STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
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GEOLOGY AND MINERAL RESOURCES MAP OF THE MITCHELL BUTTE QUADRANGLE, MALHEUR COUNTY, OREGON

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Geology and Mineral Resources Map of the Mitchell Butte Quadrangle, Malheur County, Oregon

By Mark L. Ferns and Kevin M. Urbanczyk

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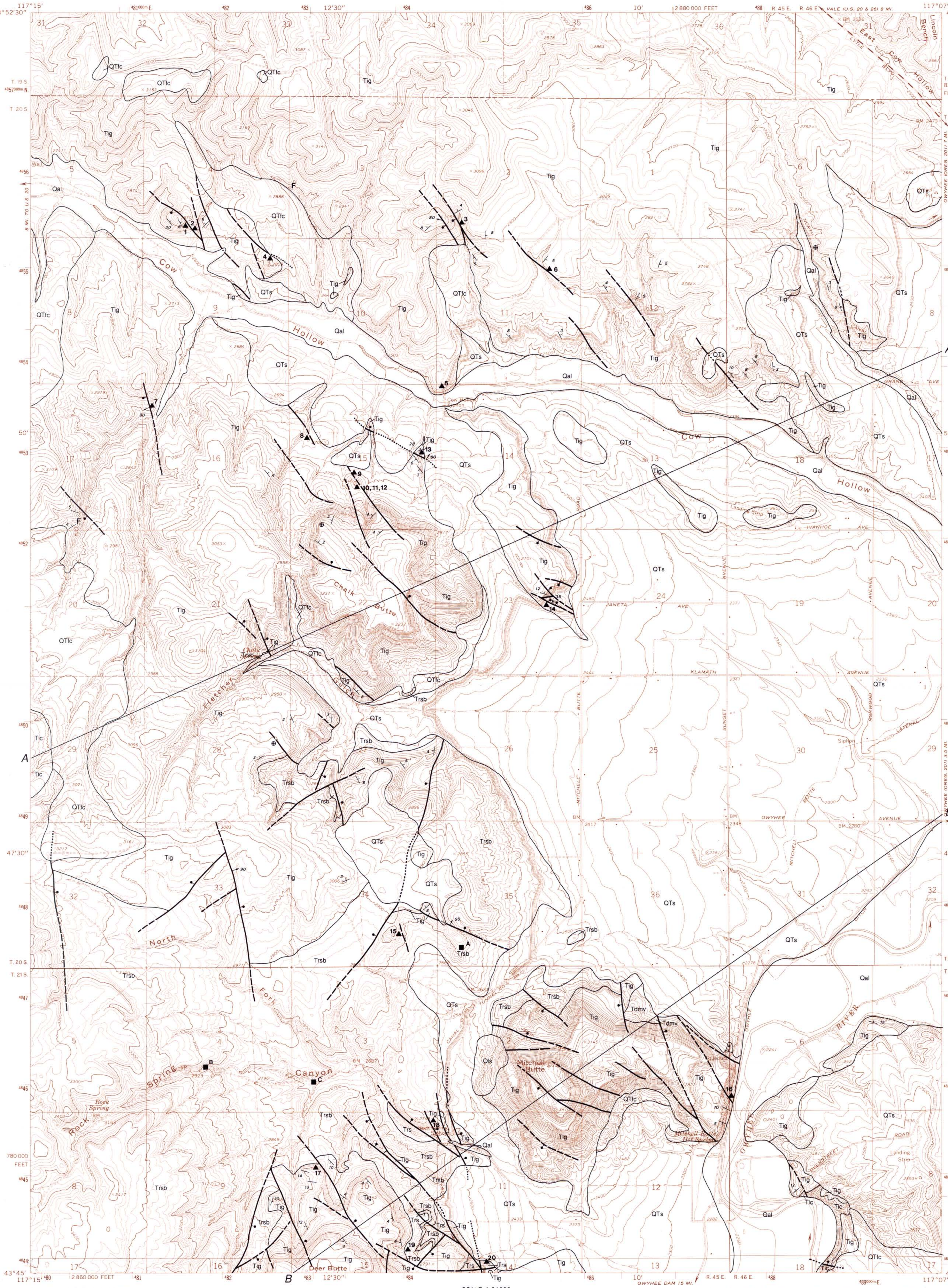

Base map by U.S. Geological Survey

Control by USGS and USC&GS

Topography by photogrammetric methods from aerial photographs taken 1966–67. Field checked 1967

Polyconic projection. 1927 North American datum
10,000-foot grid based on Oregon coordinate system, south zone

UTM GRID AND 1967 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:24000

CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

QUADRANGLE LOCATION

Geology by Mark L. Ferns, Oregon Department of Geology and Mineral Industries, and Kevin M. Urbanczyk, Washington State University

Field work conducted in 1989

Reviewed by John D. Beaulieu, Oregon Department of Geology and Mineral Industries, Portland, Oregon; Marshall W. Gannett, Oregon Department of Water Resources, Salem, Oregon; and Spencer H. Wood, Boise State University, Boise, Idaho.

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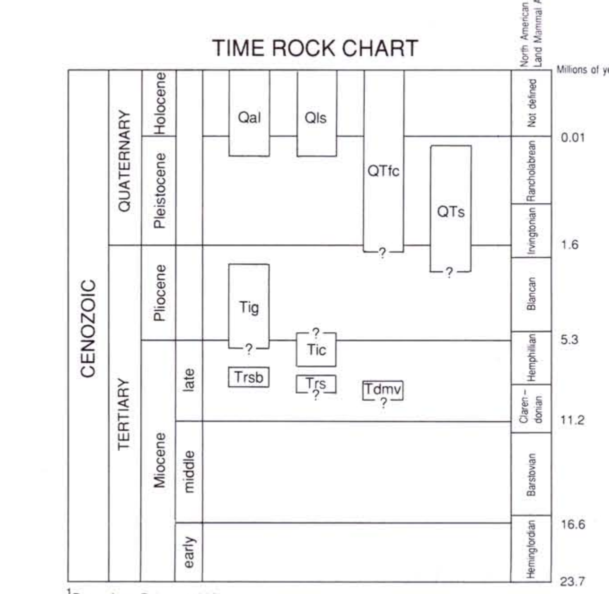
TIME ROCK CHART



[1]Dates from Palmer (1983)

Table 1. Whole-rock analyses, Mitchell Butte quadrangle, Malheur County, Oregon[1]

Map no.	Field and laboratory no.	1/4	1/4	Sec.	T. (S.)	R. (E.)	UTM coordinates	Elev. (ft)	Lithology	Map unit	Oxides (wt. percent) SiO_2	Al_2O_3	TiO_2	Fe_2O_3	MnO	CaO	MgO	K_2O	Na_2O	P_2O_5	LOI	Total	Trace elements (ppm) Cr	Rb	Sr	Y	Zr	Nb	Ba
A	AXB-302	SW	SW	35	20	45	484752N 48462E	2,840	Olivine basalt	Trsb	46.7	15.7	0.94	10.4	0.18	10.5	9.70	0.83	2.15	0.17	2.16	99.5	383	21	220	23	53	15	184
B	AXB-330	NE	SW	4	21	45	484620N 48182E	2,900	Olivine basalt	Trsb	46.1	15.8	1.55	11.7	0.19	10.4	8.94	0.53	2.34	0.34	2.16	100.2	258	18	223	13	107	18	220
C	AXB-329	SW	SW	3	21	45	484694N 48302E	2,640	Olivine basalt	Trsb	46.3	15.6	1.57	11.9	0.18	10.7	8.20	0.48	2.22	0.33	2.62	100.2	273	21	244	32	116	41	253

[1]XRF analyses by XRAL.

Table 2. Trace-element analyses, Mitchell Butte quadrangle, Malheur County, Oregon[1]

Map no.	Laboratory no.	1/4	1/4	Sec.	T. (S.)	R. (E.)	UTM coordinates	Elev. (ft)	Lithology	Map unit	Ag (ppm)	As (ppm)	Au (ppb)	Cu (ppm)	Hg (ppm)	Mo (ppm)	Pb (ppm)	Sb (ppm)	Tl (ppm)	Zn (ppm)	Bi (ppm)	Cd (ppm)	Ga (ppm)	Se (ppm)	Te (ppm)	U (ppm)	Sn (ppm)
1	AXB-213	SE	SW	4	20	45	485548N 48162E	2,760	Weakly silicified conglomerate	Tig	0.310	15.0	< 1	5.82	0.190	9.16	4.68	0.419	< 0.5	8.49	< 0.25	< 0.1	1.44	< 1.0	< 0.5	0.3	10
2	AXB-214	SE	SW	4	20	45	485544N 48172E	2,700	Sandstone	Tig	0.048	30.1	< 1	5.50	0.111	16.9	3.39	0.441	< 0.5	8.73	< 0.25	0.099	1.54	< 1.0	< 0.5	0.3	< 5
3	AXB-215	SW	SW	2	20	45	485548N 48466E	2,760	Silicified conglomerate	Tig	0.125	34.5	5	10.2	< 0.10	2.39	5.89	0.918	< 0.5	19.4	< 0.25	0.107	1.86	< 1.0	< 0.5	0.7	6
4	AXB-216	NE	NE	9	20	45	485508N 48256E	2,800	Sandstone	Tig	0.046	16.6	< 1	5.35	0.285	2.89	2.90	0.578	< 0.5	14.8	< 0.25	0.121	1.78	< 1.0	< 0.5	0.3	6
5	AXB-220	NW	NW	14	20	45	485368N 48446E	2,560	Silicified conglomerate	Tig	0.139	165.	< 1	18.6	< 0.10	16.0	5.49	3.62	< 0.5	96.2	< 0.25	0.225	4.14	< 1.0	< 0.5	5.3	< 5
6	AXB-217	NE	NE	11	20	45	485512N 48560E	2,720	Silicified conglomerate	Tig	0.09	8.42	< 1	7.80	< 0.10	2.22	2.22	0.559	< 0.5	11.1	< 0.25	0.129	1.40	< 1.0	< 0.5	< 0.1	7
7	AXB-210	NW	NW	16	20	45	485278N 48346E	2,720	Silicified conglomerate	Tig	0.08	25.2	< 1	9.14	< 0.10	2.69	2.75	0.769	< 0.5	15.7	< 0.25	< 0.1	1.27	< 1.0	< 0.5	0.8	< 5
8	AXB-218	SW	NW	15	20	45	485314N 48298E	2,660	Silicified conglomerate	Tig	0.129	29.6	< 1	8.56	1.39	3.58	3.78	0.911	< 0.5	10.9	< 0.25	0.128	1.97	< 1.0	< 0.5	1.2	< 5
9	AXB-219	NE	SW	15	20	45	485278N 48352E	2,700	Silicified conglomerate	Tig	0.281	38.7	15	14.8	< 0.10	7.29	5.82	1.18	< 0.5	15.4	< 0.25	0.176	2.90	< 1.0	< 0.5	1.2	< 5
10	AXB-209	NE	SW	15	20	45	485260N 48352E	2,800	Argillic sandstone	Tig	0.937	130.	207, 200[2]	24.0	< 0.10	5.32	8.79	4.12	< 0.5	28.7	< 0.25	0.178	3.02	< 1.0	< 0.5	< 0.5	< 5
11	AXB-221	NE	SW	15	20	45	485260N 48352E	2,800	Silicified conglomerate	Tig	0.172	77.9	20	13.5	< 0.10	4.30	7.14	1.78	< 0.5	29.7	< 0.25	0.150	3.68	< 1.0	< 0.5	1.0	5
12	AXB-224	NE	SW	15	20	45	485260N 48352E	2,800	Argillic sandstone	Tig	0.056	130.	8	13.9	< 0.10	6.08	7.22	1.97	< 0.5	30.8	< 0.25	0.143	4.20	< 1.0	< 0.5	1.4	< 5
13	AXB-222	SE	NE	15	20	45	485298N 48420E	2,580	Limonitic sandstone	Tig	0.137	79.5	< 1	7.13	< 0.10	5.46	2.23	0.761	< 0.5	7.18	< 0.25	0.094	1.25	< 1.0	< 0.5	1.2	< 5
14	AXB-251	SE	NE	23	20	45	485216N 48558E	2,600	Weakly silicified conglomerate	Tig	0.072	64.4	2	17.2	< 0.10	8.56	59.5	0.865	< 0.5	16.1	< 0.25	0.119	1.53	< 1.0	< 0.5	2.1	< 5
15	AXB-223	SW	SE	34	20	45	484766N 48396E	2,860	Chalcedony veinlets	Trsb	0.025	6.60	< 1	8.30	< 0.10	3.26	0.794	0.271	< 0.5	11.0	< 0.25	< 0.1	1.68	< 1.0	< 0.5	0.4	< 5
16	AXB-225	SW	SW	6	21	46	484586N 48760E	2,300	Weakly silicified sandstone	Tig	0.089	29.3	< 1	8.12	0.155	2.89	6.04	1.05	< 0.5	20.2	< 0.25	0.099	3.83	< 1.0	< 0.5	1.2	7
17	AXB-211	SW	NW	10	21	45	484506N 48302E	2,940	Silicified conglomerate	Tig	0.057	5.11	< 1	10.7	< 0.10	1.45	3.77	0.555	< 0.5	37.8	< 0.25	0.157	3.76	< 1.0	< 0.5	0.4	< 5
18	AXB-226	NE	NE	10	21	45	484554N 48432E	2,640	Chalcedony and limonitic gouge	Trsb	0.054	57.5	6	23.1	0.236	1.98	7.69	1.73	< 0.5	32.1	< 0.25	0.183	4.98	< 1.0	< 0.5	3.1	5
19	AXB-227	SE	SE	10	21	45	484416N 48406E	2,720	Calcite veinlets	Trsb	0.059	5.46	9	44.7	< 0.10	1.16	1.96	0.432	< 0.5	48.5	< 0.25	0.141	8.18	< 1.0	< 0.5	0.5	9
20	AXB-212	NE	NW	14	21	45	484400N 48492E	2,560	Silicified conglomerate	Trs	0.08	4.62	< 1	9.00	< 0.10	1.67	5.50	0.451	< 0.5	33.5	< 0.25	< 0.1	3.47	< 1.0	< 0.5	1.0	< 5

[1]Gold analyses by Bondar-Clegg; other trace-element analyses by GSI.
[2]Gold analysis by GSI.

EXPLANATION

Qal — **Alluvium (Pleistocene and Holocene)**—Unconsolidated and generally poorly sorted deposits of gravel, sand, and silt accumulated along modern streams and flood plains

Qls — **Landslide deposit (Pleistocene or Holocene)**—Unconsolidated and chaotic accumulation of large silicified sandstone blocks on the west flank of Mitchell Butte

QTfc — **Colluvial and alluvial fan deposits (Pliocene?, Pleistocene, and Holocene)**—Colluvial deposits of diverse origins and ages, including thick accumulations of wind-blown silt (loess) and sand on the tops of benches and ridges along Cow Hollow and alluvial fan and slope deposits consisting of unconsolidated coarse gravels and silts

QTs — **Terrace gravels and unconsolidated and poorly consolidated silt and sandstones (upper Pliocene? and Pleistocene)**—Mainly unconsolidated flood-plain deposits of silt and sand deposited above the existing flood plains of the Owyhee and Snake Rivers. Includes fringing terrace deposits of poorly consolidated basalt and rhyolite clast conglomerates that cap benches north of Cow Hollow and south of Chalk Butte. Includes poorly consolidated deposits of cross-bedded sands and gravels. May be in part correlative with Pleistocene and upper Pliocene lake deposits such as the Bruneau Formation of Malde and Powers (1962). Equivalent to the terrace gravels mapped by Doak (1953), Privrasky (1953), and Corcoran and others (1962). Gravels separated from unit **Tig** on basis of abundant basalt clasts

Tig — **Tuffaceous conglomerates and sandstones (upper Miocene? and Pliocene)**—Mainly tuffaceous arkosic sandstone and siltstone with interbedded lenses and sheets of black chert-pebble conglomerate. Includes light-colored, fine-grained tuffaceous fluviatile and deltaic sandstone, conglomerate, siltstone, and mudstone. Conglomerate lenses range from half an inch to 4 ft in thickness and range from discontinuous lenses to thick cross-bedded sheets with a quarter-inch in diameter black chert, basalt, granite, quartz, and rhyolite pebbles and angular petrified wood fragments. Lower part of the unit at Deer Butte includes medium-grained, cross-bedded arkosic sandstones, interbedded fossiliferous (gastropods) calcareous sandstones, and white waterlain tuff. Basal part of the unit at Mitchell Butte and Deer Butte includes a 4-ft-thick bed of a coarse arkosic conglomerate with abundant rhyolite and pumice clasts. Unit grades upward into finer grained arkosic sandstones and siltstones that are mapped separately by Brown (1982) as the sedimentary rocks of Captain Keeney Pass. Some of the finer grained sandstones contain fossil fish bones. Unit unconformably overlies limestone of unit **Tic** in sec. 29, T. 20 S., R. 45 E. Unit can be traced southeastward into Pliocene arkosic sandstones and chert-pebble conglomerates of unit Tig exposed in the Adrian quadrangle (Ferns, 1989a) that are considered by Kimmel (1982) and Smith and others (1982) on the basis of fish fossils to be equivalent to the basal transgressive sandstones of the Pliocene Glenns Ferry Formation of Malde and Powers (1962). Includes the upper part of the Chalk Butte Formation as defined by Corcoran and others (1962), the upper part of unit Tis as mapped by Ferns (1989b) in the Owyhee Dam quadrangle to the south, and the Mitchell Butte Member of the Deer Butte Formation as defined by Kittleman and others (1965). Sandstone and conglomerate form resistant yellowish outcrops in areas near hydrothermal systems where silica and/or carbonate cement has been introduced. Some of these areas, e.g., Mitchell Butte, were previously considered to be isolated erosional remnants of older, more resistant Deer Butte Formation (Corcoran and others, 1962)

Tic — **Tuffaceous siltstone, sandstone and limestone (upper Miocene and Pliocene?)**—Mainly lacustrine deposits of poorly consolidated light-gray, fine-grained, tuffaceous sandstone, siltstone, and mudstone. Includes thin beds of diatomaceous siltstone, tuff, and pebbly sandstone. Westernmost exposures include a distinctive 4- to 5-ft-thick bed of massive white limestone with apparent algal structures and abundant fragments of gastropod shells near the contact with underlying basalt of unit Trsb at Mud Springs in the adjacent Double Mountain quadrangle (Ramp and Ferns, 1989). Exposures south of Overstreet Road (sec. 7, T. 20 S., R. 46 E.) are cross-bedded, medium- to fine-grained sandstones with interbedded light-gray diatomaceous siltstones. Correlative with the lower part of the Chalk Butte Formation of Corcoran and others (1962) and unit Tis as mapped by Ferns (1989b) in the Owyhee Dam quadrangle to the south. Based on stratigraphic position beneath the arkosic sandstone and chert-pebble conglomerate of unit **Tig**, believed to be equivalent to late Miocene lake sediments exposed west of Adrian (Smith and others, 1982; Ferns, 1989a) that are considered correlative with the Chalk Hills Formation of Malde and Powers (1962)

Trsb — **Olivine basalts at Rock Spring (upper Miocene)**—"Snake River-type" olivine basalt flows and interbedded deposits of tuffaceous siltstone and sandstone. Unit **Trsb** is composed of approximately equal amounts of flows and intraflow sedimentary rock. Flows are thin, dark-black to bluish- and greenish-black amygdaloidal olivine basalts. Texturally, these holocrystalline and hyalocrystalline olivine basalt flows contain olivine and plagioclase phenocrysts with ophitic or intergranular clinopyroxene. Chemically distinguished by relatively high K_2O (>0.40 percent) content. Includes "water-affected basalts"; i.e., outcrops characterized by a tendency to weather to zones of granular soil composed of basalt fragments separated by basal red baked zones or paleosols. About 400 ft of section is exposed on the lower end of Rock Spring canyon. Unit is the upper part of the Grassy Mountain Basalt of Bryan (1929). Fiebelkorn and others (1982) report a K/Ar age of 7.4 m.y. for a flow from this unit in the Grassy Mountain quadrangle to the southwest (Ferns and Ramp, 1989)

Trs — **Granite-clast conglomerate (upper Miocene)**—Mainly reddish-weathering, granite-clast conglomerates and white to tan arkosic sandstones with interbedded white tuffaceous sandstones and tuff. Clasts include rhyolite, coarse granite, and white quartz and are as much as 8 in. in diameter. Absence of black chert clasts distinguishes unit **Trs** conglomerates from conglomerates in overlying unit **Tig**. Occurs as conglomerate lenses within and apparently underlying unit **Trsb**. Includes 20-ft-thick massive beds of coarse matrix-supported granite-clast conglomerates near exposed base of the unit and a well-exposed interbed of granite-clast conglomerate and arkosic sandstone in unit **Trsb** on the east flank of Deer Butte. Well-rounded granite cobbles that litter the ground surface in the south half of sec. 3, T. 20 S., R. 45 E., are probably derived from similar interbeds in unit **Trsb**. Coarse conglomerates exposed along the North Canal at the quadrangle boundary in sec. 14, T. 21 S., R. 45 E., either underlie or occur as interbeds in the basalts of unit **Trsb** and are not part of the overlying upper Miocene to lower Pliocene sedimentary package (unit **Tis**). Ferns (1989b) had erroneously assumed that these gravels were a part of unit Tis mapped in the Owyhee Dam quadrangle to the south. Exposures east of Deer Butte are probably equivalent to sedimentary interbeds (unit Trs) as mapped in the Double Mountain quadrangle to the west (Ramp and Ferns, 1989). Well-indurated granite-clast conglomerates underlying unit **Trsb** along the canal may correlate with the underlying middle Miocene conglomerates of map unit Tas that are exposed to the south and west in the Owyhee Dam quadrangle (Ferns, 1989b)

Tdmv — **Andesite (upper Miocene?)**—A medium-gray, platy, plagioclase-phyric pyroxene andesite exposed on the west slope of Mitchell Butte in sec. 1, T. 21 S., R. 45 E. Locally hematite-stained. Considered by Privrasky (1953) to be a Pliocene sill. However, other platy basaltic andesite and andesite lava flows are a part of unit Tdmv in the Double Mountain quadrangle (Ramp and Ferns, 1989), which forms the part of the late Miocene basement to the west

MINERAL RESOURCES

The main potential mineral resource in the quadrangle is gold. Possible gold resources may occur in hot-springs type of epithermal systems hosted in both volcanic and sedimentary rock. The prominent buttes in the quadrangle (e.g., Deer Butte, Mitchell Butte, and Chalk Butte) have resistant caps of red- and yellow-weathering, well-indurated arkosic sandstone and conglomerate through which silica- and/or carbonate-rich fluids have percolated, cooled, and precipitated cement.

Anomalous levels of gold (8 to 220 ppb) were detected in samples from a small knob on the north flank north of Chalk Butte in sec. 5, T. 20 S., R. 45 E. The highest level of gold was detected in a composite sample from weakly silicified, northwest-trending fracture zones cutting the knob. The fracture system includes a narrow zone of vertically aligned pebbles that may be a small pebble dike.

Slightly anomalous levels of gold were also detected from calcite veins in basalt north of Deer Butte. Deer Butte itself consists of weakly silicified conglomerates. Highly silicified sandstones crop out along the canal northeast of Deer Butte.

Both natural gas and geothermal energy resources may occur in the quadrangle. An odorless inflammable gas is reported at Mud Spring in the NW¼ sec. 29, T. 20 S., R. 45 E. (Washburne, 1909). The reported gas shows may be with unit Tic. Washburne (1909) reports petroliferous sandstones with abundant mollusk fossils in the NW¼ sec. 2, T. 20 S., R. 44 E., and to the north in the Vale West quadrangle in sec. 29, T. 19 S., R. 44 E. A more than 815-ft-deep exploration well by drilled by Eastern Oregon Oil Company in 1909 reportedly encountered a small flow of gas in an interval of sand at 250- to 335-ft depth (Washburne, 1909).

High heat-flow areas around Cow Hollow and Mitchell Butte may be underlain by geothermal resources. The Oregon Department of Geology and Mineral Industries (1982) reports that much of the area may be underlain by low-temperature (<100 °C) resources suitable for direct use at depths as shallow as 300 m, intermediate-temperature (100 °C-150 °C) resources at depths of 1,000-1,500 m, and high-temperature (>150 °C) resources in permeable rocks at depths below 2,000 m. The lower ends of Cow Hollow and East Cow Hollow have been designated as Known Geothermal Resource Areas (KGRA's). A temperature of 62 °C and a flow rate of 60 liters/minute is reported for the Mitchell Butte hot springs (Brown and others, 1980).

GROUND-WATER RESOURCES

General

Very little ground-water information is available for the mapped area. There is record of only one well drilled north and west of the North Canal, which represents about two-thirds of the mapped area. There are 26 water-well reports (well logs) on file for wells drilled in the developed agricultural area south and east of the North Canal. Static water levels in wells in the developed area, lower than 2,540-ft elevation, are generally within 20 to 40 ft of land surface. Most of these wells are in areas mapped as unit QTs.

Most wells in the area mapped as unit QTs appear to penetrate through that unit and produce from permeable zones within the underlying unit Tig sediments. Nonindurated coarser facies and fractured indurated zones within unit Tig are sufficiently permeable to provide amounts of water necessary for domestic use or stock watering. There is only one record of a well producing water sufficient for irrigation in the mapped area. That is a 350-ft well (sec. 7, T. 21 S., R. 46 E.), which reportedly produces 300 gallons per minute, apparently from within unit Tig.

Summaries of individual units

Unit Qal: There are no records of wells producing water from unit Qal on the map. Well-log information on this map and on the adjacent Owyhee quadrangle suggest that unit Qal along the lower portions of the Owyhee River contains sand and gravel horizons 10 to 20 ft thick. Saturated portions of unit Qal that contain thicknesses of coarse sand or gravel could yield moderate amounts of water to wells by virtue of high permeability and hydraulic connection with surface water sources.

Unit QTfc: The ground-water characteristics of this unit are unknown.

Unit QTs: Most water wells in areas mapped as unit Qts appear to produce from underlying sediments of unit Tig. This unit may be unsaturated at higher elevations. Where saturated at lower elevations, gravels within unit QTs will yield quantities of water sufficient for domestic or stock use.

Unit Tig: Nonindurated sands and gravels and fractured indurated zones with unit Tig will yield quantities of water sufficient for domestic or stock use. Static water levels in this unit may be a few hundred feet below ground level at higher elevations but are generally a few tens of feet at lower elevations in the southeastern part of the mapped area. One flowing artesian well is reported in sec. 6, T. 21 S., R. 46 E.

Unit Tic: The ground-water characteristics of this unit are unknown.

Unit Trsb: There are no records of wells drilled in this unit in the mapped area. Therefore, the ground-water characteristics of this unit are largely unknown. The presence of springs indicates that the basalt is saturated and transmits water in places.

Unit Trs: Ground-water characteristics of this unit are unknown.

Unit Tdmv: Ground-water characteristics of this unit are unknown.

MAP SYMBOLS

- **Contact**—Approximately located
- **Fault**—Dashed where approximately located; dotted where concealed; ball and bar on downthrown side
- 57 **Strike and dip of fault surface**
- 49 **Strike and dip of beds**
- ⊕ **Horizontal bed**
- ■C **Location of whole-rock sample analyzed in Table 1**
- ▲20 **Location of mineralized sample analyzed in Table 2**
- F **Fossil fish localities**

GEOCHEMISTRY

Sample preparation

Samples for whole-rock analysis (Table 1) were crushed to minus ¼-in. in a steel-jawed Braun chipmunk crusher and split in a Jones-type splitter in the Oregon Department of Geology and Mineral Industries (DOGAMI) laboratory. A split of about 100 g of each sample was ground to minus 200 in agate grinding media by X-ray Assay Laboratories (XRAL) of Don Mills, Ontario.

Samples for trace element analysis (Table 2) were crushed to minus ¼-in. and split as indicated above. Each sample split was ground to about minus-200 mesh in chrome-steel grinding media in an Angstrom disc mill in the DOGAMI laboratory. Each minus-200 mesh split was split again to produce two subsamples: one for gold, and one for the other trace elements to be determined.

Chemical analysis

Whole-rock analysis: X-ray fluorescence (XRF) analyses were performed by XRAL. XRAL used a fused button for its analyses (1.3 g of sample roasted at 950 °C for one hour, fused with 5 g of lithium tetraborate, and melt cast into a button). Loss on ignition (LOI) was determined by the roasting.

Trace-element analysis:

1. Gold, uranium, tin. Bondar-Clegg, Ltd., of North Vancouver, British Columbia, performed the analyses for gold, uranium, and tin. The method employed for gold was fire assay preconcentration of the gold in a 20-g sample (gold was collected in added silver), acid dissolution of the resulting bead, and a directly coupled plasma (DCP) emission spectrometer finish. The detection limit was 1 part per billion (ppb). For uranium, a 0.1-g sample was digested with concentrated nitric acid, the solution diluted, an aliquot fused with NaF, and the uranium determined by fluorimetry. The detection limit was 0.2 ppm. Tin was determined (on an unpacked sample on a mylar film support) by X-ray fluorescence (XRF) on an energy dispersive XRF spectrometer. Corrections were made for inter-element interferences. The detection limit was 5 ppm.

2. Other trace elements. Geochemical Services, Inc. (GSI), of Torrance, California, performed the analyses for 15 other trace elements. The method employed a proprietary acid dissolution/organic extraction of a 5-g sample. The finish was by induction coupled plasma (ICP) emission spectrometry. GSI considers the digestion to provide total metal contents except for gallium and thallium.

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