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Preliminary Geologic map of the Star Creek Reservoir quadrangle, Malheur County, Oregon

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Open-File Report 99-583

1999

U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

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INTRODUCTION

The Star Creek Reservoir quadrangle is located about 75 km southwest of the town of Vale, Malheur County, Oregon (figure 1). The quadrangle can be reached from U.S. Highway 20 by a graded county road that goes south from the Harper turn-off on U.S. 20, or from a county road (Shumway Grade) south from U.S. 20 at Juntura. Numerous jeep trails provide easy access from the county roads to most parts of the quadrangle.

Most of the formations of the quadrangle were originally named and described by Kittleman and others (1965). Later, Kittleman and others (1967) produced a geologic map of the Owyhee region at the scale of 1:125,000, which was incorporated into a geologic map of eastern Oregon at the scale of 1:500,000 (Walker, 1977) and a geologic map of the State of Oregon at the scale of 1:500,000 (Walker and MacLeod, 1991). The geology of the Star Creek Reservoir quadrangle was mapped at the scale of 1:24,000 in 1991-92 by J.G. Evans and J.J. Rytuba as part of a cooperative project between the Oregon Department of Geology and Mineral Industries, Portland State University, and the U.S. Geological Survey. The geology was incorporated into the geologic map of the Mahogany Mountain 30 by 60 minute quadrangle (Ferns and others, 1993b) at the scale of 1:100,000. G.B. Binger and P.R. Hooper analyzed numerous volcanic rock samples for major oxides and selected trace elements.

The chemical classification of the volcanic rocks used in this report is based on the total alkali-silica diagram of Le Bas and others (1986). The correspondence between absolute ages and geologic ages is from Palmer (1983).

The rocks exposed in the Star Creek Reservoir quadrangle comprise a flat-lying to gently dipping section of volcanic, pyroclastic, and volcaniclastic rocks of late Tertiary age. The quadrangle includes part of the western margin of the horst that borders the north-trending, 50 x 100 km, middle Miocene Oregon-Idaho graben (OIG; Ferns and others, 1993a,b; Cummings and others, in press). The horst lies between the OIG and a north-northwest-trending graben that includes the Stockade Mountain silicic volcanic center, and shows a largely flood basalt-rhyolite volcanic rock association that extends unchanged lithologically for about 100 km to the north. At the latitude of the Star Creek Reservoir quadrangle, the eastern margin of the horst is found about 4 km to the east in the Skull Springs quadrangle (Evans and Binger, 1999b). The western part of the Star Creek Reservoir quadrangle includes the eastern margin of the Stockade Mountain volcanic center and possibly the southern part of the Juntura Basin of Shotwell (1963). The middle Miocene age of rocks in the Stockade Mountain center indicates at least partial contemporaneity of graben subsidence and largely silicic volcanism on both sides of the horst, as well as in the horst. Late Miocene volcanism was widespread (Ferns and others, 1993a,b; Hart and others, 1984), of small volume, and, at least in the Star Creek Reservoir quadrangle and adjacent Skull Springs quadrangle, effected the OIG and the horst.

STRATIGRAPHY

Horst

The oldest exposed unit of the horst, the early to middle Miocene basalt of Malheur Gorge (map unit Tm; Evans, 1990a,b; formerly the "unknown igneous complex" of Kittleman and others, 1965), is exposed in the southeastern part of the quadrangle along Road Canyon and Cold Spring Creek. No more than 120 m of the unit is exposed in the quadrangle, but to the north (Evans, 1996) the unit is as much as 1 km thick and to the southeast (Ferns and Williams, 1993a) as much as 250 m thick. This thick sequence of tholeiitic basalt flows is petrologically, stratigraphically, and geochemically, equivalent to the Imnaha Basalt and Grande Ronde Basalt of the Columbia River Basalt Group (Binger, 1997). The basalt of Malheur Gorge, however, probably did not erupt from dike swarms like the ones that fed the Columbia River Basalt Group to the north. A vent complex related to or possibly a source for the basalt of Malheuer Gorge is located in the Jones Butte area, 15 km to the north (Evans, 1996). The unit in the Star Creek Reservoir quadrangle consists of fine-grained, sparsely phyric and aphyric mafic lava flows, and generally resembles the upper part of the formation in the Malheur Gorge area. Four samples of the unit were analyzed for major oxides (table 2) and include basaltic andesite, trachyandesite and trachydacite; two splits of one sample were analyzed by the U.S. Geological Survey (USGS) and Washington State University at Pullman (WSU) and showed major differences in composition (#478=basaltic andesite; #49=trachydacite). The apparent discrepancy may be due to local silicification and hydrothermal alteration of the rocks at the sample site. Low-grade metamorphic neomineralization of the unit includes formation of biotite and garnet and alteration of plagioclase and pyroxene to epidote and zoisite. The basalt of Malheur Gorge was dated at 16.8±1.2 Ma, 16.9±0.67 Ma, 17.9±1.76 Ma, and 18.5±1.37 Ma ($^{40}Ar/^{39}Ar$ method; Lees, 1994; Lees' samples KL-91-49, KL-91-80, KL-91-164, and KL-92-231). These dates are generally consistent with the ages of the Imnaha, Picture Gorge, and Grande Ronde Basalts of the Columbia River Basalt Group (Baksi, 1989).

The 15 Ma Dinner Creek Welded Tuff of Kittleman and others (1965) is widespread over the basalt of Malheur Gorge in quadrangles to the north (Evans, 1990a,b; Evans 1966; Evans and Binger, 1997, 1998a,b), but is absent in the Star Creek Reservoir quadrangle.

The Hunter Creek Basalt (map unit Th; Greene and others, 1972; Kittleman and others, 1965) overlies the Dinner Creek Welded Tuff to the north. Outcrops that resemble the Hunter Creek physically and chemically (table2, samples 39 and 40) are found in secs. 14 and 15, T. 25 S., R. 39 E. in upper Road Canyon. The Hunter Creek is black and generally aphyric. Only about 27 m of the unit is exposed. Chemically, the Hunter Creek Basalt north of the quadrangle is an icelandite (Carmichael, 1964; typical Hunter Creek contains Al_2O_3=Fe_2O_3=14 percent), or a basaltic andesite according to the scheme of Le Bas and others (1986; Evans, 1990a,b). In samples 39 and 40 in table2, Al_2O_3=nearly 14 percent and FeO=12.49 and 12.70 percent. The Hunter Creek is assigned a middle Miocene age, very close in age to the Dinner Creek (Evans and Binger, 1998b). Lees ($^{40}Ar/^{39}Ar$ method, 1994; Lees' samples HOR-9, KL-91-100, KL-91-102, KL-92-269, and KL-92-278) dated Hunter Creek at 15.0±0.73, 15.8±0.6, 15.9±0.26, 16.5±1.2, and 18.6±0.63 Ma. The youngest date is most in accord with the hypothesis that the Hunter Creek erupted shortly after the emplacement of the Dinner Creek Welded Tuff.

The Littlefield Rhyolite (map unit Tlr; Kittleman and others, 1965; table 2) overlies Hunter Creek Basalt in quadrangles to the north and is remarkable for its regional extent (1,100 km^2) and volume (100 km^3). In the Star Creek Reservoir quadrangle, only the uppermost 15 m of the Littlefield Rhyolite is exposed. Stratigraphic relations and relatively abrupt changes in thickness of the rhyolite in the Tims Peak and Alder Creek quadrangles (Evans and Keith, 1996; Evans and Binger, 1998b) suggest that the Littlefield Rhyolite erupted from a series of vents along the western margin of the OIG; the nearest identified vent, which erupted flows and formed a dome, is in the Alder Creek quadrangle (Evans and Binger, 1998a), about 10 km to the northeast of the Star Creek Reservoir quadrangle. Lees ($^{40}Ar/^{39}Ar$ method, 1994; Lees' samples KL-91-46, KL-91-47, and KL-92-258) dated Littlefield Rhyolite in the Namorf quadrangle (Ferns and O'Brien, 1992) 35 km to the northeast at 15.2±0.31, 16.3±0.87, and 16.8±0.4 Ma. The youngest date is most in accord with accepted radiometric dates of underlying map units.

The younger and older sandstone map units, Tssy and Tsso, are differentiated largely by their stratigraphic relations to Wildcat Creek Welded Ash-Flow Tuff (map unit Twc; see below). The older sandstone unit, Tsso, is below the Wildcat Creek and the younger sandstone, Tssy, is above the Wildcat Creek. The variable thicknesses of the two sandstone units in adjacent fault blocks indicates that the fault blocks were moving up and down during deposition.

The older welded tuff unit, Twt_1, is present in SW1/4 sec. 12, T. 25 S., R. 39 E. and near the NE corner sec. 14, same township, within the older sandstone (map unit Tsso). This welded tuff is also recognized in the Skull Springs quadrangle to the east (Evans and Binger, 1999b). The possibility that the welded tuff is a distal facies of the Dinner Creek Welded Tuff was rejected because the welded tuff appears to be too high in the section.

The Wildcat Creek Welded Ash-Flow Tuff (map unit Tw; Kittleman and others, 1965) overlies the older sandstone (see above). Because of its varied appearance, eight samples of the welded tuff from the Star Creek Reservoir quadrangle were analyzed for major oxides. Seven of the samples are rhyolitic, like many of the samples from adjoining quadrangles (Alder Creek, Evans and Binger, 1998a; Shumway Reservoir, Evans and Binger, 1999a; Skull Springs, Evans and Binger, 1999b). One of the samples from the Star Creek Reservoir quadrangle, however, is a trachydacite, as are some samples of the unit in the Shumway Reservoir, Alder Creek and Skull Springs quadrangles. This compositional variation of the welded tuff may be due to the variable amount of lapilli of fine-grained hematite-rich basalt or basaltic andesite in samples of the unit. This variation in lapilli content is reflected in the FeO content. The trachydacite contains 5.63 % FeO in comparison to the 1.91 to 3.05 % FeO in the rhyolite samples. The unit is 6 to 18 m thick in the quadrangle; exposures of more than 100 m of the welded tuff are found to the north in the Shumway Reservoir quadrangle (Evans and Binger, 1999a). The vent of the Wildcat Creek has not been identified.

The younger welded tuff unit, Twt_2, is found above or within the younger sandstone, map unit Tssy. The variations in stratigraphic position within the interval between Wildcat Creek and Shumway Ranch Basalt are most likely due to nonuniformity of deposition and erosion of the younger sandstone unit. In NE1/4 sec. 34, the younger welded tuff rests directly on the Wildcat Creek Welded Ash-Flow Tuff. The younger welded tuff unit varies in thickness from 3 to 12 m. A similar welded tuff is found in places as far north as the northeastern corner of the Little Black Canyon quadrangle (Evans and Binger, 1998b), 55 km to the north-northeast. Its stratigraphic position in strata beneath the middle Miocene Shumway Ranch Basalt (see below) in sec. 34, T. 24 S., R. 39 E. places it in the middle Miocene. The vent for the unit has not been identified.

The Shumway Ranch Basalt (map unit Tsr; Kittleman and others, 1965) was named for outcrops near Shumway Ranch in the Shumway Reservoir quadrangle to the north (type locality in S1/2 sec. 30, T.23 S., R. 39 E., Alder Creek quadrangle, Kittleman and others, 1965). Although the unit has been shown to be present on the horst and in the Oregon-Idaho graben (Evans and Binger, 1998a), and therefore, could be classified as post or late extensional, it is included here in the horst section. Six samples of the unit were analyzed for major oxides (table 2). Their compositions are basalt, basaltic andesite, andesite and trachyandesite. The lower part of the unit is more silicic (andesitic) than the upper part (basaltic), and presumably could have erupted from the andesite dike (map unit Tad; see below) in the southwestern part of the quadrangle. Another possible vent for the bulk of the Shumway Ranch may be beneath summit 5745 in sec. 28, T. 24 S., R. 39 E., where a deep magnetic low is located (see below). A sample of the Shumway Ranch from Red Butte in the Alder Creek quadrangle was dated at 12.4±0.5 Ma (K-Ar method; Fiebelkorn and others, 1983). A sample from the The Monuments in SE1/4 sec. 22, T. 24 S., R. 39 E. was dated at 13.4±0.6 Ma (K-Ar method; Monument Rock Basalt in Fiebelkorn and others, 1983).

The dacite (Tdf), and rhyolite (Trf) flow units and the volcanic breccia (Tvb) are related components of a small volcanic system that developed in the central and eastern part of the quadrangle, and includes part of a dacite ridge, called The Roostercomb that extends into the adjoining Skull Springs quadrangle (Evans and Binger, 1999b). Magma extruded through one or more vents, including the dike now occupied by the volcanic breccia. The principal vent or vents may be buried beneath the flows, and are shown on cross-section AA′ as one vertical intrusion, labelled Tdi, that is located at a magnetic anomaly (see below). Small domes may have formed in the area west of the volcanic breccia dike where summits 5324, 5549, and 5514 are found. The first magma to exit was rhyolite which was followed by the more extensive dacite flows. The dacite flowed to the northeast down a narrow paleovalley eroded into the Wildcat Creek Welded Ash-Flow Tuff and possibly also into the younger sandstone (map unit Tssy) that may have been present above the tuff. The sides of the paleovalley were mostly eroded away, leaving the resistent dacite flows as the ridge called The Roostercomb.

The trachyandesite valley-fill (map unit Ttv) in the southeastern part of the quadrangle overlies map units as young as the younger sandstone (map unit Tssy). The unit extends 4 km to the east in the adjacent Skull Springs quadrangle (Evans and Binger, 1999) and resulted from a small volume lava flow that filled a narrow paleovalley eroded into the underlying middle Miocene rocks; the vent of the flows has not been identified. Three samples of the unit were analyzed for major oxides; two are highly alkaline andesites and one is trachyandesite (table 2). A sample of this unit in the Skull Springs quadrangle is also trachyandesite (Evans and Binger, 1999b). The trachyandesite flows may have come from the east from the Cedar Mountain volcanic center which contains flows of trachyandesite composition. If this source of the flows is correct the flows must be late Miocene in age, the same age as the Cedar Mountain volcanic center (Ferns and others, 1993b; map unit Tbcm, Evans and Binger, 1999b). Hart and Mertzman (K-Ar method; 1982) dated a sample of basalt of Cedar Mountain at 10.2 Ma, or late Miocene.

Stockade Mountain Volcanic Center

The oldest map unit of the Stockade Mountain volcanic center exposed in the southwestern part of the quadrangle is the tuffaceous sandstone (map unit Tts). Part of the tuffaceous sandstone may correlate with one or both of the sandstone units (Tssy and Tsso) in the Star Creek Reservoir quadrangle, and (or) one or more of the sedimentary rock units described in the Shumway Reservoir quadrangle (Evans and Binger, 1999a) to the north.

Much of the welded tuff of Stockade Mountain (map unit Tws), informally named here, which overlies the tuffaceous sandstone, appears to have undergone silicification and has hematite, carbonate, and chalcedony veins. The welded tuff is the most likely candidate as the source of white to light gray laminated welded tuff clasts in middle Miocene conglomerates in the western part of the OIG in the Alder Creek (map unit Tspo, Evans and Binger, 1998a) and Tims Peak (map unit Ts_3, Evans and Keith, 1996) quadrangles, and therefore, is most likely middle Miocene in age. The well-rounded shape of the welded tuff clasts along the western margin of the OIG supports transport for some distance, consistent with the hypothesis that the clasts were transported from the Stockade Mountain-Star Mountain area.

The rhyolite at Star Mountain (named by Ferns and others, 1993b) may form a small rhyolite dome on Star Mountain. Basal parts of the rhyolite flow include vitrophyre and, locally, a light gray very vesicular welded tuff (Trsw). Ferns and Williams (1993b) noted carapace vitrophyre breccias on the more extensive exposures of the rhyolite to the south in the Crowley quadrangle. Based on aeromagnetic data, discussed below, the rhyolite in the southwest corner of the quadrangle is interpreted to be the eroded part of a dome over a rhyolite intrusion, labeled Tri, on cross-section BB'. The age of the rhyolite is greater than 11.3±0.8 Ma, based on a K-Ar age of a basalt flow that overlies the rhyolite west of Crowley Ranch (Hart and Carlson, 1985; Ferns and Williams, 1993b), or middle Miocene

The north-trending andesite dike (map unit Tad) that intrudes the welded tuff of Stockade Mountain could be a vent for the lower andesitic flows included in the Shumway Ranch Basalt.

The Drinkwater Basalt (map unit Tdb; Bowen, Gray, and Gregory in Shotwell, 1963) which overlies the tuffaceous sandstone (map unit Tts; see above) is continuous with Drinkwater Basalt mapped by Greene and others (1972) to the west. A sample of the basalt was dated at 6.91±1.09 Ma, or late Miocene, by J.C. Engels in Greene and others (1972).

Post-Volcanic Deposits

Alluvial fan deposits (map unit QTf) are widespread in the western part of the quadrangle. They could be as old as late Miocene or as young as Quaternary and include more than one episode of alluvial fan formation and probably episodic uplift and erosion.

An area of about 0.5 km^2 along the east-central margin of the quadrangle is interpreted as older alluvium (map unit QTa) that may be as old as Pliocene or Quaternary.

Landslide deposits (map unit Qls) are found along north-trending faults, especially where basalt, welded tuff, or rhyolite overlie poorly lithified sedimentary rocks. Especially large landslide deposits are found below the western exposures of Shumway Ranch Basalt on the east side of Star Creek and along both flanks of the the dacite flows unit, Tdf, in the east-central part of the quadrangle

Alluvium (map unit Qa) is found along the creeks in the quadrangle. The most extensive alluvium is found along Star Creek.

STRUCTURE

The quadrangle contains a major north-northwest-trending fault zone, largely buried, that separates the early to late Miocene rocks of a horst in the eastern part from the Stockade Mountain silicic volcanic center and possibly the southern part of the Juntura Basin of Shotwell (1963) in the west. The horst is just west of the OIG (Ferns and others, 1993a,b) and is 100-km-long. The mostly north-striking faults within the horst and the north-striking andesite dike (map unit Tad) indicate that middle Miocene extension was largely east-west.

The isostatic residual gravity map of the Star Creek Reservoir and adjacent quadrangles (figure 2; data from Griscom and Halverson, 1994) shows that the eastern part of the quadrangle is underlain by relatively dense rock, probably reflecting the thick flood-basalt sequence that is inferred to comprise the bulk of the volcanic section of the horst; the eastern part is on the flank of an area underlain by relatively low density rock. Part of the low is associated with the Stockade Mountain silicic volcanic center, most of which is located west and south of the Star Creek Reservoir quadrangle.

The magnetic intensity over the Star Creek Reservoir quadrangle (figure 3; data from Griscom and Halvorson, 1994) is characterized by a deep low in the northern half and a group of lows and highs in the southern half. The deep magnetic low in the northern part of the quadrangle could reflect a basin or caldera filled with relatively nonmagnetic rocks, consistent with the hypothesis that the western half of the quadrangle is underlain by low-density rocks (figure 2). Alternatively, the low may reflect volcanic rocks with reversed magnetic polarity, and could mark the concealed vent of the Shumway Ranch Basalt. If a concealed vent in the middle of the quadrangle is the source of the lava flows, stacking of basaltic flows over andesite flows, as in the Shumway Ranch, would be consistent with emptying a small compositionally zoned magma chamber.

The small aeromagnetic high in the southeastern part of the quadrangle underlies SW1/4 sec. 9, T. 25 S., R. 39 E., which is covered by alluvial fan deposits (QTf), and is just west of the thick dacite flows unit (Tdf) that may comprise one or more small domes (summits 5324, 5549, and 5514). Samples of the dacite flows unit contain more than 5 percent FeO (table 2), which may account for the small high in and near map unit Tdf. In cross-section AA', the aeromagnetic high is interpreted as the principal vent for the dacite flows and domes (?), and the bulk of the dacite is in the intrusion (cross-section AA', unit Tdi). If a concealed vent is the source of most of the dacite (map unit Tdf) and rhyolite (Map unit Trf) flows, stacking of dacite flows over rhyolite flows would be consistent with emptying of a small compositionally zoned magma chamber.

The rhyolite at Star Mountain is 300 m thick and appears to be floored by welded tuff (map units Tws and (or) Trsw) and tuffaceous sandstone (map unit Tts) on its eastern flank. The small aeromagnetic high in the southwest corner of the quadrangle may mark the vent of the rhyolite of Star Mountain. The center of the high is under exposures of the rhyolite at Star Mountain and suggests that the core of the vent for the rhyolite may be located in the vicinity of the southwest corner of the quadrangle. In cross-section BB', the area coincident with the aeromagnetic high is interpreted as the principal vent for the rhyolite of Star Mountain, and the bulk of the rhyolite shown is in the vent (unit Tri). Surface samples of the rhyolite contain between 1 and 2 percent FeO, most of which must be preserved as magnetite in the vent, or possibly the magnetite content is greater at depth. Ten of the 19 samples of altered rock come from the southwestern corner of the quadrangle near the proposed vent, but the hydrothermal alteration apparently did not destroy magnetic minerals in that area or at depth.

The narrow northwest-trending aeromagnetic low in the south-central part of the quadrangle lies along Road Canyon and the southwestern flank of the canyon. This low may reflect the difference in magnetism shown by the basalt of Malheur Gorge, which is exposed on the northeastern flank of the canyon, and the largely sandstone units, Tsso and Tssy, which may be much thicker here than elsewhere in the quadrangle. Alternatively, hydrothermal alteration related to the Stockade Mountain volcanic center may have destroyed magnetic minerals in basaltic rocks underlying Road Canyon and its southwestern flank. The basalt of Malheur Gorge on the northeast side of Road Canyon contains numerous quartz, chalcedony, carbonate, and hematite veins related to hydrothermal alteration, and the rock was affected by weak low-grade metamorphism, both processes which may have destroyed magnetite in the basalt.

The location of the western margin of the horst, shown by a line of stippled hotdogs in figures 2 and 3, is drawn in the central part of the quadrangle in the south and is extrapolated toward the north based on outcrops of Littlefield Rhyolite in northwestern Shumway Reservoir (Evans and Binger, 1999) and western Monument Peak quadrangles (Evans, 1996). The location of the margin is drawn assuming that there are no significant offsets of the margin along subsurface faults and that exposures of Littlefield Rhyolite imply the presence of the widespread underlying volcanic sequence of the horst that usually includes Hunter Creek Basalt and basalt of Malheur Gorge.

The largely concealed western margin of the horst (figure 3) is drawn through the deep magnetic low in the center of the quadrangle, a possible vent for Shumway Ranch Basalt, and the small magnetic high southeast of it, a possible vent for the dacite flows. These relations suggest that the locations of these two putative vents were structurally controled.

The north-northwest-trending Stockade Mountain silicic volcanic center and graben appear to be an on-trend continuation of the Northern Nevada rift (Stewart and others, 1978; Zoback and others, 1994) which can be traced in Oregon from the southwestern part of the Star Creek Reservoir (Griscom and Halvorson, 1994) northward to the Beulah area (M.L. Cummings, unpub. mapping, 1993-98). The distribution of map units on the Geologic Map of the State of Oregon (Walker and MacLeod, 1991) suggests a further continuation of the rift north to the Unity area.

METAMORPHISM AND (OR) HYDROTHERMAL ALTERATION

The basalt of Malheur Gorge and the Wildat Creek Welded Ash-Flow Tuff show evidence of low-grade metamorphism and (or) hydrothermal alteration in thin sections; these two processes of mineralogical change may not be easily differentiated where neomineralization is incipient, as in the study area. In the basalt of Malheur Gorge, plagioclase and pyroxene are altered to epidote and zoisite; clinopyroxene is altered to biotite; and a garnet porphyroblast was found in a rock with widespread epidote. In the Widcat Creek Welded Ash-Flow Tuff, biotite and sericite are found along contacts between devitrified glass shards. Whether the heat source was directly from an intrusion, like the one responsible for the dacite flows, or from hydrothermal solutions derived from the intrusion(s) is not clear. In general, the basalt of Malheur Gorge is very fractured and oxidized and parts of it have abundant veins of hematite, carbonate, and chalcedony, consistent with hydrothermal alteration. Hydrothermal alteration (silicification and iron oxide enrichment) is also common in the silicic rocks west of the horst. The thermal effects could be due in part to the emplacement of a hypabyssal dacite-rhyolite intrusion in the southeastern part of the quadrangle (cross-section AA', unit Tdi) and in part to volcanism to the southwest of the quadrangle in the Stockade Mountain volcanic center (Ferns and Williams, 1993), including a rhyolite intrusion under the west flank of Star Mountain (cross-section BB', unit Tri). Some of the hydrothermal alteration may substantially post-date recognized volcanism. For example, evidence of hydrothermal activity estimated to be as late as Quaternary in the horst was found to the north in the Monument Peak quadrangle (Evans, 1996).

GEOCHEMISTRY

Sixty-one unaltered volcanic rocks (table 1) and nineteen altered rocks (table 4) were collected for analysis by James G. Evans. Of the unaltered rocks, 14 were analyzed by the U.S. Geological Survey, Branch of Geochemistry (samples 472 to 485 and 502), for major oxides using wave-length dispersive x-ray fluorescence spectroscopy (Taggart and others, 1990) by D.F. Siems and J.S. Mee. Forty-seven samples, including splits of 6 of the samples analyzed by the USGS, were analyzed for major oxides and 17 minor elements by x-ray spectroscopy (samples 2 to 122; Hooper and others, 1993) by G.B. Binger and P.R. Hooper at the GeoAnalytical Laboratory, Washington State University, Pullman. The major-oxide analyses are shown in table 2. The trace-element analyses are shown in table 3.

The nineteen altered rocks (table 4) were analyzed by the U.S. Geological Survey, Branch of Geochemistry, for 31 major and trace elements by the inductively coupled plasma atomic emission spectrometry method (Briggs, 1990) by D.L. Fey, and Z.A. Brown; the results are reported in table 5. However, the following elements are not included in table 5 because they occur in uniformly low concentrations in all samples: silver, <2 parts per million (ppm); bismuth, <10 ppm; tin, <5 ppm; thallium, <40 ppm; and uranium, <100 ppm. The samples were analyzed for gold by the flame and graphite-furnace atomic absorption spectrophotometry method (O'Leary, 1990) and the results are shown in table 5. Mercury was analyzed by the cold-vapor atomic absorption spectrophotometry method (O'Leary and others, 1990) and the results are shown in table 5. The gold and mercury analyses were by B.H. Roushey, R.M. O'Leary, and A.H. Love. Of the nineteen altered rock samples, 8 are altered sedimentary rocks from map units Tsso, Tssy, Tts, and QTf, six are from map unit Tws, and the rest are from silicic volcanic rock units Trs, Tsw, Trf, Tvb, and Twc.

The altered sedimentary rocks are rich in hematite and (or) rich in silica in the form of chalcedony. Iron content ranges from 0.14 to 29 weight-percent; the highest concentration was found in hematitic silicified sandstone (sample 361) in map unit QTf.

The only sample containing gold above the lower detection limit is sample 351, which was taken from an exposure of the older sandstone unit, Tsso adjacent to the Sack Canyon Reservoir near the middle of sec. 34, T. 24 S., R. 39 E. This sample is also remarkable for its relatively high content of iron (16 percent) and arsenic (41 ppm). Arsenic above the lower limit of detection of 10 ppm was also found in two other samples (map unit Tssy, sample 363, 22 ppm and map unit QTf, sample 361, 57 ppm). These samples are close to north-northeast-striking faults (sample 361, 210 m; sample 363, 60 m).

Relatively high mercury content (>0.50 ppm) was found in samples 356 and 357 (0.52 and 1.1 ppm) which are from silicified welded tuff of Stockade Mountain. Both samples are from exposures about 60 m from a northeast-striking fault. Of the other 17 samples, 9 contained mercury ranging from 0.02 ppm, the lower limit of detection, to 0.32 ppm; most of these samples are of sedimentary rock, although the one with the highest mercury concentration is from a chalcedony cemented breccia from the welded tuff of Stockade Mountain.

The concentrations of other elements, such as barium, chromium, copper, manganese, rare-earth elements, and zinc, are not remarkable in comparison to crustal abundance, or their concentrations in iron-rich sedimentary rocks (see Brobst and Pratt, 1973), or in unaltered volcanic rocks (see table 3).

In general, although hydrothermal effects are widespread in the quadrangle, significant deposition of metals, rare-earths, and precious metals, or pathfinder elements was not found. Arsenic and mercury, two elements common in hydrothermal systems were not in high concentrations, although the mercury was widespread and in highest concentrations in the welded tuff of Stockade Mountain.

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Table 1. Locations and descriptions (map unit) of unaltered volcanic rock samples analysed for major oxides. Sample splits indicated by sample number in parentheses.

Sample No.	Lithology(map unit)	Location
472	basaltic andesite(Tsr)	SE1/4 sec 20, T. 24 S., R. 39 E.
473	dacite(Tdf)	NE1/4 sec. 26, T. 24 S., R. 39 E.
474	dacite(Tdf)	Near center sec. 25, T. 24 S., R. 39 E.
476	welded tuff(Twt_2; rhyolite)	same
477	andesite (Ttv)	Near center sec. 23, T. 25 S., R. 39 E.
478	basaltic andesite(Tm)	NW1/4 sec. 25, T. 25 S., R. 39 E.
479	welded tuff(Tws; rhyolite)	SE1/4 sec. 12, T. 25 S., R. 38 E.
480	trachyandesite(Ttv)	E1/2 sec. 24, T. 25 S., R. 38 E.
481	trachyandesite(Tm)	NW1/4 sec. 12, T. 25 S., R. 39 E.
482	rhyolite(Trf)	NE1/4 sec. 3, T. 25 S., R. 39 E.
483	welded tuff(Twc; rhyolite)	SW1/4 sec. 2, T. 25 S., R. 39 E.
484	andesite(Tsr)	SE1/4 sec. 22, T. 24 S., R. 39 E.
485	basalt(Tsr)	NW1/4 sec. 16, T. 24 S., R. 39 E.
502	andesite(Tbi)	NW1/4 sec. 18, T. 25 S., R. 39 E.
2	trachyandesite(Tsr)	SE1/4 sec. 20, T. 24 S., R. 39 E.
5	basaltic andesite(Tsr)	SE1/4 sec. 21, T. 24 S., R. 39 E.
12	welded tuff(Twc; rhyolite)	NW1/4 sec. 14, T. 24 S., R. 39 E.
14	rhyolite(Tlr)	SE1/4 sec. 14, T. 24 S., R. 39 E.
15(473)	dacite(Tdf)	NE1/4 sec. 26, T. 24 S., R. 39 E.
16	welded tuff(Twc; rhyolite)	same
17	welded tuff(Twc; trachydacite)	SE1/4 sec. 23, T. 24 S., R. 39 E.
18(474)	dacite(Tdf)	E1/2 sec. 12. T. 24 S., R. 39 E.
21(476)	welded tuff(Twt_2; rhyolite)	NW1/4 sec. 34, T. 24 S., R. 39 E.
22	welded tuff(Twc; rhyolite)	same
25	rhyolite(Tlr)	SE1/4 sec. 33, T. 24 S., R. 39 E.
28	basalt(Tdb)	Near ctr. sec. 30, T. 24 S., R. 39 E.
30	welded tuff(Twt2; rhyolite)	NE1/4 sec. 16, T. 25 S., R. 39 E.
39	basaltic andesite(Th)	SE1/4 sec. 15, T. 25 S., R. 39 E.
40	same	same
43	welded tuff(Twt2; rhyolite)	SW1/4 sec. 22, T. 25 S., R. 39 E.
44	welded tuff(Trsw; rhyolite)	N1/2 sec. 27, T. 25 S., R. 39 E.
45	vitrophyre(Trsw; rhyolite)	NE1/4 sec. 27, T. 25 S., R. 39 E.
48	basaltic andesite(Tm)	NW1/4 sec. 25, T. 25 S., R. 39 E.
49(478)	trachydacite(Tm)	same
50	trachyandesite (Tm)	SW1/4 sec. 24, T. 25 S., R. 39 E.
52	trachyandesite(Ttv)	Near center sec. 24, T. 25 S., R. 39 E.
53	same	NW1/4 sec. 24, T. 25 S., R. 39 E.
54	welded tuff(Twc; rhyolite)	NW1/4 sec. 24, T. 25 S., R. 39 E.
56	vitrophyre(Trs; rhyolite)	Near ctr. sec. 8, T. 25 S., R. 39 E
60(479)	welded tuff(Tws; rhyolite)	SE1/4 sec. 12, T. 25 S., R. 38. E.
61	same	same
63	high-silica rhyolite(Trs)	NE1/4 sec. 13, T. 25 S., R. 38 E.
64	same	same
65	same	same
66	welded tuff(Tws; rhyolite)	SW1/4 sec. 7, T. 25 S., R. 39 E.
67	same	same
78	high-silica rhyolite(Trs)	NE1/4 sec. 13, T. 25 S., R. 38 E.

Table 1 (continurd)

Sample No.	Lithology(Map unit)	Location
80	rhyolite(Trs)	Near center sec. 19, T. 25 S., R. 39 E.
82	rhyolite(Trs)	NW1/4 sec. 29, T. 25 S., R. 39 E.
83	welded tuff(Tws; high-silica rhyolite)	SW1/4 sec. 19, T. 25 S., R. 39 E.
85	same	NW1/4 sec. 19, T. 25 S., R. 39 E.
86	welded tuff(Tws; rhyolite)	SW1/4 sec. 18, T. 25 S., R. 39 E.
88	welded tuff(Twt_2; rhyolite)	NE1/4 sec. 16, T. 25 S., R. 39 E.
89	volcanic breccia(Tvb; rhyolite)	SE1/4 sec. 3, T. 25 S., R. 39 E.
90	same	same
93	welded tuff(Twt_1;rhyolite)	SW1/4 sec. 12, T. 25 S., R. 39 E.
103(482)	rhyolite(Trf)	NE1/4 sec. 3, T. 25 S., R. 39 E.
104	same	same
105	dacite(Tdf)	same
107	rhyolite(Trf)	NW1/2 sec. 2, T. 25 S., R. 39 E.
108	welded tuff(Twc; rhyolite)	same
111	same	SE1/4 sec. 3, T. 25 S., R. 39 E.
119	andesite(Tsr)	NW1/4 sec. 26, T. 24 S., R. 39 E.
120	welded tuff(Twt_2; rhyolite)	SW1/4 sec. 9, T. 24 S., R. 39E
122(485)	basalt(Tsr)	NW1/4 sec. 16, T. 24 S., R. 39 E.

Table 2. Major-oxide analyses of volcanic rock samples listed in Table 1. Results are given in weight-percent. In samples 472 to 502, total iron is given as Fe_2O_3. In samples 2 to 122, total iron is given as FeO.

Sample No.	472	473(25)	474(18)	476(21)	477	478(49)	479(60)	480	481	482
Map unit	Tsr	Tdf	Tdf	Twt$_2$	Ttv	Tm?	Tws	Ttv	Tm	Trf
Rock name	basaltic andesite	dacite	dacite	rhyolite	andesite	trachy-dacite	rhyolite	andesite	trachy-andesite	rhyolite
Oxides										
SiO_2	54.35	68.10	68.37	74.55	60.36	66.97	77.83	60.34	59.92	75.81
Al_2O_3	16.76	13.47	13.33	14.65	16.59	14.43	12.75	17.45	14.31	13.36
FeO3	9.41	5.91	5.74	1.38	7.33	6.84	1.12	7.72	10.36	1.23
MgO	4.72	1.10	1.24	0.29	2.26	0.39	0.11	2.04	1.53	<0.10
CaO	8.27	2.81	2.75	0.90	5.46	2.22	0.36	5.20	4.44	0.79
Na_2O	3.00	3.29	3.26	2.93	3.82	4.66	2.47	3.24	4.08	3.87
K_2O	1.67	3.88	3.93	5.12	2.55	3.40	5.16	2.33	2.75	4.75
TiO_2	1.22	1.11	1.05	0.12	1.11	0.74	0.17	1.13	1.70	0.13
P2O$_5$	0.46	0.28	0.25	<0.05	0.41	0.24	<0.05	0.44	0.76	<0.05
MnO	0.14	0.05	0.08	0.06	0.11	0.11	0.03	0.11	0.15	0.06

Sample No.	483	484	485(122)	502	2	5	12	14	15(473)	16	17
Map unit	Twc	Tsr	Tsr	Tbi	Tsr	Tsr	Twc	Tlr	Tdf	Twc	Twc
Rock name	rhyolite	andesite	basalt	andesite	trachy-andesite	basaltic trachy-andesite	rhyolite	rhyolite	dacite	rhyolite	trachy-dacite
Oxides											
SiO_2	74.67	59.33	51.06	58.66	59.54	54.46	75.17	73.50	68.67	76.74	68.00
Al_2O_3	13.53	17.00	16.31	17.94	16.79	16.67	12.01	12.24	13.56	11.36	13.78
Fe_2O_3	1.91	7.39	12.36	7.18							
FeO					6.76	9.48	2.69	4.47	5.07	2.66	5.63
MgO	0.18	2.62	4.95	2.55	2.71	3.73	0.35	0.18	1.19	0.29	0.72
CaO	1.01	5.88	7.88	6.77	6.16	7.42	0.53	0.83	2.78	0.21	2.13
Na_2O	3.71	3.73	3.25	3.56	4.20	3.80	4.75	4.20	3.49	4.51	4.75
K_2O	4.60	2.45	1.50	1.87	2.27	1.86	3.96	4.01	3.85	3.81	3.60
TiO_2	0.27	1.08	1.96	1.02	1.073	1.866	0.293	0.392	1.095	0.294	0.939
P_2O_5	0.07	0.40	0.55	0.34	0.369	0.567	0.111	0.078	0.247	0.044	0.329
MnO	0.05	0.12	0.18	0.11	0.118	0.151	0.138	0.097	0.052	0.091	0.129

Sample No.	18(474)	21(476)	22	25	28	30	39	40	43	44	45
Map unit	Tdf	Twt$_2$	Twc	Tlr	Tdb	Twt$_2$	Th	Th	Twt$_2$	Trsw	Trsw
Rock name	dacite	rhyolite	rhyolite	rhyolite	basalt	rhyolite	basaltic andesite	basaltic andesite	rhyolite	rhyolite	rhyolite
Oxides											
SiO_2	68.20	74.15	73.77	73.22	48.81	77.56	54.47	54.25	76.22	73.48	73.96
Al_2O_3	13.35	14.66	13.23	12.77	17.56	10.55	13.71	13.82	10.82	13.52	13.25
FeO	5.33	1.27	2.46	4.21	9.03	2.35	12.49	12.70	2.91	2.12	1.91
MgO	1.43	0.49	0.32	0.31	8.83	0.43	3.74	3.65	0.29	0.61	0.45
CaO	2.86	0.97	0.14	0.61	11.77	0.18	7.40	7.48	0.31	1.29	1.13
Na_2O	3.59	3.25	5.23	4.43	2.40	4.34	3.15	3.25	4.58	2.86	3.36
K_2O	3.81	5.00	4.46	3.97	0.26	4.34	1.64	1.49	4.49	5.63	5.54
TiO_2	1.085	0.099	0.318	0.362	0.978	0.186	2.628	2.632	0.206	0.322	0.282
P_2O_5	0.245	0.062	0.033	0.054	0.157	0.022	0.565	0.528	0.061	0.111	0.082
MnO	0.098	0.058	0.037	0.064	0.201	0.041	0.209	0.199	0.055	0.055	0.041

Table 2 (continued)

Sample No.	48	49(478)	50	52	53	54	56	60(479)	61	63	64
Map unit	Tm	Tm?	Tm?	Ttv	Ttv	Twc	Trs	Tws	Tws	Trs	Trs
Rock name	basaltic andesite	trachy-dacite	trachy-andesite	trachy-andesite	andesite	rhyolite	rhyolite	rhyolite	rhyolite	rhyolite	high-silica rhyolite
Oxides											
SiO_2	56.86	67.53	61.26	61.15	61.83	73.33	73.76	76.85	77.45	77.38	78.12
Al_2O_3	16.55	14.61	14.95	16.88	16.59	13.19	13.37	12.40	12.46	12.20	11.77
FeO	8.37	5.80	8.11	6.02	5.96	3.06	1.96	1.00	1.34	1.18	1.12
MgO	3.70	0.50	1.74	2.21	2.02	0.41	0.54	0.38	0.32	0.24	0.27
CaO	7.43	2.18	4.58	5.41	5.25	0.28	1.19	0.71	0.42	0.14	0.11
Na_2O	3.45	4.93	4.18	3.84	4.26	4.98	3.46	3.25	2.68	4.13	4.33
K_2O	1.85	3.38	2.76	2.79	2.50	4.28	5.31	5.21	5.14	4.63	4.20
TiO_2	1.360	0.761	1.797	1.118	1.101	0.356	0.292	0.146	0.151	0.053	0.048
P_2O_5	0.265	0.218	0.461	0.478	0.381	0.043	0.074	0.036	0.028	0.024	0.023
MnO	0.161	0.096	0.165	0.107	0.110	0.071	0.043	0.021	0.012	0.021	0.012

Sample No.	65	66	67	78	80	82	83	85	86	88	89
map unit	Trs	Tws	Tws	Trs	Trs	Trs	Tws	Tws	Tws	Twt_2	Tvb
Rock name	rhyolite	rhyolite	rhyolite	high-silica rhyolite	rhyolite	rhyolite	rhyolite	high-silica rhyolite	rhyolite	rhyolite	rhyolite
Oxides											
SiO_2	77.44	76.29	77.61	79.16	75.45	71.88	77.21	81.05	76.80	76.91	77.24
Al_2O_3	12.19	12.75	12.17	11.39	12.97	13.66	12.31	10.03	12.65	10.97	11.75
FeO	1.12	1.02	0.96	0.96	1.85	2.80	0.67	0.51	1.01	2.41	1.96
MgO	0.20	0.13	0.11	0.06	0.12	0.96	0.40	0.30	0.06	0.10	0.38
CaO	0.12	0.82	0.67	0.17	0.86	1.68	0.59	0.40	0.69	0.14	1.06
Na_2O	4.44	3.36	3.16	3.81	3.16	3.97	2.93	2.03	3.19	4.58	3.45
K_2O	4.39	5.38	5.11	4.36	5.21	4.63	5.67	5.52	5.34	4.63	3.74
TiO_2	0.055	0.154	0.150	0.046	0.282	0.475	0.154	0.123	0.153	0.191	0.280
P_2O_5	0.025	0.084	0.037	0.030	0.077	0.164	0.061	0.034	0.077	0.032	0.072
MnO	0.016	0.018	0.024	0.013	0.024	0.085	0.009	0.009	0.029	0.036	0.065

Sample No.	90	93	103	104	105	107	108	111	119	120	122(485)
Map Unit	Tvb	Twt_1	Trf	Trf	Trf	Trf	Twc	Twc	Tsr	Twt_2	Tsr
Rock name	rhyolite	rhyolite	rhyolite	rhyolite	rhyolite	rhyolite	rhyolite	rhyolite	andesite	rhyolite	basalt
Oxides											
SiO_2	72.56	76.45	76.19	74.09	74.64	76.08	73.54	75.99	60.39	76.29	51.82
Al_2O_3	13.51	12.44	13.47	13.56	13.46	13.08	13.02	12.24	17.15	10.92	16.15
FeO	3.21	1.95	1.14	2.12	1.57	1.03	3.05	2.26	6.05	2.93	11.43
MgO	0.53	0.06	0.07	0.35	0.30	0.10	0.23	0.47	2.41	0.13	4.88
CaO	1.19	0.44	0.63	1.13	1.17	0.83	0.20	1.47	5.99	0.20	8.00
Na_2O	3.60	2.71	3.54	3.95	3.96	4.15	5.08	2.30	4.19	3.75	3.40
K_2O	4.66	5.74	4.78	4.34	4.55	4.54	4.40	4.64	2.28	5.51	1.54
TiO_2	0.558	0.161	0.109	0.336	0.241	0.096	0.328	0.444	1.072	0.198	2.068
P_2O_5	0.124	0.022	0.025	0.070	0.069	0.036	0.054	0.105	0.374	0.026	0.522
MnO	0.056	0.027	0.043	0.055	0.039	0.056	0.099	0.082	0.099	0.050	0.189

Table 3. Selected trace elements in volcanic rock samples 2 to 122.

Sample No.	2	5	12	14	15(473)	16	17	18(474)	21(476)	22	25
Map unit	Tsr	Tsr	Twc	Tlr	Tsr	Twc	Twc	Tdf	Twt_2	Twc	Tlr
Elements											
Ni	9	33	14	10	20	10	20	20	9	14	5
Cr	11	33	4	0	53	5	23	45	5	3	0
Sc	17	19	3	6	11	4	11	7	3	0	5
V	159	270	10	43	108	24	107	100	5	16	8
Ba	1,028	959	2,448	2,060	446	853	1,625	456	24	859	1,871
Rb	33	28	87	112	100	86	76	98	182	100	120
Sr	505	519	105	141	163	42	209	158	26	29	132
Zr	202	193	375	466	131	355	330	134	104	417	514
Y	27	37	66	76	33	51	72	33	33	54	60
Nb	13.4	16.4	28.6	37	20.9	27.1	26.9	21.1	27.7	29.5	40.5
Ga	20	19	20	24	19	18	21	18	20	22	26
Cu	23	39	8	6	6	3	17	15	4	0	0
Zn	82	120	102	152	69	106	130	69	45	121	171
Pb	8	7	3	15	13	12	16	16	26	13	16
La	57	29	55	63	39	46	47	60	25	50	68
Ce	56	48	89	90	69	95	88	70	40	77	117
Th	4	4	6	13	11	6	7	9	19	6	14

Sample No.	28	30	39	40	43	44	45	48	49	50	52
Map unit	Tdb	Twt_2	Th	Th	Twt_2	Trsw	Trsw	Tm	Tm	Tm	Ttv
Elements											
Ni	153	30	7	6	10	11	9	40	2	0	9
Cr	264	4	24	19	1	5	0	83	2	6	9
Sc	41	0	28	33	0	0	2	24	16	15	20
V	256	13	387	403	0	6	13	217	14	123	164
Ba	323	63	656	721	28	1,128	936	933	1,215	856	1,316
Rb	3	129	43	36	148	140	146	39	88	67	46
Sr	208	11	326	331	11	102	94	393	255	343	488
Zr	56	980	182	184	1,056	229	208	148	308	241	209
Y	22	121	42	41	125	47	35	34	47	41	25
Nb	4.9	83.9	15.2	14.2	92.1	18.2	17.7	10.0	24.4	18.3	13.8
Ga	15	29	23	25	29	18	15	22	22	22	23
Cu	54	3	93	129	1	6	1	67	1	16	17
Zn	59	209	128	129	245	44	39	85	120	114	83
Pb	0	28	2	8	31	16	16	3	10	10	8
La	0	76	16	36	97	51	45	32	22	25	28
Ce	18	176	40	37	191	74	68	41	63	66	45
Th	0	12	7	5	12	8	8	5	7	4	5

Table 3 (continued)

Sample No.	53	54	56	60	61	63	64	65	66	67	78
Map Unit	Ttv	Twc	Trs	Tws	Tws	Trs	Trs	Trs	Tws	Tws	Trs
Elements											
Ni	9	9	10	11	12	20	15	13	11	10	13
Cr	8	5	2	0	0	0	0	1	0	0	0
Sc	14	2	3	0	0	1	0	0	3	5	0
V	159	29	13	7	9	0	1	9	4	7	0
Ba	1,051	972	920	723	516	80	0	0	644	733	247
Rb	48	94	145	183	178	229	239	256	181	174	244
Sr	464	45	99	75	50	11	7	4	61	61	31
Zr	205	405	209	128	128	179	176	179	137	129	166
Y	24	47	38	38	46	72	100	95	31	37	67
Nb	13.4	30.7	17.5	22.8	22.4	69.1	66.6	68.3	24.6	24.0	62
Ga	20	22	20	17	15	25	25	25	15	16	24
Cu	21	5	0	0	4	8	6	4	8	5	10
Zn	90	95	39	29	29	118	101	94	28	24	84
Pb	10	12	17	16	18	19	27	28	22	19	27
La	46	47	42	51	45	21	17	43	25	40	33
Ce	47	61	70	69	62	47	65	85	65	73	52
Th	6	6	10	15	15	16	17	15	19	20	19

Sample No.	80	82	83	85	86	88	89	90	93	103	104
Map unit	Trs	Trs	Tws	Tws	Tws	Twt_2	Tvb	Tvb	Twt_1	Trf	Trf
Elements											
Ni	7	19	8	10	13	15	17	14	9	12	12
Cr	2	5	3	0	0	0	10	22	0	6	14
Sc	4	6	0	0	6	2	4	7	1	5	1
V	6	27	1	8	8	1	23	49	1	11	29
Ba	980	1,364	526	456	617	24	291	449	1,362	209	198
Rb	147	131	187	164	179	141	174	174	90	212	208
Sr	98	163	52	38	61	7	49	73	28	24	47
Zr	206	273	131	109	134	1,039	88	108	383	91	95
Y	35	44	35	21	35	141	44	31	87	23	29
Nb	18.2	19.6	24.1	18.5	24.6	90	21.8	24.2	28.3	24.9	26.3
Ga	15	14	17	12	15	28	16	18	25	19	18
Cu	12	20	5	1	12	6	13	6	7	11	10
Zn	37	53	15	14	28	232	33	56	146	35	57
Pb	15	10	13	24	19	27	24	18	14	25	24
La	21	46	48	271	36	91	54	30	36	13	21
Ce	66	57	59	531	74	207	62	30	73	20	33
Th	12	8	12	10	21	15	10	11	10	1`7	11

Table 3 (continued)

Sample No.	105	107	108	111	119	120	122(485)
Map unit	Trf	Trf	Twc	Twc	Tsr	Twt_2	Tsr
Elements							
Ni	12	11	10	16	12	12	47
Cr	9	3	7	18	12	0	81
Sc	1	2	4	1	17	0	25
V	25	10	24	30	158	0	259
Ba	97	127	1,006	379	1,295	8	2,907
Rb	205	201	100	159	35	146	17
Sr	45	20	38	95	521	7	625
Zr	92	92	416	91	199	1,061	169
Y	31	32	53	29	24	151	38
Nb	30.0	26.0	31.1	24.8	13.3	90.1	14.2
Ga	20	19	22	16	18	30	21
Cu	15	0	2	10	26	0	37
Zn	42	34	125	48	85	237	126
Pb	22	27	15	21	7	30	4
La	13	24	37	7	14	107	36
Ce	47	33	75	37	57	228	27
Th	65	15	7	15	3	12	5

Table 4. Descriptions and locations of samples of altered rock.

Sample No.	Description(map unit)	Location
350	brown and red clay(Tssy)	NE1/4 sec. 14, T. 24 S., R. 39 E.
351	chalcedony-cemented sandstone(Tsso)	Near center sec. 34, T. 24 S., R. 39 E.
352	chalcedony-cemented sandstone(Tts)	W1/2 sec. 7, T. 25 S., R. 39 E.
353	hematitic welded tuff(Tws)	SE1/4 sec. 12, T. 25 S., R. 38 E.
354	red clay(Tts)	NW1/4 sec. 18, T. 25 S., R. 39 E.
355	welded tuff with chalcedony(Tws)	Near center sec. 18, T. 25 S., R. 39 E.
356	chalcedony(Tws)	SE1/4 sec. 13, T. 25 S., R. 39 E.
357	silicified welded tuff(Tws)	same
358	red-brown silicified welded tuff(Tws)	SW1/4 sec. 19, T. 25 S., R. 39 E.
359	chalcedony cemented breccia(Tws)	NW1/4 sec. 19, T. 25 S., R. 39 E.
360	red clay(Tvb)	SE1/4 sec. 3, T. 25 S., R. 39 E.
361	hematitic silicified sandstone(QTf)	SE1/4 sec. 1, T. 25 S., R. 39 E.
362	chalcedony cenented basalt breccia(Tsso)	SE1/4 sec. 2, T. 25 S., R. 39 E
363	red clay(Tssy)	NW1/4 sec. 16, T. 24 S., R. 39 E.
263	welded tuff with red veins and staining(Tsw)	SW1/4 sec. 18, T. 25 S., R. 39 E.
264	rhyolite with opalite veins(Trs)	Near center sec. 19, T. 25 S., R. 39 E.
265	sandstone with black and brown oxides(Tssy)	SW1/4 sec. 35, T. 24 S., R. 39 E.
421	brown and black oxide veins(Trf)	NW1/4 sec. 2, T. 25 S., R. 39 E.
422	red welded tuff breccia(Twc)	SW1/4 sec. 2, T. 25 S., R. 39 E.

Table 5. Major- and minor-element analyses of samples of altered rock listed in Table 4. Al, Ca, Fe, K, Mg, Na, P, and Ti are given in weight-percent. The other elements are given in ppm. "N"=element not present at the lower detection level indicated. "<"=element present, but at concentration less than lower confidence limit indicated`1`

Sample No.	350	351	352	353	354	355	356	357	358	359	360
Map unit	Tssy	Tsso	Tts	Tws	Tts	Tws	Tws	Tws	Tws	Tws	QTf
Elements											
Al	9.1	6.1	6.5	6.3	9.3	4.2	1.1	6.4	6.1	4.4	11
Ca	2.5	1.3	1.4	0.34	1.9	0.41	0.35	0.31	0.87	0.20	0.82
Fe	4.2	16	3.9	1.2	4.5	0.53	0.14	2.4	0.78	0.12	6.5
K	0.30	0.26	1.0	4.1	1.4	2.7	0.55	4.7	4.4	3.9	0.85
Mg	2.0	0.42	0.75	0.09	1.1	0.14	0.09	0.05	0.23	0.01	0.49
Na	0.45	0.51	0.93	1.9	0.84	1.5	0.07	1.5	1.2	1.1	0.46
P	0.16	0.09	0.05	0.009	0.06	0.02	0.05	0.08	0.01	0.02	0.04
Ti	0.64	0.37	0.45	0.09	0.59	0.06	0.02	0.17	0.13	0.07	1.0
As	<10	57	<10	<10	<10	<10	<10	<10	<10	<10	<10
Au	<0.002	0.004	N	N	N	N	N	N	N	N	N
Ba	360	490	930	550	990	1,000	190	350	1,000	410	330
Be	2	7	2	3	2	3	<1	3	3	2	2
Cd	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Ce	51	37	44	74	69	46	9	84	71	49	75
Co	19	7	10	1	21	<1	<1	1	<1	<1	20
Cr	34	11	22	<1	40	<1	<1	3	2	<1	68
Cu	51	67	31	4	37	6	2	6	5	2	34
Eu	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Ga	21	13	15	16	21	11	4	18	15	10	27
Hg	0.02	0.13	0.04	N	0.03	N	0.52	1.1	0.32	0.12	0.04
Ho	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4
La	42	26	42	44	36	33	6	52	44	29	33
Li	20	11	28	17	24	19	3	7	11	7	59
Mn	440	140	530	100	1,200	140	190	58	92	24	550
Mo	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Nb	11	8	10	14	10	7	<4	15	15	10	22
Nd	37	24	37	30	33	21	<4	22	30	18	23
Ni	51	9	21	<2	31	3	<2	<2	<2	<2	25
Pb	9	9	9	23	12	17	10	19	16	20	26
Sc	17	12	13	2	16	<2	<2	3	3	<2	17
Sr	210	180	190	50	210	61	110	130	310	31	100
Th	6	5	6	18	7	11	<4	21	18	12	15
V	76	290	76	9	110	6	<2	47	8	<2	200
Y	41	27	33	36	28	22	7	12	32	15	24
Yb	4	4	3	4	3	2	<1	1	4	2	2
Zn	100	130	67	37	68	17	3	7	25	3	81

Table 5 (continued)

Sample No.	361	362	363	263	264	265	421	422
Map unit	QTf	Tsso	Tssy	Tws	Trs	Tssy	Trf	Twc
Elements								
Al	2.9	5.4	10	5.6	5.8	7.5	6.6	6.3
Ca	0.82	6.7	1.1	0.23	0.70	3.1	0.32	0.20
Fe	29	7.7	10	0.58	1.3	9.1	2.6	2.5
K	0.16	0.66	0.37	4.1	3.5	0.68	3.5	3.4
Mg	0.24	2.1	0.69	0.05	0.09	0.72	0.16	0.05
Na	0.18	1.5	0.21	1.4	2.1	1.3	3.4	3.2
P	0.22	0.14	0.12	0.01	0.03	0.14	0.08	0.06
Ti	0.27	1.0	1.7	0.09	0.13	1.0	0.22	0.23
As	41	<10	22	<10	<10	<10	<10	<10
Au	N	N	N	<0.002	<0.002	<0.002	<0.002	<0.002
Ba	2,100	680	570	540	910	1,300	1,100	880
Be	11	<1	3	2	2	2	3	3
Cd	3	<2	<2	<2	<2	<2	<2	<2
Ce	190	30	110	70	78	80	96	64
Co	81	38	33	<1	2	140	2	<1
Cr	10	15	48	4	3	57	6	8
Cu	77	94	39	2	11	34	7	4
Eu	3	<2	4	<2	<2	2	<2	<2
Ga	31	17	28	15	15	21	23	20
Hg	0.08	N	0.08	<0.02	<0.02	<0.02	<0.02	<0.02
Ho	7	<4	<4	<4	<4	<4	<4	<4
La	42	21	65	35	45	41	81	42
Li	5	88	42	5	8	6	17	7
Mn	6,700	1,400	1,200	43	250	2,100	1,200	470
Nb	7	5	26	21	15	20	34	31
Nd	51	26	77	23	35	43	69	40
Ni	17	15	42	<2	3	16	7	3
Pb	33	<4	12	19	14	6	16	14
Sc	8	27	29	2	4	20	7	6
Sr	120	290	130	58	91	420	46	40
Th	5	<4	7	15	10	5	7	7
V	860	420	360	8	14	260	36	28
Y	210	40	73	19	36	36	63	39
Yb	28	3	8	2	4	4	5	4
Zn	180	100	110	11	31	100	140	110