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TO: Alex Schriener

FM: Brian P. Hausback *Brian Hausback*

RE: SURFICIAL GEOLOGY OF THE MEDICINE LAKE HIGHLAND

INTRODUCTION

Medicine Lake Highland is a youthful volcanic complex lying in northeastern California, 35 miles northeast of Mount Shasta (figure 1). The Highland lies in the portion of the Tertiary to Recent Cascade volcanic arc that stretches from British Columbia to Mt. Lassen in California. This younger portion of the Cascade range is a north to south-trending narrow line of volcaniclastic-dominated strato-volcanoes including such peaks as Mt. Shasta, Mt. St. Helens, and Mt. Rainier. The Medicine Lake Highland is one of three strikingly similar Quaternary lava flow-dominated shield-like volcanic systems lying on the east side of the chain of major strato-volcanoes. The other two are Newberry Volcano in Oregon and the Simco Volcanics in Washington.

The goal of this study was to produce a geologic map (plate 1) and report outlining the surficial geology of the central Medicine Lake Highland in order to guide future geothermal exploration in the area.

PREVIOUS STUDIES

The first comprehensive geologic study in the Medicine Lake Highland was by Charles Anderson (1941) who mapped the area in reconaissance and outlined the general stratigraphy upon which all successive work has been based. Recently, there has been abundant interest in the area and the attached bibliography summarizes these works. Of particular interest to the surficial mapping are studies by Mertzman (1977b), several bachelor theses (Burnell, 1974; Hackett, 1974; Huffman, 1981; Hughes, 1974; Thomas, 1981; Walter, 1975; Weaver, 1976) completed at Franklin and Marshall College, Pennsylvania under the guidance of Mertzman, as well as studies by Fink (1983a).

Presently, Julie Donnelly-Nolan of the U. S. Geological Survey is mapping the Highland in detail but this work will not be available for a couple of years.

REGIONAL GEOLOGY

Basement rocks are nowhere exposed in the Medicine Lake Highland. Regional outcrop and structural trends would suggest one of two basement types: Sierran granitic rocks or Klamath terrane rocks (metavolcanics, metasediments, ultramatics, serpentinites, granitics). The type of basement underlying the Highland is suggested by xenoliths found in the extrusive rocks. These include granitic and gneissic rocks suggesting a Sierran basement; no xenoliths were found to represent any of the distinctive Klamath Terrain suite of rocks.

The oldest rocks surficially exposed adjacent to the Medicine Lake Highland is the Cedarville Series (Anderson, 1941), a set of lavas and pyroclastics of late Tertiary age. Directly overlying the Cedarville Series is the Warner Basalt, a voluminous set of high-alumina olivine basalts spread over much of the Modoc Plateau region (Alturas Sheet, CDMG, 1958). One K-Ar date on a Warner Basalt by Thompson (1981) yielded about 1 m.y.. The Medicine Lake volcanic edifice is apparently built on the plateau of Warner Basalt. Neither the Cedarville Series nor Warner Basalt were encountered within the mapped area (plate 1).

Overlying the Warner Basalt-dominated Modoc Plateau is a belt of Pleistocene to Recent volcanic rocks stretching from Mt. Shasta to Medicine Lake. The transition between the stratovolcanic rocks of Mt. Shasta and the shield volcanic series at Medicine Lake has not been studied, hence the relationship between these two closely-spaced volcanic edifices is still not understood.

STRATIGRAPHY OF THE MEDICINE LAKE HIGHLAND

General Statement

At 600 km^3, the Medicine Lake extrusive system is the largest of the Cascade volcanoes, the next largest being its neighbor, Mt. Shasta (Julie Donnelly-Nolan, personal communication). Stratovolcanoes such as Mt. Shasta typically form steep-sided cones composed of intercalated pyroclastics and lavas of strongly porphyritic andesites and dacites (including minor rhyolite and basalt) with typical phenocryst assemblages of plagioclase, hornblende, pyroxene, quartz and sanidine. In comparison, the Medicine Lake Highland is a flattened shield-shaped mountain, with a central basin morphologically reminicent of the collapsed caldera at Oregon's Newberry Volcano and is composed almost entirely of lava flows with a complete range from rhyolite to basalt (figure 2). As opposed to the strato-volcano rocks, Medicine Lake intermediate-composition lavas contain fewer and much finer-grained phenocrysts. None of the Medicine Lake lavas contain quartz or hydrous phenocrysts (e. g. biotite, hornblende). The likely explanation for the limited phenocryst assemblages Medicine Lake is that the magmas were erupted at relatively high temperatures. The temperatures of the silicic lavas must have been higher than the quartz liquidus and hot enough to preclude the crystallization of hydrous phenocrysts, above about 870°C (Maaloe and Wyllie, 1975; Naney, 1982).

Anderson (1941) pointed out a general lack of basaltic rocks in the central Medicine Lake Highland. This central paucity of basalts has been noted at several large volcanic systems and is termed a basaltic shadow zone. It is generally attributed to the existence of a silicic, at least partially molten, magma chamber. Basaltic liquids cannot rise through molten or plastic rhyolitic magmas because of the large density contrast.

Hornblende Rhyolite Obsidian

The oldest unit on the periphery of the Medicine Lake Highland is a set of hornblende-bearing rhyolites. These rhyolites occur only on the west side of the mapped area (plate 1). On the southeast flank of Red Cap Mtn. this unit appears as dense, black, poorly-outcropping glassy porphyritic rhyolite (plagioclase + sanidine? hornblende) and has been dated at the summit of Red Cap Mtn. at 1.01 $\pm$ 0.05 m.y. (Mertzman, 1982). On the southeast side of Dock Well there are two exposures of similar, but entirely devitrified, rhyolite with an age of 1.18 $\pm$ 0.06 m.y. (Mertzman, 1982). These exposures may represent either old lava flows, domes or extremely shallow intrusive stocks. These silicic bodies are the only rocks in the Medicine Lake Highland found to contain hydrous phenocrysts and thus their genetic relationship to the Recent Medicine Lake magmatic system is probably remote.

Old Rhyolite, Dacite; Rampart Andesite and Basalt

Situated along the periphery of the Highland are a series of rhyolite, dacite, andesite and basalt exposures that appear to be the oldest lavas of Medicine Lake affinity. The Old Rhyolite and Dacite members are typically black glassy flow-banded lavas, either aphyric or with minor plagioclase and pyroxene phenocrysts. Most exposures appear to be flows overlain by Shield Basalts and Andesites, however, the Old Dacite exposed southwest of Schonkin Spring is an elongate body with consistently-oriented internal foliations suggesting that it is a large dike-like body intruding a Shield Basalt exposure. K-Ar dates on the old rhyolites range from 0.61 to 0.33 m.y. (Mertzman, 1982; refer to Explanation Sheet of Plate 1).

The Shield Andesites and Basalts are typically younger than the Old Rhyolites and are exposed almost exclusively along the foot of the Highland. These basic to intermediate lavas have flow fronts with subdued to rounded topographic expressions compared with younger lavas. This is probably due to the subsequent deposition of the widespread Andesite Tuff, which created a topographic smoothing effect, covering-up craggy surfaces and filling-in topographic depressions.

Andesite Tuff

The Andesite Tuff directly overlies the older sequence of rhyolite to basalt flows. This distinctive gray-colored (red to orange when weathered) scoriacious ash flow tuff covers a large area on the northwest flank of the volcano and is the only marker bed in the older Medicine Lake stratigraphy. It is a poorly exposed unit since it deposited principally in topographic depressions. In outcrop it breaks into large tabular blocks displaying densely welded to completely unwelded textures.

Anderson (1941) reported that the Andesite Tuff underlies the Medicine Lake volcanic stratigraphy, however, one small, possibly resurgent, exposure within the Medicine Lake depression indicates that the tuff was erupted from the Medicine Lake magmatic system. Examination of the size distribution of the maximum lithic clast incorporated in the tuff (figure 3) shows a systematic decrease in size to the northwest, indicating a northwest transport direction from the vicinity of Medicine Lake, where the maximum size lithic was encountered. Donnelly-Nolan (1983) estimated a rough volume of about 2 km^3 based on rather tenuous thickness control (she used an average thickness of 20 feet). This small volume estimate would not allow for much of a caldera collapse. However, the distribution of Rampart Andesite eruptive centers along an elliptical arc (plate 1) surrounding Medicine Lake (active immediately following the Andesite Tuff eruption and covering up any ring-fractures) indicates that there was a ring-fracturing event associated with the Andesite Tuff eruption, whether or not any measurable caldera collapse actually occurred.

Rampart Andesites

The most common unit encountered in the Medicine Lake region is the crystal-poor Rampart Andesites. These voluminous flows issued from an elliptical set of vents surrounding Medicine Lake as well as several peripheral vents on the northerly and southerly slopes of the Highland. These flows directly overlie the Andesite Tuff and retain distinct flow morphology in areas that have not been glaciated. The flows compose a section of at least 120 feet thick along the northwestern Highland rim and it is probable that the true thickness is several times greater. Individual flows have distinctive platy-jointed interiors and massive to vesicular tops. The platy-joints are generally subhorizontal but commonly fold and swirl, suggesting that they follow flow-generated shear surfaces. The strike of these joints (and the fold axes of intraflow folds) are roughly perpendicular to the direction of local flow. Mertzman (1981, 1977) reports two K-Ar dates on these andesitic lavas of 0.21 ± 0.05 m.y. and 0.07 ± 0.04 m.y. These K-Ar dates analysed by Mertzman are suspect for several reasons:

1. Potassium analyses were attained from XRF procedures, a highly inaccurate, low precision method.

2. Sample splits were taken for potassium analysis prior to treating the remaining sample for argon analysis. Treating the K-split with different preparatory acids than the corresponding Ar-split introduces inhomogeneity into the sample.

3. Whole rock samples were heated to 250°C prior to argon extraction. Temperatures in excess of 100°C are well known to change the original argon isotopic abundances in whole rock samples and give spurious dates, some too old, some too young (McDougall, et al., 1976; Robert Drake, personal communication).

Post Rampart Andesite Eruptive Units

Following, and in part overlapping with, the voluminous Rampart Andesite eruptions, the Medicine Lake magmatic system substantially diversified, producing numerous flows of various lithologies and textures. These flows are primarily aligned along three major linear zones on the Highland (discussed in the Structure section).

This post Andesite Tuff eruptive sequence is primarily composed of basalt through basaltic andesite with several voluminous rhyolitic to dacitic lavas. There appears to be a compositional gap at the intermediate composition series-andesite (see Correlation Chart with explanation to plate 1). Several of these younger units will be discussed here; for more comprehensive descriptions see the explanation to plate 1.

Lake Basalt

Three notable exceptions to the "basaltic shadow zone" in the central Highland are the young Lake Basalt and the Modoc basalts at Little Mt. Hoffman and the southwest foot of Mt. Hoffman. These occurrences cast doubt on the existence of a large Holocene silicic molten chamber beneath Medicine Lake.

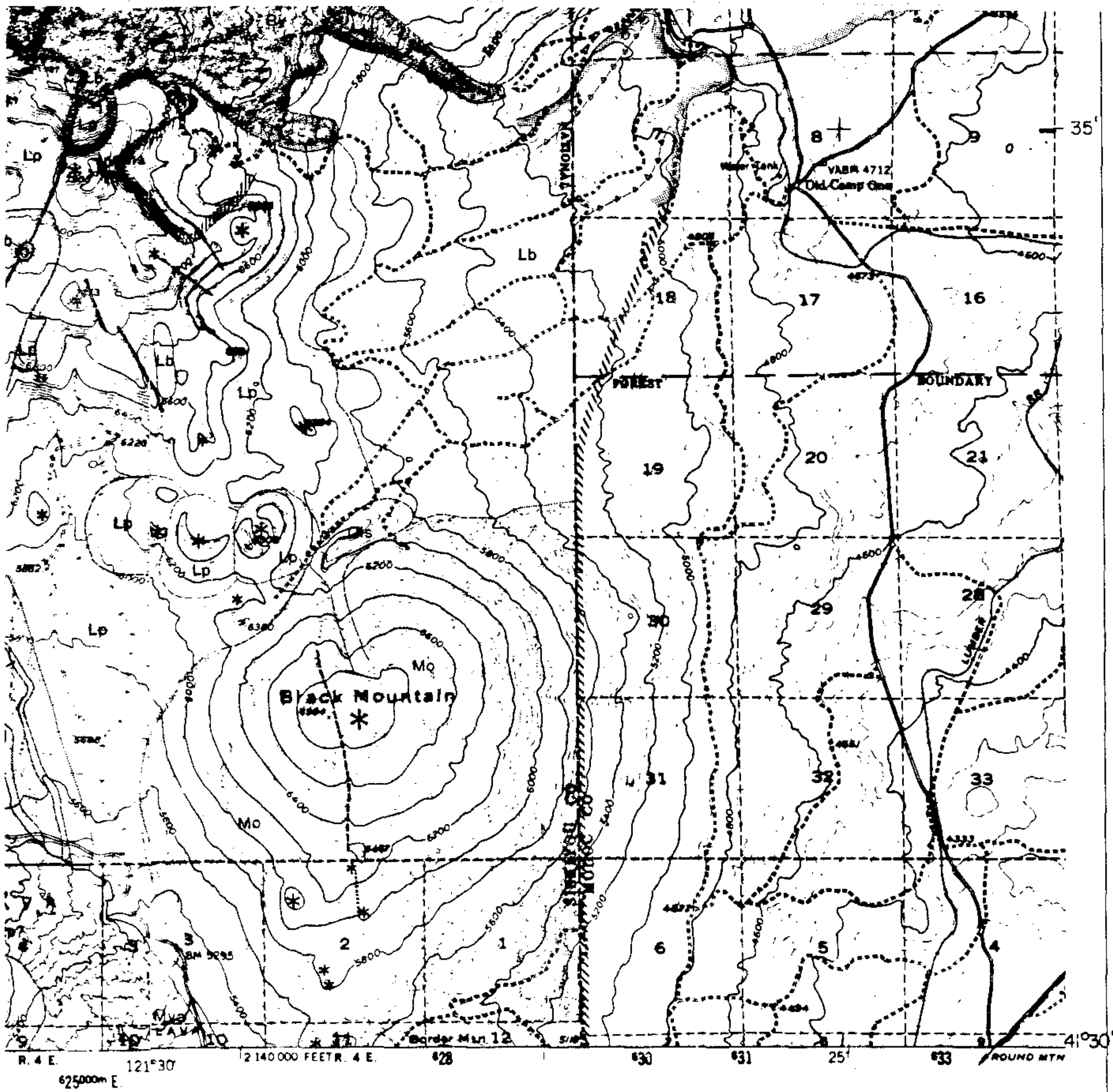
The Lake Basalt is a voluminous sequence of olivine basalt flows that erupted primarily from the area of Lyons Peak with two eruptive cones to the west within the Medicine Lake basin itself. The highest occurrence of the basalt is on the southwest flank of Lyons Peak but the original eruptive cones are covered by a younger sequence of basaltic andesites. The flows are draped over the eastern rim of the basin and flowed far down the flank of the Highland.

Older Modoc Lavas

Subsequent to the Lake Basalt a sequence of medium-grained diktytaxitic high-alumina basalts vented from numerous cones situated primarily on the flanks of the Highland and concentrated in the northeastern sector. Most of these eruptive vents retain a very sharp cone morphology since they largely postdate the Pleistocene glaciation. Texturally and chemically thes basalts are indestinguishable from the older Warner Basalt series.

Fissure-Erupted Basaltic Andesite

An unusual eruptive event at Medicine Lake vented andesitic to basaltic tephra from a major fracture zone trending southwest from Lyons Peak. The resultant poorly sorted tephra unit mantles the topography for a mile around the fracture zone. Subsequent to the tephra eruption, and probably during the last stages of it, numerous violent explosions occurred along the fracture zone creating large (up to 200 feet deep) craters (figure 4). These explosions cut through the agglutinated tephra, locally ejecting blocks of underlying Lake Basalt up to 10 feet or more in average diameter (figure 5) out of the craters onto the surrounding surface.



REVISIONS	
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	UNION OIL COMPANY OF CALIFORNIA - GEOTHERMAL DIVISION
	GLASS MOUNTAIN PROSPECT
	GEOLOGIC MAP OF THE
	MEDICINE LAKE HIGHLAND, CALIFORNIA
	BY BRIAN P. HAUSBACK
	MARCH 1984
	SISKIYOU COUNTY, CALIFORNIA
	Scale 1:62500 DRAWN: DANA WILLIS April, 1983

Origl color map in
File GmT 916-1

Youngest Bimodal Volcanism

The youngest eruptive phase at Medicine Lake consists of a bimodal eruption sequence of obsidian flows and Young Modoc basalts and basaltic andesites along the Little Glass Mountain and Glass Mountain structural trends. The basic members of this sequence are confined to the periphery of the Highland.

The youngest of these units are high silica rhyolite obsidian flows at Glass Mountain and Little Glass Mountain (both with several smaller satellite vents). The pumice tephra deposits associated with the obsidian flows were dated at about 1000 years by ^{14}C methods (Chesterman, 1955; Luedke and Smith, 1981). Based on tephra chronologic studies by Heiken (1981), Glass Mountain is the youngest unit and immediately postdates the eruption of Little Glass Mountain which, in turn, postdates basaltic eruptions probably from Cinder Butte and/or High Hole Crater.

Along the Glass Mountain structural trend are two distinct parallel lines of obsidian domes and flows. The southwestern line of vents is slightly older than the northeastern line of rhyolite vents, (including Glass Mountain) and is composed entirely of dacites, including the Hoffman Dacite (Dy).

STRUCTURE

Medicine Lake Structural Setting

The Modoc Plateau is dominated by north-northwest trending Basin and Range normal faults. The Medicine Lake edifice covers most of these faults and thus, in large part, postdates their activity. However, these older structures continue to act as deep crustal zones of weakness allowing magma to vent along them. The relative ease of magma rise along these zones may be the reason for the higher temperatures of magma at Medicine Lake compared to Mt. Shasta to the west.

There are two main orientations of structures in the Medicine Lake Highland: northwest and northeast. The Glass Mountain structure trends about N20W and is defined by the alignment of vents from Black Mountain to the south through the parallel vents of Glass Moutain and the Hoffman Dacite flow, and extending northward through aligned Older Modoc cinder cones to the prominent Basin and Range Gillem Fault (figure 6) in the Lava Beds National Monument. The high relief of the abrupt eastern margin of the Medicine Lake Highland over the Modoc Plateau can be attributed to normal faulting along this structure occurring either before or during the Pleistocene eruptive period.

Little Glass Mountain Structural Trend

The other major orientation of structures and alignment of volcanic vents is about N30E. There are two zones following this orientation: the Little Glass Mountain and Lyons Peak Structural Trends. These zones do not extend into the surrounding regional structural pattern, suggesting that their formation is peculiar to the stress field associated with magma rise at Medicine Lake.

The Little Glass Mountain Structural Trend is defined by alignment of obsidian domes, and other more basic eruptive units young ground fissures. Along this structural trend the sequence of formation is: basaltic vent eruptions, pumice tephra eruptions and formation of local explosion craters, ground fissuring, and finally, the extrusion of the obsidian domes (from the same vents that issued the pumice tephra). Much of this activity (tephra eruptions, ground fissuring and dome extrusions) was nearly synchronous and took place about 1000 years ago.

The ground fissures (figure 7) along this trend are believed by Fink (1983) to have formed from the near-surface approach of silicic dikes. The cracks have dilitational opening patterns up to 12 feet wide and greater than 30 feet deep and seem to be associated with local topographic bulges. The extrusion of obsidian domes directly from these fissures is strong evidence that these structures have formed from the upward-shouldering of silicic magma along this northeasterly trending zone.

Lyons Peak Structural Trend

Parallel to the Little Glass Mountain structure is a set of ground fissures and prominent explosion craters southwest of Lyons Peak. This zone lacks any silicic extrusions but was the locus of a basalt flow along its southerly extension and the eruption of a tephra of andesitic basalt (detailed in stratigraphy section) on the southwest flank of Lyons Peak. This set of structures and associated eruptive units immediately predates the 1000 year old pumice tephra erupted from Glass Mountain.

Other Structures

One other set of faults cuts east-west across Medicine Mountain on the south side of the Highland and to the west of Fourmile Hill on the north side of the Highland. These linear topographic escarpments are too high to be flow fronts and do not have the arcuate morphology of glacial cirques. They tend to downdrop the outside of the central Highland possibly suggesting that they are resurgent structures associated with the central 'caldera'.

SURFICIAL ALTERATION

Surface exposures displaying hydrothermal alteration are rare in the Medicine Lake Highland. This is conceivably due to the masking-effect that the widespread pumice tephra eruptions had on the area 1000 years ago. Nevertheless, through this young mantle there are two exposure displaying intense argillic hydrothermal alteration. The first and most prominent is the Hot Spot located on the Glass Mountain Structural Trend just northwest of Glass Mountain (plate 1). This is the only active zone of mild fumarolic activity in the Highland. At this locality the 1000 year old pumicious soil is thoroughly altered to clays. In the largest fumarole at this site a temperature of 168°F was recorded on July 25, 1983 by extending a thermometer 12 feet down into the vent. The other area of surficially exposed argillic alteration (and local silicification) is the area between Schonkin Springs and Crystal Springs, immediately west of Medicine Lake. This area is not an active hydrothermal zone but there are numerous localized occurences of argillically altered Andesite Tuff, Rampart Andesite, Shield Basalt and associated cinder deposits.

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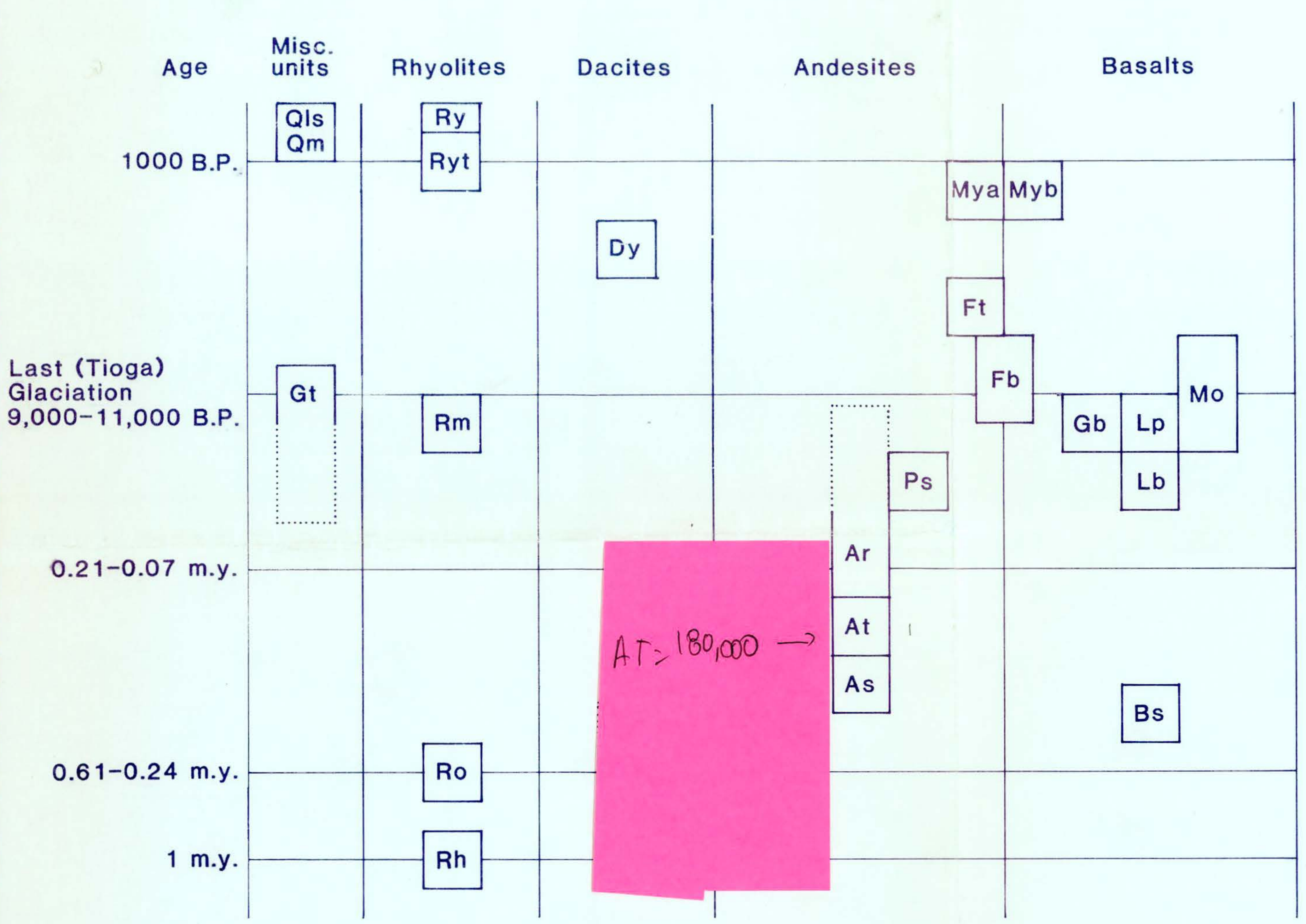
FIGURES

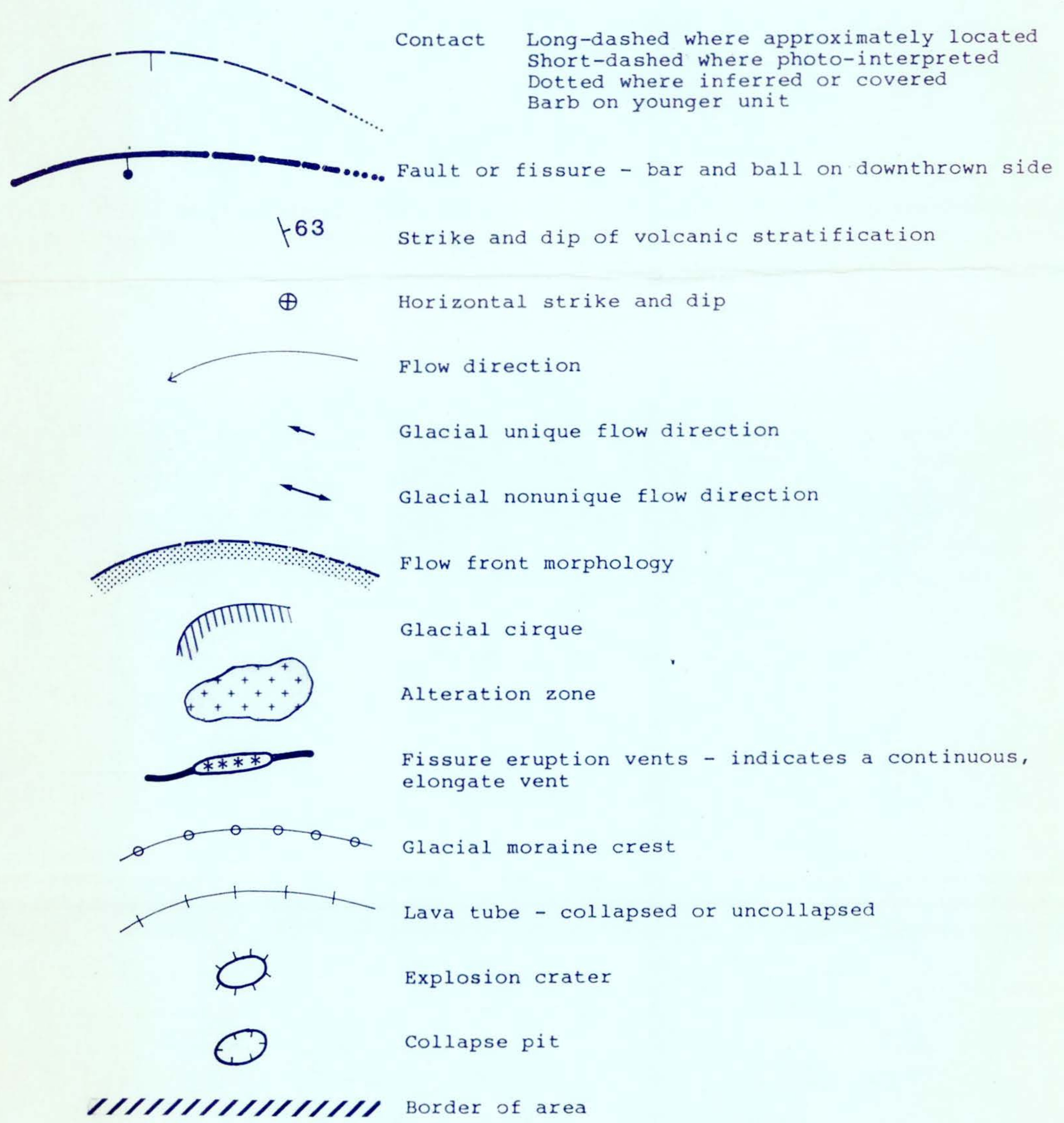
PLATE

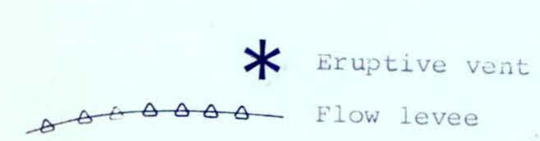
CORRELATION OF MAP UNITS



Wb Warner basalt

MAP SYMBOLS





UNIT DESCRIPTIONS

Qls Qm — Recent landslide and mudflow deposits.

Ry — Young Rhyolitic Glass Flows.
Coulee-type high-viscosity lava flows of black glass with extremely young flow morphology. Obsidians on the eastern side of Medicine Lake are aphyric while the flows to the west contain 2-5% plagioclase phenocrysts.

Rt — Young Rhyolitic Near-Source Agglutinated Pumicious Tephra.
Tephra rings of pumice surrounding the smaller glass flows; contain blocks up to 2 feet diameter of white angular pumice with local pink tuffaceous interblock groundmass. Locally the blocks have glazed exteriors and indicate an airfall origin; also locally, the stratified pumice ring deposit is welded to dense black glass. Heavy distal pumice concentration at Arnica Sink is included in Rt designation; overlain only by young rhyolitic glass flows; C-14 age on pumice tephra of Glass Mountain 1360 ± 240 yrs. B. P. (Chesterman, 1955).

Mya Myb — Young Modoc Basalt and Andesite.
Youthful cone and flow morphology with little soil development and few trees growing on these dark gray to black craggy aa and, locally, pahoehoe flows; microcrystalline, locally diktytaxitic groundmass with 0-10% phenocrysts of plagioclase, olivine and clinopyroxene. The Paint Pot Crater flow and the Callahan flow are high-alumina basalts while the Burnt lava flow is a basaltic-andesite (55.5% SiO_2). C-14 date on the Callahan Flow 1100 yrs. B. P. (Julie Donnelly-Nolan, person communication); C-14 dates on the Burnt Lava Flow are 200 ± 200 yrs. B. P. (Luedke and Smith, 1981). However, the Burnt Lava Flow is sprinkled with pumice airfall from Glass Mountain or Little Glass Mountain, as are all of the young Modoc flows, and is therefore > 1000 yrs. B. P.

Dy — Young Dacite Flows.
Gray to brown waxy-luster glassy dacite lavas; dacite on the northeast of Mt. Hoffman is 30% porphyritic with phenocrysts of plagioclase ≫ orthopyroxene(?); this body and the larger Hoffman Dacite to the southeast are very lithic-rich with numerous clasts of frothy to dense andesite, commonly associated with large vesicles; overlain only by Glass Mountain pumice airfall.

Ft — Fissure-Erupted Andesite Tephra.
Burnt-chocolate-brown angular scoria block to lapilli andesite tephra and near-vent intertonguing glassy lavas; tephra contains frothy hair-like fibers of glass(?) Next to the fissure-vents the tephra has locally incorporated lithic blocks as large as 20 feet in diameter; overlies glacial till; overlain by pumice from Glass Mountain. At the north end of the large explosion crater southwest of Lyons Peak the glassy andesite flow and tephra can be seen frozen in the act of emerging from the fissure.

Gt — Glacial Till.
Matrix supported unsorted boulder to sand deposit of varying lithologies; subrounded, locally striated clasts; matrix has a light purple color probably due to an abundance of incorporated cinder; forms local morainal-ridge topography; overlain by fissure-erupted andesitic tephra.

Fb — Fissure-Erupted Basalt or Andesite.
Elongate fissure-vented black, weathered red-brown, scoria: consists of bomb and lapilli spatter; vents align with north to northeast-trending fractures; typically very fluid ejecta forms dripstone and slag-like bombs; 1-20% fine-grained phenocrysts of plagioclase > olivine + clinopyroxene(?); most fissure eruptives have extremely youthful morphology and lack soil cover; the fissure eruptive 1 mile southwest of Shotgun Peak is a bit older with a well-developed soil cover and lacks vent morphology.

Rm — Mount Hoffman Rhyolite.
Crumbly black porphyritic vitric rhyolite flow 200-400 feet thick; retains most of its flow morphology but has been glaciated on its north flank. Foliated lava is locally flow-folded; 30% medium-grained phenocrysts of plagioclase ≫ orthopyroxene(?); local spherulitic devitrification; overlies older Modoc Basalts and Rampart Andesites; overlain by a young Dacite flow.

Mo — Older Modoc Lavas.
Well-preserved cinder cones and aa lavas of medium-gray diktytaxitic vesicular basalts; microcrystalline groundmass with 0-15% fine-grained phenocrysts of plagioclase = olivine + clinopyroxene; commonly glomeroporphyritic ; overlie Rampart Andesites and are overlain by young Modoc Lavas and the Mt. Hoffman Rhyolite.

Gb — Grasshopper Hill Basalts.
Scoriacious red-brown to black strombolian spatter cones and minor flows of high-alumina basalt; aphanitic groundmass with 2-12% fine-grained phenocrysts of plagioclase > olivine + clinopyroxene. Small spatter agglutinate cone on the north side of Grasshopper Flat has a central collapse(?) crater.

Lp — Lyons Peak to Shotgun Peak Basalts and Basaltic Andesites.
Primarily spatter and bomb strombolian cinder cones with local black crystal-poor glassy thin (< 50 feet) basalt to basaltic andesite flows; about 1-2% fine-grained phenocrysts of plagioclase > clinpyroxene + olivine; overlies Lake Basalt and, probably, the Black Mountain older Modoc cone.

Lb — Lake Basalt.
Dense medium-gray massive lava flows up to 120 feet thick with red scoriacious flow top (where not glacially removed) and platy-jointed base of porphyritic high-alumina basalt; 30-40% medium-grained phenocrysts of plagioclase > olivine + clinopyroxene. Overlies Rampart Andesite and is overlain by the Lyons Peak Basaltic Andesites; probably erupted from proto-Lyons Peak-Red Shale Butte edifice.

Ps — Pumice Stone Mountain Andesites.
Cones with highly subdued vent morphology of medium-gray to light-brown massive holocrystalline(?) lavas; 40-50% fine-grained phenocrysts of plagioclase olivine + clinopyroxene; overlies Rampart Andesites on the north and has an unclear contact with Andesite Tuff on the south; overlain by Old Modoc flows.

Ar — Rampart Andesites.
Flows of largely nonvesicular flow-laminated platy-jointed (parallel to flow laminations) crystal poor andesite with vesicular to scoriacious flow tops and intraflow agglutinated scoria lenses; near source lavas are commonly altered to a red and purple stain of fine-grained hematite(?) with uncommon specularite found on crack surfaces; sources are typically spindle-bomb-laden strombolian cinder cones; aphanitic-stony, locally glassy groundmass with typically < 1% phenocrysts of plagioclase > olivine ± clinopyroxene; overlies the Andesite Tuff and an Old Modoc flow just southwest of the Callahan flow; K-Ar dates of 0.21 ± 0.005 my (Mertzman, 1981) and 0.07 ± 0.04 my (Mertzman, 1977); probably at least 1000 feet thick on the north and south rims of the Medicine Lake basin.

At — Andesite Tuff
Ash-flow tuff with a maximum exposed thickness of 12 feet at the northern edge of the mapped area; eutaxitic texture varies from strongly-welded to punky-unwelded; gray, weathers red, poorly-sorted tuff with abundant dark-brown finely-vesiculated scoria lapilli and probably < 5% lithic fragments of basalts and andesites; groundmass with abundant phenocrysts, plagioclase > orthopyroxene(?). Overlies Shield Basalts and Andesites and is overlain by Rampart Andesites. Stratigraphic relationships tend to be very unclear as the ash-flow was primarily deposited in low-relief valley locations. Isopleth mapping on maximum lithic size indicates the Medicine Lake depression as the probable source with most of the flow emanating to the northwest.

As — Shield Andesite Flows.
Typically subdued low flow fronts and blocky flow surfaces; flow-laminated, non-vesicular andesites; crystal-poor, commonly black vitric goundmass; 1-3% phenocrysts plagioclase > olivine ± clinopyroxene; principally overlies Shield Basalts; overlain by a Shield-Basalt flow 2-1/2 miles north of Dock Well; also overlain by the Andesite Tuff and Older Modoc lavas.

Bs — Shield Basalts.
Craggy aa flows with local schollendome structures; medium-gray microcrystalline groundmass, locally diktytaxitic and microvesicular, porphyritic basalts; 5-30% phenocrysts with medium to fine-grained plagioclase > olivine, commonly glomeroporphyritic. Overlies a Shield Andesite flow north of Dock Well but is more commonly overlain by Shield Andesites.

Do — Old Dacites.
Black foliated porphyritic glassy dacite intrusive/extrusive bodies. Exposure SW of Schonchin Spring probably a narrow intrusive body cutting Shield Basalts; about 50% prophyritic with plagioclase orthopyroxene(?); overlain by Rampart Andesites. Exposure east of Dock Well is probably a dome or intrusive neck with numerous internal roughly vertical dikes striking N50-70W of black banded obsidian cutting though lithic-inclusion-rich obsidian; about 10% plagioclase phenocrysts; overlain by Rampart Andesites.

Ro — Old Rhyolitic Obsidians.
Large flow and domes with preserved flow-fronts at least 80 feet thick; primarily flow banded, devitrified (locally spherulitic on southeast side of the Callahan flow) banded aphyric obsidians; black and glassy in rare outcrops and float; overlain by Rampart Andesites; K-Ar dates on these units are 0.61 ± 0.03 my, 0.33 ± 0.04 my, 0.43 ± 0.04 my, 0.24 ± 0.03 my (Mertzman, 1982).

Rh — Hornblende Rhyolite Obsidian.
Sparse outcrop of dense, black, glassy porphyritic lavas; contains about 15% plagioclase and about 1/2% hornblende. Exposure on the southeast side of Dock Well is completely devitrified; overlain by the Andesite Tuff; K-Ar age of the rhyolite at the summit of Red Cap Mountain 1.01 ± 0.05 my and 1.18 ± 0.06 my southeast of Dock Well (Mertzman, 1982)

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GEOTHERMAL DIVISION

EXPLANATION TO ACCOMPANY GEOLOGIC MAP OF THE MEDICINE LAKE HIGHLAND, CALIFORNIA

BY BRIAN P. HAUSBACK

SEPTEMBER 1983

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