GEOLOGIC MAP OF THE MORMON LAKE QUADRANGLE
COCONINO COUNTY, ARIZONA

by

Richard F, Holm
Department Of Geology, Northern Arizona University

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Introduction

The Mormon Lake quadrangle is in the northern part of the Mormon volcanic field, a late Cenozoic volcanic province on the southern margin of the Colorado Plateau (Holm and others, 1989). Except for Pleistocene and Holocene surficial deposits, all of the rocks mapped on the quadrangle are Miocene and Pliocene volcanic rocks.

All geologic contacts and faults were traced in the field. Map units were defined on the bases of lithology and morphology, and stratigraphic relationships were determined in the field on the basis of traditional geologic principles such as superposition and cross-cutting relationships.

The mapping strategy was to map all lava flows and vent structures that could be distinguished in the field as discrete units, and to trace each flow to its source vent. Each vent structure was given an identification number (see "Vent and flow identification numbers"), and related lava flows were identified with the same number. Small vent deposits and related flows (Tys and Tyb) that lack morphologic distinction on the map were not, however, given separate identification numbers. Multiple contiguous lava flows of the same lithology from the same vent, and individual flow units of compound lava flows and lava flow fields were not mapped separately (for example, Tibv, Tobs).

The rocks are classified in 2 ways. Petrographic features observable in hand specimen at the outcrop were used to assign lithologic names to the rocks (see "Lithologic classification for volcanic rocks in the Mormon volcanic field"). Lithologic type is one of the principal bases for distinguishing map units, and each volcanic map unit has a lithologic symbol. Subtypes characterized by distinctive textures or microscopic features are also represented by lithologic symbols on the map. Sixteen chemical analyses of rocks in the quadrangle are given in Table 1. The oxide and normative mineral compositions of the analyzed rocks were used to classify them chemically (see "Chemical classification for volcanic rocks in the Mormon volcanic field"), and the names are given on Table 1.

The map differs from traditional geologic maps because some map units (such as Tibf and Tibv) have internal contacts where subdivision could be made on the basis of different source vents and lithology. The internal units were not given separate map unit
symbols because of uncertainties in correlation within the quadrangle and with mapped units in adjacent quadrangles; the internal units are, however, distinguished with different lithologic symbols and identification numbers, and local relative age relationships are shown with contact symbols (o=older, y=younger). Some lavas and vent deposits with different lithologies and identification numbers in different parts of the map were included in the same map unit because they have the same general stratigraphic position, but they could not be correlated with confidence because of isolation (for example Tib, Tibf, Tisc, Tibi).

Geology

Late Miocene sheet lavas of subalkali to transitional basalt (Tobs) underlie most of the region north and east of Mormon Lake. The lavas were extruded from vents in the southern part of the quadrangle (and probably from some vents farther south and southwest), flowed generally northeast, and spread out on the Triassic Moenkopi Formation in a northwest trending strike valley. Extensional stress in the late Miocene or early Pliocene created horsts and grabens in the sheet lavas that were buried by early Pliocene alkali and basanitic basalt lavas that erupted from local centers (Tpbf and Tfb). The faults, which strike principally north and northwest, are in a broad area of intersection of the north striking Oak Creek Canyon fault system and the northwest striking Cataract Creek fault system (Holm and others, 1991).

Early Pliocene shield volcanoes of alkali and basanitic basalt (Tibv) cover the sheet lavas in the south and southwest parts of the quadrangle, and probably cover most of their vents. The shields overlap in a northwest trending zone subparallel with faults in the Cataract Creek fault system. Scoria cones and dikes (Tisc and Tibi) that are parasitic on the shields display strong northwest alignments and strikes. Some of the basalt lavas (Tibf) from the parasitic cones have abundant quartz xenocrysts and hybrid compositions. Later in the early Pliocene, extensional stress reactivated old faults and produced new faults, most of which strike north and northwest. Most of the throw on the fault that bounds the east side of Mormon Lake was produced at this time, as were the displacements on the faults that bound Ashurst Run and Long Park grabens.

Post-tectonic volcanism occurred in the southeast and northwest parts of the quadrangle. A dacite dome (Tydd) that was erupted along a fault that displaces the flank and summit of a shield volcano (7902A) was followed shortly by eruptions of alkali and basanitic basalt (Tysc, Tybf and Tys, Tyb) at numerous sites in a narrow northwest trending zone that crosses the summit of the shield; the largest cone (Tysc) covers the scarp of the fault that bounds the east side of Mormon Lake. In the late Pliocene, andesite and dacite lavas that were erupted from Mormon Mountain entered the northwest part of the quadrangle and blocked any drainage that may have existed from Mormon Lake. Mormon Lake is in a volcano-tectonic basin that originated between 6.16+/-0.30 and 3.1+/-0.6 million years ago (Damon and others, 1974; Luedke and Smith, 1978).
CORRELATION OF MAP UNITS

SURFICIAL DEPOSITS

MORMON VOLCANIC FIELD

Silicic Rocks  Andesitic Rocks  Basaltic Rocks

\[ T_{mdy} \pm 0.6 \text{ Ma} \]

\[ T_{mam} \]

\[ T_{ydd} \quad T_{yf} \]

Faulting

\[ T_{ypb} \quad T_{ypc} \quad T_{ypd} \quad T_{ypf} \quad T_{ypg} \]

3.89 ± 0.01 Ma

Faulting

\[ T_{tpf} \quad T_{tpi} \quad T_{tpc} \quad T_{tpd} \quad T_{tpf} \quad T_{tpg} \]

Pliocene

TERTIARY

Mesoronic

\[ T_{sca} \quad T_{obi} \quad T_{obs} \]

6.16 ± 0.30 Ma

\[ T_{iaf} \quad ? \quad ? \]

\[ 4.38 \pm 0.20 \text{ Ma} \]

1 Analyzed sample is from summit of Mormon Mountain on Mormon Mountain quadrangle (Luedke and Smith, 1978).

2 Analyzed sample is from Anderson Mesa on Lower Lake Mary quadrangle (Damon and others, 1974).
Tyb  YOUNGER BASALT (PLIOCENE)-Small, dark gray, vesicular basalt lava flows that erupted from vents at Tys on and near the summit of shield volcano 7902A; prominent phenocrysts of olivine and clinopyroxene are in approximately equal amounts. Composition is alkali basalt. Flows are 0.5 to 9 m thick at edges.

Tysc  BASALTIC SCORIA CONE OF VENT 7902B (PLIOCENE)-Scoria cone of red lapilli and bombs; nonconsolidated. The pyroclasts are moderately to highly vesicular, and carry phenocrysts of olivine and clinopyroxene. The elongated cone is within the northwest trending zone of Tys deposits; it erupted on the scarp of the fault that bounds the east side of Mormon Lake.

Tybf  BASALT LAVA FLOWS OF VENT 7902B (PLIOCENE)-Small lava flows of dark gray to maroon clinopyroxene-olivine basalt; phenocrysts are 0.5 to 1 mm in diameter. Flows are 1 to 5 m thick at edges.

Tybi  YOUNGER DIKES AND PLUGS (PLIOCENE)-Dikes and plugs of clinopyroxene-olivine basalt. The unit includes: 1) the intrusions in scoria cone 7902B, 2) the large feeder dike of Tyb flow about 0.5 km east of cone 7902B, 3) basalt plugs in dacite dome Tydd (7903A), and 4) basalt dikes of lava cone 8936. Dikes in cone 7902B carry phenocrysts around 0.5 mm in diameter in a dense, dark gray matrix, whereas the large dike to the east is vesicular and maroon in color. Composition is basanitic alkali basalt. Most dikes and elongated plugs in cone 7902B strike northwest parallel to the elongation of the cone and the zone of Tys deposits. K-Ar age of plug at the summit of the cone is 3.89 ± 0.01 Ma (Holm and Shafiqullah, in press), which is the youngest possible time of movement on the fault that bounds the east side of Mormon Lake.

Tybl  YOUNGER BASALT LAVA CONES (PLIOCENE)-Parasitic lava cones (8926, 8936) on the lower north side of shield volcano 7902A. Lavas are dark to medium gray clinopyroxene-olivine basalt that may carry local plagioclase phenocrysts; composition is alkali basalt. Flows are 1 to 2 m thick at edges. Lavas of cone 8926 flowed into the graben of Ashurst Run.

Tyf  DACITE BLOCK AND ASH DEPOSIT (PLIOCENE)-Chaotic, nonsorted, structureless deposit containing dacite blocks up to 1 m in diameter in a matrix of dacite lapilli and ash; deposit is nonconsolidated. Blocks are light gray, microvesicular to poorly
pumiceous, and contain phenocrysts of hornblende and plagioclase in a hyalopilitic matrix. The deposit originated as a small block and ash flow during the eruption of Tydd; it was deposited along the west-facing scarp of the fault that bounds the east side of Mormon Lake. The deposit is poorly exposed along forest road 124C.

**Tydd DACITE LAVA DOME, VENT 7903A (PLIOCENE)**-Light gray to pink dacite forms an endogenous lava dome and small satellite dome (7903B, 500 m south) that were erupted along the fault that bounds the west side of the graben at the south end of Mormon Lake. Phenocrysts of hornblende and plagioclase are set in a dense to sparsely vesicular hyalopilitic matrix. Blocks of flow-foliated dacite make a crumble breccia through which spines project on the flanks and around the summit of the dome; flow structures in the spines, including color banding and flow-oriented hornblende crystals, dip toward the center of the dome. During emplacement, the dome uplifted a trap door flap of the Tibv shield volcano (7902A). Scoriaceous tuff about 1 m thick overlies the crumble breccia on the lower west side of the dome.

**Tisc INTERMEDIATE BASALTIC SCORIA CONES (PLIOCENE)**-Nonconsolidated to agglutinated deposits of red scoriaceous basaltic lapilli and bombs. Deposits range from well-defined cones to erosionally subdued cones to poorly exposed cones partly buried by younger lava flows. The cones are parasitic on shield volcanoes in the southwest and western parts of the map.

**Tibf INTERMEDIATE BASALT (PLIOCENE)**-Dark to medium gray basalt lava flows. Unit includes lavas erupted from parasitic vents on shield volcanoes in the southwest and western parts of the map, and a flow in the east part of the map that was erupted from a cone on the Kinnikinick Lake quadrangle (Pine Hill, vent 8020). Flows range from 1 to 10 m thick at edges. Basalt lithologies of different flows are related to the individual vents. Phenocrysts of olivine, clinopyroxene, and plagioclase occur in different proportions in different flows, and quartz xenocrysts are common in some flows; see map for lithology of specific flows.

**Tibi INTERMEDIATE DIKES AND PLUGS (PLIOCENE)**-Dikes and plugs of basalt. Most are in scoria cones that are parasitic on shield volcanoes in the southwestern part of the map. Different proportions of olivine, clinopyroxene, and plagioclase phenocrysts occur in the dikes of different cones; see map for lithology of
specific dikes and plugs. Most dikes in the cones strike northwest subparallel to faults in the southwest part of the map. The unit also includes dikes of clinopyroxene-olivine basalt that are oriented approximately radially around the summit of shield volcano 7902A, and a plug of similar composition in the graben at the south end of Mormon Lake

**Tis** INTERMEDIATE BASALTIC SCORIA DEPOSITS (PLIOCENE)- Small deposits of red scoriaceous lapilli and bombs at the summit of shield volcano 8836A. The basaltic pyroclasts carry phenocrysts of olivine. Deposits are nonconsolidated to agglutinated

**Tibv** BASALT SHIELD VOLCANOES (PLIOCENE)-Three overlapping basalt shield volcanoes in the south and southwest parts of the map. The basalt is medium gray, and contains different proportions of olivine, clinopyroxene, and plagioclase phenocrysts in different volcanoes; see map for lithology of specific shields. The largest shield (7902A) is 150 m high and over 8 km in base diameter; its composition is basanitic alkali basalt. Each shield is composed of multiple lava flows that range from about 1-2 m to over 10 m in thickness

**Tib** INTERMEDIATE BASALT LAVA FLOWS OF UNKNOWN OR UNCERTAIN SOURCE (PLIOCENE OR POSSIBLY MIocene)-Dark to medium gray basalt lava flows that cannot be correlated with a specific source vent. Phenocrysts of olivine, clinopyroxene, and plagioclase occur in different proportions in different flows; see map for lithology of specific flows. Lava 7902A? in the southeast part of the map possibly erupted from a vent covered by the summit lavas of shield 7902A; it is a feldspar-rich alkali basalt

**Tpse** BASALTIC SCORIA CONE OF PINE GROVE HILL, VENT 9931B (PLIOCENE)-Low cone of weakly to strongly agglutinated red and dark gray scoriaceous lapilli and bombs; pyroclasts carry scattered phenocrysts and abundant microphenocrysts of olivine

**Tpbi** DIKES AND PLUG OF PINE GROVE HILL (PLIOCENE)-Dark gray dikes and plug of basalt in scoria cone of Pine Grove Hill. Olivine occurs as scattered phenocrysts (1 mm) and abundant microphenocrysts (<0.5 mm)

**Tpbf** BASALT LAVA FLOWS OF PINE GROVE HILL (PLIOCENE)-Dark gray lava flows of basalt extruded from Pine Grove Hill scoria cone
Scattered phenocrysts (1 mm) and abundant microphenocrysts (<0.5 mm) of olivine are set in an aphanitic matrix. Outcrops weather to distinctive mottled or spotted appearing lumpy surfaces. Composition is alkali basalt. Multiple lava flows covered faulted Miocene sheet lavas (Tobs); thickness of the unit ranges from over 68 m in paleograbens to about 3 m on paleohorsts. The fault that bounds the east side of Mormon Lake displaces the lavas; thicknesses of the unit around the graben at the north end of the lake indicate that the fault was also active during the earlier period of horst and graben faulting. K-Ar age of 4.38 +/- 0.20 Ma (Holm and Shafiquallah, in press) gives the oldest possible time for the latest movement on the fault that bounds the east side of Mormon Lake.

**Tfb**  
**BASALT OF FLYING M RANCH (PLIOCENE OR POSSIBLY MIOCENE)**- Very dark gray to black lava flows of olivine basalt; olivine occurs as scattered phenocrysts (1 mm, rarely to 5 mm) and very abundant microphenocrysts. Composition is basanitic alkali basalt. Unit ranges in thickness from 1-3 m at flow edges to over 18 m around Camillo Tank on the east edge of the map. Lack of an exposed vent structure and distribution of unit indicates its vent is covered by shield volcano 7902A. Wide range in thickness in the distal part of the unit around Camillo Tank suggests it postdates earlier horst and graben faulting of the underlying Miocene sheet lavas (Tobs).

**Tiaf**  
**ANDESITE LAVA FLOW (PLIOCENE OR POSSIBLY MIOCENE)**- Light to medium gray andesite exposed in small outcrop on west side of graben at the south end of Mormon Lake. Sparse phenocrysts of hornblende and plagioclase are 0.5-2 mm in length; matrix is dense and aphanitic. Composition is trachyandesite. Composition, texture, and stratigraphic position identify its vent as a scoria cone on the Hutch Mountain quadrangle (7915P).

**Tobs**  
**BASALT SHEET LAVA FLOWS (MIOCENE)**- Medium gray lava flows of olivine basalt that underlie low-relief topography north and east of Mormon Lake. Common olivine phenocrysts are 1-5 mm in diameter; plagioclase phenocrysts are uncommon and clinopyroxene is rare. In most outcrops the matrix texture is diktytaxitic. Compositions are subalkali basalt and transitional basalt. Two to seven flows, some displaying pahoehoe flow structures, are exposed in different sections in the fault scarps along the east and north sides of Mormon Lake; flows are 3-17 m thick, and either lack or have thin (<0.5 m) autoclastic breccias. K-Ar age of similar lavas
on Anderson Mesa about 15 km to the northwest is 6.16 +/- 0.30 Ma (Damon and others, 1974)

**Tosc BASALTIC SCORIA CONE OF VENT 8934 (MIOCENE)-**
Nonconsolidated to weakly aggluginated red scoriaceous basaltic lapilli and bombs exposed in scarp of the fault that bounds the east side of Mormon Lake. Abundant olivine phenocrysts are 0.5-1 mm in diameter. Moderately sorted to well sorted planar beds 1 cm to 1 m thick display normal and inverse grading; many beds are structureless. Beds dip 16° to 27° into the scarp and radially away from a central plug (Tobi). Exposed thickness is about 40 m. The cone is partly covered by basalt sheet lavas (Tobs)

**Tobi BASALT PLUG OF VENT 8934 (MIOCENE)-**Dark gray plug of olivine basalt; abundant olivine phenocrysts 0.5-1 mm in diameter are altered to iddingsite
EXPLANATION OF GEOLOGIC MAP SYMBOLS FOR QUADRANGLES IN THE MORMON VOLCANIC FIELD:

MORMON LAKE QUADRANGLE, ARIZONA

Line, Point, and Structure Symbols

Geologic contact; where relative ages of adjacent units are not readily interpreted from the map data, but have been determined from field relationships, \( o \) = older unit, \( y \) = younger unit.

Fault; dotted where concealed by younger lava flows and cones and surficial deposits. Bar and ball on down-thrown side.

Locality and age (millions of years) of sample dated by K-Ar analysis.

Locality and number of sample with chemical analysis listed in Tables 1 and 2.

Strike and dip of flow structures such as platy joints and flow banding.

Strike and dip of bedding.

Map Unit Symbols

1st symbol: Age:

- \( T \) = Tertiary
- \( QT \) = Quaternary and (or) Tertiary
- \( Q \) = Quaternary

2nd symbol: Letter of a geographic feature; \( m \) = Mormon Mtn; OR

Age group, if unit is not identified with a geographic feature:

- \( o \) = older; generally, the late Miocene sheet lavas;
- \( i \) = intermediate; generally, the early Pliocene shields, cones, and cone-related flows;
- \( y \) = younger; generally, the cones, domes, and flows that are known to have young ages by K-Ar analysis, and which post-date the faults with which they are associated.
Following Q:

s = surficial deposits
l = landslide deposits

3rd symbol: Lithology

b = basalt
a = andesite
d = dacite
r = rhyolite
s = scoria, agglutinate, scoriaceous basaltic tuff
t = palagonitic tuff
p = felsic tuff (pumiceous)
f = felsic block and ash deposits
l = lahars

4th symbol: Age group, or volcano structure; may be omitted, especially if source of flow or type of structure is not known or is uncertain.

Age group following a specific geographic feature with more than one stratigraphic unit:

o = older
m = middle
y = younger

Volcano structure:

s = sheet lava, intracanyon lava flow
v = shield volcano
l = lava cone
c = scoria cone, agglutinate cone
f = flow related to a cone; simple and compound flows
d = lava dome
i = intrusion such as dike or plug (may be unlabelled where size and shape are consistent with a dike)
p = pyroclastic sheet deposits, scoriaceous
t = tuff cone, tuff ring
b = breccia pipe, tuffisite dike or pipe
Lithologic symbols

2c,q. Lithologic types are identified on the map by a number or a number with a letter suffix defined in Lithologic Classification For Mormon Volcanic Field. Composite map units, or composite areas within generally homogeneous map units, have 2 or more lithologic symbols; the most common lithologic type is listed first.

Additional letter suffixes that identify petrographic features that may be seen in an outcrop in different lithologic types include:

, q = quartz and/or atoll clinopyroxene in a mafic or intermediate rock.
,x = xenoliths; typically mafic to ultramafic, but locally granitic, especially in basalts containing abundant quartz.
,d = diktytaxitic texture in basalts other than type 1a sheet lavas.
,m = microporphyritic

Vent and flow identification numbers

7802B Vent structures are identified with a 4-digit number based on location according to the township, range, section system. The first digit is the second integer of the township; the second digit is the second integer of the range; the last two digits identify the section. If two or more vent structures are in a section they are identified with letter suffixes A, B, etc. The suffix "P" identifies a polygenetic cone with a compound or composite structure or composition.

Shield volcanoes without summit cones are identified according to the section containing the topographically highest part of the volcano.

7802B-3 Lava flows that extend beyond the base of a cone are identified by the vent identification number. If 2 or more flows extend beyond the base of a cone they are identified by number suffixes -1, -2, etc; the numbers are arbitrary if the relative ages of the flows cannot be determined. If the source of the flow is uncertain the identification number is queried (?).

For example, 7802B-3 identifies the 3rd lava flow (not necessarily by age) from the 2nd vent structure in section 2 of Range 8 East, Township 17 North.
LITHOLOGIC CLASSIFICATION FOR VOLCANIC ROCKS IN THE MORMON VOLCANIC FIELD

Lithologies of volcanic rocks in the Mormon volcanic field are defined on the basis of outcrop-scale petrographic features, principally the types and abundances of phenocrysts, and phenocryst and matrix textures. The lithologic categories are listed below according to number. For most categories, the petrographic criteria are observable in hand specimens at the outcrop and therefore are one of the principal bases for identifying map units. In general, categories 8, 10, and 40 require a microscopic or chemical analysis, or both for identification.

Basalt categories 1 - 4 and 6 have 2 or more subcategories that typically require microscopic analysis for identification.

Definitions:
  p, phenocryst: crystal >0.5 mm in diameter in finer matrix.
  mp, microphenocryst: crystal <0.5 mm in diameter in finer matrix.
  porphyritic: >1% phenocrysts.
  subporphyritic: <1% phenocrysts.
  aphyric: rare, scattered phenocrysts.
  matrix: mass of crystals (+/- glass) distinctly smaller in size than phenocrysts and microphenocrysts in the rock.
  ol, olivine
  cpx, clinopyroxene
  opx, orthopyroxene
  plag, plagioclase
  hbl, hornblende
  phl, phlogopite
  opa, opaque oxide
  gl, glass

1. Olivine basalt.
   >1% ol p; no cpx p; mp of ol, cpx, plag can be present. Matrix is composed of plag + cpx + ol + opa + gl, textures include intergranular, intersertal, granular, and locally ophitic.
   special varieties:
     a. fairly coarse intergranular matrix, diktytaxitic.
     b. abundant cpx in matrix, strong violet-tan color.
2. Clinopyroxene-olivine basalt.
   >1% ol + cpx p, ol>cpx.
   Matrix is composed of plag + cpx + ol + opa + gl, textures include
   intergranular, granular, microcrystalline, intersertal.
   special varieties:
   a. sieve texture and green-core cpx p and mp.
   b. abundant cpx and plag mp.
   c. abundant ol, plag, cpx mp.
   d. abundant ol and cpx mp.
   e. abundant cpx p, cpx = ol.

   >1% ol + plag p, ol>plag or plag>ol.
   Matrix is composed of plag + cpx + ol + opa + gl, textures include
   intergranular, granular, locally ophitic.
   special varieties:
   a. abundant ol and plag mp.
   b. ophitic matrix.
   c. subporphyritic.

   >1% ol + cpx + plag p, variable proportions of p, plag p are
   euhedral.
   Matrix is composed of plag + cpx + ol + opa + gl, textures include
   intergranular, granular, hyalocristalline, intersertal.
   special varieties:
   a. plag p display sieve texture.
   b. cpx p and mp display sieve texture.
   c. green-core cpx p.

5. Aphyric to subporphyritic basalt.
   <1% p of any type to rare p.
   Composed of plag + cpx + ol + opa, texture is intergranular.

6. Picritic basalt. (none in Mormon Lake quad)
   >15% ol + cpx p, ol>cpx, local brown spinel.
   Matrix is composed of plag + cpx + ol + opa +/-analcime, textures are granular
   and intergranular.
   special varieties:
   a. cpx > or = ol.
   b. feldspathoid (?) in matrix.
7. Olivine-clinopyroxene basalt. (none in Mormon Lake quad)
   >1% cpx + ol p, cpx>ol, ol-cpx and cpx glomerocrysts display rosette texture,
   abundant cpx as mp and in matrix along with plag, opa, and analcime, textures
   include granular and microcrystalline.

8. Feldspathoidal basalt (basanite). (none in Mormon Lake quad)
   >1% ol + cpx p, ol and cpx mp, feldspathoid (apparently analcime) in matrix
   along with plag + cpx + ol + opa, cpx displays strong violet-tan color, textures
   include granular and microcrystalline.

9. Olivine melanephelinite. (none in Mormon Lake quad)
   very abundant ol mp and p, sparse cpx p; matrix is dense, aphanitic, and very dark
   gray to black (in contrast to most basalts that are medium to dark gray); very
   abundant granular cpx in matrix along with nepheline + analcime + ol + plag +
   opa + biotite + apatite.

10. Hybrid basaltic andesite. (none in Mormon Lake quad)
    >1% plag + cpx p, cpx > plag, ol mp, presence of hornblende p displaying sieve
    texture and reaction to opaque oxide, may contain quartz with cpx reaction rim
    and abundant sieve texture plag p. Matrix rich in plag.

13-18. Feldspathoidal phanerites. (none in Mormon Lake quad)
   use QAPF diagram of International Union of Geological Sciences Subcommission
   on the Systematics of Igneous Rocks (Le Maitre, 1989).

19. Lamprophyre (minette). (none in Mormon Lake quad)
    >1% cpx + phl +/- ol p, K-feldspar in matrix.

    (none in Mormon Lake quad)
    >1% cpx + hbl + plag p.

    >1% hbl + plag p.
    Matrix is composed of plag + pyx + opa, textures include intergranular,
    microcrystalline, hypocrystalline, trachytic.

22. Clinopyroxene-orthopyroxene-hornblende-plagioclase andesite.
    (none in Mormon Lake quad)
    >1% cpx + opx + hbl + plag p.
23. Clinopyroxene-hornblende andesite.
   >1% cpx + hbl p.
   Matrix is composed of plag + pyx + opa + gl, textures include microcrystalline,
   intergranular, hypocrystalline, trachytic.

   >1% hbl + plag p.
   Matrix is composed of plag + pyx + opa + gl, texture is hyalopilitic.

31. Orthopyroxene clinopyroxene-hornblende dacite.
   >1% opx + cpx + hbl p, opx < cpx < hbl.
   Matrix is composed of plag + pyx + opa + gl, textures include intersertal,
   hyalopilitic, trachytic.

32. Orthopyroxene-clinopyroxene dacite.
   >1% opx + cpx p, opx < cpx.
   Matrix is composed of plag + pyx + opa + gl or alkali feldspar, textures include
   intersertal, hyalopilitic, microcrystalline, trachytic.

40. Hornblende-plagioclase rhyolite.
   (none on Mormon Lake quad)
   >1% hbl + plag p.

50. Ultramafic and gabbroic xenoliths.
   (none on Mormon Lake quad)

60. Granitic and granulitic xenoliths.
   (none on Mormon Lake quad)

Miscellaneous:
quartz crystals, generally 0.5 to 3 mm in diameter, are common in basalt types 2
and 4, scattered in types 5 and 6, and uncommon in type 1; quartz crystals
typically display a reaction rim of clinopyroxene. Atoll-texture of
clinopyroxene records former presence of quartz.
CHEMICAL CLASSIFICATION FOR VOLCANIC ROCKS IN THE MORMON VOLCANIC FIELD

1. Volcanic rocks in the Mormon volcanic field are classified with the total alkali-silica (TAS) diagram recommended by the International Union of Geological Sciences Subcommission on the Systematics of Igneous Rocks (Le Bas and others, 1986). Some of the suggestions by Wilkinson (1986) are incorporated in the subdivision of the mafic rocks.

2. Most of the volcanic rocks in the field are basaltic in composition. Basalts are regarded as containing 45-52 weight percent SiO₂ (normalized), and normative An-content (100an/(an+ab)) greater than 50. The following basalt types are defined on the basis of CIPW normative compositions:

   a. quartz subalkali basalt: norm Q > 0
   b. subalkali basalt: norm ol, di/hy < 2 (generally hy > 9)
   c. transitional basalt: norm ol, di/hy > 2 (generally hy < 9)
   d. alkali basalt: norm ne > 0, to 5
   e. basanitic alkali basalt: norm ne > 5
   f. basanite: modal feldspathoid, norm ab > 5, norm ne < 20, (irregardless of SiO₂) (prefix "hawaiitic" if An-content < 50 and Na₂O+K₂O < 5 )

3. For trachybasalt, S₁ (Na₂O+K₂O > 5):

   a. use "hawaiite", but only if An-content < 50;
   b. use terms a - f above in 2. if An-content > 50;
   c. prefix "ne-" to hawaiite if nepheline in norm;
   d. prefix "hy-" to hawaiite if hypersthene in norm.

4. Criteria for hybrid basalt:
   a. Presence of quartz xenocrysts with clinopyroxene reaction rims or atoll clinopyroxenes or both.
   b. Typical Mg-number but low normative An-content for basalt.
   c. Ni and Ti abundances typical for basalt.
   d. Relatively low CaO, FeO, MgO for basalt.
   e. Relatively high SiO₂, Na₂O, K₂O for basalt.
   Note: because of quartz xenocrysts some hybrid basalts may plot in the basaltic andesite or basaltic trachyandesite fields on the TAS diagram.
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¹ Table 1: X-ray fluorescence analyses of lavas from the Mormon Lake quadrangle, Arizona

² Major-element analyses, weight percent

³ C.I.P.W. normative minerals

4 Subalkaline, transitional, alkali, basanitic, alkali basalt

5 C.I.P.W. normative minerals: ap = amphibole, il = ilmenite, mt = magnetite, or = orthoclase, ab = albite, hy = hornblende, ol = olivine, ne = nepheline, c = clinopyroxene, o = orthopyroxene.
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**C.I.P.W. normative minerals**

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<td>1</td>
<td>8</td>
<td>27</td>
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<tr>
<td>Ba</td>
<td>-</td>
<td>-</td>
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<td>696</td>
<td>830</td>
<td>790</td>
<td></td>
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Mg-number<sup>6</sup> 63  44  51  31  61  66  68  67
An-content<sup>7</sup> 63  26  28  37  54  53  61  35

<sup>2</sup>Analysis by W. Plueger, Institut fur Mineralogie und Lagerstattenlehre, RWTH, Aachen, Germany.
<sup>3</sup>See Lithologic classification for Mormon volcanic field.
<sup>4</sup>See Chemical classification for Mormon volcanic field.
<sup>5</sup>Calculated from reported values normalized to 100 percent on volatile-free basis and hypothetical values of FeO and Fe2O3 determined according to the relationship: FeO/Fe2O3=9.627-0.0921xSiO2. This relationship is based on the ratio of FeO to Fe2O3 in the 15 least oxidized of 599 rocks ranging from basalt to rhyolite in the San Francisco volcanic field, Arizona for which both FeO and Fe2O3 were analyzed (Wolfe and others, 1987).
<sup>6</sup>100Mg2+/(Mg2++Fe2+) with all iron as FeO.
<sup>7</sup>100An/(An+Ab).
<sup>8</sup>Vent is on Hutch Mountain quadrangle.
TABLE 2. INAA values for selected trace- and rare-earth elements of lavas from the Mormon Lake quadrangle, Arizona

(Values are in parts per million)

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>7-1</th>
<th>17-1</th>
<th>19-1</th>
<th>24-1</th>
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<td>0.339</td>
<td>0.579</td>
<td>0.625</td>
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<td>0.690</td>
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<td>1.01</td>
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</table>

1Analysis by D.M. McKown, U. S. Geological Survey, Lakewood, CO
ACKNOWLEDGEMENTS

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REFERENCES


