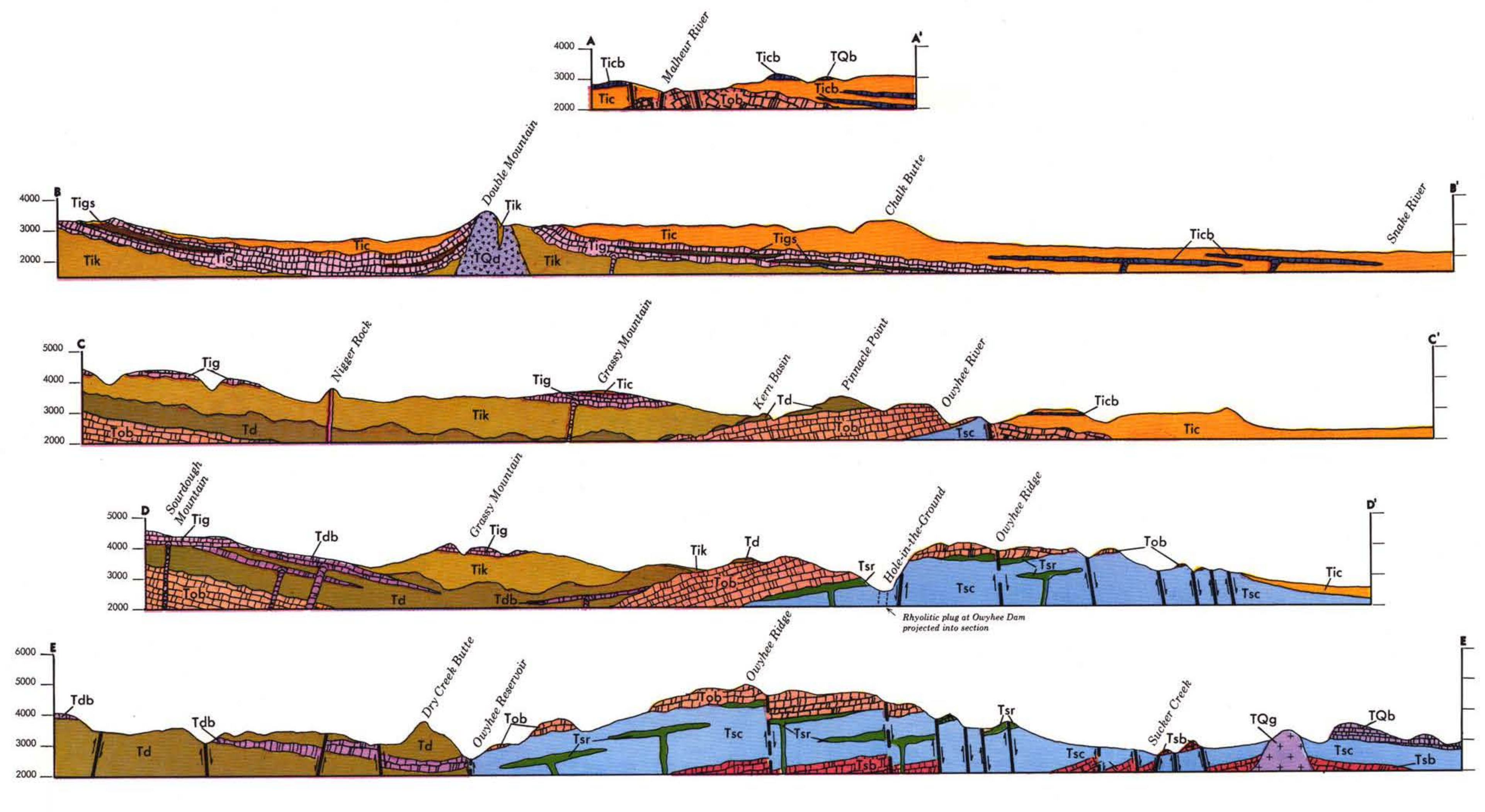
Plant Remains x_L

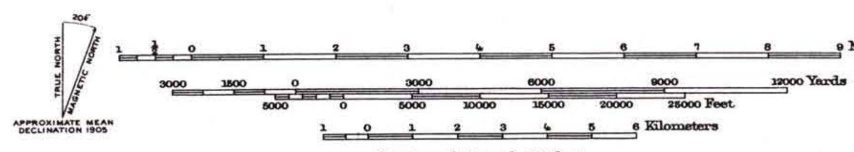
OIL AND GAS EXPLORATORY TESTS

Significant Oil and Gas Tests in the Mitchell Butte Quadrangle.

Map No.	Company or Owner	Well Name	Location and Elevation	When Drilled	Depth
3	El Paso Natural Gas Co.	Federal #1	NE¼NE¼ sec. 5, T. 20 S., R. 44 E. 2,519' grnd.	1954-55	7,470
5	Frank Freel water well.		SE¼SW¼ sec. 14, T. 21 S., R. 46 E. 2,200' ±grnd.	1942	508'
1	Idaho-Oregon Prod. Co.	Recla #1	SE¼SE¼ sec. 9 T. 19 S., R. 44 E. 2,342 R.T.	1950	4,611'
2	R. A. Stamey	Russell #1	NW¼NW¼ sec. 14 T. 19 S., R. 44 E. 2,290' grnd.	1954	4,367'
4	H. K. Riddle	Kiesel Estate #1	SE¼SW¼ sec. 8 T. 19 S., R. 47 E. 2,177' grnd.	1954	5,141'

GENERALIZED GEOLOGIC SECTIONS





Contour interval 50 feet.
Datum is mean sea level

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The tuffaceous sediments of the Sucker Creek Formation exposed in the Hole-in-the-Ground have largely been drowned by the reservoir which fills the Owyhee River canyon above the dam. The beds in this area are generally less deformed than those farther east and this indicates that they are nearer the axis of a major synclinal trough. Before the dam was built, Renick (1930) measured a 500-foot section between the floor of the canyon and the base of the overlying Owyhee Basalt.

The most northerly exposure of the Sucker Creek Formation occurs a short distance east of the Owyhee River in the eastern portion of T. 21 S., R. 45 E. At this locality light-colored beds of tuffaceous siltstone and associated pyroclastics a few hundred feet thick are exposed along a major fault zone trending almost due north. Fossil bones found at this locality indicate an age equivalent to those in the Sucker Creek Formation farther south, or perhaps slightly older.

From the southern edge of the Mitchell Butte quadrangle through Sucker Creek canyon to Rockville, Oregon (approximately 20 miles), there are a number of outcrops of varicolored tuffaceous sediments of the Sucker Creek Formation underlying or interbedded with extensive flows of rhyolite. Many fossil leaf and bone localities occur within this area, mostly in fine-grained tuffaceous sediments.

Lithology of the sediments: The sediments of the Sucker Creek Formation are characterized chiefly by their high volcanic tuff content and lack of induration. Most beds are platy shales and massive siltstones and claystones. Pyroclastic ash and pumice tuffs are fairly widespread but make up only a small proportion of the total section.

Because of its relatively unstable volcanic content, most of the original material in these beds has been altered largely to bentonite (montmorillonite). This has resulted in a type of weathered surface characteristic of many outcrops in this area. When saturated with moisture during the rainy season, the bentonite absorbs excess water and swells considerably. Subsequent dry periods cause the clay to shrink, giving the weathered outcrop a cracked or "expanded" aspect. Plates of selenite are also quite common as a product of surface weathering of the bentonites.

Another typical feature of the formation, also generally true for the younger sediments in the quadrangle, is its lack of continuity. The lithologic units of this series, because of their lacustrine or fluvial origin, are invariably local in extent, and individual members usually show a fairly rapid lateral facies change or else lens out completely.

The base of the formation has been covered in the eastern part of the quadrangle by the younger sediments of the Idaho Group or the alluvium of the Snake River valley. To the west, the lavas of the Owyhee Basalt lie disconformably on the Sucker Creek tuffs or rhyolites.

Basalt flows (Tsb): Lava flows of generally basaltic composition interbedded with the lower part of the Sucker Creek Formation are exposed in the southeastern quarter of the quadrangle in the vicinity of lower Sucker Creek. The lavas crop out as a group of subparallel west-dipping cuestalike ridges which have been considerably dissected by Sucker Creek and its tributaries. The eastern margin of the flows appears to be marked by a fault scarp where beds of the lower Sucker Creek Formation have been down-thrown against the lavas. Farther west the sedimentary rocks are intercalated with the upper flows. Northward the lavas thin out or are wedged out along faults within the Sucker Creek Formation.

The basalt ridges extend approximately 7 miles into the quadrangle from its southern border and have a definite north-south alignment paralleling and probably controlled by several recognizable fault zones in this area. Due in part to the complexity of this fault pattern, it is not possible to trace a single flow for more than a mile and a half in any one direction along the strike.

The width of the outcrop section is about 2½ miles. As the base of the basalts is not exposed and, in addition, because of the faulted nature of the flows, no measurement of the thickness was made. Although the dip of the lavas is inconsistent in degree, probably due largely to the effect of the block faulting, the direction of dip is west. The total thickness, including the intercalated sediments is estimated at 500 to 1,000 feet.

Some of the basalts are platy and fine-grained, but others, especially those lowest in the section, are massive and vesicular. Most hand specimens are fine grained without any visible phenocrysts. Weathered surfaces are usually brownish-red, but fresh breaks show the rock to be typically black or dark gray. Deposits of pumice tuff are often found interbedded with the flows and represent the more explosive phases of eruption.

Microscopically the lavas are found on the average to have hypidiomorphic intergranular ophitic or diabasic texture. Small plagioclase laths are associated with intergranular augite, magnetite, olivine, and glass or chlorite. In one sample studied, the glass has been altered to palagonite. Glass, however, is only a minor constituent in most flows.

Rhyolite flows and intrusives (Tsr): The rhyolite consists of a group of acid rocks of various types that occur in the upper part of the Sucker Creek Formation. Lavas of a similar type having approximately the same stratigraphic position crop out in many areas bordering the Snake River plains in Oregon, Idaho, Utah, and Nevada. These have

been mapped as "Neocene rhyolite" by Lindgren (1898a), and "Tertiary Eocene (?) rhyolite" by Lindgren and Drake (1904a), "Tertiary porphyritic rhyolite" by Bryan (1929), and "Owyhee rhyolite" by Kirkham (1931c).

The rhyolites in the quadrangle appear to be the northern end of a very large mass of acidic lavas that are more widespread farther south in the Sheaville and Silver City quadrangles. The exposures in the Mitchell Butte area are of no great extent and indicate that the extrusive magmas did not flow very far before cooling to an immobile mass. The rhyolite is best exposed along the eastern scarp of the Owyhee Ridge in the general vicinity of Devils Gate and along the sides of the Owyhee River canyon above the dam at the Hole-in-the-Ground.

A typical mode of occurrence is that of a large wedge-shaped block usually no more than a mile or two long and as much as 300 to 400 feet thick in its central portion. An apparent exception to this general mode occurs in the Hole-in-the-Ground. At the north end the rhyolite crops out on both sides of the Owyhee Canyon confining the river to a narrow deep gorge, and it is here that the abutments of the Owyhee Dam have been emplaced. The mass is a feeder vent at this point, but becomes a flow south and west of here for a distance of at least 5 miles.

In the area of Devils Gate the rhyolite crops out as a series of subparallel ridges generally conformable with the interbedded Sucker Creek beds, dipping to the west at angles ranging from 10° to 15°, with a few small feeder dikes visible in the underlying sediments. A series of north-trending normal faults in this area has dropped blocks of the overlying Owyhee Basalt into contact with wedges of rhyolite, and possible repetition or omission of zones obscures the contact relationships of the unit both with younger beds in the upper part of the Sucker Creek Formation and the Owyhee Basalt.

Later erosion has in some areas stripped the uppermost sediments of the Sucker Creek Formation, with the result that locally the Owyhee Basalt now lies directly on rhyolite flows or vents. This is particularly well shown in the Hole-in-the-Ground on the west side of the reservoir, where a wedge of rhyolite intervenes between flows of Owyhee Basalt and tuffs of the Sucker Creek Formation.

Lithologically the rhyolite is a complex of many types of flow rocks, intrusives, and associated pyroclastics, including rhyolite breccias and agglomerates, porphyritic rhyolite, dark-colored pitchstones, and, most commonly, dense microcrystalline or microporphyritic varieties showing well-developed flow banding. Excess silica is frequent as veins crisscrossing the rhyolite outcrops.

In the Hole-in-the-Ground, Bryan (1929) describes four separate phases of the "porphyritic rhyolite": red felsite, felsite breccia, pitchstone, and pitchstone agglomerate. Only the red felsite has any great areal extent, the others being largely confined to the zone around the vent or to surface-cooled phases of the flows.

The felsite is a dusky red, massive, dense, aphanitic rock, which is very resistant to erosion. The Owyhee Dam abutments rest on this rock where it crops out in "The Box." It shows well-developed flow banding which is nearly vertical and has a general northeasterly trend. The rock, however, is locally contorted, and small-scale folds and crenulations are prominent below the dam. The flow structure is noticeable even at a distance because of the well-developed jointing and fracturing in this rock which tends to parallel the banding.

Microscopically, the rock is microporphyritic with a cryptocrystalline groundmass in which are embedded a few microphenocrysts of calcic andesine (An 57) and potash feldspar. The groundmass is composed of glass and crystallites of two varieties; margarites and globulites. The long dimensions of these crystallites show a preferred orientation in the common direction of the flow banding. No quartz could be discerned in the sections studied, the excess silica apparently being taken up as glass in the groundmass. Chemical analysis of several samples of the red felsite (Bryan, 1929) shows a silica content of approximately 72 percent.

The rhyolite observed in the Devils Gate area is a pale reddish brown, also with prominent flow banding. Microscopic examination shows that the groundmass of the rock consists of spherulitic chalcedony which seems to be an original crystallization feature in the rock. The groundmass constitutes 60 to 70 percent of the total mineral content. Phenocrysts are present in variable amounts, usually about 25 percent. Orthoclase and plagioclase phenocrysts , along with minor amounts of magnetite, are also present.

Depositional environment: The concept that the sediments of the Sucker Creek Formation were deposited in a large body of water was held by most of the earlier geologists. Lindgren (1898a) postulated a lake extending over at least the lower part of the Snake River Valley, and he described some of the highest of the present outcrops as representing the elevations of the former "Lake Payette" shoreline. Umpleby (1913) extended "Lake Payette" over the whole Snake River valley.

The mode of occurrence and the varied sedimentary facies found in the Sucker Creek Formation are not of the type one would expect to find in a single large lake. Kirkham (1931a) was the first to realize the somewhat more complex origin of these sediments and visualized a series of temporary shallow lakes which varied in size from one season to another with intervals of complete dessication.

As the majority of the sediments are generally tuffaceous in composition, their origin must have been an area beyond the boundaries of the quadrangle where there was much volcanic activity. The fine-grained texture of the deposits shows also that there were no nearby high-standing mountains undergoing erosion, and the general topography in this vicinity was probably one of fairly low relief.

Throughout the entire region of what is now southwestern Idaho and southeastern Oregon, sporadic volcanic activity during Sucker Creek time gave rise to a disruption of the drainage channels, both through the extrusion of lava flows and the subaerial deposition of pyroclastic material. Small, shallow lakes formed by damming of streams, acted as basins of deposition for varying amounts of volcanic detritus. These lakes probably lasted only a short time before they were filled with sediments or were breached and drained. The varied lithologic character and lateral discontinuity of the beds in the formation reflect the constantly changing depositional phases that occurred throughout Sucker Creek time.

The overall climate in eastern Oregon and the neighboring area of southwestern Idaho at this time was probably warm to cool temperate. The Sucker Creek flora as described by Chaney (1922) and Smith (1933) contains some tropical genera, but the majority are north temperate forms. The presence of Pinus (pine), Quercus (tan oak), and Mahonia (related to the living Oregon grape) indicates a dry foothills environment similar to the Sierra and Siskiyou foothills in northwestern California and southwestern Oregon. A typical stream-border assemblage is represented by Platanus (sycamore), Acer (maple), and Betula (birch). The fact that swamps existed bordering the numerous small lakes is shown by the presence of Equisetum (horsetail rush) and Nymphaeites (water lily).

According to Scharf (1935), brachydont ungulates found in these beds suggest a glade or forest environment. Other grazing mammals such as Merychippus and Merycodus signify that there may have been extensive grasslands interspersed with the forest areas.

Age and correlation: Lindgren (1898a, 1898b) and Lindgren and Drake (1904a, 1904b) were the first to do detailed mapping in the Snake River area of Idaho, the results of which were published by the U. S. Geological Survey as the Boise, Nampa, and Silver City folios and as a report on the mining districts.

In the course of this work, Lindgren collected a number of fossil leaves in sediments bordering the Snake River valley, particularly along the lower Payette River, which were determined by Knowlton (1898) to be Miocene in age. To these Miocene beds he gave the name "Payette formation," but on the accompanying maps he did not separate these leaf-bearing sediments from younger, arkosic sandstones that now would be considered almost certainly as part of the Plio-Pleistocene Idaho Group.

Also, he did not describe any specific type locality for the "Payette" in either Idaho or Oregon, although the name apparently was suggested by exposures along the Payette River near Horseshoe Bend.

Later collections of fossil leaves by Chaney (1922) and Smith (1933) near Sucker Creek in the Rockville area south of the Mitchell Butte quadrangle established a Miocene age for these beds which were at that time correlated with the "Payette formation" of Lindgren.

Buwalda (1924) and Scharf (1935) made vertebrate collections from the "Payette formation" in Sucker Creek, both within the quadrangle in beds now assigned to the Sucker Creek Formation as well as farther south toward Rockville in sediments of similar lithology and stratigraphic position. The presence of Merychippus, Dromomeryx, and Merycodus remains in these beds is typical of other middle and upper Miocene faunas of western North America.

The writer spent some time in the lower Payette River area of western Idaho in an effort to locate and examine typical exposures of "Payette" sediments from which Lindgren made his original collections. Although a few very restricted outcrops were seen of varicolored tuffs and tuffaceous shales, most of the sediments in this region are coarse arkosic sandstones and pebbly conglomerates that bear little resemblance to the finer-grained material typical of the Miocene beds in Sucker Creek.

As it is impossible to trace lithologic units from one side of the Snake River plains to the other because of the Plio-Pleistocene covering in the intervening area, and as Lindgren did not name or describe a type locality, it does not seem warranted at this time to call the beds in Sucker Creek the "Payette Formation." There is no doubt that sedimentary units of similar age are present on both sides of the Snake River plains, but exact correlation of the Miocene in these separated areas can be determined only when more detailed work has been done in Idaho.

Owyhee Basalt (Tob)

General description: The Owyhee Basalt, consisting of a thick section of flows and interbedded tuffs of upper Miocene age, was named by Bryan (1929) from exposures along the canyon of the Owyhee River below the dam. Other thick lava sections of similar age and lithology outside the quadrangle are probably correlatives of this unit.

I. C. Russell (1902) was one of the first geologists to make note of the numerous basalt flows which are so prevalent in this part of Oregon and Idaho. His work, however, was limited to a general reconnaissance of this region, and he merely noted that there appeared to be lavas of two different ages: the older flows belonging to the "Columbia River lava" and younger flows which he named the "Snake River lava."

Later workers who have modified the work on these basalts begun by Russell are Bryan (1929), Renick (1930), and Kirkham (1931c).

Distribution and thickness: The main mass of the Owyhee Basalt crops out in the canyon walls of the Owyhee River from the southern border of the quadrangle to a point just south of Mitchell Butte. The flows form the high ridges that constitute the main portion of the Owyhee Ridge. In general the basalts have a westward dip and are overlain to the west by younger sediments and lavas of the Deer Butte Formation or the Idaho Group.

In the northwest corner of the quadrangle, the Owyhee Basalt forms a small isolated highland in an anticlinal fold that has been cut through by the Malheur River.

The westward dip of the lavas along the Owyhee Ridge is between 10° and 15°, with individual flows ranging in thickness from 5 feet to about 100 feet. Locally, dips as high as 22° were measured along the east side of the Owyhee Ridge, but these are thought to be caused by faulting or slumping of separate blocks. Thickness of individual flows is fairly constant over wide areas, except in local zones where a lava has filled a valley or downfold in the underlying surface.

In the Hole-in-the-Ground, Renick was able to measure approximately 1,300 feet of basalt before the Owyhee Dam was built and the canyon became flooded. In the lower Sucker Creek area, the Owyhee lavas are at least 1,500 feet thick. Their original thickness was probably much greater before erosion removed some of the overlying sediments and the upper layers of basalt.

Interbedded tuff and ash deposits, representing explosive phases of volcanic activity, are common throughout the Owyhee Basalt section. In some outcrops these layers, as much as 10 or 15 feet thick, appear to make up at least half of the total section, but their nonindurated character causes them to weather down readily and they usually are hidden beneath the basalt rubble of the overlying flows.

Lithology: In hand specimen the rock is generally fine grained to aphanitic, dark gray to black, and ranges from very dense to highly vesicular. On weathered surfaces or where it has been baked by overriding flows it becomes dusky red. Most of the vesicular layers occur in the upper part of the flows and in many instances are elongated parallel to the apparent direction of flow giving the rock a faint "flow-banded" appearance.

Under the microscope the basalt is usually micro-porphyritic or seriate in texture. A few specimens were noted which contained phenocrysts of calcic plagioclase as much as 3 millimeters long. The rock is typically holocrystalline, but glass is occasionally present, especially around the vesicles. Diabasic texture is at times developed, with lathlike plagioclase crystals enclosed in large augite grains.

The minerals that are commonly present in the basalts are plagioclase feldspars (in the groundmass and as phenocrysts), augite, hypersthene, olivine, magnetite, and minor amounts of glass, chlorite, iddingsite, and calcite. Zeolites fill the vesicles of many of the less dense flows.

The feldspars are mostly within the labradorite range, but some of the flows contain andesine plagioclase. Augite usually occurs as small crystals occupying spaces between plagioclase laths in the groundmass. Phenocrysts of augite are sometimes evident but are not common in these basalts. Hypersthene generally occurs in the same manner as the augite but in smaller amounts.

The beds of tuff and ash which are found between the separate flows are characteristically lenticular. Where visible above the basalt rubble in the talus slopes, the deposits usually show no bedding and most, if not all, appear to have been deposited subaerially. It should also be noted that many of these beds are very finely vesicular, which would also attest to their subaerial origin. Volcanic glass and angular basalt fragments make up the bulk of the material. The finer grained ashes are usually light gray to white except where baked a deep red by overriding flows. The coarser grained tuffs are somewhat darker, ranging from yellowish-gray to grayish-green in color. Some of the beds have been altered to clay, probably by surface weathering during interflow periods.

Age and correlation: The Owyhee Basalt lies disconformably on the Sucker Creek Formation, from which numerous fossil leaves and bones of upper Miocene (Barstovian) age have been collected. This basalt series is overlain unconformably by the Deer Butte Formation, which, on the basis of vertebrate remains, is also of upper Miocene age (Johnson, 1961). The age of the Owyhee Basalt in the Mitchell Butte quadrangle is therefore restricted to the upper Miocene epoch, the unconformities which separate it from both the overlying and underlying sedimentary units indi-

cating that the lavas flowed out in a comparatively short period of time.

Bryan (1929) correlated the Owyhee Basalt with both the Yakima Basalt of Washington and the Columbia River Basalt of Oregon. More recent studies by Waters (1961) indicate that the Yakima Basalt is of Pliocene age, and is therefore probably younger than the Owyhee Basalt.

In western Idaho, across the Snake River plains from the Mitchell Butte quadrangle, Kirkham (1931c) mapped a series of basalt flows which overlie his "Owyhee rhyolite" and "Payette formation." He called these the upper series of the Columbia River Basalt. The present interpretation of the Columbia River Basalt is that the formation includes a thick section of flows and associated pyroclastics in Oregon, Washington, and Idaho, which are approximately middle to upper Miocene in age.

Lavas in Picture Gorge which are called Columbia River Basalt (Coleman, 1949) can be traced eastward to the John Day area (Thayer, 1956) and the Ironside Mountain quadrangle (Lowry, 1959). Basalts of apparently similar age and stratigraphic position crop out a few miles south of the Ironside Mountain quadrangle in the Malheur River gorge between Juntura and Harper (Dole and Corcoran, 1954). Those along the Malheur River dip gently to the east beneath Miocene and Pliocene sediments and lavas and appear to form the west limb of a large syncline, the east limb of which crops out along the Owyhee Ridge in the Mitchell Butte quadrangle as the Owyhee Basalt. Although the Columbia River Basalt cannot be traced continuously from Picture Gorge to the Owyhee Ridge, it seems probable that the Owyhee Basalt is at approximately the same stratigraphic position and geologic age.

Deer Butte Formation (Td)

General description: The Deer Butte Formation of upper Miocene age contains a section of fine-grained tuffaceous sediments with a few intercalated basalt flows (Tdb) in the lower part, grading upward into massive sandstones and conglomerates. Deer Butte, the type locality for which the formation is named, is a resistant knob underlain by the coarser and more indurated part of this series. Farther south, in the area west of the reservoir, the less resistant fine-grained tuffaceous sediments predominate.

In the earlier reports (Corcoran 1953, Doak 1953), these rocks were included with the younger beds of the Idaho Group, but more detailed study has shown that this formation is older and separated by a distinct erosional unconformity from the Idaho sediments.

Distribution and thickness: The formation is a fairly widespread unit within the quadrangle, particularly in the southwestern corner. The well-cemented arkoses and conglomerates characteristic of the upper part of the section are well exposed in Deer Butte and underlie many of the more prominent hills, including Dry Creek Butte, Pinnacle Point, and Mitchell Butte. In several places these knobs crop out as isolated steptoes separated from the main body of the formation by younger sediments and lavas of the Idaho Group. The Vale Buttes are a good example of this type of erosional feature.

South of Dry Creek the less indurated lower part of the formation predominates with only occasional layers of the coarse cemented sandstone. Conglomerates are almost entirely lacking. Within the lower part are several lava flows that are generally similar in composition to and may represent a late phase of the underlying Owyhee Basalt.

One area of Deer Butte exposures too small to show on the map is in the vicinity of North Alkali Creek in the east-central part of the quadrangle. Here, almost vertically dipping beds of arkosic sandstone crop out along a north-trending valley apparently along a fault zone. Although the rocks in this area are mostly fine-grained tuffaceous sediments assigned to the Sucker Creek Formation, it is possible that the block faulting in this region bordering the Snake River plain has brought down wedges of Deer Butte sediments into contact with the older unit.

As the Deer Butte sediments were deposited on a dissected erosion surface, the total thickness of the formation varies considerably from place to place.

The thickest section of the upper coarser member is exposed in Deer Butte, where 1,248 feet was measured in relatively flat-lying sediments. The finer grained, more tuffaceous lower part of this series is better developed south of the quadrangle in the vicinity of Red Butte (sec. 22, T. 25 S., R. 43 E.), where Johnson (1961) measured a thickness of 591 feet. A partial section of this lower member within the quadrangle in the NW¼ sec. 22, T. 23 S., R. 43 E. had a thickness of 415 feet. The Deer Butte beds in the southwest corner of the quadrangle have been repeated several times by block faulting, and, although there appear to be several thousand feet of the lower member exposed both here and in the adjoining basin to the west, the actual thickness is considerably less.

Where the formation crops out along the reservoir near the mouth of Dry Creek, the beds lie on the upper flows of the Owyhee Basalt; but farther south the lavas have been stripped and the Deer Butte sediments were deposited on the eroded surface of the Sucker Creek Formation. The disconformable relationship between the Deer Butte and the

Sucker Creek Formations has been obscured by the reservoir which fills the Owyhee canyon along the contact zone. This relationship can be seen best in the adjoining Sheaville quadrangle near Red Butte where sediments of the Deer Butte Formation fill valleys cut into the Sucker Creek Formation during the post-basalt erosion interval (Kittleman 1961).

Tuffaceous siltstone member: The lower part of the formation is composed largely of fine-grained tuffaceous siltstones, claystones, and shales, with at least three intercalated basalt flows. A few thin beds of platy carbonaceous shales are also present in the section. The color is characteristically pale orange to yellowish orange, although tinges of red, green, and gray are not uncommon.

Most of the sediments show some bedding and appear to have been deposited in small lakes under much the same environmental conditions as the older Sucker Creek deposits. The lithologic similarity of the lower member of the Deer Butte Formation to the Sucker Creek Formation makes identification and separation in the field difficult, particularly when the vertebrate fossils collected from the two series indicate they are nearly the same age (Barstovian). Both formations are relatively soft, weathering down into subdued ridges held up by more resistant strata, and fresh outcrops are comparatively rare.

One characteristic of the formation, particularly of the lower member, is the occurrence of calcite veins in several of the outcrop sections. These veins are as much as 25 feet in width and half a mile long. In 1943 the department investigated these occurrences to determine whether any crystals of sufficient size for optical purposes could be extracted from these veins. The results of the investigation are discussed later in this report.

Arkosic sandstone: Probably the most characteristic feature of the upper member is the coarseness of the sedimentary unit as a whole and the highly resistant nature of these beds due to the secondary silica cementation. The silica has been concentrated in the coarser sandstone and conglomerate zones because of their greater permeability as compared to the finer grained and clayey tuffaceous siltstones and shales which also occur throughout the section.

Examination of these sandstones shows that they are composed predominantly of quartzite, quartz, and chert grains, with plagioclase feldspar usually making up less than 10 percent of the material. A few samples studied showed a relatively high percentage (15 to 25 percent) of orthoclase feldspar and probably reflect weathering of a granitic terrane.

The cobbles which make up the conglomerates are as much as 6 or 8 inches across and are composed predominantly of granites, rhyolites, quartzites, and quartz. The amount of basaltic material in these beds is quite low, which is rather surprising in view of the fact that this formation rests disconformably upon the thick sequence of flows that make up the Owyhee Basalt. Examination of 14 conglomerates from various localities in the Deer Butte Formation by Ladwig (1957) showed that only one of these contained as much as 5 percent basalt detritus.

The source area for these rocks is not definitely known, but it appears to be in the vicinity of Silver City, approximately 35 miles southeast of the Mitchell Butte quadrangle on the west side of the Snake River plains. A mineralized granite stock about 10 miles wide by 25 miles long has been unroofed in this mountainous region by erosion of the overlying Tertiary rhyolites, tuffs, and basalts (Lindgren and Drake, 1904b). They also report seeing a belt of "quartz-biotite-schists and normal quartzites which, beyond doubt, are contact metamorphosed sediments." It is also possible that some of the sandstones in this unit may have come from the Idaho batholith area, the western edge of which lies along the northern and eastern borders of the Snake River plains in Idaho. The writer has seen siliceous sandstone similar in lithology to those of the upper member of the Deer Butte Formation lying on a thick basalt sequence east of Emmett, Idaho, in the vicinity of Black Canyon Dam and also southeast of Weiser, Idaho, at the Idaho-Almaden mercury mine. Granite crops out only a few miles east of these localities, and it is possible that the structural basin of the Snake River plains now separating the batholith from the Mitchell Butte area did not exist during upper Miocene time or was not as fully developed. Wheeler and Cook (1954) and Taylor (1960) present evidence to show that the flow of the Snake River northward into the Columbia River is a fairly recent development (early Pleistocene?) and before this time may have followed an independent course southwestward to the sea.

The change in grain size and lithology between the lower and upper members of the Deer Butte Formation may be significant in showing the time at which the granites became exposed in this area by erosion of the overlying older Tertiary volcanic cover.

Age and correlation: Fossil leaves, bones, and fresh water mollusks have been found in the lower member, and mollusks also in the upper member of this formation. The vertebrate remains appear to be the most diagnostic, and according to Shotwell are of Barstovian (upper Miocene) age (Johnson, 1961).

The Deer Butte Formation lies disconformably on the Owyhee Basalt and therefore occupies about the same stra-

tigraphic position as the Mascall Formation in central Oregon (Coleman, 1950).

Other probable stratigraphic equivalents of the Deer Butte and Mascall Formations are the beds at Beatys Butte in southwestern Harney County. These beds also contain an upper Miocene vertebrate fauna (Wallace, 1946) and lie on the thick sequence of basaltic and andesitic flows that make up the bulk of the Steens Mountain fault block (G. W. Walker, oral communication, 1961). Although the fossil evidence concerning the age of the Steens Basalt is contradictory, the general lithologic character and thickness of the lavas suggest that they, too, are a correlative of the Columbia River Basalt.

On the west side of the Harper Basin, approximately 10 miles west of the Mitchell Butte quadrangle, are pale-orange massive tuffs and arkosic sandstones lying disconformably on east-dipping Owyhee Basalt (Dole and Corcoran, 1954). The general lithology of these sediments and their relationship to the underlying lavas indicate they may be a northwesterly extension of the Deer Butte Formation.

Lastly, as has been noted earlier in this report, certain coarse, well-cemented sandstone beds above a thick section of basaltic lavas along the east side of the Snake River plains in the vicinity of Weiser, Emmett, and Boise, Idaho, show a very similar lithology and stratigraphic position to that of the Deer Butte Formation in Oregon.

Idaho Group

General description: Cope (1883) described an extensive fauna of fresh-water fishes from fossil collections made by Clarence King from sediments along Castle and Sinker Creeks in the Snake River area. On the basis of these determinations, Cope proposed the name "Idaho formation" for the sediments and assigned them a Pliocene age. Later work in the Snake River basin by Lindgren and Drake (1904a,b), Kirkham (1931a,b), and Malde and Powers (in press) has resulted in a better knowledge of the areal distribution of the "Idaho formation," but because of the diverse lithologies of the sediments and associated volcanics found in this series, it has been proposed to elevate this formation to group status. In this way distinctive lithologic units characteristic of various areas in and bordering the Snake River plains, but which cannot be closely correlated over wide areas, can be adequately described.

In the Mitchell Butte area the Idaho Group has been subdivided into three units: the Kern Basin Formation (lower Pliocene), Grassy Mountain Basalt (lower Pliocene?), and Chalk Butte Formation (middle Pliocene). The separation of the Idaho Group into three formations is facilitated by the presence of a distinctive series of flows separating two predominantly sedimentary sections. The Grassy Mountain Basalt thins to the east, however, and probably it would be difficult to distinguish the two sedimentary formations on an entirely lithologic basis if the basalt sequence were absent.

Distribution and thickness: The Idaho Group crops out over much of this area as a broad, almost flat-lying sedimentary blanket. The two sedimentary units (the Kern Basin and Chalk Butte Formations) are exposed in the northern two-thirds of the quadrangle and also along the eastern boundary. The Grassy Mountain Basalt, the middle unit of the Idaho Group, crops out in the central and southern parts of the map area.

In general, the beds dip 6 to 10 degrees northeast towards the center of the Snake River basin in Idaho. This regional dip is only slightly modified by minor folding or faulting, except in the vicinity of Double Mountain, where the group has been folded into a sharp anticlinal upwarp by intrusion of post-Idaho igneous rocks.

As the top of the Idaho Group is not exposed in Oregon, no true thickness could be determined. Within the quadrangle, the thickness of the combined sedimentary and basaltic section may be as much as 13,000 feet, but part of this may be repetition of the section by faulting. Ditch samples examined from the El Paso Natural Gas Co. well drilled near Willow Springs in sec. 5, T. 20 S., R. 44 E., penetrated at least 6,000 feet of Idaho sediments and volcanics before bottoming in a dacitic intrusive at 7,470 feet. Farther east, in the more central portion of the Snake River basin, Kirkham (1931a) measured a section in the Idaho Group that was 18,633 feet. He notes that much of this thickness could be due to repetition by faulting. It would seem likely, however, that there are at least 10,000 feet of sediments and associated volcanics of the Idaho Group along the Oregon margin of the Snake River plains.

Kern Basin Formation (Tik): Good exposures of the Kern Basin Formation can be seen in Oxbow, Sourdough, and Kern basins where the sediments form steep bluffs from 100 to more than 600 feet in height capped by Grassy Mountain Basalt. The beds vary in color from white to green with occasional dark bands. A partial section measured at the type locality in Kern Basin (sec. 1, T. 22 S., R. 44 E.) showed a thickness of approximately 750 feet.

Most of the beds are loosely consolidated and tend to weather into pinnacled or "hoodoo" forms. They include tuff, tuffaceous siltstone and sandstone, low-rank graywacke, and occasional conglomerates deposited under con-

ditions that fluctuated from lacustrine to fluviatile.

Microscopic analysis of the tuffaceous sediments shows them to contain calcite, glass shards, and a clay of the montmorillonite group. The conglomerates which occur near the base of the section contain rhyolites, pegmatites, granites, and basalts and were probably derived in part from the conglomerates of the underlying Deer Butte Formation.

Basaltic flows and sills are present in the Kern Basin Formation but are quite minor compared to the volcanic rocks that characterize the overlying Grassy Mountain Basalt, and were not mapped separately.

Grassy Mountain Basalt (Tig): Overlying the Kern Basin Formation is the series of flows referred to by Kirk Bryan (1929) as the "Grassy Mountain basalt." The basalts cap the hills along the western border of the quadrangle and can be traced eastward through the central portion to the western edge of Mitchell Butte. In the north-central part of the mapped area, the basalt dips beneath sediments of the Chalk Butte Formation, while to the south the lavas have been removed by erosion exposing the underlying Kern Basin Formation.

Flows of the Grassy Mountain Basalt are interbedded in most places with sediments, the number and thickness of which vary considerably. The total thickness, including the sediments, may be more than 1,000 feet, as indicated by the sample log of the El Paso Gas Co. Federal No. 1 well (NE¼NE¼ sec. 5, T. 20 S., R. 44 E.). Where the basalts and interflow sediments are exposed farther to the south in Grassy Mountain, the observed thickness is about 500 feet. The basalts tend to be massive, but usually no more than three or four separate flows can be observed in any one locality. Individual flows range in thickness from a few feet to about 100 feet.

In the hand specimen, the basalt is brownish-gray to olive-black in color, aphanitic to porphyritic, with phenocrysts of plagioclase and olivine. Most of the flows are quite dense, but some are vesicular with the vesicles elongated in the flow direction. Some of the more vesicular varieties have become lined or filled with zeolites and secondary calcite. One of the distinguishing mineralogic characteristics of the flows in this unit is the presence of olivine, readily visible in both the hand specimen and under the microscope. In some sections the olivine has altered wholly or in part to iddingsite. Large first-generation feldspars and phenocrysts of olivine, augite, and occasionally hypersthene, in a groundmass of small second-generation feldspars, characterize most of the thin sections examined.

Feeder dikes were noted in the vicinity of Poison Springs and on the southwestern tip of Grassy Mountain; the largest of them was traced for a distance of more than 200 yards and ranged in thickness from 10 to 20 feet. It is difficult to designate a specific zone of intrusive activity for the source of these lavas, because Sourdough, Oxbow, and Kern basins are the only areas in which erosion has exposed the sediments beneath the Grassy Mountain flows. From the apparent thickening of the lavas south and southwestward, it is probable that the locus of volcanism in this area at that time was in the general vicinity of Sourdough Mountain and the southern end of Grassy Mountain.

Chalk Butte Formation (Tic): The most widely distributed beds in the quadrangle are those of the Chalk Butte Formation. Sediments of this unit cover most of the northern half of the quadrangle, a large part of the eastern margin, and continue north and east into the main part of the Snake River plains in Idaho. The general dip of these beds is east and northeast as much as 6° to 8° into the central part of the downwarp. The Snake River now occupies the axis of the basin in Idaho a short distance across the state line from Oregon.

The formation is in contact with the Grassy Mountain Basalt in the northern part of the quadrangle, lying on its slightly eroded surface, but along the eastern margin the sediments rest with a marked angular as well as erosional unconformity upon the westward-dipping Sucker Creek Formation and Owyhee Basalt.

The Chalk Butte Formation is somewhat coarser grained than the older Kern Basin Formation, and conglomeratic facies are relatively common. The predominating lithologic types are tuffaceous sandstones, siltstones and conglomerates with lesser amounts of tuff, ash beds, and fresh water limestone. A partial section measured at the type locality (SE¼ sec. 22, T. 20 S., R. 45 E.) showed a thickness of approximately 538 feet. Because of the relatively unconsolidated nature of the beds, the formation crops out mostly as low, subdued hills with the best exposures along the numerous dry washes where streams have scoured out deep gullies.

In appearance the sediments are light colored with well-marked bedding ranging from microscopic laminae to massive, 20-foot zones. Fluctuation from a fluviatile to lacustrine environment is shown by scour channeling and plant-bearing clays, and small-scale deltaic deposits can be observed in many of the conglomeratic horizons.

Most of the specimens examined under the microscope were found to contain varying amounts of glass shards in a clayey matrix. Shell fragments of fresh water gastropods, pelecypods, and ostracods are common. In general the upper part of the formation, particularly in the northern portion of the quadrangle, bears a more lacustrine aspect than does the lower. An outstanding feature of the sediments contained in the upper part is the nearly universal pres-

ence of carbonate in amounts greater than 30 percent. In secs. 16 and 21, T. 19 S., R. 45 E., is a ridge capped by a 15-foot bed of oolitic limestone. Locally the oolites are cemented and partially replaced by chalcedony. Gastropod remains are scattered throughout this bed, the fossils being completely replaced by silica.

A few flows of basalt are enclosed within beds assigned to the Chalk Butte Formation, particularly in the vicinity of Brown Butte. The lavas are generally less than 30 feet thick, however, and do not show any great lateral extent. It is probable that these represent minor eruptions that followed the greater volcanic activity that gave rise to the Grassy Mountain Basalt.

Age and correlation: Lindgren (1898a, 1898b), and Lindgren and Drake (1904a, 1904b) recognized two separate formational units in the Snake River plains which they called the Payette and Idaho Formations, but they did not show these separately on the published maps, since the units were considered too similar in appearance to be distinguished in the field.

Later studies on the problem by Merriam (1918), Buwalda (1924), and Kirkham (1931a) in this region and the more recent work in the Mitchell Butte quadrangle have shown that the two formations have distinctive lithologic characteristics and fossil assemblages and are usually separated by a fairly thick rhyolite and basalt sequence.

Several fresh water mollusk and leaf localities have been found in sediments of the Idaho Group, but the fossil remains of this type have either not been sufficiently distinctive or adequately studied as to justify more definite dating than a Pliocene age.

Vertebrate collections made at two localities, one in the Kern Basin unit and the other in the Chalk Butte, have been studied by J. A. Shotwell, who reported that the fauna from the Kern Basin suggests a lower Pliocene (Clarendonian) age, while that of the Chalk Butte is clearly of middle Pliocene (Hemphillian) age. Later discovery of a Merychippus tooth from one of the lower beds in the Kern Basin Formation by Kittleman and Johnson (oral communication, 1960) indicates the possibility that the lower part of this unit may be as old as upper Miocene. The amount of vertebrate material obtained from the Kern Basin Formation has been rather meager, but it is hoped that future finds in this unit will establish its age range with greater precision than is presently possible.

Farther west in Oregon, several basins contain sediments, the youngest of which are middle Pliocene age. These deposits are sometimes called the Rattlesnake Formation (Merriam, 1901), Danforth Formation (Piper and others, 1939; Campbell and others, 1958), and Drewsey Formation (Gray, 1956; Bowen, 1956). The deposits are relatively local in extent and do not appear to have any close relationship with the Snake River basin sediments to the east.

Basic and acidic flows and intrusives (TQi)

General description: Scattered throughout the Mitchell Butte area are intrusive domes with associated flows of igneous rocks which range in composition from basalt-gabbro to dacite. Most of these are localized centers of volcanism which began after the major part of the period of deposition in this region represented by the Idaho Group. The total extent of such rocks is only a few square miles and involves a relatively small portion of the mapped area.

Three main rock types have been included under the general symbol TQi: (1) vitrophyres at Double Mountain and other isolated exposures in the western part of the quadrangle; (2) a coarse-grained gabbro dome near Price's ranch in the southeastern corner of the quadrangle; and (3) a basaltic andesite also in the vicinity of Price's ranch.

Lithology: The Double Mountain-type rocks are porphyritic with a very high percentage of glass in the groundmass, and are thus classified as dacite, andesite, or basalt vitrophyres based on the mineral composition of the phenocrysts. A typical specimen contains 85 percent glass and 15 percent crystals; the phenocrysts are composed mostly of labradorite, andesine, or oligoclase, with lesser amounts of pyroxene, quartz, and sanidine. Near the south end of Double Mountain is a large complex area broken up by post-intrusion faulting, characterized by sills, dikes, volcanic necks, and flows. Although there is some variation in rock type, most of the samples studied were basaltic or andesitic vitrophyres.

The gabbro and basaltic andesite near Price's ranch show no close mineralogic relationship to the vitrophyres described above.

The gabbro, in secs. 34 and 35, T. 23 S., R. 46 E., and secs. 2 and 3, T. 24 S., R. 46 E., has the appearance of a large intrusive mass about 3 square miles in area forming a prominent hill of approximately 500 feet relief. The rock is dark yellowish-brown and massive, with vertical joint planes trending generally east or southeast. It is coarse-grained with well-formed crystals of labradorite associated with numerous blebs of magnetite. Large augite and olivine crystals occur between the labradorite laths, giving it an intergranular texture, with the augite making up as much as 25 percent of the rock.

The basaltic andesite, occupying approximately 7 square miles in the southeast corner of the quadrangle, is

dark reddish-brown, vesicular, and microporphyritic. Most of the vesicles are lined or filled with secondary silica. Under the microscope the rock is almost completely holocrystalline, having the appearance of a felted mass of randomly oriented feldspar laths interspersed with considerable magnetite or hematite "dust." A few small crystals tentatively identified as augite were noted but make up less than 5 percent of the rock. Because the feldspars fall in the range An 48 to 52, the rock lies on the border of the andesite-basalt class, and the term "basaltic andesite" is applied to this type of flow.

Age and correlation: Most of the vitrophyric intrusives, especially those at Double Mountain, are clearly younger than the rocks that surround them as shown by baked contacts, upturned beds around the periphery of the bodies, and small-scale lit-par-lit injection. Double Mountain, the center of a major anticlinal structure in this region, has been developed, at least in part, through the upwarping of the sediments and lavas of the Pliocene Idaho Group by these intrusions.

Vitrophyre flows considered to be Plio-Pleistocene in age are found a few miles north and west of the Mitchell Butte quadrangle (Moore, 1937; Carlat, 1954). Lavas lying on middle Pliocene sediments called "Pliocene olivine basalt" near Juntura (Bowen, 1956), "Post-Idaho basalt" near Huntington (Beeson, 1955), and "Mesa basalt" west of the Pueblo Mountains (Merriam, 1910) also appear to occupy about the same stratigraphic position as these rocks. South and west of the Mitchell Butte quadrangle, in various parts of the "Owyhee Plateau," are a number of rhyolitic or dacitic plugs which, on the basis of reconnaissance mapping by Corcoran, appear to be post-Idaho in age.

In the Price's ranch area, dikelike feeders to the basaltic andesite have baked the surrounding Miocene Sucker Creek beds along the contact zone, proving that the flows are at least younger than the lower part of this formation. The generally flat-lying nature of these lavas, in contrast to the moderately deformed Sucker Creek sediments, is another indication that the volcanics are younger. Just east of the quadrangle, very gently dipping beds of the Chalk Butte Formation lap against the basaltic andesite, and if this relationship exists in the map area the lavas were probably extruded at about the same time as the Grassy Mountain Basalt farther east.

The gabbro intrusive is surrounded, and in some spots overlain, by Sucker Creek sediments. The contact zone is obscured by talus, but the sediments do not appear to have been disturbed by the intrusive, which may indicate that the gabbro is the oldest exposed rock in the quadrangle.

Quaternary deposits

Terrace gravels (Qtg): The "terrace gravels" are the coarse, poorly consolidated basaltic gravels which lie on the Idaho Group from 50 to 150 feet above the present drainage channels. These gravels cap the low-lying hills along the margins of the major rivers and in a few areas to the north and west of Double Mountain.

The deposits range in thickness from about 3 feet along the upper benches to as much as 30 feet at the mouth of Bully Creek. The gravels are generally very coarse, and boulders are commonly up to 6 inches in diameter. The matrix is pebbly or sandy with some fine silt, and, being poorly consolidated, the terrace gravels tend to drape down the sides of the ridges.

Most exposures show good cross bedding. At one time these deposits probably occupied the flood plains of the Malheur, Owyhee, and Snake Rivers and their tributaries. A general lowering of base level in the region has caused the streams to cut down through these beds leaving them as benches above the present drainage channels.

A camel jaw found in terrace gravels near Adrian, Oregon, by I. S. Allison suggests a Pleistocene age. The disconformable stratigraphic relationship of these deposits to the underlying Chalk Butte Formation would support this general age assignment.

These beds are probably roughly equivalent to Kirkham's (1930) Lower and Upper Mesa gravels, although the deposits were not mapped separately in this area.

Recent alluvium (Qal): The alluvium is mostly confined to the major valley floors, particularly in the area occupied by the present flood plain of the Snake and Malheur Rivers. The material is generally fine grained, somewhat clayey, and derived for the most part from the poorly indurated sediments of the Idaho Group.

STRUCTURAL GEOLOGY

The most prominent structural feature in this part of Oregon is the Snake River downwarp. This is a large structural trough which extends from Yellowstone Park across southern Idaho and into eastern Oregon. The western extremity of the depression is in the vicinity of Vale, Oregon. Kirkham (1931b) was the first to apply the term "Snake

River downwarp" to this region and showed that in the western part, thousands of feet of sediments had collected in the gradually sinking basin.

Kirkham, however, apparently did not fully appreciate the extent or magnitude of the faulting which took place along the periphery of the depression in late Miocene or early Pliocene time. The numerous faults which can be seen cutting the westward-dipping Sucker Creek beds along the eastern side of the quadrangle probably have resulted in a total vertical displacement of the sediments on the order of several thousand feet, although the amount of offset in any one zone is usually no more than a few hundred feet. The recent field studies by Malde (1959) and the gravity survey conducted by Baldwin and Hill (1960) farther east in Idaho also show that there is widespread faulting along the margin of the downwarp in that area. As more studies are completed in the Snake River downwarp, the extent of this large-scale structure may show it to be comparable in size and complexity to such grabens as the Rhone Valley in Germany and the rift valleys of East Africa.

After the sediments of the Idaho Group were laid down on the older Miocene erosion surface, folding with some faulting on a lesser scale continued. The two major post-Idaho structures in this area are: a broad syncline extending northeastward through the quadrangle from Burnt Mountain to Grassy Mountain and the previously mentioned anticlinal fold through Double Mountain.

The Grassy Mountain syncline dies out to the north near Lone Willow Springs, and the sediments of the Chalk Butte Formation show only a low regional dip into the center of the downwarp. The Double Mountain anticline appears to be caused, at least in part, by numerous basaltic to dacitic intrusives which shouldered aside the overlying sediments and volcanics of the Idaho Group in late Pliocene or early Pleistocene time. The exploratory hole put down on the north end of this structure by El Paso Oil & Gas Co. in 1954 penetrated several dacitic and andesitic sills before bottoming in a thick dacite intrusive at 7,470 feet.

In general, the trend of the fault pattern in this area, both Miocene and Pliocene, is north. A complicating factor when attempting to delineate faults, particularly in the Sucker Creek Formation, is the tendency for large blocks of these soft tuffaceous sediments overlain by rhyolite or Owyhee Basalt to break away from erosion scarps and slump down hill. These slump blocks range in area from a few feet to as much as a square mile and produce outcrop patterns similar to those caused by faulting. A good example of typical slumped topography occurs in secs. 30 and 31, T. 22 S., R. 46 E.

ECONOMIC GEOLOGY

A clay deposit near Vale is the only mineral resource produced commercially in the quadrangle at the present time. Semi-precious gemstone material found in this region consists primarily of assorted varieties of agate, opal, and petrified wood. The calcite veins in the vicinity of Dry Creek were investigated by the Oregon Department of Geology and Mineral Industries (Lowry, 1943), as a possible source of optical grade crystals. Unfortunately, no effective method was found for removing the crystals from the vein without cleaving them to sub-specification sizes.

Exploration for oil and gas has taken place sporadically throughout the Vale-Ontario portion of the Snake River plains since the beginning of the century (Washburne, 1909). Although no commercial quantities of either oil or gas have been discovered, the presence of several thin gas zones in the Pliocene sediments, together with increased interest in exploration of non-marine basins, has prompted the drilling of several exploratory wells in recent years (see table on map sheet).

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