Sample Designation: **Well GMF 31-17, depth 4940-4950 ft** (cuttings), Medicine Lake volcano and geothermal system

Petrographer: JBH – Jan. 15, 2000

Rock Type and Composition: Weakly altered pyroxene andesite. Pilotaxitic and intersertal texture. About 5% disseminated, 20-30 micron, subequant, rounded to irregular clinopyroxene crystals. Clinopyroxene also occurs, more commonly, as evenly distributed, 0.3-1 mm, highly irregular crystals poikilitically enclosing plagioclase microlites. About 5% disseminated leucoxene (titanite), as highly irregular clots averaging 30-50 microns in diameter and composed of microcrystals <1 micron in diameter. About 5% rounded, ovoid, or amoeboid amygdules filled with secondary minerals. Roughly 3% of the sample is composed of chips consisting entirely of secondary phases (derived from veinlets and amygdule fillings).

Alteration and Mineralization: Weak propylitic alteration. Even most of the clinopyroxene is fresh (unaltered). There is, however, about 5% epidote erratically disseminated throughout the rock as highly irregular clots, up to a few tenths of a mm in diameter, replacing plagioclase for the most part. The disseminated leucoxene could be a deuteric or hydrothermal alteration product. Minor chlorite replacing groundmass mafic phases.

Amygdules are former vesicles now filled with epidote with or without quartz, titanite, chlorite, traces of actinolite, and anhydrite. A few vesicles are lined with quartz, filled with chlorite, and contain no other seconedary phases. Discrete drill chips of epidote and other secondary phases are likely derived not only from disaggregation of the amygdules, but also break-up of veinlets. A few veinlets, in fact, are seen traversing the andesite in some chips. The veinlets are mostly epidote, but some of these encapsulate minor amounts of earlier-formed acicular actinolite.

Sample Designation: **Well GMF 31-17, depth 5230-5240 ft** (cuttings)

Petrographer: JBH – Jan. 15, 2000

Rock Type and Composition: Two rock types – porphyritic (plagioclase-phyric) dacite and finely-crystalline pyroxene diabase. The dacite is characterized by a gauzy-appearing, brownish, patchily devitrified matrix which is a mosaic aggregate of quartz, albite, and K-feldspar; individual crystals are highly irregular, interlocking, and average 30-50 microns in diameter; sparsely scattered throughout the matrix are irregular masses of relatively more coarsely crystalline monomineralic quartz; these could be related to the devitrification, or they could be alteration features. Phenocrysts in the dacite are stubby, ragged-bordered, plagioclase laths up to at least 1.5 X 1.3 mm in diameter. The diabase consists of randomly oriented, subhedral to euhedral plagioclase laths, up to at least 1 mm in length (average about 0.5 mm), and with aspect ratios averaging about 3-5/1 (some stubbier crystals locally present). Interstitial to the plagioclase laths, forming triangular masses, are comparably sized clinopyroxene crystals and crystal aggregates, and an unknown former mafic mineral now wholly altered to chlorite/smectite; the chlorite/smectite is commonly intergrown with what are probably relict primary grains of ilmenite or magnetite – irregular and up to 0.3 mm in diameter. Discrete drill chips consisting wholly of veinlet material are present but not particularly abundant (more below).

Alteration and Mineralization: The dacite is strongly propylitized, at least to the extent that this relatively non-reactive rock can be affected. Former mafic minerals in the dacite are altered to chlorite with or without leucoxene (microcrystalline titanite); epidote occurs as sparse to locally abundant, erratically disseminated and irregular clots from a few microns to 0.3 mm in diameter; leucoxene occurs as disseminated aggregates averaging about 30 microns in diameter (up to 0.3 millimeters) rather uniformly disseminated throughout the matrix (thin, irregular zones surrounding the more coarsely crystalline quartz clots (see above) are relatively free of the leucoxene. Alteration in the diabase is of a much different character. Many diabase chips are essentially unaltered except for late magmatic, partial conversion of clinopyroxene to hornblende. Other chips are partially altered, but the alteration is confined to the unknown former mafic mineral, which is now altered to chlorite-rich (about 80% chlorite interlayers) chlorite/smectite.

Drill chips which consist entirely of hydrothermal phases are present but not common. Many are medium-crystalline epidote with or without quartz and chlorite. Others are chlorite/smectite (disaggregated from the diabase); still others consist of chlorite/smectite, chlorite, and possibly minor serpentine. Veinlets seen cutting chips of the two main rock types are separate epidote and quartz (in dacite) and chlorite/smectite (in diabase).

Comments, Interpretations: The relationships described, particularly the absence of epidote in the diabase and the generally unaltered character of that rock, argue in favor of the diabase having been intruded after propylitic alteration of the dacite.

Sample Designation: **Well GMF 31-17, depth 5320-5330 ft** (cuttings)

Petrographer: JBH – Jan. 15, 2000

Rock Type and Composition: A mixture of two rock types – porphyritic basalt and porphyritic dacite with abundant discrete drill chips of veinlet and amygdule fillings. Dacite accounts for about 35% of the sample. It consists of sparse, relatively fresh, stubby lath-shaped oligoclase phenocrysts, up to at least 2.5 X 1.8 mm, embedded in a probably devitrified, formerly glassy matrix which is now a mosaic aggregate of interlocking, highly irregular quartz, albite, and K-feldspar crystals, with individual crystals averaging 30-50 microns in diameter. Also disseminated througout the matrix are similarly shaped chlorite clots which undoubtedly are altered primary mafic phases. Distinctive in the devitrified matrix of the dacite are curved, long, thin slivers of chlorite which were clearly developed along perlitic cracks. Basalt chips make up about 45% of the sample. The basalt is highly propylitized (see below) and conspicuously amygdaloidal. It consists of randomly oriented plagioclase microlites averaging about 0.05-0.07 mm X 5-7 microns, embedded in a nondescript microcrystalline aggregate of chlorite, plagioclase, and titanite (leucoxene) which probably developed after an initially glassy matrix. The amygdules are amoeboidal to rounded and reach at least 1 mm in diameter. All are filled by secondary phases. The remaining 20% of the sample (excluding a few obviously contaminating drill chips) are vein fragments and amygdular aggregates liberated from their host rocks.

Alteration and Mineralization: Intense propylitic alteration of the basalt, accompanied by veining and amygdular infilling by (in decreasing order of abundance), epidote, quartz, chlorite, leucoxene (titanite), and K-feldspar. The dacite was probably subjected to the same alteration conditions but appears less altered because of its inherently less reactive character. Nonetheless, former mafics in the dacite are altered to chlorite, and the matrix hosts small clots of disseminated epidote and leucoxene.

The veinlet fragments and disaggregated amygdular fills are dominated by intergrown, coarsely crystalline (up to 1.5 mm), pistachio-green epidote crystals which are commonly surrounded by microcrystalline epidote and by thin rims of chlorite. A few amygdules are rimmed with chlorite and filled with coarsely crystalline hydrothermal quartz. K-feldspar is finely crystalline and comparatively rare as a veinlet or amygdular phase. It is most commonly associated with hydrothermal quartz.

Comments, Interpretations: The relict perlitic cracks in the dacite make it likely that the unit is truly volcanic rather than a subvolcanic or hypabyssal intrusive. Likewise, the formerly glassy and highly vesicular nature of the basalt argue in favor of its having been erupted at the surface as well. The vesicles once constituted isolated and noneffective porosity, but were clearly connected by fractures to enhance the porosity and permeability structure of the circulating hydrothermal system.

Sample Designation: **Well GMF 31-17, depth 5780-5790 ft** (cuttings)

Petrographer: JBH – Jan. 14, 2000

Rock Type and Composition: Strongly altered and veined microdiabase and diabase. Discrete veinlet fragments (more below) account for about 25% of the rock; diabase for about 5%; and microdiabase for the remainder. The microdiabase consists primarily of randomly oriented subhedral to euhedral plagioclase laths from 0.03 to 0.30 mm in length, and with aspect ratios of 3-7/1. Interstitial to the plagioclase laths are masses of chlorite, with or without actinolite and with minor titanite, replacing a primary mafic mineral. Also present are a few disseminated, subequant, ragged-bordered, former mafic crystals, up to 0.1 mm in diameter, which have been altered to actinolite with minor chlorite; these crystals were probably pyroxene. Diabase in this sample is compositionally and texturally identical to the microdiabase but more coarsely crystalline, with plagioclase laths reaching at least 0.7 mm in diameter. Some of the microdiabase is microbrecciated and rehealed with secondary phases.

Alteration and Mineralization: Intense propylitic alteration and moderate silicification accompanied by abundant veinlets (mostly disaggregated into discrete drill chips) consisting principally of epidote and quartz in various combinations with or without K-feldspar, titanite, and traces of acicular actinolite as well as anhedral subequant pyrite grains. The silicification forms mosaic aggregates of irregular, interlocking quartz crystals mostly <10 microns in diameter (the individual crystals, not the aggregates).

Sample Designation: **Well GMF 31-17, depth 6080-6090 ft** (cuttings)
Medicine Lake volcano and geothermal system

Petrographer: JBH – Jan. 14, 2000

Rock Type and Composition: Porphyritic microdiorite or microdiabase, same as 6560-6570 ft (see description for that sample), except apparently fewer plagioclase phenocrysts.

Alteration and Mineralization: Moderate propylitic alteration (chlorite-epidote ± actinolite) probably superimposed on deuteric alteration, the latter expresssed principally as massive alteration of original mafic phases to fibrous green actinolite.

Veinlets and veinlet fragments are moderately abundant, and consist of the following hydrothermal phases (in decreasing order of abundance) in various combinations, with epidote always dominant: epidote, chlorite, quartz, K-feldspar, titanite, actinolite.

Sample Designation: **Well GMF 31-17, depth 6560-6570 ft** (cuttings)
Medicine Lake volcano and geothermal system

Petrographer: JBH – Jan. 14, 2000

Rock Type and Composition: Moderately altered (see below) porphyritic microdiorite to microdiabase. 10-12% subequant to stubby-prismatic, subhedral to euhedral but commonly ragged-bordered plagioclase phenocrysts, up to at least 1 mm in diameter or length, embedded in a microcrystalline matrix consisting of smaller plagioclase laths (0.01-0.2 mm in length), randomly oriented and intergrown with actinolite pseudomorphs of an unknown primary mafic mineral. Also present in the matrix are disseminated ilmenite or magnetite grains (2-3% of the rock) averaging <0.05 mm in diameter.

Alteration and Mineralization: Plagioclase has remained relatively fresh. Former primary mafic phases are entirely altered to fibrous, pale brownish-green to pale "bottle green" actinolite, with minor accompanying microcrystalline titanite. The titanite (4-5% overall) also occurs as rather evenly disseminated clots, averaging about 0.05 mm in diameter, composed of microcrystals <1 micron in diameter. Non-veinlet epidote occurs as disseminated, highly irregular grains 0.03-0.1 mm in diameter for the most part. Trace disseminated microcrystalline pyrite.

Veinlet fragments are common but not abundant. They consist principally of epidote, either by itself or with various combinations of quartz, K-feldspar, chlorite, and microcrystalline titanite.

Comments, Interpretations: Most of the alteration seen in this rock is interpreted as deuteric – fibrous actinolite replacing original mafic phases. Weak to moderate propylitic alteration is superimposed on the deuteric. Epidote and chlorite are the dominant propylitic phases. The absence of actinolite in veinlet fragments bolsters the interpretation that actinolite in the rock itself is not hydrothermal.

Sample Designation: **Well GMF 31-17, depth 7020-7030 ft** (cuttings)

Petrographer: JBH – Jan. 14, 2000

Rock Type and Composition: Intensely propylitized microdiabase. Rock consists principally of plagioclase, chlorite, and epidote (more about alteration below). The plagioclase (32%) occurs as "felted" , randomly oriented laths, subhedral to euhedral initially but etched and corroded so that they now appear somewhat ragged; the laths have aspect ratios of 5-7/1, and range in length from 0.03 mm to 0.5 mm (averge about 0.15 mm). The chloritized former mafic mineral occurs as angular (commonly triangular) masses interstitial to the plagioclase. About 1% disseminated, microcrystalline ilmenite or magnetite, as anhedral grains avg. <0.03 mm in diameter.

Alteration and Mineralization: Strong propylitic alteration, affecting at least two thirds (and likely more) of the total rock volume. Typical assemblage of epidote-albite-chlorite with minor accompanying K-feldspar, titanite, and actinolite. Alteration (as opposed to vein-filling) epidote has a bimodal size distribution; most common are relatively large, disseminated, subequant to crudely tabular and more coarsely crystalline masses between 0.3 and 1 mm in diameter – these clots consist of individual pistachio green crystals 0.1-0.2 mm in diameter, and the clots are typically rimmed by microcrystalline, nearly opaque epidote (individual crystals just a few microns in diameter. A second size of epidote crystals, 0.03-0.3 mm, is also disseminated rather evenly throughout the rock. Chlorite interstitial to plagioclase laths (which have been partially albitized) is pale green in transmitted light and commonly with anomalous birefringence under crossed nicols. Titanite occurs as disseminated, highly irregular clots averaging about 0.05 mm in diameter, and composed of microcrystals <1 micron in diameter; some of the titanite replaces primary ilmenite/magnetite. Actinolite is primarily a vein mineral (see below) but also occurs as minute needles and needle clusters embedded in epidote. K-feldspar is also a common vein mineral, but partially replaces plagioclase as randomly disseminated irregular clots.

Many drill chips are composed wholly of secondary minerals. In many cases it is impossible to identify these as veinlet fragments, since they could also be derived from the large clots described above. True veinlet fragments, texturally distinctive from the clots, consist of (in decreasing order of abundance) epidote, quartz, K-feldspar, actinolite, and titanite. These phases occur in various combinations, with epidote always dominant.

Sample Designation: **Well GMF 31-17, depth 7450-7460 ft** (cuttings)

Petrographer: JBH – Jan. 14, 2000

Rock Type and Composition: Rhyolite or dacite (depending upon how much of the K-feldspar in the rock is an alteration product), initially glassy and sparsely vesicular, now wholly devitrified to quartz-Kspar-plagioclase aggregates. Devitrification of two textural types, commonly in the same drill chip: (1) spherulitic – mass of pale brownish partial rosettes, sheaves, and sprays, with individual crystals of the main constituents unresolvable even at 500X; relict perlitic cracks commonly present; (2) mosaic – aggregates of highly irregular, subequant, interlocking quartz and feldspar crystals typically ranging from 0.03 to 0.3 mm in diameter. Both types of devitrification encompass disseminated and randomly oriented slender prisms of an unknown former mafic mineral, accounting for 5-6% of the rock; the prisms, now wholly chloritized, are typically tapered slightly toward the ends, and average 0.10 X 0.01 mm (up to 0.30 mm long at the same widths). About 4% "skeletal" ilmenite or magnetite crystals averaging 20-30 X <2 microns; many of these crystals have "T" terminations.

Alteration and Mineralization: Weak potassic and moderate propylitic alteration. The propylitic alteration involves complete chloritization of the former mafic prisms, sparse replacement of the rock by disseminated epidote, and localized replacement of the margins of more coarsely crystalline devitrification aggregates by microcrystalline titanite. Potassic alteration involves localized "flooding" of the rock by secondary Kspar; this type of alteration is difficult to separate visually from normal matrix Kspar, but the patchy nature of the flooding belies its secondary origin.

Veinlets and veinlet fragments account for about 5% of the sample. Most of these are dominated by epidote, chlorite, titanite, and quartz with or without Kspar. Also present are a few monomineralic Kspar veinlets.

Comments, Interpretations: Because this rock was initially >90% glass, and because it is (was) also sparsely vesicular, it was almost certainly emplaced at the surface or in the very shallow subsurface (subvolcanic rather than hypabyssal). Its relative lack of alteration is probably due more to its high-silica, non-reactive composition rather than lack of exposure to circulating hydrothermal fluids.

Sample Designation: **Well GMF 31-17, depth 8030-8040 ft** (cuttings)
Medicine Lake volcano and geothermal system

Petrographer: JBH – Jan. 14, 2000

Rock Type and Composition: Altered, amygdaloidal metabasalt. 17-20% mostly subhedral to euhedral plagioclase microphenocrysts, most in the range 0.1 to 0.4 mm in length and with aspect ratios of 1.5 to 5/1, randomly oriented and embedded in a microcrystalline (<10 microns) aggregate of plagioclase, ilmenite or magnetite, titanite, and altered former mafic minerals (more below). Amygdules, now filled with hydrothermal phases (see below) are typically subequant, rounded, and up to 1 mm in diameter. Magnetite occurs as disseminated anhedral grains mostly <20 microns in diameter. Titanite occurs as disseminated irregular clots, up to 0.15 mm in diameter, composed of microcrystals <<1 micron in diameter. Some former mafic microphenocrysts, now replaced by secondary phases, up to 0.7 X 0.3 mm – subhedral, typically prismatic, but locally subequant.

Alteration and Mineralization: Moderate potassic alteration, principally secondary biotite but also including minor secondary K-feldspar. Secondary biotite (about 5% of the rock) is of two modes – (1) scattered, irregular crystals up to 0.1 mm in diameter, which are pleochroic from pale yellow brown to deep orange brown; these could be in part of metamorphic rather than hydrothermal origin; this type of biotite also occurs as relict masses in the iteriors of chloritized primary mafic minerals; (2) rather evenly disseminated, 5-10 micron, pale brownish-green crystals throughout the matrix of the rock. Actinolite (15%) is also texturally bimodal; one variety occurs as relatively coarse, radiating crystal clots, up to 0.2 mm in length (individual crystals) both replacing former mafic minerals and infilling, along with albite and other secondary phases, former vesicles (amygdules). A second variety of actinolite is microcrystalline (typically <0.05 mm in length) and disseminated evenly throughout the matrix, where it probably replaces a former mafic phase (likely a pyroxene). Epidote (about 2%) occurs as disseminated irregular clots up to 0.2 mm in diameter, replacing all primary phases.

Veinlet fragments and amygdules account for about 7% of the rock. The following assemblages are present: (1) actinolite-albite; (2) actinolite-epidote-K-feldspar ± biotite; (3) epidote-actinolite-quartz. Actinolite and biotite appear to have been contemporaneously deposited; epidote was precipitated next, and was followed by deposition of quartz and potassium feldspar. In some cases secondary phases apparently replaced older amygdular fillings; in others, relict vesicles were filled with hydrothermal phases.

Sample Designation: **Well GMF 31-17, depth 8090-8100 ft** (cuttings)

Petrographer: JBH – Jan. 14, 2000

Rock Type and Composition: Pyroxene micro-metadiabase. Rock consists dominantly of plagioclase (52%) and clinopyroxene (17%), the former inherited from the premetamorphic rock, the latter occurring exclusively as metamorphic crystals. Very well-developed diabasic texture, with subhedral to euhedral plagioclase laths averaging <0.1 mm in diameter, and with aspect ratios of 4 or 5 to 1. Clinopyroxene occurs as anhedral, equant, rounded, pale green crystals averaging about 0.02 mm (5 microns to 0.1 mm) in diameter. The clinopyroxene has relatively low birefringence, but this is probably due to the small size of the crystals for the most part (XRD clearly indicates CPX as dominant); the clinopyroxene is commonly crowded with <1 micron disseminated ilmenite grains. Minor orthopyroxene, however, as highly irregular, sieve-textured crystals (up to 0.3 mm in diameter) which may be inherited from the premetamorphic rock. Metamorphic biotite (about 2% of the rock) occurs as disseminated, irregular crystals up to 0.7 mm in diameter, but averaging about 0.1 mm in diameter; this biotite is pleochroic from pale yellow-brown to deep and nearly opaque orange-brown. About 5% ilmenite or magnetite, as disseminated, anhedral grains averaging about 0.03 mm in diameter. About 1% accessory apatite needles and prisms. There are a few other chips in this sample which are interpreted as, for the most part, contamination. The chips include metabasalt and micrographic quartz-K-spar intergrowths.

Alteration and Mineralization: Very weak potassic alteration, manifested principally as irregularly disseminated, pale greenish-brown aggregates of 5 micron secondary biotite aggregates. This biotite replaces both plagioclase and metamorphic biotite. Actinolite is locally present as a fibrous alteration product of primary (?) orthopyroxene. <1% epidote as disseminated, irregular clots <0.07 mm in diameter, in plagioclase. Chlorite partially replaces actinolite and biotite. Potassium feldspar (about 2-3% of the rock) seems to occur interstitial to the plagioclase laths. It could be a primary phase rather than a potassic alteration product. Talc (about 5%) occurs as angular, plagioclase-interstitial aggregates of highly birefringent microcrystals; based on this texture, the talc probably replaces a premetamorphic interstitial, primary mafic mineral.

Comment: This rock is very similar to the one represented by core at 8420 ft

Sample Designation: **Well GMF 31-17, depth 8250-8260 ft** (cuttings)

Petrographer: JBH – Jan. 14, 2000

Rock Type and Composition: Potassically altered hornblende quartz diorite to granodiorite, finely crystalline (avg. grain size probably about 0.5-0.7 mm), subhedral-granular. Rock consists dominantly of plagioclase (about 50% by weight), potassium feldspar (23% – a mixture of primary magmatic and secondary [more below]), and quartz (17%), with accessory hornblende (about 3% prior to alteration), ilmenite (2%), and apatite (0.5%), with a trace of zircon. Most of the K-feldspar is an alteration product of primary plagioclase; the K-spar forms thick, irregular rims, up to 1/4 the width of the replaced crystals, either intergrown with or replacing albite (the bulk of the plagioclase is oligoclase or andesine); the K-spar (with albite) is very turbid-appearing, with abundant vapor-rich fluid inclusions. There are a few drill chips of quartz microdiorite, compositonally similar to the main plutonic rock type in this sample but finer grained; the microdiorite could represent chilled dike margins. Other chips in the sample are considered to be contamination. Some of the quartz diorite chips are microbrecciated or converted to gouge; it is likely that these chips are "bit gouge" produced during the drilling process.

Alteration and Mineralization: Moderate potassic alteration, almost certainly a late-magmatic rather than strictly hydrothermal effect. The alteration consists of peripheral replacement of primary oligoclase/andesine crystals by turbid rims of albite and (mostly) secondary K-feldspar. There are traces of secondary, microcrystalline, pale brownish-green secondary biotite. Primary hornblende is altered partially to actinolite, and ilmenite is locally rimmed with titanite. Both actinolite and hornblende are locally partly replaced by pale green chlorite. About 1% disseminated epidote, principally as a replacement of plagioclase. Trace of prehnite replacing primary hornblende.

About 1% of the rock consists of veinlet fragments. Most of these consist of epidote and chlorite, with or without minor quartz and K-feldspar.

Sample Designation: **Well GMF 31-17, depth 8420 ft** (core)

Petrographer: JBH – Jan. 11, 2000

Rock Type and Composition: Pyroxene micrometadiorite or metagabbro, pseudodiabasic or decussate texture defined by felted and randomly oriented plagioclase laths 0.1-0.4 mm in length, and with aspect ratios averaging about 4/1. Plagioclase laths (accounting for about 50% of the rock) are subhedral to euhedral, twinned and zoned, with "dirty"-appearing rims. The plagioclase does not appear recrystallized metamorphically, but rather is inherited from the pre-metamorphic microdiorite. Clinopyroxene, on the other hand, is clearly metamorphic – it occurs as evenly disseminated, anhedral and typically rounded-appearing, pale green crystals averaging about 0.05 mm (up to 0.1 mm) in diameter. Orthopyroxene has two habits: (1) larger crystals, commonly sieve-textured, up to 0.3 mm in diameter (about 3% of the rock), which appear to be relict from the pre-metamorphic microdiorite; crystals are typically >50% altered (more below); (2) smaller crystals, clearly metamorphic, both disseminated irregularly along with clinopyroxene, and as discrete crystals in metamorphic veinlets with clinopyroxene, quartz, plagioclase, and biotite. Magnetite (about 9% of the rock) occurs as evenly disseminated, anhedral grains averaging about 0.04 mm in diameter. Metamorphic biotite (see also secondary [hydrothermal] biotite below) accounts for about 3% of the rock; occurs as irregular to subhedral crystals ranging from <10 microns to 0.2 mm in diameter or length; pleochroic from pale yellowish brown to deep orange brown (nearly opaque).

Alteration and Mineralization: Weak potassic alteration, exclusively in the form of microcrystalline secondary biotite. This biotite (about 7% of the rock) occurs as disseminated single crystals (<5 microns) and as irregular clots composed of these crystals and reaching at least 0.7 mm in diameter. The biotite is very pale brownish green. Actinolite (about 3% of the rock) occurs as discrete, ragged clots of medium green acicular crystals, with or without intergrown secondary biotite, and as crystals and masses of the same form and color partially replacing original orthopyroxene. Talc (about 1%) occurs as microcrystalline masses generally intergrown with actinolite.

Sample Designation: **Well GMF 31-17, depth 8423 ft** (core)

Petrographer: JBH -- Jan. 10, 2000

Rock Type and Composition: Potassically altered hornblende quartz diorite, subhedral to euhedral granular; average grain size about 1.3 mm. Rock consists dominantly of plagioclase (about 50% by weight), quartz (about 20%), and potassium feldspar (about 15%, principally secondary) with subordinate altered hornblende (about 5%), ilmenite or magnetite (3-4%), and apatite (about 1%). The plagioclase occurs as subhedral to euhedral (but commonly with ragged borders), lath-shaped, twinned and concentrically zoned oligoclase or andesine crystals, which are peripherally altered to thick, irregular rims of albite and potassium feldspar (more below). Quartz occurs as anhedral masses clearly precipitated late in the magmatic sequence. About 1-2% irregular, late-stage, micrographic intergrowths of quartz and orthoclase, and probably <5% primary orthoclase as discrete crystals. Hornblende (originally about 5%) is irregular to subhedral, in single crystals and aggregates, and is pleochroic from light to medium greenish-brown; this primary amphibole is extensively altered to actinolite (more below). Ilmenite/magnetite (3-4%) occurs as mostly unaltered, anhedral to subhedral grains averaging about 0.2 mm in diameter; a few of these grains are partially rimmed with microcrystalline sphene. Apatite (1%) occurs as slender to stubby prisms up to 0.3 mm in diameter (generally much smaller) and with aspect ratios averaging about 5-7/1. This rock contains a few scattered microxenoliths of more mafic-rich hornblende diorite with a distinctive pseudodiabasic or decussate texture.

Alteration and Mineralization: Moderate potassic alteration, principally manifested as thick, irregular and ragged, K-spar rims on primary plagioclase crystals. The K-spar, in turn, partially replaces texturally similar secondary albite, the initial phase forming the rims. Both the K-spar and the albite are very turbid-appearing (by contrast with the relatively clear cores of the primary plagioclase crystals), due to the presence of abundant, mostly vapor-rich fluid inclusions, some of which reach 30-40 microns in length or diameter. Both the rims and the cores of the plagioclase crystals have undergone locally extensive dissolution, giving them a "moth-eaten" texture. Primary hornblende is about 50% (in terms of the entire sample) altered to fibrous actinolite, which is not only texturally distinctive but is pleochroic from pale to medium "bottle" green. The actinolite, in turn, is partially altered to chlorite. Secondary biotite (about 3% of the rock), occurs as irregular, disseminated aggregates, up to a few tenths of a mm in diameter (generally much smaller), consisting of pleochroic brownish-green to pale green crystals only a few microns in average diameter. The biotite is also partially altered to chlorite. Epidote (about 2%) occurs as scattered, irregular aggregates up to at least 0.5 mm in diameter, typically replacing plagioclase or hornblende, and commonly intergrown with actinolite. The epidote aggregates have relatively coarsely crystalline cores, and are thinly rimmed with a microcrystalline variety. There are no obvious veinlets of secondary minerals disrupting this rock.

Sample Designation: **Well GMF 31-17, depth 4480-4490 ft** (cuttings), Medicine Lake volcano and geothermal system

Petrographer: JBH – Jan. 15, 2000

Rock Type and Composition: Strongly altered, amygdaloidal basalt or basaltic andesite. Rock consists of randomly oriented plagioclase microlites embedded in a nondescript matrix consisting dominantly of chlorite and leucoxene (microcrystalline titanite). In spite of the alteration, about 5% clinopyroxene remains as a relict primary phase. Amygdules are former vesicles ranging from 0.10 to 1.0 mm in diameter now filled exclusively with secondary minerals (see below).

Alteration and Mineralization: Strong, but not complete, propylitic alteration, a classical variety dominated by chlorite after mafic minerals, and epidote after mafics and plagioclase alike. The epidote occurs as disseminated irregular clots from a few microns to a few tenths of mm in diameter. The variety is pistacite.

Amygdule fills are mostly epidote with subordinate chlorite, leucoxene, and quartz, but a few amygdules are quartz-lined and chlorite-filled with no other secondary phases. Two amygdules examined contained late-stage wairakite, and several others contained late-stage anhydrite. Leucoxene typically forms thin microcrystalline rims around epidote-dominated amygdules; the leucoxene also occurs as thin selvages on epidote veins. Those veins are uncommon, but also contain minor quartz and K-feldspar.