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REPORT 27

STRATIGRAPHY OF THE TERTIARY ASH-FLOW TUFFS IN THE YERINGTON DISTRICT, NEVADA

BY JOHN M. PROFFETT JR. AND BETH H. PROFFETT

A detailed description and formal stratigraphic treatment of middle Tertiary ash-flow tuffs in the Yerington mining district, western Nevada.

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INTRODUCTION

In the Yerington district, Nevada (fig. 1), a thick sequence of Oligocene quartz latite to rhyolite ash-flow tuffs lies unconformably upon Mesozoic basement rocks. These ash-flow tuffs are overlain disconformably by a unit of dacite breccias and ash-flow tuffs, which in turn is overlain disconformably or possibly with minor angular unconformity by Miocene andesites. The Miocene andesites are unconformably overlain by 8 to 11 m.y. old fanglomerate and olivine basalt. As a result of extensive basin-and-range faulting and east-west extension along numerous curved, concave upward, east-dipping normal faults (Proffett, 1971a, 1972), the Tertiary section, as well as the pre-Tertiary basement, is now well exposed in a number of steeply west-tilted blocks. The Tertiary section has been divided into several map units by mapping such exposures in detail at a scale of 1 inch = 1000 feet. The areal distribution of units, and lateral variations within them were determined by detailed mapping of more than 80 square miles, by mapping core and cuttings from about 100,000 feet of drilling, and by reconnaissance work in surrounding areas. The units are grouped into genetically related formations and shown on a generalized map of the main part of the district (centerfold). Since many of the formations extend well beyond the Yerington district (fig. 1), it is thought that published descriptions and formally established names for the formations will be useful to others working in west central Nevada.

This paper will be concerned with that part of the Tertiary section which is mainly older than basin-and-range structure. Fanglomerate and basalt, dated 8 to 11 m.y. old (centerfold and fig. 2), deposited during basin-and-range faulting will not be described here.

The entire ash-flow tuff sequence in the Yerington district has been referred to as the Hartford Hill Rhyolite Tuff (Moore, 1969), a name first applied in the Virginia City area. Certain units of the Yerington section may be present in the lower part of the Hartford Hill Rhyolite Tuff near Virginia City, but the Hartford Hill includes many units dated at about 23 m.y., that are considerably younger than the Yerington ash-flow tuff section (Bonham, 1969). Since there are four distinct units in the Oligocene sequence at Yerington that have differing composition, distribution, and probably different sources, it has been necessary to establish new names for these units.

TERMINOLOGY

In this paper an age of 22.5 m.y. is used for the Oligocene-Miocene boundary (Turner, 1970). To avoid confusion, rocks that may be close to the Miocene-Pliocene boundary are referred to by their radiometric age.

The following rock names are used (Williams and others, 1955, p. 93, 121, 126). Rocks with 10 percent or more total quartz: *rhyolite* – alkali-feldspar comprises two-thirds or more of total feldspar; *quartz latite* – alkali-feldspar comprises one-third to two-thirds of total feldspar; *dacite* – alkali-feldspar comprises one-third or less of total feldspar. Rocks with less than 10 percent total quartz:

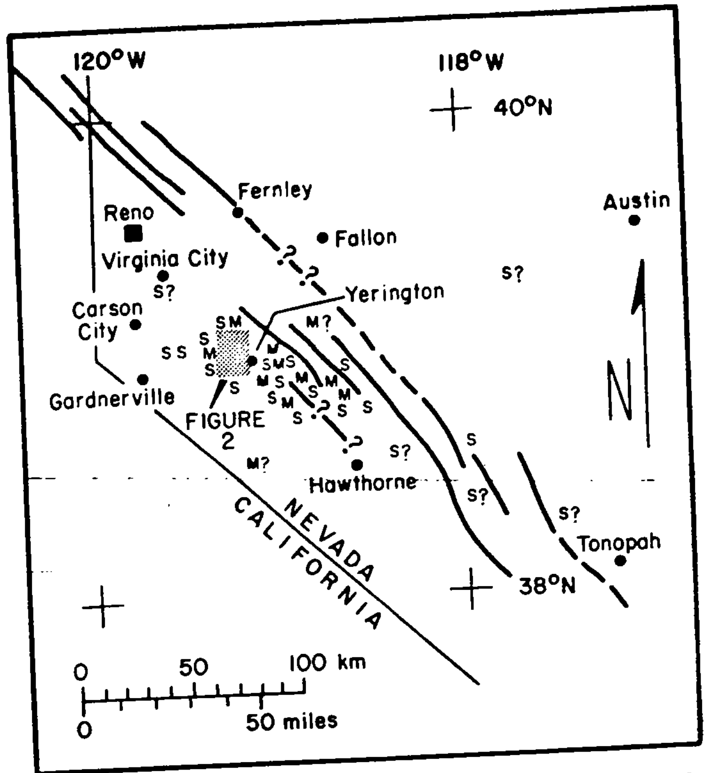


FIGURE 1. Map of part of west central Nevada showing location of centerfold. Also shown are other locations where the Mickey Pass Tuff (M) and Singatse Tuff (S) have been identified, or tentatively identified (M?, S?), and approximate locations of some right lateral Walker Lane faults (heavy lines). In most areas where Mickey Pass Tuff is shown, both members are present, except 30 miles south of Yerington (Nye Canyon) where only the upper part of the Guild Mine Member has been tentatively identified.

andesite – alkali-feldspar comprises one-third or less of total feldspar. "Total" quartz and feldspar as used here means phenocryst minerals plus groundmass minerals or normative minerals in rocks with an aphanitic groundmass. Certain groups of rocks are referred to by a single name even though the group may contain some rocks of other compositions, as for example the "Miocene andesite" group contains rocks on both sides of the andesite-dacite boundary. Some workers use a chemical classification that subdivides the dacite field into "rhyodacite" and "dacite". Therefore where chemical analyses are available and indicate a different rock name according to the O'Connor (1965, p. B82) classification, it will be indicated in this paper.

The division between *ash* (*tuff* if consolidated) and *lapilli* is 4 mm and that between *lapilli* and *blocks* (*volcanic breccia* if consolidated) is 32 mm (Williams and others, 1955). Tuff containing significant lapilli is *lapilli tuff* and that containing significant blocks is *tuff breccia*. The term *ash-flow tuff* will be used here in the sense defined by Ross and Smith (1961) to designate a rock deposited by a "nuee ardente" or "ash flow". As such the term "ash flow" may refer to mixtures of ash and lapilli or blocks as well as just ash, and the term "ash-flow tuff" may designate rocks that are lapilli tuff or tuff breccia as well as strictly tuff. Thus the term "ash-flow tuff" is equivalent to the more preferable term ignimbrite (E. Cook, 1955, 1965; Mackin,

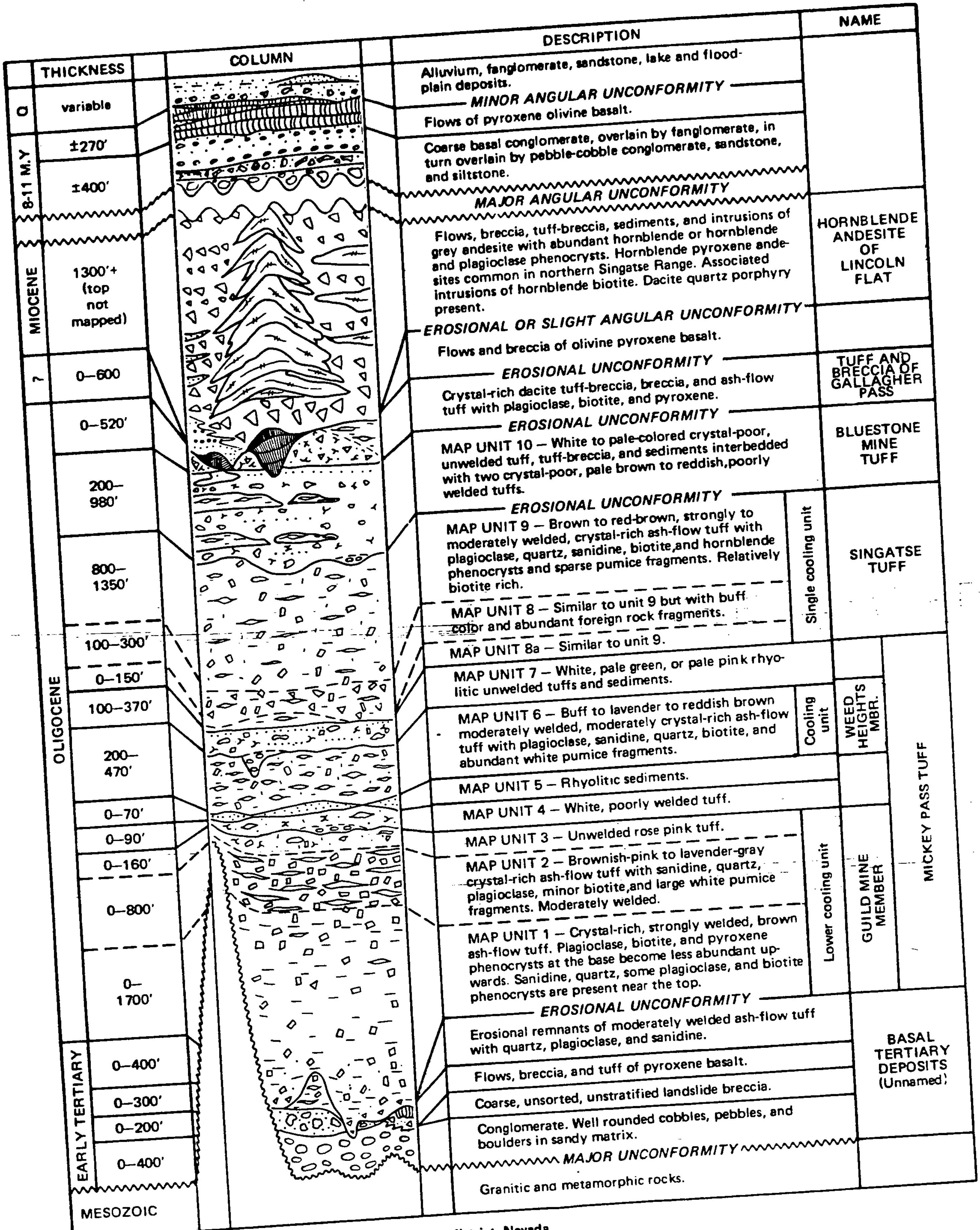


FIGURE 2. Tertiary stratigraphic section for the Yerington district, Nevada.

1960; H. Cook, 1968) but the former is used here to conform to widespread current usage.

ACKNOWLEDGMENTS

The work reported here was done between 1966 and 1971, and this paper is taken largely from reports written for the Anaconda Company during that time. Some of the Tertiary map units were defined earlier by R. Roy, J. R. Wilson and other former Anaconda geologists. During the course of the project some areas were mapped by R. F. Meyer, D. L. Gustafson, G. H. Ware, M. T. Einaudi, G. Salas, and D. A. Heatwole. The work also benefited from visits to the field and discussions with J. P. Hunt, C. Meyer, H. Williams, L. B. Gustafson, L. H. Knight, R. Seklemian and W. H. Swayne. The magnetic polarity of many of the units was determined by G. Secor and other Anaconda geophysicists. Drafts of the paper were read by Meyer, Williams, Hunt, E. C. Bingler, and H. F. Bohnam. Norms were calculated by a computer program provided by Stan Evans at the University of Utah.

BASAL TERTIARY DEPOSITS AND THE EARLY TERTIARY SURFACE

During early Tertiary and possibly Late Cretaceous time a widespread erosion surface was developed on the pre-Tertiary rocks of much of Nevada and eastern California (for example, Bateman and Wahrhaftig, 1966). The Oligocene ash-flow tuff sequence of the Yerington district was deposited upon this early Tertiary surface either directly or, as in the central and northwestern parts of the district, upon conglomerate and other basal Tertiary deposits which lie on the early Tertiary surface (centerfold and fig. 2).

Where the basal conglomerate occurs, it ranges in thickness up to 400 feet, but is usually between 100 and 250 feet thick. It consists of about 25 to 30 percent matrix which is composed of moderately consolidated, poorly sorted, coarse, angular sandstone and about 70 to 75 percent well-rounded to subrounded cobbles, coarse pebbles and boulders, in ill-defined beds 10 feet to more than 100 feet thick (fig. 8a). It is thought to be of fluviatile origin.

Pre-Tertiary rocks generally comprise about one fourth of the pebbles, cobbles, and boulders in the conglomerates. Many of these are of Jurassic granitic and volcanic rocks and Triassic metasediments and metavolcanics which were derived from the southern part of the district and the surrounding region. Rock types not found in the Yerington district, such as various types of chert, chert pebble conglomerate, and red quartzite are also present in the conglomerate and these are thought to have been derived from east of the Yerington district.

One-half to three-fourths of the cobbles, pebbles and boulders consist of nearly fresh pyroxene- or hornblende-andesite. Boulders and cobbles of basalt and silicic ash-flow tuff are less common. A K-Ar age date by Geochron of 28.8 m.y. was determined on biotite from an ash-flow tuff boulder. This would suggest an Oligocene age for at least part of the conglomerate, if it can be assumed that the K-Ar age was not reset by heat from the overlying ash flow of the Mickey Pass Tuff.

Locally the conglomerate is overlain by coarse, unsorted sedimentary breccia up to 200 feet thick. The fragments in the breccia are locally derived, and the breccia is thought to be of landslide origin.

Other basal Tertiary deposits include flows, breccia, and tuff, up to 350 feet thick, of pyroxene basalt, which locally is interbedded with and overlies the conglomerate in the north part of the district. The pyroxene basalt, as well as the andesite cobbles in the conglomerate, may represent predominantly andesitic volcanism that took place in regions to the north, northeast and east of the Yerington district, before eruption of widespread silicic ash-flow tuffs (Bonham, 1969, McKee and others, 1971; Armstrong, 1970).

Isolated small exposures up to 400 feet thick of a rhyolitic ash-flow tuff locally lie upon the early Tertiary surface, or on the conglomerate, but beneath the main ash-flow tuff sequence. These are thought to represent remnants of an early ash-flow tuff that was largely eroded away before deposition of the main sequence.

A brick-red colored soil up to a few feet thick underlain by a red weathering zone up to 150 feet thick characterizes the early Tertiary surface in many places. This zone may be developed on bedrock, conglomerate, or sedimentary breccia. Locally it was removed by erosion prior to deposition of the overlying ash-flow tuffs. It is thought to represent a period of temperate to subtropical weathering known to have occurred in early to middle Tertiary time in parts of the western United States (Bateman and Wahrhaftig, 1966).

Detailed mapping of the ash-flow tuff sequence shows that each ash-flow sheet came to rest with a basal contact that conformed to the underlying topography and an upper surface that was nearly horizontal. The ash flows pinch out against hills that surrounded valleys of larger volume than the ash flow. That the "pinch-outs" of Tertiary ash-flow tuff units in the Yerington district are due to pre-ash-flow topography, and not to "running out of gas" at the distal end of the flow, is shown by several observations: 1) the abrupt nature of the "pinch-outs"; 2) the uniformity in thickness of the next overlying unit across the "pinch-outs"; 3) the fact that the attitudes in the units are parallel to the top of the units rather than the early Tertiary unconformity (fig. 3); and 4) the presence of boulders and cobbles of pre-Tertiary rock, derived from the pre-Tertiary hills beyond the "pinch-outs", in channels in the tops of units that pinch out. Thus, the distribution of Tertiary ash-flow tuff units can be used to determine the topography on the early Tertiary surface.

A geologic map of one of the west-tilted blocks of the district (fig. 3) shows the distribution of several ash-flow tuff map units in what was originally an approximately north-south cross section. The trace of the early Tertiary unconformity on this map, when untilted, nearly represents an original north-south topographic profile on the early Tertiary surface. By removing the effects of faulting and tilting from maps of the various blocks of the district, the original distribution of the Tertiary units, and the early Tertiary topography thus reflected, has been reconstructed on a "paleogeologic" and "paleotopographic" map (fig. 4). On this map the line along which a unit pinches out is approx-

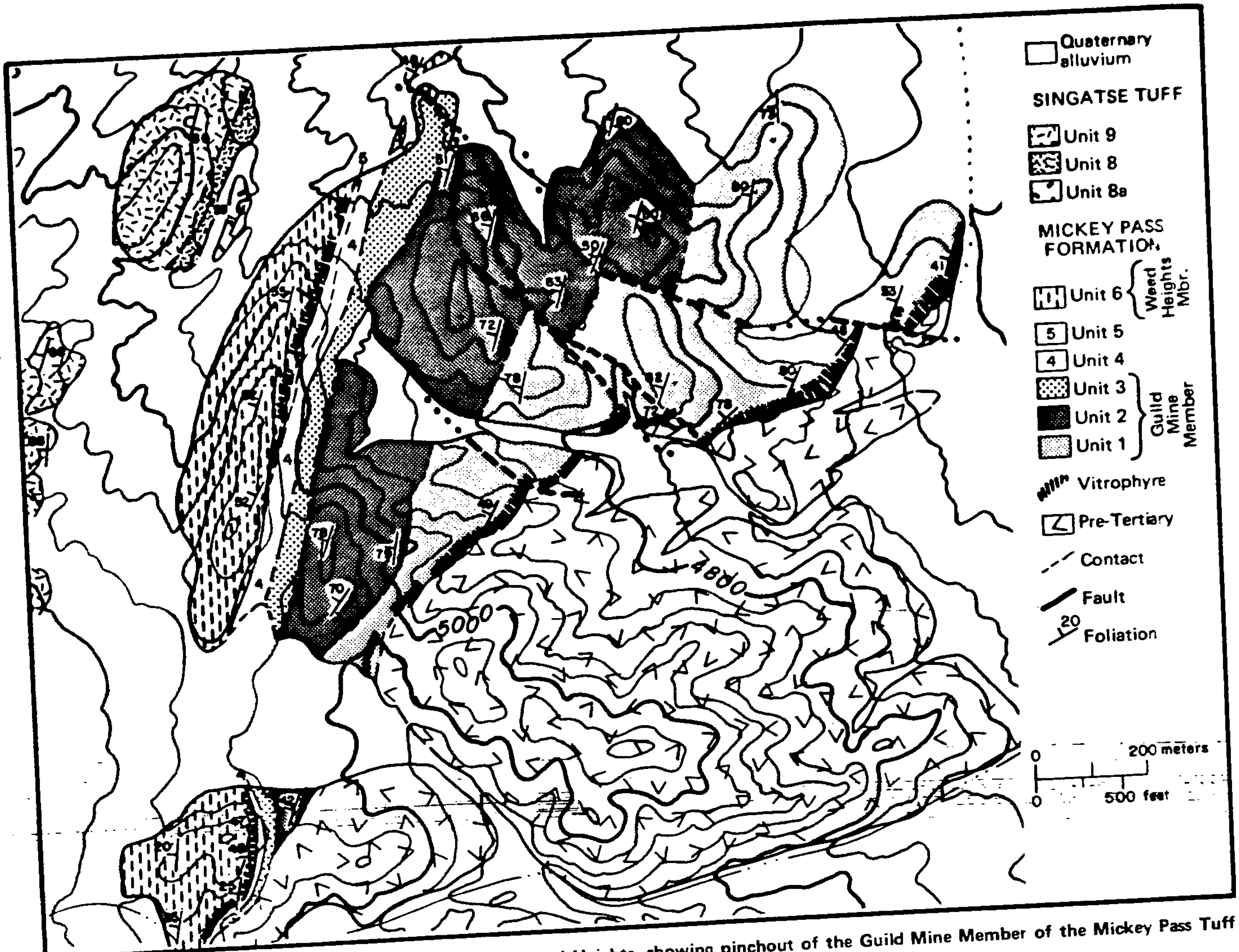


FIGURE 3. Map of an area one-half mile southwest of Weed Heights, showing pinchout of the Guild Mine Member of the Mickey Pass Tuff against an early Tertiary hill to the south, and the distribution of basal vitrophyre.

imately equivalent to a contour line on the early Tertiary surface. The elevation difference between such contours is equal to the thickness of the unit between them.

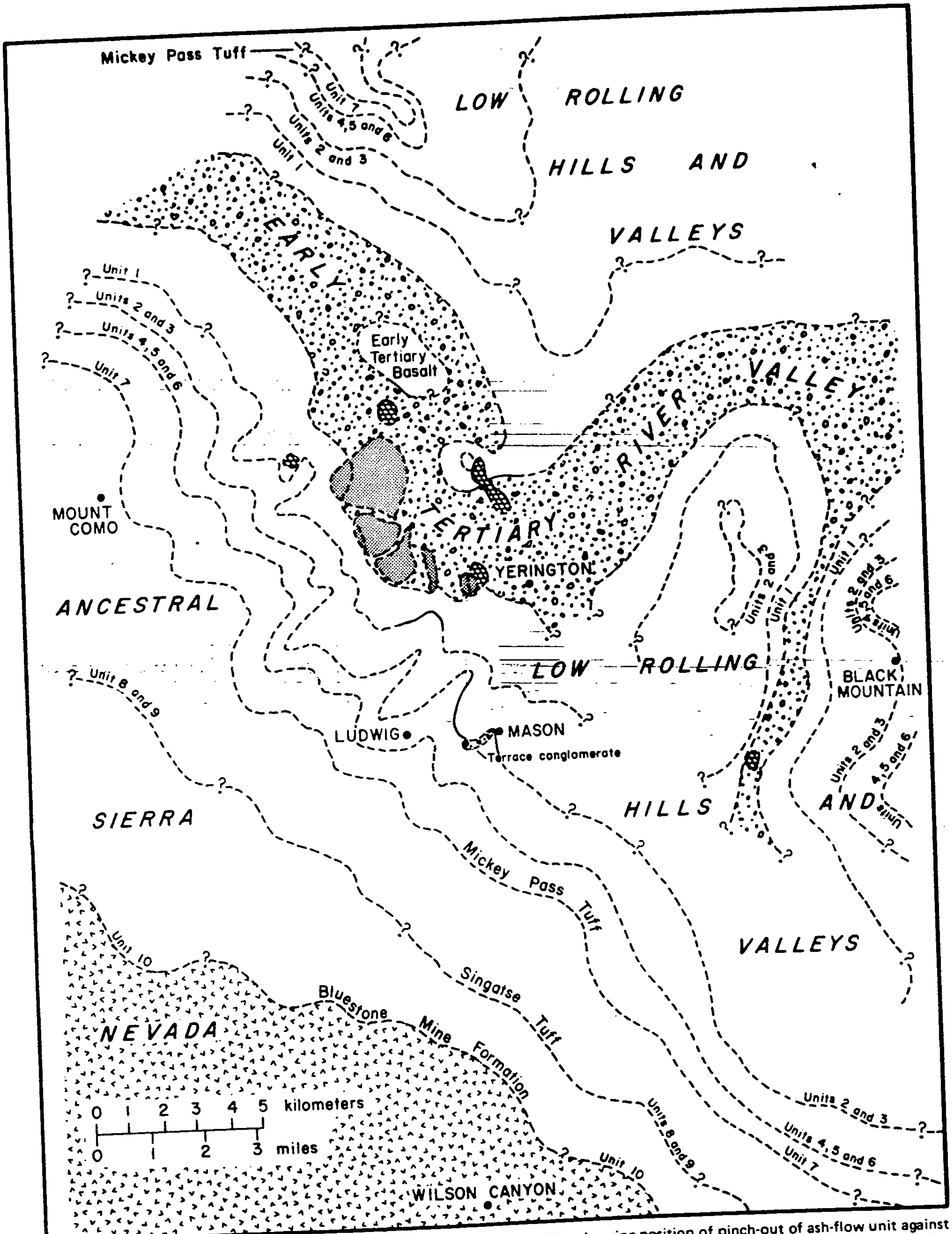
The main features in the early Tertiary topography were a broad eastwest to northwest-trending, conglomerate-covered river valley, bordered by a large mountain mass to the south and west, and by hills to the north and east (fig. 4). The mountain mass was probably the eastern part of the ancestral Sierra Nevada mountains. Rounded cobbles of pre-Tertiary rock derived from the mountain mass lie on the top of the Singatse Tuff north of Gallagher Pass, some 4,000 feet stratigraphically above the river valley of the early Tertiary surface. Topographic relief on the early Tertiary surface thus apparently exceeded 4,000 feet.

OLIGOCENE ASH-FLOW TUFF SEQUENCE

Mickey Pass Tuff

The Mickey Pass Tuff is here named for exposures just northeast of Mickey Pass in the Singatse Range (section I; fig. 5). It is about 2,400 to 2,500 feet thick in its type area northeast of Mickey Pass (SE¼,S13,T13N,R24E; and SW¼, S18,T13N,R25E, M.D.B.M.) but may be over 3,000 feet thick southwest of the Guild Placer Mines. The Mickey Pass Tuff contains two major ash-flow tuff cooling units, with interbedded rhyolitic tuffs and sediments (fig. 3). The lower cooling unit, consisting of map units 1, 2, and 3, is designated the Guild Mine Member for exposures 1¼ miles

FIGURE 4. (on facing page) Map depicting distribution of Tertiary rock units and generalized topography on the early Tertiary surface prior to basin-and-range faulting, tilting, and extension. The lines showing pinchout of Tertiary ash-flow tuff units are approximately equivalent to topographic contours on the early Tertiary surface. The vertical distance between contours is the thickness of the unit between them, and is somewhat variable over the map area. Absolute elevations are not known, but paleoclimatic data based on paleobotany (Axelrod, 1968) suggest that the ancestral Sierra Nevada Mountains were 3,500 to 5,000 feet high and the early Tertiary river valley should have been less than 1,000 feet deep.



• Location of present day reference points, shown in their early Tertiary positions.

Conglomerate covered areas on early Tertiary surface.

Area covered by early Tertiary landslide debris.

Early ash-flow remnants.

Unit 7 — Line showing position of pinch-out of ash-flow unit against early Tertiary surface. Ash-flow unit covers the area on the labeled side of the line and lies directly upon the early Tertiary surface between this line and any line showing the pinch-out of an older unit.

Area of early/middle Tertiary surface covered chiefly by Miocene andesites and tuff and breccia of Gallagher Pass.

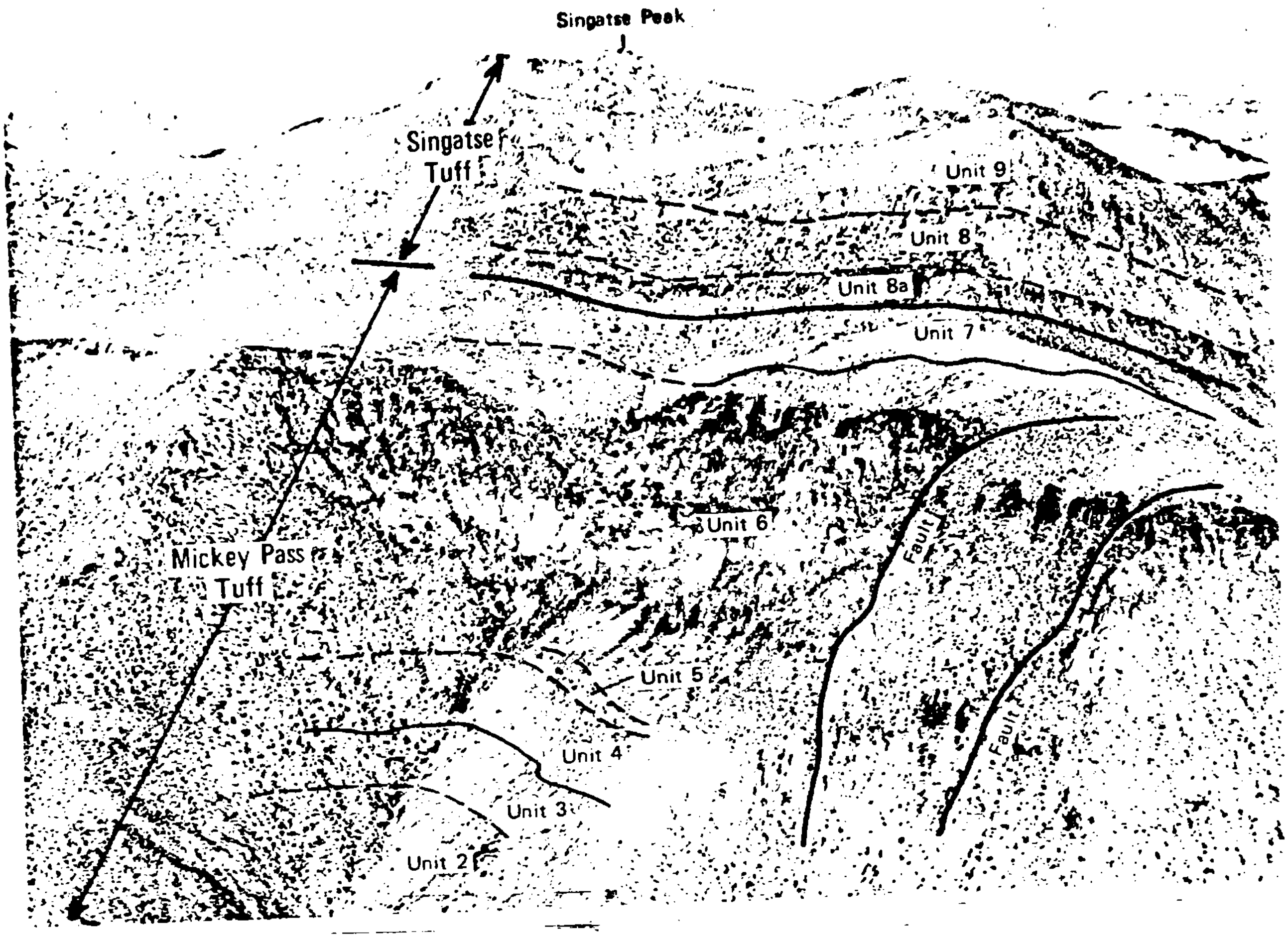


FIGURE 5. Aerial view of the map units in the upper part of the Mickey Pass Tuff and the Singatse Tuff in the type area near Singatse Peak (view looking west).

southwest of the Guild Placer Mines (centerfold), and the upper cooling unit, consisting of map unit 6 is designated the Weed Heights Member for exposures one-half mile southwest of Weed Heights (centerfold; fig. 3). Map units 4 and 5 are thin tuffs and sedimentary beds between the two cooling units, and map unit 7 consists of tuffs and sedimentary beds at the top of the formation (fig. 3).

Guild Mine Member

The Guild Mine Member is 1,700 to 1,800 feet thick near Mickey Pass, but is up to 2,600 feet thick southwest of the Guild Mines (section IA; fig. 2). It is compositionally zoned from dacite (rhyodacite according to O'Connor's 1965 classification) near the base, through quartz latite upward to rhyolite near the top (figs. 6 and 7a; tables 2 and 4). This ash-flow tuff is rich in crystals (fig. 7) and the compositional zoning is reflected in modal analyses of the phenocrysts, determined by point counting samples collected every 100 to 200 feet stratigraphically.

Locally, the basal part of map unit 1 is crowded with angular to subangular lithic fragments, up to three inches in size, consisting of rock types found in the underlying conglomerate and pre-Tertiary rocks. This lithic-rich basal part is 0 to 200 feet thick and is yellow-brown to dark-brown in color. Above this, or lying directly at the base of the unit where the lithic-rich zone is not present, is a discontinuous black vitrophyre, 0 to 100 feet thick (fig. 3). Strongly flattened welded shard texture is visible in thin sections of the vitrophyre. The vitrophyre commonly occurs at the base of the cooling unit, even where the unit is only a few hundred feet thick, and the top of map unit 1 or some part of map unit 2 lies directly upon the early Tertiary surface (fig. 3) (in such occurrences there may be less flattening of welded shard texture). The virtophyre has commonly been converted to brown devitrified rock characteristic of the bulk of the unit (see below), along joints and fractures. Hence, all but the upper few hundred feet of the cooling unit might have been vitrophyre before devitrification, and the present vitrophyre probably owes its preservation to lack of devitrification near the base of the cooling unit.

The main part of map unit 1 is hard, chocolate-brown colored, quartz latite ash-flow tuff with small, sparse, well-flattened, brownish colored pumice fragments and a devitrified groundmass of strongly welded shards. Columnar jointing, with 30 to 15 foot long by 3 to 15 inch diameter 4 or 5 sided columns, is commonly present (fig. 8b). The upper 100 to 200 feet of map unit 1 shows some characteristics of both unit 1 and unit 2. Here, a few white, flattened pumice fragments are present, phenocrysts are more abundant than in underlying unit 1 (fig. 7a), and the rock is purplish to lavender in color.

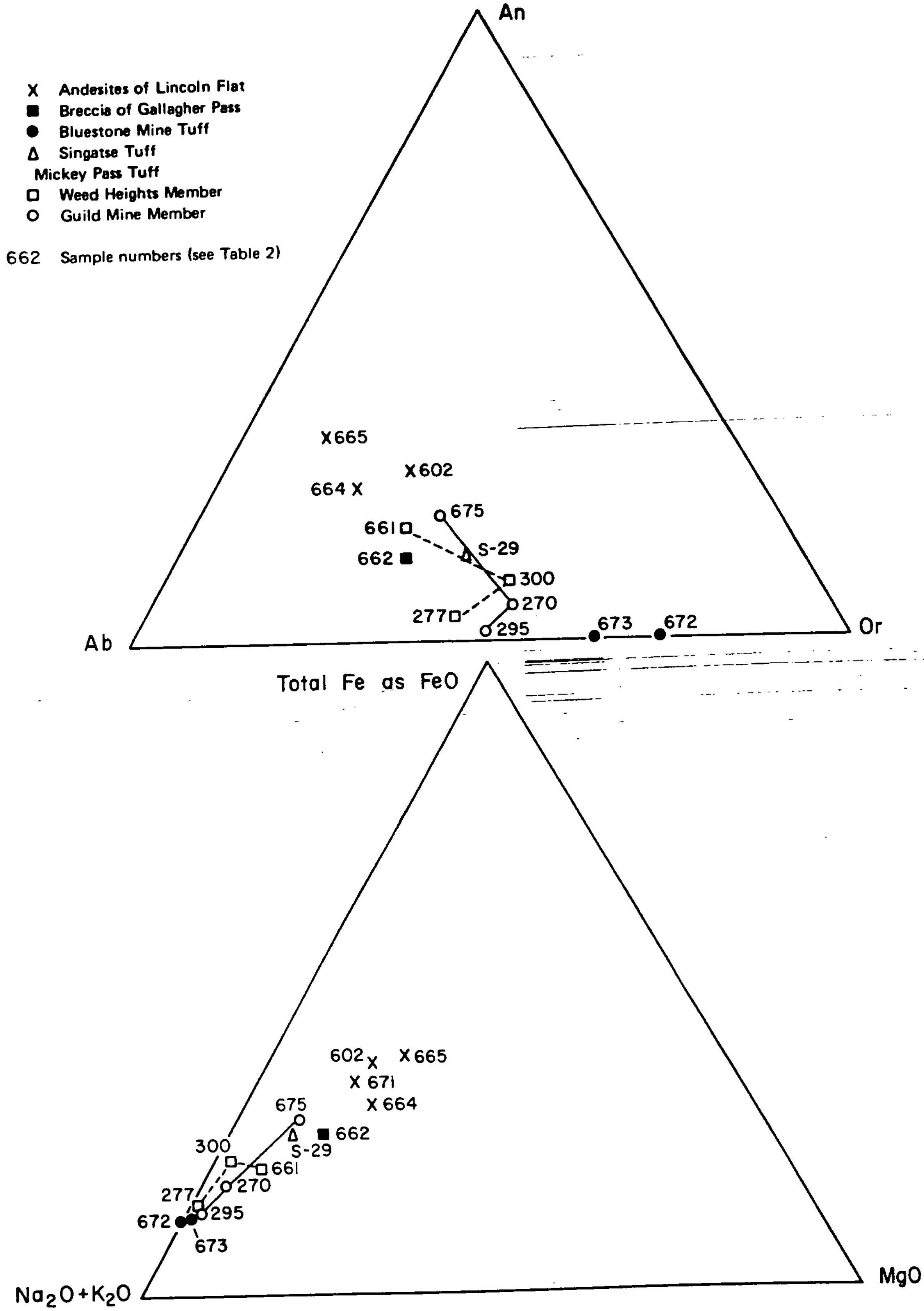
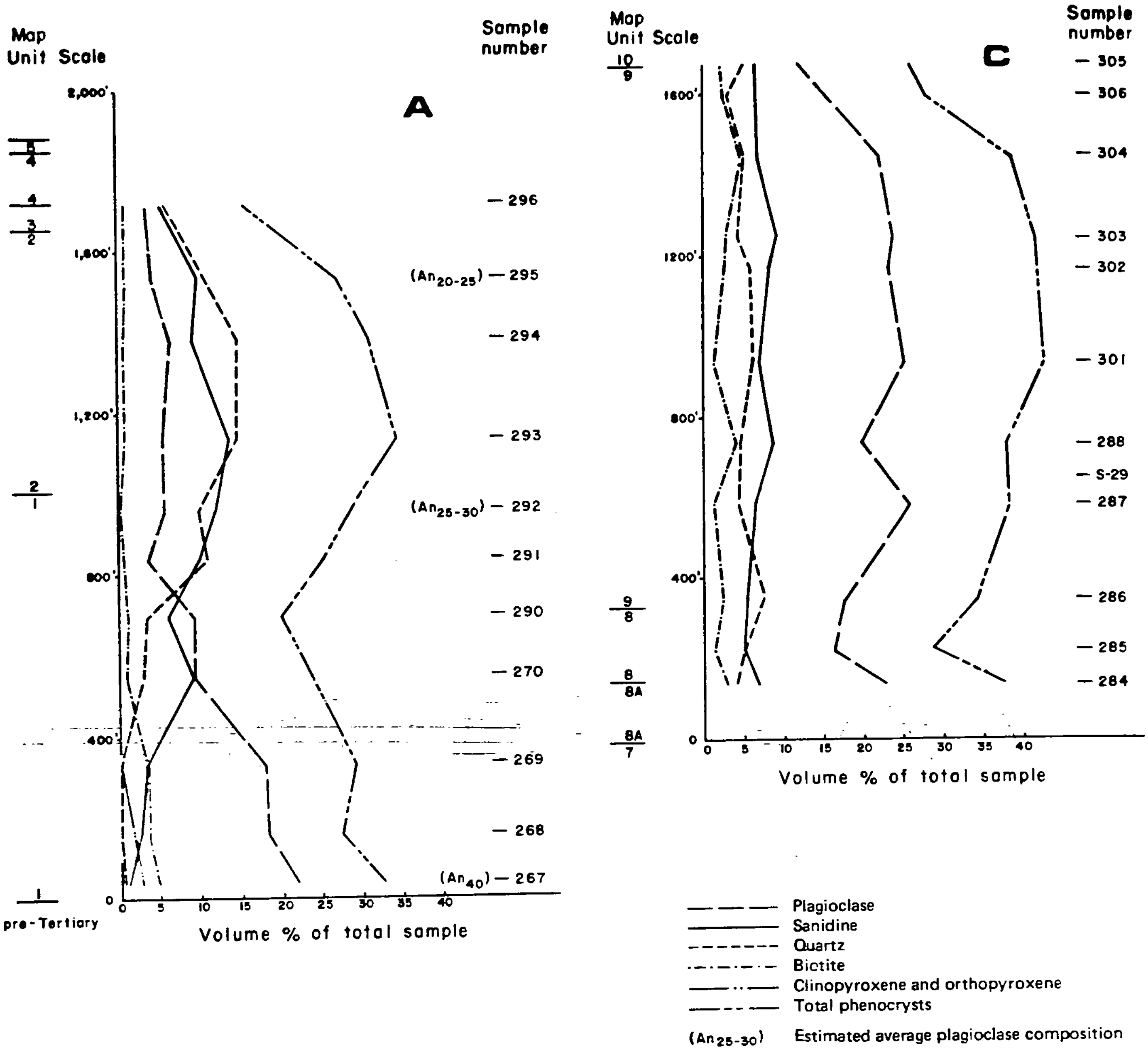


FIGURE 6. Chemical analyses of Tertiary volcanic rocks from the Yerington district plotted on triangular normative feldspar diagram (a); and on an AFM diagram (b). Both in weight percent. Note trends in the two cooling units of the Mickey Pass Tuff. See table 2 for sample numbers.



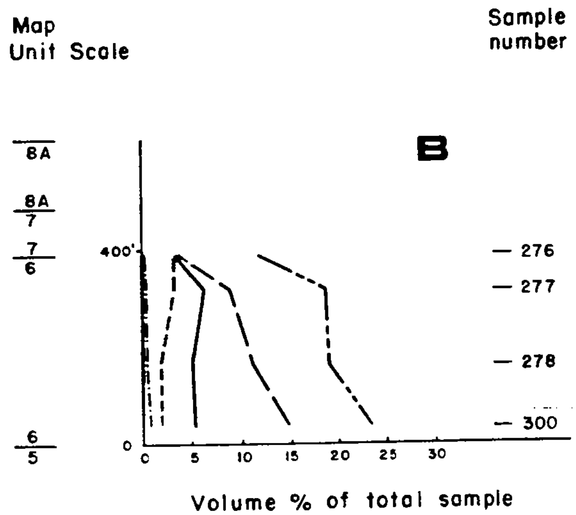


FIGURE 7. Graph showing phenocrysts type and abundances for the Mickey Pass and Singatse Tuffs. (a) Guild Mine Member (lower cooling unit) of the Mickey Pass Tuff at its type section northeast of Mickey Pass. Two thin sections, one parallel to bedding and one perpendicular to bedding were point counted (400 to 500 points per section) under the microscope for each sample. Refractive index of glass: sample 292 = 1.498 ± 0.002 and sample 267 = 1.502 ± 0.002. Glass R.I. value for 292 is not from that sample, but from a vitrophyre developed where that horizon is in contact with the early Tertiary surface. (b) Weed Heights Member (map unit 6, the upper cooling unit) of the Mickey Pass Tuff at its type section northeast of Mickey Pass. (c) Singatse Tuff at its type section near Singatse Peak. Minor hornblende, although it doesn't show on the graph, is characteristic of the unit. Sample S-29 is shown for reference only. It was not used to compose the histogram statistics.

Map unit 2 is usually pale brownish-pink to reddish-brown, or pale lavender in color but may be buff colored due to later alteration. It has abundant, large, white, flattened pumice fragments commonly 1 to 4 inches in length, but rarely up to 12 inches in length (fig. 9). The groundmass is devitrified and little shard texture is evident (except rarely, where unit 2 lies directly on pre-Tertiary rocks and a vitrophyre is present). The unit has abundant phenocrysts, and breaks and weathers in a rough, crumbly fashion (fig. 9). Unit 2 is commonly a ridge-former (fig. 5).

Map unit 3 is comprised of small, sparse quartz and feldspar phenocrysts and rare, unflattened or slightly flattened white pumice fragments in a porous, chalky, pink groundmass consisting of unflattened glass shards. The unit is lavender to pink at its base and a characteristic deep rose pink towards its top.

No sharp contacts have been found between map units 1 and 2 or between map units 2 and 3. The contacts between these units are chosen for mapping convenience only, for the characteristics of the units change gradationally across a zone 100 feet or more thick between units 1 and 2, and several feet thick between units 2 and 3. Phenocryst type and abundance seems to vary gradationally through the cooling unit also, at least within the resolution provided by the sample spacing (fig. 7). A possible welding reversal occurs locally about 100 feet above the unit 1 to unit 2 contact. Here pumice fragments appear to be less flattened than in overlying unit 2. Locally a thin flow parting that separates nearly identical rock above and below can be found near here, indicating that unit 2 was deposited by at least two flows. Except for this reversal, the amount of welding appears to decrease upward from the strongly welded base of unit 1 to the moderately welded upper part of unit 1 and unit 2, to unit 3, the unwelded top of the cooling unit. No other partings, sorted horizons, dissected fossil fumaroles, or other evidence of multiple eruptions have been found in this cooling unit. The size and number of pumice fragments increase upward, suggesting that gas pressure was highest during the early part of the eruption.

Differential compaction during welding and cooling over early Tertiary hills and valleys apparently resulted in 100 to 150 feet of relief on the upper surface of the lower cooling unit. This is suggested by the fact that map units 4 and 5 are only a few feet thick over early Tertiary hills and are 100 to 150 feet thick over early Tertiary valleys.

Throughout the cooling unit feldspar phenocrysts are subhedral, and bipyramidal quartz phenocrysts are rounded and embayed. Phenocryst size ranges from 0.5 to 2 mm near the base of unit 1, to 2, or 3 mm in unit 2. These phenocrysts are almost always cracked or broken, and some of the phenocryst material consists of angular broken fragments that range in size down to less than one tenth of a millimeter. Although phenocrysts are little more than half as abundant in unit 3 as in unit 2, sanidine, plagioclase, and quartz are present in about the same proportions in both units. In unit 3, phenocrysts are generally small and broken and rarely exceed 2 mm in diameter.

The large, white pumice fragments of unit 2 also include phenocrysts, but these are present in slightly different proportions than those of the rock as a whole. A typical

FIGURE 8a. Outcrop of early Tertiary conglomerate of the Yerington district.

FIGURE 8b. Outcrop of Map unit 1. Crude columnar joints trend from lower left to upper right; bedding dips steeply toward upper right.

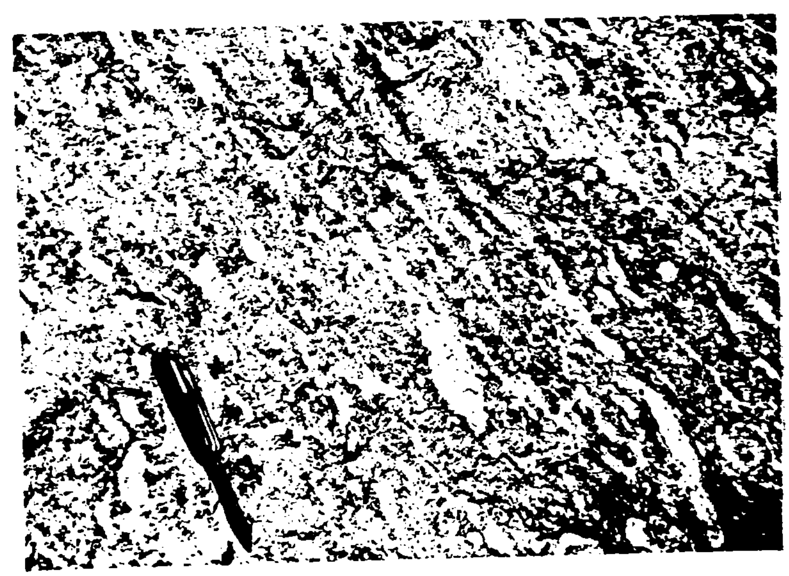
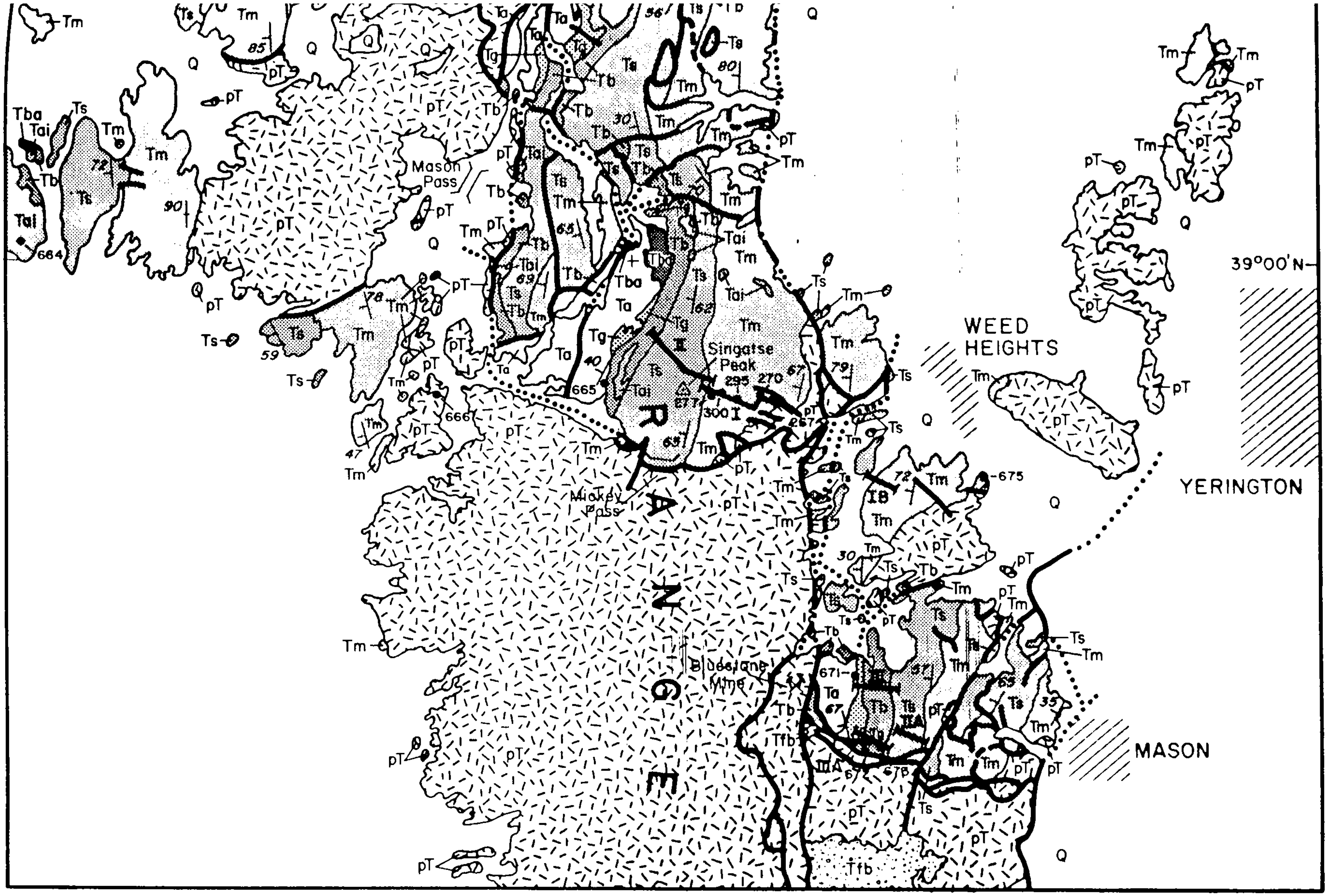


FIGURE 9. Map unit 2 approximately 150 feet below the top. Streaky appearance of flattened pumice is accentuated by bleaching along bedding planes.


Mason Pass
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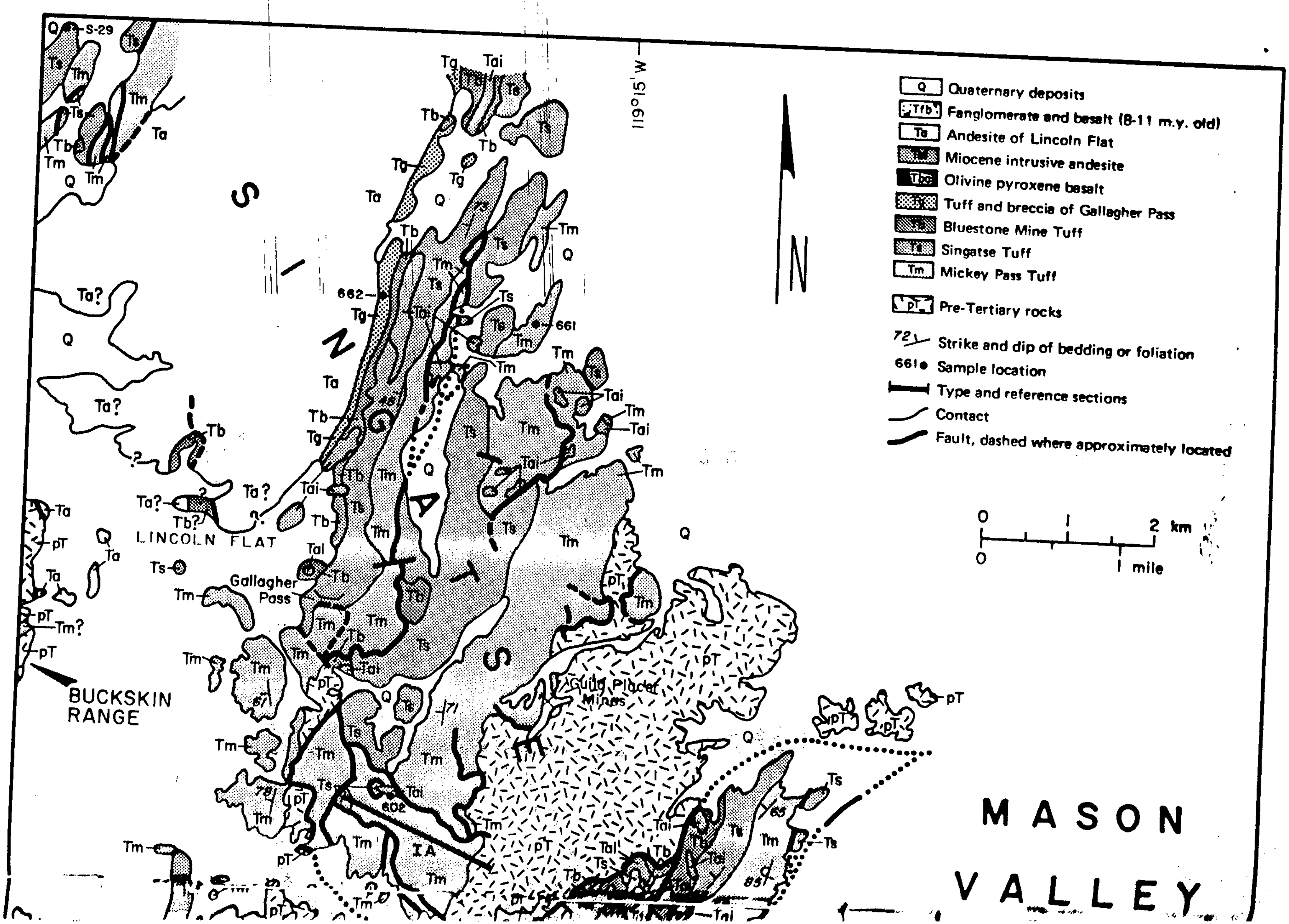

Q Quaternary deposits
Tfb Fanglomerate and basalt (8-11 m.y. old)
Ta Andesite of Lincoln Flat
Tai Miocene intrusive andesite
Tbo Olivine pyroxene basalt
Tg Tuff and breccia of Gallagher Pass
Tb Bluestone Mine Tuff
Ts Singatse Tuff
Tm Mickey Pass Tuff
pT Pre-Tertiary rocks
Strike and dip of bedding or foliation
661 Sample location
Type and reference sections
Contact
Fault, dashed where approximately located
0 2 km
0 1 mile
N
119°15' W
SINGATSE
LINCOLN FLAT
Gallagher Pass
BUCKSKIN RANGE
Gold Placer Mines
MASON VALLEY

TABLE 1. K-Ar ages of Cenozoic rocks from the Yerington district, Nevada. Determinations by Geochron Laboratories, Inc.

Rock unit	Sample no.	Mineral	Age (million years)
Mickey Pass Tuff Guild Mine Member (Map Unit 1)	267 675 675	Biotite Biotite Plagioclase	27.1 (±0.9) 28.0 (±1.0) 25.1 (±1.8)
Weed Heights Member (Map Unit 6)	661 661	Biotite Sanidine	27.8 (±1.0) 26.1 (±0.9)
Singatse Tuff	S-29 S-29	Biotite Hornblende	27.2 (±1.1) 31.7 (±1.8)
Tuff and breccia of Gallagher Pass Pumice block	662 662	Biotite Plagioclase	24.1 (±0.9) 23.6 (±2.0)
Andesites of Lincoln Flat Porphyritic hornblende andesite breccia just above tuff and breccia of Gallagher Pass	671 671	Hornblende Plagioclase	18.7 (±1.9) 17.0 (±2.5)
Hornblende andesite flow just above porphyritic hornblende andesite breccia	665	Hornblende	17.7 (±2.4)
Porphyritic hornblende andesite dike–cuts and intrudes one of oldest basin and range normal faults in district	602 602	Hornblende Plagioclase	18.5 (±2.5) 18.9 (±2.8)
Porphyritic hornblende biotite dacite intrusive–related to hornblende andesite sequence of Lincoln Flat	664 664 664	Hornblende Plagioclase Biotite	18.7 (±2.5) 18.5 (±2.7) 14.2 (±0.6)

pumice fragment contains 1 or 2 percent plagioclase, 5 or 6 percent sanidine, 8 or 10 percent quartz phenocrysts, and a trace of biotite.

A little magnetite is present near the base of unit 1 and decreases in amount toward the top of unit 1. It is generally absent in unit 2 and 3 where hematite seems to have taken its place. A little hornblende is sometimes present in the basal vitrophyre of unit 1 in addition to pyroxene and biotite (table 4)

The Guild Mine Member of the Mickey Pass Tuff is present throughout the Yerington district and surrounding areas except where it pinches out against early Tertiary topographic highs to the south and southwest, and locally in the north part of the district (fig. 4). In most places where the Guild Mine Member has been identified outside the Yerington district, only the upper few hundred feet is present; the base usually lies directly on pre-Tertiary rocks. The full thickness of the unit is evidently only developed over the deepest part of the early Tertiary river valley previously described. Variations in certain field characteristics have been observed in some areas, as in the northwest Gillis Range, where the upper several hundred feet of the unit is redder in color than at Yerington and weathering has created many small caverns sub-parallel to bedding.

K-Ar ages of 27.1 (±0.9) m.y. and 28.0 (±1.0) m.y. on biotite, and 25.1 (±1.8) m.y. on plagioclase, all from the basal vitrophyre of map unit 1 of the Guild Mine Member of the Mickey Pass Tuff, have been determined by Geochron Laboratories and indicate an Oligocene age. The paleomagnetic polarity of the unit is normal.

Map Unit 4.

This unit disconformably overlies the Guild Mine Member. A few feet of erosional relief was developed locally on the surface of the Guild Mine Member, and a few thin lenses of conglomerate or rhyolite tuff were deposited on this surface before deposition of unit 4. Some of the conglomerate contains boulders of pre-Tertairy rock derived from early Tertiary hills to the south. Map unit 4 ranges from 25 to 100 feet thick over most of the district, but thickens to about 200 feet in the north part. The unit is absent in the westernmost part of the district (Buckskin Range) where map unit 6 lies directly on the Guild Mine Member.

Map unit 4 is a white, poorly welded, moderately lithified, rhyolite ash-flow tuff. Locally there is a thin vitrophyre at the base. Occasionally thin interbeds of white volcanic sandstone are present in unit 4, indicating that it was deposited by multiple, small, closely spaced ash flows. It commonly weathers to a crumbly material and underlies valleys or saddles.

Map unit 4 contains about 1 percent of dark lithic fragments up to 2 cm in size. It contains 2 to 5 percent white to buff-colored pumice fragments that are generally slightly flattened and usually oriented sub-parallel to bedding. Original pumice structure is commonly preserved. Map unit 4 contains about 3 percent plagioclase phenocrysts, 8 percent sanidine phenocrysts, 6 to 7 percent quartz phenocrysts, and less than 1 percent biotite. The groundmass consists of undeformed or slightly deformed devitrified glass shards and bits of pumice in a structureless devitrified matrix that was probably originally glass dust. The index of refraction of the glass in the vitrophyre is 1.485 ± 0.002.

Map unit 4 may represent mild volcanism during the period of general quiescence between the eruptions of the Guild Mine Member and the Weed Heights Member, or perhaps it may be the thin edge of an ash-flow tuff sheet which is more extensive and thicker to the east.

Map Unit 5.

This unit consists of thin lenses of rhyolitic sediments. Maximum thickness is about 100 feet but commonly its thickness is only 10 to 20 feet, and in some areas it is missing altogether. The unit consists mainly of beds of reddish-stained, coarse, volcanic sandstone and fine, angular conglomerate alternating with beds of white, thin-bedded, fine volcanic sandstone and siltstone. A few ash-flow tuff interbeds up to 5 to 6 feet thick similar to unit 4 occur locally.

The red volcanic sandstones consist largely of angular sanidine, plagioclase, and quartz crystal fragments and rhyolitic lithic fragments. The thin-bedded, white sandstone and siltstone consist of well-sorted, angular fragments of quartz, sanidine, plagioclase, and glass shards, some of which are devitrified. Minor biotite and rarely hornblende and pyroxene are present.

The lack of petrified wood or soil horizons associated with unit 5 suggest that the time break between units 4 and 6 may not have been very long. The lateral persistence of unit 5 suggests that the surface upon which it was deposited was relatively flat.

Weed Heights Member.

The Weed Heights Member of the Mickey Pass Tuff, (section IB) map unit 6, is about 400 feet thick near Mickey Pass, but thins gradually to the north and is only 100 to 200 feet thick in the northern part of the district. It attains a maximum thickness of 500 to 600 feet in part of the area immediately west of Mason. It is generally 300 to 400 feet thick along the east margin of Mason Valley.

Map unit 6 commonly has a vitrophyre at its base. This vitrophyre is light gray and perlitic and is 5 to 10 feet thick near Mickey Pass, but is medium to dark gray and up to 20 feet or more thick in the northern part of the district and along the east margin of Mason Valley. The lowest 20 to 100 feet above the vitrophyre is commonly light buff or gray. Above this the color is lavender to lavender-gray changing upward to pinkish-brown or reddish-brown towards the top. The uppermost part of map unit 6 is a dark pink or hematite red color but in some areas where the unit is thin, the pink or red top is absent, and was apparently removed by erosion before deposition of map unit 7.

Map unit 6 is a prominent ridge former and it sometimes exhibits crude columnar jointing resulting in columns several tens of feet long by several feet in diameter (figs. 5 and 10). The unit breaks along fractures that vary from moderately smooth to rough. The surfaces of weathered outcrops are usually covered with a thin skin of hard reddish-brown siliceous material.

Careful examination of excellent exposures (figs. 5 and 10), continuous across nearly 400 feet of stratigraphic thickness, revealed no partings, sorted horizons, or dissected fumaroles that would indicate multiple eruptions. This suggests that map unit 6 was deposited during one continuous or nearly continuous eruption. Small fossil fumaroles were found in the unwelded red hematitic top.

Lithic fragments make up less than 2 to 3 percent of the rock and usually are less than 1 or 2 cm in size, although rarely, lithic fragments of volcanic origin 5 to 15 cm in size are present. An abundance of small, white, flattened, pumice fragments characterizes unit 6 in most of the district (fig. 11). These increase in abundance upwards, and in the lavender-gray to reddish-brown colored zones, 5 to 10 percent or more of them are present and are mostly 0.5 to 2 cm in maximum dimension by 0.1 to 0.3 cm thick. Rarely, pumice fragments up to a foot in length are present near the center of unit 6.

Based on the flattening of glass shards and pumice fragments, unit 6 appears to be moderately welded throughout most of its thickness. The strongest welding is generally at the base, and decreases gradually upwards. The top few feet are generally unwelded to very poorly welded; here glass shards and pumice fragments are generally undeformed. Welding appears to increase to the north, northeast and east, where pumice fragments are more flattened and larger in longest dimension.

Type and abundance of phenocrysts in unit 6 are shown in fig. 7b. In addition to the phenocrysts shown in the graph, ferrohypersthene is found in the vitrophyre. The average composition of zoned plagioclase is andesine (An_{40-45}). Glass from the vitrophyre has a refractive index of 1.497 ± .002. Composition of the unit varies from silicic dacite (quartz keratophyre according to O'Connor's [1965] classification) in the basal vitrophyre through quartz latite (rhyolite according to O'Connor's classification) to rhyolite at the top (figs. 6 and 7b, tables 2 and 4). The phenocrysts reflect this variation, just as in the lower cooling unit. The base of unit 6 has sparse magnetite, which decreases upward, with only hematite at the top.

Quartz phenocrysts are rounded and embayed bipyramids and feldspar phenocrysts are subhedral, but all of the phenocrysts are fractured, and much of the phenocryst material consists of broken fragments of quartz and feldspar. The groundmass consists of flattened glass shards that, except in the basal vitrophyre, are devitrified. Locally the vitroclastic texture is accentuated by the devitrification products which in these localities consist largely of radiating fibrous clumps of feldspar, cristobalite, montmorillonite, and quartz. Elsewhere devitrification products are very fine and equigranular; quartz is present instead of cristobalite.

The Weed Heights Member of the Mickey Pass Tuff extends throughout and well beyond the Yerington district (fig. 1), except where it pinches out against pre-Tertiary topography.

K-Ar ages of 27.8 (±1.0) m.y. on biotite and 26.1 (±0.9) m.y. on sanidine (table 1) from the basal vitrophyre of the Mickey Pass Member are nearly indistinguishable from K-Ar

TABLE 2. Chemical analyses of Tertiary volcanic rocks from the Yerington district, Nevada–Oligocene ash-flow tuff sequence

ample umber	675	270	295	661	300	277	S-29(a)	S-29(b)	673	672	662	666
O_2	64.63	68.93	71.95	67.69	70.36	73.07	67.59	68.06	75.64	75.84	63.70	70.52
iO_2	0.58	0.23	0.14	0.50	0.41	0.20	0.46	0.48	0.24	0.22	0.68	0.47
l_2O_3	16.25	12.67	11.48	16.37	15.27	12.38	15.50	14.28	12.61	11.57	15.61	14.18
e_2O_3	2.31			1.47			2.79			1.06	2.26	2.31
eO	1.18	0.13	0.00	0.66	0.16	0.15	0.22		0.0[illegible]	0.00	1.28	0.28
Total Fe as Fe_2O_3		1.57	1.11		2.21	1.26	3.03	2.83	1.2[illegible]	1.06		
MnO	0.07	0.11	0.06	0.04	0.06	0.05	0.16	0.16	0.03	0.03	0.08	0.02
MgO	1.12	0.30	0.09	0.64	0.29	0.09	1.07	1.14	0.06	0.04	1.82	0.35
CaO	3.06	1.09	0.71	2.52	1.79	1.11	2.53	2.40	1.24	0.29	4.05	0.62
Na_2O	4.00	2.70	2.92	4.14	3.13	3.56	3.65	3.32	2.42	1.54	4.68	1.21
K_2O	4.01	4.35	4.06	3.36	4.81	4.35	4.21	4.09	6.20	6.12	3.92	6.86
H_2O^+	2.62	1.62	0.92	2.55	1.44	0.64	0.72		1.00	0.82	1.91	2.00
H_2O^-	0.76	NA	NA	NA	NA	NA	NA	NA	NA	0.66	0.43	0.38
P_2O_5	0.16	NA	NA	0.10	NA	NA	0.12		NA	0.05	0.20	0.13
CO_2	0.03	0.35	0.40	0.08	0.53	0.56	0.49		1.08	0.33	0.10	0.06
Sr	0.051	0.009	0.007	0.042	0.031	0.014		0.040	0.004	0.003	0.061	NA
Rb	0.013	0.018	0.020	0.019	0.016	0.017		0.014	0.025	0.024	0.013	NA
Zr	0.016	0.012	0.011	0.013	0.014	0.012		0.011	0.040	0.040	0.0088	NA
Ba	<0.0010	NA	NA	<0.0010	NA	NA	NA	NA	NA	NA	<0.0010	NA
S	0.03	0.005	0.013	Tr	0.008	0.035	0.01		0.036	0.006	0.02	0.03
Total	100.07	94.00	93.89	100.15	100.38	97.34	99.59	98.18	101.89	97.91	100.38	99.04

Analyses by Harold A. Vincent, Chief Chemist, and V. C. Petersen and J. Cardwell, Chemists, the Anaconda Company, Salt Lake City, Utah, 1970, 1971, and 1972. Numbers 675, 661, S-29(a), 672, 662, and 666 by classical chemical whole rock analysis except Sr, Rb, Zr, and Ba by X-ray fluorescence. Numbers 270, 295, 300, 277, S-29(b) and 673 by X-ray fluorescence except MgO and Na_2O by flame photometry; MnO by colorimetric method; FeO, CO_2, H_2O^+ and S by wet chemical methods. NA – not analysed for. 675. Vitrophyre at base of map unit 1, Guild Mine Member, Mickey Pass Tuff, from south of Weed Heights and northwest of Mason. Coll. by D. L. Gustafson. 270. Guild Mine Member, Mickey Pass Tuff, map unit 1, 550 feet above base. From canyon 4,000 feet northeast of Mickey Pass. 295. Near top of map unit 2, Guild Mine Member of Mickey Pass Tuff. From canyon 3,700 feet northeast of Mickey Pass. 661. Vitrophyre at base of Weed Heights Member, Mickey Pass Tuff. From north of Gallagher Pass. 300. Near base of Weed Heights Member of Mickey Pass Tuff. From canyon 3,500 feet northeast of Mickey Pass. 277. Near top of Weed Heights Member, Mickey Pass Tuff. 3,500 feet north of Mickey Pass. S-29. Singatse Tuff, ridge forming part of map unit 9, about one-third to one-half of the way above base. Churchill Canyon, 700 feet SSE of Sario Well. 673. Bluestone Mine Tuff, map unit 10A. Poorly welded, lithified vitric lapilli-tuff. A few hundred feet north of Mason Valley Mine. Coll. by L. P. Giovacchini, P. Rippee, D. L. Gustafson and J. Proffett. 672. Bluestone Mine Tuff, map unit 10B. Poorly welded, lithified vitric lapilli tuff. A few hundred feet north of Mason Valley Mine. Collected by L. P. Giovacchini, P. Rippee, D. L. Gustafson and J. Proffett. 662. Biotite pyroxene dacite pumice block in tuff-breccia from tuff and breccia of Gallagher Pass. From north of Gallagher Pass. 666. Tertiary silicic intrusive, with biotite, kaolinized plagioclase, and sparse sanidine phenocrysts, from west of Singatse Peak.

ages on the Guild Mine Member and indicate an Oligocene age for these units. Both members of the Mickey Pass Tuff could be very close in age. They are similar in composition and in zoning, and may be genetically related. Map units 4 and 5, which lie between them, could have been deposited in a short time interval.

Map Unit 7.

This unit consists of a thin sequence of sedimentary and volcanic rocks similar in composition to unit 6. It ranges in thickness from about 50 to 200 feet; its average thickness is about 150 feet. Rock types present are grayish-green to reddish-brown rhyolitic sandstone and siltstone, white, gray, and greenish air-fall tuff and pisolite tuff, rhyolitic sedimentary breccia, and white to pale green, unwelded, pumice tuff-breccias and lapilli tuffs that may be pumice lahars or unwelded ash-flow tuffs. The unwelded pumice tuff-breccias contain phenocrysts of plagioclase, quartz, and sanidine, and less than 1 percent biotite in a glassy rhyolitic matrix. The sediments are in beds usually less than 5 to 10 feet thick, and the unwelded tuff-breccias are in beds generally less than about 20 feet thick. Unit 7 underlies valleys and saddles and does not form prominent outcrops.

Map unit 7 contains fossil plant remains about 1,500 feet S20°E of Singatse Peak, just below the base of the Singatse Tuff. These include sticks, leaves, and seed impressions in a fine-grained, pale-gray, poorly bedded, biotite-rich, rhyolitic water-laid or air-fall tuff associated with a lignitic bed. Leaves of unidentified species of oak and other broadleaf trees were found along with acorns, leaf fragments resembling juniper, and reed-like stems. Silicified wood is present here and is abundant in many other localities in unit 7. Specimens diagnostic of age have not been identified, but the implications of a fossil forest plus the local presence of possible fossil soil horizons suggest that map unit 7 represents a relatively long time span between the eruption of map unit 6 and the Singatse Tuff, compared to the time span between the two member units of the Mickey Pass Tuff.

Singatse Tuff

The Singatse Tuff, named for exposures on Singatse Peak in the Singatse Range (fig. 5), consists of a single ash-flow tuff cooling unit 800 to 1,500 feet thick, which overlies the Mickey Pass Tuff without angular discordance. The type area is just north of Singatse Peak (section II; S13, T13N,R24E, M.D.B.M.) (centerfold and fig. 5), and an additional reference section (section IIA) is designated 8 miles S74E of Yerington (N½,S36,T13N,R26E, M.D.B.M.). The Singatse Tuff is divided into map units 8A, 8, and 9. Map unit 8A is 0 to 100 feet thick and constitutes the base of the cooling unit between Singatse Peak and Mason. It is usually brownish-gray in color and forms prominent outcrops. Map unit 8, which is buff in color, and rich in lithic fragments forms the base of the cooling unit except where it is underlain by unit 8A. Unit 8 varies from 100 to 200 feet in thickness. It forms small rounded crumbly outcrops near the base of slopes formed by unit 9, or more commonly is covered by detritus from unit 9. Unit 9, which forms the main part of the Singatse Tuff ranges in thickness from about 700 to 1,200 feet. It is medium-brown, pinkish-brown, or lavender-gray at the base and center and changes to lavender near the top. The upper 10 to 50 feet is bright reddish-brown or hematitic-red, but is commonly missing, apparently due to erosion that preceded deposition of the overlying Bluestone Mine Tuff. Unit 9 is the most prominent ridge former of the Tertiary section and forms much of the backbone of the Singatse Range from Singatse Peak north. No vitrophyres are known in the Singatse Tuff in the Singatse Range, but at the reference section southeast of Yerington black, glassy, flattened pumice fragments are present in map unit 8. Flattening of glass shards and pumice fragments shows that the lower part of the cooling unit is moderately to strongly welded with the strongest welding about one-third to one-half of the way above the base of the cooling unit, coinciding with the most prominent ridge forming horizon. Welding is moderate above this zone except for the top 50 to 100 feet which is virtually unwelded.

The change from unit 8A to unit 8 and from unit 8 to unit 9 takes place over a stratigraphic distance of a few feet to a few tens of feet; abrupt changes represented by sharp contacts have not been found. Unit 8A probably represents a separate ash flow that slightly preceded units 8 and 9. A sorted horizon about a foot thick approximately in the middle of unit 8 indicates that unit 8 was deposited by at least two flows of identical composition but slightly separated in time. Other than this, no partings, sorted horizons, pumice lump horizons, welding reversals, dissected fossil fumaroles or other evidence of multiple eruptions have been found within the Singatse Tuff. Exposures are not as good as those of the Mickey Pass Tuff, however, and it is not yet certain if map unit 9 represents a huge continuous eruption or a few large multiple eruptions.

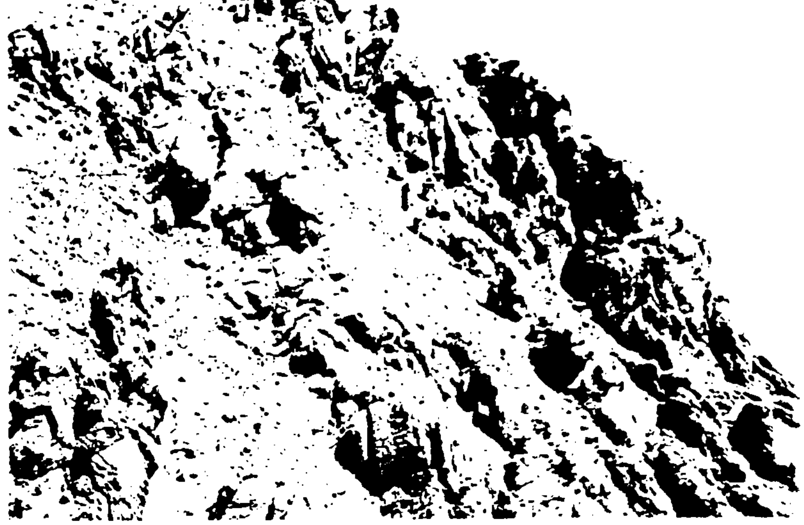

FIGURE 10. Careful examination of these outcrops of map unit 6, which afford excellent continuous exposures of about 400 feet of thickness, revealed no "partings" indicative of multiple flows.

FIGURE 11. Map unit 6, 70 feet below top showing abundant small, white, flattened, pumice fragments. Large oval pumice fragment in lower right is 1-5/8 inches in long dimension.

FIGURE 12. Outcrop of map unit 8, viewed looking north. Bedding is parallel to head of pick. Crude columnar jointing is parallel to pick handle.

Coarse columnar joints several tens of feet long by 1 to 5 feet in diameter are present locally in the upper part of unit 8 and the lower part of unit 9. Map units 8A and 9 are lithologically very similar and in both, outcrops commonly display a thin skin of a dark-brown siliceous material due to weathering.

Unit 8A contains about 5 to 10 percent foreign lithic fragments that rarely exceed 1 or 2 cm in size. Unit 8 contains 10 to 30 percent angular to subangular foreign lithic fragments that vary from 1 mm to 10 cm in size (fig. 12). These fragments are dominantly of volcanic rocks, including andesite and rhyolite, but metamorphic rocks, limestone and granitic rocks are also present. The amount of lithic fragments decreases gradually over a distance of a few tens of feet at the contact with unit 9 such that unit 9 generally contains less than 5 percent lithic fragments. The entire cooling unit has 2 to 4 percent of white, buff, or gray flattened pumice fragments 2 mm to 2 cm in largest dimension. In unit 8 these are commonly weathered out of outcrops, apparently because they have been altered to clay. In much of unit 9, pumice fragments are rather inconspicuous and of somewhat irregular shape, making it difficult to obtain foliation attitudes.

Phenocryst abundance (fig. 7c) is fairly uniform throughout most of the cooling unit. There is a slight tendency for phenocrysts to be more abundant about one-half of the way above the base, probably due to stronger welding and less dilution from lithic fragments here. The upper 75 feet of unit 9, however, has considerably less phenocrysts than the rest of the unit, though the different types of phenocrysts are present in roughly the same proportion as in the rest of the unit (fig. 7c). This is due in part at least to lack of welding. In addition to the phenocrysts shown in figure 7c, ½ to 1 percent green hornblende is characteristically present in the Singatse Tuff. Much of the hornblende is altered near Singatse Peak but is fresh and can be seen in hand specimen in most areas, including the reference section southeast of Yerington. Rarely, a trace of pyroxene is present in the Singatse Tuff. The average composition of zoned plagioclase is about An_{50}. The Singatse Tuff contains about 0.5 percent or less of magnetite as small phenocrysts and microlites in the groundmass. The index of refraction of glass from unit 8 at the reference section southeast of Yerington is 1.498 ± .002. The composition of the Singatse Tuff is quartz latite (rhyolite according to O'Connor's 1965 classification) and is more mafic than the Mickey Pass Tuff (figs. 6 and 7b; tables 2 and 4).

Quartz phenocrysts are 2 to 3 mm rounded and partially resorbed bipyramids; feldspar phenocrysts are 2 to 3 mm in size and subhedral, but these phenocrysts are usually broken. Some of the quartz and sanidine phenocrysts are smoky-colored or stained yellowish or reddish-brown.

The groundmass is made up largely of devitrified glass shards generally less than 0.1 mm in size. Devitrification products are very fine-grained, low birefringence material, consisting of feldspar, quartz, montmorillonite, and probably cristobalite.

The Singatse Tuff occurs throughout and well beyond the Yerington district. It pinches out to the south and southwest against an early Tertiary mountain mass (fig. 4). The Singatse Tuff has been identified or tentatively identified at a number of localities well outside the Yerington district during reconnaissance work (fig. 1). At most of the localities specimens have been collected and point counted under the microscope, and found to closely resemble the Singatse Tuff at Yerington.

A K-Ar date of 27.2 (±1.1) m.y. on biotite from the Singatse Tuff falls within the spread of K-Ar ages on the Mickey Pass Tuff, but the 31.7 (±1.8) m.y. K-Ar age on coexisting hornblende is considerably older (table 1). The Singatse Tuff has normal paleomagnetic polarity.

Bluestone Mine Tuff

The type area (centerfold) of the Bluestone Mine Tuff (map units 10, 10A, 10B) is just east of the Bluestone Mine (NW¼,S32,NE¼,S31,SE¼,S30,SW¼,S29,T13N,R25E, M.D.B.M.). Here exposures are good enough that some of the main features of the unit can be seen on ERTS photos. Devitrification is strong in the type areas as in most of the Singatse Range. A reference section (section IIIA) that

TABLE 3. Chemical analyses of Tertiary volcanic rocks from the Yerington district, Nevada–Miocene andesites of Lincoln Flat

Sample Number	602	664	665	671
SiO_2	59.04	62.19	59.47	58.92
TiO_2	0.63	0.62	0.88	0.81
Al_2O_3	17.92	16.94	17.40	18.29
Fe_2O_3	4.31	3.18	4.09	3.68
FeO	1.14	0.98	1.07	1.21
MnO	0.12	0.11	0.09	0.05
MgO	2.24	2.43	2.53	2.02
CaO	5.22	4.96	6.40	5.62
Na_2O	4.11	4.70	4.60	4.87
K_2O	3.19	2.40	1.38	2.77
H_2O^+	1.36	0.71	1.68	0.44
H_2O^-	1.71	0.67	1.58	0.22
P_2O_5	0.24	0.28	0.34	0.34
CO_2	0.68	0.25	0.15	0.24
Sr	0.055	0.098	0.138	0.133
Rb	0.008	0.005	0.003	0.005
Zr	0.004	0.003	0.008	0.006
Ba	NA	NA	NA	NA
S	0.02	0.06	0.01	0.06
Total	100.21	99.78	100.09	99.3

Analyses by Harold A. Vincent, chief chemist, and V. C. Petersen, chemist, of the Anaconda Company, Salt Lake City, Utah, 1970 and 1971. Analyses are by whole rock wet chemical techniques, except for Sr, Rb, and Zr which are by XRF. 602. Tertiary porphyritic hornblende andesite intrusion with plagioclase phenocrysts. From a dike that cuts and intrudes a flat normal fault south of Gallagher Pass. 664. Tertiary porphyritic hornblende biotite dacite intrusive with quartz eyes and abundant plagioclase phenocrysts, from west part of Yerington district. 665. Tertiary hornblende andesite flow with microphenocrysts of plagioclase and clinopyroxene from west of Singatse Peak. 671. Tertiary porphyritic hornblende andesite with abundant plagioclase phenocrysts from block in extrusive breccia, west of Mason.

shows the tuff where it is less devitrified is designated 7¾ miles S71E of Yerington. The Bluestone Mine Tuff (consists of crystal-poor rhyolitic vitric tuffaceous rocks) and related sedimentary rocks. It overlies the Singatse Tuff without angular discordance, but its lower contact is slightly irregular due to erosion of the Singatse Tuff before deposition of the Bluestone Mine Tuff, and its upper contact is even more irregular due to erosion before deposition of the overlying units. The Bluestone Mine Tuff averages about 500 to 600 feet in thickness, but it ranges in thickness from about 250 to about 900 feet.

Most of the unit is easily weathered and eroded and underlies saddles and valleys, but there are two thin, well lithified ash-flow tuffs that are ridge formers (map units 10A and 10B).

The dominant rock type in the Bluestone Mine Tuff is unsorted, unwelded to poorly welded pumice tuff-breccia that is white, pale buff, pale green, or pale pink in color (fig. 13). These deposits are in beds a few feet to a few tens of feet thick. They contain 10 to 30 percent of unflattened to slightly flattened fragments of pumice with less than 1 percent sanidine and plagioclase phenocrysts, 5 to 10 percent dark lithic fragments less than 1 cm in size, about 5 percent crystal fragments including plagioclase, quartz, sanidine, and less than 0.5 percent biotite, in a partially devitrified groundmass containing abundant undeformed glass shards. Thin beds of fine- to medium-grained crystal-vitric and vitric tuff of air-fall or water-deposited origin are also present. These are usually light-colored and poor in crystals, but 75 feet above the base of the unit a 20 foot thick bed of purplish-gray tuff was found which contains about 30 percent plagioclase crystal fragments and minor sanidine, biotite, pyroxene, and iron oxides in a matrix of undeformed glass shards. Well-bedded sandstone and siltstone of dominantly rhyolitic composition occur in beds a few feet thick throughout the unit. The lower-most of the two lithified ash-flow tuffs (map unit 10A), is 75 to 100 feet above the base of the formation and is 100 to 150 feet thick in the type area. It is generally brownish to bright brick-red in color. It contains only 1 percent sanidine phenocrysts, less than 1 percent quartz phenocrysts, and no plagioclase. The only mafic minerals are a trace of pyroxene and iron oxide. The rock contains 1 or 2 percent pale pink or brown devitrified, flattened pumice fragments. The remainder of the rock consists of flattened, devitrified glass shards. The uppermost of the two lithified ash-flow tuffs (map unit 10B) occurs 250 to 300 feet above the top of map unit 10A, and is about 150 feet thick in the type area. It is brown to reddish-brown in color. It contains 3 to 4 percent quartz phenocrysts, 3 to 4 percent sanidine phenocrysts, no plagioclase, and a trace of biotite and oxyhornblende. The quartz and sanidine are in well-formed euhedral crystals that are commonly broken, and only part of the quartz bipyramids are rounded and embayed. The rock contains moderately flattened, white, buff, or pink devitrified pumice fragments. The groundmass consists of unflattened to partially flattened glass shards, indicating that this ash flow is only poorly welded. Unflattened shards can be seen with a hand lens.

At the reference section southeast of Yerington pumice fragments and shards are still glassy in most of the Bluestone Mine Tuff including map units 10A and 10B.

The Bluestone Mine Tuff is poor in mafics as well as other crystals and is chemically potash-rich rhyolite (fig. 6, tables 2 and 4).

Fragments of petrified wood occur at many localities in the Bluestone Mine Tuff, but no identifiable fossils have been found. K-Ar dates from the units above and below the Bluestone Mine Tuff bracket its age as between about 23 m.y. and about 26 m.y., or late Oligocene. It is interesting to note that crystal-poor ash-flow tuff of this approximate age, such as the Shingle Pass Tuff and parts of the Bates Mountain Tuff (McKee and Stewart, 1971; Ekren and others, 1974) are widespread in central Nevada, though no correlations with the Bluestone Mine Tuff are attempted at this time.

Tuff and Breccia of Gallagher Pass

A sequence of dacite tuff, tuff-breccia, and welded tuff with plagioclase, biotite, and green augite as the main phenocrysts, overlies the Bluestone Mine Tuff and is named for exposures north of Gallagher Pass. The contact between the Bluestone Mine Tuff and the tuff and breccia of Gallagher Pass is a disconformity representing a few tens to a few hundred feet of local relief developed by erosion after deposition of the Bluestone Mine Tuff. There is no evidence in the Singatse Range or surrounding area for an angular unconformity at this contact. Near the Bluestone Mine, beds of rhyolitic detritus derived from erosion of the Bluestone Mine Tuff are locally interbedded with the lower part of the tuff and breccia of Gallagher Pass. In a few places the tuff and breccia of Gallagher Pass are missing, apparently due to its removal by erosion before deposition of the overlying Miocene andesite. In most of the Singatse Range the tuff and breccia of Gallagher Pass ranges from 200 to 500 feet thick.

There is considerable lateral variation in the tuff and breccia of Gallagher Pass in the Singatse Range. North of Gallagher Pass, a 300 to 400 foot thick section of unwelded pumiceous tuff-breccia is overlapped to the north by a 200 foot thick welded tuff. The tuff-breccia contains 10 to 20 percent of undeformed lapilli and blocks of gray, glassy pumice, containing plagioclase, biotite, clinopyroxene, orthopyroxene and iron oxide phenocrysts (fig. 14). About one-third to one-half of the volume of the pumice fragments is void. Recalculating volume percentage estimates of the components of these fragments without including the voids indicates that 30 to 35 percent is plagioclase phenocrysts, 5 to 10 percent is biotite phenocrysts, 2 to 3 percent is pyroxene phenocrysts, 1 to 2 percent is magnetite phenocrysts, and 55 to 60 percent is glass. Traces of apatite prisms and quartz are present in the pumice fragments, but no trace of sanidine was found. Plagioclase phenocrysts are strongly oscillatory zoned from calcic andesine to sodic labradorite, and have an average composition of about An_{50}. The index of refraction of the glass is 1.497 ± .002. A chemical analysis of one of the pumice blocks (tables 2

TABLE 4. CIPW norms and modal analyses of Tertiary volcanic rocks from the Yerington district, Nevada (see tables 2 and 3 for chemical analyses and sample descriptions).

CIPW norms (in weight percent)

	675	270	295	661	300	277	S-29(a)	S-29(b)	673	672	662	666	602	664	665	671
Q	18.21	34.83	38.86	24.81	30.92	34.72	24.82	27.93	37.74	43.40	12.61	35.91	10.93	13.57	12.57	7.47
C	.13	2.42	1.92	1.69	2.89	1.09	1.69	1.45	1.92	2.41		4.09	.37			
Or	23.70	25.71	23.99	19.86	28.42	25.71	24.88	24.17	36.64	36.16	23.16	40.54	18.85	14.18	8.15	16.37
Pl	48.04	25.85	25.70	46.57	32.01	32.09	39.75	36.12	20.48	13.03	49.61	12.09	54.81	57.81	61.68	61.07
Ab	33.85	22.85	24.71	35.03	26.49	30.12	30.89	28.09	20.48	13.03	39.60	10.24	34.78	39.77	38.92	41.21
An	14.19	3.01	.99	11.54	5.53	1.97	8.87	8.02			10.01	1.85	20.03	18.04	22.76	19.87
Di											6.57			2.46	4.53	3.33
Hy	2.79	.75	.22	1.59	.72	.22	2.66	2.84	.15	.10	1.49	.87	5.58	4.91	4.20	3.49
Mt	2.24	.11		.81							2.34		2.17	1.5	1.16	1.50
Il	1.10	.44	.10	.95	.51	.37	.78	.83		.06	1.29	.56	1.20	1.18	1.67	1.54
Hm	.76	1.35	1.11	.91	2.03	1.09	2.79	2.59	1.26	1.06	.64	2.31	2.81	2.14	3.29	2.65
Ru			.08		.14		.03	.05	.24	.19		.17				
Ap	.38			.24			.28	.28		.12	.47	.31	.57	.66	.81	.81
Py	.06		.02			.07	.02	.02	.05		.04	.06	.04	.11	.02	.11
Calc	.07	.86	.91	.18	1.21	1.27	1.11	1.11	2.21	.40	.23	.14	1.55	.57	.34	.55
rest	3.38	1.62	.92	2.55	1.44	.64	.72	.72	1.00	1.48	2.34	2.38	3.07	1.38	3.26	.66
Total	100.86	93.94	93.84	100.16	100.30	97.30	99.56	98.10	101.69	98.41	100.84	99.42	101.94	100.48	101.68	99.54

Modal analyses (volume percent)

	675	270	295	661	300	277	S-29(a)	S-29(b)	673	672	662	666	602	664	665	671
Q	0.15	See figure 7a.		1.7	See figure 7b.		See figure 7c.						1.75	2.5		0.17
San	0.28			1.3												
Pl	18.2			24.8							31.8		13.2	29.4	19.6	27.5
Bt	3.7			1.2							3.57			3.9		
Hb	0.7												9.5	9.5	8.6	12.0
Pyx	1.1			1.65							3.22				0.6	
"Mt"	.45			.05							0.36		0.54		2.4	1.83
Calc													0.81		0.2	
Gdms	65.4			65.8							60.8		74.15	54.2	68.0	58.7
Lithic frags	9.7			3.0												
Secondary														0.3	0.6	

Q – quartz
C – corundum
Or – K-feldspar
Pl – plagioclase
Ab – albite
An – anorthite
Di – diopside

Hy – hypersthene
Mt – magnetite
Il – ilmenite
Hm – hematite
Ru – rutile
Ap – apatite
Py – pyrite

Calc – calcite
San – sanidine
Bt – biotite
Hb – hornblende
Pyx – pyroxene
Gdms – groundmass

and 4) confirms the dacite composition suggested by the petrography (rhyolite near quartz keratophyre according to O'Connor's 1965 classification).

The plagioclase phenocrysts are 0.5 to 3 mm in size, and the biotite plates are .5 to 2 mm in size. Within the pumice blocks much of the phenocryst material consists of broken fragments even though the pumice matrix is not clastic. The pumice blocks and lapilli are in a tuffaceous matrix consisting largely of the same material that comprises the blocks and lapilli, plus a trace of brownish-green hornblende and about 5 to 10 percent of foreign lithic fragments (mainly of intermediate to silicic volcanics). The tuffaceous matrix includes undeformed glass shards. The glassy material of the tuffaceous matrix has more of a tendency to be devitrified than the material of the pumice blocks and lapilli.

About three miles north of Singatse Peak the tuff and breccia of Gallagher Pass consists entirely of tuff-breccia containing 1 to 10 cm rock fragments in a soft, fine-grained matrix. The rock fragments contain 20 to 25 percent plagioclase phenocrysts up to 8 mm in size, 2 to 4 percent biotite phenocrysts 0.05 to 1 mm in size, 1 to 3 percent green augite phenocrysts .2 to 4 mm in size, and less than 1 percent magnetite phneocrysts. Augite commonly occurs in well-formed eight-sided prisms. Hornblende and biotite are strongly altered to finely divided iron oxide along their rims. The plagioclase phenocrysts are commonly euhedral Carlsbad twins. They have an average composition of An_{60}, but show reverse and oscillatory zoning with zones as calcic as calcic bytownite and rims of calcic andesine. The phenocrysts are in a pink to light-gray groundmass that consists of 10 to 15 percent sub-parallel andesine laths .03 to .05

mm long in a microcrystalline mosaic of low birefringence material and finely divided iron oxide that probably represents devitrified glass. The rock fragments appear to have been derived from a flow or shallow intrusion. The soft matrix surrounding the rock fragments is similar in composition to the fragments except that the devitrified glass part appears to be altered to pale green clay. This deposit could be an autobrecciated flow or a flow breccia.

Just northwest of Singatse Peak the tuff and breccia of Gallagher Pass includes white, buff, pale pink, and pale green unwelded tuff and pumice tuff-breccia. These contain 25 to 30 percent plagioclase phenocrysts up to 3 mm in size, zoned from calcic andesine to calcic labradorite, 5 to 10 percent biotite phenocrysts up to 2 mm in size, and traces of sanidine phenocrysts, quartz fragments, and apatite prisms. No pyroxene or hornblende is present. The phenocrysts are contained in undeformed pumice fragments or are present as fragments in a matrix of undeformed glass shards. The glassy matrix has devitrified to low birefringence material.

Near the Bluestone Mine, breccia similar to that described 3 miles north of Singatse Peak occurs at the base of the tuff and breccia of Gallagher Pass. The breccia is overlain by a moderately to poorly welded, buff-colored welded tuff 50 to 250 feet thick that contains phenocrysts of plagioclase, biotite, and pyroxene. Above the welded tuff is about 200 feet of moderately-sorted angular sandstone interbedded with well-rounded pebble conglomerate. The conglomerates contain fragments of rhyolite, quartz latite and hornblende andesite as well as fragments of biotite pyroxene dacite.

A thick section of the tuff and breccia of Gallagher Pass occurs 7¼ miles S71E of Yerington. A few hundred feet of unwelded tuff at the base is overlain by a few hundred feet of welded ash-flow tuff. Fragments of massive biotite pyroxene dacite lava or intrusive rock occur in the unwelded tuff near the base. At this locality an ash-flow tuff, with "sieve"-textured resorbed quartz, which is not present in the Singatse Range locally occurs between the Bluestone Mine Tuff and the tuff and breccia of Gallagher Pass.

The tuff and breccia of Gallagher Pass was deposited in part by ash-flow eruptions and apparently in part by breccia flows of other types, by air falls, and part was water laid. Some of the breccia fragments were apparently derived from shallow intrusions or lava flows. This suggests a fairly nearby source, although no intrusions or other indications of an eruptive center for the tuff and breccia of Gallagher Pass are known in the Yerington district.

K-Ar dates of 24.1 (±0.9) m.y. on biotite and 23.6 (±2.0) m.y. on plagioclase (table 1) from one of the pumice blocks from north of Gallagher Pass indicate a latest Oligocene age for at least part of the tuff and breccia of Gallagher Pass.

OLIVINE PYROXENE BASALT

In a few localities flows and coarse breccia of olivine pyroxene basalt fill channels cut into or through the tuff and breccia of Gallagher Pass. The maximum thickness of basalt is 600 feet. It is overlain by the Miocene andesites of Lincoln Flat, and therefore is either latest Oligocene or

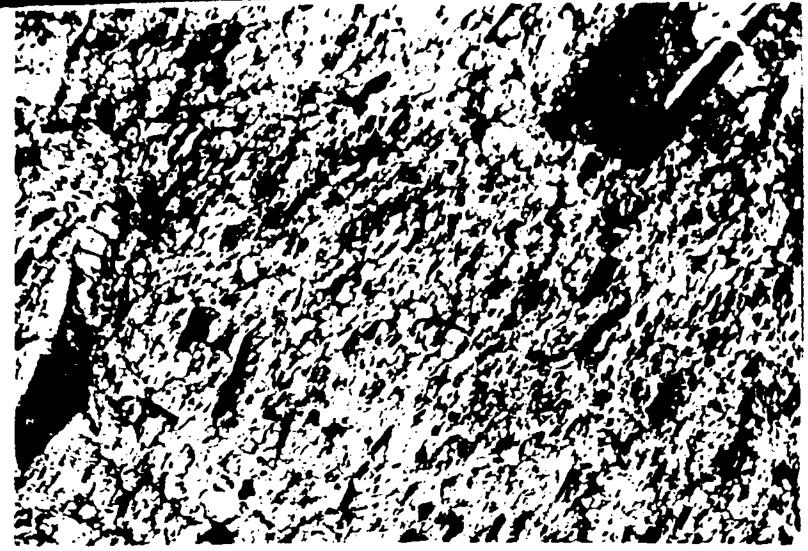

FIGURE 13. White pumice tuff-breccia in the Bluestone Mine Tuff east of the Bluestone Mine. Dark areas are where partially flattened pumice blocks and lapilli are weathered out of the rock.

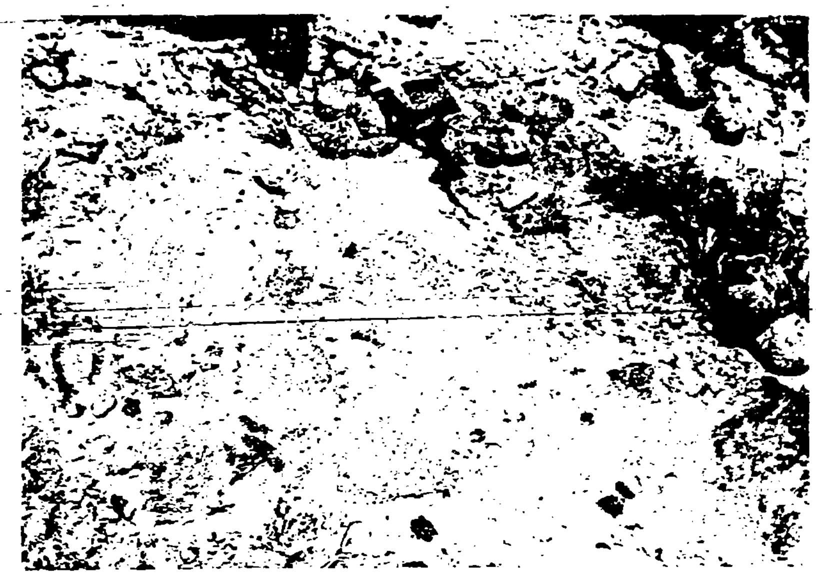

FIGURE 14. Outcrop of tuff-breccia north of Gallagher Pass (sample 662 collected from this locality).

early Miocene in age. Because of its limited distribution no formal name is applied to this unit.

The basalt has 5 to 15 percent of 0.2 to 1 mm olivine (65 to 80 percent forsterite) phenocrysts and 5 to 15 percent of 0.2 to 1 mm clinopyroxene phenocrysts. The remainder of the rock consists of 2 to 3 percent magnetite phenocrysts, 2 to 3 percent hematite specks, 5 to 10 percent of 0.02 mm clinopyroxene grains, 55 to 65 percent of 0.1 mm subparallel oriented labradorite laths, and 10 to 15 percent medium-brown interstitial glass (R.I. of 1.57) and a fine titanium oxide mineral. Serpentine and hematite occur as alteration products.

MIOCENE ANDESITES OF LINCOLN FLAT

A sequence of hornblende-bearing andesite and closely related dacites overlies the tuff and breccia of Gallagher Pass (or locally the Tertiary basalt) in the Singatse Range. These andesites and related dacites are named informally for exposures north of Lincoln Falt (centerfold). They predate most of the basin-and-range normal faulting and tilting in the district, but minor angular unconformities, and dikes intruded along fault planes and subsequently refaulted, indicate that some basin-and-range faulting began during eruption of the Miocene andesites (Proffett, 1971a, 1972). The maximum thickness exposed in the well-mapped part of the Singatse Range is 1,500 feet, but the sequence is more than 5,000 feet thick north of Lincoln Flat (centerfold), where the full thickness has not yet been mapped.

The andesites are all characterized by hornblende phenocrysts in a light-gray groundmass, but they can be subdivided into three main types on the basis of their other phenocrysts. These types are: (1) those that have significant plagioclase as well as hornblende phenocrysts, (2) those that have only hornblende phenocrysts, and (3) those with significant quartz phenocrysts as well as plagioclase, biotite and hornblende phenocrysts, and which are chemically dacite in composition.

Andesite with Plagioclase and Hornblende Phenocrysts

This type of andesite commonly occurs as extrusive breccia (figs. 15 and 16), but also as intrusions and more rarely as flows. Such extrusive andesite breccia usually forms the basal part of the Miocene andesite section, where it overlies the tuff and breccia of Gallagher Pass, the Bluestone Mine Tuff, or the Tertiary basalt. The contact between the andesite breccia and these underlying units is an erosional disconformity with up to a few hundred feet of relief, but is not an angular unconformity. The thickness of andesite breccia ranges from more than 1,300 feet near the Bluestone Mine, to 200 feet or less west of Singatse Peak.

The andesite breccias are crudely bedded in layers a few feet to several tens of feet thick. Different beds are defined mainly by differences in the average size of fragments. Fragments in many beds are mostly three inches to two feet in size, but in some beds boulders up to 10 feet in diameter are present, and some beds are made up primarily of fragments less than three inches in size. Beds of sandstone-size material are present near the Bluestone Mine near the base of the sequence and also are interbedded with the coarser material higher in the sequence. Fragments of fossilized wood have been found in some beds. Some breccias are in a sense heterolithologic, that is, although all of the fragments are of hornblende andesite with abundant plagioclase phenocrysts, they differ from one another in color, which varies from gray to reddish-brown, in oxidation state of the hornblende, in grain size of the groundmass, and in grain size and abundance of the phenocrysts.

Typically these andesites contain 20 to 35 percent of 0.3 to 3 mm plagioclase phenocrysts, 10 to 20 percent of 0.4 to 4 mm hornblende phenocrysts and 2 to 4 percent of 0.1 to 0.2 mm opaque phenocrysts in a fine-grained gray groundmass. The groundmass consists mainly of fine, subparallel laths and microphenocrysts of plagioclase up to 0.1 mm in length with subordinate 0.005 to 0.01 mm opaque grains leucoxene, fine-grained low birefringence material, and glass. The fine, low birefringence material consists in part, of potassium feldspar and a silica mineral, and probably originated from the devitrification of glass. The plagioclase phenocrysts are strongly zoned, often with reverse and oscillatory zoning. The zones range in composition from andesine to calcic labradorite and the average composition is An_{50-60}. The plagioclase of the groundmass varies from sodic oligoclase to sodic andesine in some specimens and is labradorite in others. The hornblende is usually brownish-green in color in intrusive rocks, and reddish-brown in extrusive rocks. The hornblende commonly has a reaction rim of finely divided iron oxides, and is sometimes altered to serpentine or chlorite. Hematite is the common iron oxide in extrusive rocks and magnetite is more abundant in intrusives. North of Gallagher Pass a few phenocrysts of clinopyroxene are present in addition to the hornblende and plagioclase.

Chemical analysis of a block from the andesite breccia (671) near the Bluestone Mine shows that it is silicic andesite with about 7 percent normative quartz (tables 3 and 4). An intrusion of the same type of andesite south of Gallagher Pass (602) is very similar in composition (tables 3 and 4), though it falls into the rhyodacite field in O'Connor's (1965) classification.

Andesite with only Hornblende Phenocrysts

This type of andesite occurs as a pile at least 800 feet thick of columnar jointed layers that appear to be lava flows and related subvolcanic intrusives, west of Singatse Peak. These rocks appear to overlie the andesite breccia containing plagioclase and hornblende phenocrysts, described above, on a slight angular unconformity.

The hornblende andesite flows and intrusions contain 10 to 15 percent hornblende phenocrysts, 0.5 to 5 mm long, and 0 to 2 percent of 0.5 to 2 mm plagioclase phenocrysts in a pale gray aphanitic groundmass. Very rarely, strongly resorbed quartz phenocrysts or xenoliths are present. The groundmass consists of weakly zoned 0.03 to 0.3 mm plagioclase microphenocrysts (calcic andesine to calcic labradorite) which make up 30 percent of the rock, 0.02 to 0.2 mm microphenocrysts of clinopyroxene which constitute 2 to 3 percent of the rock, and 0.03 to 0.05 mm opaque grains which make up 2 to 3 percent of the rock, in a matrix of fine low birefringence material; leucoxene, occasional tiny plagioclase laths, apatite needles (?), 0.002 to 0.004 mm equant opaque grains, and glass. Chemically the rock is mafic K-poor dacite near andesite in composition, with 11 percent normative quartz (No. 665 of tables 3 and 4).

Hornblende Biotite Dacite

This rock type occurs mainly as large sill-like intrusions, cutting the Bluestone Mine Tuff and other soft units in the western and northern parts of the district.

These rocks are similar to the other rocks of the Miocene andesite sequence, except for the presence of biotite and quartz "eyes". They consist of about 25 percent of 0.5 to 2 mm plagioclase phenocrysts; 10 to 15 percent 0.2 to 2 mm green hornblende phenocrysts; 3 to 5 percent, 0.5 to

2 mm biotite books; 1 to 3 percent bipyramidal quartz phenocrysts, rounded by resorbtion; and 1 to 2 percent magnetite in a gray aphanitic groundmass. The plagioclase phenocrysts have reversed and oscillatory zoning, from An_{60} to An_{35}, and average composition of about An_{50}. The hornblende and biotite phenocrysts have a thin reaction rim of finely divided iron oxide. The groundmass consists mainly of sub-parallel laths of andesine less than 0.05 mm in length with interstitial very low birefringence material that may be a silica mineral. Also present in the groundmass are finely divided iron oxide, titanium oxide, chlorite and apatite. Chemically the rock is a dacite with 12 percent normative quartz (No. 664 of tables 3 and 4).

K-Ar dates on hornblende and plagioclase from all three petrographic types of hornblende-bearing andesites and related dacites of the andesites of Lincoln Flat range from 17 to 19 m.y., or early to middle Miocene (table 1; the 14.2 m.y. determination on biotite from the hornblende biotite dacite is considered incorrect, and the concordant ages on hornblende and plagioclase are considered correct. However, it may be necessary to use the biotite age in correlating with rocks in some other areas where only biotite has been used for K-Ar determinations). The presence of abundant intrusive feeders of the same composition and age as the extrusive rocks indicates that the Yerington district was part of a Miocene andesitic volcanic center. Regionally it was probably part of a northerly trending chain of Miocene to Pliocene(?) andesitic volcanoes that existed in western Nevada and eastern California and which has apparently been offset 40 to 50 miles right laterally by the Walker Lane fault zone (Proffett, 1971b, 1972).

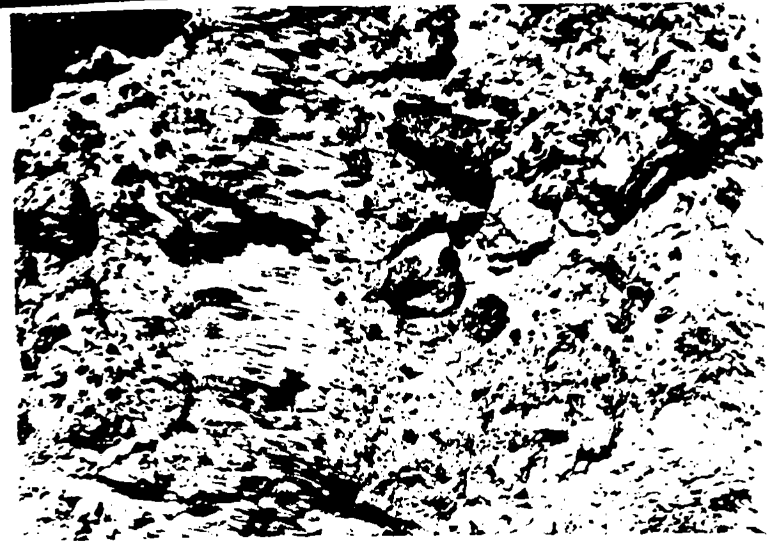

FIGURE 15. Lowermost porphyritic hornblende andesite breccia north of Gallagher Pass.

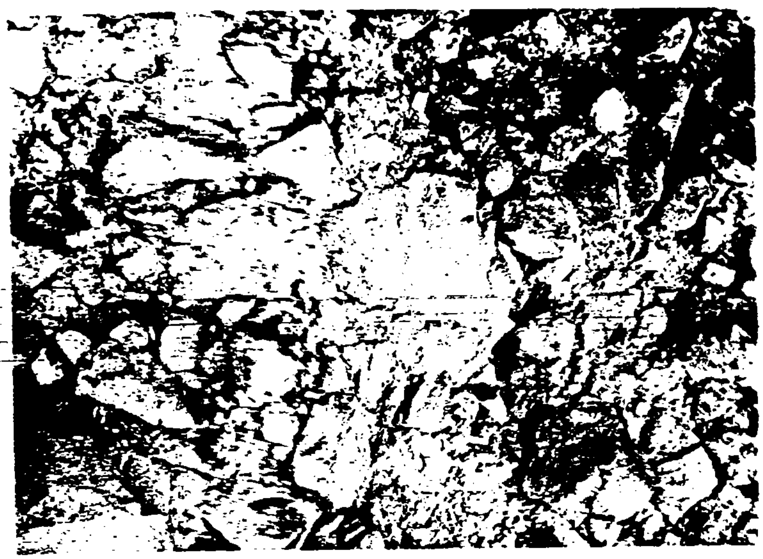

FIGURE 16. Porphyritic hornblende andesite breccia just east of the Bluestone Mine. The large block in the center of the photograph is one foot across.

SUMMARY OF ASH-FLOW TUFFS AT YERINGTON AND COMPARISONS WITH OTHER ASH-FLOW TUFFS

The Yerington ash-flow tuffs are part of an Oligocene ash-flow tuff province that extends throughout much of Nevada and western Utah (E. F. Cook, 1965; H. E. Cook, 1968; McKee, 1970, 1974; McKee and Stewart, 1971; Ekren and others, 1973, 1974a, 1974b). The tuffs of this province were apparently erupted in a tectonic setting in which the continental margin was being underthrust by crust of the Pacific Ocean, before basin-and-range faulting began in the area (Proffett, 1971b, 1972). Generation of the magma was apparently related to subduction. Many other ash-flow tuffs which have been studied in detail were erupted in the Great Basin and other parts of the western United States in quite a different tectonic setting, that is, after subduction ceased and after extensional faulting began in the area (Proffett, 1971b, 1972). These include many of the Miocene to Pliocene tuffs of the Nevada Test Site (Christiansen and others, 1965; Lipman and others, 1966; Byers and others, 1968; Noble, 1968; Noble and others, 1968), the Bishop Tuff in California (Gilbert, 1938), tuffs of the Valles Caldera (Smith and Bailey, 1966), and the tuffs of Yellowstone Park (Christiansen and others, 1968; Christiansen and Blank, 1972). A third type of setting from which ash-flow tuffs are erupted are large andesitic strata volcanoes of subduction-related island arcs and continental margins, such as Crater Lake, Oregon (Williams, 1942, 1968). In comparing characteristics of ash-flow tuffs, it is useful to keep in mind to which of these three settings they belong.

Eruptive Source

The source of the Yerington ash-flow tuffs is unknown. One small rhyolitic intrusive, somewhat similar in composition to some of the ash-flow tuffs, but which cannot be matched with any of them, occurs in the Yerington district (centerfold and table 2). It is likely that the source of the ash-flow tuffs is mainly or entirely outside the district. The source vents are well known for few of the really large volume Oligocene ash-flow tuffs of Nevada. Among the best documented ones are ignimbrite dikes and plugs, up to 1½ square miles in area, in the southern Hot Creek Range (H. E. Cook, 1968). There are no well defined calderas in the region of these vents although the possibility of some volcano-tectonic collapse cannot be ruled out. Just northeast of the southern Hot Creek Range an area of apparent large scale volcano-tectonic (cauldron) collapse has been mapped, and is inferred to be the source of at least two very large volume Oligocene ash-flow tuffs (Ekren and others, 1973, 1974b). Some smaller-volume ash-flow tuffs also had their sources in the area, and some were accompanied (or followed) by caldron collapse while others were not (Ekren and others, 1974b). Some other relatively small-volume Oligocene ash-flow tuffs of Nevada are interpreted as having caldera-related sources (McKee, 1970, 1974).

Of the ash-flow tuffs erupted after basin-and-range faulting began, many are known to have their sources in well-defined calderas of the Valles type (Gilbert, 1938; Smith and Bailey, 1966, 1968; Christiansen and others, 1965; Byers and others, 1968; Noble, 1968; Noble and others, 1968; Christiansen and Blank, 1972).

Krakatoa-type calderas (Williams, 1968) formed at the source of the larger-volume ash-flow tuffs erupted from andesitic strata-volcanos, such as Crater Lake, Oregon (Williams, 1942). Smaller-volume ash flows from such centers were accompanied by little collapse or by Katmai-type caldera collapse (Williams, 1968).

Vertical Zoning

Both major cooling units of the Mickey Pass Tuff are zoned from mafic to silicic upwards, but the Singatse Tuff shows little vertical zoning. Cook (1968) found mafic to silicic upward zoning in at least three Oligocene ash-flow tuff cooling units in the Hot Creek Range. Just to the east another ash-flow tuff with such zoning has been identified (Ekren and others, 1974b). A number of other Oligocene ash-flow tuffs east of the Hot Creek Range have silicic to mafic upward zoning (Ekren and others, 1974b).

Silicic to mafic upward zoning is common in ash-flow tuffs that are related to calderas of the Valles type and Krakatoa type (Williams, 1942, 1968; Smith and Bailey, 1966; Lipman and others, 1966). Such silicic to mafic upward zoning can be attributed to eruption and deposition of the upper silicic part followed by lower more mafic parts of a zoned, differentiating magma chamber. Ash-flow tuffs with mafic to silicic upward zoning are more difficult to explain, but could perhaps have been erupted from a zoned magma chamber if the mafic magma was allowed to escape first. This may have been caused by tapping the bottom of the magma chamber (Cook, 1968), by tapping the lower end of an inclined magma chamber, or by tapping the magma chamber after partial convective overturn of magma. An alternative explanation suggested by Cook (1968), is that the magma was *generated* with a mafic to silicic variation by anatexis with decreasing water pressure.

Lateral Extent

The Singatse Tuff has a lateral extent of at least 70 miles by 40 miles, even after the effect of basin-and-range extension is removed, and it may have been much more extensive than this. The only place where it is now known to pinch out is against existing topographic highs. The known lateral extent of the Mickey Pass Tuff is only 35 miles after removing the effect of basin-and-range extension, but it may be much more extensive than is now known. Some other ash-flow tuffs of the Nevada Oligocene province are thought to extend well over 100 miles (Cook, 1965) and some are smaller (McKee, 1970, 1974; Ekren and others, 1974b). Ash-flow tuffs related to well-defined calderas of the Valles type and Krakatoa type usually extend no more than 20 to 30 miles and rarely 50 miles from their source where they may pinch out even where they do not encounter topographic highs (Gilbert, 1938; Williams, 1942; Smith and Bailey, 1966; Byers and others, 1968; Noble and others, 1968).

Volume

The known volume of the Guild Mine Member of the Mickey Pass Tuff is at least 600 km^3 and that of the Singatse Tuff is at least 3,500 km^3. These volumes may be considerably larger. Many other ash-flow tuff cooling units from the Nevada Oligocene province are thought to have volumes of between 500 and 2,000 km^3 (Cook, 1965), although some are smaller (Cook, 1965; McKee, 1970, 1974; Ekren and others, 1974b). On the average, ash-flow tuff cooling units related to well-defined calderas of the Valles type are smaller in volume, generally ranging from 200 to 1,000 km^3 (Smith and Bailey, 1966; Byers and others, 1968; Noble, 1968; Noble and others, 1968) and even these are often compound cooling units (Smith, 1960). Ash-flow tuffs related to calderas of the Krakatoa type are even less voluminous; they generally range in volume from 10 to 100 km^3 (Williams, 1968).

Number and Thickness of Individual Flow Units

Partings between flows within cooling units are only rarely seen in the major cooling units of the Oligocene ash-flow tuffs at Yerington. Partings between flows are commonly seen within some other ash-flow tuffs, such as those of the Yellowstone region, which are associated with Valles-type calderas (Christiansen and others, 1968; R. L. Christiansen, oral communication, 1968). These flow partings define flows that are mostly 5 to 20 feet thick and rarely more than 50 feet thick. Evidently the Yerington ash-flow cooling units were erupted in relatively larger, less numerous eruptions.

Welding and Devitrification

The Guild Mine Member of the Mickey Pass Tuff seems to show zoning similar to Smith's thick-cooling-unit, high-temperature type (Smith, 1960, pl. 20C) with the basal unwelded or partially welded zone very thin or absent. The most densely welded zone comprises the lowermost few hundred feet of the unit with welding decreasing upward from this zone to the unwelded top. The entire unit is devitrified except for a zone a few tens of feet thick near the base (the vitrophyre). This vitrophyre persists at the base of the cooling unit even where the unit thins against topography to where the basal vitrophyre is only a few hundred feet below the top of the unit. Evidently all the upper few hundred feet of the unit was sufficiently welded to form vitrophyre but devitrification destroyed all but the basal vitrophyre.

A non-welded zone is thin or absent at the base of the Weed Heights Member, but a vitrophyre is usually present. A vitrophyre is locally present at the base of map unit 4 even though strong welding is not evident. The Singatse Tuff has a zone of fairly dense partial welding near its base and the densest welding seems to be one-third to one-half of the way above the base of the unit, similar to Smith's moderate temperature type (Smith, 1960, pl. 20A). Glass is preserved only locally in the lower part of the unit. Most of the Bluestone Mine Tuff is nonwelded to poorly welded. In some areas it is devitrified and in some it is still glassy, but no densely welded vitrophyre has been found in this unit in the Singatse Range.

Composition

The Mickey Pass Tuff and Singatse Tuff are quartz latite in average composition, as are many of the Oligocene ash-flow tuffs of Nevada. Some, such as the Bluestone Mine Tuff are rhyolite. Ash-flow tuffs that were erupted after basin-and-range faulting began are similar in composition, though perhaps a little more silicic on the average (Smith and Bailey, 1966; Lipman and others, 1966). Ash-flow tuffs associated with calderas of the Krakatoa type are probably a little more basic than the Nevada Oligocene ash-flow tuffs, and are commonly dacite (Williams, 1968).

Rock Association

No other rock types are yet known to be genetically associated with the quartz latite and rhyolite ash-flow tuffs of Yerington. Relatively small amounts of andesite are found near some of the Oligocene ignimbrite vents in the Hot Creek Range (Cook, 1968) but it is not known if they are genetically related to the ignimbrites. With few exceptions, only silicic rocks are associated with the cauldron complex east of the Hot Creek Range (Ekren and others, 1974b). Eruptive centers for some smaller ash-flow tuffs in the Nevada Oligocene province (McKee, 1970, 1974) do not appear to be genetically associated with intermediate or basic rocks. Ash-flow tuffs that followed the beginning of basin-and-range faulting are dominantly rhyolitic, but many appear to be part of a basalt-rhyolite association (Gilbert and others, 1968; Noble, 1968; Christiansen and Blank, 1972). Ash-flow tuffs related to calderas of the Krakatoa type or Katmai type are associated with calc-alkaline andesite, in volumes commonly larger than that of the ash-flow tuff, and with differentiated dacite to rhyolite (Williams, 1968).

Conclusions

The ash-flow tuffs at Yerington have many field and petrologic characteristics in common with other ash-flow tuffs that have been studied in detail. The units defined at Yerington, as well as some other Oligocene ash-flow tuffs of Nevada, exhibit characteristics such as mafic to silicic upward zoning and very large volume flow units that differ from ash-flow tuffs studied in other parts of the world. Differences such as these are perhaps most apparent between ash-flow tuffs erupted in different tectonic settings. Those doing field work in these units should be aware of such possible differences, as well as the similarities, in ash-flow tuffs.

REFERENCES CITED

Armstrong, R. L. (1970) Geochronology of Tertiary igneous rocks, eastern Basin and Range Province, western Utah, eastern Nevada, and vicinity, U.S.A.: Geochemica et Cosmochimica Acta, v. 34, p. 203–232.

Axelrod, Daniel (1956) Mio-Pliocene floras from West-Central Nevada: Univ. Calif. Pub. Geol. Sci., v. 33, p. 1–322.

——— (1968) Tertiary floras and topographic history of the Snake River Basin, Idaho: Geol. Soc. America Bull., v. 79, p. 713–734.

Bateman, P. C., and Wahrhaftig, C. (1966) Geology of the Sierra Nevada: Geology of Northern California, Bull. 190, Calif. Div. Mines and Geol., p. 107–169.

Bonham, H. F., Jr. (1969) Geology and mineral deposits of Washoe and Storey Counties, Nevada: Nev. Bur. Mines Bull. 70, 140 p.

Byers, F. M., Jr., Orkild, P. P., Carr, W. J., and Quinlivan, W. D. (1968) Timber Mountain Tuff, southern Nevada and its relation to caldron subsidence: Geol. Soc. America Mem. 110, p. 87–97.

Christiansen, R. L., and Blank, H. R., Jr. (1972) Volcanic stratigraphy of the Quaternary rhyolite plateau in Yellowstone National Park: U.S. Geol. Survey Prof. Paper 729-B, 18 p.

Christiansen, R. L., Blank, H. R., Jr., and White, D. E. (1968) Some volcanic features of Yellowstone rhyolite plateau, with comments on hydrothermal features, *in* Igneous and Hydrothermal Geology of Yellowstone National Park: Guidebook to field trip, No. 6; Geol. Soc. America, Rocky Mountain Section Annual meeting.

Christiansen, R. L., Lipman, P. W., Orkild, P. P., and Byers, F. M., Jr. (1965) Structure of the Timber Mountain caldera, southeastern Nevada, and its relation to Basin-Range structure: U.S. Geol. Survey Prof. Paper 525-B, p. 43–48.

Cook, E. F. (1955) Nomenclature and recognition of ignimbrites [abs]: Geol. Soc. America Bull., v. 66, p. 1544.

——— (1965) Stratigraphy of Tertiary volcanic rocks in eastern Nevada: Nev. Bur. Mines Report 11, p. 1–61.

Cook, H. E. (1968) Ignimbrite flows, plugs, and dikes in the southern part of the Hot Creek Range, Nye County, Nevada; Studies in volcanology: Geol. Soc. Amer., memoir 116, p. 107–152.

Ekren, E. B., Hinricks, E. N., Quinlivan, W. D., and Hoover, D. L. (1973) Geologic Map of the Moores' Station quadrangle, Nye County, Nevada: U.S. Geol. Survey Misc. Geol. Inv. Map I-756, 1:48,000.

Ekren, E. B., Bath, G. D., Dixon, G. L., Healy, D. L., and Quinlivan, W. D. (1974a) Tertiary history of Little Fish Lake Valley, Nye County, Nevada, and implications as to the origin of the Great Basin: Jour. Research, U.S. Geol. Survey, v. 2, no. 1, p. 105–118.

Ekren, E. B., Quinlivan, W. D., Snyder, R. P., and Kleinhampl, F. J. (1974b) Stratigraphy, structure and geologic history of the Lunar Lake caldera of northern Nye County, Nevada: Jour. Research, U.S. Geol. Survey, v. 2, no. 5, p. 599–608.

Gilbert, C. M. (1938) Welded tuff in eastern California: Geol. Soc. America Bull., v. 49, p. 1829–1862.

Gilbert, C. M., Christensen, M. N., Al-Rawi, Y. and Lajoie, K. L. (1968) Structural and volcanic history of Mono Basin, Calif.-Nevada; Studies in volcanology: Geol. Soc. America Mem. 116, p. 275–329.

Lipman, P. W., Christiansen, R. L., O'Connor, J. T. (1966) A compositionally zoned ash-flow sheet in southern Nevada: U.S. Geol. Survey Prof. Paper, 524-F, 47 p.

Mackin, J. H. (1960) Structural significance of Tertiary volcanic rocks in southwestern Utah: American Jour. Sci., v. 258, p. 81–131.

McKee, E. H. (1970) Fish Creek Mountains Tuff and volcanic center, Lander County, Nevada: U.S. Geol. Survey Prof. Paper 681, 17 p.
_______ (1974) Northumberland Caldera and Northumberland Tuff: Nev. Bur. Mines and Geol. Rep. 19, p. 35–41.
McKee, E. H., Silberman, M. L., Marvin, R. F., and Obradovich, J. D. (1971) A summary of radiometric ages of Tertiary volcanic rocks in Nevada and eastern California–central Nevada: Isochron/West, no. 2, p. 21–42.
McKee, E. H. and Stewart, J. H. (1971) Stratigraphy and potassium-argon ages of some Tertiary tuffs from Lander and Churchill Counties, Nevada: U.S. Geol. Survey Bull. 1311-B, 28 p.
Moore, J. G. (1969) Geology and mineral deposits of Lyon, Douglas and Ormsby Counties, Nevada: Nevada Bur. Mines Bull. 75, 45 p.
Noble, D. C. (1968) Kane Springs Wash volcanic center, Lincoln County, Nevada: Geol. Soc. America Mem. 110, p. 109–116.
Noble, D. C., Sargent, K. A., Mehnert, H. H., Ekren, E. B., and Byers, F. M., Jr. (1968) Silent Canyon volcanic center Nye County, Nevada: Geol. Soc. America Mem. 110, p. 65–75.
O'Connor, J. T. (1965) A classification for quartz-rich igneous rocks based on feldspar ratios: U.S. Geol. Survey Prof. Paper 525-B, p. 79-84.
Proffett, J. M., Jr. (1971a) Late Cenozoic structure in the Yerington district, Nevada, and the origin of the Great Basin [abs]: Geol. Soc. America, Abstracts with Programs, v. 3, no. 2, p. 181.
_______ (1971b) Cenozoic geology in the Yerington district, Nevada, and the origin of volcanic associations in the Great Basin [abs]: Geol. Soc. America Abstracts with Programs, v. 3, no. 6, p. 405–406.
_______ (1972) Nature, age and origin of Cenozoic faulting and volcanism in the Basin and Range Province (with special reference to the Yerington district, Nevada): Univ. Calif. Berkeley Ph.D. thesis, 77 p.
Ross, C. S., and Smith, R. L. (1961) Ash-flow tuffs: their origin, geologic relations and identification: U.S. Geol. Survey Prof. Paper 366, 81 p.
Smith, R. L. (1960) Zones and zonal variations in welded ash flows: U.S. Geol. Survey Prof. Paper 354-F, p. 149–159.
Smith, R. L., and Bailey, R. A. (1966) The Bandelier Tuff: A study of ash-flow eruption from zoned magma chambers: Bulletin Volcanologique, Tome XXIX, p. 83–104.
_______ (1968) Resurgent cauldrons: Studies in volcanology, Geol. Soc. America Mem. 116, p. 613–662.
Turner, D. L. (1970) Potassium-Argon dating of Pacific Coast Miocene foraminiferal stages: Geol. Soc. America Spec. Paper 124, p. 91–129.
Williams, Howel (1942) The geology of Crater Lake National Park, Oregon, with a reconnaissance of the Cascade Range southward to Mount Shasta: Carnegie Inst. Wash. Pub. 540.
Williams, Howel, and McBirney, A. R. (1968) Geologic and geophysical features of Calderas: NASA, Houston, Texas, 87 p.
Williams, Howel, Turner, F. J., and Gilbert, C. M. (1955) Petrography: W. H. Freeman and Co., San Francisco, 406 p.