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Geologic Map of the Fort Klamath Quadrangle, Klamath County, Oregon

by

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1.0 INTRODUCTION

The Fort Klamath quadrangle (Figure 1.1) straddles a low divide between the Wood River on the west and the Williamson River on the east. Located about 10 km (6 mi) south of Crater Lake National Park and 55 km (34 mi) north-northwest of the city of Klamath Falls, the quadrangle is traversed by U.S. Highway 97 and Oregon State Highways 62 and 232. The largest town is Fort Klamath, which is located along the Wood River in the wide alluvial valley that defines the Klamath graben.

Two geographic reference points are mentioned repeatedly in this report and named informally for convenience: The first is the "Forest Boundary area," which refers to the northeast quarter of the quadrangle and is crossed by several boundary lines of the Winema National Forest. The second is the "Collier grade," which refers to the climbing section of U.S. Highway 97 two miles north of Collier Memorial State Park and just east of the quadrangle edge.

Constructional volcanism appears to have alternated with extensional volcanism, terrestrial sedimentation, and faulting to create the features we see today. Along the eastern side of the Klamath graben a dramatic scarp marks the East Klamath Lake fault zone. Evidence for earlier extension includes wide-spread, flat-lying lava flows and fluvial or lacustrine sedimentary deposits. The Klamath graben itself lies in a transition zone between the Cascade Range volcanic arc to the west and the Basin and Range extensional province to the east. Rocks in this area are generally young. Most units are assigned a Quaternary age. The oldest units are probably of Pliocene age.

1.2 Methodology

1.2.1 Mapping Constraints

The Fort Klamath quadrangle is largely blanketed by a uniform layer of Mazama ash that offers few clues to the bedrock geology. This results in a bedrock geologic map that is in large part based on widely scattered, tiny outcrops and float. Color, mineralogy, texture, weathering, and outcrops of the lava flows are fairly uniform; subtle variations in size and amount of olivine and plagioclase phenocrysts and groundmass texture generally provide the only means to distinguish between map units in hand specimen. Map-unit descriptions emphasize the characteristics used to distinguish between adjacent units in the fields. Contacts are only rarely exposed, so relationships between units and the nature of the contacts themselves are generally constrained only by large-scale features. With only one radiometric age and one fossil age from the quadrangle to the east, the ages assigned to rock units are very poorly constrained. Most age assignments are based on stratigraphic position relative to Mazama ash and dated rock units (units Qsh1 and QTs). Several units (e.g. unit QTba) have been assigned older ages on the basis of incised drainage or other geomorphic features.

1.2.2 Geochemistry

The classification of igneous rocks that is used in this report follows the geochemical method of Le Bas and Streckeisen (1991). Units for which no analytical data were available were assigned rock names based on the following criteria: the name "basalt" was used for rocks having abundant fresh or incipiently altered olivine phenocrysts, typically with granular to felty groundmass; the name "basaltic andesite" was used for rocks containing altered olivine ± orthopyroxene phenocrysts with intersertal to intergranular groundmass; the name" andesite" is used for rocks that are aphyric and those that contain clinopyroxene phenocrysts with orthopyroxene and perhaps a few thoroughly altered olivine phenocrysts in an intersertal to intergranular groundmass.

Stanley A. Mertzman (Department of Geosciences, Franklin and Marshall College, Lancaster, Penn.) provided XRF analyses for samples listed in Table 1.1. Analyses were performed with the following procedures:

The original rock/mineral powder was crushed with aluminum oxide milling media until the entire sample passed

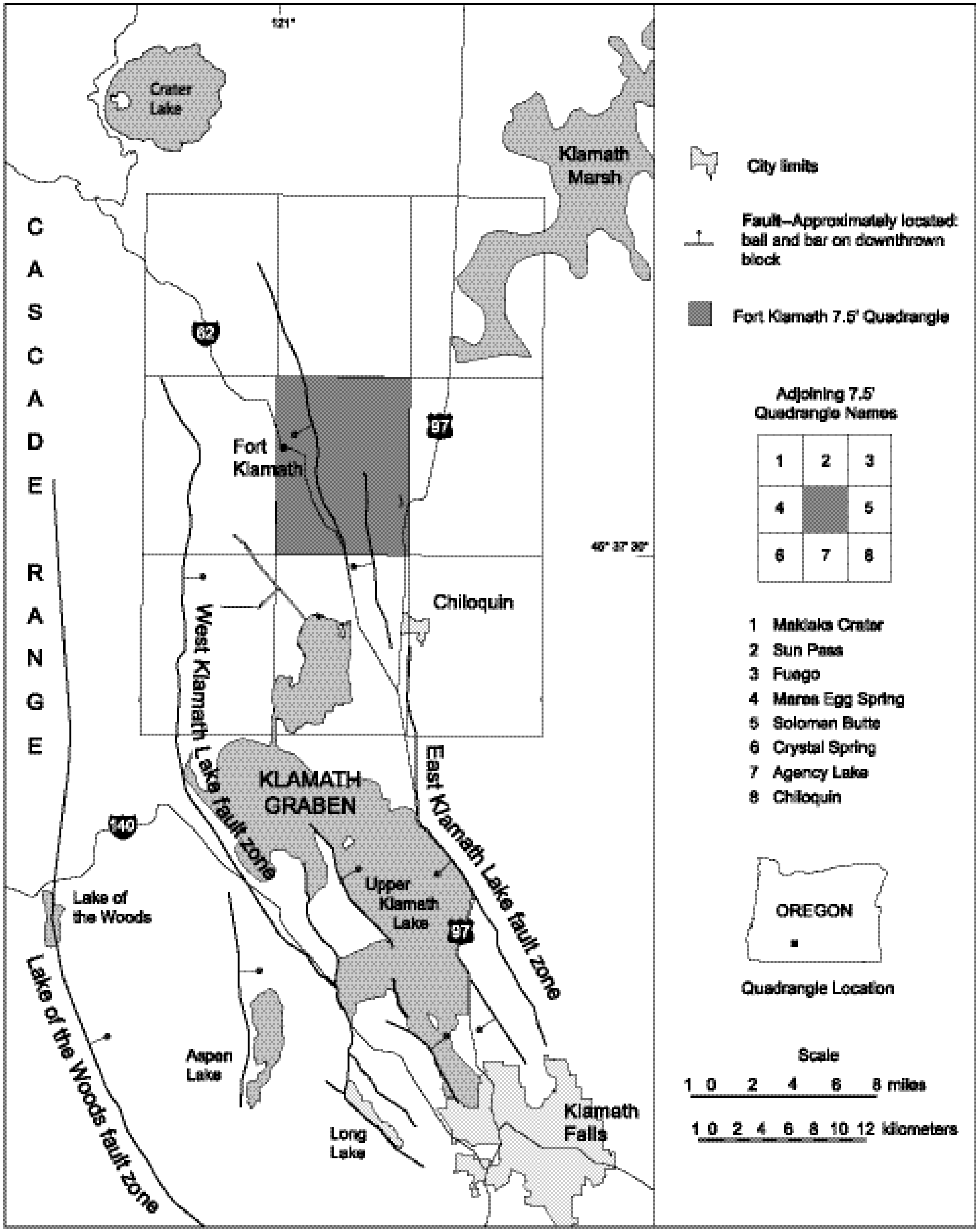

Figure 1.1 Map showing location of Fort Klamath quadrangle and its vicinity.

through a clean 80-mesh sieve. Then 3.6 g of lithium tetraborate and 0.4 g of rock powder were mixed in a Spex Mixer Mill. The powder was transferred to a 95-percent-Pt/5-percent-Au crucible, 3 drops of a 2-percent solution of LiI was added, the mixture was covered with a 95-percent-Pt/5-percent-Au lid (which also acted as a mold), and was heated for 10 minutes. After being stirred and thoroughly convected, the molten contents of the red-hot crucible were poured into the lid to cool.

Working curves for each element of interest were determined by analyzing geochemical rock standards, data for which have been synthesized in Abbey (1983) and Govindaraju (1994). Between 30 and 50 data points were gathered for each working curve; various elemental interferences were also taken into account, e.g., $SrK_{ß}$ on Zr, $RbK_{ß}$ on Y, etc. The Rh Compton peak was utilized for a mass absorption correction. Slope and intercept values, together with correction factors for the various wavelength interference, were calculated and then stored on a computer. A Philips 2404 X-ray fluorescence vacuum spectrometer equipped with a 102-position sample changer and a 4-KW Rh X-ray tube was used for automated data acquisition and reduction. The major elements were determined via this technique together with Cr and V.

The X-ray procedure determined the total Fe content as Fe_2O_3T. The amount of ferrous Fe was titrated according to a modified Reichen and Fahey (1962) method, and loss on ignition was determined by heating an exact aliquot of the sample at 950°C for one hour.

Trace element analysis was accomplished by weighing out 7 g of whole-rock powder and adding 1 g of high-purity microcrystalline cellulose, mixing for 10 minutes, and pressing the sample into a briquette. Copolywax powder was substituted for cellulose when the whole-rock SiO_2 content was >55 weight percent. Data were reported as parts per million (ppm). The elements measured this way included Rb, Sr, Y, Zr, Nb, Ni, Ga, Cu, Zn, U, Th, Co, Pb, Sc, Cr and V. Elements La, Ce, and Ba were calibrated by means of an L X-ray line and a mass-absorption correction.

2.0 EXPLANATION OF MAP UNITS

The general interrelationships of the map units are shown in Figure 2.1 below. A detailed explanation of the map units follows. The units in Figure 2.1 are arranged in chronologic sequence, the youngest unit at the top and the oldest at the base.

Surficial Units

Qal	Quaternary alluvium (Holocene and Pleistocene)
Qc	Colluvium (Holocene and upper Pleistocene)
Qm	Mazama ash (Holocene)
Qma	Mazama ash-flow deposits (Holocene)

Volcanic Rocks of the Forest Boundary Area

Qcv	Basaltic andesite to andesite cinders (Pleistocene)
Qav	Andesite vent deposits (Pleistocene)
Qbav	Basaltic andesite vent deposits (Pleistocene)
Qfb1	Vesicular olivine basalt (Pleistocene)
Qfa1	Andesite (Pleistocene)
Qfb2	Intracanyon vesicular olivine basalt (Pleistocene)
Qba1	Glomeroporphyritic olivine basaltic andesite (Pleistocene)
Qba2	Basaltic andesite (Pleistocene)
Qba3	Olivine and pyroxene basaltic andesite (Pleistocene)
Qfa2	Glomeroporphyritic olivine and two-pyroxene andesite and basaltic andesite (Pleistocene)
Qfa3	Vesicular andesite (Pleistocene)
Qba4	Prophyritic olivine basaltic andesite (Pleistocene)
Qba5	Vesicular plagioclase basaltic andesite (Pleistocene)
Qba6	Glomeroporphyritic olivine basalt (Pleistocene)
Qfa4	Andesite (Pleistocene)
Qfb3	Glomeroporphyritic olivine basalt (Pleistocene)
Qfb4	Vesicular basalt (Pleistocene)
Qba7	Basaltic andesite (Pleistocene)
Qba8	Vesicular pyroxene basaltic andesite (Pleistocene)
Qba9	Olivine basaltic andesite and andesite (Pleistocene)

Volcanic Rocks of the Spring Hill Area

Qsh1	Porphyritic olivine and pyroxene basaltic andesitie (Pleistocene)
Qsh2	Glomeroporphyritic olivine basaltic andesite (Pleistocene)
Qta	Diktytaxitic olivine trachyandesite with trachytic groundmass (Pleistocene)

Volcanic Rocks of the Sun Mountain Area

Qsb1	Olivine basalt (Pleistocene)
Qsb2	Diktytaxitic olivine basalt (Pleistocene)
Qsa1	Olivine andesite (Pleistocene)
Qsba	Glomeroporphyritic olivine basaltic andesite (Pleistocene)
Qsb3	Vesicular olivine basalt (Pleistocene)
Qsb4	Vesicular olivine basalt and basaltic andesite (Pleistocene)
Qsa2	Pyroxene andesite (Pleistocene)

Other Quarternary Volcanic Rocks

Qb	Diktytaxitic olivine basalt (Pleistocene)
Qcb	Diktytaxitic olivine basalt (Pleistocene)
QTcc	Basalt of Copeland Canyon (Pleistocene or Pliocene)
QTsh	Andesite of Sugar Hill (Pleistocene or Pliocene)
QTba	Basaltic andesite and andesite (Pleistocene or Pliocene)

Tertiary Volcanic Rocks

Tah	Basaltic andeistie of Agency Hill (Pleistocene)
Tahc	Basalt of Spring Creek (Pleistocene)
Tba	Olivine basaltic andesite (Pliocene)

Sedimentary Rocks

QTs	Siltstone, sandstone, conglomerate, and mudstone, undivided (lower Pleistocene and Pliocene)
Ts	Siltstone, siliceous mudstone, and sandstone, undivided (Pliocene)

Figure 2.1 Map units.

2.1 Surficial Units

Qal **Quaternary alluvium (Holocene and Pleistocene)**—Unconsolidated sand, gravel, silt, mud, and clay deposited in the Klamath graben along the Wood River and its tributaries and along Spring Creek. Contains large amounts of reworked Mazama ash (unit Qm), particularly in the sand-sized fraction. Sand and gravel make up a larger percentage of the deposits in upland areas. Nearby water wells and geophysical profiles indicate that this unit is up to 125 m thick. Only Holocene alluvium is depicted on the map; older (Pleistocene) alluvium is shown beneath the Mazama ash in the cross sections.

Qc **Colluvium (Holocene and upper Pleistocene)**—Unconsolidated deposits of mixed rock fragments in varying states of decomposition, displaced and native soil, redeposited Mazama ash, and angular talus. Largely obscures underlying rocks, especially on the lower parts of fault scarps and other steep slopes. Includes landslide deposits, predominantly formed by rockfall but also by debris flows and other mechanisms. Also includes small alluvial fans. Thickness is extremely variable, rarely more than 20 meters.

Qm **Mazama ash (Holocene)**—Pumiceous hornblende dacite airfall ash and lapilli covers all but the steepest slopes and streambeds. These deposits generally thin from 1.5 m in the north to less than 30 cm along the southern edge of the quadrangle. Thicker accumulations may occur in valleys (where the ash has been reworked by wind and streams) and at the base of slopes. Erupted during the climactic eruption that resulted in the collapse of Mount Mazama, about 25 km to the north-northwest, and formation of Crater Lake. Calculated age 6,845 ± 50 yr B.P. (average of ^{14}C data; Bacon, 1983). Locally divided to show Mazama ash-flow deposits (unit Qma).

Qma **Mazama ash-flow deposits (Holocene)**—Mazama ash that includes ash-flow and block-and-ash tuff containing fragments of hornblende dacite pumice as large as 15–35 cm. These ash-flow deposits are as thick as 20 m and fill several of the upland valleys. Along the eastern edge of the Klamath graben they formed fanlike deposits when they decelerated after reaching the flat valley floor. The largest of these has a radius of about 3 km.

2.2 Volcanic Rocks of the Forest Boundary Area

Qcv **Basaltic andesite to andesite cinders (Pleistocene)**—Defines vent locations at volcanic cones and along fault zones. Many occurrences too small to map.

Qav **Andesite vent deposits (Pleistocene)**—May be aphyric or contain phenocrysts of plagioclase or clinopyroxene. Typically vesicular to scoriaceous. Exposures are commonly cone shaped with a central crater surrounded by partial rings of more massive lava.

Qbav **Basaltic andesite vent deposits (Pleistocene)**—Plagioclase or olivine phyric, locally aphyric. Vesicular to scoriaceous. Exposed in cones with central craters that are typically surrounded by partial rings of more massive lava. Table 1.1, map no. 10, from Hill 5239 in sec. 7, T. 33 S., R. 7 E., is glomeroporphyritic with intergranular groundmass.

Qfb1 **Vesicular olivine basalt (Pleistocene)**—Float and low blocky outcroppings erupted on the southern side of the young cone that forms Hill 5395 at the northern edge of the quadrangle. Fresh rock is light gray. Vesicles may be partly filled by botryoidal zeolite(?). Olivine <1 percent, up to 1 mm. Plagioclase phenocrysts 1–2 mm, some iridescent. Occasional small glomerocrysts in NE¼ sec. 6, T. 33 S., R. 7 E., Table 1.1, map no. 5.

Qfa1 **Andesite (Pleistocene)**—Vent(s) and flow in sections 16 and 17, T. 33 S., R. 7 E. Locally platy; locally amygdaloidal; locally vesicular with 0–20 percent vesicles up to 2×2×5 mm. Zoned plagioclase tablets to 2 mm; also <1 mm plagioclase combined with clinopyroxene in felty, rounded, porous clots (<1 percent of the rock). Uncommon 0. 5 mm, elongate, rounded, orthopyroxene with corroded grain boundaries. Hyalophitic groundmass of <1 mm, plagioclase, opaque oxides (0.05 mm), and clinopyroxene (rarely 0.5 mm) in dark green altered glass. Table 1.1, map nos. 14 and 18.

Qfb2 **Intracanyon vesicular olivine basalt (Pleistocene)**— Intracanyon flow that seems to have originated on a broad ridge in the south half of sec. 8, T. 33 S., R. 7 E., and flowed southward down a small stream valley. This relatively young flow overlaps many units and seems to be overlain only by ash and pumice flows from the climactic eruption of Mount Mazama (unit Qma). Exposed as low outcrops and 1- to 2-m boulders. Light-gray when fresh, tan when weathered. Olivine grades from very fresh to incipiently altered, comprising about 2 percent of the rock; 0.5–3 mm in size. Scattered plagioclase phenocrysts to 1 mm. Locally glomeroporphyritic with olivine and plagioclase crystals; glomerocrysts may be anomalously porous (40 percent voids). Locally diktytaxitic with a trachytic groundmass. Table 1.1, map no. 12.

Qba1 **Glomeroporphyritic olivine basaltic andesite (Pleistocene)**—Blocky (to 1.5 m) lava flow(s) exposed in erosional windows through younger units in sections 21 and 28, T33S, R7E. Tan-gray when weathered, dark-gray when fresh. Typically vesicular with oval to round vesicles 1–20 mm (average 2 mm) that comprise 15 percent of the rock; locally amygdaloidal with clear to white botryoidal or acicular zeolite; locally massive in NE¼SW¼ sec. 21. Individual olivine crystals are <2 mm. Plagioclase occurs as single crystals to 2 mm and in clots composed of several grains. Intergranular groundmass dominated by 0.5- to 1.0-mm plagioclase tablets. Table 1.1, map no. 25.

Qba2 **Basaltic andesite (Pleistocene)**—Locally blocky. Locally vesicular. Surrounds Hill 5330 in sections 6 and 7, T. 33 S., R. 7 E. Contains millimeter-sized plagioclase crystals and rare olivine.

Qba3 **Olivine and pyroxene basaltic andesite (Pleistocene)**—Poorly exposed vesicular glomeroporphyritic olivine and orthopyroxene basaltic andesite exposed in the northeastern part of the quadrangle. Occurs as float blocks to 1 m across in the area east of two volcanic cones (Hills 5395 and 5346). Olivine occurs in 1- to 2-mm clots with plagioclase or as individual grains to 1 mm; light-green to straw-yellow; <1 percent. Millimeter-size and smaller crystals of orthopyroxene. Plagioclase to about 3 mm, zoned with corroded cores. Vesicles up to 1.5 cm in diameter, smaller vesicles may be diktytaxitic.

Qfa2 **Glomeroporphyritic olivine and two-pyroxene andesite and basaltic andesite (Pleistocene)**—Crops out in and around the southern half of sec. 29, T. 33 S., R. 7 E. Changes in flow morphology from the steep exposures in the north to generally flat ones in the south suggest multiple flows. Altered olivine to 1 mm, generally in glomerocrysts. Plagioclase in glomerocrysts and as larger, zoned phenocrysts to 2 mm, often with corroded cores. Orthopyroxene and clinopyroxene to 1 mm singly and in glomerocrysts. Opaque oxides to 0.4 mm. Elongate orthopyroxene and plagioclase phenocrysts and microlites are crudely aligned in an intersertal groundmass. Vesicles <1 mm are diktytaxitic. Table 1.1, map no. 32.

Qfa3 **Vesicular andesite (Pleistocene)**— Ridge-capping flows of blocky (2–3 m across) lava in sec. 16, T. 33 S., R. 7 E. Dark gray fresh, orange-red weathered. Vesicles 0–8 mm make up 2–10 percent of the rock; vesicles <1 mm are irregular and most are diktytaxitic. Rare phenocrysts of plagioclase average 1.5 mm in diameter. Crudely aligned plagioclase laths (average 0.5 mm), variably altered orthopyroxene and clinopyroxene, and opaque oxides in altered glass form an intersertal groundmass texture. Table 1.1, map no. 20.

Qba4 **Porphyritic olivine basaltic andesite (Pleistocene)**—Poorly exposed across several square miles in the northeastern part of the quadrangle. Small variations in the phenocryst assemblage suggest more than one flow. Massive to blocky, forms rim of valley in W½ sec. 16, T. 33 S., R. 7 E. Pinkish-gray to gray when fresh, tan to brown when weathered. Olivine 1–2 mm in diameter forms 1–2 percent of the rock and shows varying degrees of alteration to iddingsite(?); contains opaque inclusions. Subangular to rounded plagioclase phenocrysts up to about 5 mm across make up 2–3 percent of the rock; zoned and possibly resorbed; also occurs as clots and needles. Clinopyroxene(?) forms rare, <1 mm-size, dark, equant crystals. Contains occasional corroded orthopyroxene <1 mm. Dark-green to blue-gray groundmass contains crudely aligned plagioclase laths of <1-mm size. Poorly exposed, but seems to overlie andesite and basalt units Qba5, Qfa4, and Qfb3; overlain by andesite and basalt units Qfa1, Qfa3, Qfb2, and Qba3 and an andesitic cone that forms Hill 5118. Table 1.1, map no. 6.

Qba5 **Vesicular plagioclase basaltic andesite (Pleistocene)**—Crops out in NW¼ sec. 20, T. 33 S., R. 7 E. Contains occasional plagioclase phenocrysts to 3 mm in an intersertal to subophitic groundmass of plagioclase microlites, opaque oxides, and pyroxene with tiny patches of greenish glass. Vesicles form a bimodal population with one group of smooth-walled ovoids and spheroids that are typically 1–10 mm in diameter and a second group that is generally smaller, irregular in form, rough-walled, and diktytaxitic. Table 1.1, map no. 17.

Qba6 **Glomeroporphyritic olivine basalt (Pleistocene)**—Blocky (to 1.5 m), locally platy flow in NW¼ sec. 21, T. 33 S., R. 7 E. Medium-gray when fresh, orange-tan to gray when weathered. Locally vesicular or amygdaloidal with botryoidal zeolite; pores range from <1 mm to 1 cm; smaller pores are angular. Olivine is typically <1 mm across and may have altered rims. Scattered tabular plagioclase phenocrysts to 3 mm are zoned with corroded cores. Glomerocrysts comprise 2–5 mm aggregates of <1 mm plagioclase and olivine; composition varies from 100 percent plagioclase to 100 percent olivine. Intersertal to subophitic groundmass consists of plagioclase microlites that may be partially or wholly included in pyroxene crystals or interspersed with pyroxene, opaque oxides, and gray (pink) glass. Table 1.1, map no. 23.

Qfa4 **Andesite (Pleistocene)**—Flow(s) that form low outcrops with blocky or platy fabrics in E½ sec. 16 and NE¼ sec. 4, T. 33 S., R. 7 E. Dark-gray to gray when fresh, medium-gray to tan when weathered. Locally vesicular (up to 50 percent in some samples), locally amygdaloidal; subrounded to jagged vesicles are typically 0.1–8 mm, although some are as large as 1.2 cm in diameter. Generally aphyric with occasional 1 mm plagioclase and rare 0.5 mm red, altered olivine(?) and pyroxene phenocrysts. Table 1.1, map nos. 3 and 19.

Qfb3 **Glomeroporphyritic olivine basalt (Pleistocene)**—Poorly exposed flow(s) on valley sides in sections 16 and 21, T. 33 S., R. 7 E. Typically occurs as 1 m float blocks, some of which have platy fabric. Medium-gray when fresh, orange when weathered. Vesicles may contain partial or complete zeolite fills, and seem to be of two types: (1) angular, up to 5 mm, <8 percent; and (2) spherical, <2 mm, and <1 percent. Olivine comprises up to 2 percent of the rock, is up to 1 mm in diameter, and is either fresh or has altered rims. Zoned plagioclase phenocrysts are 2–3 mm. Glomerocrysts of plagioclase and olivine range up to 1 cm in diameter with a few vuggy glomerocrysts to 1.5 cm in diameter. A large percentage of glomerocrysts are entirely granular olivine.

Qfb4 **Vesicular basalt (Pleistocene)**—Exposed as float in sec. 12, T. 33 S., R. 7½ E. Millimeter-sized olivine and plagioclase crystals each comprise about 1 percent. Groundmass crystals are coarse, approaching 1 mm, granular. Locally diktytaxitic. Appears to lie beneath and thus to be older than basaltic andesite of unit QTba, however the relationship is not well exposed.

Qba7 **Basaltic andesite (Pleistocene)**—Plagioclase to 3 mm includes both anhedral crystals with rotted cores and subhedral to euhedral crystals that are zoned but have sharper edges and less alteration. Olivine occurs as occasional 1 mm grains with altered rims. Two pyroxenes; orthopyroxene to 1 mm is typically anhedral with corroded rims and altered cores; clinopyroxene is fresh, angular. Locally vesicular, locally amygdaloidal, vesicles <1 mm are diktytaxitic. Intergranular to intersertal groundmass. Float and low outcrops occur north, east, and southeast of Sugar Hill. A few outcrops with larger olivine phenocrysts (olivine basaltic andesite) occur in NW¼ sec. 31, T. 33 S., R. 7 E. Table 1.1, map no. 35.

Qba8 **Vesicular pyroxene basaltic andesite (Pleistocene)**—Contains zoned plagioclase phenocrysts to 4 mm. Some samples have glomeroporphyritic aggregates of pyroxene, plagioclase, and <1-mm olivine. Olivine present as single crystals to 1 mm generally with altered rims. Scattered orthopyroxene occurs as elongate, rectangular to round, corroded crystals to 2 mm. Clinopyroxene in equant crystals to 0.5 mm. Vesicles include both large, smooth-walled and smaller, sub-millimeter diktytaxitic varieties. Blocky flow exposed in road cuts in a small canyon (SW¼ sec. 28, T. 33 S., R. 7 E). Table 1.1, map no. 30.

Qba9 **Olivine basaltic andesite and andesite (Pleistocene)**—Extensive group of blocky flows that crop out in sections 20, 21, 28, and 29, T. 33 S., R. 7 E. Dark-gray when fresh, orange-tan when weathered; locally with black to iridescent manganese oxide(?) staining. Vesicles are small (average diameter 0.5–1.0 mm, rarely larger than about 4 mm); many of the flows appear massive unless closely examined; may be amygdaloidal; may be diktytaxitic. Olivine crystals are uncommon and small. Contains both orthopyroxene and clinopyroxene. Plagioclase is seriate, up to 2 mm; creamy to clear, and may occur in clumps of four to ten <1-mm grains. Intersertal groundmass may have crudely aligned plagioclase microlites. Table 1.1, map nos. 21 and 26

2.3 Volcanic Rocks of the Spring Hill Area

Distribution and morphology of these rocks suggest that they are derived from a volcanic center or centers located just east of the quadrangle in the vicinity of Spring Hill.

Qsh1 **Porphyritic olivine and pyroxene basaltic andesite (Pleistocene)**—Crops out as blocky lava flow(s) in NE¼ sec. 33, T. 33 S., R. 7 E. Blocks are subrounded and average 0.8 m across, with 2.5-m maximum diameter; dark brownish gray when fresh, medium-gray when weathered. Generally massive but locally vesicular or diktytaxitic with scattered small, elongate, irregular vesicles to 3 mm. Plagioclase forms 5–6 percent of the rock and occurs as rounded, zoned tablets with dimensions up to 4×4×1 mm. Olivine is bimodal, consisting of 3 percent brown clumps of altered crystals 2 mm or smaller that occur in association with plagioclase and scattered fresh 0.5-mm crystals. Dark-green orthopyroxene has aspect ratios up to 4:1 and maximum long dimension of 3 mm and comprises <1 percent of the rock. Groundmass consists predominantly of tiny equant to elongate (tabular?) plagioclase and equant crystals of clinopyroxene in glass. Sherrod and Pickthorn (1992) suggest that this unit was erupted from the vent that forms Spring Hill. Radiometric age of 1.14 ± 0.10 Ma has been reported from basaltic andesite believed to be from this unit, sampled at the top of the Collier grade (George Priest, written communication, 1999). Table 1.1, map no. 33.

Qsh2 **Glomeroporphyritic olivine basaltic andesite (Pleistocene)**—Exposed in low outcrops and road cuts along the rim north of Spring Creek in S½ sec. 28, T. 33 S., R. 7 E. Locally contains spherical vesicles to 1 cm in diameter that may be surrounded by haloes of relatively coarser groundmass (locally producing a diktytaxitic texture). Olivine shows altered rims and occurs as individual crystals to 1 mm or with plagioclase in glomerocrysts. Plagioclase occurs as tablets (and needles?) to 3 mm; tabular crystals are zoned with altered interiors. Irregularly shaped glomerocrysts of olivine and plagioclase are up to 7 mm across. Intergranular groundmass with plagioclase, clinopyroxene and opaque oxides (to 0.2 mm). Table 1.1, map no. 31.

Qta **Diktytaxitic olivine trachyandesite (Pleistocene)**—Extensive flow exposed in low outcrops and road cuts and as float in sections. 21, 22, 27, and 28, T. 33 S., R. 7 E. Outcrops appear massive or blocky (typically 2 m across), but are locally platy (1- to 2-cm layers). Light-gray to tan-gray when fresh, light-gray to orange-red when weathered; locally mottled with pinkish-tan alteration, especially around vesicles. Angular, irregular, elongate vesicles are typically tiny with average diameters of 0.3 mm and maximum diameters of about 2 cm. Olivine is grass-green when fresh, brown when weathered; occurs as individual phenocrysts to 2 mm and occasional clumps of <1--mm grains to 3 mm; 1–2 percent of the rock. Augite to 1 mm. Rimmed, zoned plagioclase is distinctive; typically 2–3 mm long, rarely 1×5 mm. May show scattered, relatively dark, approximately 1×2 mm, oval zones of discoloration (which in thin section appear to be rims around corroded orthopyroxene crystals). Locally glomeroporphyritic. Trachytic groundmass shows locally altered (pinkish-tan) glass with aligned plagioclase microlites and abundant opaque oxides to 0.3 mm. Table 1.1, map no. 29.

2.4 Volcanic Rocks of the Sun Mountain Area

Qsb1 **Olivine basalt (Pleistocene)**—Exposed as float east of Sun Mountain along the northern edge of the quadrangle. May be vesicular, amygdaloidal, or diktytaxitic. Olivine phenocrysts, some with included opaque oxides, are up to 3 mm in diameter and constitute 3–5 percent of the rock. Contains scattered, zoned plagioclase phenocrysts to 1.5 mm. Groundmass varies from subophitic to intersertal. Chemistry is similar to that of diktytaxitic olivine basalt (unit Qsb2). Table 1.1, map nos. 2 and 4.

Qsb2 **Diktytaxitic olivine basalt (Pleistocene)**—Exposed as small (<50 cm) round blocks of float along road and logging cuts on a low hill along the northern edge of the quadrangle in sec. 36, T. 32 S., R. 7½ E., and sec. 1, T. 33 S., R. 7½ E. Altered olivine is up to 2 mm in size. Augite to 0.5 mm. Plagioclase phenocrysts and microlites are seriate to 2 mm; they have an irregular, elongate, shredded appearance that suggests that deformation or breakage occurred, perhaps as the flow was erupted. Groundmass is intergranular to intersertal with abundant opaque oxides and patches of greenish altered glass(?). Chemistry is similar to that of nearby olivine basalt (unit Qsb1). Table 1.1, map no. 1.

Qsa1 **Olivine andesite (Pleistocene)**—Float exposed along roads near the rim in sec. 11, T. 33 S., R. 7½ E. Generally massive; dark-gray when fresh, tan when weathered. Olivine up to 3 mm in diameter. Plagioclase to 2 mm in long dimension. Many feldspar, olivine, and pyroxene phenocrysts are jacketed by overgrowths or have altered or corroded cores suggesting that significant changes have influenced the phenocryst-groundmass equilibrium. Intersertal to hyalophitic groundmass of dark-green, altered glass. Table 1.1, map no. 8.

Qsba **Glomeroporphyritic olivine basaltic andesite (Pleistocene)**—Exposed in two canyons that cut across the East Klamath Lake fault zone in sections 11 and 14, T. 33 S., R. 7½ E, and along roads that traverse the fault zone farther north. Locally vesicular. Glomerocrysts to 1 cm are accumulations of olivine and plagioclase.

Qsb3 **Vesicular olivine basalt (Pleistocene)**—Exposed along fault scarps in the northwestern corner of the quadrangle. Olivine phenocrysts to 1 mm have a granular appearance in hand sample; crystals are rounded (resorbed?) and exhibit incipient alteration to iddingsite. Plagioclase crystals are typically lath shaped to 3 mm with a few rounded (resorbed) tabular crystals to 5 mm. Greenish-gray groundmass. Table 1.1, map nos. 7, 9, 11, and 22.

Qsb4 **Vesicular olivine basalt and basaltic andesite (Pleistocene)**—Exposed along fault scarps in the northwestern corner of the quadrangle. Road cuts reveal blocky flows with blocks to 3 m across. Medium-gray both fresh and weathered. Vesicles to 1 cm, typically 0.5–3 mm, with aspect ratios of 1:1 to 6:1, locally diktytaxitic. About 1 percent olivine phenocrysts 0.5–2.0 mm in diameter, some show incipient alteration at crystal edges, may include opaque oxides. Plagioclase is seriate to 1 mm in diameter with rare 3-mm phenocrysts. Granular or felty groundmass texture, pinkish-gray color .

Qsa2 **Pyroxene andesite (Pleistocene)**—Fresh samples blue-gray, weathered samples brown; locally vesicular; generally blocky but locally platy. Light-green, 1- to 2-mm olivine is fresh to altered, granular, and angular; it may occur in clots with plagioclase; contains few to no opaque inclusions, makes up <1 percent of the rock. Brown, 1- to 3-mm orthopyroxene and dark-green, 1- to 2-mm clinopyroxene each make up less than 1 percent of the rock. Plagioclase forms tabular crystals 0.5–3 mm across that make up 1–2 percent of the rock, twinning can be distinguished in hand sample. Intersertal groundmass. Table 1.1, map no. 16.

2.5 Other Quaternary Volcanic Rocks

Qb **Diktytaxitic olivine basalt (Pleistocene)**—Crops out in blocky flows that form a prominent bluff in NW¼ sec. 5 and NE¼ sec. 6, T. 34 S., R. 7 E., and extend 1 mi to the north. Vesicles up to 2 cm in diameter with aspect ratios of 1:1 to 2:1 commonly make up 5 percent (locally 30 percent) of the rock and contain partial zeolite fills; <1-mm pores between groundmass plagioclase grains locally form a diktytaxitic texture and may be sufficiently connected to create good permeability. Unaltered olivine phenocrysts to 1 mm form up to 1 percent of the rock; crystals are angular to subangular and straw-yellow to grass-green and contain opaque inclusions (magnetite?). Plagioclase is seriate, up to 2 mm, with rare tabular crystals up to 3 mm. Lacks glomerocrysts. The groundmass is typically granular, with a felty intergrowth of 0.5–1.0 mm plagioclase crystals giving it a sugary appearance; locally trachytic. Table 1.1, map no. 41.

Qcb **Diktytaxitic olivine basalt (Pleistocene)**—Exposed as float on a low hill north of Copeland Canyon and along the rim north and south of Sugar Hill. Vesicles to >1 cm in diameter, typically bimodal with small, irregular, diktytaxitic vesicles <3 mm in diameter and a second group of larger, ovoid to spheroidal vesicles with few projecting plagioclase crystals. Scarce 1- to 2-mm olivine and plagioclase laths. Intergranular to intersertal with plagioclase laths, clinopyroxene, altered (green) olivine, and opaque minerals, with or without dark-green glass(?). Table 1.1, map nos. 34 and 39.

QTcc **Basalt of Copeland Canyon (Pleistocene or Pliocene)**—Basalt and olivine basalt exposed in Copeland Canyon, overlain to the north by olivine basalt (unit Qcb); laps onto the basaltic andesite of Agency Hill (unit Tah). Massive to vesicular; diktytaxitic in places; may be bimodal with large smooth-walled vesicles to 2 cm and irregular diktytaxitic vesicles <2 mm. Olivine usually occurs as small equant grains with altered rims; large phenocrysts, where present, are fresh to altered and up to 2.5 mm in diameter. Plagioclase consists of crudely aligned, broken, shredded, irregular, lath-shaped crystals 0.5–1 mm long. Groundmass is intersertal to trachytic in texture and composed of plagioclase, clinopyroxene, equant olivine with altered rims, abundant opaque oxides, and dark-brown altered glass. Table 1.1, map nos. 40 and 42.

QTsh **Andesite of Sugar Hill (Pleistocene or Pliocene)**—Blocky flows that crop out on steep slopes along roads and rims and at ridge crests. Locally transitional to diktytaxitic with a few <1-mm plagioclase laths projecting into vesicles as large as 1 mm. Plagioclase phenocrysts to 2 mm. Rare orthopyroxene rods to 0.6 mm, equant augite to 0.4 mm. Groundmass texture is intersertal to trachytic. Table 1.1, map nos. 24, 27, and 28.

QTba **Basaltic andesite and andesite (Pleistocene or Pliocene)**—A thick unit that probably includes multiple flows. Outcrops and float are blocky to platy. Scattered plagioclase phenocrysts to 1.5 mm are typically zoned and have corroded cores. Individual olivine crystals are up to 1 mm in diameter and are commonly enclosed in gray (pyroxene?) haloes or have altered rims. Rounded, elongate, and <1-mm orthopyroxene is scattered throughout the trachytic groundmass. Vesicles <1 mm are diktytaxitic. Unmapped horizons in the lower part of the unit occur low on hillsides in sections 18 and 19, T. 33 S., R. 7 E., and contain tiny (1- to 2-mm) glomerocrysts consisting of two to seven grains of plagioclase with or without olivine or pyroxene. Table 1.1, map nos. 13 and 15.

2.6 Tertiary Volcanic Rocks

Tah **Basaltic andesite of Agency Hill (Pleistocene)**—Glomeroporphyritic olivine basaltic andesite that forms Agency Hill. Unit is exposed in blocky to massive outcrops on steep slopes and ridge tops. Vesicle percentage is variable, as the rock ranges from massive to scoriaceous; locally diktytaxitic. Glomerocrysts include clumps of 0.5- to 1.0-mm plagioclase and 0.5- to 1.0-mm olivine. Occasional zoned plagioclase phenocrysts are up to 4 mm long but more commonly 0.5–1 mm. Olivine to 2 mm may be fresh where enclosed in glomerocrysts but typically has altered rims or pyroxene overgrowths. Groundmass is intergranular with crudely aligned plagioclase microlites interspersed with equant clinopyroxene, orthopyroxene(?), and opaque oxides. Predates the diktytaxitic olivine basalt (unit Qcb2) that laps onto the northern end of the hill. Table 1.1, map nos. 45 and 46. Locally divided to show:

Tahc **Cinders and vent deposits of Agency Hill (Pleistocene)**—Mineralogy similar to basaltic andesite of Agency Hill (unit Tah).

Tscb **Basalt of Spring Creek (Pleistocene)**—Olivine basalt exposed in low outcrops at the base of the prominent rim in E½ sec. 32, T33S, R7E. Regular to irregular vesicles with aspect ratios of 1:1 to 4:1 make up 0–20 percent of the rock; vesicles <1 mm are diktytaxitic. Light-green olivine phenocrysts with incipient red alteration at crystal edges generally make up <1 percent of the rock, have long dimensions <2 mm, and may include opaque oxides (magnetite?). Rectangular prisms of plagioclase also have long dimensions <2 mm and make up <1 percent of the rock. Groundmass is intersertal to ophitic. Table 1.1, map nos. 36, 37, and 38.

Tba **Olivine basaltic andesite (Pliocene)**—Exposed in fault blocks in the southeastern part of the quadrangle. Vesicles occupy up to 30 percent of the rock, are typically irregularly shaped, and have aspect ratios up to 6:1. Light-green olivine crystals about 1 mm in diameter have rounded outlines and typically occur in glomerocrysts with plagioclase. Plagioclase is rounded to angular, clear to white to light green, and up to 3 mm across. Groundmass is hyalophitic, with small crystals in glass. Local development of propylitic alteration in the S½ sec. 5, T. 34 S., R. 7 E, is the only occurrence recognized in the quadrangle. Table 1.1, map nos. 43, 44, and 47.

2.7 Sedimentary Rocks

QTs **Siltstone, sandstone, conglomerate, palagonite tuff, and mudstone, undivided (lower Pleistocene and Pliocene)**—Siltstone, sandstone, pebbly sandstone, conglomerate, palgonite tuff, and siliceous mudstone, with less common diatomite, lignite, and epiclastic ash and lapilli tuff. The best exposures are in road cuts that begin a few hundred meters east of the quadrangle boundary, along the Collier grade in the adjacent Soloman Butte quadrangle. At that locality, sandy facies are typically cross bedded, ripple bedded, or plane laminated and reveal extensive soft-sediment deformation. Pebble and granule conglomerate exposed in roadcuts on the Collier grade were probably deposited in low-relief fluvial systems, freshwater deltas, or channels on the bottoms of very shallow lakes. Fine-grained facies, including siliceous mudstone, diatomite, and lignite, were deposited as lake beds and overbank deposits on meandering streams. Clastic units are commonly tuffaceous. Diatoms collected from diatomaceous mudstone at the Collier grade indicate an age of 1.8–2 Ma (unpublished data and interpretation of J. Platt Bradbury, U.S. Geological Survey, written communication, 1998). Chemical correlation of a tuff bed in the upper section of the same location with known tuff beds of the western United States suggests an age >0.614 Ma and probably >1.45 Ma (A.M. Sarna-Wojcicki, U.S. Geological Survey, written communication, 1998). A radiometric age of 1.14 ± 0.10 Ma from the basaltic andesite (unit Qsh1) that caps the rim above the sedimentary section defines a minimum age for rocks of this unit.

The unit is not well exposed in the Fort Klamath quadrangle; rather it is commonly buried by younger pumice, colluvium, and alluvium. Small pieces of sandstone were dug from hillsides in only three places. Soil containing well-rounded coarse sand, pebbles, and an occasional fine cobble is the most common indication that sedimentary rock is present. Hills and ridges underlain by these rocks typically have low to moderate relief with steeper south or southwest sides and gentler north and northeast sides, suggesting west to northwest strikes and shallow north to northeast dips. May include unmapped areas of older sedimentary rock (unit Ts) or palagonite tuff near the mouth of Spring Creek and in the southwestern corner of the quadrangle.

Ts **Siltstone, siliceous mudstone, sandstone, and palagonite tuff, undivided (Pliocene)**—Siltstone, siliceous mudstone, sandstone, and palgonite tuff with less common pebbly sandstone, conglomerate, diatomite, and epiclastic tuff. Dominated by fine-grained facies including siltstone, siliceous to diatomaceous mudstone, and fine-grained sandstone, that were probably deposited as lake beds, deltas, and overbank deposits on meandering streams. Locally includes areas of volcaniclastic and/or hydrovolcanic deposits. Poorly exposed in the Fort Klamath quadrangle, may be equivalent to sedimentary, pyroclastic, and volcaniclastic rocks exposed along U.S. Highway 97 and Oregon Highway 62 in the Chiloquin and Agency Lake areas to the south. Underlying and perhaps interbedded with this area's olivine basaltic andesite flows (unit Tba). Difficult to distinguish from sediments of unit QTs. Depicted where stratigraphic relations suggest the presence of a sedimentary unit beneath the olivine basaltic andesite flows (unit Tba)

3.0 GEOLOGIC HISTORY

3.1 Structural Geology

Evidence for three episodes of extension includes mapped faults, an unconformity, and associations of interbedded lacustrine, fluvial, and chemically primitive volcanic rocks. The youngest extensional event formed the modern Klamath Graben. In the Fort Klamath quadrangle, extension associated with this event appears to be localized along the East Klamath Lake fault zone. This Holocene fault cuts all but the youngest alluvium; one trace cuts colluvium exposed in a quarry on the west side of Agency Hill. Sedimentary deposits interpreted as fluvial and lacustrine(?) beds that form unit Qal have been sampled by water wells drilled into the graben fill. To the south, Agency Lake and Upper Klamath Lake occupy the graben formed by this ongoing extensional event.

An earlier, Plio-Pleistocene extensional event resulted in the eruption of primitive diktytaxitic basalt flows (units Qb and Qcb) and in deposition of adjacent fluvial and lacustrine sedimentary rocks (unit QTs). Faults interpreted as active during this extensional event appear to limit the extent of units QTs and Qb, but only locally cut those units. Unit QTs unconformably overlaps older, tilted, fault blocks in the southeastern corner of the map.

Evidence for an older (Pliocene) extensional event includes interbedded lava sheets and fluvio-lacustrine sedimentary rock in the tilted fault blocks exposed in the southeastern part of the quadrangle.

Data from this quadrangle suggest that extension occurred during several distinct episodes. However, it is not clear whether these were regional or local events.

3.2 Volcanic History

Rocks in the Fort Klamath quadrangle reveal a history dominated by Cenozoic (Pliocene?) and Quaternary transitions from constructional (arc?) volcanism to extensional volcanism and back. During extensional episodes, valley-filling lava flows, air-fall ash, and ash-flows punctuated thick sedimentary sequences dominated by fluvial and lacustrine processes. Rock chemistry is rather monotonous, with high-alumina, quartz-normative, olivine-bearing basalt and basaltic andesite flows predominating. A few andesite flows and one trachyandesite flow were mapped. Early (Pliocene) lavas are more commonly andesite and basaltic andesite. Flows erupted during extensional events are typically more primitive mafic, diktytaxitic basalt but include basaltic andesite and at least one andesite. More recent edifices have a wider range of composition and include trachyandesite, basalt, basaltic andesite, and andesite. About 7,000 years ago, the eruption of Mount Mazama, located 25 km to the north-northwest, blanketed the quadrangle with dacitic air-fall ash and filled many of the small canyons with ash-flow deposits.

The oldest rocks in the quadrangle are believed to be Pliocene mudstone and sandstone (unit Ts) and associated basaltic andesite (unit Tba), exposed in fault blocks between the Williamson River and Agency Creek. The morphology of several fault blocks suggests that they are tilted to the east; however only a single eastward dip of 11° was recorded. In the north-central part of the quadrangle, an andesitic upland displays significant erosional dissection and so is assigned a Pleistocene to Pliocene age (unit QTba). However, this age assignment remains problematic, because the rocks do not appear to have been faulted or significantly tilted. Andesite and basaltic andesite volcanoes at Sugar Hill and Agency Hill, respectively, are thought to be of similar age and were probably formed as small volcanic edifices erupted onto the western equivalent of the above-mentioned Pliocene basaltic andesite (unit Tba).

A regional extensional event followed (or perhaps began with) the eruptions at Sugar Hill and Agency Hill, burying parts of the quadrangle in broad sheets of lava (units Qcb, Ob, Qba7, and QTcc) whose compositions range from diktytaxitic olivine basalt to pyroxene andesite. A second episode of fluvial deposition accompanied this extensional event and laid down the sedimentary section that is so well exposed along the Collier grade in the Soloman Butte quadrangle to the east. Within the Fort Klamath quadrangle, however, these sedimentary rocks are generally obscured by colluvium derived from younger units; they are never well enough exposed to allow measuring strikes and dips without excavation. Mapped as unconformably lapping across the northern ends of several fault blocks, these sedimentary rocks were involved in the late stages of faulting that formed the graben east of Agency Hill. Although cut by faults, the resulting sequence is only broadly warped, no dips >5° are found at the Collier grade or in mapped contact relations within the quadrangle. Many of the small drainages in the upland areas were once in equilibrium with surfaces that coincided with either the top or bottom of this sedimentary sequence; they reach current base level only after traversing anomalously steep reaches (For an example see the drainage in the SW¼, sec. 28, T. 35 S., R. 7 E.). The sedimentary rocks underlie (1) basaltic andesite and trachyandesite flows that were erupted near Spring Hill in the adjacent Soloman Butte quadrangle, (2) a thick, valley-filling flow in the southeastern part of the quadrangle (unit Qb), and (3) volcanic units that form the base of the volcanic rocks in the Forest Boundary area on the east side of the quadrangle. Diatom and tephra ages reported from the Collier grade locality and a radiometric age from the overlying basaltic andesite (unit Qsh1) place the age of this sequence between 0.64 and 2 Ma. Otherwise, the ages of Pleistocene and Pliocene rocks are poorly constrained. Other units in the quadrangle are assigned Pliocene ages where they can be shown to be older than the sedimentary rocks and Pleistocene ages where they are considered to be younger.

The vents at Sun Mountain and along the northern part of the ridge that parallels the Winema National Forest boundary are constructional features surrounded by relatively small flows of basalt, basaltic andesite, and andesite. Among the younger lavas (including the Spring Hill volcanic rocks in the east-central part of the quadrangle), the chemistry generally becomes more primitive toward the zone of extension marked by the East Klamath Lake fault zone. Diktytaxitic basaltic andesite lavas similar to those described here have been reported from the western side of the Klamath graben in the Pelican Butte 15-minute quadrangle (Smith, 1988) and in more southerly parts of the Medford 1°×2° quadrangle, where they were assigned to a regional Quaternary-Tertiary basaltic andesite unit (Smith and others, 1982).

The cataclysmic eruption of Mount Mazama at about 7 ka blanketed the quadrangle with hornblende dacite ash and lapilli. These deposits take two forms: (1) well-sorted to moderately sorted deposits that occur as well-defined layers interpreted as air-fall deposits and (2) poorly sorted deposits interpreted as ash flows and block-and-ash flows (pumice flows). Both types more or less obscure the bedrock geology. Several near-surface exposures of these beds show only poorly sorted deposits, which indicates that either the ash flows were locally the last deposits laid down by this event or the deposits were mixed to depths up to 3 m by surface processes, including rooting of trees and burrowing by mammals. Although not shown on the map, a layer up to 4 m thick of hornblende dacite airfall ash and lapilli and reworked airfall deposits covers most of the quadrangle. This surface cover generally thickens from south to north but is locally thin, possibly where removed by wind erosion or colluvial processes along the crests of narrow ridges and volcanic cones and also by stream erosion in confined reaches of stream canyons. Anomalously thick epiclastic layers are believed to have accumulated through deposition that accompanied the erosion described above. These were noted in several settings, including the bases of ridges and cones and where steep-walled bedrock canyons empty onto broad valley floors. Average thickness of the air-fall deposits ranges from about 25 cm in the southern part of the quadrangle to 1.5 m along its northern edge.

Ash flows and block-and-ash flows from the eruption of Mount Mazama followed topography southward into the quadrangle. In the northern part of the quadrangle, they deposited coarse pumice blocks in most of the low-lying areas as well as thinner deposits on several upland benches. Where only float was available to distinguish air-fall from ash-flow deposits, clasts with diameters >8 cm were assigned to ash flows. The largest pumice blocks measured have long dimensions of 30–35 cm. Fan-shaped topography occurring where small streams enter low-relief valleys indicates areas where the ash flows lost energy and the transported material fell out of suspension. Two areas east-northeast of Sugar Hill would have been protected from flows coming from the north; each of these is defined by a depression indicated by closed contours on the map.

Portland State University geologists mapping in the Soloman Butte and Wocus Bay quadrangles to the east have demonstrated that Mazama ash flows blocked the Williamson River near the outlet from Klamath Marsh (Conaway and Cummings, 1999) They document a scenario in which the river flooded the marsh to create a large lake that eventually overtopped and breached its dam. It appears likely that, during the flood that followed, the channel of the Williamson River shifted southeast, from a location near the modern channel of Spring Creek to its current location farther south and east. Much of the area mapped as Mazama ash east of Spring Creek is probably underlain by reworked ash and alluvium deposited by this flood event.

Streams have reworked the deposits of Mazama ash along most drainages. Young alluvial deposits, composed primarily of reworked ash, make up most of the areas labeled on the map as unit Qal. A thick sequence of older alluvium has been encountered in water wells in the Klamath graben beneath the pumice. Several wells in the western part of the quadrangle were drilled through 200–300 ft (60–90 m) of older alluvium. Only one well in this area bottoms in rock that could be volcanic basement. This well drilled west of the Fort Klamath quadrangle, about 2 miles north and one mile west of the town of Fort Klamath, in NE¼NW¼ sec. 8, T. 33 S., R. 7½ E. (Dr. Clark Roeder, landowner, personal communication, 2002), and penetrated 406 ft (124 m) of sand, gravel, and clay before reaching "hard gray rock" interpreted here as lava. (When drillers in this area report "hard gray rock," they are usually describing a lava flow. Dr. Roeder confirmed that the rock encountered was volcanic.)

4.0 GEOLOGIC HAZARDS AND RESOURCES

4.1 Earthquake Hazards

The most widely reported earthquake in the Fort Klamath area was a hoax. In 1867, a soldier stationed at Fort Klamath produced a fanciful description of a large earthquake and had it published in the Jacksonville newspaper, *The Sentinel*. He escaped punishment because his superiors did not reveal his name until the company was mustered out later that year (Stone, 1990).

Historic records of seismicity in the quadrangle include a magnitude (M) 3.7 earthquake that occurred during October 1947. That quake, although imprecisely located, was assigned an epicenter in the northwestern corner of the quadrangle near the surface trace of the East Klamath Lake fault zone.

Prehistoric seismicity is suggested by the well-developed fault scarps in the southeastern part of the quadrangle and along the eastern side of the Klamath graben at the East Klamath Lake fault zone. In the Fort Klamath quadrangle, some olivine andesite and basalt (units Qsb1, Qsa1, and Qcb) are the youngest rocks to crop out along this scarp. They are offset at least 90 m (to the top of the valley fill in the Klamath graben) and perhaps as much as 300 m (to the highest volcanic flows penetrated by water wells in the graben fill). In this study area, they are the best candidates for dating to constrain slip rates on the East Klamath Lake fault zone. Stratigraphic relations suggest that these units are younger than 1.45 and possibly younger than 0.6 Ma. Ages as old as 1 Ma would result in slip rate estimates between 0.09 to 0.3 mm per year. If ages are closer to 300 ka (reported by Bacon and others (1999) for the extensional event that produced the West Klamath Lake fault zone) then slip rates would range from 0.27 to 0.9 mm per year. In terms of length and total offset, the East Klamath Lake fault zone is similar to the West Klamath Lake fault zone as reported by Bacon and others (1999). Fault planes developed in colluvium on the western side of Agency Hill suggest that the East Klamath Lake fault zone has been active during the Holocene, as do seismic experiments that record multiple offsets of the Mazama ash in the eastern part of Upper Klamath Lake (Colman and others, 2000). Taken together, these data suggest that the East Klamath Lake fault zone should be considered an active zone capable of producing M 7.25 earthquakes.

4.1.2 Controlled-Source Audio-Magnetotelluric (CSAMT) Experiment

A 225-m CSAMT traverse was completed across the East Klamath Lake fault zone where a small canyon intersects that fault in the N½ sec. 14, T. 33 S., R. 7½ E. CSAMT is a geophysical technique that reveals the approximate subsurface distribution of resistivity as a function of the combined resistivity of rocks and groundwater. This traverse clearly shows that several resistivity units are truncated along the East Klamath Lake fault zone. An estimated best-fit line along the ends of the truncated resistivity zones suggests that the fault dips westward.

Two other resistivity boundaries deserve mention. The first records a change in the graben fill, from values of 600–700 Watt-meters (W.m) to values of 400–500 W.m, at an elevation of about 3,800 ft (1,160 m) above sea level. Assuming that groundwater resistivity remains relatively constant within this zone, such a downward decrease in resistivity can reflect a downward transition from sedimentary to volcanic rocks. The elevation at which this occurs is similar to the 3,800-ft (1,160-m) elevation at which "hard gray rock" was first encountered in a well northwest of the town of Fort Klamath. The second, much deeper boundary lies along the top of a high-resistivity (1,400–1,700 Ω•m) layer at an elevation of 350 ft (105 m) above sea level. Such high resistivity values may reflect the presence of low conductivity (low salinity, i.e. "fresh") water at a depth of about 1,200 m below ground level. (Harvey Waff, University of Oregon, oral communication, 1998).

4.2 GROUNDWATER RESOURCES

Aquifers are interlayered with low-permeability zones (aquitards) in both alluvial and volcanic sequences. In the alluvium, coarse-grained sandy and gravelly aquifers are separated by silty and clayey aquitards. Holocene deposits include meandering-stream facies in the larger valleys as well as alluvial, talus, ash flow, and pumice fans at the valley margins. These facies relationships should be used to construct models for understanding the distribution of different grain-size fractions (and corresponding groundwater transmissivity) in the valley fill. Studies of meandering streams in other areas suggest that, in general, sand and gravel associated with ancient channel, levee, and crevasse-splay deposits will form elongate, sinuous high-permeability zones in low-permeability overbank, flood-plain, or deltaic silt, mud, and clay. Exposures of young sedimentary rocks at the Collier grade locality include sandstone composed of well-rounded, well-sorted, lithic-volcanic sand with open pore space. Medium- to coarse-grained black sand intervals logged in wells that penetrate alluvium along Wood River and Spring Creek are probably similar, but may include tachylite or palagonite tuff.

Interflow zones, fractured lava flows, vesicular (especially diktytaxitic) flows, and, perhaps, lava tubes in the volcanic sequences probably provide porous, permeable pathways. The occurrence of springs, ponds, and perennial streams in areas underlain by older volcanic rock suggests that the older units are generally less permeable and may play an important role in determining flow patterns and distribution of groundwater. Both Reservation Spring and the springs at the Klamath State Fish Hatchery occur where younger lava flows lap onto the sides of the older volcanoes that form Sugar Hill and Agency Hill, respectively.

Springs at the head of Spring Creek can be seen to flow out of open cracks in the upper part of the gently north dipping basalt of Spring Creek (unit Tscb). These springs discharge in an area just south of the unit's contact with the overlying sedimentary section that forms the westward continuation of the section exposed at the Collier grade locality. The topographic expression of those sedimentary rocks and associated lava flows suggests that they cover the southern end of an ancient stream valley (perhaps that of the ancestral Williamson River) that drained areas to the north. It seems likely that Spring Creek receives much of its water from porous units within that valley fill. Because discharge into Spring Creek is fairly constant, its springs probably tap a source different from the one that feeds seasonal springs along the Williamson River or a deeper part of that source. During the low-flow period from August through November, springs in the Fort Klamath quadrangle account for most of the 60,000 acre-ft per month that the Wood and Williamson Rivers deliver to Upper Klamath Lake (Hubbard, 1970).

Dacitic pumice air-fall and ash-flow deposits from the ~7-ka eruption of Mount Mazama blanketed the valleys and much of the upland terrain. In the uplands, groundwater can be seen to seep from the contact between these deposits and bedrock. Except for the local development of pumice fans along the basin margin, the effect of the eruption of Mount Mazama on the streams in the larger Klamath graben is unknown. The Mazama eruption caused significant changes at Spring Creek and along the Williamson River. The ash flows dammed the outlet of Klamath Marsh, forming a lake that eventually breached the dam, and greatly modified the channel morphology downstream (Conaway and Cummings, 1999).

The presence of low-pressure artesian wells in the Fort Klamath area indicates that one or more overpressured permeable zone exists in this part of the graben. It seems likely that such zones relate either to structural complications or to downstream pinchouts of permeable (coarse-grained) units in the valley fill. The occurrence of large springs along the valley margin might be explained by the escape of water from an overpressured zone at this level or another at greater depth. Several escape pathways can be imagined, including (1) a permeable alluvial/colluvial/talus wedge derived from the upthrown block and progressively buried by repeated faulting; (2) a permeable unit in the footwall itself, which might cause water to seep out of the footwall above the valley floor, as it does at Klamath State Fish Hatchery; (3) fracture permeability on faults along the valley margin: or (4) fracture permeability associated with faults intersecting the valley margins, such as the spring in the southwest corner of sec. 36, T. 33 S., R. 7½ E. Alternatively, the springs and any overpressured zone could draw water from the upland east of the fault zone. Determination of water volume available from such a source awaits an analysis of precipitation and recharge areas.

Formation of well-developed north-trending (apparently normal) faults along the East Klamath Lake fault zone is attributed to the ongoing extension that formed the Klamath graben. Crossing faults probably represent an older structural episode. While groundwater movement is clearly influenced by the presence of these features, it is not clear that they function consistently as conduits or barriers to groundwater movement, either across or along trend. While most of the springs are located along the East Klamath Lake fault zone, geologic conditions at the springs, as described in the paragraphs above, often complicate a clear assessment.

High-volume springs on the eastern side of the Klamath graben discharge along or a few tens of feet above fault contacts between bedrock and alluvium. They occur in a narrow elevation range between 4,160 and 4,200 ft. Surface drainage is generally across this trend, from northeast to southwest. A quantitative water-balance model has not been constructed; however, the large flows with small seasonal variations document the presence of significant groundwater resources.

4.3 MINERAL RESOURCES

The potential for future development of mineral resources in the quadrangle is limited. Aggregate in the form of cinders and scoria has been removed from a few small test pits. Additional tests could be conducted at each of the mapped cinder localities (unit Qcv). Crushed rock has been produced from three quarries located along the East Klamath Lake fault zone; however, most of the remaining rock is not so closely jointed and would probably be more difficult to produce. Sand and gravel deposits in the alluvial sequences are generally interlayered with large amounts of silt, mud, and clay, so large-scale production seems unlikely. Known diatomite resources are not of high quality. Pumice could be produced from Mazama ash-flow deposits, but larger, thicker, coarser deposits exist farther north.

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Table 1.1 Analyses of major and trace elements from samples collected in the Fort Klamath quadrangle, Klamath County, Oregon. Major elements in percent, trace elements in parts per million (ppm).

Map no.	Sample no.	Unit	Lithology	North latitude	West longitude	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O
1	**1098-27-1**	Qsb2	Basalt	42.7499	121.9392	50.34	1.24	18.18	2.41	6.12	0.15	6.88	9.22	3.41
2	**1098-28-1**	Qsb1	Basaltic andesite	42.7488	121.9708	51.63	1.22	17.52	1.87	6.34	0.14	6.63	9.04	3.48
3	**1098-23-9**	Qfa4	basaltic andesite	42.7472	121.8853	52.97	1.13	18.27	2.61	5.60	0.14	5.19	8.02	3.59
4	**1298-15-4**	Qsb1	basalt	42.7471	121.9550	49.14	1.26	18.29	2.67	6.18	0.17	6.90	9.28	3.22
5	**1098-23-10**	Qfb1	basalt	42.7448	121.9172	49.96	1.13	18.11	1.27	7.58	0.16	7.09	9.88	3.07
6	**1098-23-8**	Qba4	basaltic andesite	42.7318	121.8888	54.19	1.13	17.65	2.27	5.86	0.14	4.99	7.75	3.72
7	**1298-15-3**	Qsb3	basalt	42.7293	121.9681	50.45	1.03	17.14	1.89	6.90	0.16	7.70	9.82	3.04
8	**1298-15-5**	Qsa1	andesite	42.7290	121.9630	57.29	0.80	17.90	1.69	4.78	0.12	4.08	6.32	3.83
9	**1298-15-1**	Qsb3	basalt	42.7289	121.9711	48.93	1.08	18.07	3.12	5.98	0.16	7.98	9.52	2.79
10	**1098-21-1**	Qbav	basaltic andesite	42.7285	121.9212	56.11	0.91	17.90	3.05	3.94	0.13	4.02	7.66	3.92
11	**1298-15-2**	Qsb3	basalt	42.7277	121.9682	49.60	1.06	17.39	3.57	5.58	0.16	8.01	10.35	2.89
12	**1098-29-5**	Qfb2	basalt	42.7198	121.9183	49.56	1.06	17.40	2.86	6.22	0.16	8.36	9.45	2.99
13	**1298-17-4**	QTba	basaltic andesite	42.7157	121.9249	54.01	0.85	19.49	3.19	4.14	0.14	3.92	6.93	3.48
14	**1098-29-4**	Qfa1	andesite	42.7131	121.8939	56.63	1.08	17.21	2.12	5.46	0.13	3.98	6.63	3.72
15	**1298-17-3**	QTba	andesite	42.7114	121.9257	59.32	0.76	17.61	2.05	4.09	0.12	3.32	6.47	3.99
16	**1198-9-1**	Qsa2	andesite	42.7102	121.9601	56.42	1.01	17.64	1.40	5.94	0.13	3.89	6.56	3.87
17	**1298-17-1**	Qfba5	basaltic andesite	42.7094	121.9164	55.57	1.04	17.57	1.58	5.83	0.15	4.40	7.05	3.61
18	**1098-29-3**	Qfa1	andesite	42.7092	121.8950	56.98	1.08	16.95	1.54	5.88	0.13	3.97	6.55	3.76
19	**1098-23-7**	Qfa4	andesite	42.7089	121.8779	56.06	0.96	17.54	1.93	5.22	0.13	4.41	6.88	3.65
20	**1098-29-6**	Qfa3	andesite	42.7074	121.9138	56.85	1.04	17.07	1.79	5.61	0.13	4.05	6.65	3.83
21	**1298-17-2**	Qfba9	andesite	42.7070	121.9173	56.94	1.07	17.24	1.40	5.94	0.13	3.96	6.59	3.67
22	**1198-9-2**	Qsb3	basalt	42.6995	121.9593	47.21	1.08	17.61	1.67	7.97	0.17	9.33	10.98	2.49
23	**1098-23-6**	Qba1	basaltic andesite	42.6978	121.8895	53.47	1.01	17.84	2.20	5.62	0.14	5.29	8.31	3.53
24	**1198-3-1**	QTsh	andesite	42.6921	121.9496	58.09	0.74	17.83	1.90	3.96	0.11	3.48	6.84	3.93
25	**1098-23-5**	Qfba9	basaltic andesite	42.6920	121.8842	53.83	1.01	18.01	1.89	5.70	0.13	5.00	8.01	3.58
26	**1098-23-4**	Qba9	basaltic andesite	42.6875	121.8893	55.74	1.11	17.43	2.82	5.02	0.14	4.13	6.64	3.67
27	**1198-2-1**	QTsh	andesite	42.6869	121.9603	57.41	0.81	18.16	2.32	3.89	0.11	3.30	6.92	3.98
28	**1198-3-2**	QTsh	andesite	42.6849	121.9507	58.38	0.79	17.79	2.32	3.71	0.12	2.89	6.48	4.18
29	**1098-23-3**	Qta	trachyandesite	42.6824	121.8801	55.78	1.13	16.48	3.69	3.42	0.12	4.35	6.80	4.10
30	**1098-23-2**	Qba8	basaltic andesite	42.6795	121.8899	54.26	1.05	17.57	2.75	4.67	0.12	5.08	7.72	3.87
31	**1298-16-1**	Qsh2	basaltic andesite	42.6767	121.8870	54.31	1.01	17.86	1.92	5.83	0.14	5.14	7.85	3.76
32	**1298-16-5**	Qfa2	andesite	42.6753	121.9120	57.79	0.93	17.04	1.80	4.79	0.12	3.79	6.39	4.00
33	**1098-23-1**	Qsh1	basaltic andesite	42.6742	121.8812	51.89	1.04	18.91	3.25	5.34	0.13	5.02	8.15	3.69
34	**1198-3-3**	Qcb	basalt	42.6724	121.9571	48.91	1.38	16.85	1.72	8.11	0.17	8.14	9.54	3.08
35	**1098-29-7**	Qfba6	basaltic andesite	42.6707	121.9176	56.19	1.03	17.46	2.42	5.37	0.13	4.03	6.69	3.96
36	**1298-16-4**	Tscb	basalt	42.6702	121.9013	48.25	1.07	17.59	1.28	8.06	0.17	8.76	10.46	2.79
37	**1298-16-2**	Tscb	basalt	42.6692	121.8846	49.52	1.51	16.77	2.26	8.01	0.17	6.57	9.36	3.14
38	**1298-16-3**	Tscb	basalt	42.6651	121.8860	50.05	1.51	16.72	1.83	8.24	0.18	6.90	9.35	3.19
39	**1298-18-3**	Qcb	basalt	42.6595	121.9455	49.74	1.43	16.61	1.86	7.81	0.17	7.97	9.56	3.18
40	**1298-17-6**	QTcc	basalt	42.6572	121.9404	48.19	1.24	17.67	3.55	6.39	0.16	7.58	9.69	3.28
41	**1098-29-2**	Qb	basalt	42.6557	121.9191	48.41	1.04	17.73	1.43	7.74	0.16	8.61	10.74	2.86
42	**1298-17-5**	QTcc	basalt	42.6553	121.9424	49.36	1.17	17.72	2.61	6.77	0.16	7.85	9.28	3.28
43	**1098-29-1**	Tba	basaltic andesite	42.6512	121.9045	54.31	1.00	17.77	2.52	5.58	0.14	4.37	7.87	3.73
44	**1298-18-1**	Tba	basaltic andesite	42.6453	121.8857	52.58	1.09	17.57	1.85	6.46	0.15	5.72	8.69	3.44
45	**1198-5-1**	Tah	basaltic andesite	42.6419	121.9380	54.38	1.00	17.95	1.28	6.30	0.14	4.62	8.01	3.67
46	**1198-5-2**	Tah	basaltic andesite	42.6389	121.9298	54.06	0.99	18.10	2.13	5.61	0.14	4.53	7.98	3.67
47	**1298-18-2**	Tba	basaltic andesite	42.6382	121.8927	51.85	1.19	17.61	1.87	6.95	0.16	5.92	8.98	3.42

Table 1.1 Analyses of major and trace elements from samples collected in the Fort Klamath quadrangle, Klamath County, Oregon. Major elements in percent, trace elements in parts per million (ppm)-Continued.

K_2O	P_2O_5	LOI	Total	Rb	Sr	Y	Zr	V	Ni	Cr	Nb	Ga	Cu	Zn	Co	Ba	La	Ce	U	Th	Sc	Pb
0.54	0.34	0.91	**99.74**	14.4	694	20.2	130	174	40	60	6.8	18.8	44	77	24	462	15	36	0.9	2.2	21	8
0.88	0.34	0.48	**99.57**	9.5	724	20.1	83	183	78	78	4.2	19.6	54	78	31	326	9	22	<0.5	1.4	21	6
0.63	0.24	0.95	**99.34**	16.9	1039	19.4	122	183	78	114	5.4	19.3	69	76	26	506	20	43	0.5	2.6	23	7
0.38	0.34	1.55	**99.38**	24.7	1231	22.2	180	143	55	90	9.0	19.8	33	87	23	881	32	66	2.1	5.7	16	10
0.35	0.18	0.72	**99.50**	19.4	532	19.7	105	162	50	59	5.0	19.3	37	81	26	442	12	26	0.5	2.8	17	8
0.84	0.26	0.69	**99.49**	12.5	581	19.6	102	184	67	104	4.6	18.3	51	75	30	370	11	28	<0.5	1	23	7
0.39	0.15	0.73	**99.40**	11.1	576	19.9	98	181	65	123	4.6	18.4	49	71	28	379	11	25	0.9	2.2	21	6
1.25	0.22	1.24	**99.52**	19.7	546	19.3	108	159	59	62	4.5	17.7	48	73	26	412	11	27	<0.5	2.6	20	7
0.20	0.11	2.08	**100.02**	14.8	562	21.6	97	178	67	92	5.1	18.3	71	74	29	372	11	23	<0.5	1.6	20	7
1.06	0.26	0.53	**99.49**	9.8	591	19.9	97	181	70	101	4.8	19.2	52	78	28	410	12	25	<0.5	1.6	23	6
0.25	0.11	0.68	**99.65**	6.1	448	25.2	93	225	65	152	3.6	18.2	48	78	36	217	11	17	<0.5	1.5	29	5
0.29	0.17	0.96	**99.48**	4.9	837	22.5	129	219	93	171	8.3	19.9	64	85	32	523	24	42	1.2	2.2	25	7
0.76	0.15	2.84	**99.90**	9.1	718	20.8	124	203	103	159	8.0	19.5	62	77	31	409	18	35	<0.5	1.9	22	6
1.30	0.25	1.24	**99.75**	15.3	586	21.2	124	179	46	71	6.3	19.2	62	77	28	428	15	29	0.7	1.5	24	7
1.24	0.18	0.77	**99.92**	2.5	327	24.3	69	216	150	207	1.9	16.5	78	67	44	142	10	10	<0.5	<0.5	32	4
1.28	0.22	1.20	**99.56**	25.3	534	18.7	99	167	47	54	4.9	19.1	44	77	25	474	11	23	1.3	2.8	19	8
1.00	0.23	1.63	**99.66**	22.2	535	20.4	103	169	47	62	4.9	19.0	44	79	24	439	12	21	<0.5	2.6	19	8
1.42	0.25	1.04	**99.55**	3.9	430	21	82	193	122	297	3.4	17.6	43	74	39	200	8	15	<0.5	0.7	26	5
1.21	0.22	1.83	**100.04**	24.4	530	19.7	103	168	49	62	5.0	18.6	44	76	24	426	12	28	0.7	2.8	19	8
1.28	0.24	1.03	**99.57**	15.6	554	20.1	116	148	48	58	5.6	19.8	53	76	23	410	8	23	<0.5	2.4	18	7
1.38	0.29	1.14	**99.75**	15.3	1012	15.4	106	161	11	19	5.2	20.0	44	70	18	411	17	36	<0.5	2.2	18	7
0.11	0.10	1.07	**99.79**	17.8	953	15.1	107	147	21	43	4.4	18.9	37	69	20	429	17	31	1.1	2.9	19	7
0.75	0.23	1.63	**100.02**	18.6	937	16	116	148	10	28	4.9	19.6	27	73	17	472	19	37	1.2	3.5	16	8
1.36	0.21	0.96	**99.41**	5.3	409	24.9	111	222	143	305	7.0	18.0	54	80	41	235	8	20	<0.5	0.9	25	5
0.86	0.23	1.23	**99.48**	13.6	602	20.7	122	182	40	66	6.7	19.8	66	76	26	434	14	28	0.6	1.6	21	8
1.18	0.25	1.58	**99.71**	12.1	601	20.9	120	195	40	64	6.1	19.7	52	81	27	427	12	35	<0.5	1.1	23	8
1.28	0.22	1.00	**99.40**	16.9	565	20.2	113	157	47	55	5.5	19.6	54	81	24	404	14	26	1	1.7	19	8
1.35	0.23	1.13	**99.37**	2.1	248	24.5	63	216	144	175	1.6	16.4	82	61	46	79	4	10	<0.5	<0.5	32	3
1.85	0.43	1.30	**99.45**	2.8	352	25.6	93	207	117	209	2.4	17.4	59	71	40	248	8	16	0.9	1.9	31	5
1.13	0.31	0.84	**99.37**	4.6	311	24.3	83	210	127	215	2.4	16.1	58	68	41	158	5	13	<0.5	0.6	32	6
0.86	0.23	0.52	**99.43**	6.1	336	23.9	88	201	119	215	2.6	16.9	73	64	40	204	7	15	<0.5	0.7	30	5
1.51	0.34	0.97	**99.47**	3.1	846	24.4	128	223	111	172	8.1	19.8	75	88	37	501	20	38	0.5	1.6	26	6
0.67	0.19	1.08	**99.36**	22.3	582	17.4	108	139	58	102	4.9	17.7	33	72	24	486	14	29	1.4	3.3	19	8
0.40	0.25	0.82	**99.37**	14.6	571	21.1	99	166	64	102	4.6	18.4	44	67	27	383	14	28	<0.5	2	20	7
1.09	0.22	0.90	**99.49**	9.5	382	28.9	118	247	78	181	5.4	19.0	46	88	38	234	8	25	<0.5	<0.5	29	5
0.22	0.13	0.96	**99.74**	9.3	376	29.6	117	241	79	186	5.2	18.0	58	85	40	229	13	22	0.6	0.9	29	5
0.54	0.32	1.42	**99.59**	3.4	307	23.2	69	218	139	214	1.9	16.4	85	66	43	141	2	11	<0.05	<0.5	29	4
0.61	0.31	0.73	**99.62**	21.5	735	21.2	145	142	47	66	7.6	19.8	41	79	21	577	23	42	1	2.4	17	9
0.47	0.26	0.54	**99.60**	17.2	540	21.6	103	167	55	56	4.9	19.4	49	78	26	483	14	27	<0.5	2.5	20	8
0.23	0.20	1.22	**99.40**	25.3	533	19.3	101	174	48	54	4.8	19.2	44	81	25	453	13	28	0.6	3.6	19	7
0.19	0.12	0.48	**99.51**	27.4	570	16.9	104	143	23	48	4.6	18.7	39	65	20	544	15	29	2.1	3.2	18	8
0.35	0.19	0.84	**99.58**	11.8	605	17.5	119	173	32	59	5.1	20.5	29	76	24	575	16	27	0.9	2.7	23	9
0.89	0.30	1.15	**99.63**	4.4	449	22.8	95	209	155	308	3.7	17.9	62	75	42	200	5	16	0.7	0.9	29	5
0.86	0.31	0.94	**99.66**	2.5	472	22.5	94	202	151	279	4.3	18.7	65	74	42	238	9	20	0.6	<0.5	26	4
0.96	0.30	0.81	**99.42**	11.6	544	22.7	121	193	65	108	6.8	19.0	60	76	30	395	17	32	0.5	0.8	22	7
0.97	0.29	0.89	**99.36**	9.9	505	24.4	118	206	65	115	6.5	19.3	56	76	33	345	12	26	0.8	1	25	7
0.71	0.30	0.68	**99.64**	5.8	403	25.6	110	224	128	298	7.1	17.8	57	77	40	208	9	16	1.1	<0.5	26	5