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GEOCHEMISTRY, AGE AND STRONTIUM ISOTOPE COMPOSITION OF LATE TERTIARY AND QUATERNARY BASALTS AND ANDESITES IN WESTERN NEVADA AND THEIR RELATION TO GEOTHERMAL POTENTIAL

Final Report for the Period October 1, 1982—December 31, 1983

By
L. A. Fultz
E. J. Bell
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Work Performed Under Contract No. FC03-80RA50075

Division of Earth Sciences
University of Nevada, Las Vegas
Reno, Nevada

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October 1, 1982 - December 31, 1983

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EXECUTIVE SUMMARY

This research was undertaken to characterize the late Cenozoic volcanic rocks associated with active geothermal systems in west-central Nevada. This characterization will serve as a model for comparison with future exploration target sites to evaluate their geothermal resource potential.

The Division of Earth Sciences, UNLV, utilized petrographic and microprobe, geochemical and isotopic analysis and age dating techniques to characterize these young volcanic rocks. These data were combined with the limited data previously reported in the literature on these same volcanic areas to interpret their petrogenesis. The overall characterization resulted from integrating the petrogenesis with a structural-tectonic model of the region.

Potassium-argon isotopic ages ranging up to 14 million years were determined for eight localities within the Reno 1 x 2° study region. These ages are consistent with the morphology of the volcanic landforms, the active geothermal systems associated with them, and with other isotopic ages reported in the literature for these and similar rocks within the study region.

Petrographic analysis of hand specimens and thin-sections indicated mineralogic assemblages of the respective rock types and specific mineral textures and phenocryst compositions and characteristics. These identifications were further substantiated by microprobe analysis of selected phenocrysts and groundmass phases. Classification of the respective rock types was also based on chemical composition and normative calculations using the program PETCAL. Basaltic andesites are identified and described for Steamboat Hills, Table Mountain, Silver Springs, Churchill Butte, Cleaver Peak, Desert Peak and Carson City sites. Basalts are identified and described for McClellan Peak, Rattlesnake Hill, Soda Lake and Upsal Hogback. Siliceous rocks are identified and described for Steamboat Hills, Desert Peak and Upsal Hogback. The siliceous rocks at Desert Peak, described by previous workers as Pliocene andesite flows, are redefined by this study as rhyolitic ignimbrites that are Miocene in age. Reversely zoned plagioclase phenocrysts and partially resorbed quartz phenocrysts were identified in thin-sections of samples from Steamboat Hills, Soda Lake and Upsal Hogback.

Petrochemical analysis of these volcanic rocks for major and minor element chemistry and for strontium isotopic composition indicated that these rocks represent a bimodal suite having either less than 59% or greater than 69% silica. No province differences are evident based on major element chemistry. However, based on both minor element chemistry and isotopic ratios, rocks in the western portion of the study region (i.e., within the Walker Lane and Sierra Nevada Provinces) can be distinguished from rocks in the eastern portion of the region (i.e., the Carson Desert and Desert Peak areas within the northern Basin and Range Province).

Petrogenesis of these volcanic rocks, incorporating the petrographic and petrochemical data with the known structural-tectonic setting of this region, is interpreted as an immature volcanic system in which silicic pods derived from melting of lower crustal material and mafic dikes of mantle-derived magma have not aggregated into large chambers. Active faults provide the conduits for migration of basaltic magma to the surface, as well as for downward percolating groundwater which results in the associated geothermal systems by conducting heat. A simple depth-pressure relationship explains the cognate reversely zoned plagioclase phenocrysts and the incompletely resorbed refractory quartz phenocrysts as originating at upper mantle depths. As these magmas rise through the crust, contamination by crustal rocks would affect their major and minor element chemistry and their isotopic composition - such an effect is not

observed. Specific chemical and mineralogic variations in these rocks is therefore attributed to inherent regional variations (both laterally and vertically) in the age and composition of the upper mantle and lower crust source regions for the magmas.

Late Miocene and younger volcanism in west-central Nevada is bimodal (basalt-rhyolite) occurring in an actively extending tectonic environment. These primarily basaltic magmas originate in the upper mantle and rise, essentially uncontaminated, through the crust via structural conduits. Recurring volcanic activity associated with these mantle derived magmas provides a sustained heat source for the associated geothermal systems.

INTRODUCTION

The Division of Earth Sciences, University of Nevada, Las Vegas, under contract no. AC03-82RA50075 from the U.S. Department of Energy, San Francisco Operations Office, has investigated the relationship of late Tertiary to Quaternary volcanic rocks to active geothermal systems in west-central Nevada.

Previous studies of igneous related geothermal systems by Smith and Shaw (1975) indicate that large high-level (shallow crustal) silicic magma chambers are often accompanied by geothermal systems with economic potential. Evaluation of geographical areas having geothermal potential currently involves young volcanic systems dominated by the presence of silicic flows, tuffs and domes believed indicative of high-level magma chambers (e.g., Coso, Long Valley and Clear Lake volcanics (Geysers) in California, and Yellowstone in Wyoming).

The importance of basaltic volcanism in the development of large silicic magma chambers has been increasingly emphasized. Eichelberger and Gooley (1977) have suggested that additional heat input to a silicic magma chamber by underplating of basaltic magma offers a plausible explanation for the observed life spans of some silicic magma systems. Discrepancies between the observed life spans of geothermal systems and the shorter life spans calculated from conventional models may be explained by sustained heat input to the geothermal systems by basaltic magmas (Lachenbruch and others, 1976; Crecraft and others, 1980; Hildreth, 1981).

Late Miocene and younger volcanism in west-central Nevada (fig. 1), however, has been primarily bimodal (basalt-rhyolite) in nature (Stewart and Carlson, 1976; Silberman and others, 1975; Christiansen and Lipman, 1972). Rocks of basaltic composition are derived from the mantle and lowermost crust. These magmas rise rapidly to the surface through narrow fissures and do not

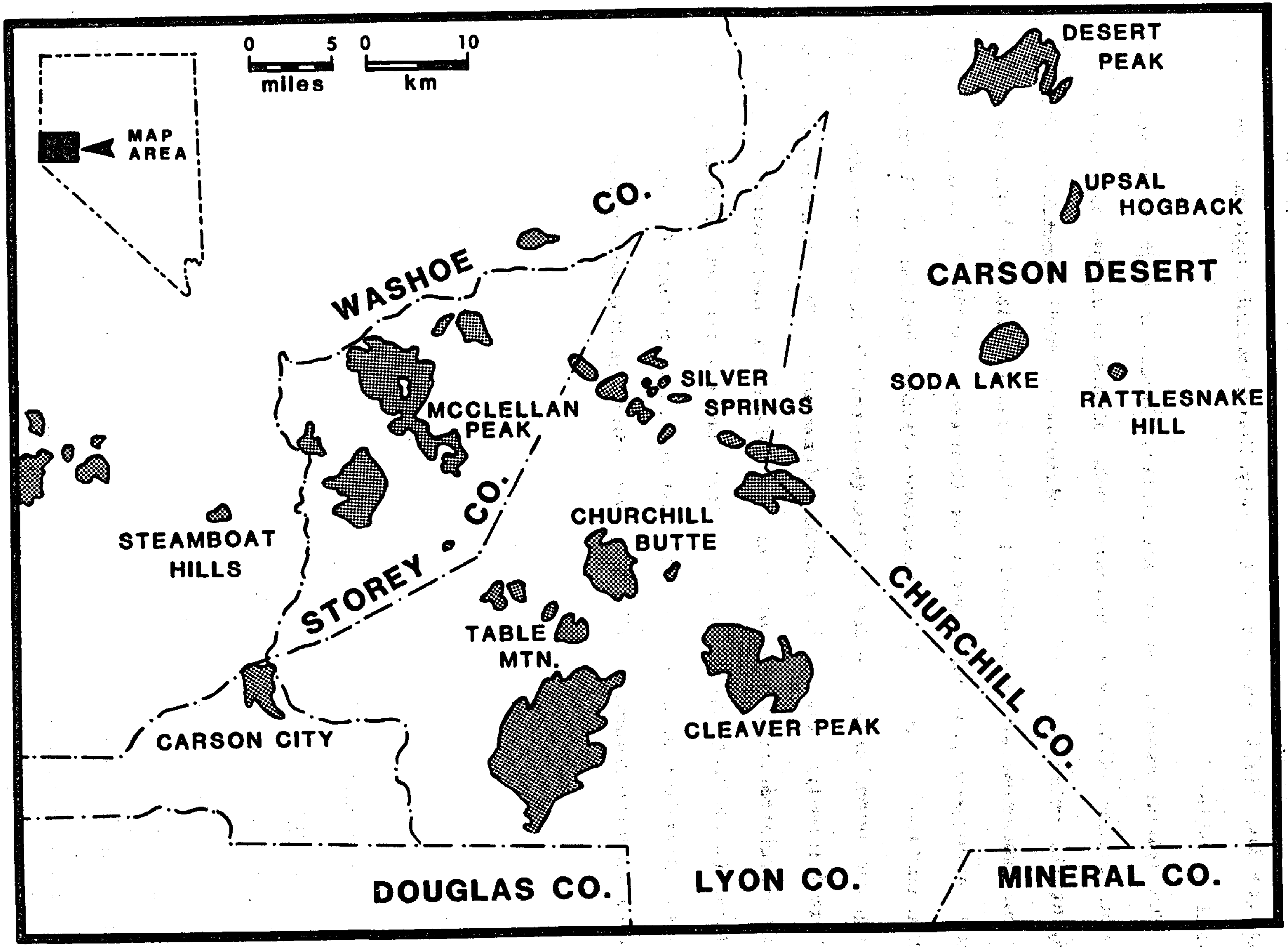


Figure 1. Index map of study area and distribution of young volcanic rocks (shaded areas).

contribute significant amounts of stored heat to the crust. For this reason, Smith and Shaw (1975) suggest that purely basic volcanic systems rarely form thermal anomalies.

The spatial association in west-central Nevada of high temperature geothermal systems with young volcanic rocks offers a unique opportunity for studying the relationship of bimodal volcanism to active geothermal systems. Numerous geothermal springs and wells in the area include some high temperature systems with power production potential (temperatures >350°F within 4000 feet of the surface). These high temperature systems include the Steamboat Hot Springs geothermal area, the Desert Peak geothermal field and the Carson Desert geothermal anomaly. Two of these areas (Steamboat and Carson Desert) are spatially associated with young volcanic rocks of basaltic and rhyolitic affinity. The Division of Earth Sciences has utilized petrographic and microprobe, geochemical, geochronologic and strontium isotopic compositions for an evaluation of volcanic rocks associated with high temperature geothermal systems.

METHODS

LITERATURE REVIEW

The available literature was reviewed for specific references containing 1) data on the chemical and isotopic character and age of young volcanic rocks in the study area, 2) geochemical indicators of magma chamber conditions, and 3) models for magma generation and differentiation.

A review of published sources indicates that limited data are available on the geochemical and isotopic character of the young volcanic rocks within the study area. The most extensive rock chemistry data were reported for the Steamboat area by Thompson and White (1964). Six strontium isotopic values from the area are given by Morton and others (1980, 1983). Isotopic ages have been compiled on a regional basis by Luedke and Smith (1981). Computer programs for fractionation modeling of basaltic magmas were obtained from Michigan Technological University (Rose, written commun., 1982).

PHOTOGEOLOGIC INTERPRETATION

Detailed photogeologic interpretation of the Steamboat Hills and vicinity was conducted using 1:12,000 scale aerial photographs (GS-VBMQ; 5-21-66) and supplemented by analysis of 1:16,000 scale color aerial photographs (GS-VBMQ-C; 10-16-67) and 1:8,000 scale low sun-angle aerial photographs (4-28-78). Specific structural features (faults) were identified and delineated to define the structural setting for the Steamboat Hills geothermal area. The various volcanic flows in the Steamboat Hills were delineated based on flow morphology and sampling sites were defined. Photogeologic interpretations were verified by field reconnaissance and comparison with published data (Szecsody and Nichol, 1982; Bell, 1981; Thompson, 1956; Thompson and White, 1964; White and others, 1964).

Small-scale (1:62,500) AMS aerial photography of the entire study area was reviewed to evaluate other exposures of young volcanic rocks in the remainder of the study area and to identify potential sampling sites.

PETROGRAPHY

A total of 64 samples collected from stratigraphic sequences and various flow units at 15 sites within the study area (see fig. 3) were submitted to the Nevada Bureau of Mines and Geology for the preparation of polished thin sections. These samples and thin sections were evaluated for the presence and degree of secondary alteration. Based upon the lack of secondary alteration and geographic distribution of the samples within the study area, the 31 samples listed in Table 1 were selected for further petrographic and geochemical analyses.

The majority of the samples are from the young volcanic rocks at Steamboat Hills (see fig. 6). As noted above, the various time-sequential flows at Steamboat could be delineated; this was not possible at the other sampling sites since flow morphology was not well preserved or was not as distinct. The characteristics of these Steamboat Hills volcanic rocks were then used as a basis for evaluating other volcanic-geothermal associations in west-central Nevada.

GEOCHRONOLOGY

Mineral separates and whole rock samples were prepared by L.A. Fultz and submitted to Krueger Enterprises, Inc., Geochron Laboratories Division, Cambridge, Massachusetts. The determinations were run by Thomas Bills, K-Ar Lab Manager, Geochron Laboratories Division. All samples were treated with dilute HF and HNO_3 to reduce atmospheric argon. Argon analyses were performed

TABLE 1

Sample Numbers, Lithology and Location

SAMPLE NO.	LOCATION
	STEAMBOAT HILLS
	basaltic andesite
3301	NW¼ S.32 T18N, R20E
3304	SE¼ S.31 T18N, R20E
3305	SE¼ S.32 T18N, R20E
3307	NW¼ S.32 T18N, R20E
3308	NW¼ S.32 T18N, R20E
3310	SW¼ S.32 T18N, R20E
3312	SW¼ S.32 T18N, R20E
3314	NW¼ S.5 T17N, R20E
3316	SW¼ S.32 T18N, R20E
3320	NW¼ S.5 T17N, R20E
3327	SW¼ S.33 T18N, R20E
3330	SW¼ S.33 T18N, R20E
3333	NE½ S.32 T18N, R20E
	rhyolite
3323	NE¼ S.1 T17N, R19E
	**
	TABLE MOUNTAIN (TM)
	basaltic andesite
3344	NW¼ S.3 T16N, R23E
	**
	SILVER SPRINGS (SS)
	basaltic andesite
3345	NE¼ S.31 T19N, R25
	**
	CHURCHILL BUTTE (CB)
	basaltic andesite
3347	NE¼ S.25 T17N, R23E
	**
	CLEAVER PEAK (CP)
	basaltic andesite
3348	NW¼ S.33 T16N, R25E
	McCLELLAN PEAK (MP)
	olivine basalt
3346	NW¼ S.6 T18N, R22E
	**
	DESERT PEAK (DP)
	ignimbrite
DP-2A	SW¼ S.30 T22N, R28E
DP-3	SW¼ S.30 T22N, R28E
DP-5B	SW¼ S.3 T22N, R28E
3357	SW¼ S.25 T22N, R28E
	basaltic andesite
3360	SW¼ S.10 T22N, R27E
	**
	CARSON CITY (CC)
	basaltic andesite
3339	SE¼ S.21 T16N, R20E
3340	NE¼ S.1 T15N, R20E
	**
	RATTLESNAKE HILL (RH)
	basalt
3350	NW¼ S.29 T19N, R29E
	**
	SODA LAKE (SL)
	basalt
3356	SW¼ S.8 T19N, R28E
	**
	UPSAL HOGBACK (UH)
	rhyolite
3352	SE¼ S.2 T20N, R28E
	basalt
3354	SE¼ S.2 T20N, R28E
3358	SE¼ S.2 T20N, R28E

by standard isotope dilution procedures (Dalrymple and Lanphere, 1969) using an AEI MS-10 mass spectrometer. Potassium analyses were performed by the lithium metaborate flux fusion-flame photometry technique (Ingamels, 1970). Samples were run in duplicate, except for triplicate argon analyses of sample H-3312 (plagioclase) and sample H-3344 (whole rock).

Ages supplied by Geochron Laboratories Division were recalculated using the following constants:

$$\lambda_{\beta} = 4.963 \times 10^{-10}\ \mathrm{yr}^{-1}$$

$$\lambda_{\varepsilon} = 0.572 \times 10^{-10}\ \mathrm{yr}^{-1}$$

$$\lambda_{\varepsilon'} = 8.78 \times 10^{-13}\ \mathrm{yr}^{-1}$$

$$^{40}\mathrm{K}/\mathrm{K}_{\mathrm{total}} = 1.167 \times 10^{-4}$$

These constants are based on data on the abundance of ^{40}K (Garner and others, 1975) and its decay constants (Beckinsale and Gale, 1969) and are refined compared to those used prior to 1976. The analytical data and calculated isotopic ages are listed in Appendix A. Other ages reported in the literature were recalculated, as indicated in the text. Ages not recalculated vary by 10 to 12 percent, being younger than if recalculated.

X-RAY FLUORESCENCE

Thirty-one samples were analyzed by x-ray fluorescence at Michigan Technological University (MTU), using an automated Phillips spectrometer unit with a dedicated computer. Rocks were pulverized to <325 mesh, mixed with a starch binder and pelletized. MTU used an analytical scheme modified from Leake and others (1969) and utilized 30 international geochemical standards and published values of Flanagan (1973) for calibration. Subsets of the standard group were selected to approximate the matrix of the unknowns. W-1 diabase was used as a ratio standard in all determinations. Results of replicate determinations of basalt standard BCR-1 for major elements are tabulated in Appendix B. For the trace elements, the special glasses GSA, GSB, GSC, GSD, and GSE (Myers and others, 1976) were used in addition to the international standards. Trace element detection limits and precisions at typical concentrations are tabulated in Appendix B. Trace element concentrations for the 31 samples analyzed during this study are listed in Appendix C.

The major element concentrations, as oxides, were entered into the PETCAL program (modified from Bingler and others, 1976; Appendix D) to obtain various oxide ratios, normative mineral contents and mineral ratios, petrochemical indices, and the IUGS classification of the rock samples. The PETCAL output for each sample is presented in Appendix E.

MICROPROBE

Microprobe analyses of selected samples, and in particular of phenocrysts, were conducted at the University of California-Berkeley using an 8 channel SEM Q microprobe. All analyses were converted to percent oxide using a Digital Electronics Corporation PDP-11 computer with a code written by Mark Rivers (University of California-Berkeley). A 15 KV filament current was used with a 54020 nominal beam current. No drift corrections were applied to the analyses. The six standards used for determination of SiO_2, Al_2O_3, Na_2O, K_2O, CaO, FeO (total iron), MgO and MnO are reproduced in Appendix B.

Samples selected for microprobe analysis included: 3304, 3312, 3314, 3323, 3346, 3354, 3356 and 3357 (see Table 1). The ranges in composition of minerals are presented in the Petrography section and the section on Microprobe of Plagioclase Phenocrysts. Microprobe traverse data for selected plagioclase phenocrysts are presented in Appendix F.

STRONTIUM ISOTOPES

Fourteen samples (twelve whole rock and two plagioclase separates) were submitted to Teledyne Isotopes, Westwood, New Jersey, for determination of strontium isotopic ratios. The analytical technique utilized by Teledyne Isotopes is as follows.

Approximately 300 mg of each sample was dissolved in approximately 6 ml of HF, 0.5 ml $HClO_4$, 0.5 ml HNO_3, allowed to digest cold overnight, then evaporated to dryness. The samples were then redissolved in 2.5 N HCl and eluted through an ion exchange column. The strontium fraction was collected and evaporated to dryness. All reagents used are distilled at sub-boiling temperatures. The lab blank is approximately 0.2 ng of strontium. All evaporations were conducted in filtered air.

The samples were then run using an NBS design 68° sector, 12-inch radius mass spectrometer equipped with computer controlled peak switching and on-line data acquisition and reduction. The samples were run on baked-out, oxidized, single tantalum filaments. Between 50 and 100 ratios were taken for each sample.

The $^{87}Sr/^{86}Sr$ ratios were normalized to $^{86}Sr/^{88}Sr = 0.11940$ and to the Eimer and Amend $SrCO_3$ standard value of 0.7080. The resulting Sr isotopic ratios are presented in a separate section of this report. The data were subjected to a two sigma filter. The analytical uncertainty quoted is the standard deviation of the mean and is generated from each mass spectrometer run.

GENERAL GEOLOGY

The study area, within the Reno 1 x 2° quadrangle (fig. 1), extends from the eastern margin of the Sierra Nevada into the western Great Basin Province. The following general geology of the study region is summarized from Bonham (1969), Moore (1969) and Silberman and others (1975).

Igneous, metamorphic and sedimentary rocks of Permian (?) through Recent age are present within the study area. The pre-Tertiary rocks, predominantly Mesozoic in age, are metasedimentary and metavolcanic rocks intruded by granitic plutons. Rocks of Cenozoic age include Tertiary volcanic sequences and Quaternary volcanics and alluvial and lacustrine sediments.

Volcanism during mid-Tertiary (pre-Miocene) was predominantly rhyolitic and rhyodacitic in composition and occurred as ash flow sheets. Late Miocene volcanism was dominantly calc-alkaline andesitic with transition to predominantly basaltic volcanism with minor amounts of rhyolite since 5 to 7 million years (m.y.) ago (Silberman and others, 1975). Rock units of specific interest to this study include volcanics of the Lousetown Formation, Steamboat Hills rhyolite, McClellan Peak olivine basalt, and the basaltic andesite of Steamboat Hills.

The Lousetown Formation (Thayer, 1937) consists predominantly of flows and associated intrusions of olivine basalt and pyroxene andesite with isotopic age of 6.8 to 7.1 Ma at the type section in Lousetown Creek. Basalt flows at Clark Mountain (Thompson, 1956) and in the Steamboat Hills (Thompson and White, 1964) have been correlated with the Lousetown Formation.

The structural complexity of the area is defined first by a Mesozoic episode of deformation that included folding, faulting, low-grade regional metamorphism and granitic plutonism. A second, continuing episode of deformation that is Cenozoic in age began in the Miocene and includes normal faulting and associated tilting, warping, wrench faulting and related folding and volcanism.

GEOTHERMAL RESOURCES

STEAMBOAT HOT SPRINGS

The Steamboat Hot Springs system (fig. 2) is the oldest and most studied geothermal area in Nevada (White and others, 1964; Thompson and White, 1964; Silberman and others, 1979; White, 1968). The geothermal system is associated with the Steamboat Hills basaltic andesite dated by Silberman and others (1979) at 2.53 ± 0.11 Ma (Mega-annum) (Appendix A). The thermal area is associated with four rhyolite domes ranging in age from 1.14 to 3.0 Ma, the largest of which lies 5 km southwest of the hot springs (Silberman and others, 1979). Silberman and others (1979) estimated that 3000 km^3 of magma would be required to sustain 3 m.y. of continuous thermal activity at Steamboat.

The resource has been designated a KGRA (Known Geothermal Resource Area) and shows promise of being economically exploitable for electric power generation. A 3050 foot deep geothermal test well drilled in 1979 by the Phillips Petroleum Company in the basaltic andesite vent area yielded temperatures greater than 400°F (Garside and Schilling, 1979).

CHURCHILL BUTTE AREA

A moderate-temperature geothermal resource (Wabuska Hot Springs) is located approximately 5 miles south of Cleaver Peak in the Churchill Butte area. A well drilled by Magma Power Company in 1959 encountered a bottom hole temperature of 227°F at 2223 feet (Garside and Schilling, 1979). A hydroponic green house was constructed at Wabuska, but current aquaculture efforts are directed toward growing spririulina algae.

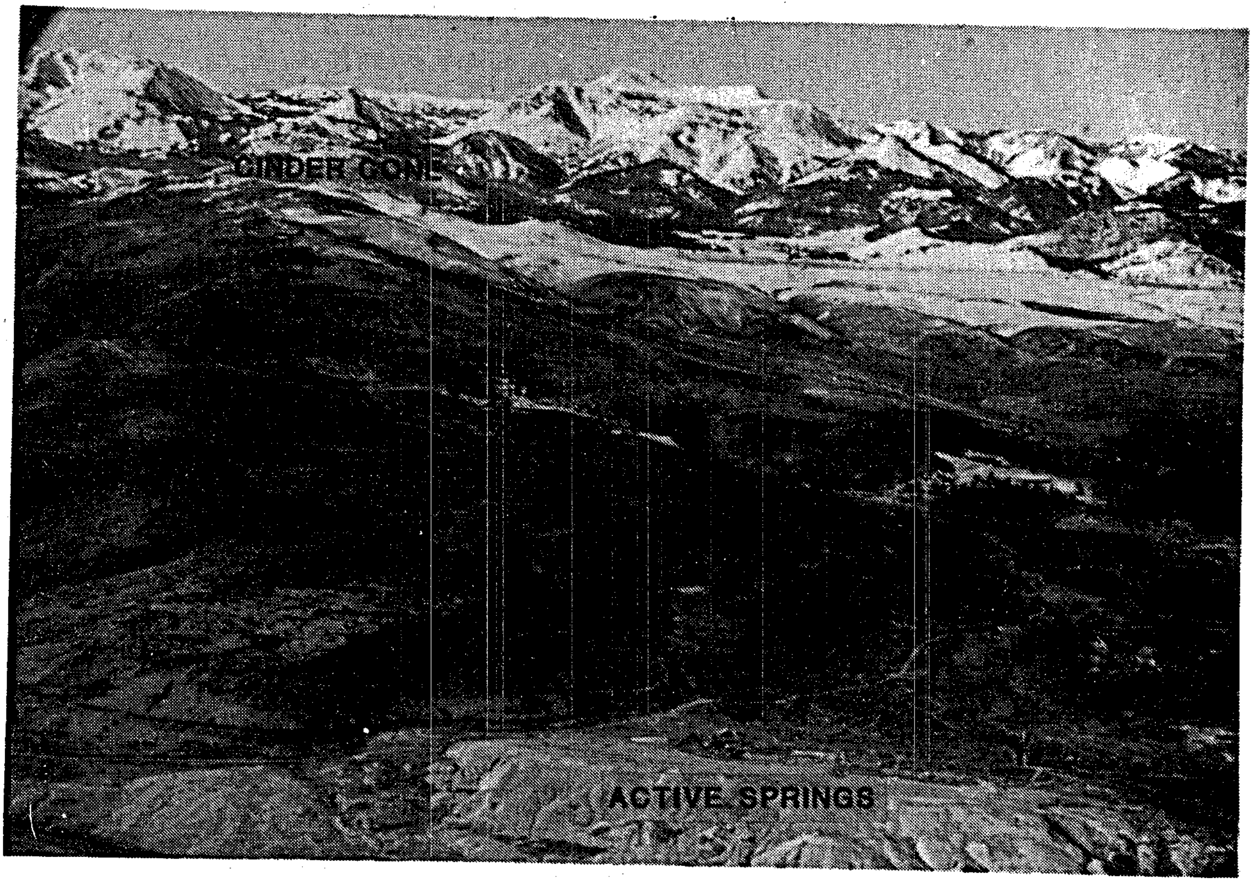


Figure 2. View of Steamboat Hills looking west. Cinder cone is located in upper left portion of photo, with flows extending toward the Main Terrace. Active steam vents and springs mark the Main and Lower Terraces. Sierra Nevada are in the background.

CARSON CITY

Numerous hot springs having temperatures up to 120°F have been reported in the Carson-Eagle Valley area (Garside and Schilling, 1979; Trexler and others, 1979). The waters have been used to heat a public swimming pool and bath house.

CARSON DESERT

A shallow thermal anomaly with temperatures in excess of 350°F at 2000 feet occurs north of Soda Lake (Hill and others, 1979). In addition, a 10,000 foot drill hole, located approximately 16 miles to the east in the Stillwater geothermal prospect, has a reported bottom hole temperature in excess of 350°F (Ash, 1981).

DESERT PEAK

The Desert Peak geothermal field is located in the northern portion of the Hot Springs Mountains, northwest of the Carson Desert. Phillips Petroleum Company has a continuing program of exploration and development of this geothermal resource. To date, they have encountered temperatures in excess of 400°F within 2000 feet of the ground surface (Benoit and others, 1982).

STRUCTURAL GEOLOGY

The Reno AMS 1 x 2° sheet study area encompasses portions of three structural regimes (fig. 3), each characterized by continuing late Cenozoic tectonic activity. From east to west, these are the: 1) northern Basin and Range, 2) Walker Lane, and 3) Sierra Nevada.

NORTHERN BASIN AND RANGE

The northern Basin and Range is recognized by regionally high elevation, horst and graben morphology (Eaton, 1979) and an extensional stress field (Wright, 1976). Pre-Basin-Range shallow extension along a WSW-ENE axis occurred during the period 40 to 20 m.y. ago. The thermal regime produced by major episodes of intrusive activity developed hot, thermally weakened crust and resulted in the widespread occurrence of steep-walled caldera complexes and tremendous volumes of calc-alkaline magmatism (McKee, 1971; Noble, 1972).

Prior to approximately 15 m.y. ago, the time-transgressive superposition of dextral shear associated with the developing San Andreas transform fault rotated the stress field within the northern Basin and Range to EW to WNW-ESE directed least principal stress (extension direction). This change in stress regime within the Basin and Range allowed for the initiation and development of deeply penetrating faults in the upper 10 to 15 km of crust suggesting overall cooling of the crust, facilitating tapping of subcrustal magma systems responsible for the associated basalt and bimodal basalt-rhyolite magmatism (Elston and Bornhorst, 1979; Rehrig and others, 1980; Christiansen and Lipman, 1972; McKee, 1971; Noble, 1972). Basaltic volcanism is concentrated near the margins of the Basin and Range (Best and Brimhall, 1974). Dickinson and Snyder (1975, 1979) attribute Basin and Range extensional faulting with bimodal volcanism to

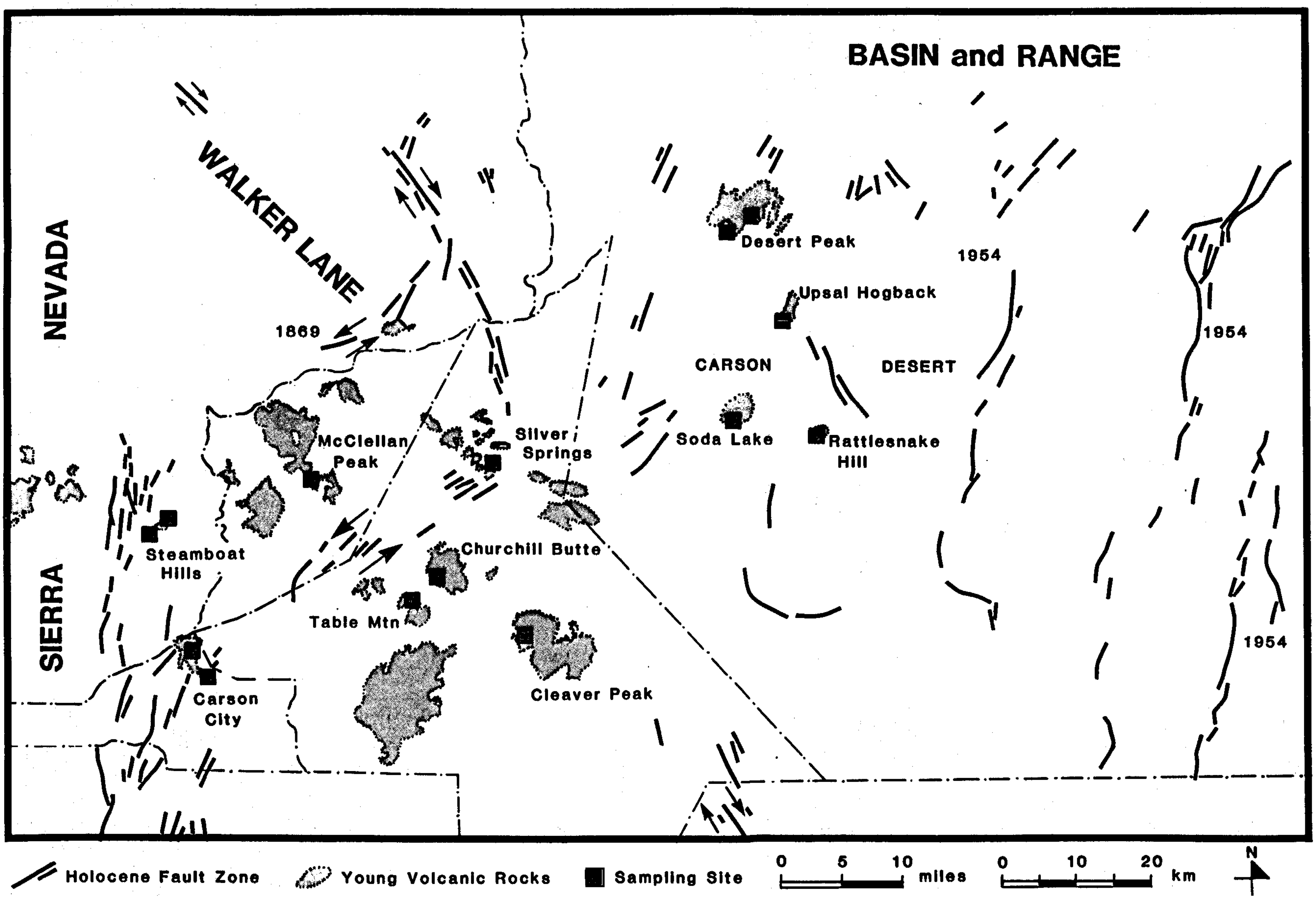


Figure 3. Generalized structural map of study area. Structural zones, defined by areas of known Holocene and historic faulting, are shown with respect to areas of young volcanic rocks and sample sites. (modified after Bell, 1981)

the upwelling of hot asthenosphere to replace volume occupied by the subducted lithospheric slab behind the transform.

Modern Basin and Range structure is defined (Stewart, 1978) as normal fault controlled ranges and sedimentary basins. In the northern Basin and Range (including the study area of this report), this type of normal faulting began about 10 m.y. ago and continued major development to about 7.6 m.y. ago (Zoback and others, 1981). For the last 7 million years, the Basin and Range has been characterized by elongate, fault-bounded parallel ranges with crest-crest spacing of 25 to 35 km; the average basin width is 10 to 20 km. This basin width is approximately equivalent to the thickness of the seismogenic crust (Eaton, 1980). Focal depths of 15 to 18 km were determined for mainshock and after shock events of the 1954 Dixie Valley earthquake with focal mechanisms indicating steep (60-70°) faults at these depths (Stauder and Ryall, 1967; Romney, 1957). Holocene and historic fault activity continues on most of these Basin and Range structures (fig. 3).

WALKER LANE

The Walker Lane zone of conjugate strike-slip (northwest-trending right slip and northeast-trending left slip) faulting and disrupted structure marks the western margin of the Great Basin. This zone is also characterized by eastward thinning of the crust (Greensfelder, 1965; Eaton, 1963; Prodehl, 1979). In contrast to the northern Basin and Range in which the maximum principal stress (compression) is vertical, both the maximum and minimum principal stresses are in the horizontal plane (Wright, 1976). Traces of the dominant northwest-trending Walker Lane faults occur as irregular, en echelon, discontinuous zones that terminate abruptly, commonly within mountain ranges, at intersections with conjugate strike-slip or coeval normal faults. Relatively intense spreading in a primary extensional environment occurs at the ends of en echelon strike-slip fault zones and may favor localization of volcanic centers (Wright and Troxel, 1968, 1971; Smith and Luedke, 1981). Since these sites are also generally points of structural intersections, they are favorable for geothermal potential (Trexler and others, 1978).

The stress regime and resultant extension within the Walker Lane may be related to: 1) superposition of the San Andreas transform fault; 2) acceleration between Pacific and North American plates; 3) relaxation of tectonic compression at the Juan de Fuca - North American plate boundary (Sbar, 1982); or 4) rotation of the Sierra Nevada (Wright, 1976). Strike-slip to dip-slip ratios for displacement on Walker Lane structures range up to 8:1, in contrast to values of 0.2:1 for normal faults such as the Fairview Peak fault in the northern Basin and Range (Bell and Slemmons, 1982) suggesting greater extension.

Continued Holocene and historic activity on high angle faults of the Walker Lane is evidenced by left-lateral displacement in the 1869 Olinghouse event (Sanders and Slemmons, 1979; Slemmons, 1969) (fig. 3) and the 1934 Excelsior Mountain event (Callaghan and Gianella, 1935) south of the study area and by the right-lateral 1932 Cedar Mountain event (Gianella and Callaghan, 1934) also south of the study area. Late Cenozoic cumulative displacement within the northern Walker Lane (Bell and Slemmons, 1982) is estimated to range from 30 to 50 km (Bonham, 1969; Hardyman and others, 1975).

SIERRA NEVADA

The Sierra Nevada behave as a large integral fault-bounded block despite the presence of faults within the block. Primary frontal fault systems bound the block on both the western and eastern margins. The large-scale major frontal fault system on the eastern boundary appears related to major throughgoing structures that probably cut the lithosphere based on the 2 to 3° backtilt of the internal blocks and gravity data that indicates the uplifted blocks are isostatically compensated (Zoback and others, 1981). Preliminary data from the COCORP seismic reflection lines across the northern Sierra Nevada eastern frontal fault zone suggest a steeply dipping structural zone extending to depth (D. Nelson, pers. commun., 1983).

Eaton (1932) first suggested the westward migration of the Sierra Nevada block with extensional features on the east largely compensated for by compressional features on the west. Smith (1962) estimated 60 to 80 km of left-lateral displacement along the Garlock fault with displacement decreasing westward; Taubeneck (1971) estimated 50 km of offset in Cenozoic time by right-lateral faults, dike intrusions and normal faulting at the north end of the Sierra block. Wright (1976) provides a detailed discussion of the westward migration and rotation of the Sierra Nevada.

Extension across the northern Basin and Range is estimated to range from 15 to 30 percent in the last 10 million years (Zoback and others, 1981). The average width of the Basin and Range at the latitude of the study area is approximately 700 km; a minimum 100 km to as much as 200 km of extension is distributed across this width. While much of this extension is undoubtedly taken up by the northwest-trending Walker Lane structures, it still suggests a greater amount of E-W extension than is compensated for by the westward migration of the Sierra Nevada.

STEAMBOAT HILLS

Within the Steamboat Hills area (fig. 4), the dominant north-south structural trend represents the Sierra Nevada frontal fault zone. These normal,

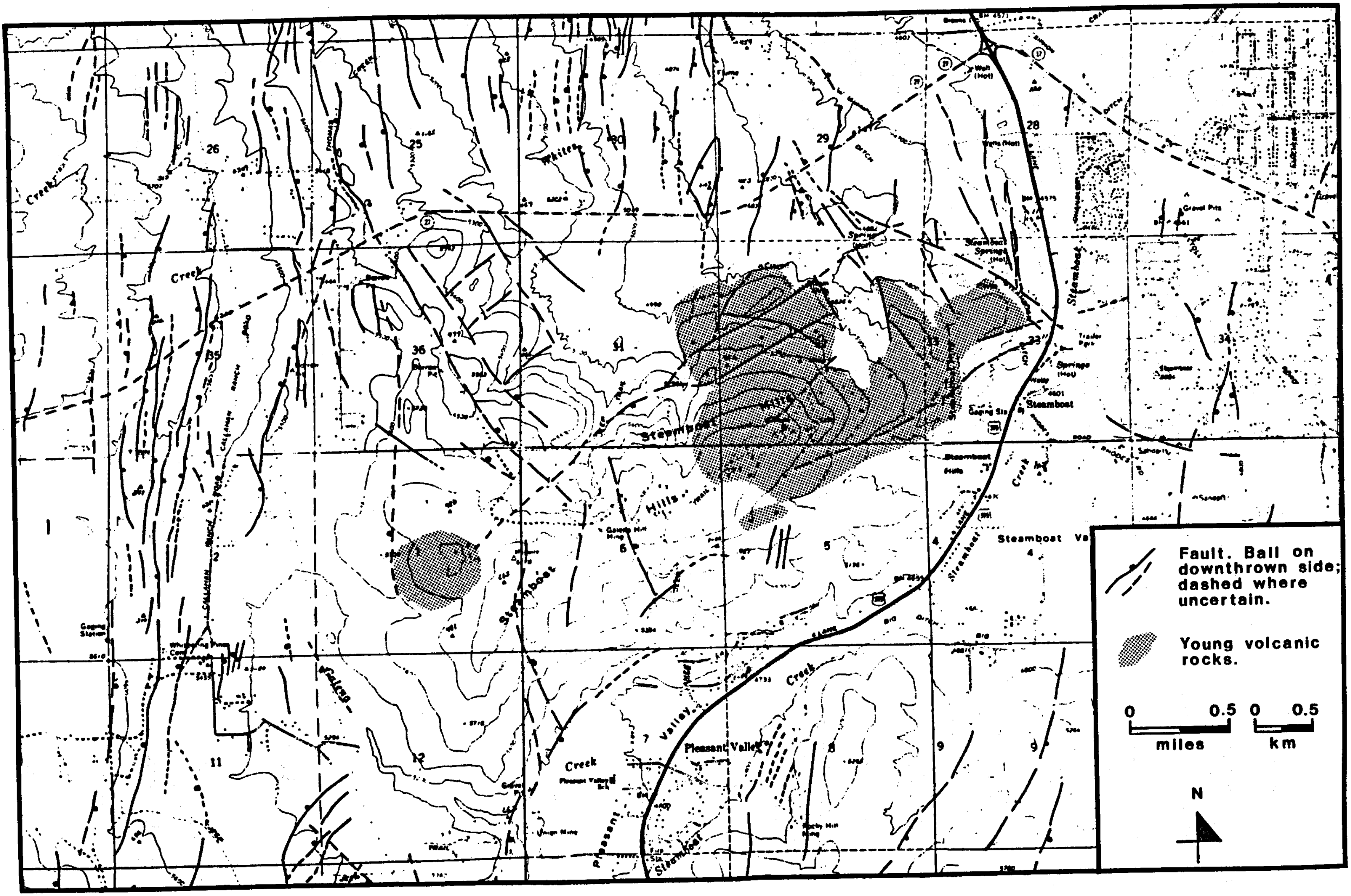


Figure 4. Structural setting of young volcanic rocks in the Steamboat Hills area. (modified after Szecsody and Nichol (1982) and Bell (1981))

antithetic and graben faults become progressively more complex, apparently progressively younger and more recurrent in this area south of Reno (Bell, 1981). Various ages of displacement and recurrent Holocene faulting have been demonstrated (Cordova, 1969; Bell, 1981; Szecsody and Nichol, 1982).

Northeast-trending structures are primarily antithetic faults associated with the Steamboat Hills anticline (Thompson and White, 1964). These structures may represent the northeast trends of the Olinghouse-Carson Lineament structural zone (Bell and Slemmons, 1982).

Major faulting within the Steamboat Hills occurred after Kate Peak volcanism and before cutting of the pre-Lousetown pediment, with at least 300 m of displacement on the Steamboat Hills fault system underlying the main sinter terraces (White and others, 1964; Silberman and others, 1979). Structural control of the thermal area is suggested by the location of the hot springs along the Low and Main Terraces and other hot springs located along fault traces. The thermal area also lies along the line of Quaternary pumiceous rhyolite domes that extend 3 km southwest of Steamboat Springs and 5 km to the northeast (Silberman and others, 1979).

A detailed discussion of the local geology, structural and stratigraphic relationships is provided by Thompson (1956) and Thompson and White (1964). The significant structural characteristics are the predominance of antithetic faults and folding of strata in local anticlinal forms. The concentration of these features in this area may be a result of intrusive igneous activity, the intersection of the Sierra Nevada frontal fault and the northeast-trending structures related to the Olinghouse-Carson Lineament zone, and/or the localized compressional environment produced by westward impingement of the Basin and Range on the Sierra Nevada.

GEOCHRONOLOGY

Potassium-argon isotopic ages and analytical data for eight whole rock samples and mineral separates determined for this study are listed in Appendix A. These ages (fig. 5) and those determined by other workers for young (<15 m.y.) volcanic rocks within the study area are also compiled in Appendix A.

STEAMBOAT HILLS BASALTIC ANDESITE

Two discordant isotopic ages (plagioclase 29.6 ± 2.0 Ma; whole rock 0.21± 0.07 Ma) have been determined for a sample (#H-3312) of the Steamboat Hills basaltic andesite. The variability in argon analyses indicates non-homogeneous argon distribution in the plagioclase phenocrysts. The discordancy between the plagioclase and whole rock ages suggests the possibility of argon loss from the groundmass (Damon and others, 1967). Silberman and others (1979) and Morton and others (1980, 1983) report ages ranging from 2.0 to 2.5 Ma for the Steamboat Hills basaltic andesite (Appendix A). Silberman and others (1979), Thompson and White (1964) and Morton and others (1980) report ages ranging from 1.1 to 3.0 Ma for the rhyolite domes in the Steamboat area. Possible causes for the suspect discordant ages obtained in this study include the loss of argon from the groundmass affecting the whole rock age as noted above, or the contamination of the plagioclase content during volcanic activity (e.g., inclusion of lithic fragments of Mesozoic granodiorite) or during sample preparation (e.g., failure to exclude any such lithic fragments from the plagioclase separate).

TABLE MOUNTAIN BASALTIC ANDESITE

The 6.7 ± 0.7 Ma isotopic age determined for the basaltic andesite flow on

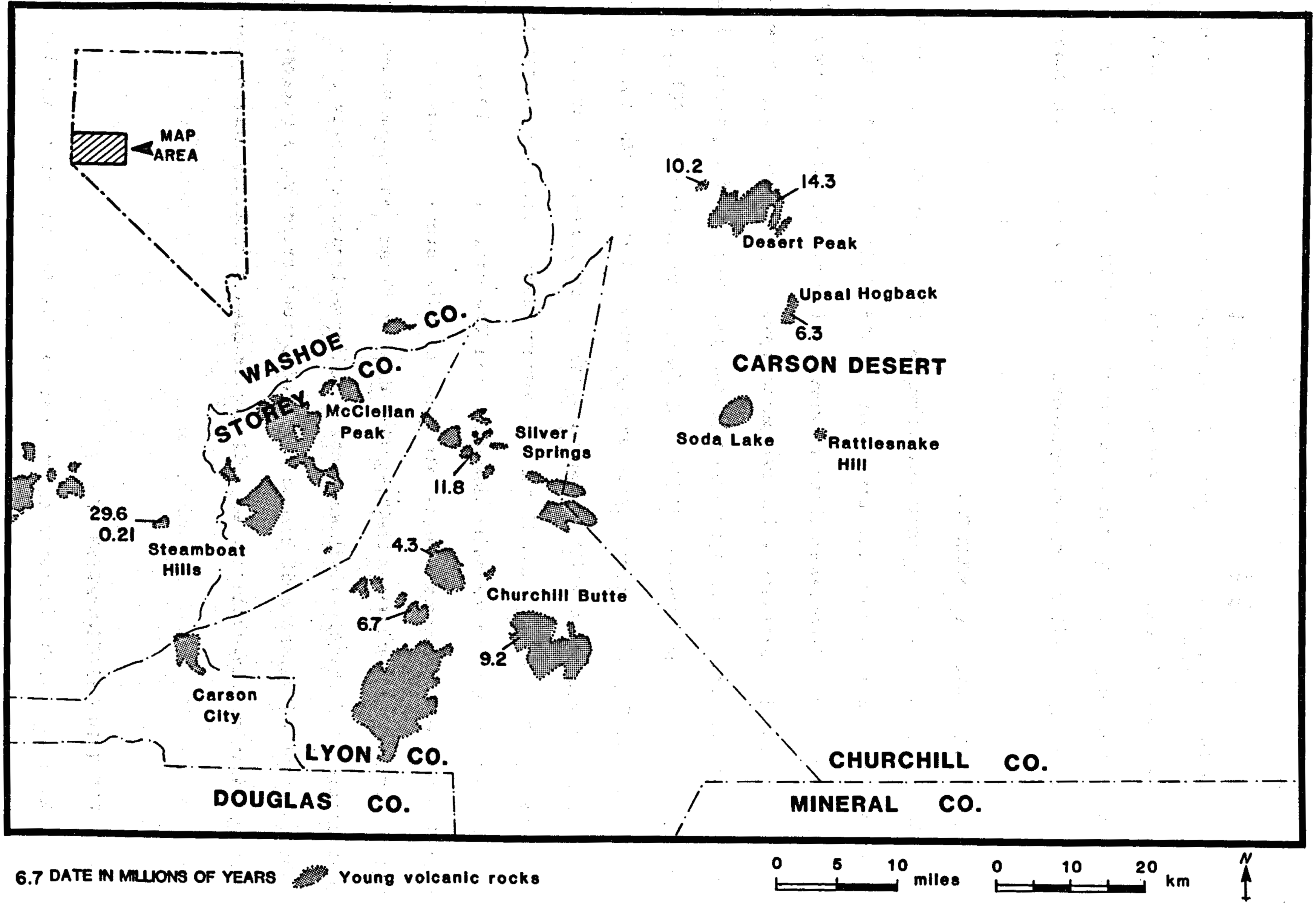


Figure 5. Potassium-argon isotopic ages of young volcanic rocks determined in this study.

top of Table Mountain is compatible with the age (6.83 ± 0.16 Ma) of the Lousetown Creek section of the Lousetown volcanics reported by Morton and others (1980, 1983) (Appendix A).

SILVER SPRINGS BASALTIC ANDESITE

The 11.8 ± 0.7 Ma isotopic age of the basaltic andesite at Silver Springs is older than the Lousetown volcanic rock ages reported by Morton and others (1980, 1983), but comparable to the age (10.9 ± 0.3, biotite) of the Washington Hill rhyolite dome (Silberman and others, 1979) (Appendix A).

CHURCHILL BUTTE BASALTIC ANDESITE

The isotopic age of 4.3 ± 0.6 Ma determined for the basaltic andesite of Churchill Butte is younger than the ages of the Lousetown volcanics reported by Morton and others (1980, 1983). It is consistent, however, with K-Ar ages of 3.3 ± 0.2 and 3.5 ± 0.2 Ma obtained on two samples of the basalt flow collected by Converse Consultants (H. A. Spellman, Jr., pers. commun., 1983; Nichols-Tingley, 1981) (Appendix A).

CLEAVER PEAK BASALTIC ANDESITE

The whole rock isotopic age of 9.2 ± 0.6 Ma obtained for the basaltic andesite at Cleaver Peak is compatible with the age (9.1-9.2 Ma) of the Mustang Andesite and the age (8.7 Ma) of the andesite at Glendale (Morton and others, 1977) and is within the age range (7.35-9.66 Ma) for the Clark Mountain flows of the Lousetown Formation reported by Morton and others (1980, 1983) (Appendix A).

UPSAL HOGBACK RHYOLITE

A whole rock isotopic age of 6.3 ± 0.3 Ma was obtained for a block of glassy flow-banded rhyolite that was contained in a basalt flow at Upsal Hogback. The basalt at Upsal Hogback is interbedded with Wyemaha age sediments having a relative age of 0.04 to 0.1 million years (Morrison, 1964) and is comparable to the basalt at Soda Lake. A block of basalt in tephra from the maar at Upsal Hogback has been dated at 200,000 years old (M. L. Silberman, pers. commun., 1983). The youngest identified activity of the Upsal Hogback vent is a basaltic tephra layer within the Sehoo Formation of pluvial Lake Lahontan that overlies the Wono ash bed (± 25,000 years) (Davis, 1978). The K-Ar content of the rhyolite was probably reset by the younger basaltic volcanism (H. F. Bonham, Jr., pers. commun., 1983). Therefore, the 6.3 Ma isotopic age should be considered a minimum age for the rhyolite.

DESERT PEAK VOLCANICS

Two isotopic ages were determined for samples from Desert Peak: 1) an age of 14.3 ± 1.1 Ma was determined on a plagioclase separate from the vitrophyre of the ignimbrite and 2) an age of 10.2 ± 0.7 Ma was obtained for a whole rock sample of the basaltic andesite flow on Desert Peak. Four discordant isotopic ages of 12.0 ± 1.1 (plagioclase, recalculated), 4.1 and 4.6 (hornblende), and 2.3 (plagioclase) Ma were obtained for samples of the ignimbrite approximately 40 percent above the base of the sequence (Hiner, 1979; Benoit and others, 1982). The 4.1, 4.6 and 2.3 Ma ages are somewhat suspect since the analyses showed very low argon content and argon loss is possible (W. R. Benoit, pers. commun., 1983). The 12.0 ± 1.1 Ma age, however, is in chronostratigraphic agreement with the two isotopic ages obtained in this study. If correct, then these Desert Peak volcanic units are Miocene in age and not Pliocene as previously mapped by Willden and Speed (1974) and Hiner (1979). These 12 to 14 Ma ages are consistent with ages reported by Willden and Speed (1974) for similar units bordering the Carson Sink in the Desert Mountains.

PETROGRAPHY AND PETROCHEMISTRY

INTRODUCTION

Petrographic and petrochemical analyses of the selected samples (Table 1) served as the basis for classifying the respective rock types. Rock types are identified based on 1) the mineralogic composition and character of the ground mass and 2) the chemical composition and normative calculations of the rock. Because of the multitude of classification schemes for volcanic rocks, the IUGS classification based on normative chemical composition is used in this report (Appendix E). Additional classification systems were selected to illustrate particular chemical variations and comparisons. Normalized oxide values and normative mineral compositions (CIPW norms) are listed in the output (Appendix E) computed for each sample using PETCAL (modified from Bingler and others, 1976; Appendix D). Chemical analyses of the trace element compositions for the 31 samples are listed in Appendix E.

Mineral compositions or ranges of composition determined by microprobe analyses are presented to support the petrographic discussion, where appropriate. A more detailed discussion of microprobe data on plagioclase phenocrysts is presented in a separate section of this report.

PETROGRAPHY

Petrologic and petrographic descriptions of the various volcanic rocks are presented in the following sections.

Steamboat Hills

The Steamboat Hills volcanics (Thompson and White, 1964) include a series of flows erupted from a central vent along the eastern summit of the Steamboat

Hills (fig. 2) and a number of rhyolite domes intruded along a northeasterly trend in the vicinity. The flows cover an area of approximately 1.5 square miles with individual flows recognized by topographic and morphologic expression (fig. 6). Specific locations of the samples analyzed in this study are shown on Figure 6 for both the flows and the rhyolite dome to the southwest in Steamboat Hills.

basaltic andesite. White and others (1964) informally designated the flows as Steamboat basaltic andesite. Based on mineralogic content, this is an appropriate petrographic classification since the flow samples generally contain prominent olivine and plagioclase phenocrysts to the exclusion of pyroxene in a ground mass of microlites, olivine, opaques (magnetite ?) and glass. Quartz phenocrysts (0.1 to 5 mm diameter) are also present, but in thin section (fig. 7) always exhibit a reaction rim of clinopyroxene that completely surrounds each grain. A few quartz grains show various stages of pseudomorphic replacement by pyroxene. These quartz grains, as suggested by Thompson and White (1964), may represent foreign inclusions, possibly derived from the pre-Tertiary granodiorites or quartz monzonites that underlie the flows in the Steamboat Hills, or may be cognate phenocrysts.

Olivine phenocrysts (generally <1 mm diameter) occur as subrounded to subangular grains. Based on microprobe analysis of olivine grains in samples 3304a, 3304, 3312 and 3314, the composition of the olivine is predominantly magnesium olivine or forsterite (Fo), ranging from Fo 58 to Fo 70, with some Mg-fayalite phenocrysts ranging from Fo 40 to Fo 50. Dueteric alteration of olivine to iddingsite is common along grain boundaries and internal grain fractures; some grains have been almost completely altered to iddingsite. Some of the larger olivine grains interlock with plagioclase phenocrysts. Olivine in

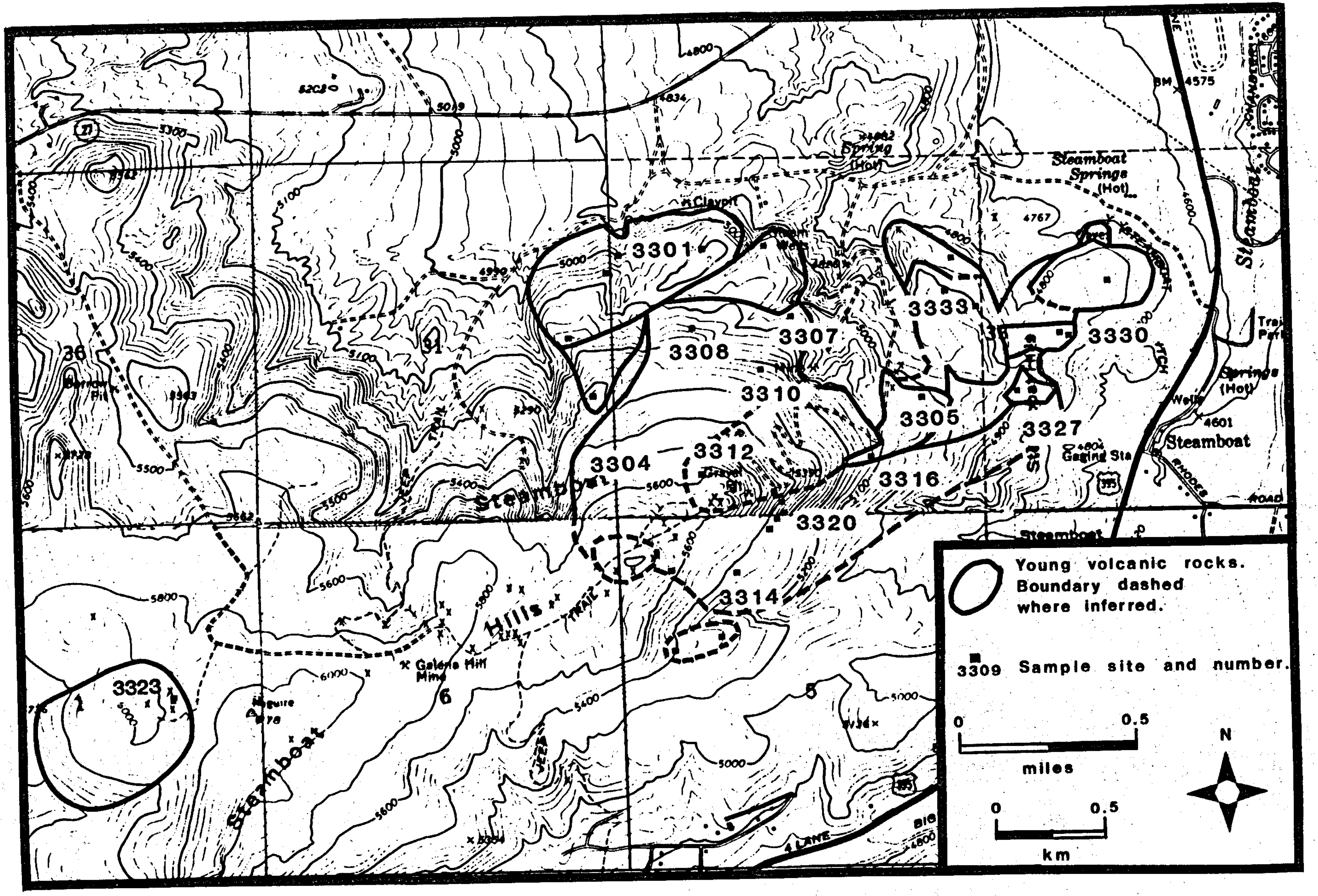


Figure 6. Map showing distribution of volcanic rocks in Steamboat Hills and sample sites.

Figure 7. Photomicrograph from Steamboat Hills basaltic andesite, sample #3308. Quartz phenocryst (center of photo) shows resorption as indicated by fiberous growth of clinopyroxene along borders.

the groundmass, while typically more iron-rich than larger olivine phenocrysts, is generally altered to iddingsite.

Plagioclase phenocrysts display distinct differences in shape and type of zoning and are identified here as Generation One and Generation Two phenocrysts (fig. 8). Generation One phenocrysts are most abundant (80-85%), typically euhedral, lath-shaped and albite twinned, with oscillatory to predominantly normal zoning; some of these phenocrysts are intergrown with olivine. Compositions of these lath-shaped plagioclase crystals range from An 50 to An 72 (An = anorthite). This is generally comparable to the normative plagioclase ranging from labradorite to andesine described by Thompson and White (1964) for the Lousetown volcanics of this area.

The Generation Two plagioclase phenocrysts are subhedral to rounded with distinct reverse zoning displayed by a central solid sodic (oligoclase - andesine) core (An 30 to An 40) surrounded by a granular (included cellular) zone that is rimmed by a more calcic (labradorite) overgrowth (An 50 to An 60). These phases of the Generation Two phenocrysts are shown in Figure 8.

<u>rhyolite</u>. The dome in the western Steamboat Hills is the type locality for the Steamboat Hills rhyolite. This dome is one of the youngest of the domes associated with more than 10 m.y. of rhyolite magma generation in this region (Silberman and others, 1979). Approximately one-half mile wide and about 300 feet high, the dome is capped by eroded remnants of the crater from which small amounts of pyroclastic pumice were ejected.

The rhyolite is predominantly light gray pumiceous glass and is generally phenocryst poor. Sparse phenocrysts of sanidine, quartz, Na-plagioclase (oligoclase; microprobe data: An 23 to An 26), and biotite are observed in thin section. Microprobe analysis of sample 3323 indicates 79% SiO_2 composition of

Figure 8. Photomicrograph from Steamboat Hills basaltic andesite, sample #3304 showing a Generation Two feldspar phenocryst. Note cellular zone is represented by numerous inclusions of glass and opaques. Small lath-like phenocrysts represent Generation One.

the glass; this is consistent with the 77% SiO_2 composition determined by chemical analysis of the rock sample (Appendix E).

Carson City Basalt

The Carson City flows are related to a small cinder cone on the north margin of Carson-Eagle Valley. The cone is composed of well-bedded scoria fragments primarily of pebble size but including some cobble-size fragments; most of the scoria is gray to dark gray and black fine-grained olivine basalt (Bingler and Trexler, 1977). Most of the flows are composed of vesicular or flow banded basaltic andesite. Bingler (1977) reported a K-Ar isotopic age of 1.36 ± 0.29 Ma on a sample south of the cinder cone (Appendix A).

In thin section, the flow banding is expressed by the alignment of the lath-shaped plagioclase crystals in the groundmass. The rock has a microlitic texture of plagioclase (85%), olivine (5-10%), opaques (3-5%) and glass. Larger (0.1-0.5 mm) plagioclase phenocrysts are very rare. Olivine grains show at least partial alteration to iddingsite.

Silver Springs Basaltic Andesite

The Silver Springs flows were probably erupted from a vent in the eastern Virginia Range and flowed southeastward. The basalt is black with phenocrysts of plagioclase, olivine, and pyroxene in a microlitic matrix of plagioclase, olivine, pyroxene, opaques and glass.

Plagioclase phenocrysts are lath-shaped and commonly albite-twinned, ranging in size from matrix to as long as 1 mm. Carlsbad twinning is common. Other larger (1 mm average) plagioclase phenocrysts display zonary banding (Tilley and others, 1964) generally due to ultra-microscopic-twinning. But in some phenocrysts, this zonary banding is also due to compositional zoning in the phenocrysts, with margins of the zones within the crystals marked by cellular zones of included olivine and pyroxene (?). As many as 15 bands were observed in a single crystal.

Olivine phenocrysts occur as subrounded to subangular grains, or interlocked with plagioclase. Margins of the olivines are altered to iddingsite. Grains generally range in size from matrix to .5 mm.

Pyroxene phenocrysts have abundant opaque inclusions along cleavage planes and crystal boundaries. Pyroxene is generally found interlocked with plagioclase.

McClellan Peak Olivine Basalt

The McClellan Peak olivine basalt (Thompson, 1956) is present in the McClellan Peak-American Flat area of central Storey County and in the Long Valley area south and west of Clark Mountain (Bonham, 1969). Potassium-argon analyses of the flows indicate isotopic ages of 1.1 to 1.5 Ma (Schilling, 1965; Silberman and McKee, 1972; Morton and others, 1980) (Appendix A).

The flows are a dark gray to black vesicular basalt containing large phenocrysts of olivine, clinopyroxene (augite) and plagioclase (labradorite) in an intergranular groundmass of microlites, opaques, and glass. The clinopyroxenes are generally oscillatory zoned and contain abundant inclusions of olivine, plagioclase and opaque minerals. Olivine (microprobe composition: Fo 68 to Fo 75) occurs generally as angular to subangular grains larger than 2 mm in diameter. Plagioclase phenocrysts are lath-shaped and vary from phenocryst to groundmass sizes; zoning is present but relatively uncommon; and both albite and pericline twin laws apply. Microprobe composition of the plagioclase phenocrysts range from An 65 to An 78 (labradorite to bytownite). Biotite grains have been identified in thin section, but are rare.

Churchill Butte Basaltic Andesites

Basaltic andesite samples in the Churchill Butte area were collected from Table Mountain, Churchill Butte, and Cleaver Peak (see Table 1).

Table Mountain. The Table Mountain flow is a small agglomerate flow located on top of Susan's Bluff. The rock is composed predominantly of lath-shaped plagioclase (approximately 70%) ranging in size from groundmass to phenocrysts averaging 0.7 mm in diameter. Albite and pericline twinning are common, with average composition of andesine to labradorite (about An 50). Oscillatory zoned and zonary banded phenocrysts show some resorption along grain boundaries.

Other phenocrysts present in small amounts include oxyhornblende (± 5%) and pyroxene (1-2%); olivine is rare. The oxyhornblende phenocrysts range up to 1 mm in size and typically have opaque reaction rims. The pyroxene (augite) grains range from 0.5 to 1 mm in size, with opaques present as inclusions and along cleavage planes. Some of these phenocrysts appear to have been totally replaced by opaques (magnetite ?). Opaques are also commonly distributed in the groundmass.

Churchill Butte. The Churchill Butte flows are black and porphyritic with occasional large (up to 4 mm diameter) phenocrysts of interlocking plagioclase and pyroxene. Plagioclase phenocrysts typically are lath-shaped or rectangular, and exhibit albite, pericline and carlsbad twinning. Zonary banding, while generally due to ultra-microscopic-twinning, is marked within plagioclase crystals by cellular zones or zones of opaque inclusions. Pyroxene phenocrysts are common (5-10%) and occur as subrounded to subangular grains, generally with opaque inclusions. Subophitic textures are common. Olivine, though rare, occurs as small (<0.1 mm) rounded grains. These phenocrysts occur in a groundmass of plagioclase, pyroxene, opaques and glass.

Cleaver Peak. A series of flows cap Cleaver Peak. The flow sampled (#3348) is a black, vesicular basaltic andesite. Mineralogically, the rock is predominantly (80-85%) plagioclase. These lath-shaped, albite and pericline twinned crystals range in size from groundmass to phenocrysts 1.5 to 2 mm in length. Normal zoning is observed, but is not common.

Olivine phenocrysts occur as subrounded to subangular grains or may be interlocking with plagioclase. Margins of the grains and fracture borders exhibit minor alteration to iddingsite; small opaque inclusions are common. Generally, the olivine grains are less than 0.5 mm diameter.

These phenocrysts are contained in a microlitic groundmass of plagioclase, olivine, opaques, and glass. Minor secondary alteration is evidenced by a very thin calcite vein (fracture-filling) in thin section and by very thin coatings of calcite on vesicle walls.

Carson Desert Volcanics

The youngest volcanic rocks in the Carson Desert area have been mapped by Morrison (1964) as basalt flows, basaltic sediments and basaltic lapilli tuffs. These include, as part of this study, Rattlesnake Hill, Upsal Hogback, and Soda Lake.

Rattlesnake Hill. Morrison (1964) describes Rattlesnake Hill as a much eroded cone one mile in diameter and 200 feet high with a shallow crater 1000 feet in diameter at its center. Black to dark gray flows dip outward from the cone. The crater is underlain by a chaotic agglomerate of vesicular basaltic blocks. The flows yield a K-Ar isotopic age of 1.03 ± 0.05 Ma (Evans, 1980) (Appendix A).

In thin section, sample #3350 is porphyritic with interlocking grains of plagioclase, olivine, pyroxene, and opaques; the opaques are typically needleshaped masses. The texture appears plutonic; no fine-grained groundmass is present. Feldspars are typically lath-shaped with albite and pericline twinning or rectangular with oscillatory zoning or zonary banding due to twinning. Pyroxene and olivine display poikiolitic texture.

Upsal Hogback basalt. Upsal Hogback consists of a series of maars, tuff rings and base surge deposits, with at least four and possibly seven vents identified by Morrison (1964). Maars are crater-like depressions up to several miles in diameter resulting from repeated phreatomagmatic explosions and consequent subsidence; they commonly contain appreciable amounts of tuffaceous material. The youngest (?) vent is at the north end of Upsal Hogback; its crater is roughly circular and about one-half mile in diameter. The cones are composed of well-indurated basalt cinder tuff, highly (up to 30%) olivine rich.

In thin section, these basalts are composed of phenocrysts of olivine (10%) and plagioclase (10%) in a fine microlitic groundmass of plagioclase, opaques, olivine, glass and minor pyroxene. Flow structures in the groundmass are evidenced by alignment of lath-shaped plagioclase crystals around phenocrysts and vesicles. Some of the vesicles have a very thin lining of calcite.

Phenocrysts of olivine (microprobe composition: Fo 77 to Fo 87) are typically large (up to 7 mm diameter), with only minor alteration to iddingsite along grain margins. Plagioclase phenocrysts (microprobe composition: An 60 to An 71) show both cellular zones similar to the Generation Two phenocrysts of Steamboat Hills (fig. 9) and cellular cores. A few quartz phenocrysts were observed; these grains exhibit resorption with pyroxene reaction rims enclosing them.

Upsal Hogback rhyolite. In the southern portion of Upsal Hogback, blocks and fragments of flow-banded rhyolite were found within the basaltic flows. In thin section, the rhyolite is very fine grained with flow banding emphasized by

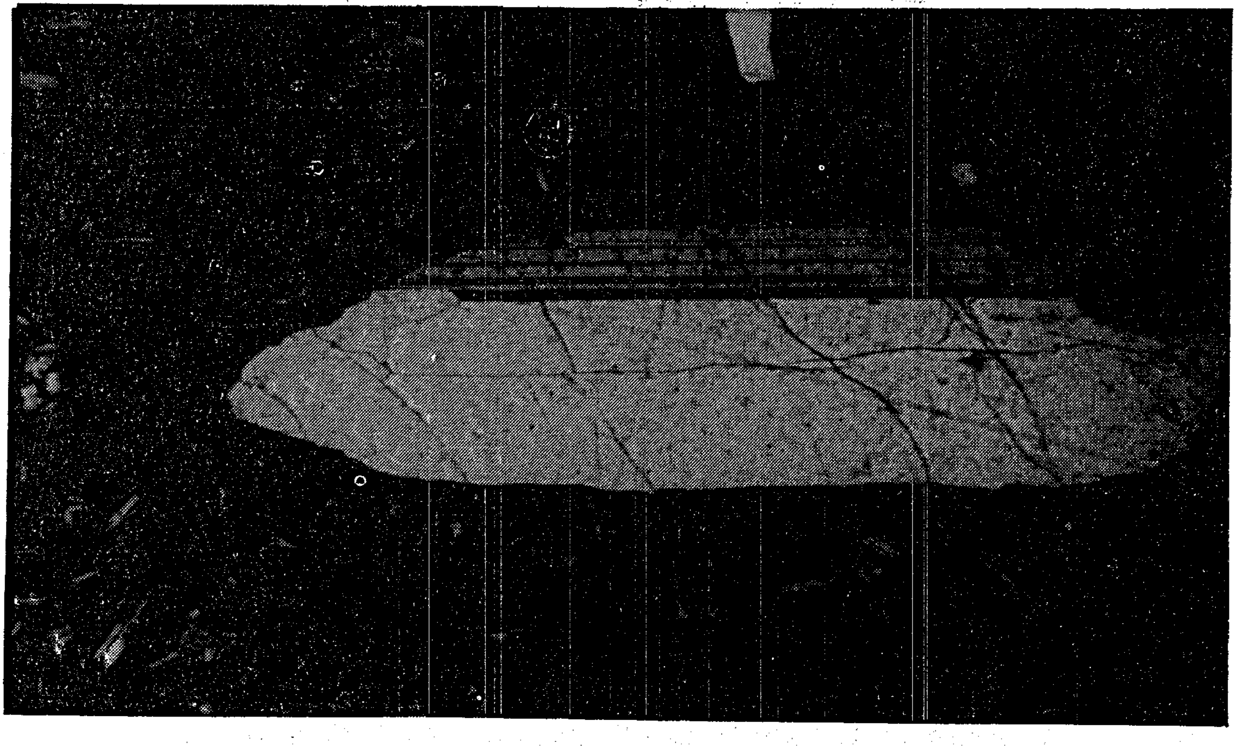


Figure 9. Photomicrograph of feldspar phenocryst from Upsal Hogback basalt, sample #3351. Note cellular zone with overgrowth within crystal, similar to phenocrysts from Steamboat Hills as shown in Figure 8.

small (0.1 to 0.3 mm) lath-shaped feldspars oriented subparallel to the flow banding in the glassy matrix. Sparse phenocrysts of biotite and K-feldspars are typically less than 0.5 mm diameter. The K-feldspar phenocrysts are typically twinned.

Soda Lake. Morrison (1964) describes the Soda Lake volcanic complex as an elliptical cone, 100 feet high and 1 1/3 to 2 1/3 miles in diameter, with Soda and Little Soda Lakes occupying craters within the cone of sandy pyroclastic debris. Similar to Upsal Hogback, the Soda Lake volcanics consist of an overlapping complex of maar volcanoes and associated base surge deposits.

Two lower stratigraphic units originally described by Russell (1885) as dominated by basaltic lapilli are now essentially below lake level. The upper unit composed of four zones is exposed around Soda Lake. The lowermost zone is composed mainly of basaltic lapilli sand and tufa; the second zone is slope wash of pebbly sand. The third zone (45 to 60 feet thick) is lacustrine sediments locally containing up to 60% basaltic lapilli and less than a few percent volcanic bombs and blocks of basalt. This third zone is also described by Morrison (1964) as containing rare pebbles of gneiss, rhyolite and other non-basaltic rocks. The fourth zone is similar to the third but is poorly sorted, unconsolidated and probably subaerial. These zones are correlated by Morrison (1964) with Sehoo age (35,000 to 6,000 years) deposits.

In thin section, this basalt (#3356) has phenocrysts of olivine and plagioclase in a glassy groundmass that contains microlites of olivine and plagioclase with minor opaques. Based on microprobe analysis, the olivines range in composition from Fo 65 to Fo 68 and the plagioclase phenocrysts range from An 60 to An 74 (labradorite to bytownite). A few large (up to 2 mm) plagioclase phenocrysts are present, but generally the phenocrysts are less than 0.75 mm diameter. Some plagioclase phenocrysts display cellular zones similar to those of the Steamboat Hills basaltic andesite (fig. 8) or Upsal Hogback basalt (fig. 9) or have cellular cores. A few lithic fragments of non-basaltic composition and a few resorbed quartz grains with clinopyroxene reaction rims were also observed in thin section.

Desert Peak Volcanics

The Desert Peak volcanics cover approximately 10 square miles in the Hot Springs Mountains adjacent to the Desert Peak geothermal area (fig. 10). The volcanics include ignimbrites and limited areas of basalt that were mapped by Willden and Speed (1974), Hiner (1979) and Benoit and others (1982).

ignimbrite. Hiner (1979) and Benoit and others (1982) describe these ignimbrites as plagioclase-hornblende andesitic tuffs unconformably overlying sedimentary units. Based on chemical data (Appendix E), these ignimbrites are rhyodacite to rhyolite in composition (see figs. 12 through 17, PETROCHEMISTRY section), even though prior studies have identified them as andesites based on field criteria (Hiner, 1979; Willden and Speed, 1974). Folding and faulting preceded and in part controlled deposition of the ash flows. The sequence is composed of several ash flow sheets; the surface is presently erosional.

The ignimbrites grade upward from a pumice-rich non-welded lower section (fig. 11) into a densely welded vitrophyric middle zone. Degree of welding decreases higher up in the section. The basal portion contains abundant dark gray pumice fragments that commonly show fluidal banding with more siliceous light gray pumice. The abundance of pumice and lithic fragments decreases upward.

In thin section, the tuff (samples DP-2A and DP-3) exhibits eutaxitic texture and fluidal banding. The glassy groundmass contains microlites of plagio-

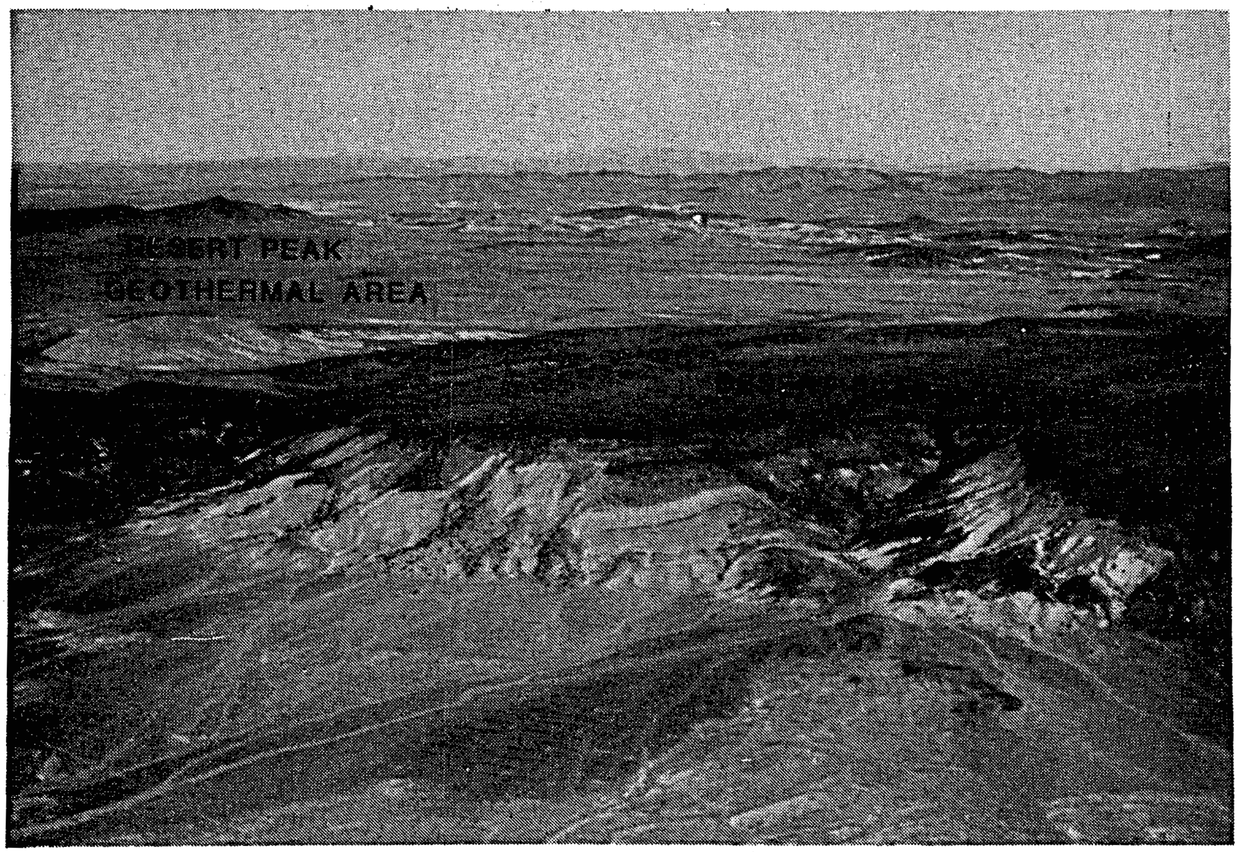


Figure 10. Oblique aerial photograph of Desert Peak area showing ashflow and Desert Peak geothermal area.

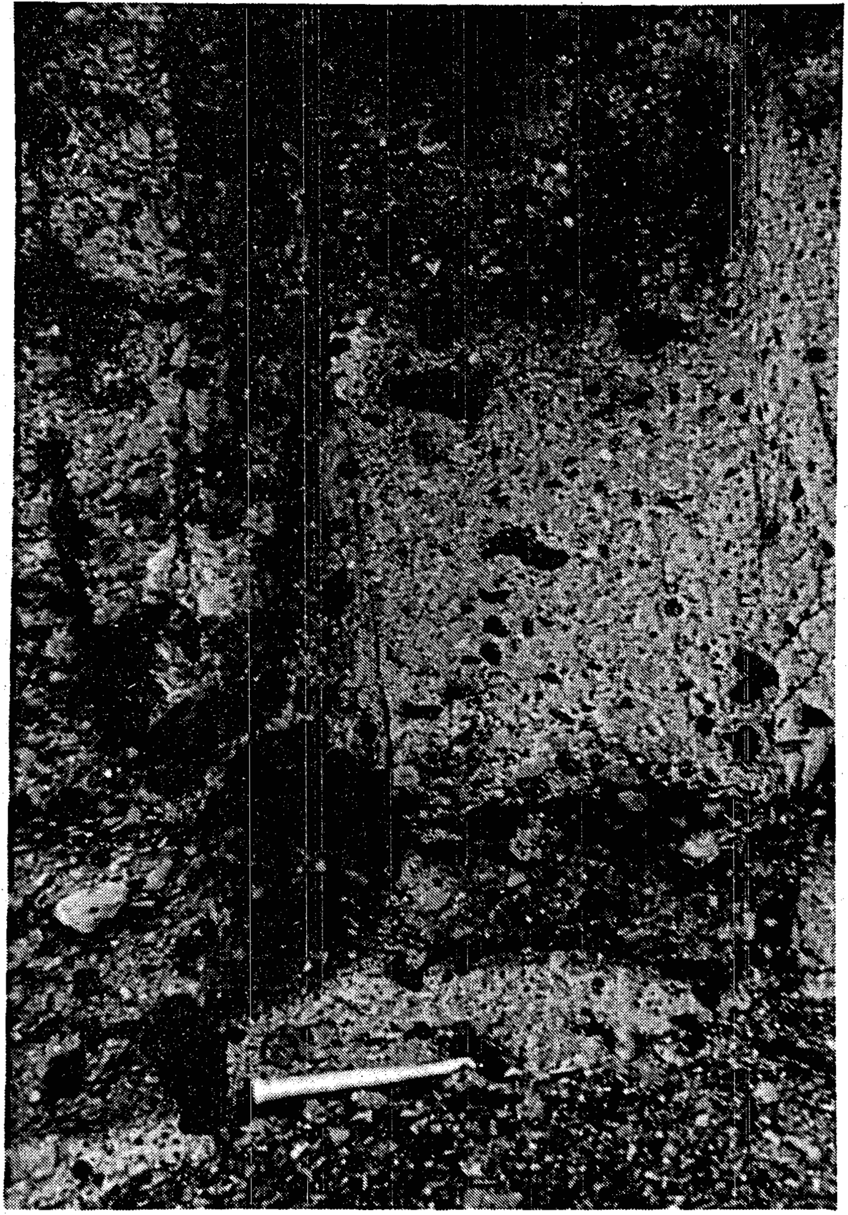


Figure 11. Lower portion of Desert Peak ashflow showing mixed light and dark pumice blocks. Hammer in lower portion of photo for scale.

clase, K-feldspar, pyroxene and opaques; it is generally phenocryst poor with K-feldspar, hornblende and plagioclase phenocrysts less than 0.25 mm in size.

The vesicular dark gray, lower silica (63%, Appendix E) pumice (sample DP-5B) in thin section is very glassy with plagioclase (<0.5 mm), olivine (<0.25 mm), and hornblende (<0.3 mm) phenocrysts and minor pyroxene. Opaques are present as large masses (<0.3 mm) or within the groundmass.

The more siliceous (69% SiO_2, Appendix E), light gray pumice from the lower portion of the sequence (sample #3357) is composed of a very fine microlitic groundmass of plagioclase and minor opaques with rare (1-2%) plagioclase phenocrysts (<0.5 mm). Glass shards and pumice fragments predominate.

basaltic andesite. The basaltic andesite flow sample (#3360) from the top of Desert Peak is composed of a microlitic groundmass of predominantly plagioclase, opaques, and olivine. Phenocrysts, typically less than 1.5 mm in size, include plagioclase, olivine and opaques. The plagioclase phenocrysts are typically albite and pericline twinned with zonary banding due to ultra-microscopic-twinning; no cellular textures were observed in thin section. Olivine is present either as single grains or intergrown with plagioclase.

PETROCHEMISTRY

The petrochemical character of the volcanic rocks from localities within this study area (Table 2) can be evaluated based on the major element and minor element chemistry. Isotope chemistry of these samples is discussed in a separate section of this report.

Major Element Chemistry

Analyses of the young volcanic rocks in the study area (Appendix E and fig. 12) show that rocks containing between 59% and 69% silica are absent (DB-5B with 62.9% silica is an included pumice). Therefore, these volcanics represent a bimodal suite similar to those described by Christiansen and Lipman (1972) for the Basin and Range Province. As shown in Figure 12, the major element compositions can be used to identify those volcanics that are alkaline or high-alumina in composition. Two distinct subtrends are recognized within the alkalic trend (Stewart and Thornton, 1975), one rich in K_2O and the other poor in K_2O. The distinction between these two trends is shown on Figure 13. Similar variation in the alkali versus silica composition can be seen in Figure 14. Although the Steamboat Hills basaltic andesite samples show a slightly higher Na_2O content than rocks from other portions of the study area, the relationship shown here suggests that K_2O replaced Na_2O in a base exchange reaction (Lipman, 1965) during primary crystallization or secondary reactions.

Figure 15 is a plot of normative quartz and feldspar for those volcanic rocks with more than 10% normative quartz, based on PETCAL normative calculations (Appendix E). The rock types determined by these normative calculations are shown in Figure 16. All of these samples have a K_2O/Na_2O ratio of less than 2 (0.37 to 1.33, Appendix E). These data (fig. 13 through 15) suggest that chemical composition of these rocks was probably controlled by crystal-liquid or liquid-state differentiation.

ABBREVIATION	**SAMPLE LOCALITY**
CB	Churchill Butte
CC	Carson City
CP	Cleaver Peak
DP	Desert Peak
MP	McClellan Peak
RH	Rattlesnake Hill
SL	Soda Lake
SS	Silver Springs
TM	Table Mountain
UH	Upsal Hogback

(NOTE: Abbreviations are used on Figure 12 through 31. Steamboat Hills samples are identified by open circles.)

Table 2. Sample locality abbreviations.

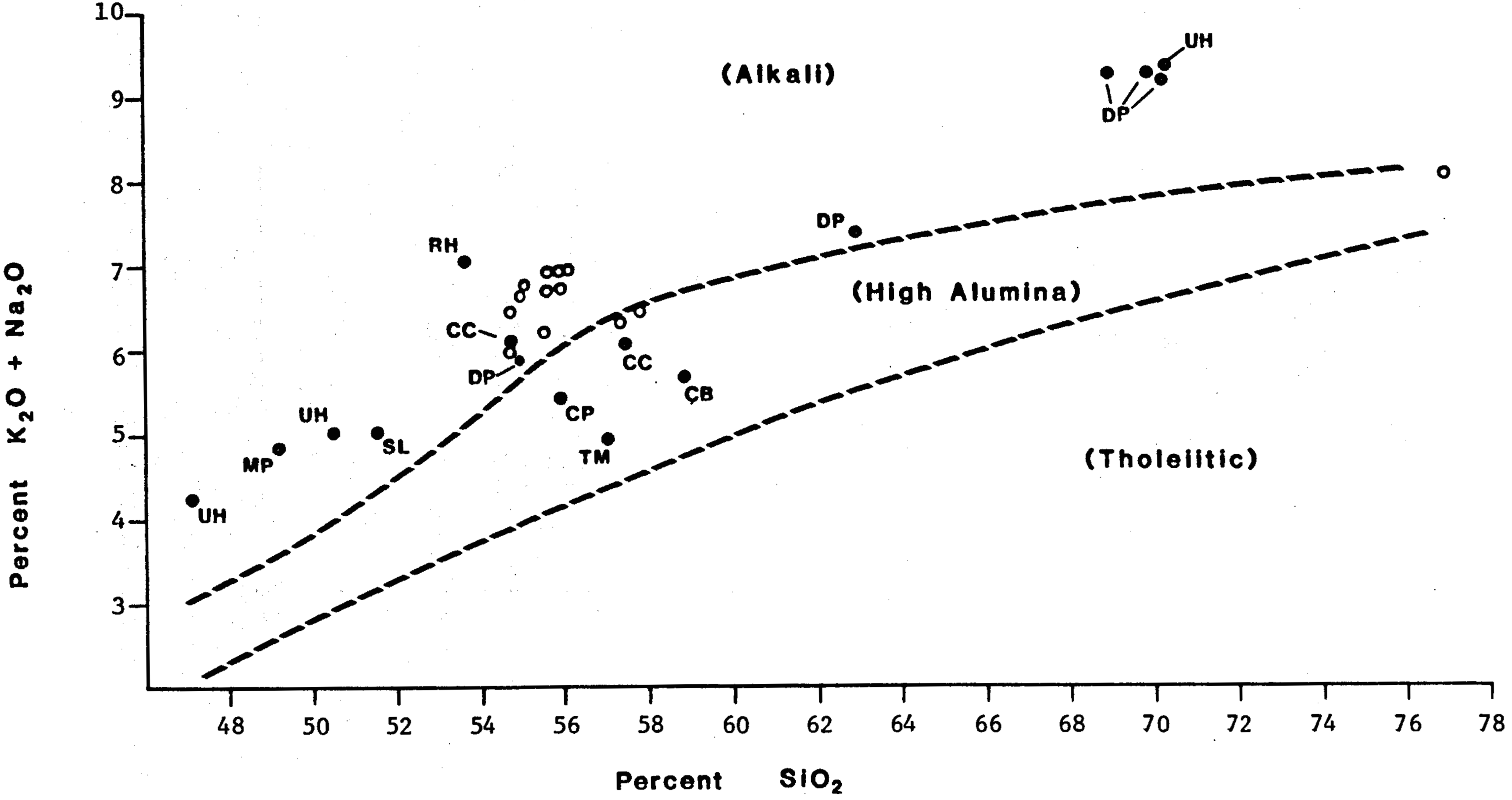
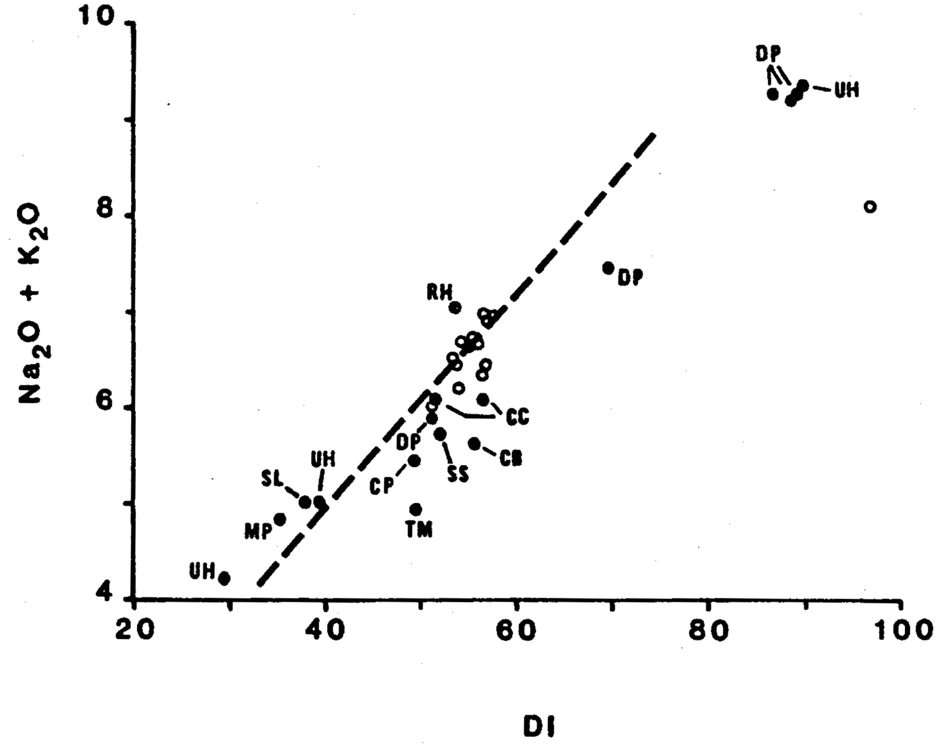
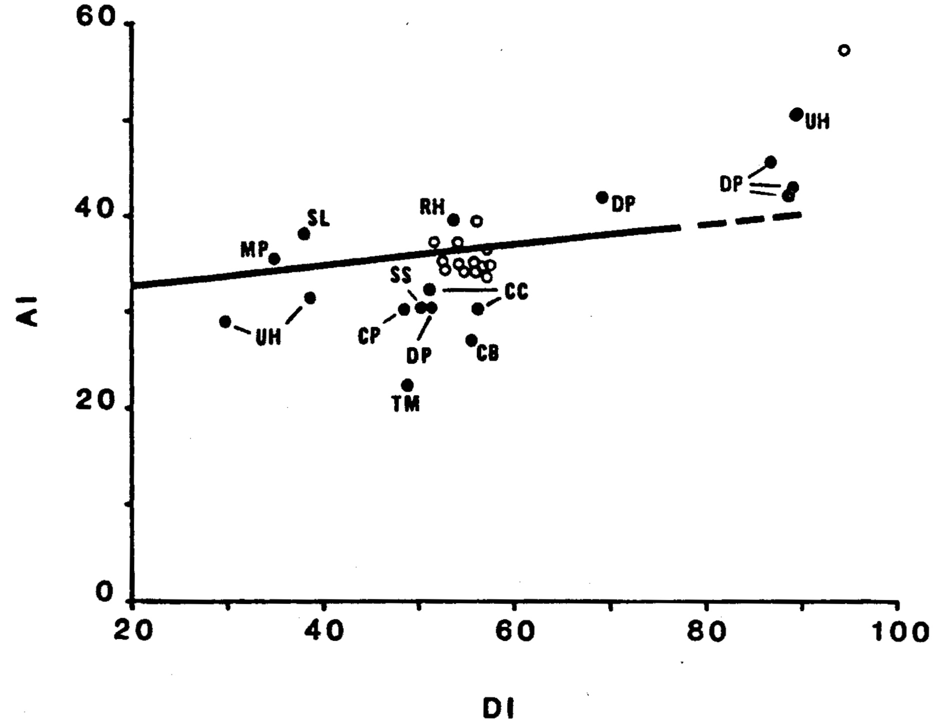


Figure 12. Total alkali vs. silica for volcanic rocks of west-central Nevada. Abbreviations listed in Table 2.



a. Total alkalis (wt. percent) vs. Differentiation Index (DI). Dashed line separates alkalic from tholeiitic series (from Stewart and Thornton, 1975).



b. Alkali Index(AI) vs. Differentiation Index (DI). Solid line separates high-K (alkalic series) from low-K (alkalic and tholeiitic series), (from Stewart and Thornton, 1975).

Figure 13. Variation diagrams.

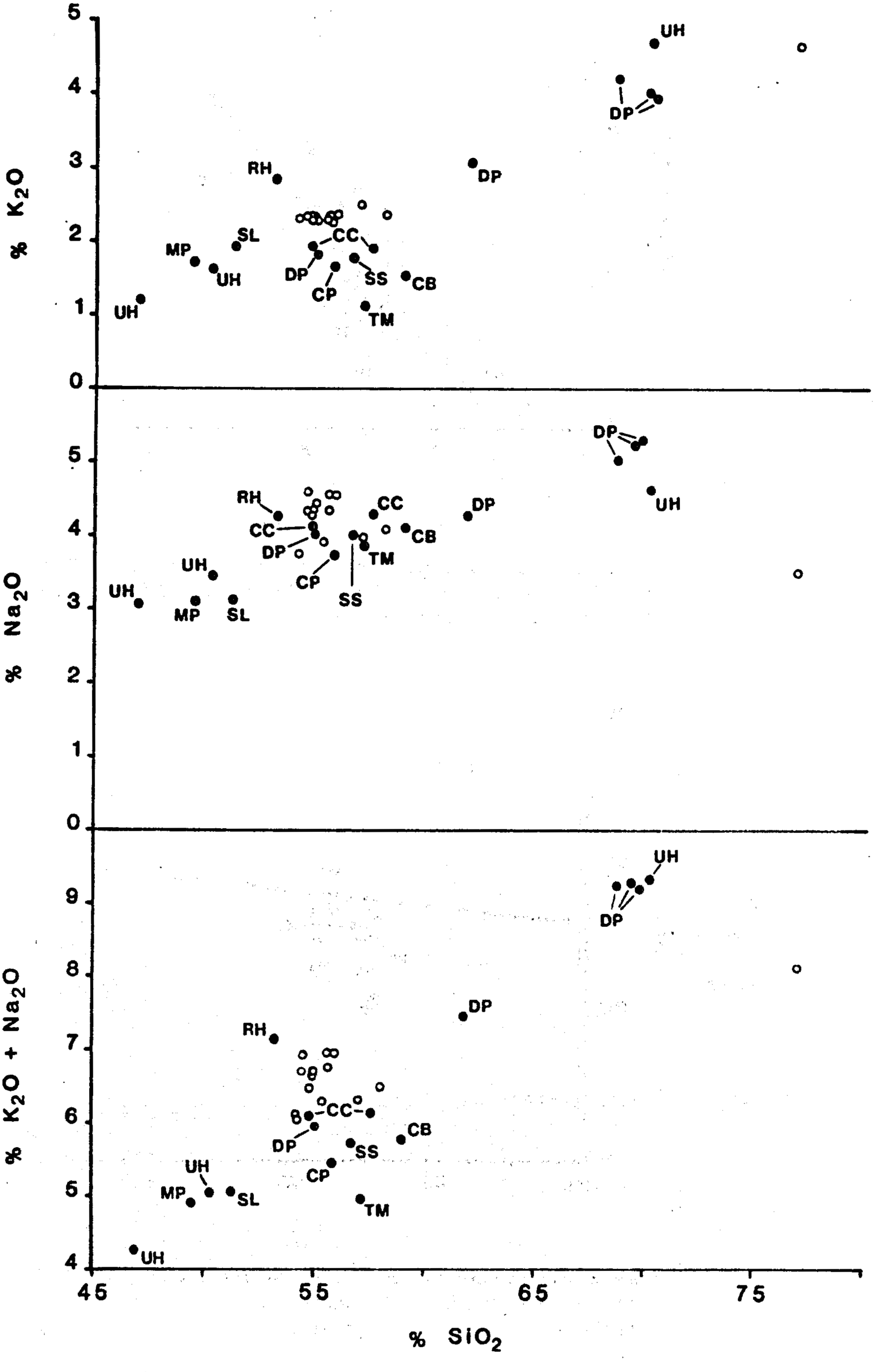


Figure 14. K_2O, Na_2O and total alkalis versus SiO_2 variation diagram.

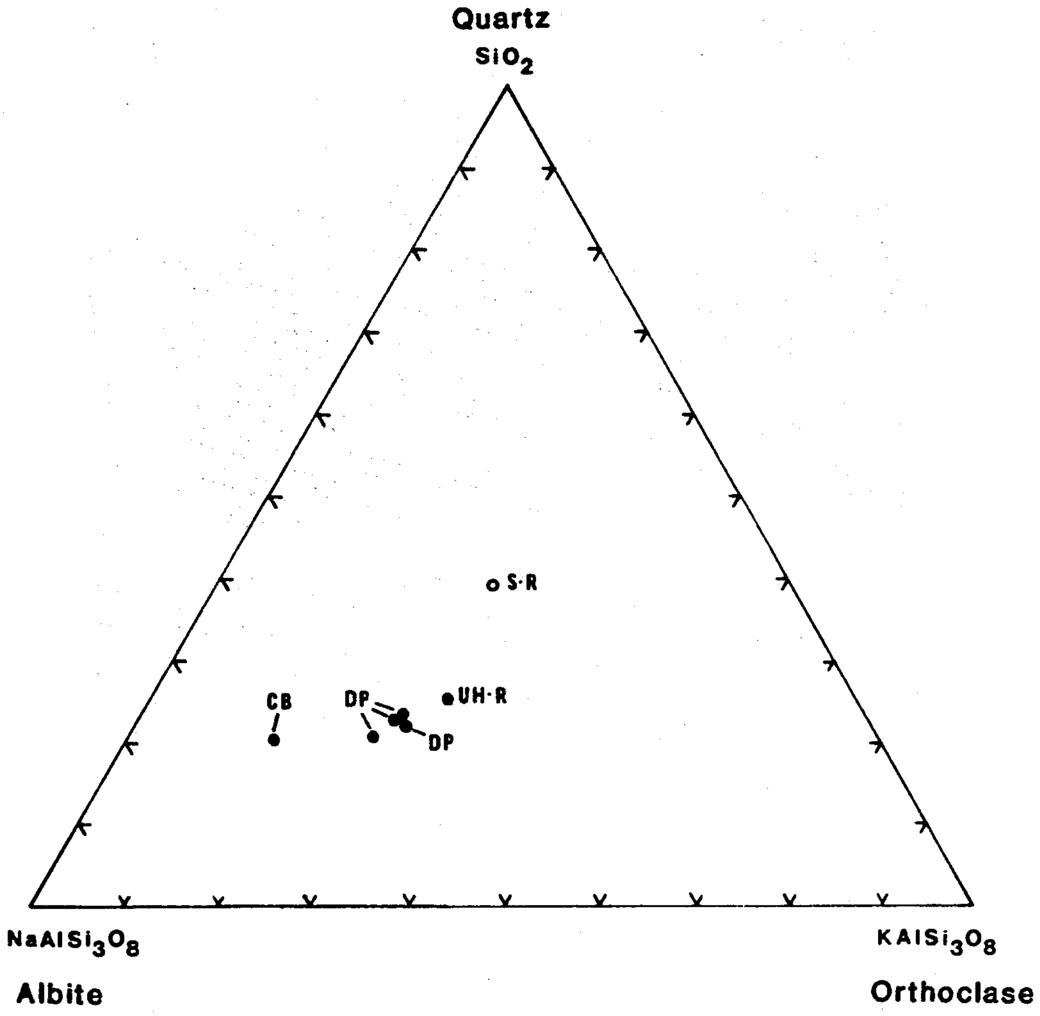


Figure 15. Quartz-albite-orthoclase plot of volcanic rocks with more than 10 percent normative quartz. UH-R= Upsal Hogback rhyolite inclusion; S-R= Steamboat Hills rhyolite.

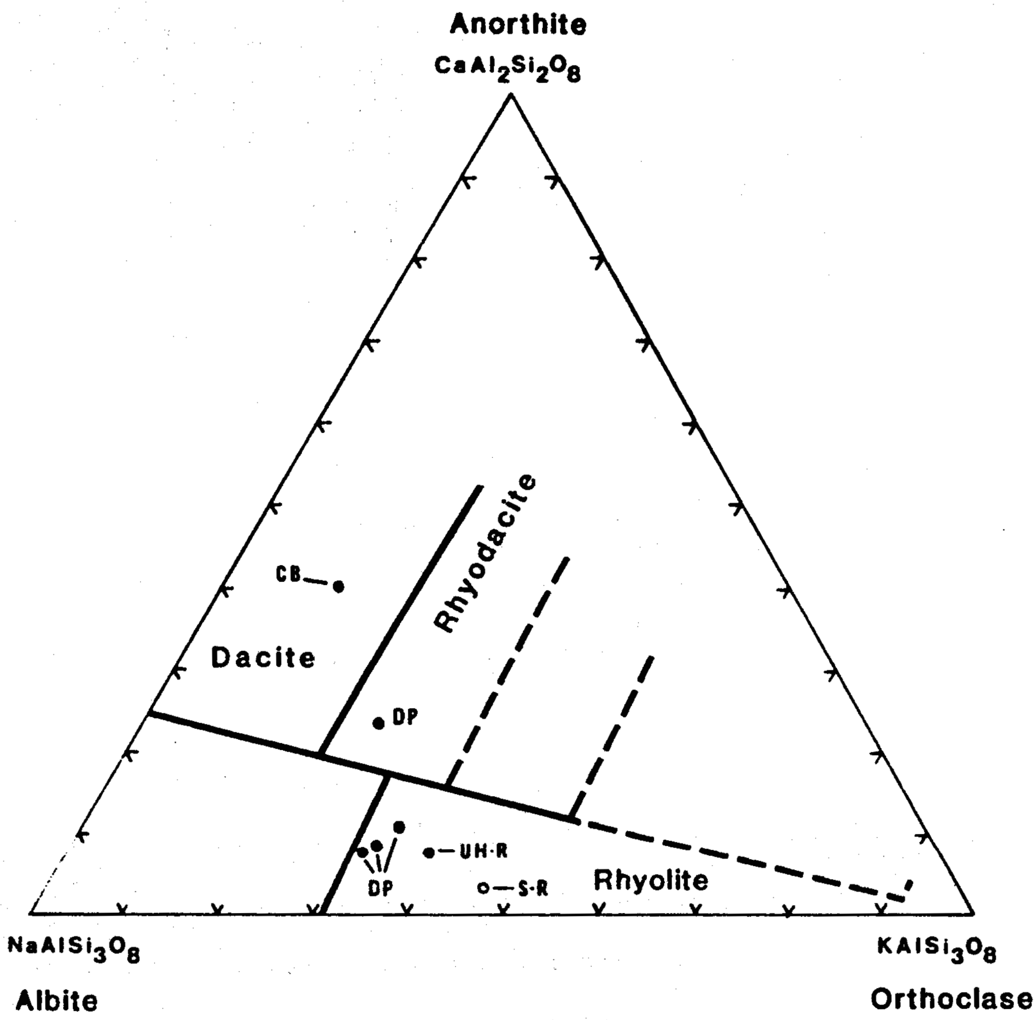


Figure 16. Rock types of volcanic rocks with more than 10 percent normative quartz. Field boundaries from O'Conner (1965). UH-R= Upsal Hogback rhyolite inclusion; S-R= Steamboat Hills rhyolite.

Figure 17 compares the alkali-mafic (AMF) compositions of the suite of rocks in this study to the Cascade and Snake River Plain (SRP) volcanics. The mafic rocks of the suite are depleted in total FeO and enriched in MgO with respect to the continental basalts from the Snake River Plain, and are slightly enriched in total FeO and slightly depleted in MgO compared to the continental margin volcanics of the Cascades.

Two samples, the McClellan Peak basalt (#3346) and the Upsal Hogback basalt (#3354), are strongly enriched in MgO relative to all other rocks and trends plotted on Figure 17. The high MgO content of these two rocks was also reflected in their mineralogy (abundant olivine phenocrysts) and in the microprobe composition of the olivines (Fo 68 to Fo 87). Computed Mg-values (= 100 MG/(MG + Fe^{+2})) for these two samples ranged from 53 to 56. These values are comparable to those computed by Suneson and Lucchita (1983) for mafic volcanic rocks in the southern Basin and Range Province (Castaneda Hills, Arizona, Mg-values = 40 to 57). The abundance of Mg-rich olivines in these basalts suggest that crystal fractionation probably occurred, and would have resulted in lower Mg content in the magma.

The alkali-rich silicic rocks that range from dacite to rhyolite composition (fig. 16) are comparable in major element composition and in range of mafics to both the silicic rocks of the Cascades and the Snake River Plain rhyolites (fig. 17). The siliceous (>68% SiO_2) volcanic rocks at Desert Peak (#DP-2A, DP-3, 3357) are high-K alkalic in character and should more properly be referred to as rhyolitic (figs. 12 through 17). This is a revision of the previous identification of these rocks as andesites based on field criteria by Willden and Speed (1974) and Benoit and others (1982). Hiner (1979) has also mapped these units as andesites, although he refers to chemical analyses (not included in his report) that suggest identification as trachy-andesites.

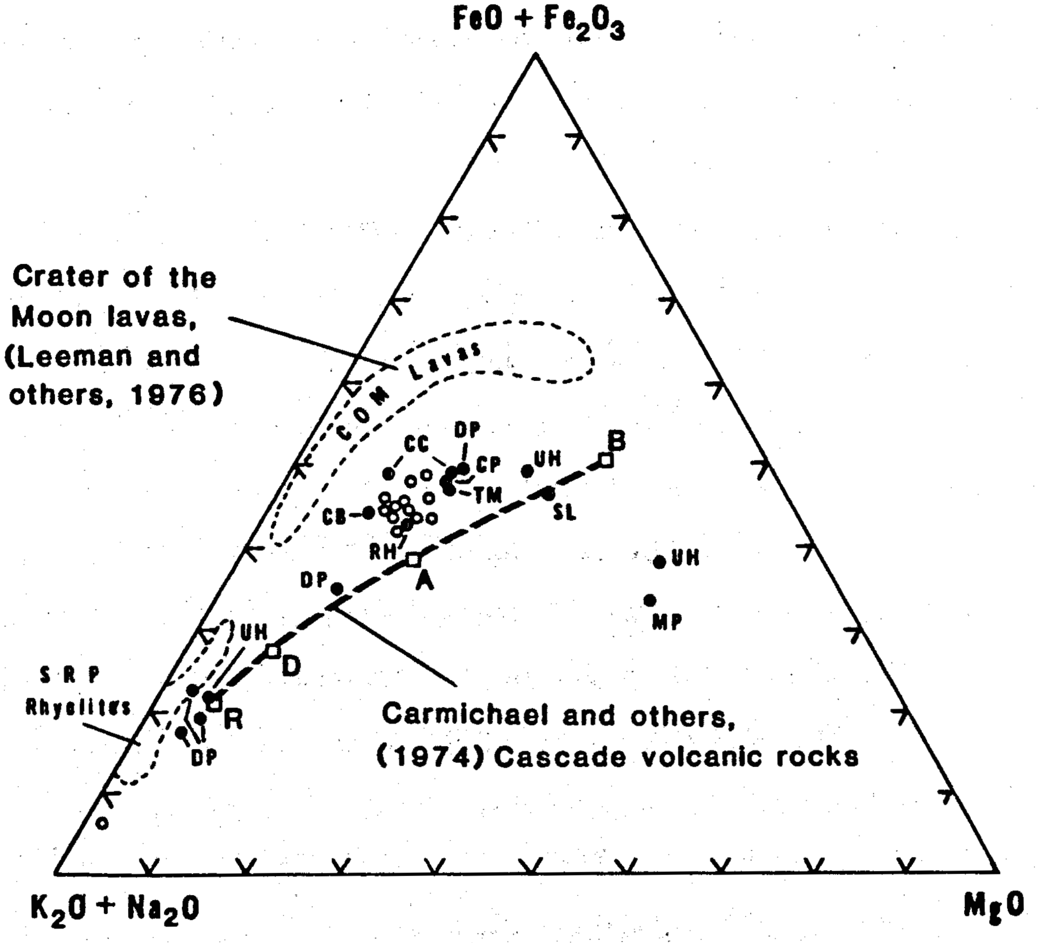


Figure 17. AMF diagram comparing volcanic rocks of western Nevada to rocks from similar settings. SRP-Snake River Plain. Cascade volcanic trend indicated by line along composition changes from Basalt-Andesite-Dacite-Rhyolite (B-A-D-R).

Trace Element Chemistry

Analysis of the trace element data (Appendix C) reveals both regional trends within the volcanics of west-central Nevada and at least two enrichment-depletion patterns reflected in samples from specific localities.

Rubidium (Rb), strontium (Sr), the light Rare Earth Elements (REE; yttrium (Y), cesium (Ce), lanthanum (La), scandium (Sc)) and chromium (Cr) were selected for variation analysis since these elements are most susceptible to fractionation effects and showed the most variation within the volcanic rocks studied. Variation diagrams of Rb/Sr (fig. 18), Sr/Y (fig. 19), Ce/La (fig. 20) and Sc/Cr (fig. 21) depict the regional trends in these trace element abundances.

The trend of the Rb/Sr data (fig. 18) may represent a liquid line of descent for magmas having similar source regions or compositions but affected by crystal fractionation. Two portions of the trend show a negative correlation between Rb and Sr. These are 1) the siliceous rocks of Desert Peak and the rhyolites of Upsal Hogback and Steamboat Hills and 2) the mafic volcanic rocks of the western portion of the study area, with the Steamboat Hills samples closely clustered. These negative Rb/Sr correlations could be due to fractionation of the feldspars. The positive Rb/Sr correlation exhibited by the Carson Desert volcanics (Upsal Hogback, Soda Lake and Rattlesnake Hill) may be due to fractionation of the mafic minerals.

Similarly, two distinct trends can be identified for Sr/Y values (fig. 19). A positive coincident correlation is evident for Sr/Y values of the Carson Desert basalts and the Desert Peak volcanics. Data on Sr/Y values for the western portion of the study area exhibit a negative correlation, with the Steamboat Hills samples clustering. These different trends may reflect varying patterns of fractionation and/or differing initial magma compositions.

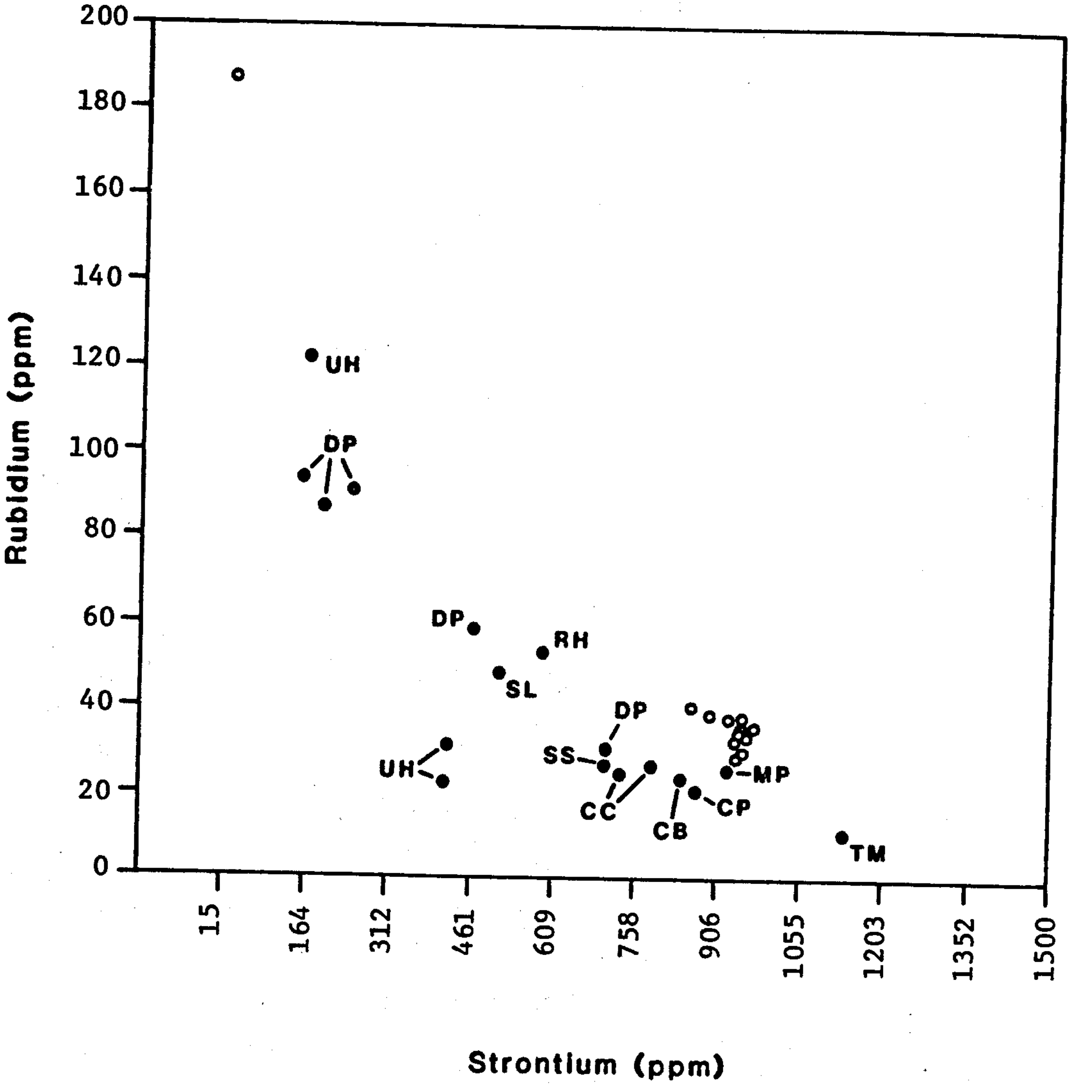


Figure 18. Rubidium-strontium trace element plot for volcanic rocks from west-central Nevada.

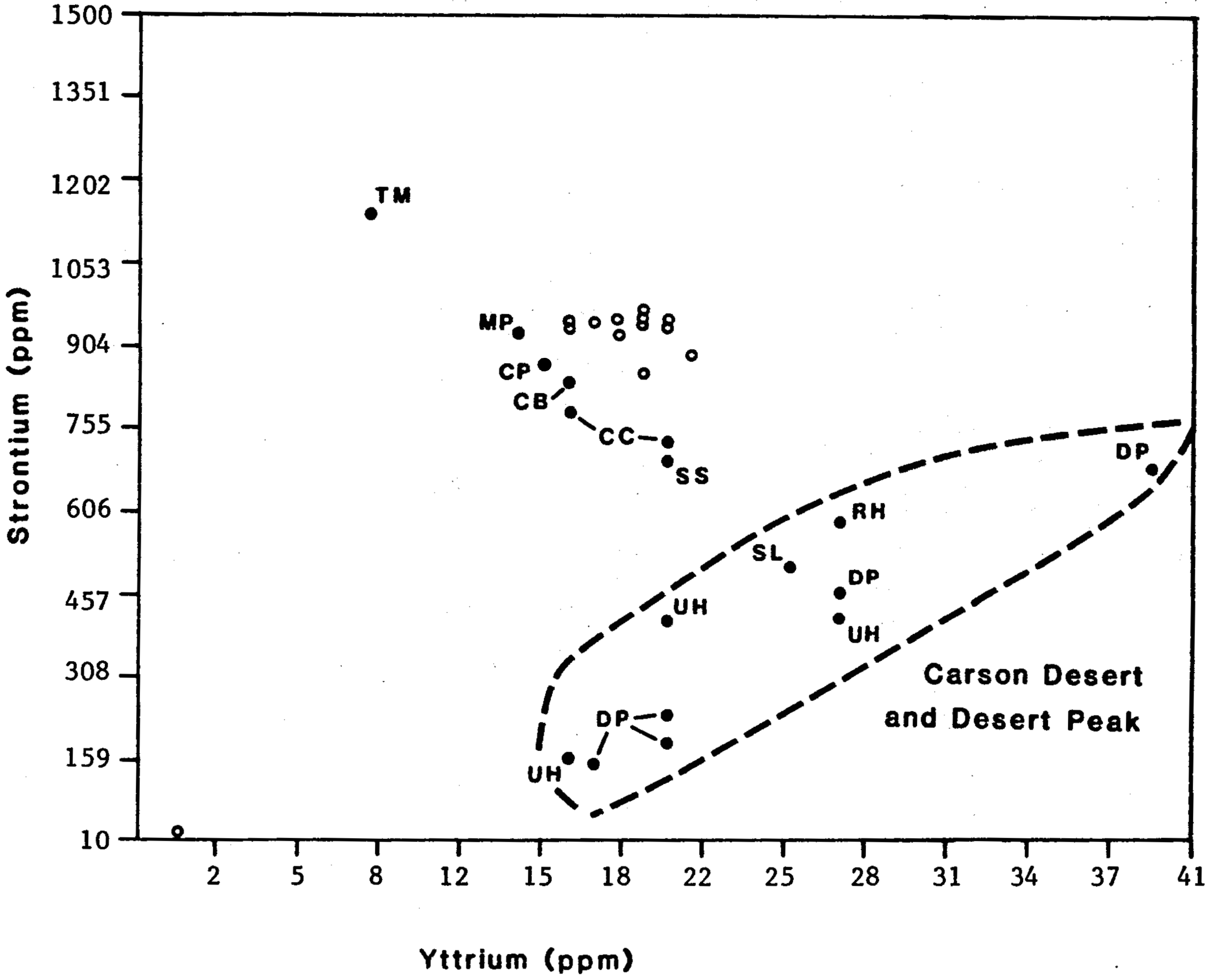


Figure 19. Strontium-yttrium trace element plot for volcanic rocks from west-central Nevada.

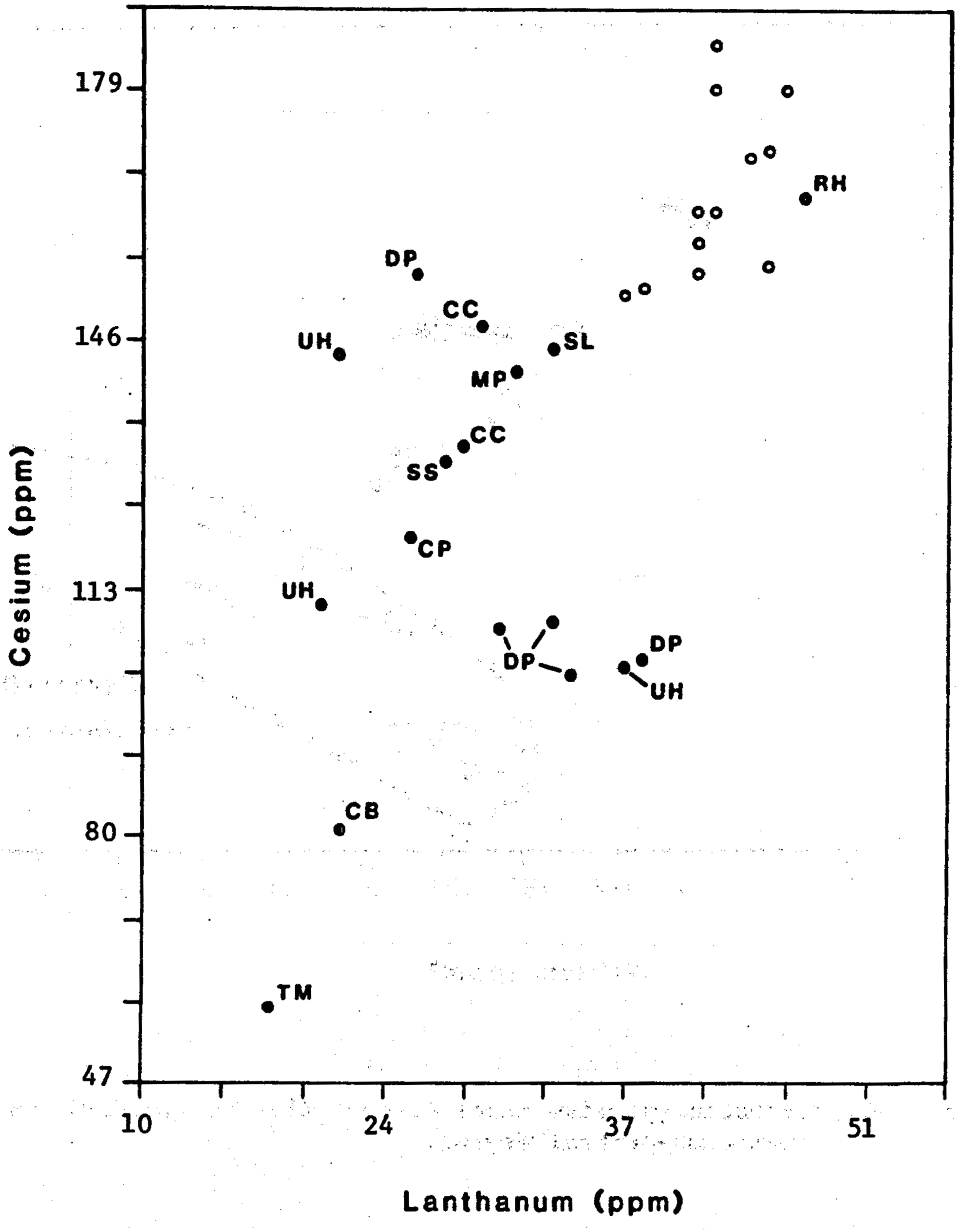


Figure 20. Cesium-lanthanum trace element plot for volcanic rocks from west-central Nevada.

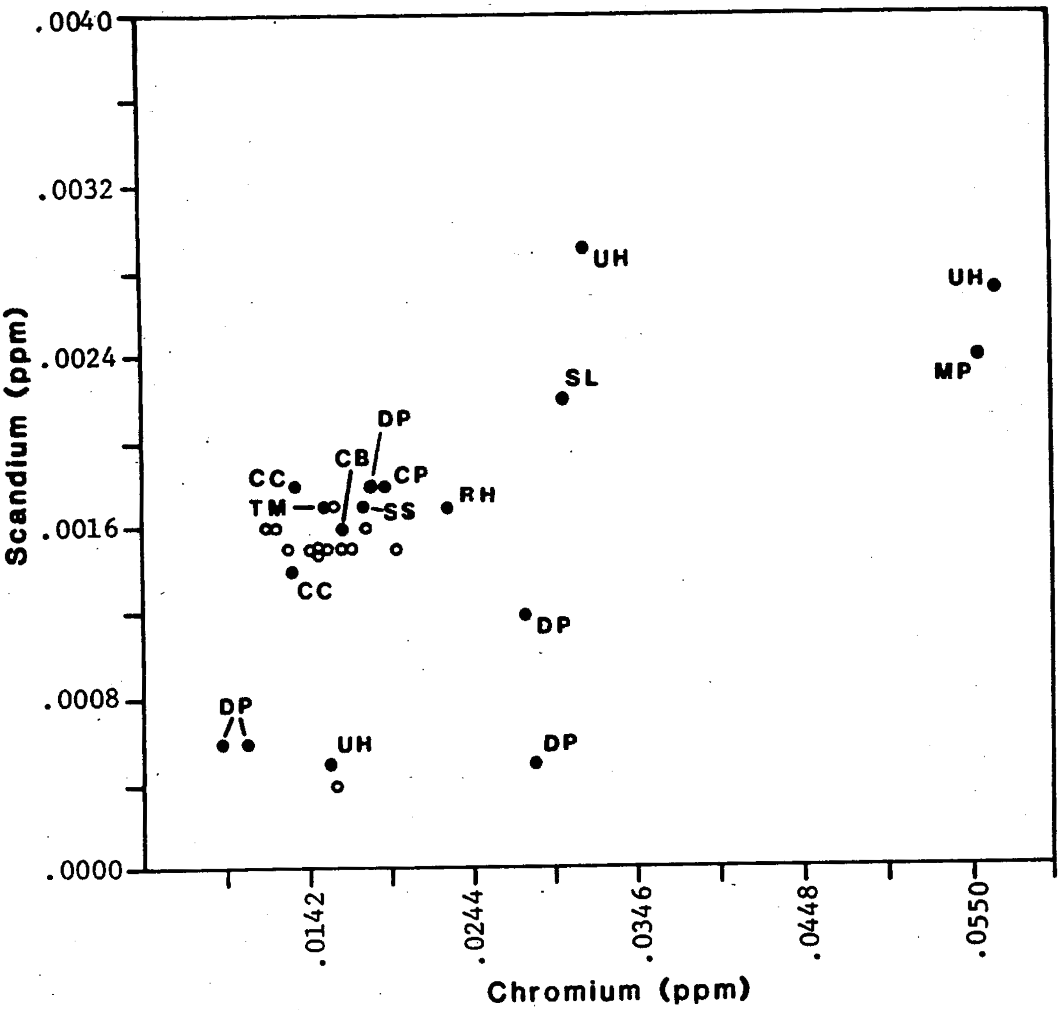


Figure 21. Scandium-chromium trace element plot for volcanic rocks from west-central Nevada.

Data on the light REE abundances (Ce/La, fig. 20) do not indicate any differences in regional trend for the Carson Desert-Desert Peak samples as compared to the other volcanics of this study. The positive correlation and variability of Ce/La values of the regional data include the Steamboat Hills samples that are enriched in both Ce and La compared to the other volcanics.

The ignimbrites of Desert Peak and the rhyolites of Steamboat Hills and Upsal Hogback show variable Cr content but are generally depleted in Sc (fig. 21) compared to the more mafic volcanics. The basalts of Upsal Hogback, Soda Lake and McClellan Peak show enrichment in both Sc and Cr. The remainder of the samples are fairly similar (clustered) in Sc/Cr content.

Two contrasting enrichment-depletion patterns are reflected by the elemental compositions of the samples from Steamboat Hills and the pumice samples from Desert Peak. The various basaltic andesite flows of the Steamboat Hills do not exhibit any consistent variation in elemental content; this is illustrated by the trace element variation diagrams (fig. 18 through 20) in which the Steamboat Hills data points closely cluster. Comparison of the basaltic andesite elemental composition (typified by sample #3327) with the elemental composition of the rhyolite dome at Steamboat Hills shows depletion of all elements except for major enrichment in silica (Si), potassium (K), rhubidium (Rb) and niobium (Nb) and minor enrichment of chromium (Cr) (fig. 22).

This pattern is in sharp contrast to the enrichment pattern based on the pumice samples from Desert Peak (fig. 23). The low silica (63%) pumice in the lower portion of the Desert Peak ignimbrites is most closely representative of the magma composition. The specific enrichment-depletion pattern shown in Figure 23 depicts the changes in the magma composition as eruption continues and fractionation and crystallization affect the magma. Similar to the Steamboat Hills enrichment pattern (fig. 22), comparison of the light gray siliceous

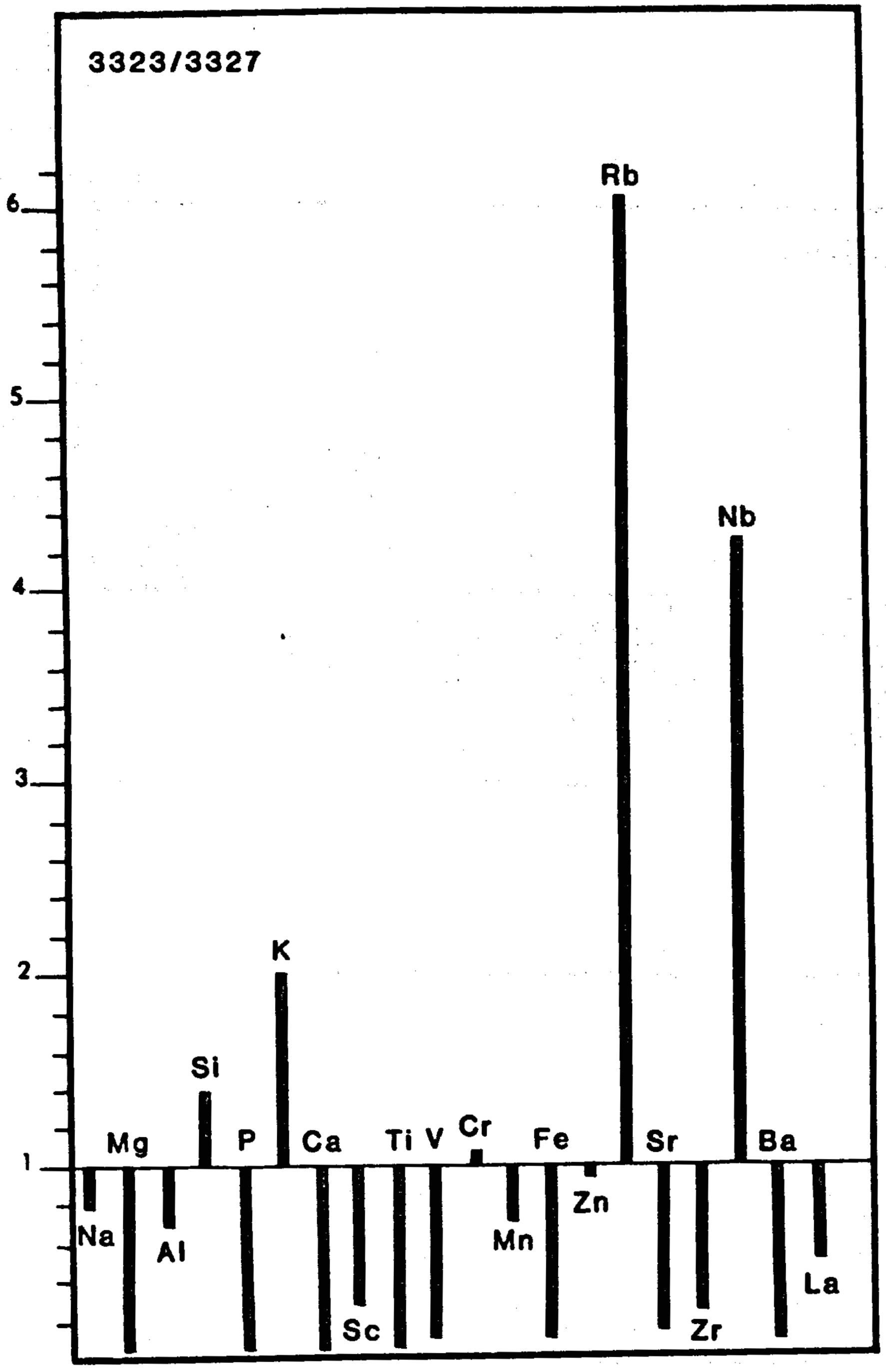


Figure 22. Enrichment factors for 20 elements of the Steamboat Hills rhyolite compared to the composition of the basaltic andesite typified by sample 3327. Arranged by atomic number, the enrichment factor is the ratio of the element content in 3323 to 3327.

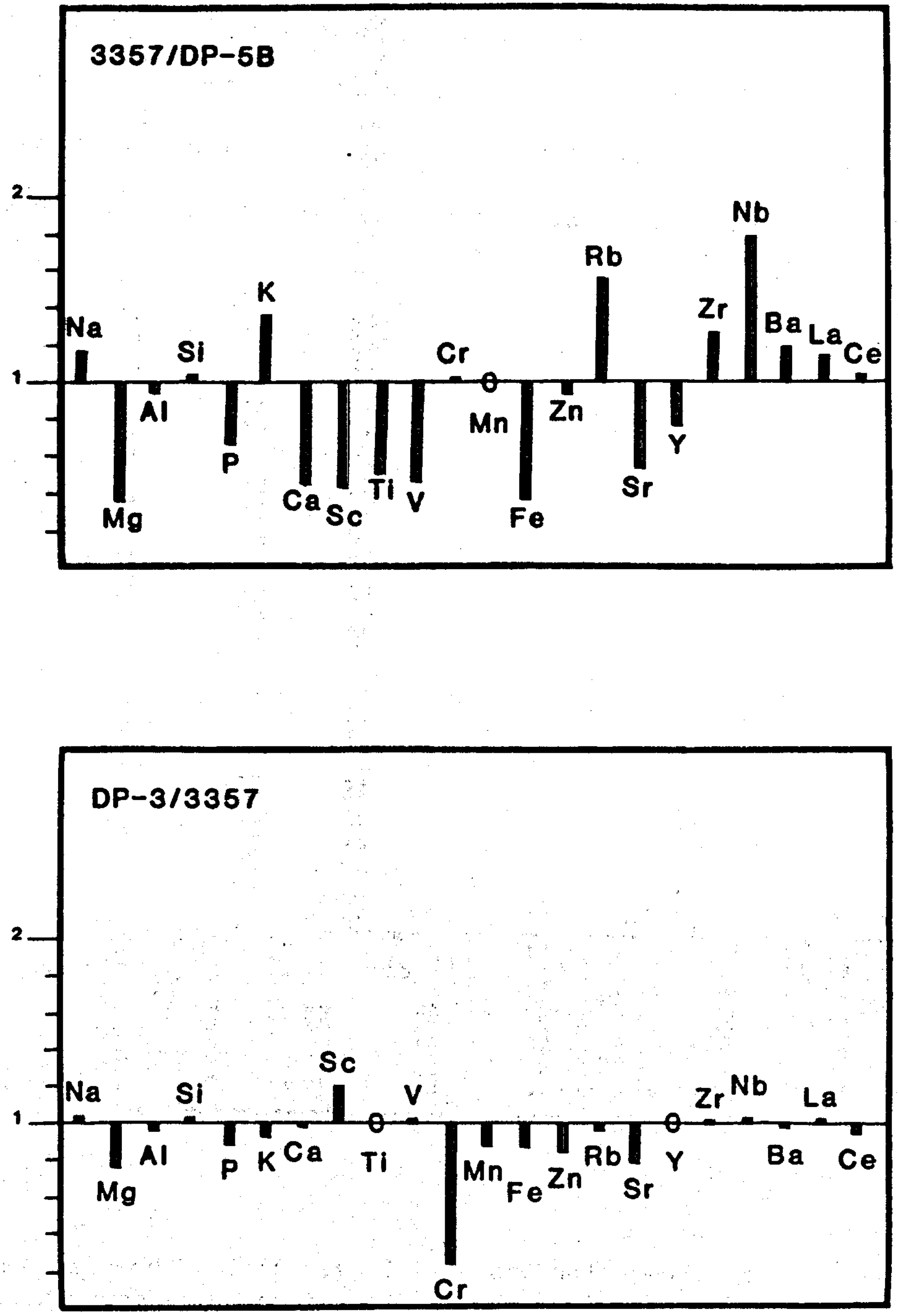


Figure 23. Enrichment factors for 22 elements in Desert Peak pumice. Arranged by atomic number, the enrichment factor is the ratio of the element content in 3357 to DP-5B and DP-3 to 3357.

(69% SiO_2) pumice (#3357) to the dark gray, low silica (63%) pumice (DP-5B) (fig. 23) of Desert Peak shows enrichment of Si, K, Rb, and Nb, but the magnitude of enrichment is decreased by a factor of 2 or 3. Minor enrichment of sodium (Na), zirconium (Zr), barium (Ba), lanthanum (La), and cesium (Ce) are also indicated. The enrichment depletion factors comparing the siliceous light gray pumice (#3357) with the highest silica content (70%, Appendix E) pumice (DP-3) shows only minor enrichment or depletion of each element, with the exception of chromium.

MICROPROBE OF PHENOCRYST PHASES

Microprobe analyses were performed on cellular plagioclase phenocrysts in samples of Steamboat Hills basaltic andesites and Upsal Hogback and Soda Lake basalts. Representative anorthite histograms of microprobe traverses from these samples are shown in Figures 24 and 25. Normalized oxide compositions and calculated feldspar contents for these traverses are listed in Appendix F.

These cellular plagioclase phenocrysts are reversely zoned, typically with more sodic cores (An 20 to An 35) and more calcic rims (An 50 to An 70). The ranges of variation in composition are reflected by the eight histograms in Figures 24 and 25. The compositions of the phenocryst rims approach those of non-cellular, lath-shaped plagioclase crystals (shaded portions of histograms, fig. 24 & 25) that occur either within the groundmass or as a second phenocryst generation (see fig. 8).

The cellular zones and differences in composition between the cores of these phenocrysts and the rims suggest that these feldspars were not in equilibrium with the crystallizing conditions (P-T-X; pressure-temperature-chemical) of the host rock. Two origins are therefore possible; the phenocrysts may have no relation to the host rock or they may be cognate phenocrysts.

These Steamboat Hills basaltic andesites and Carson Desert basalts have been intruded through a variety of older volcanic and sedimentary rocks and igneous masses. Lithic fragments or selective mineral phases (e.g., the feldspars) could have been incorporated into the rising magma. Arguments against any significant contamination are based on normative feldspar compositions, bulk chemical composition and Sr isotopic data. The modal compositions of the normative feldspars in these rocks (andesine to labradorite) are in fair agreement with the range of An composition of the phenocrysts determined by micro-

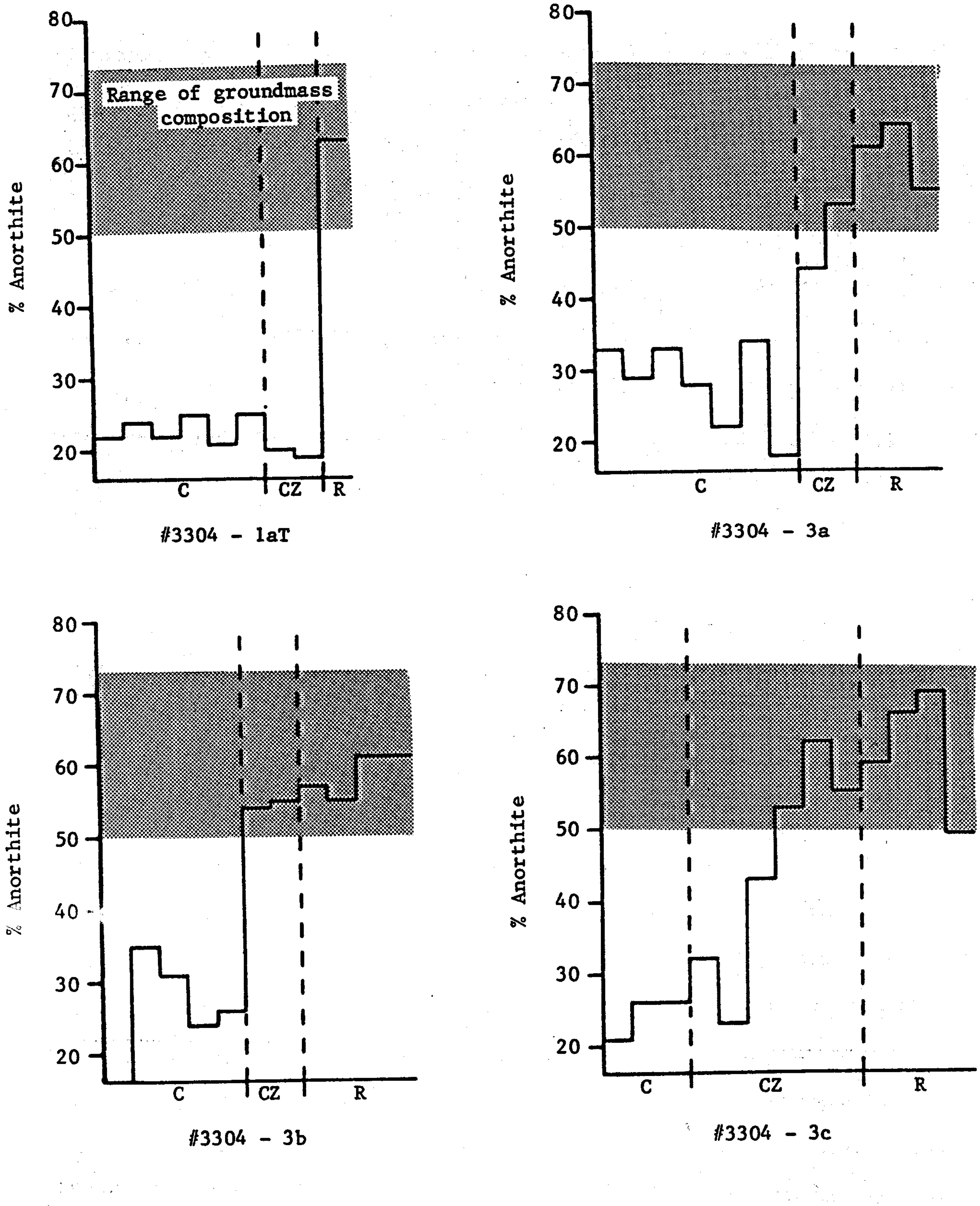
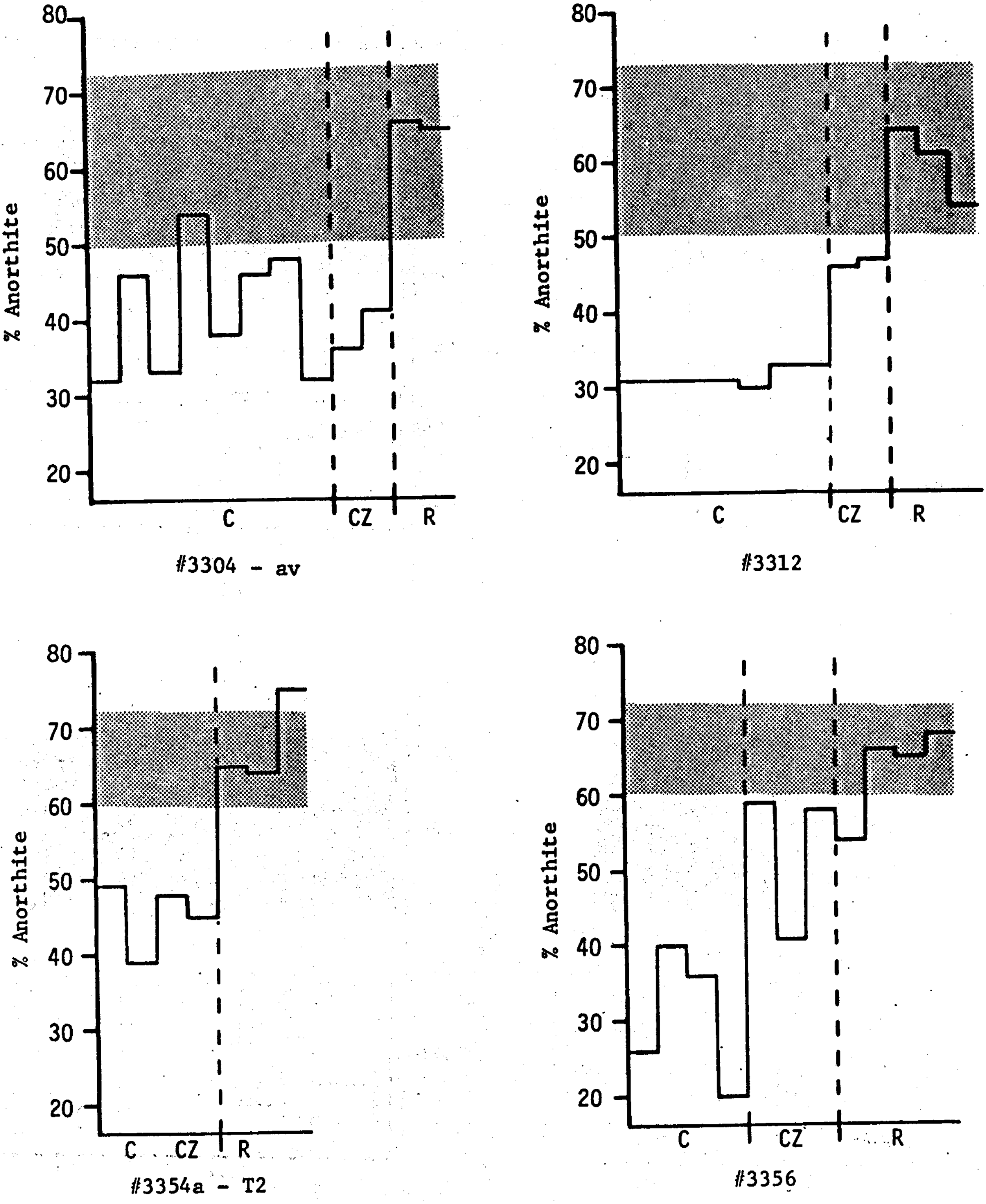


Figure 24. Anorthite histograms of microprobe traverses.
(C = Core, CZ = Cellular Zone, R = Rim)



#3304 - av

#3312

#3354a - T2

#3356

Figure 25. Anorthite histograms of microprobe traverses of Steamboat Hills basaltic andesite, Soda Lake and Upsal Hogback basalt.

probe analysis (fig. 24 and 25). The bulk chemistry, both major (Appendix E) and minor (Appendix C) chemistry, of these rocks has not been significantly altered by contamination with generally more silicic crustal rocks. The Sr isotopic ratios of plagioclase separates are comparable to whole rock ratios (see Strontium Isotope discussion), at least for the Steamboat Hills basaltic andesites.

Therefore, since these phenocrysts are not foreign to the magma, they must be cognate phenocrysts that crystallized under a particular set of P-T-X conditions that differ from those conditions under which the host rock crystallized. The implications of these cognate phenocrysts on the petrogenesis of these rocks is discussed in a later section of this report.

STRONTIUM ISOTOPES

Twelve whole rock samples, representing the range of rock types within the study area, were selected for Sr isotopic analysis (Table 3). Plagioclase mineral separates from two of the samples (#3304-S and #3312-S) from the Steamboat Hills basaltic andesite were also included. Because of the relative young ages and low Rb/Sr ratios (Table 3) in these samples, there has not been significant build-up of radiogenic $^{87}Sr/^{86}Sr$ through decay of Rb. Therefore, the Sr isotope ratios observed are consistent with initial values, except for the Steamboat Hills rhyolite (Table 3).

The three basalts (McClellan Peak #3346, Rattlesnake Hill #3350 and Upsal Hogback #3354) have Sr ratios of 0.7036 to 0.7048. The basaltic andesites range from 0.7042 to 0.7051. The more silicic (rhyolitic) rocks have high Rb/Sr ratios, with Steamboat Hills rhyolite (#3323) having a $^{87}Sr/^{86}Sr$ ratio of 0.7059 (calculated initial) and Desert Peak ignimbrite (#3357) having a ratio of 0.7044. Although within the range of values for oceanic basalts (Hedge and others, 1972), Sr ratios for these western Nevada rocks are higher than almost all oceanic rocks which typically are less than 0.7040. In the Great Basin and eastern Sierra Nevada, basalts commonly have Sr ratios of 0.7027 to 0.708 (Hedge and Noble, 1971; Mark and others, 1974; Leeman and Rogers, 1970; Scott and others, 1971; Leeman, 1982). These values (Table 3) are: 1) comparable to the range of Sr ratios (0.7027 to 0.7043) for the southern Cascades (Peterman and others, 1970; Mertzman, 1979); 2) within the range of initial values (0.7034 to 0.7062) for 5 to 12 m.y. old basalts in the southern Basin and Range (Suneson and Lucchita, 1983); and 3) generally within the range (0.7043 to 0.7056) reported by Morton and others (1980, 1983) for younger volcanic rocks in the northern Virginia Range including McClellan Peak and Steamboat Hills. The Sr ratios (Table 3) are lower than values (0.7054 to 0.7076) reported by

SAMPLE	LOCALITY	Sr^{87}/Sr^{86}	Rb/Sr
3304	Steamboat Hills	0.70466 ± 0.00007	0.036
3312	Steamboat Hills	0.70456 ± 0.00011	0.038
3314	Steamboat Hills	0.70506 ± 0.00012	0.057
3323	Steamboat Hills	0.70633 ± 0.00008 0.70586 ± 0.00008*	11.600
3339	Carson City	0.70453 ± 0.00006	0.035
3344	Table Mountain	0.70419 ± 0.00006	0.010
3346	McClellan Peak	0.70483 ± 0.00010	0.029
3347	Churchill Butte	0.70474 ± 0.00009	0.029
3348	Cleaver Peak	0.70460 ± 0.00010	0.025
3350	Rattlesnake Hill	0.70426 ± 0.00004	0.090
3354	Upsal Hogback	0.70364 ± 0.00005	0.056
3357	Desert Peak	0.70443 ± 0.00009	0.379
3304-S	Steamboat Hills	0.70451 ± 0.00004	--
3312-S	Steamboat Hills	0.70487 ± 0.00006	--

*Initial Sr ratio corrected for growth of radiogenic Sr^{87}.

Table 3. Strontium isotope data for young volcanic rocks from west-central Nevada.

Leeman and Manton (1971) for the Snake River Plain volcanics but are comparable to values (0.703 to 0.706) for basalts and rhyolites in the Modoc Plateau region of northwest Nevada and adjoining states (Leeman, 1982).

Correlations of $^{87}Sr/^{86}Sr$ with Sr (fig. 26) and with Rb/Sr (fig. 27) are used to evaluate the role of crustal contamination in generating the mafic (<59%, SiO_2) volcanic rocks in the study area. If a mafic magma were contaminated by crustal material with high Rb content, high Rb/Sr ratio and high $^{87}Sr/^{86}Sr$ ratio, plots of $^{87}Sr/^{86}Sr$ versus Sr would show a negative correlation and $^{87}Sr/^{86}Sr$ versus Rb/Sr would show a positive correlation. As shown on Figures 27 and 28, positive correlations exist in both of these data sets. Therefore, contamination of these magmas by crustal material with significant amounts of radiogenic Sr can be ruled out.

Examination of Figures 26 and 27 and a plot of $^{87}Sr/^{86}Sr$ versus Rb (fig. 28) reveals regional trends that parallel trends in the trace element chemistry (see fig. 18 through 21). In particular, there is a distinction between the Carson Desert-Desert Peak volcanics and the volcanics of the western portion of the study area. Figure 26 illustrates the generally low Sr content and lower $^{87}Sr/^{86}Sr$ ratios of the Carson Desert/Desert Peak volcanics. Figure 27 indicates two subparallel positive trends, with the Upsal Hogback and Rattlesnake Hill basalts having lower $^{87}Sr/^{86}Sr$ ratios but higher Rb/Sr ratios than any of the other mafic rocks; sample #3357 from Desert Peak exhibits these same charactersitics, although more siliceous. Figure 28 also shows two trends with the Carson Desert-Desert Peak samples having a more systematic correlation between $^{87}Sr/^{86}Sr$ and Rb than the volcanics of the western portion of the study area which generally tend to be more depleted in Rb.

Sample #3323 of the Steamboat Hills rhyolite with an initial Sr isotope ratio of 0.7059 is within the range reported by Noble and others (1972) for siliceous volcanic rocks in the western Great Basin. Morton and others (1980)

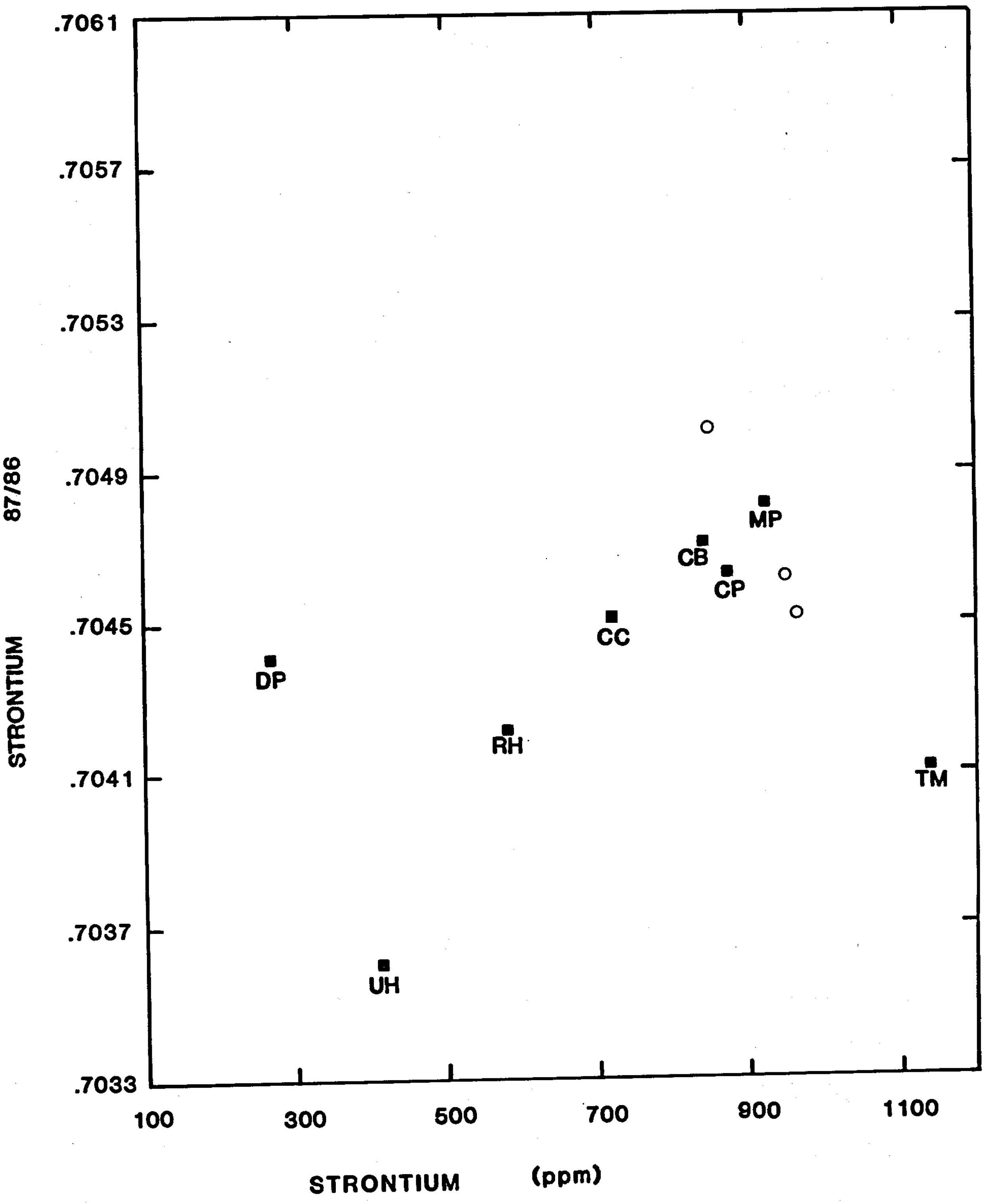


Figure 26. Strontium versus strontium isotope ratio for non-rhyolitic volcanic rocks of west-central Nevada.

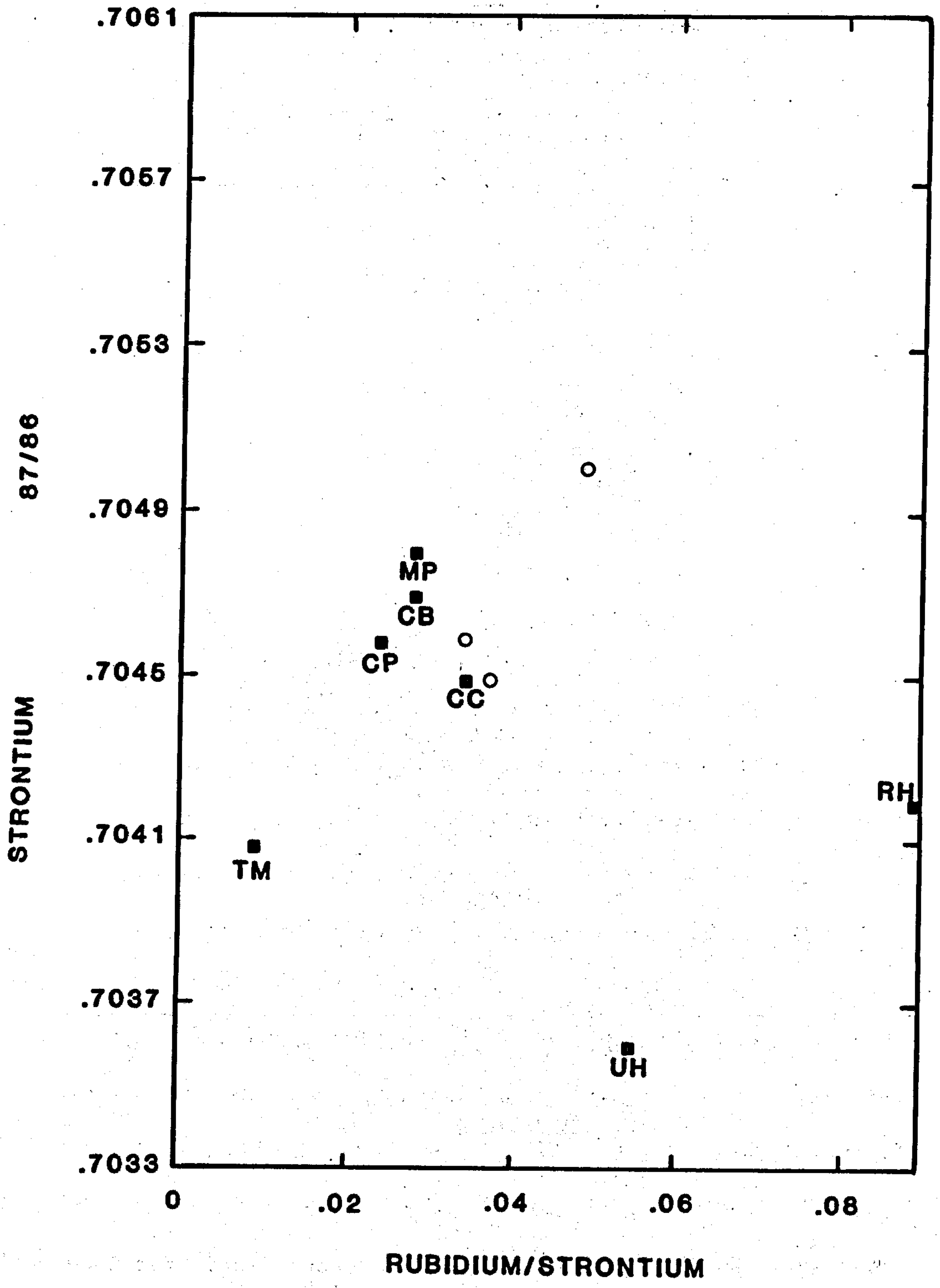


Figure 27. Rubidium/strontium ratio versus strontium isotopic ratio for mafic (<59% SiO_2) volcanic rocks from west-central Nevada. DP-3357, with 69% SiO_2 has Rb/Sr of 0.379.

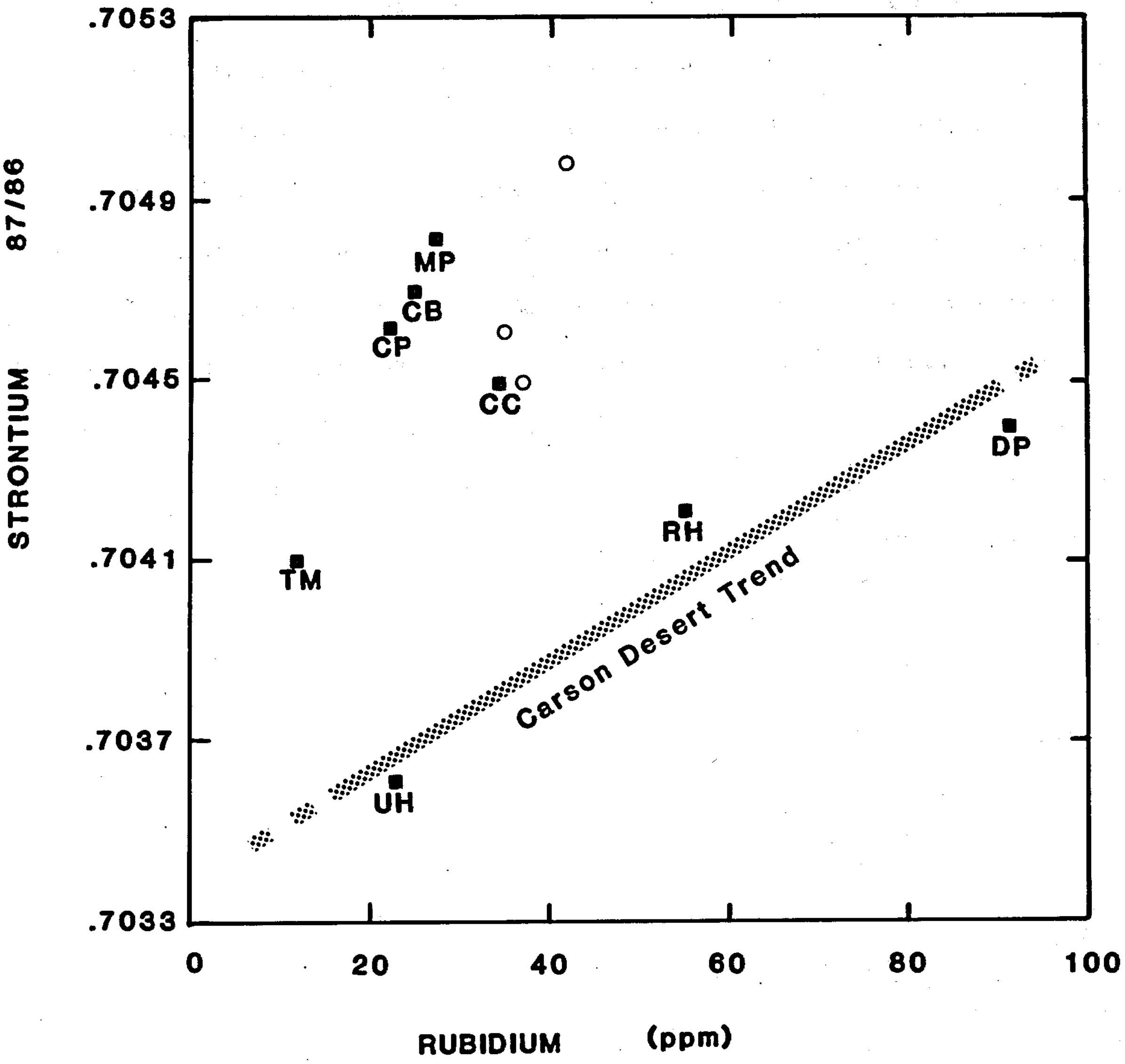


Figure 28. Rubidium versus strontium isotopic ratio for non-rhyolitic volcanic rocks of west-central Nevada.

report a comparable $^{87}Sr/^{86}Sr$ ratio of 0.7055 for the Steamboat Hills rhyolite.

The three basaltic andesite samples of Steamboat Hills have Sr isotope values ranging from 0.7046 to 0.7051 (Table 3). Morton and others (1980) report a comparable value of 0.7052. This range of Sr isotopic ratios is probably not due to crustal contamination because of the high Sr contents (Appendix C) and low Rb/Sr ratios (fig. 28). Large proportions of crustal material would have to be assimilated to modify $^{87}Sr/^{86}Sr$, and this would be reflected in the chemical compositions of these basaltic andesites (Leeman, 1970; Hedge and Noble, 1971). Such contamination by crustal material is not reflected in either the major or trace element chemistry of these volcanics (Appendix C, fig. 18 through 22). Lack of contamination is further substantiated by the Sr isotopic ratios for the two mineral separates (Table 3) which are consistent with the whole rock values.

PETROGENESIS

Eruptions of bimodal (basalt-rhyolite) magma are common to areas of continental crustal extension, particularly the Basin and Range Province (Best and Brimhall, 1974; Christiansen and Lipman, 1972; Metz and Bacon, 1980). Rhyolite-basalt volcanism does not generally occur in other continental crustal settings, since thick non-extending crust retards penetration by basalt and favors hybridism and the production of intermediate (dacitic-andesitic) activity (Eichelberger and Gooley, 1977). Hildreth (1981) indicates that the co-eruption of rhyolite and basalt is only likely to occur around the periphery of large silicic systems (fig. 29) or in immature zones of crustal melting where silicic pods and mafic dikes have not yet aggregated into chambers larger than a few cubic kilometers in volume. To facilitate basaltic eruptions, conduits (e.g., faults) must provide connection between the mafic magma source and the surface.

Petrographic, chemical and isotopic data can be interpreted to outline more specific characteristics of the petrogenesis of these young volcanic rocks in west-central Nevada.

PHENOCRYSTS

The ranges of composition in the cognate plagioclase phenocrysts can be used to calculate pressures under which they crystallized (Table 4). The more sodic cores of these phenocrysts generally crystallized at pressures greater than about 18 kilobars (kb). The groundmass plagioclase typically crystallized at pressures of about 8 kb. The calcic rims of the phenocrysts show intermediate crystallization pressures (10-13 kb, Table 4) that reflect conditions of re-equilibration within the rising magma. Equilibration pressures of 8 to 18

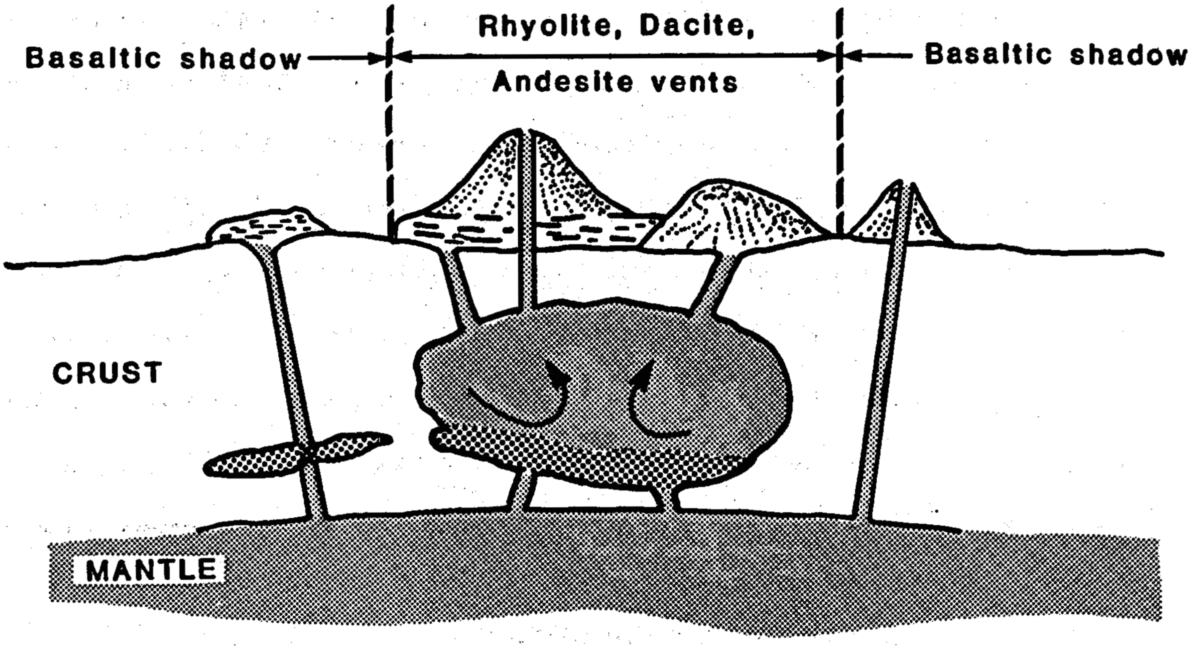


Figure 29. Basaltic shadow around large silicic magma system (after Eichelberger and Gooley, 1977).

Locality	Anorthite Range	Crystallization Pressure*
Steamboat Hills	An 30 - An 40 (Na-rich cores)	$P_{kb} = 23.3 - 19.5$
	An 55 - An 65 (Ca-rich rims)	$P_{kb} = 13.2 - 10.0$
	An 50 - An 70 (groundmass)	$P_{kb} = 15.7 - 8.1$
McClellan Peak	An 65 - An 78	$P_{kb} = 10.0 - 5.1$
Upsal Hogback	An 40 - An 50 (Na-rich cores)	$P_{kb} = 19.5 - 15.7$
	An 60 - An 71 (groundmass & rims)	$P_{kb} = 11.9 - 7.7$
Soda Lake	An 30 - An 40 (Na-rich cores)	$P_{kb} = 23.3 - 19.5$
	An 60 - An 74 (groundmass & rims)	$P_{kb} = 11.9 - 6.6$

*$P_{kb} = -0.38\ (\%\ \text{An}) + 34.7$ from Nash (1973)

Table 4. Calculated Crystallization Pressure for Plagioclase Phenocrysts

kb represent depths of 30 to 70 km. This suggests an upper mantle origin for these mafic magmas.

Chemical conditions under which these phenocrysts crystallized can be inferred from the normative feldspar compositions (Appendix F). Binns and others (1970) cite numerous experimental studies which indicate the tendency of near-liquidus plagioclase to become more sodic at higher pressures. This explains the relationship of composition and depth shown on Table 4. In comparison to other regions (fig. 30), the composition of the phenocrysts from Steamboat Hills and the Carson Desert samples ranges from An 20 to An 70 with no divergence toward orthoclase (<3%). This composition range is similar to the plagioclase megacryst compositions determined by Irving (1974). In contrast, potassium content has been found to increase for Na-plagioclase co-existing in potassic magmas approaching equilibrium (Carmichael and others, 1974) (fig. 30). In silicic rocks, a similar increase (approximately 3 to 10%) is seen in the data of Bacon and Metz (1983) (fig. 30). This suggests that the potassium content of the parent mafic magma has remained low and essentially constant with no contamination by potassium-rich crustal rocks.

Similar consideration must be given to the presence of quartz phenocrysts in these rocks (see Petrography section). Quartz-bearing basalts and basaltic andesites are found in a variety of tectonic settings in the western U. S. (Best and Brimhall, 1974). Contamination from intruded crustal rocks has been suggested by Thompson and White (1964) for the Steamboat Hills system. As discussed previously, significant contamination would be reflected in the chemical and isotopic compositions; it is not. These quartz phenocrysts and their enclosing pyroxene reaction rims (fig. 7) together with olivine may also be cognate phenocrysts evolving with the magma. Nicholls and others (1971) showed that quartz can crystallize in basaltic magma at pressures between 15 and 25 kb

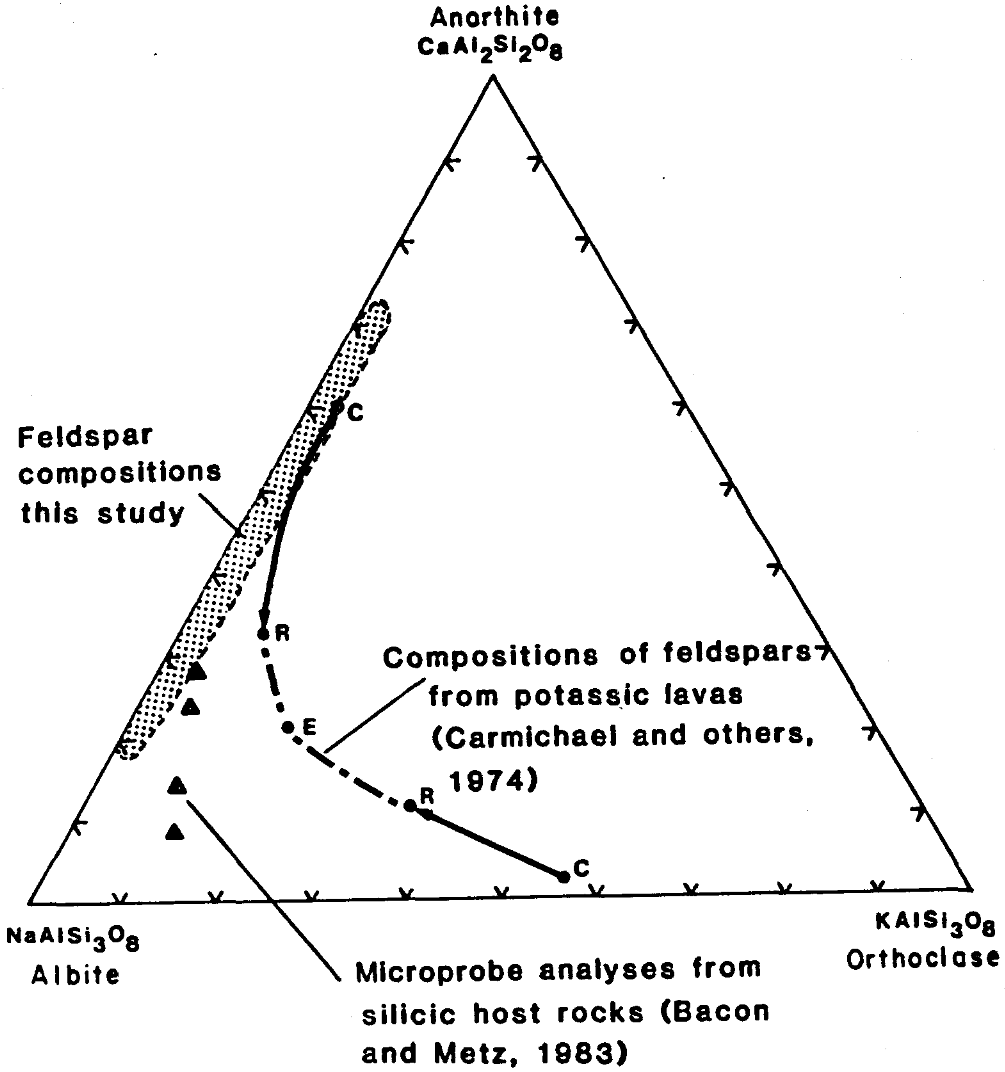


Figure 30. Albite-anorthite-orthoclase triangular diagram showing compositions from this study compared to other studies.

(corresponding to depths of 55 to 85 km within the mantle). Experimental work by Green and Ringwood (1967) showed that at pressures greater than 13.5 kb, pyroxenes are the first phase to crystallize; olivine is the dominant phase at pressures of about 9 kb or less. This suggests, along with the depth-pressure ranges for the plagioclase phenocrysts (Table 4), that the quartz crystallized at depths within the mantle and then re-equilibrated with the rising basaltic magma forming pyroxene reaction rims, with olivine crystallizing at shallower depths (lesser pressures). The quartz remains as incompletely resorbed refractory phenocrysts.

Reversely zoned feldspars have been attributed to magma mixing (Evashko, 1982; Hibbard, 1981) in Miocene volcanic rocks in western Nevada. The explanation provided above, however, is favored here since it explains by a simple depth-pressure model both the feldspar compositions and quartz phenocrysts without invoking complex variations in temperature, pressure, magma interaction and/or contamination.

CHEMICAL MODELING

The bulk chemistry of the volcanic rocks can be used with least squares mixing models (Wright and Doherty, 1970) and Raleigh fractionation (Shaw, 1970) to test the possibility of magmatic differentiation in this region. Table 5 lists the chemical and mineralogic results of these models for deriving the Desert Peak ignimbrites and the Steamboat Hills basaltic andesite from respectively more mafic parent materials. The partition coefficients used in these models are given in Table 6.

Mixing calculations for the Desert Peak pumice were made using a basaltic parent material with composition equivalent to the Soda Lake basalt. Fractionation modeling as shown on Table 5 demonstrates that fractionating out 12%

	A			B			C		
	PARENT	OBSERVED	CALCULATED	PARENT	OBSERVED	CALCULATED	PARENT	OBSERVED	CALCULATED
	Soda Lake 3356	pumice DP-5	Model	pumice DP-5	tuff DP-2A	Model	McClellan Peak 3346	Steamboat Hills 3308	Model
SiO_2	51.55	62.91	62.84	62.91	69.84	69.84	49.24	55.68	55.46
Al_2O_3	15.62	16.68	16.77	16.68	15.34	15.34	14.91	18.45	18.59
FeO	10.59	5.68	5.68	5.68	3.08	3.08	8.66	8.08	8.08
MgO	6.07	1.72	1.81	1.72	.38	.38	10.28	2.11	2.28
CaO	8.12	4.17	4.25	4.17	1.34	1.34	9.7	6.45	6.78
Na_2O	3.15	4.31	4.12	4.31	5.23	5.23	3.11	4.6	5.12
K_2O	1.94	3.13	3.71	3.13	4.09	4.07	1.74	2.34	3.40
TiO_2	1.81	.89	.89	.89	.38	.38	1.55	1.45	1.45
P_2O_5	.52	.24	1.07	.24	.07	.32	.57	.57	1.14
MnO	.17	.14	.35	.14	.11	.18	.14	.14	.27
Plag.	-	-	12.5 %	-	-	10.7 %	-	-	16.0 %
Oliv.	-	-	-	-	-	2.0 %	-	-	13.0 %
CPX	-	-	3.8 %	-	-	-	-	-	17.0 %
Magn	-	-	3.2 %	-	-	<1.0 %	-	-	<1.0 %
Ill	-	-	1.2 %	-	-	<1.0 %	-	-	1.5 %
Amp	-	-	30.0 %	-	-	10.7 %	-	-	-
SUM OF RESIDUAL^2	-	-	1.13	-	-	.07	-	-	1.39
Rb	32	59	57	59	94	75	27	31	51
Sr	416	461	488	461	150	451	923	945	1113
Ba	892	1105	1659	1105	1316	1407	974	1259	1854
La	21	30	36	30	38	38	31	41	51

Table 5. Mixing Model Calculations.

*	Plag	Oliv	CPX	Mag	Ill	Amph
Rb	.05	0.0	.03	0	0	.29
Sr	2	.014	.12	0	0	.46
Ba	.01	.01	.026	0	0	.2
La	.01	-	.56	0	0	.3

Table 6. Crystal-Liquid Partition Coefficients used for Crystal Fractionation Modeling

plagioclase and 30% amphibole of the basalt is capable ($\Sigma R^2 < 2.0$) of producing the low silica (63%) pumice at Desert Peak. Continued fractionation of 10% amphibole and plagioclase would produce compositions similar to that of the main tuff sequence. Trace element compositions employing the above phase percentages show close agreement (except for Sr concentration) with observed values (compare with fig. 23). Excessive amphibole fractionation is supported by a depletion of Sc and Cr within the Carson Desert and Desert Peak samples as shown on Figure 21.

The derivation of the Steamboat Hills basaltic andesite was modeled using a high-potassium olivine basalt parent material with composition equivalent to the McClellan Peak olivine basalt (Table 5). Calculations using 16% plagioclase, 13% olivine and 17% clinopyroxene produce compositions similar to the basaltic andesite. Trace element compositions differ by an order of magnitude with observed values, but their general trends are comparable. Enrichment of light REE in the Steamboat Hills basaltic andesite may therefore be compatible with low pressure liquid state fractionation from a parental basaltic magma similar in composition to the McClellan Peak olivine basalt but having lower K, Rb, La and Ce.

STRONTIUM ISOTOPES

The strontium isotope ratio values for the mafic volcanics range from 0.7036 to 0.7051. The Steamboat Hills rhyolite has a ratio of 0.7059. A comparison of these values with age of the respective units (fig. 31) does not reveal a time-trend. This suggests that the variations in initial Sr isotopic ratios have persisted through this time interval (± 15 m.y.) and must be explained by other factors. Hildreth (1981) and Leeman (1982) suggest that the variations in observed isotopic ratios can be a function of the structural (tectonic) setting, composition and age of the underlying crust.

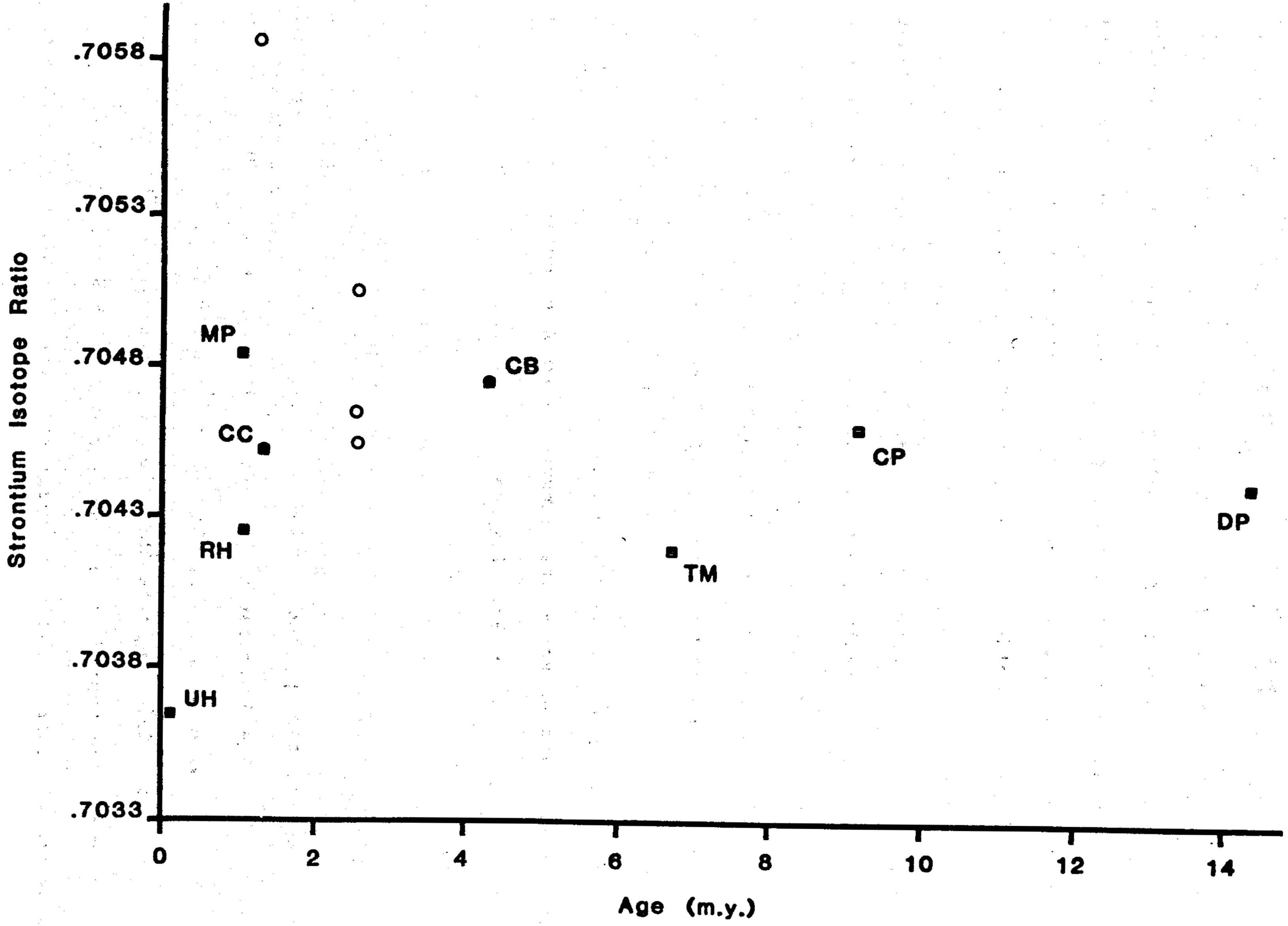


Figure 31. Variation in strontium isotope ratios with age for young volcanic rocks in west-central Nevada.

As Leeman (1982) indicates, the northwestern Great Basin is underlain by Cordilleran eugeosynclinal rocks and magmatic arc-type igneous rocks (all of "oceanic" character). The magmas derived from these 'oceanic' sources are systematically lower in $^{87}Sr/^{86}Sr$ ratios, but are high in total strontium (see fig. 30). These Sr values together with the petrologic data discussed above, suggest that the magmas originated in the upper mantle and lower crust of this region.

The structural character of this region is dominated by the normal faulting of the Great Basin and the high-angle faulting of the Walker Lane and the Sierran frontal fault systems. These fault zones may serve as the conduits for rising basaltic magmas from the upper mantle and lower crust. The relatively thin crust in the Walker Lane region cut by high angle faults would allow rapid upward movement of magmas without the possibility of mixing of basaltic magma and rhyolitic magma generated in the lower crust.

The relatively thicker unfaulted crust in the Great Basin region to the east would tend to inhibit the upward movement of magma and allow for possible hybridism and the generation of more intermediate magmas such as the ash flows in early to middle Tertiary time. This Tertiary calc-alkaline volcanism was related to the subduction zone along the western continental margin. Progressive shut-down of the subduction zone occurred, beginning about 25 to 29 m.y. ago, as the triple junction migrated northward. Subsequent bimodal volcanism was initiated within the new tectonic regime and migrated through the Basin and Range Province. With progressive development of Basin and Range normal faults during late Tertiary time, conduits developed that allowed for more rapid ascent of basaltic magma to the surface.

The age of the lower crustal and upper mantle material in this region is unknown. It is likely that there is both lateral and vertical variation in age of these rocks as well as lateral and vertical compositional variation. The extent of influence on the young volcanic rocks of western Nevada is uncertain. However, the major chemical distinction between the volcanic rocks of the Desert Peak-Carson Desert area and those volcanic rocks further west might best be explained by regional variation in age and composition.

CONCLUSIONS

During early and middle Tertiary time, volcanism in the northern Basin and Range region was primarily silicic and intermediate in character, removing much of the low-melting silicic phases in the lower crust. The initiation of crustal extension and development of normal faulting starting in late Miocene time coincided with the change to dominantly bimodal (basalt-rhyolite) volcanism. The variations in strontium isotopic ratios and chemical composition of these young volcanic rocks reflect the lateral and vertical inhomogeneities of the mantle source region. The total volume of these late Cenozoic bimodal volcanic rocks is minor compared to the early Tertiary intermediate silicic volcanism. However, they represent magmas that originated in the modern mantle beneath the Basin and Range and ascended via structural conduits with little or no contamination.

The development of an extensional tectonic environment with normal faults and high angle strike-slip faults, as well as the transition from intermediate to bimodal volcanism, was not instantaneous in time nor geographically coincident within the Great Basin. The older Desert Peak volcanics may represent this transitional period. The age of the bimodal Desert Peak volcanics (10 to 14 Ma) suggests that the present tectonic regime in the western margin of the Great Basin has maintained an "immature" volcanic regime for the last 15 m.y. This immature regime is characterized by silicic pods and mafic dikes that have not yet aggregated, or matured, into chambers larger than a few cubic kilometers in volume and can not generate hybrid intermediate magmas.

The observed volcanic rock suites with particular chemical, isotopic and petrologic characteristics are therefore a function of the magma composition and the tectonic setting of the eruption area. The rhyolite-basalt magmatism in west-central Nevada is similar to the model of Hildreth (1981, fig. 15A), with basalt locally erupted within and between the rhyolite dome clusters as at Steamboat Hills, or with rhyolitic intrusions that are not observed at the surface (except as inclusions in the basalts) as at Upsal Hogback and Soda Lake. Variation in the proportion of basalt to rhyolite erupted at the surface is probably due to lateral variation in crustal thickness (eastward thinning) across this region. The volcanism is fundamentally basaltic in an extensional regime that suppressed mixing of the rhyolite and basalt (Hildreth, 1981). Thus, the volcanic rocks observed at the surface form a bimodal suite.

The geothermal resources associated with these bimodal volcanic systems in west-central Nevada are predominantly a function of the tectonic setting. The requisite heat source is provided by continued basaltic magmatism from the mantle in a continuing extensional stress regime. The structural zones which serve as conduits for the upward migration of magma toward and to the surface also serve as conduits for circulating groundwaters to depth where heat is probably conductively acquired and then convectively carried to the near-surface or surface. This circulation requires at least several thousand years; Flynn and Ghusn (1984) concluded that the Steamboat recharge cycle is on the order of several thousand to 40,000 years, with little modern (<0.03 Ka) water dilution.

The spatial relationships of geothermal systems with lineament intersections noted by Trexler and others (1978) and the temporal associations and alignment of volcanic loci noted by Smith and Luedke (1981) are supported by the distribution of young bimodal volcanic rocks and geothermal systems in west-central Nevada. These relationships and the magmatic-tectonic associations described in this report suggest a high probability for the presence of as yet unrecognized geothermal resources in western Nevada where primary basaltic magmatism has occurred but surficial expression of a geothermal system is lacking.

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APPENDIX A

Isotopic Age Determinations

ISOTOPIC AGE DETERMINATIONS

Isotopic age determinations for eight samples are listed below. Analytical methods are discussed in the introduction to this report. The ages were calculated using the following constants:

$$\lambda_\beta = 4.963 \times 10^{-10}\ yr^{-1}$$

$$\lambda_\varepsilon = 0.572 \times 10^{-10}\ yr^{-1}$$

$$\lambda_\varepsilon' = 8.78 \times 10^{-13}\ yr^{-1}$$

$$^{40}K/K_{\text{Total}} = 1.167 \times 10^{-4}$$

Sample locations are illustrated on the accompanying map (fig. 1). Where appropriate, additional comments are included under the sample descriptions in this report. Further discussion of the results is presented in the text of this report. These isotopic ages and those reported in the literature for young (<15 m.y.) volcanic rocks within the study region are tabulated.

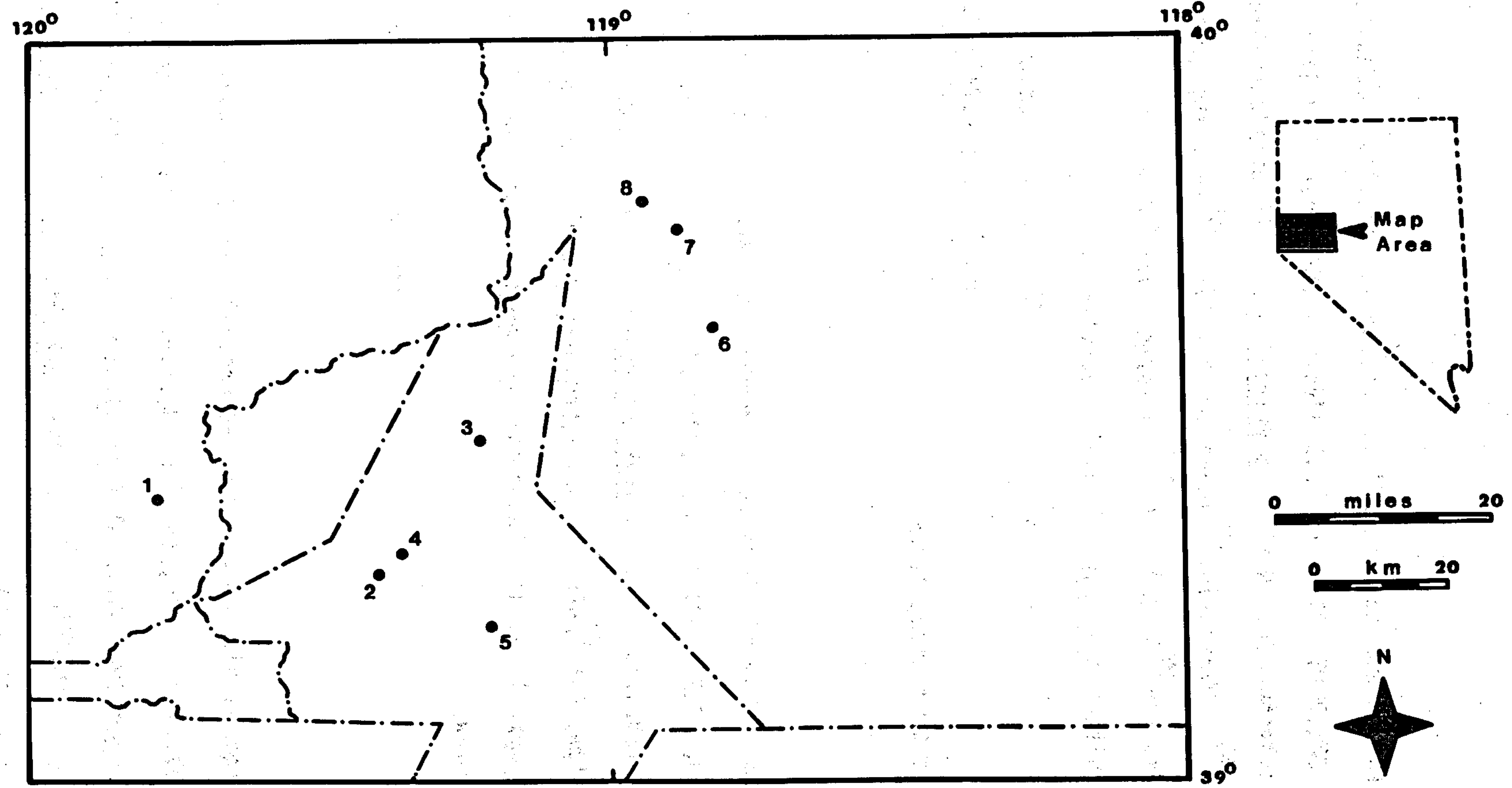

Figure A-1. Map of Reno 1 x 2° AMS quadrangle showing sample localities. Numbers are keyed to sample descriptions.

1. H - 3312 K-Ar

Steamboat Hills Basaltic Andesite. Porphyritic basaltic andesite (SW/4, sec. 32, T18N, R20E; 39°22.6'N, 119°46.0' W; Mt. Rose NE 7 1/2' quadrangle; Washoe Co., NV). Analytical data: (Plagioclase) K_2O = 0.425%, $*Ar^{40} = 8.39 \times 10^{-10}$ moles/gm, $*Ar^{40}/\Sigma Ar^{40} = 0.018$; (Whole Rock) K_2O = 2.003%, $*Ar^{40} = 2.9 \times 10^{-11}$ moles/gm, $*Ar^{40}/\Sigma Ar^{40} = 0.008$; collected by: L. A. Fultz; dated by: T. Bills, Geochron.

(Plagioclase) 29.6 ± 2.0 Ma

(Whole Rock) 0.21 ± 0.07 Ma

$*Ar^{40}$ refers to radiogenic Ar^{40}

2. H - 3344 K-Ar

Table Mountain Basaltic Andesite. Porphyritic basaltic andesite (NW/4, sec. 3, T16N, R23E, 39°17.2' N, 119°23.5' W; Churchill Butte 15' quadrangle; Lyon Co., NV). Analytical data: K_2O = 1.052%, $*Ar^{40} = 4.71 \times 10^{-10}$ moles/gm, $*Ar^{40}/\Sigma Ar^{40} = 0.042$; collected by: L. A. Fultz and E. J. Bell; dated by: T. Bills, Geochron. Comment: Twenty foot thick aggomerate flow.

(Whole Rock) 6.7 ± 0.7 Ma

3. H - 3345 K-Ar

Silver Springs Basaltic Andesite. Porphyritic basaltic andesite (NE/4, NW/4, sec. 31, T19N, R25E; 39°28.5' N, 119°13.4' W; Silver Springs 15' quadrangle; Lyon Co., NV). Analytical data: K_2O = 1.443%, $*Ar^{40} = 1.141 \times 10^{-9}$ moles/gm, $*Ar^{40}/\Sigma Ar^{40} = 0.249$; collected by: L. A. Fultz and E. J. Bell; dated by: T. Bills, Geochron.

(Whole Rock) 11.8 ± 0.7 Ma

4. H - 3347 K-Ar

Churchill Butte Basaltic Andesite. Porphyritic olivine-bearing basaltic andesite (NE/4, sec. 25, T17N, R23E, 39°18.9' N, 119°20.7' W; Churchill Butte 15' quadrangle; Lyon Co., NV). Analytical data: K_2O = 1.205%, $*Ar^{40} = 3.45 \times 10^{-10}$ moles/gm, $*Ar^{40}/\Sigma Ar^{40} = 0.126$; collected by: L. A. Fultz and E. J. Bell; dated by: T. Bills, Geochron.

(Whole Rock) 4.3 ± 0.6 Ma

5. H - 3348 K-Ar

Cleaver Peak Basaltic Andesite. Porphyritic basaltic andesite (NW/4, sec. 33, T16N, R25E; 39°12.8' N, 119°11.6' W; Wabuska 15' quadrangle; Lyon Co., NV). Analytical data: K_2O = 1.292%, $*Ar^{40} = 7.87 \times 10^{-10}$ moles/gm, $*Ar^{40}/\Sigma Ar^{40} = 0.155$; collected by: L. A. Fultz and E. J. Bell; dated by: T. Bills, Geochron. Comment: Thin vesicular flows overlying an earlier Tertiary andesite.

(Whole Rock) 9.2 ± 0.6 Ma

6. H - 3355 K-Ar

Upsal Hogback Rhyolite. Black glassy rhyolite (SE/4, sec. 2, T20N, R28E; 39°37.4' N, 118°48.2' W; Soda Lake 15' quadrangle; Churchill Co., NV). Analytical data: K_2O = 3.835%, $*Ar^{40} = 1.619 \times 10^{-9}$ moles/gm, $*Ar^{40}/\Sigma Ar^{40} = 0.518$; collected by: L. A. Fultz and E. J. Bell; dated by: T. Bills, Geochron.

(Whole Rock) 6.3 ± 0.3 Ma

7. H - DP-2A K-Ar

Desert Peak Rhyolitic Ignimbrite. Vitrophyre of ignimbrite (SW/4, sec. 30, T22N, R28E; 39°44.7' N, 118°53.0' W; Churchill Butte 15' quadrangle; Churchill Co., NV). Analytical data: $K_2O = 0.698\%$, $*Ar^{40} = 6.66 \times 10^{-10}$ moles/gm, $*Ar^{40}/\Sigma Ar^{40} = 0.163$; collected by: L. A. Fultz and D. T. Trexler; dated by: T. Bills, Geochron.

(Plagioclase) 14.3 ± 1.1 Ma

8. H - 3360 K-Ar

Desert Peak Basaltic Andesite. Basaltic andesite flow (NW/4, SW/4, sec. 10, T22N, R27E; 39°47.2' N, 118°56.8' W; Desert Peak 15' quadrangle; Churchill Co., NV). Analytical data: $K_2O = 1.277\%$, $*Ar^{40} = 8.66 \times 10^{-10}$ moles/gm, $*Ar^{40}/\Sigma Ar^{40} = 0.161$; collected by: L. A. Fultz; dated by: T. Bills, Geochron.

(Whole Rock) 10.2 ± 0.7 Ma

RADIOMETRIC AGES OF YOUNG (<15 Ma) VOLCANIC ROCKS

Rock Type, Locality	Age (Ma)	Location	Reference
1. Basaltic andesite, Steamboat Hills	2.54 ± 0.2 (ave.) feldspars 2.15 ± 0.10 whole rock	SW/4, Sec. 33 T18N, R20E	Silberman and others, 1979
2. Rhyolite dome, Steamboat Hills	1.14 ± 0.05 sanidine	SW/4, Sec. 1 T17N, R19E	"
3. Rhyolite dome, Truckee Meadows	1.21 ± 0.06 sanidine	NW/4, Sec. 27 T18N, R20E	"
4. Rhyolite dome, Truckee Meadows	2.97 ± 0.09 3.03 ± 0.12 whole rock 1.16 ± 0.05 sanidine	NW/4, Sec. 23 T18N, R20E	"
5. Sutro Rhyolite dome, Virginia Range	1.51 ± 0.22 feldspar 1.51 ± 0.06 obsidian	NW/4, Sec. 16 T17N, R22E	"
6. Rhyolite dome, Mustang	8.2 ± 0.3 plagioclase	NE/4, Sec. 8 T19N, R21E	"
7. Rhyolite dome, Washington Hill	10.9 ± 0.3 biotite 9.7 ± 0.3 plagioclase	S/2, Sec. 34 T19N, R21E	"

Rock Type, Locality	Age (Ma)	Location	Reference
8. Andesite tuff in Coal Valley Formation	5.7 plagioclase	N/C, Sec. 16 T19N, R18E	Evernden and James, 1964 Silberman and McKee, 1972
9. Olivine basalt	11.0 whole rock	Sec. 14 T19N, R18E	"
10. Dacite tuff	12.4 plagioclase	S/C, Sec. 4 T23N, R21E	"
11. Andesitic tuff, Chloropagus Formation	13.9 plagioclase	Sec. 3 T22N, R27E	"
12. Olivine basalt flow, Chloropagus Formation	14.5 ± 1.5 whole rock	SE/4, Sec. 4 T21N, R23E	Bonham, 1969 Silberman and McKee, 1972 Krueger and Schilling, 1971
13. Olivine basalt, Pyramid Formation	15.2 ± 2.4 plagioclase	NW/4, Sec. 3 T23N, R21E	"
14. Porphyritic dacite flow, Kate Peak Formation	12.8 ± 0.8 plagioclase	NE/4, Sec. 9 T16N, R21E	"
15. Basalt, Lousetown Formation	6.90 ± 0.19 whole rock	NW/4, Sec. 21 T18N, R21E	Dalrymple and others, 1967 Silberman and McKee, 1972

Rock Type, Locality	Age (Ma)	Location	Reference
16. Olivine basalt, McClellan Peak basalt	1.14 ± 0.04 whole rock	SE/4, Sec. 8 T16N, R21E	Doell and others, 1966 Silberman and McKee, 1972
17. Pumiceous rhyolite tuff breccia, Coal Valley or Truckee Fm.	12.3 ± 0.5 biotite	S/C, Sec. 30 T18N, R22E	Silberman and McKee, 1972
18. Virtophyre, glassy rhyolite flow, upper Kate Peak Formation	12.4 ± 0.2 biotite	W/C, Sec. 29 T18N, R22E	"
19. Dacite flow	12.0 hornblende	NE/4, Sec. 21 T24N, R28E	Willden and Speed, 1974 Silberman and McKee, 1972
20. Hornblende andesite, lapilli tuff	12.2 hornblende	NW/4, Sec. 29 T16N, R29E	"
21. Basalt, Rattlesnake Hill	1.03 ± 0.05 whole rock	NW/4, Sec. 29 T19N, R29E	Evans, 1980 Sibbitt, 1983, pers. commun.
22. Basalt, Red Mountain	6.96 ± 0.42 whole rock	SW/4, Sec. 20 T18N, R27E	"

Rock Type, Locality	Age (Ma)	Location	Reference
23. Basalt, Churchill Butte	3.3 ± 0.2 whole rock	Sec. 25 T17N, R23E	Michols-Tingley, 1981 Spellman, 1983, pers. commun.
24. Basalt, Churchill Butte	3.5 ± 0.2 whole rock	Sec. 25 T17N, R23E	"
25. Andesite flows, Desert Peak	12.0 ± 1.1 plagioclase 4.1, 4.6 hornblende 2.3 plagioclase	T22N, R28E	Hiner, 1979 Benoit and others, 1982 Benoit, 1983, pers. commun.
26. Basalt flow, North of Carson City	1.36 ± 0.29 whole rock	C/E, Sec. 22 T16N, R20E	Bingler, 1977
27. Andesite, Glendale	8.7 ± 0.3 biotite	SW/4, Sec. 12 T14N, R18E	Morton and others, 1977
28. Porphyritic hornblende andesite, Mustang Andesite	9.2 ± 0.3 whole rock	SE/4, Sec. 18 T19N, R22E	Morton and others, 1977, 1980, 1983
29. Porphyritic hornblende andesite, Mustang Andesite	9.1 ± 0.3 whole rock	NE/4, Sec. 18 T19N, R22E	"

Rock Type, Locality	Age (Ma)	Location	Reference
30. Lousetown Formation, Lousetown Creek	6.83 ± 0.16 whole rock	NE/4, Sec. 15 T18N, R21E	Morton and others, 1980, 1983
31. Mustang Andesite	8.65 ± 0.26 hornblende	NE/4, Sec. 26 T19N, R21E	"
32. Lousetown Formation, Clark Mountain	9.66 ± 0.30 whole rock	C/NW, Sec. 26 T19N, R21E	"
33. Olivine basalt, McClellan Peak	1.51 ± 0.18 whole rock	NE/4, Sec. 7 T18N, R22E	"
34. Olivine basalt, McClellan Peak	1.54 ± 0.13 whole rock	NE/4, Sec. 12 T18N, R21E	"
35. Lousetown Formation, Clark Mountain	7.35 ± 0.70 whole rock	NW/4, Sec. 26 T19N, R21E	"
36. Alta Formation	14.4 ± 0.4 plagioclase	NE/4, Sec. 5 T16N, R21E	Whitebread, 1976
37. Kate Peak Formation	13.8 ± 0.3 biotite	SW/4, Sec. 9 T17N, R21E	"
38. Kate Peak Formation	13.7 ± 1.6 hornblende	NW/4, Sec. 32 T18N, R21E	"

Rock Type, Locality	Age (Ma)	Location	Reference
39. Kate Peak Formation	12.9 ± 0.4 hornblende	NE/4, Sec. 33 T17N, R21E	Whitebread, 1976
40. Kate Peak Formation	12.3 ± 0.2 biotite	NE/4, Sec. 5 T18N, R21E	"
41. Basaltic andesite, Table Mountain	6.7 ± 0.7 whole rock	NW/4, Sec. 3 T16N, R23E	This study
42. Basaltic andesite, Silver Springs	11.8 ± 0.7 whole rock	NW/4, Sec. 31 T19N, R25E	"
43. Basaltic andesite, Churchill Butte	4.3 ± 0.6 whole rock	NE/4, Sec. 25 T17N, R23E	"
44. Basaltic andesite, Cleaver Peak	9.2 ± 0.6 whole rock	NW/4, Sec. 33 T16N, R25E	"
45. Rhyolite inclusion, Upsal Hogback	6.3 ± 0.3 whole rock	SE/4, Sec. 2 T20N, R28E	"
46. Rhyolitic ignimbrite, Desert Peak	14.3 ± 1.1 plagioclase	SW/4, Sec. 30 T22N, R28E	"
47. Basaltic andesite, Desert Peak	10.2 ± 0.7 whole rock	SW/4, Sec. 10 T22N, R27E	"

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APPENDIX B

Analytical Precision Data

XRF Whole Rock Analysis

15 replicate determinations of BCR-1 (one pellet)

	Publ. Value	Mean	One Sigma	% Precision
SiO_2	54.50	54.12	0.27	0.5
Al_2O_3	13.61	13.66	0.05	0.4
FeO*	13.40	13.26	0.04	0.3
MgO	3.46	3.32	0.01	0.4
CaO	6.92	6.80	0.04	0.6
Na_2O	3.27	3.32	0.03	0.8
K_2O	1.78	1.76	0.01	0.5
TiO_2	2.20	2.20	0.01	0.3
P_2O_5	0.36	0.39	-0.01	2.0
Total	99.50	98.83		

XRF Trace element detection limits and typical precisions

Element	Detection Limit, ppm	% Precision	(at value ppm)
Ba	25	5%	1000
Cr	15	4%	100
Cu	10	3%	100
La	5	4%	100
Mn	25	3%	1000
Ni	10	6%	100
Pb	2	6%	50
Rb	3	7%	100
S	50	4%	500
Sc	3	3%	30
Sn	2	4%	50
Sr	10	8%	300
V	15	4%	100
Y	3	6%	30
Zn	10	3%	100
Zr	5	5%	200

Averages of Analyses of Laboratory Standards Used for Microprobe Analysis

	AMELIA ALBITE	ORTHOCLASE OR-1	DIOPSIDE HESS #35	BYTOWNITE	HESS 30 TITANAUGITE
SiO_2	68.77	64.74	55.21	49.50	51.36
Al_2O_3	19.78	18.50	0.21	32.26	1.94
FeO	0.00	0.00	2.90	0.44	11.36
CaO	0.02	0.01	25.04	15.53	19.34
Na_2O	11.75	1.09	0.11	2.70	0.30
K_2O	0.16	14.95	0.00	0.07	0.00
MgO	0.00	0.01	17.21	0.11	14.88
MnO	0.00	0.01	0.17	0.01	0.25
TOTAL	100.45	99.30	100.83	100.63	99.43

APPENDIX C

Trace Element Data

STEAMBOAT HILLS

SAMPLE # (ppm) ELEMENT	3301	3304	3305	3307	3308	3310	3312	3314
Ba	1809	1293	1228	1268	1259	1290	1336	1318
Nb	16	16	18	18	16	18	19	15
Zr	271	261	264	261	264	257	273	255
Y	21	19	20	18	17	16	19	19
Sr	889	949	947	945	945	936	966	855
Rb	40	35	39	37	31	30	37	42
Sc	15	15	16	15	15	16	16	16
Ce	185	155	153	170	155	159	171	153
La	42	41	38	44	41	41	45	37
Zn	266	89	79	78	78	92	76	87
Cu	801	<10	<10	<10	<10	<10	<10	<10
Ni	18	42	39	37	41	42	43	19
V	132	150	144	146	148	146	152	141
Cr	147	104	69	80	95	128	71	114

	STEAMBOAT HILLS						SILVER SPRINGS	MCCLELLAN PEAK
SAMPLE # / (ppm) ELEMENT	3316	3320	3323	3327	3330	3333	3345	3346
Ba	1256	1499	103	1373	1490	1341	1168	974
Nb	20	17	68	16	18	15	4	11
Zr	273	261	59	261	267	257	216	208
Y	16	18	ND*	18	20	19	20	14
Sr	944	922	16	947	932	936	698	923
Rb	36	39	187	31	34	34	28	27
Sc	15	15	4	15	17	15	17	24
Ce	156	179	ND	163	179	163	130	142
La	45	42	20	41	46	42	27	31
Zn	81	90	54	59	82	82	97	68
Cu	<10	<10	<10	<10	<10	<10	<10	<10
Ni	40	49	<5	42	41	44	6	192
V	150	143	15	149	150	143	141	174
Cr	94	119	108	100	108	113	127	506

*ND = None detected.

	CARSON CITY		CHURCHILL BUTTE AREA			CARSON DESERT		
SAMPLE # (ppm) ELEMENT	3339	3340	TABLE MTN. 3344	CHURCHILL BUTTE 3347	CLEAVER PEAK 3348	RATTLESNAKE HILL 3350	UPSAL HOGBACK 3352	UPSAL HOGBACK 3354
Ba	1156	1241	591	872	1217	1106	1351	709
Nb	20	12	-	-	-	48	37	27
Zr	205	192	182	194	200	307	336	155
Y	20	16	8	16	15	27	16	20
Sr	729	782	1132	838	865	585	159	409
Rb	26	28	12	25	22	54	122	23
Sc	18	14	17	16	18	17	5	27
Ce	148	132	56	81	120	165	103	111
La	29	28	17	21	25	47	37	20
Zn	86	89	88	83	111	65	59	66
Cu	<10	<10	<10	<10	<10	<10	<10	<10
Ni	20	<5	5	7	8	30	<5	246
V	159	134	103	104	130	171	42	172
Cr	85	82	103	113	140	178	104	517

	CARSON DESERT		DESERT PEAK				
SAMPLE # / (ppm) ELEMENT	SODA LAKE 3356	UPSAL HOGBACK 3358	DP-2A	DP-3	DP-5B	3357	3360
Ba	1005	892	1316	1322	1105	1323	1159
Nb	31	32	42	37	20	35	-
Zr	207	187	330	331	257	324	252
Y	25	27	17	20	27	20	39
Sr	506	416	150	190	461	240	701
Rb	49	32	94	87	59	91	33
Sc	22	29	6	6	12	5	18
Ce	145	144	104	102	108	109	153
La	33	21	38	34	30	33	26
Zn	78	72	112	86	112	102	97
Cu	<10	9	<10	<10	<10	45	<10
Ni	90	54	<5	<5	<5	<5	21
V	174	199	33	44	88	41	161
Cr	251	264	37	53	226	231	153

APPENDIX D

PETCAL: A Basic Language Computer Program for Petrographic Calculations

INTRODUCTION

A discussion of the operation of PETCAL (PETrologic CALculations) program can be found in PETCAL: A BASIC LANGUAGE computer program for petrologic calculations, by Bingler, E.C., Trexler, D.T., Kemp, W.R., and Bonham, H.F., Jr., (1976), Nevada Bur. Mines and Geol., Rept. 28.

Modifications to the original code were made by Wayne Kemp and Don Hudson while graduate students at Mackay School of Mines, University of Nevada, Reno. These modifications include various lithologic discriminators based on normative mineral composition. The following references cover the modifications to the original code.

Irvine, T.N., and Baragar, W.R.A., 1971, A guide to the chemical classification of the common volcanic rocks: Can. Jour. Earth Sci., v. 8, p. 523-548.

Ishikawa, Y., Sawaguchi, T., Iwaya, S., and Horiuchi, M., 1976, Delineation of prospecting targets for Kuroko deposits based on modes of volcanism of underlying dacite and alteration haloes: Mining Geol., v. 26, p. 105-117 (in Japanese).

Kuno, H., 1966, Lateral variation of basalt magma type across continental margins and island arcs: Bull. Volcanol., v. 29, p. 195-222.

Macdonald, G.A., and Katsura, T., 1964, Chemical composition of Hawaiian lavas: Jour. Petrology, v. 5, p. 82-133.

Maldrett, A.J., and Arnt, N.T., 1976, AIME Trans., v. 260, p. 14.

Miyashiro, A., 1974, Volcanic rock series in island arcs and active continental margins: Amer. Jour. Sci., v. 274, p. 321-355.

Rittman, A., 1960, Vulkane und ihre Tatigkeit, 2nd ed., Stuttgart, Ferdinand Enke: 336 p.

Sugimura, A., 1968, Spatial relations of basaltic magmas in island arcs, in Hess, H.H., and Poldervaart, Arie, eds., Basalts, v. 2: New York, Interscience Publishers, p. 537-571.

```
-00100 DIM W(20),M(20),N(20),Z(30),A(15),M$(30)
 00110 FOR A=1 TO 30
 00120 READ M$(A)
 00130 NEXT A
 00140 DATA QUARTZ, CORUNDUM, ORTHOCLASE, ALBITE, ANORTHITE
 00150 DATA LEUCITE,NEPHELINE,KALSILITE,ACMITE
 00160 DATA SODIUM METASILICATE, POTASSIUM METASILICATE
 00170 DATA WOLLASTONITE, DIOPSIDE, HYPERSTHENE, OLIVINE
 00180 DATA CALCIUM ORTHOSILICATE, MAGNETITE, HEMATITE
 00190 DATA ILMENITE, SPHENE, PEROVSKITE, RUTILE, APATITE
 00200 DATA WOLLASTONITE(DIOPSIDE),ENSTATITE(DIOPSIDE)
 00210 DATA FERROSILITE(DIOPSIDE),ENSTATITE(HYPERSTHENE)
 00220 DATA FERROSILITE(HYPERSTHENE),FORSTERITE(OLIVINE)
 00230 DATA FAYALITE(OLIVINE)
 00240 PRINT
 00250 PRINT "HAS DATA BEEN ENTERED ON TEXT EDITOR? (YES=1,NO=0)" INPUT S1
 00260 PRINT "SHALL I USE NORMALIZED OXIDE VALUES? (YES=1,NO=0)"  INPUT S2
 00270 PRINT "SHALL I RECALCULATE FE203-FEO? (YES=1,NO=0)"        INPUT S3
 00280 FOR T=1 TO 999
 00290 IF S1=1 THEN 00410
 00300 PRINT "TYPE IN SAMPLE NUMBER (REAL NUMBER ONLY)"  INPUT S4
 00310 IF S4=0 THEN 05800
 00320 PRINT "TYPE IN SAMPLE NAME"  INPUT S$
 00330 PRINT
 00340 PRINT "TYPE IN DATA IN THIS ORDER  (ALL ON ONE LINE): "
 00350 PRINT "SIO2,AL203,FE203,FEO,MGO,CAO,NA20,K20,TIO2,P205,MNO  "
 00360 INPUT W(1),W(2),W(3),W(4),W(5),W(6),W(7),W(8),W(9),W(10),W(11)
 00370 PRINT
 00380 PRINT "$$$$$*****$$$$$*****$$$$$*****$$$$$*****$$$$$*****$$$$$"
 00390 PRINT "SAMPLE NUMBER  "S$;S4
 00400 GO TO 00490
 00410 PRINT
 00420 PRINT "$$$$$*****$$$$$*****$$$$$*****$$$$$*****$$$$$*****$$$$$"
 00430 PRINT
 00440 READ S$
 00450 PRINT S$
 00460 FOR J=1 TO 11
 00470 READ W(J)
 00480 NEXT J
 00490 PRINT
 00500 PRINT "** INPUT DATA **"
 00510 PRINT "SIO2";W(1),"AL203";W(2),"FE203";W(3),"FEO";W(4)
 00520 PRINT "MGO ";W(5),"CAO  ";W(6),"NA20 ";W(7),"K20";W(8)
 00530 PRINT "TIO2";W(9),"P205 ";W(10),"MNO  ";W(11)
 00540 IF S3 = 0 THEN 00750
 00550 IF W(1)>=52 THEN 00620
 00560 IF W(3)=0 THEN 00580
 00570 IF W(3)/(W(3)+W(4))=<0.2 THEN 00750
 00580 B1=W(4)
 00590 W(4)=.816*W(4)+.735*W(3)
 00600 W(3)=.204*B1+.184*W(3)
 00610 GO TO 00730
 00620 IF W(3)=0 THEN 00670
 00630 IF W(3)<W(9)+1.50 THEN 00750
 00640 W(4)=.8998*(W(3)-W(9)-1.50)+W(4)
 00650 W(3)=W(9)+1.50
 00660 GO TO 00730
 00670 W(3)=W(9)+1.50
 00680 IF W(4)>W(3)*.8998 THEN 00720
 00690 W(3)=0
 00700 PRINT "$$ NORMS ARE CALCULATED ASSUMING NO FE203 $$"
 00710 GO TO 00730
 00720 W(4)=W(4)-.8998*W(3)
 00730 PRINT "MODIFIED FE203=  ";W(3)
 00740 PRINT "MODIFIED FEO=    ";W(4)
 00750 B2=W(1)+W(2)+W(3)+W(4)+W(5)+W(6)+W(7)+W(8)+W(9)+W(10)+W(11)
 00760 PRINT "SUM OF OXIDES"B2
 00770 IF S2=0 THEN 00850
 00780 PRINT "** NORMALIZED OXIDE VALUES **"
 00790 FOR J=1 TO 11
 00800 W(J)=W(J)*100/B2
 00810 NEXT J
```

```
00820 PRINT "SIO2";W(1),"AL2O3";W(2),"FE2O3";W(3),"FEO";W(4)
00830 PRINT "MGO ";W(5),"CAO  ";W(6),"NA2O ";W(7),"K2O";W(8)
00840 PRINT "TIO2";W(9),"P2O5 ";W(10),"MNO  ";W(11)
00850 W(15)=.8996*W(3)+W(4)
00860 PRINT
00870 PRINT "** MOLE NUMBERS **"
00880 M(1)=W(1)/60.08
00890 M(2)=W(2)/101.96
00900 M(3)=W(3)/159.69
00910 M(4)=W(4)/71.85
00920 M(5)=W(5)/40.31
00930 M(6)=W(6)/56.08
00940 M(7)=W(7)/61.98
00950 M(8)=W(8)/94.20
00960 M(9)=W(9)/79.90
00970 M(10)=W(10)/141.94
00980 M(11)=W(11)/70.94
00990 M(15)=W(15)/71.84
01000 PRINT "SI";M(1),"AL";M(2),"FE+3";M(3)
01001 PRINT "FE+2";M(4)
01010 PRINT "MG";M(5),"CA";M(6),"NA";M(7),"K";M(8)
01020 PRINT  "TI";M(9),"P";M(10),"MN";M(11)
01030 PRINT
01040 PRINT "** NIGGLI NUMBERS **"
01050 B3=M(2)+M(5)+M(6)+M(7)+M(8)+M(11)+M(15)
01060 PRINT "AL";(M(2)*100/B3),"FM ";(M(15)+M(11)+M(5))*100/B3
01070 PRINT "C ";M(6)*100/B3,"ALK";(M(7)+M(8))*100/B3,"SI";M(1)*100/B3
01080 PRINT "K ";M(8)/(M(7)+M(8)),"MG ";M(5)/(M(15)+M(11)+M(5))
01090 PRINT "TI";M(9)*100/B3,"P  ";M(10)*100/B3
01100 PRINT
01110 A(1)=W(1)*.4674
01120 A(2)=W(2)*.5293
01130 A(3)=W(3)*.6994
01140 A(4)=W(4)*.7773
01150 A(5)=W(5)*.6032
01160 A(6)=W(6)*.7147
01170 A(7)=W(7)*.7419
01180 A(8)=W(8)*.8301
01190 A(9)=W(9)*.5995
01200 A(10)=W(10)*.4364
01210 A(11)=W(11)*.6319
01220 A(15)=.8998*W(3)*.6994+W(4)*.7773
01230 B4=W(1)*.5326+W(2)*.4707+W(3)*.3006+W(4)*.2227+W(5)*.3968+W(6)*.2853
01240 B4=B4+W(7)*.2581+W(8)*.1699+W(9)*.4005+W(10)*.5636+W(11)*.3681
01250 PRINT "** ATOMIC WEIGHT PERCENTS **"
01260 PRINT "SI";A(1),"AL";A(2),"FE+3";A(3),"FE+2";A(4)
01270 PRINT "MG";A(5),"CA";A(6),"NA  ";A(7),"K   ";A(8)
01280 PRINT "TI";A(9),"P ";A(10),"MN";A(11),"O   ";B4
01290 PRINT
01300 PRINT "** OXIDE-SILICA RATIOS **"
01310 PRINT "AL2O3/SIO2      " W(2)/W(1)
01320 PRINT "FE2O3/SIO2      " W(3)/W(1)
01330 PRINT "FEO/SIO2        " W(4)/W(1)
01340 PRINT "FEO*/SIO2       " W(15)/W(1)
01350 PRINT "MGO/SIO2        " W(5)/W(1)
01360 PRINT "CAO/SIO2        " W(6)/W(1)
01370 PRINT "NA2O/SIO2       " W(7)/W(1)
01380 PRINT "K2O/SIO2        " W(8)/W(1)
01390 PRINT
01400 PRINT "** OTHER OXIDE RATIOS **"
01410 PRINT "NA2O/K2O        " W(7)/W(8)
01420 PRINT "K2O/NA2O        " W(8)/W(7)
01430 PRINT "FEO*            " W(15)
01440 PRINT "FEO*/MGO        " W(15)/W(5)
01450 PRINT "NA2O + K2O      " W(7)+W(8)
01460 B5=(W(7)+W(8)+W(5)+W(15))/100
01470 PRINT "A:F:M=          " (W(7)+W(8))/B5;W(15)/B5;W(5)/B5
01480 B6=(W(7)+W(8)+W(6))/100
01490 PRINT "NA2O:K2O:CAO      " W(7)/B6;W(8)/B6;W(6)/B6
01500 PRINT
```

```
01510 PRINT "MGO:AL2O3:(CAO+NA2O+K2O)      (MOLE PROP.)"
01520 B7=(M(2)+M(5)+M(6)+M(7)+M(8))/100
01530 PRINT M(5)/B7;M(2)/B7;(M(6)+M(7)+M(8))/B7
01540 PRINT
01550 B8=M(2)+M(3)-M(7)-M(8)
01560 B9=M(4)+M(5)+M(11)
01570 C1=(B8+M(6)+B9)/100
01580 PRINT "A:C:F =  "B8/C1;M(6)/C1;B9/C1
01590 PFINT
01600 C2=W(1)+W(2)+W(15)+W(5)+W(6)+W(7)+W(8)+W(11)
01610 C3=100*((W(1)/C2)/3+W(8)/C2-W(5)/C2-W(6)/C2-(W(15)+W(11))/C2)
01620 PRINT "1/3SIO2+K2O-MGO-CAO-FEO (LARSEN,1938)=" C3
01630 PRINT
01640 PRINT "**** NORMATIVE MINERALS ****"
01650 FOR K=1 TO 23
01660 Z(K)=0
01670 NEXT K
01680 FOR J=1 TO 15
01690 N(J)=M(J)
01700 NEXT (J)
01710 N(16)=N(6)
01720 N(4)=N(4)+N(11)
01730 IF N(10)>0 THEN 01750
01740 GO TO 01820
01750 Z(23)=N(10)
01760 N(6)=N(6)-3.33*N(10)
01770 IF N(6)>=0 THEN 01820
01780 Z(23)=N(16)
01790 N(10)=N(10)-N(16)/3.33
01800 N(6)=0
01810 PRINT"ROCK CONTAINS EXCESS P2O5 OVER CAO"   N(10)*141.94
01820 IF N(4)<N(9) THEN 01870
01830 Z(19)=N(9)
01840 N(4)=N(4)-N(9)
01850 N(9)=0
01860 GO TO 01900
01870 Z(19)=N(4)
01880 N(9)=N(9)-N(4)
01890 N(4)=0
01900 IF N(2)<N(8) THEN 01940
01910 Z(3)=N(8)
01920 N(2)=N(2)-N(8)
01930 GO TO 01990
01940 Z(3)=N(2)
01950 Z(11)=N(8)-N(2)
01960 N(2)=0
01970 N(8)=0
01980 GO TO 02150
01990 IF N(2)<N(7) THEN 02040
02000 Z(4)=N(7)
02010 N(2)=N(2)-N(7)
02020 N(7)=0
02030 GO TO 02070
02040 Z(4)=N(2)
02050 N(7)=N(7)-N(2)
02060 GO TO 02150
02070 IF N(2)<N(6) THEN 02130
02080 Z(5)=N(6)
02090 N(2)=N(2)-N(6)
02100 Z(2)=N(2)
02110 N(6)=0
02120 GO TO 02150
02130 Z(5)=N(2)
02140 N(6)=N(6)-N(2)
02150 IF N(9)<N(6) THEN 02210
02160 Z(20)=N(6)
02170 N(9)=N(9)-N(6)
02180 Z(22)=N(9)
02190 N(6)=0
02200 GO TO 02240
```

```
02210 Z(20)=N(9)
02220 N(6)=N(5)-N(9)
02230 N(9)=0
02240 IF N(3)<N(7) THEN 02280
02250 Z(9)=N(7)
02260 N(3)=N(3)-N(7)
02270 GO TO 02310
02280 Z(9)=N(3)
02290 Z(10)=N(7)-N(3)
02300 N(3)=0
02310 IF N(4)<N(3) THEN 02350
02320 Z(17)=N(3)
02330 N(4)=N(4)-N(3)
02340 GO TO 02390
02350 Z(17)=N(4)
02360 Z(18)=N(3)-N(4)
02370 N(3)=N(3)-N(4)
02380 N(4)=0
02390 D=N(5)+N(4)
02400 IF D=0 THEN 02520
02410 D1=N(5)/D
02420 D2=N(4)/D
02430 IF N(6)>0 THEN 02500
02440 Z(13)=N(6)
02450 D=D-N(6)
02460 N(5)=D*D1
02470 N(4)=D*D2
02480 Z(14)=D
02490 GO TO 02530
02500 Z(13)=D
02510 N(6)=N(6)-D
02520 Z(12)=N(5)
02530 D3=Z(20)+4*Z(9)+Z(10)+Z(11)+6*Z(3)+6*Z(4)+2*Z(5)+2*Z(13)+Z(14)
02540 D3=D3+Z(12)
02550 D4=N(1)-D3
02560 IF D4<0 THEN 02590
02570 Z(1)=D4
02580 GO TO 03120
02590 D4=ABS(D4)
02600 IF D4<Z(14)/2 THEN 02650
02610 Z(15)=Z(14)/2
02620 D5=D4-Z(14)/2
02630 Z(14)=0
02640 GO TO 02680
02650 Z(15)=D4
02660 Z(14)=Z(14)-2*D4
02670 GO TO 03120
02680 IF D5<Z(20) THEN 02730
02690 Z(21)=Z(20)
02700 D6=D5-Z(20)
02710 Z(20)=0
02720 GO TO 02760
02730 Z(20)=Z(20)-D5
02740 Z(21)=D5
02750 GO TO 03120
02760 IF D6<4*Z(4) THEN 02810
02770 Z(7)=Z(4)
02780 D7=D6-4*Z(4)
02790 Z(4)=0
02800 GO TO 02840
02810 Z(7)=D6/4
02820 Z(4)=Z(4)-D6/4
02830 GO TO 03120
02840 IF D7<2*Z(3) THEN 02890
02850 Z(6)=Z(3)
02860 D8=D7-2*Z(3)
02870 Z(3)=0
02880 GO TO 02920
02890 Z(5)=D7/2
02900 Z(3)=Z(3)-D7/2
```

```
02910 GO TO 03120
02920 IF D6<Z(12)/2 THEN 02970
02930 Z(16)=Z(12)/2
02940 D9=D8-Z(12)/2
02950 Z(12)=0
02960 GO TO 03000
02970 Z(16)=D8
02980 Z(12)=Z(12)-2*D8
02990 GO TO 03120
03000 IF D9<Z(13) THEN 03060
03010 Z(16)=Z(16)+Z(13)/2
03020 Z(15)=Z(15)+Z(13)/2
03030 E1=D9-Z(13)
03040 Z(13)=0
03050 GO TO 03100
03060 Z(16)=Z(16)+D9/2
03070 Z(15)=Z(15)+D9/2
03080 Z(13)=Z(13)-D9
03090 GO TO 03120
03100 Z(8)=E1/2
03110 Z(6)=Z(6)-E1/2
03120 PRINT
03130 E2=Z(13)
03140 E3=Z(14)
03150 E4=Z(15)
03160 Z(1)=Z(1)*60.08
03170 Z(2)=Z(2)*101.96
03180 Z(3)=Z(3)*556.64
03190 Z(4)=Z(4)*524.42
03200 Z(5)=Z(5)*278.20
03210 Z(6)=Z(6)*436.46
03220 Z(7)=Z(7)*284.10
03230 Z(8)=Z(8)*316.32
03240 Z(9)=Z(9)*461.99
03250 Z(10)=Z(10)*122.06
03260 Z(11)=Z(11)*154.28
03270 Z(12)=Z(12)*116.16
03280 Z(13)=(Z(13)*216.55*D1)+(Z(13)*248.09*D2)
03290 Z(14)=(Z(14)*D1)*100.39+(Z(14)*D2)*131.93
03300 Z(15)=(Z(15)*D1)*140.70+(Z(15)*D2)*203.78
03310 Z(16)=Z(16)*172.24
03320 Z(17)=Z(17)*231.54
03330 Z(18)=Z(18)*159.69
03340 Z(19)=Z(19)*151.75
03350 Z(20)=Z(20)*196.06
03360 Z(21)=Z(21)*135.98
03370 Z(22)=Z(22)*79.90
03380 Z(23)=Z(23)*328.67
03390 Z(24)=E2*116.16
03400 Z(25)=E2*D1*100.39
03410 Z(26)=E2*D2*131.93
03420 Z(27)=E3*D1*100.39
03430 Z(28)=E3*D2*131.93
03440 Z(29)=E4*D1*140.70
03450 Z(30)=E4*D2*203.78
03460 FOR K=1 TO 23
03470 A=K
03480 IF Z(K)=0 THEN 03500
03490 PRINT M$(A);Z(K)
03500 NEXT K
03510 U=0
03520 FOR K=1TO23
03530 U=U+Z(K)
03540 NEXT K
03550 PRINT "SUM"U
03560 PRINT
03570 FOR K=24 TO 30
03580 A=K
03590 IF Z(K)=<.009 THEN 03610
03600 PRINT M$(A);Z(K)
```

```
03610 NEXT K
03620 PRINT
03630 PRINT "** NORMATIVE RATIOS - CIPW **"
03640 F1=Z(3)+Z(4)+Z(5)
03650 IF F1=0 THEN 04590
03660 F2=F1/100
03670 PRINT "OR:AB:AN    "Z(3)/F2;Z(4)/F2;Z(5)/F2
03680 F3=(Z(1)+Z(3)+Z(4))/100
03690 PRINT "Q:OR:AB     "Z(1)/F3;Z(3)/F3;Z(4)/F3
03700 F4=(Z(1)+Z(3)+Z(4)+Z(5))/100
03710 PRINT "Q:OR:AB+AN     "Z(1)/F4;Z(3)/F4;(Z(4)+Z(5))/F4
03720 F5=Z(6)+Z(7)+Z(8)
03730 F6=(F1+F5)/100
03740 PRINT "LC+NE+KS:OR:AB+AN    "F5/F6;Z(3)/F6;(Z(4)+Z(5))/F6
03750 IF(Z(4)+Z(5)+(5*Z(7)/3))=0 THEN 04560
03760 F7=(100*Z(5))/(Z(4)+Z(5)+(5*Z(7)/3))
03770 PRINT "NORMATIVE PLAGIOCLASE CONTENT= AN" F7
03780 F8=Z(15)+Z(14)+Z(13)+Z(19)+Z(18)+Z(17)
03790 PRINT "NORMATIVE COLOR INDEX=     " F8
03800 PRINT
03810 PRINT "** PETROCHEMICAL INDICES **"
03820 PRINT "ALKALI INDEX      "(W(8)*100)/(W(7)+W(8))
03830 PRINT "FELSIC INDEX      "(W(7)+W(8))*100/(W(6)+W(7)+W(8))
03840 PRINT "MAFIC INDEX       "(W(3)+W(4))*100/(W(3)+W(4)+W(5))
03850 F9=W(5)*100/(W(5)+W(15)+W(7)+W(8))
03860 PRINT "SOLIDIFICATION INDEX          " F9
03870 PRINT "DIFFERENTIATION INDEX       "Z(1)+Z(3)+Z(4)+Z(7)+Z(6)+Z(8)
03880 G1=Z(5)+2.157*Z(25)+Z(29)+.70034*Z(27)
03890 PRINT "CRYSTALLIZATION INDEX       " G1
03900 G2=100*(.02756*W(5)+.02547*W(6)+.09214*W(7)+.08493*W(8))
03910 PRINT "WEATHERING INDEX (PARKER,1970)           " G2
03920 G3=(W(5)+W(8))*100/(W(5)+W(6)+W(7)+W(8))
03930 PRINT "ALTERATION INDEX (ISHIKAWA ETAL,1976) " G3
03940 PRINT "PERALUMINOUS INDEX              "100*(M(2)-M(6)-M(7)-M(8))/M(2)
03950 G4=W(1)-47*(W(7)+W(8))/W(2)
03960 PRINT "THETA INDEX (SUGIMURA,1968)      " G4
03970 G5=(W(7)+W(8))**2/(W(1)-43)
03980 PRINT "S INDEX (PITTMAN,1960)           " G5
03990 PRINT
04000 IF M(2)>M(6)+M(7)+M(8) THEN 04050
04010 IF M(2)>M(7)+M(6)+.05*(M(7)+M(8)) THEN 04070
04020 IF M(2)>M(7)+M(6)-.05*(M(7)+M(8)) THEN 04090
04030 PRINT "THE ROCK IS PERALKALINE (SHAND,1945)"
04040 GO TO 04100
04050 PRINT "THE ROCK IS PERALUMINOUS (SHAND,1945)"
04060 GO TO 04100
04070 PRINT "THE ROCK IS METALUMINOUS (SHAND,1945)"
04080 GO TO 04100
04090 PRINT "THE ROCK IS SUBALUMINOUS (SHAND,1945)"
04100 G6=W(7)+W(8)
04110 G7=(-3.3539E-4)*(G6**6)+(1.2030E-2)*(G6**5)-(1.5188E-1)*(G6**4)
04120 G7=G7+(8.6096E-1)*(G6**3)-2.111*(G6**2)+(3.9492*G6)+39
04130 IF W(1)>=G7 THEN 04160
04140 PRINT "THE ROCK IS ALKALIC (IRVINE & BARAGAR,1971)"
04150 GO TO 04280
04160 PRINT "THE ROCK IS SUBALKALIC (IRVINE & BARAGAR,1971)"
04170 IF F7<40 THEN 04200
04180 IF W(2)>= 12+.08*F7 THEN 04250
04190 GO TO 04270
04200 G8=W(5)/((G6+W(15)+W(5))/100)
04210 G9=(1.5559E-12)*(G8**8)-(7.7142E-10)*(G8**7)+(1.5664E-7)*(G8**6)
04220 G9=G9-(1.6738E-5)*(G8**5)+(1.0017E-3)*(G8**4)-(3.2552E-2)*(G8**3)
04230 G9=G9+(4.7776E-1)*(G8**2)-(1.1085)*(G8)+30
04240 IF (W(15)/((G6+W(15)+W(5))/100))>=G9 THEN 04270
04250 PRINT "THE ROCK IS CALC-ALKALIC (IRVINE & BARAGAR,1971)"
04260 GO TO 04280
04270 PRINT "THE ROCK IS THOLEIITIC (IRVINE & BARAGAR,1971)"
04280 IF W(1)>=6.4*((W(15))/W(5))+42.8 THEN 04310
04290 PRINT "THE ROCK IS THOLEIITIC (MIYASHIRO,1974)"
04300 GO TO 04320
```

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04310 PRINT "THE ROCK IS CALC-ALKALIC (MIYASHIRO,1974)"
04320 IF W(1)>57.5 THEN 04360
04330 IF W(1)<3.047*(W(7)+W(8))+38.3 THEN 04450
04340 IF W(1)<5.917*(W(7)+W(8))+37.4 THEN 04430
04350 GO TO 04410
04360 IF W(1)<9.260*(W(7)+W(8))-3.8 THEN 04450
04370 IF W(1)>60 THEN 04400
04380 IF W(1)<5.917*(W(7)+W(8))+37.4 THEN 04430
04390 GO TO 04410
04400 IF W(1)<6.667*(W(7)+W(8))+25.6 THEN 04430
04410 PRINT "THE ROCK IS THOLEIITIC (KUNO,1966)"
04420 GO TO 04460
04430 PRINT "THE ROCK IS HIGH ALUMINA (KUNO,1966)"
04440 GO TO 04460
04450 PRINT "THE ROCK IS ALKALIC (KUNO,1966)"
04460 IF W(1)>=2.71*(W(7)+W(8))+39 THEN 04500
04470 PRINT "THE ROCK IS ALKALIC (MACDONALD & KATSURA,1964)"
04480 GO TO 04490
04490 PRINT "THE ROCK IS THOLEIITIC (MACDONALD & KATSURA,1964)"
04500 IF W(4)/(W(4)+W(5))>=.03667*W(2)+.15 THEN 04530
04510 PRINT "THE ROCK IS KOMATIITIC (NALDRETT & ARNDT,1976)"
04520 GO TO 04540
04530 PRINT "THE ROCK IS THOLEIITIC (NALDRETT & ARNDT,1976)"
04540 PRINT
04550 GO TO 04580
04560 PRINT
04570 PRINT "$$ THIS ROCK IS ATYPICAL--NO PLAG OR NEPHELINE $$"
04580 IF Z(3)>0 THEN 04600
04590 PRINT "$$ THIS ROCK IS ATYPICAL--NO PLAG OR K-SPAR $$"
04600 PRINT
04610 PRINT "ACCORDING TO THE IUGS CLASSIFICATION THE ROCK IS A"
04620 IF F1<0 THEN 04660
04630 IF F8<90 THEN 04660
04640 PRINT "ULTRAMAFITITE"
04650 GO TO 05780
04660 IF Z(1)=0 THEN 05370
04670 IF (Z(1)/F4)<60 THEN 04700
04680 PRINT "QUARTZ GRANITOID"
04690 GO TO 05780
04700 IF (-.9*(Z(1)/F4)+90-((Z(4)+Z(5))/F4))=<0 THEN 04820
04710 IF (-.65*(Z(1)/F4)+65-((Z(4)+Z(5))/F4))=<0 THEN 04960
04720 IF (-.35*(Z(1)/F4)+35-((Z(4)+Z(5))/F4))=<0 THEN 05200
04730 IF (-.1*(Z(1)/F4)+10-((Z(4)+Z(5))/F4))>0 THEN 05280
04740 IF (Z(1)/F4)<20 THEN 04770
04750 PRINT "GRANITE (3A)  OR RHYOLITE"
04760 GO TO 05780
04770 IF (Z(1)/F4)<5 THEN 04800
04780 PRINT "ALKALI SYENITE  OR QUARTZ TRACHYTE"
04790 GO TO 05780
04800 PRINT "SYENITE  OR TRACHYTE"
04810 GO TO 05780
04820 IF (Z(1)/F4)<20 THEN 04850
04830 PRINT "TONALITE  OR DACITE"
04840 GO TO 05780
04850 IF F7>50 THEN 04910
04860 IF (Z(1)/F4)<5 THEN 04890
04870 PRINT "QUARTZ DIORITE"
04880 GO TO 05090
04890 PRINT "DIORITE"
04900 GO TO 05090
04910 IF (Z(1)/F4)<5 THEN 04940
04920 PRINT "QUARTZ GABBRO"
04930 GO TO 05090
04940 PRINT "GABBRO"
04950 GO TO 05090
04960 IF (Z(1)/F4)<20 THEN 04990
04970 PRINT "GRANODIORITE  OR DACITE"
04980 GO TO 05780
04990 IF F7>50 THEN 05050
05000 IF (Z(1)/F4)<5 THEN 05030
```

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05010 PRINT "QUARTZ MONZODIORITE"
05020 GO TO 05090
05030 PRINT "MONZODIORITE"
05040 GO TO 05090
05050 IF (Z(1)/F4)<5 THEN 05080
05060 PRINT "QUARTZ MONZOGABBRO"
05070 GO TO 05090
05080 PRINT "MONZOGABBRO"
05090 IF W(1)<52 THEN 05150
05100 IF (Z(1)/F4)<5 THEN 05130
05110 PRINT "OR  QUARTZ ANDESITE"
05120 GO TO 05780
05130 PRINT "OR  ANDESITE"
05140 GO TO 05780
05150 IF (Z(1)/F4)<5 THEN 05180
05160 PRINT "OR  QUARTZ BASALT"
05170 GO TO 05780
05180 PRINT "OR  BASALT"
05190 GO TO 05780
05200 IF (Z(1)/F4)<20 THEN 05230
05210 PRINT "GRANITE (3B)  OR RHYOLITE"
05220 GO TO 05780
05230 IF (Z(1)/F4)<5 THEN 05260
05240 PRINT "QUARTZ MONZONITE  OR QUARTZ LATITE"
05250 GO TO 05780
05260 PRINT "MONZONITE  OR LATITE"
05270 GO TO 05780
05280 IF (Z(1)/F4)<20  THEN 05310
05290 PRINT "ALKALI-FELDSPAR GRANITE  OR ALKALI-FELDSPAR RHYOLITE"
05300 GO TO 05780
05310 IF (Z(1)/F4)<5 THEN 05340
05320 PRINT "ALKALI-FELDSPAR QUARTZ SYENITE"
05330 PRINT "OR  QUARTZ ALKALI-FELDSPAR TRACHYTE"
05340 GO TO 05780
05350 PRINT "ALKALI-FELDSPAR SYENITE  OR ALKALI-FELDSPAR TRACHYTE"
05360 GO TO 05780
05370 IF (F5/F6)<90 THEN 05400
05380 PRINT "FOIDOLITE  OR FOIDITE"
05390 GO TO 05780
05400 IF (-.9*F6+90-((Z(4)+Z(5))/F6))=<0 THEN 05470
05410 IF (-.65*F6+65-((Z(4)+Z(5))/F6))=<0 THEN 05550
05420 IF (-.35*F6+35-((Z(4)+Z(5))/F6))=<0 THEN 05650
05430 IF (-.1*F6+10-((Z(4)+Z(5))/F6))=<0 THEN 05680
05440 IF (F5/F6)>10 THEN 05740
05450 PRINT "FOID-BEARING SYENITE  OR FOID-BEARING TRACHYTE"
05460 GO TO 05780
05470 IF (F5/F6)<10 THEN 05500
05480 PRINT "THERALITE  OR TEPHRITE"
05490 GO TO 05780
05500 IF F7>50 THEN 05530
05510 PRINT "FOID-BEARING DIORITE"
05520 GO TO 05600
05530 PRINT "FOID-BEARING GABBRO"
05540 GO TO 05600
05550 IF (F5/F6)>10 THEN 05740
05560 IFF7>50 THEN 05590
05570 PRINT "FOID-BEARING MONZODIORITE"
05580 GO TO 05600
05590 PRINT"FOID-BEARING MONZOGABBRO"
05600 IF W(1)<52 THEN 05630
05610 PRINT "OR  FOID-BEARING ANDESITE"
05620 GO TO 05780
05630 PRINT "OR  FOID-BEARING BASALT"
05640 GO TO 05780
05650 IF (F5/F6)>10 THEN 05740
05660 PRINT "FOID-BEARING MONZONITE  OR FOID-BEARING LATITE"
05670 GO TO 05780
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05680 IF (F5/F6)>10 THEN 05720
05690 PRINT "FOID-BEARING ALKALI-FELDSPAR SYENITE"
05700 PRINT "OR  FOID-BEARING ALKALI-FELDSPAR TRACHYTE"
05710 GO TO 05780
05720 PRINT "FOID SYENITE  OR PHONOLITE"
05730 GO TO 05780
05740 IF (-.5*F6+50-((Z(4)+Z(5))/F6))=<0 THEN 05770
05750 PRINT "FOID MONZOSYENITE  OR TEPHRITIC PHONOLITE"
05760 GO TO 05780
05770 PRINT "ESSEXITE  OR PHONOLITIC TEPHRITE"
05780 PRINT
05790 NEXT T
05800 STOP
99999 END
```

APPENDIX E

"PETCAL" Data

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$$$$$*****$$$$$*****$$$$$*****$$$$$*****$$$$$*****$$$$$
SAMPLE NUMBER  STEAMBOAT HILLS 3301

** INPUT DATA **
SIO2 57.36       AL2O3 17.88      FE2O3 7.44      FEO 0
MGO  2.47        CAO   6.41       NA2O  3.86      K2O 2.5
TIO2 1.31        P2O5  .4453      MNO   .1266
MODIFIED FE2O3=  2.81
MODIFIED FEO=    4.16607
SUM OF OXIDES 99.338
** NORMALIZED OXIDE VALUES **
SIO2 57.7423     AL2O3 17.9992    FE2O3 2.82873   FEO 4.19384
MGO  2.48646     CAO   6.45272    NA2O  3.88572   K2O 2.51666
TIO2 1.31873     P2O5  .448268    MNO   .127444

** MOLE NUMBERS **
SI .96109        AL .176532       FE+3 1.77139E-2
FE+2 5.83694E-2
MG 6.16835E-2    CA .115063       NA 6.26932E-2   K 2.67161E-2
TI 1.65048E-2    P 3.15815E-3     MN 1.79650E-3

** NIGGLI NUMBERS **
AL 32.7948       FM  29.2198
C  21.3756       ALK 16.6099      SI 178.545
K  .298807       MG  .39217
TI 3.06614       P   .586699

** ATOMIC WEIGHT PERCENTS **
SI 26.9887       AL 9.52695       FE+3 1.97841    FE+2 3.25987
MG 1.49983       CA 4.61176       NA   2.88282    K    2.08908
TI .790579       P  .195624       MN 8.05317E-2   O    46.0958

** OXIDE-SILICA RATIOS **
AL2O3/SIO2          .311715
FE2O3/SIO2          4.89888E-2
FEO/SIO2            7.26303E-2
FEO*/SIO2           .11671
MGO/SIO2            4.30614E-2
CAO/SIO2            .11175
NA2O/SIO2           6.72943E-2
K2O/SIO2            4.35844E-2

** OTHER OXIDE RATIOS **
NA2O/K2O           1.544
K2O/NA2O           .647668
FEO*               6.73913
FEO*/MGO           2.71033
NA2O + K2O         6.40239
A:F:M=             40.9675  43.1222  15.9103
NA2O:K2O:CAO       30.2271  19.5771  50.1958

MGO:AL2O3:(CAO+NA2O+K2O)      (MOLE PROP.)
 13.9339  39.8773  46.1888

A:C:F =     30.6764  33.6689  35.6547

1/3SIO2+K2O-MGO-CAO-FEO (LARSEN,1938)= 6.08306
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**** NORMATIVE MINERALS ****

QUARTZ 8.7317
ORTHOCLASE 14.8713
ALBITE 32.8776
ANORTHITE 24.2374
DIOPSIDE 3.93586
HYPERSTHENE 7.70372
MAGNETITE 4.10147
ILMENITE 2.5046
APATITE 1.03799
SUM 100.002

WOLLASTONITE(DIOPSIDE) 2.02396
ENSTATITE(DIOPSIDE) 1.23125
FERROSILITE(DIOPSIDE) .680649
ENSTATITE(HYPERSTHENE) 4.96115
FERROSILITE(HYPERSTHENE) 2.74257

** NORMATIVE RATIOS - CIPW **
OR:AB:AN       20.6585  45.672  33.6695
Q:OR:AB        15.4597  26.3299  58.2104
Q:OR:AB+AN        10.8175  18.4238  70.7587
LC+NE+KS:OR:AB+AN    0  20.6585  79.3415
NORMATIVE PLAGIOCLASE CONTENT= AN 42.4362
NORMATIVE COLOR INDEX=     18.2456

** PETROCHEMICAL INDICES **
ALKALI INDEX      39.3082
FELSIC INDEX      49.8042
MAFIC INDEX       73.8516
SOLIDIFICATION INDEX         15.9103
DIFFERENTIATION INDEX        56.4805
CRYSTALLIZATION INDEX        30.3702
WEATHERING INDEX (PARKER,1970)          80.4648
ALTERATION INDEX (ISHIKAWA ETAL,1976)  32.6115
PERALUMINOUS INDEX           -15.8275
THETA INDEX (SUGIMURA,1968)       41.0241
S INDEX (RITTMAN,1960)            2.78048

THE ROCK IS METALUMINOUS (SHAND,1945)
THE ROCK IS SUBALKALIC (IRVINE & BARAGAR,1971)
THE ROCK IS CALC-ALKALIC (IRVINE & BARAGAR,1971)
THE ROCK IS THOLEIITIC (MIYASHIRO,1974)
THE ROCK IS HIGH ALUMINA (KUNO,1966)
THE ROCK IS KOMATIITIC (NALDRETT & ARNDT,1976)


ACCORDING TO THE IUGS CLASSIFICATION THE ROCK IS A
QUARTZ MONZODIORITE
OR  QUARTZ ANDESITE
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$$$$$*****$$$$$*****$$$$$*****$$$$$*****$$$$$*****$$$$$*****$$$$$
SAMPLE NUMBER  STEAMBOAT HILLS 3304

** INPUT DATA **
SIO2 55.03      AL2O3 18.86     FE2O3 8.09      FEO 0
MGO  2.61       CAO   6.47      NA2O  4.36      K2O 2.32
TIO2 1.46       P2O5  .5408     MNO   .1399
MODIFIED FE2O3=  2.96
MODIFIED FEO=    4.61597
SUM OF OXIDES 99.3667
** NORMALIZED OXIDE VALUES **
SIO2 55.3807    AL2O3 18.9802   FE2O3 2.97887   FEO 4.64539
MGO  2.62664    CAO   6.51124   NA2O  4.38779   K2O 2.33479
TIO2 1.46931    P2O5  .544247   MNO   .140792

** MOLE NUMBERS **
SI .921783      AL .186153      FE+3 1.86541E-2
FE+2 6.46541E-2
MG 6.51609E-2   CA .116106      NA 7.07936E-2   K 2.47854E-2
TI 1.83893E-2   P 3.83434E-3    MN 1.98466E-3

** NIGGLI NUMBERS **
AL 32.8337      FM  29.8292
C  20.4788      ALK 16.8582     SI 162.584
K  .259319      MG  .385296
TI 3.24351      P   .676302

** ATOMIC WEIGHT PERCENTS **
SI 25.885       AL 10.0462      FE+3 2.08342    FE+2 3.61087
MG 1.58439      CA 4.65358      NA   3.2553     K    1.93811
TI .880849      P  .237509      MN 8.89663E-2   O    45.7358

** OXIDE-SILICA RATIOS **
AL2O3/SIO2        .342722
FE2O3/SIO2        5.37888E-2
FEO/SIO2          .083881
FEO*/SIO2         .13228
MGO/SIO2          4.74287E-2
CAO/SIO2          .117572
NA2O/SIO2         7.92295E-2
K2O/SIO2          4.21588E-2

** OTHER OXIDE RATIOS **
NA2O/K2O          1.87931
K2O/NA2O          .53211
FEO*              7.32578
FEO*/MGO          2.78904
NA2O + K2O        6.72258
A:F:M=            40.3153  43.9327  15.7519
NA2O:K2O:CAO      33.1559  17.6426  49.2015

MGO:AL2O3:(CAO+NA2O+K2O)      (MOLE PROP.)
 14.0736  40.206  45.7204

A:C:F =   30.5847  32.5105  36.9048

1/3SIO2+K2O-MGO-CAO-FEO (LARSEN,1938)= 4.28977
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**** NORMATIVE MINERALS ****

QUARTZ 3.5832
ORTHOCLASE 13.7966
ALBITE 37.1256
ANORTHITE 25.1978
DIOPSIDE 2.88966
HYPERSTHENE 9.03896
MAGNETITE 4.31916
ILMENITE 2.79058
APATITE 1.26023
SUM 100.002

WOLLASTONITE(DIOPSIDE) 1.4826
ENSTATITE(DIOPSIDE) .881126
FERROSILITE(DIOPSIDE) .52593
ENSTATITE(HYPERSTHENE) 5.66038
FERROSILITE(HYPERSTHENE) 3.37859

** NORMATIVE RATIOS - CIPW **
OR:AB:AN      18.1248  48.7725  33.1028
Q:OR:AB       6.57403  25.3123  68.1137
Q:OR:AB+AN       4.49568  17.3099  78.1944
LC+NE+KS:OR:AB+AN    0  18.1248  81.8752
NORMATIVE PLAGIOCLASE CONTENT= AN 40.4307
NORMATIVE COLOR INDEX=      19.0384

** PETROCHEMICAL INDICES **
ALKALI INDEX       34.7305
FELSIC INDEX       50.7985
MAFIC INDEX        74.3765
SOLIDIFICATION INDEX         15.7519
DIFFERENTIATION INDEX        54.5054
CRYSTALLIZATION INDEX        31.0654
WEATHERING INDEX (PARKER,1970)              84.0816
ALTERATION INDEX (ISHIKAWA ETAL,1976)  31.2817
PERALUMINOUS INDEX           -13.7155
THETA INDEX (SUGIMURA,1968)       38.7339
S INDEX (RITTMAN,1960)            3.65027

THE ROCK IS METALUMINOUS (SHAND,1945)
THE ROCK IS ALKALIC (IRVINE & BARAGAR,1971)
THE ROCK IS THOLEIITIC (MIYASHIRO,1974)
THE ROCK IS ALKALIC (KUNO,1966)
THE ROCK IS ALKALIC (MACDONALD & KATSURA,1964)
THE ROCK IS THOLEIITIC (MACDONALD & KATSURA,1964)
THE ROCK IS KOMATIITIC (NALDRETT & ARNDT,1976)


ACCORDING TO THE IUGS CLASSIFICATION THE ROCK IS A
MONZODIORITE
OR  ANDESITE
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$$$$$*****$$$$$*****$$$$$*****$$$$$*****$$$$$*****$$$$$
SAMPLE NUMBER  STEAMBOAT HILLS 3305

** INPUT DATA **
SI02 56.08     AL203 18.4     FE203 7.7     FEO 0
MGO  2.21      CAO   6.45     NA20  4.58    K20 2.4
TI02 1.39      P205  .5274    MNO   .134
MODIFIED FE203=  2.89
MODIFIED FEO=    4.32804
SUM OF OXIDES 99.3894
** NORMALIZED OXIDE VALUES **
SI02 56.4245   AL203 18.513   FE203 2.90775  FEO 4.35463
MGO  2.22358   CAO   6.48962  NA20  4.60814  K20 2.41474
TI02 1.39854   P205  .53064   MNO   .134823

** MOLE NUMBERS **
SI .939156     AL .181572     FE+3 1.82087E-2
FE+2 6.06072E-2
MG 5.51619E-2  CA .115721     NA 7.43487E-2  K 2.56342E-2
TI 1.75036E-2  P 3.73848E-3   MN 1.90052E-3

** NIGGLI NUMBERS **
AL 32.9308     FM  27.948
C  20.9877     ALK 18.1334    SI 170.33
K  .256386     MG  .357967
TI 3.17455     P   .678031

** ATOMIC WEIGHT PERCENTS **
SI 26.3728     AL 9.79895    FE+3 2.03368   FE+2 3.38485
MG 1.34126     CA 4.63813    NA   3.41878   K    2.00448
TI .838424     P  .231571    MN 8.51948E-2  O    45.8519

** OXIDE-SILICA RATIOS **
AL203/SI02        .328103
FE203/SI02        5.15335E-2
FEO/SI02          7.71761E-2
FEO*/SI02         .123546
MGO/SI02          .039408
CAO/SI02          .115014
NA20/SI02         .081669
K20/SI02          .042796

** OTHER OXIDE RATIOS **
NA20/K20          1.90833
K20/NA20          .524017
FEO*              6.97102
FEO*/MGO          3.13505
NA20 + K20        7.02288
A:F:M=            43.3044  42.9846  13.711
NA20:K20:CAO      34.1028  17.8704  48.0268

MGO:AL203:(CAO+NA20+K20)      (MOLE PROP.)
 12.1922  40.1319  47.676

A:C:F =   29.9523  34.7314  35.3163

1/3SI02+K20-MGO-CAO-FEO (LARSEN,1938)= 5.52659
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**** NORMATIVE MINERALS ****

QUARTZ 4.35225
ORTHOCLASE 14.269
ALBITE 38.99
ANORTHITE 22.6979
DIOPSIDE 4.91907
HYPERSTHENE 6.67245
MAGNETITE 4.21605
ILMENITE 2.65617
APATITE 1.22873
SUM 100.002

WOLLASTONITE(DIOPSIDE) 2.51871
ENSTATITE(DIOPSIDE) 1.46509
FERROSILITE(DIOPSIDE) .93527
ENSTATITE(HYPERSTHENE) 4.07261
FERROSILITE(HYPERSTHENE) 2.59984

** NORMATIVE RATIOS - CIPW **
OR:AB:AN      18.7857  51.3317  29.8826
Q:OR:AB       7.55452  24.7678  67.6777
Q:OR:AB+AN       5.41937  17.7676  76.813
LC+NE+KS:OR:AB+AN    0  18.7857  81.2143
NORMATIVE PLAGIOCLASE CONTENT= AN 36.7948
NORMATIVE COLOR INDEX=      18.4637

** PETROCHEMICAL INDICES **
ALKALI INDEX     34.384
FELSIC INDEX     51.9732
MAFIC INDEX      76.5593
SOLIDIFICATION INDEX       13.711
DIFFERENTIATION INDEX      57.6113
CRYSTALLIZATION INDEX      28.7124
WEATHERING INDEX (PARKER,1970)           85.625
ALTERATION INDEX (ISHIKAWA ETAL,1976)  29.4757
PERALUMINOUS INDEX         -18.7982
THETA INDEX (SUGIMURA,1968)     38.5952
S INDEX (RITTMAN,1960)          3.67394

THE ROCK IS METALUMINOUS (SHAND,1945)
THE ROCK IS ALKALIC (IRVINE & BARAGAR,1971)
THE ROCK IS THOLEIITIC (MIYASHIRO,1974)
THE ROCK IS ALKALIC (KUNO,1966)
THE ROCK IS ALKALIC (MACDONALD & KATSURA,1964)
THE ROCK IS THOLEIITIC (MACDONALD & KATSURA,1964)
THE ROCK IS KOMATIITIC (NALDRETT & ARNDT,1976)


ACCORDING TO THE IUGS CLASSIFICATION THE ROCK IS A
QUARTZ MONZODIORITE
OR  QUARTZ ANDESITE
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$$$$$*****$$$$$*****$$$$$*****$$$$$*****$$$$$*****$$$$$
SAMPLE NUMBER  STEAMBOAT HILLS 3307

** INPUT DATA **
SIO2 55.58      AL2O3 17.01     FE2O3 8.09      FEO 0
MGO  3.02       CAO   6         NA2O  4.39      K2O 2.33
TIO2 1.51       P2O5  .5107     MNO   .1364
MODIFIED FE2O3=  3.01
MODIFIED FEO=    4.57098
SUM OF OXIDES 98.0681
** NORMALIZED OXIDE VALUES **
SIO2 56.6749    AL2O3 17.3451   FE2O3 3.0693    FEO 4.66103
MGO  3.07949    CAO   6.1182    NA2O  4.47648   K2O 2.3759
TIO2 1.53975    P2O5  .520761   MNO   .139087

** MOLE NUMBERS **
SI .943324      AL .170117      FE+3 1.92203E-2
FE+2 6.48717E-2
MG 7.63953E-2   CA .109098      NA 7.22246E-2   K 2.52219E-2
TI 1.92709E-2   P 3.66888E-3    MN 1.96063E-3

** NIGGLI NUMBERS **
AL 30.4683      FM  32.5392
C  19.5396      ALK 17.4529     SI 168.951
K  .258828      MG  .420494
TI 3.45146      P   .657104

** ATOMIC WEIGHT PERCENTS **
SI 26.4899      AL 9.18076      FE+3 2.14667    FE+2 3.62302
MG 1.85755      CA 4.37268      NA   3.3211     K    1.97223
TI .923078      P  .22726       MN 8.78891E-2   O    45.7979

** OXIDE-SILICA RATIOS **
AL2O3/SIO2        .306045
FE2O3/SIO2        5.41562E-2
FEO/SIO2          8.22415E-2
FEO*/SIO2         .130971
MGO/SIO2          5.43361E-2
CAO/SIO2          .107953
NA2O/SIO2         7.89852E-2
K2O/SIO2          4.19216E-2

** OTHER OXIDE RATIOS **
NA2O/K2O          1.88412
K2O/NA2O          .530752
FEO*              7.42278
FEO*/MGO          2.41039
NA2O + K2O        6.85238
A:F:M=            39.4844  42.7711  17.7445
NA2O:K2O:CAO      34.5126  18.3176  47.1698

MGO:AL2O3:(CAO+NA2O+K2O)      (MOLE PROP.)
 16.8622  37.5487  45.5891

A:C:F =   26.6956  31.6946  41.6098

1/3SIO2+K2O-MGO-CAO-FEO (LARSEN,1938)= 4.61732
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**** NORMATIVE MINERALS ****

QUARTZ 5.06825
ORTHOCLASE 14.0395
ALBITE 37.876
ANORTHITE 20.2168
DIOPSIDE 5.44934
HYPERSTHENE 8.77127
MAGNETITE 4.45028
ILMENITE 2.92436
APATITE 1.20585
SUM 100.002

WOLLASTONITE(DIOPSIDE) 2.81225
ENSTATITE(DIOPSIDE) 1.77279
FERROSILITE(DIOPSIDE) .864292
ENSTATITE(HYPERSTHENE) 5.89653
FERROSILITE(HYPERSTHENE) 2.87474

** NORMATIVE RATIOS - CIPW **
OR:AB:AN       19.4635  52.5091  28.0274
Q:OR:AB         8.8942  24.6377  66.4681
Q:OR:AB+AN       6.56504  18.1857  75.2492
LC+NE+KS:OR:AB+AN     0  19.4635  80.5365
NORMATIVE PLAGIOCLASE CONTENT= AN 34.8009
NORMATIVE COLOR INDEX=      21.5953

** PETROCHEMICAL INDICES **
ALKALI INDEX      34.6726
FELSIC INDEX      52.8302
MAFIC INDEX       71.5121
SOLIDIFICATION INDEX          17.7445
DIFFERENTIATION INDEX         56.9838
CRYSTALLIZATION INDEX         28.1733
WEATHERING INDEX (PARKER,1970)            85.495
ALTERATION INDEX (ISHIKAWA ETAL,1976)     33.9898
PERALUMINOUS INDEX            -21.4133
THETA INDEX (SUGIMURA,1968)        38.107
S INDEX (RITTMAN,1960)             3.43367

THE ROCK IS METALUMINOUS (SHAND,1945)
THE ROCK IS SUBALKALIC (IRVINE & BARAGAR,1971)
THE ROCK IS CALC-ALKALIC (IRVINE & BARAGAR,1971)
THE ROCK IS THOLEIITIC (MIYASHIRO,1974)
THE ROCK IS ALKALIC (KUNO,1966)
THE ROCK IS ALKALIC (MACDONALD & KATSURA,1964)
THE ROCK IS THOLEIITIC (MACDONALD & KATSURA,1964)
THE ROCK IS KOMATIITIC (NALDRETT & ARNDT,1976)


ACCORDING TO THE IUGS CLASSIFICATION THE ROCK IS A
QUARTZ MONZODIORITE
OR  QUARTZ ANDESITE
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$$$$$******$$$$$******$$$$$******$$$$$******$$$$$******$$$$$
SAMPLE NUMBER  STEAMBOAT HILLS 3308

** INPUT DATA **
SIO2 55.68      AL2O3 18.45     FE2O3 8.08      FEO 0
MGO  2.11       CAO   6.45      NA2O  4.6       K2O 2.34
TIO2 1.45       P2O5  .5745     MNO   .1369
MODIFIED FE2O3=  2.95
MODIFIED FEO=    4.61597
SUM OF OXIDES 99.3574
** NORMALIZED OXIDE VALUES **
SIO2 56.0401    AL2O3 18.5693   FE2O3 2.96908   FEO 4.64583
MGO  2.12365    CAO   6.49172   NA2O  4.62975   K2O 2.35513
TIO2 1.45938    P2O5  .578216   MNO   .137785

** MOLE NUMBERS **
SI .932758      AL .182124      FE+3 1.85928E-2
FE+2 6.46601E-2
MG 5.26829E-2   CA .115758      NA 7.46975E-2   K 2.50014E-2
TI 1.82651E-2   P 4.07366E-3    MN 1.94228E-3

** NIGGLI NUMBERS **
AL 32.8706      FM  28.2427
C  20.8926      ALK 17.9942     SI 168.349
K  .250769      MG  .33667
TI 3.29657      P   .735235

** ATOMIC WEIGHT PERCENTS **
SI 26.1932      AL 9.82875      FE+3 2.07657    FE+2 3.6112
MG 1.28098      CA 4.63963      NA   3.43481    K    1.955
TI .874897      P  .252333      MN 8.70666E-2   O    45.7656

** OXIDE-SILICA RATIOS **
AL2O3/SIO2         .331358
FE2O3/SIO2         5.29813E-2
FEO/SIO2           8.29018E-2
FEO*/SIO2          .130574
MGO/SIO2           3.78951E-2
CAO/SIO2           .115841
NA2O/SIO2          8.26149E-2
K2O/SIO2           4.20259E-2

** OTHER OXIDE RATIOS **
NA2O/K2O           1.96581
K2O/NA2O           .508696
FEO*               7.31741
FEO*/MGO           3.44568
NA2O + K2O         6.98489
A:F:M=             42.5235  44.5479  12.9286
NA2O:K2O:CAO       34.354  17.4757  48.1703

MGO:AL2O3:(CAO+NA2O+K2O)      (MOLE PROP.)
 11.7005  40.4482  47.8513

A:C:F =   30.0593  34.4456  35.4951

1/3SIO2+K2O-MGO-CAO-FEO (LARSEN,1938)= 5.08332
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**** NORMATIVE MINERALS ****

QUARTZ 4.05659
ORTHOCLASE 13.9168
ALBITE 39.1729
ANORTHITE 22.9306
DIOPSIDE 4.50577
HYPERSTHENE 7.00352
MAGNETITE 4.30497
ILMENITE 2.77172
APATITE 1.33889
SUM 100.002

WOLLASTONITE(DIOPSIDE) 2.29626
ENSTATITE(DIOPSIDE) 1.26839
FERROSILITE(DIOPSIDE) .941119
ENSTATITE(HYPERSTHENE) 4.02044
FERROSILITE(HYPERSTHENE) 2.98308

** NORMATIVE RATIOS - CIPW **
OR:AB:AN      18.3067  51.5295  30.1638
Q:OR:AB       7.0986  24.3529  68.5485
Q:OR:AB+AN       5.06587  17.3793  77.5548
LC+NE+KS:OR:AB+AN    0  18.3067  81.6933
NORMATIVE PLAGIOCLASE CONTENT= AN 36.9232
NORMATIVE COLOR INDEX=      18.586

** PETROCHEMICAL INDICES **
ALKALI INDEX      33.7176
FELSIC INDEX      51.8297
MAFIC INDEX       78.1934
SOLIDIFICATION INDEX          12.9286
DIFFERENTIATION INDEX         57.1463
CRYSTALLIZATION INDEX         28.4842
WEATHERING INDEX (PARKER,1970)            85.0479
ALTERATION INDEX (ISHIKAWA ETAL,1976)  28.7097
PERALUMINOUS INDEX            -18.3026
THETA INDEX (SUGIMURA,1968)       38.361
S INDEX (RITTMAN,1960)            3.74142

THE ROCK IS METALUMINOUS (SHAND,1945)
THE ROCK IS ALKALIC (IRVINE & BARAGAR,1971)
THE ROCK IS THOLEIITIC (MIYASHIRO,1974)
THE ROCK IS ALKALIC (KUNO,1966)
THE ROCK IS ALKALIC (MACDONALD & KATSURA,1964)
THE ROCK IS THOLEIITIC (MACDONALD & KATSURA,1964)
THE ROCK IS KOMATIITIC (NALDRETT & ARNDT,1976)


ACCORDING TO THE IUGS CLASSIFICATION THE ROCK IS A
QUARTZ MONZODIORITE
OR  QUARTZ ANDESITE
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$$$$$******$$$$$******$$$$$******$$$$$******$$$$$******$$$$$
SAMPLE NUMBER  STEAMBOAT HILLS 3310

** INPUT DATA **
SIO2 54.62     AL2O3 18.95     FE2O3 8.25      FEO 0
MGO  2.75      CAO   6.58      NA2O  4.23      K2O 2.3
TIO2 1.52      P2O5  .529      MNO   .1386
MODIFIED FE2O3=  3.02
MODIFIED FEO=    4.70595
SUM OF OXIDES 99.3436
** NORMALIZED OXIDE VALUES **
SIO2 54.9809   AL2O3 19.0752   FE2O3 3.03996   FEO 4.73705
MGO  2.76817   CAO   6.62348   NA2O  4.25795   K2O 2.3152
TIO2 1.53004   P2O5  .532496   MNO   .139516

** MOLE NUMBERS **
SI .915128     AL .187085      FE+3 1.90366E-2
FE+2 6.59297E-2
MG 6.86721E-2  CA .118108      NA 6.86988E-2  K 2.45775E-2
TI 1.91495E-2  P 3.75155E-3    MN 1.96667E-3

** NIGGLI NUMBERS **
AL 32.6432     FM  30.474
C  20.6078     ALK 16.2751     SI 159.674
K  .263491     MG  .393191
TI 3.34126     P   .654581

** ATOMIC WEIGHT PERCENTS **
SI 25.6981     AL 10.0965      FE+3 2.12614    FE+2 3.68211
MG 1.66976     CA 4.7338       NA   3.15897    K    1.92185
TI .917261     P  .232381      MN 8.81601E-2   O    45.675

** OXIDE-SILICA RATIOS **
AL2O3/SIO2       .346943
FE2O3/SIO2       5.52911E-2
FEO/SIO2         8.61581E-2
FEO*/SIO2        .135909
MGO/SIO2         5.03479E-2
CAO/SIO2         .120469
NA2O/SIO2        7.74442E-2
K2O/SIO2         4.21091E-2

** OTHER OXIDE RATIOS **
NA2O/K2O         1.83913
K2O/NA2O         .543735
FEO*             7.4724
FEO*/MGO         2.6994
NA2O + K2O       6.57315
A:F:M=           39.094  44.4423  16.4638
NA2O:K2O:CAO     32.2654  17.5439  50.1907

MGO:AL2O3:(CAO+NA2O+K2O)     (MOLE PROP.)
 14.7005  40.049  45.2505

A:C:F =   30.7045  32.1362  37.1593

1/3SIO2+K2O-MGO-CAO-FEO (LARSEN,1938)= 3.72682
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**** NORMATIVE MINERALS ****

QUARTZ 3.46448
ORTHOCLASE 13.6808
ALBITE 36.027
ANORTHITE 26.0977
DIOPSIDE 2.66903
HYPERSTHENE 9.51602
MAGNETITE 4.40774
ILMENITE 2.90593
APATITE 1.23302
SUM 100.002

WOLLASTONITE(DIOPSIDE) 1.37138
ENSTATITE(DIOPSIDE) .827285
FERROSILITE(DIOPSIDE) .470365
ENSTATITE(HYPERSTHENE) 6.06671
FERROSILITE(HYPERSTHENE) 3.44931

** NORMATIVE RATIOS - CIPW **
OR:AB:AN        18.0472  47.5256  34.4272
Q:OR:AB         6.51557  25.7292  67.7552
Q:OR:AB+AN         4.37048  17.2585  78.371
LC+NE+KS:OR:AB+AN    0  18.0472  81.9528
NORMATIVE PLAGIOCLASE CONTENT= AN 42.0085
NORMATIVE COLOR INDEX=     19.4987

** PETROCHEMICAL INDICES **
ALKALI INDEX      35.2221
FELSIC INDEX      49.8093
MAFIC INDEX       73.7494
SOLIDIFICATION INDEX         16.4638
DIFFERENTIATION INDEX        53.1723
CRYSTALLIZATION INDEX        32.1339
WEATHERING INDEX (PARKER,1970)            83.3948
ALTERATION INDEX (ISHIKAWA ETAL,1976)  31.8411
PERALUMINOUS INDEX          -12.988
THETA INDEX (SUGIMURA,1968)       38.7851
S INDEX (RITTMAN,1960)            3.60626

THE ROCK IS METALUMINOUS (SHAND,1945)
THE ROCK IS ALKALIC (IRVINE & BARAGAR,1971)
THE ROCK IS THOLEIITIC (MIYASHIRO,1974)
THE ROCK IS ALKALIC (KUNO,1966)
THE ROCK IS ALKALIC (MACDONALD & KATSURA,1964)
THE ROCK IS THOLEIITIC (MACDONALD & KATSURA,1964)
THE ROCK IS KOMATIITIC (NALDRETT & ARNDT,1976)


ACCORDING TO THE IUGS CLASSIFICATION THE ROCK IS A
MONZODIORITE
OR  ANDESITE
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$$$$$******$$$$$******$$$$$******$$$$$******$$$$$******$$$$$
SAMPLE NUMBER  STEAMBOAT HILLS 3312

** INPUT DATA **
SIO2 55.94      AL2O3 17.64     FE2O3 8.18      FEO 0
MGO  2.59       CAO   6.55      NA2O  4.37      K2O 2.38
TIO2 1.56       P2O5  .5189     MNO   .1324
MODIFIED FE2O3=  3.06
MODIFIED FEO=    4.60698
SUM OF OXIDES 99.3483
** NORMALIZED OXIDE VALUES **
SIO2 56.307     AL2O3 17.7557   FE2O3 3.08007   FEO 4.6372
MGO  2.60699    CAO   6.59297   NA2O  4.39867   K2O 2.39561
TIO2 1.57023    P2O5  .522304   MNO   .133269

** MOLE NUMBERS **
SI .9372        AL .174144      FE+3 1.92878E-2
FE+2 .06454
MG 6.46735E-2   CA .117564      NA 7.09691E-2   K 2.54311E-2
TI 1.96525E-2   P 3.67975E-3    MN 1.87861E-3

** NIGGLI NUMBERS **
AL 31.2205      FM  30.4201
C  21.0768      ALK 17.2826     SI 168.021
K  .263808      MG  .381152
TI 3.5233       P   .659705

** ATOMIC WEIGHT PERCENTS **
SI 26.3179      AL 9.3981       FE+3 2.1542     FE+2 3.60449
MG 1.57254      CA 4.71199      NA   3.26337    K    1.9886
TI .941355      P  .227933      MN 8.42124E-2   O    45.7353

** OXIDE-SILICA RATIOS **
AL2O3/SIO2        .315338
FE2O3/SIO2        5.47015E-2
FEO/SIO2          8.23557E-2
FEO*/SIO2         .131576
MGO/SIO2          4.62996E-2
CAO/SIO2          .11709
NA2O/SIO2         7.81194E-2
K2O/SIO2          4.25456E-2

** OTHER OXIDE RATIOS **
NA2O/K2O          1.83613
K2O/NA2O          .544622
FEO*              7.40865
FEO*/MGO          2.84184
NA2O + K2O        6.79428
A:F:M=            40.4183  44.0731  15.5086
NA2O:K2O:CAO      32.8571  17.8947  49.2481

MGO:AL2O3:(CAO+NA2O+K2O)      (MOLE PROP.)
 14.2836  38.4609  47.2555

A:C:F =   28.0692  34.0087  37.9222

1/3SIO2+K2O-MGO-CAO-FEO (LARSEN,1938)= 4.53154
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**** NORMATIVE MINERALS ****

QUARTZ 5.02225
ORTHOCLASE 14.156
ALBITE 37.2176
ANORTHITE 21.6283
DIOPSIDE 6.22875
HYPERSTHENE 7.09114
MAGNETITE 4.4659
ILMENITE 2.98226
APATITE 1.20942
SUM 100.002

WOLLASTONITE(DIOPSIDE) 3.20211
ENSTATITE(DIOPSIDE) 1.94219
FERROSILITE(DIOPSIDE) 1.08445
ENSTATITE(HYPERSTHENE) 4.55038
FERROSILITE(HYPERSTHENE) 2.54076

** NORMATIVE RATIOS - CIPW **
OR:AB:AN       19.3913  50.9817  29.627
Q:OR:AB        8.90534  25.1011  65.9936
Q:OR:AB+AN        6.43678  18.1431  75.4201
LC+NE+KS:OR:AB+AN    0  19.3913  80.6087
NORMATIVE PLAGIOCLASE CONTENT= AN 36.7541
NORMATIVE COLOR INDEX=      20.7681

** PETROCHEMICAL INDICES **
ALKALI INDEX      35.2593
FELSIC INDEX      50.7519
MAFIC INDEX       74.7489
SOLIDIFICATION INDEX        15.5086
DIFFERENTIATION INDEX       56.3959
CRYSTALLIZATION INDEX       29.0067
WEATHERING INDEX (PARKER,1970)           84.8524
ALTERATION INDEX (ISHIKAWA ETAL,1976)  31.2775
PERALUMINOUS INDEX          -22.8661
THETA INDEX (SUGIMURA,1968)      38.3223
S INDEX (RITTMAN,1960)           3.46903

THE ROCK IS METALUMINOUS (SHAND,1945)
THE ROCK IS SUBALKALIC (IRVINE & BARAGAR,1971)
THE ROCK IS CALC-ALKALIC (IRVINE & BARAGAR,1971)
THE ROCK IS THOLEIITIC (MIYASHIRO,1974)
THE ROCK IS ALKALIC (KUNO,1966)
THE ROCK IS ALKALIC (MACDONALD & KATSURA,1964)
THE ROCK IS THOLEIITIC (MACDONALD & KATSURA,1964)
THE ROCK IS KOMATIITIC (NALDRETT & ARNDT,1976)


ACCORDING TO THE IUGS CLASSIFICATION THE ROCK IS A
QUARTZ MONZODIORITE
OR  QUARTZ ANDESITE
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$$$$$*****$$$$$*****$$$$$*****$$$$$*****$$$$$*****$$$$$
SAMPLE NUMBER  STEAMBOAT HILLS 3314

** INPUT DATA **
SIO2 57.81      AL2O3 17.23     FE2O3 7.45      FEO 0
MGO  2.52       CAO   6.47      NA2O  4.09      K2O 2.39
TIO2 1.31       P2O5  .478      MNO   .1324
MODIFIED FE2O3=  2.81
MODIFIED FEO=    4.17507
SUM OF OXIDES 99.4155
** NORMALIZED OXIDE VALUES **
SIO2 58.1499    AL2O3 17.3313  FE2O3 2.82652  FEO 4.19962
MGO  2.53482    CAO   6.50804  NA2O  4.11405  K2O 2.40405
TIO2 1.3177     P2O5  .48081   MNO   .133178

** MOLE NUMBERS **
SI .967875      AL .169981      FE+3 1.77001E-2
FE+2 5.84498E-2
MG 6.28831E-2  CA .116049      NA .066377      K 2.55207E-2
TI 1.64919E-2  P 3.38742E-3    MN 1.87734E-3

** NIGGLI NUMBERS **
AL 31.6805      FM  29.5631
C  21.6288      ALK 17.1276     SI 180.389
K  .277708      MG  .396437
TI 3.0737       P   .631335

** ATOMIC WEIGHT PERCENTS **
SI 27.1793      AL 9.17346      FE+3 1.97687   FE+2 3.26436
MG 1.529        CA 4.6513       NA   3.05221   K    1.9956
TI .789963      P  .209826      MN 8.41555E-2  O    46.094

** OXIDE-SILICA RATIOS **
AL2O3/SIO2        .298045
FE2O3/SIO2        4.86075E-2
FEO/SIO2          7.22206E-2
FEO*/SIO2         .115958
MGO/SIO2          4.35911E-2
CAO/SIO2          .111918
NA2O/SIO2         .070749
K2O/SIO2          4.13423E-2

** OTHER OXIDE RATIOS **
NA2O/K2O          1.7113
K2O/NA2O          .584352
FEO*              6.74292
FEO*/MGO          2.66012
NA2O + K2O        6.5181
A:F:M=            41.2647  42.688  16.0474
NA2O:K2O:CAO      31.583  18.4556  49.9614

MGO:AL2O3:(CAO+NA2O+K2O)      (MOLE PROP.)
 14.2653  38.561  47.1737

A:C:F =   28.5885  34.6371  36.7744

1/3SIO2+K2O-MGO-CAO-FEO (LARSEN,1938)= 5.99315
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**** NORMATIVE MINERALS ****

QUARTZ 8.68859
ORTHOCLASE 14.2059
ALBITE 34.8094
ANORTHITE 21.7229
DIOPSIDE 6.02584
HYPERSTHENE 6.83479
MAGNETITE 4.09827
ILMENITE 2.50264
APATITE 1.11334
SUM 100.002

WOLLASTONITE(DIOPSIDE) 3.09978
ENSTATITE(DIOPSIDE) 1.89243
FERROSILITE(DIOPSIDE) 1.03363
ENSTATITE(HYPERSTHENE) 4.4204
FERROSILITE(HYPERSTHENE) 2.41439

** NORMATIVE RATIOS - CIPW **
OR:AB:AN       20.0823  49.2088  30.7089
Q:OR:AB        15.0572  24.6185  60.3243
Q:OR:AB+AN        10.9391  17.8855  71.1754
LC+NE+KS:OR:AB+AN    0  20.0823  79.9177
NORMATIVE PLAGIOCLASE CONTENT= AN 38.4256
NORMATIVE COLOR INDEX=      19.4615

** PETROCHEMICAL INDICES **
ALKALI INDEX      36.8827
FELSIC INDEX      50.0386
MAFIC INDEX       73.4878
SOLIDIFICATION INDEX        16.0474
DIFFERENTIATION INDEX       57.7039
CRYSTALLIZATION INDEX       28.9028
WEATHERING INDEX (PARKER,1970)          81.8864
ALTERATION INDEX (ISHIKAWA ETAL,1976)  31.7388
PERALUMINOUS INDEX          -22.3351
THETA INDEX (SUGIMURA,1968)      40.4738
S INDEX (RITTMAN,1960)           2.80435

THE ROCK IS METALUMINOUS (SHAND,1945)
THE ROCK IS SUBALKALIC (IRVINE & BARAGAR,1971)
THE ROCK IS CALC-ALKALIC (IRVINE & BARAGAR,1971)
THE ROCK IS THOLEIITIC (MIYASHIRO,1974)
THE ROCK IS HIGH ALUMINA (KUNO,1966)
THE ROCK IS KOMATIITIC (NALDRETT & ARNDT,1976)


ACCORDING TO THE IUGS CLASSIFICATION THE ROCK IS A
QUARTZ MONZODIORITE
OR  QUARTZ ANDESITE
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$$$$$*****$$$$$*****$$$$$*****$$$$$*****$$$$$*****$$$$$
SAMPLE NUMBER  STEAMBOAT HILLS 3316

** INPUT DATA **
SIO2 55.94      AL2O3 18.13     FE2O3 7.9       FEO 0
MGO  2.29       CAO   6.55      NA2O  4.58      K2O 2.38
TIO2 1.45       P2O5  .5259     MNO   .1388
MODIFIED FE2O3=  2.95
MODIFIED FEO=    4.45401
SUM OF OXIDES 99.3887
** NORMALIZED OXIDE VALUES **
SIO2 56.2841    AL2O3 18.2415   FE2O3 2.96814   FEO 4.4814
MGO  2.30408    CAO   6.59029   NA2O  4.60817   K2O 2.39464
TIO2 1.45892    P2O5  .529135   MNO   .139654

** MOLE NUMBERS **
SI .936819      AL .178908      FE+3 1.85869E-2
FE+2 6.23717E-2
MG 5.71591E-2   CA .117516      NA 7.43493E-2   K 2.54208E-2
TI 1.82593E-2   P 3.72787E-3    MN 1.96862E-3

** NIGGLI NUMBERS **
AL 32.2428      FM  28.598
C  21.1786      ALK 17.9805     SI 168.833
K  .254794      MG  .360207
TI 3.29068      P   .671836

** ATOMIC WEIGHT PERCENTS **
SI 26.3072      AL 9.65523      FE+3 2.07592    FE+2 3.4834
MG 1.38982      CA 4.71008      NA   3.4188     K    1.98779
TI .874621      P  .230914      MN 8.82472E-2   O    45.778

** OXIDE-SILICA RATIOS **
AL2O3/SIO2        .324097
FE2O3/SIO2        5.27351E-2
FEO/SIO2          7.96212E-2
FEO*/SIO2         .127072
MGO/SIO2          4.09367E-2
CAO/SIO2          .11709
NA2O/SIO2         8.18734E-2
K2O/SIO2          4.25456E-2

** OTHER OXIDE RATIOS **
NA2O/K2O          1.92437
K2O/NA2O          .519651
FEO*              7.15214
FEO*/MGO          3.10411
NA2O + K2O        7.00281
A:F:M=            42.5469  43.4542  13.9989
NA2O:K2O:CAO      33.9008  17.6166  48.4826

MGO:AL2O3:(CAO+NA2O+K2O)     (MOLE PROP.)
 12.6081  39.4634  47.9286

A:C:F =   29.021  34.898  36.081

1/3SIO2+K2O-MGO-CAO-FEO (LARSEN,1938)= 5.08607
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**** NORMATIVE MINERALS ****

QUARTZ 4.16381
ORTHOCLASE 14.1502
ALBITE 38.9903
ANORTHITE 22.0163
DIOPSIDE 5.88838
HYPERSTHENE 6.49305
MAGNETITE 4.30361
ILMENITE 2.77085
APATITE 1.22524
SUM 100.002

WOLLASTONITE(DIOPSIDE) 3.01593
ENSTATITE(DIOPSIDE) 1.75994
FERROSILITE(DIOPSIDE) 1.11251
ENSTATITE(HYPERSTHENE) 3.97827
FERROSILITE(HYPERSTHENE) 2.51478

** NORMATIVE RATIOS - CIPW **
OR:AB:AN       18.8276  51.8786  29.2938
Q:OR:AB        7.26615  24.6931  68.0407
Q:OR:AB+AN        5.24935  17.8393  76.9114
LC+NE+KS:OR:AB+AN    0  18.8276  81.1724
NORMATIVE PLAGIOCLASE CONTENT= AN 36.0884
NORMATIVE COLOR INDEX=      19.4559

** PETROCHEMICAL INDICES **
ALKALI INDEX       34.1954
FELSIC INDEX       51.5174
MAFIC INDEX        76.3772
SOLIDIFICATION INDEX          13.9989
DIFFERENTIATION INDEX         57.3043
CRYSTALLIZATION INDEX         28.6006
WEATHERING INDEX (PARKER,1970)           85.9328
ALTERATION INDEX (ISHIKAWA ETAL,1976)   29.557
PERALUMINOUS INDEX           -21.4509
THETA INDEX (SUGIMURA,1968)       38.241
S INDEX (RITTMAN,1960)            3.69159

THE ROCK IS METALUMINOUS (SHAND,1945)
THE ROCK IS ALKALIC (IRVINE & BARAGAR,1971)
THE ROCK IS THOLEIITIC (MIYASHIRO,1974)
THE ROCK IS ALKALIC (KUNO,1966)
THE ROCK IS ALKALIC (MACDONALD & KATSURA,1964)
THE ROCK IS THOLEIITIC (MACDONALD & KATSURA,1964)
THE ROCK IS KOMATIITIC (NALDRETT & ARNDT,1976)


ACCORDING TO THE IUGS CLASSIFICATION THE ROCK IS A
QUARTZ MONZODIORITE
OR  QUARTZ ANDESITE
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$$$$$*****$$$$$*****$$$$$*****$$$$$*****$$$$$*****$$$$$
SAMPLE NUMBER  STEAMBOAT HILLS 3320

** INPUT DATA **
SIO2 54.67      AL2O3 18.96     FE2O3 8.88      FEO 0
MGO  2.26       CAO   6.7       NA2O  3.79      K2O 2.28
TIO2 1.62       P2O5  .5448     MNO   .144
MODIFIED FE2O3=  3.12
MODIFIED FEO=    5.18285
SUM OF OXIDES 99.2716
** NORMALIZED OXIDE VALUES **
SIO2 55.0711    AL2O3 19.0991   FE2O3 3.14289   FEO 5.22087
MGO  2.27658    CAO   6.74916   NA2O  3.81781   K2O 2.29673
TIO2 1.63189    P2O5  .548797   MNO   .145057

** MOLE NUMBERS **
SI .91663       AL .18732       FE+3 1.96812E-2
FE+2 7.26635E-2
MG 5.64768E-2   CA .120349      NA 6.15974E-2  K 2.43814E-2
TI 2.04241E-2   P 3.86640E-3    MN 2.04478E-3

** NIGGLI NUMBERS **
AL 33.2005      FM  30.23
C  21.3306      ALK 15.2389     SI 162.463
K  .283575      MG  .331126
TI 3.61996      P   .68528

** ATOMIC WEIGHT PERCENTS **
SI 25.7402      AL 10.1092      FE+3 2.19814   FE+2 4.05819
MG 1.37323      CA 4.82362      NA   2.83243   K    1.90651
TI .978316      P  .239495      MN 9.16612E-2  O    45.649

** OXIDE-SILICA RATIOS **
AL2O3/SIO2        .346808
FE2O3/SIO2        5.70697E-2
FEO/SIO2          9.48024E-2
FEO*/SIO2         .146154
MGO/SIO2          4.13389E-2
CAO/SIO2          .122554
NA2O/SIO2         .069325
K2O/SIO2          4.17048E-2

** OTHER OXIDE RATIOS **
NA2O/K2O          1.66228
K2O/NA2O          .601583
FEO*              8.04885
FEO*/MGO          3.5355
NA2O + K2O        6.11454
A:F:M=            37.1931  48.959  13.8478
NA2O:K2O:CAO      29.6789  17.8543  52.4667

MGO:AL2O3:(CAO+NA2O+K2O)      (MOLE PROP.)
 12.547  41.6151  45.8379

A:C:F =   32.4843  32.3035  35.2122

1/3SIO2+K2O-MGO-CAO-FEO (LARSEN,1938)= 3.52202
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**** NORMATIVE MINERALS ****

QUARTZ 6.05982
ORTHOCLASE 13.5717
ALBITE 32.3029
ANORTHITE 28.193
DIOPSIDE 1.40155
HYPERSTHENE 9.54572
MAGNETITE 4.55699
ILMENITE 3.09936
APATITE 1.27077
SUM 100.002

WOLLASTONITE(DIOPSIDE) .712387
ENSTATITE(DIOPSIDE) .381767
FERROSILITE(DIOPSIDE) .307393
ENSTATITE(HYPERSTHENE) 5.28794
FERROSILITE(HYPERSTHENE) 4.25778

** NORMATIVE RATIOS - CIPW **
OR:AB:AN       18.3234  43.6127  38.0639
Q:OR:AB        11.6682  26.1323  62.1995
Q:OR:AB+AN       7.56273  16.9376  75.4997
LC+NE+KS:OR:AB+AN    0  18.3234  81.6766
NORMATIVE PLAGIOCLASE CONTENT= AN 46.6032
NORMATIVE COLOR INDEX=      18.6036

** PETROCHEMICAL INDICES **
ALKALI INDEX      37.5618
FELSIC INDEX      47.5333
MAFIC INDEX       78.6043
SOLIDIFICATION INDEX        13.8478
DIFFERENTIATION INDEX       51.9344
CRYSTALLIZATION INDEX       32.7225
WEATHERING INDEX (PARKER,1970)             78.1478
ALTERATION INDEX (ISHIKAWA ETAL,1976)  30.2063
PERALUMINOUS INDEX          -10.1473
THETA INDEX (SUGIMURA,1968)      40.0242
S INDEX (RITTMAN,1960)           3.09727

THE ROCK IS METALUMINOUS (SHAND,1945)
THE ROCK IS SUBALKALIC (IRVINE & BARAGAR,1971)
THE ROCK IS CALC-ALKALIC (IRVINE & BARAGAR,1971)
THE ROCK IS THOLEIITIC (MIYASHIRO,1974)
THE ROCK IS ALKALIC (KUNO,1966)
THE ROCK IS ALKALIC (MACDONALD & KATSURA,1964)
THE ROCK IS THOLEIITIC (MACDONALD & KATSURA,1964)
THE ROCK IS KOMATIITIC (NALDRETT & ARNDT,1976)

ACCORDING TO THE IUGS CLASSIFICATION THE ROCK IS A
QUARTZ MONZODIORITE
OR  QUARTZ ANDESITE
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$$$$$*****$$$$$*****$$$$$*****$$$$$*****$$$$$*****$$$$$
SAMPLE NUMBER  STEAMBOAT HILLS 3323

** INPUT DATA **
SIO2 76.87      AL2O3 13.33     FE2O3 .7288     FEO 0
MGO  .129       CAO   .5855     NA2O  3.49      K2O 4.64
TIO2 .0616      P2O5  .0414     MNO   .1016
SUM OF OXIDES 99.9779
** NORMALIZED OXIDE VALUES **
SIO2 76.887     AL2O3 13.3329   FE2O3 .728961   FEO 0
MGO  .129029    CAO   .585629   NA2O  3.49077   K2O 4.64103
TIO2 6.16136E-2                 P2O5  4.14092E-2

** MOLE NUMBERS **
SI 1.27974      AL .130766      FE+3 4.56485E-3
FE+2 0
MG 3.20091E-3   CA 1.04428E-2   NA 5.63209E-2   K 4.92678E-2
TI 7.71134E-4   P 2.91737E-4    MN 1.43251E-3

** NIGGLI NUMBERS **
AL 50.1864      FM  5.28232
C  4.00779      ALK 40.5235     SI 491.148
K  .466601      MG  .232561
TI .295951      P   .111965

** ATOMIC WEIGHT PERCENTS **
SI 35.937       AL 7.05713      FE+3 .509835    FE+2 0
MG .07783       CA .418549      NA   2.5898     K    3.85252
TI 3.69374E-2   P  .018071      MN 6.42152E-2   O    49.4381

** OXIDE-SILICA RATIOS **
AL2O3/SIO2       .17341
FE2O3/SIO2       9.48094E-3
FEO/SIO2         0
FEO*/SIO2        8.53095E-3
MGO/SIO2         1.67816E-3
CAO/SIO2         7.61676E-3
NA2O/SIO2        4.54013E-2
K2O/SIO2         6.03616E-2

** OTHER OXIDE RATIOS **
NA2O/K2O         .752155
K2O/NA2O         1.32951
FEO*             .655919
FEO*/MGO         5.08352
NA2O + K2O       8.1318
A:F:M=           91.1969  7.35604  1.44704
NA2O:K2O:CAO     40.0436  53.2385  6.71792

MGO:AL2O3:(CAO+NA2O+K2O)     (MOLE PROP.)
 1.28037  52.3068  46.4128

A:C:F =   66.3619  23.3  10.3381

1/3SIO2+K2O-MGO-CAO-FEO (LARSEN,1938)= 28.8486

**** NORMATIVE MINERALS ****
QUARTZ 37.494
CORUNDUM 1.60143
ORTHOCLASE 27.4244
ALBITE 29.5358
ANORTHITE 2.63491
HYPERSTHENE .321339
MAGNETITE .153136
HEMATITE .623346
ILMENITE .11702
APATITE 9.58852E-2
SUM 100.001
MNO   .101622
ENSTATITE(HYPERSTHENE) .321339

** NORMATIVE RATIOS - CIPW **
OR:AB:AN        46.0179  49.5608  4.42134
Q:OR:AB         39.6954  29.0346  31.27
Q:OR:AB+AN         38.6181  28.2466  33.1352
LC+NE+KS:OR:AB+AN    0  46.0179  53.9821
NORMATIVE PLAGIOCLASE CONTENT= AN 8.19038
NORMATIVE COLOR INDEX=      1.21484

** PETROCHEMICAL INDICES **
ALKALI INDEX      57.0726
FELSIC INDEX      93.2821
MAFIC INDEX       84.9615
SOLIDIFICATION INDEX        1.44704
DIFFERENTIATION INDEX       94.4542
CRYSTALLIZATION INDEX       2.86011
WEATHERING INDEX (PARKER,1970)          73.4274
ALTERATION INDEX (ISHIKAWA ETAL,1976)  53.9205
PERALUMINOUS INDEX           11.2682
THETA INDEX (SUGIMURA,1968)      48.2216
S INDEX (RITTMAN,1960)           1.95137

THE ROCK IS PERALUMINOUS (SHAND,1945)
THE ROCK IS SUBALKALIC (IRVINE & BARAGAR,1971)
THE ROCK IS CALC-ALKALIC (IRVINE & BARAGAR,1971)
THE ROCK IS CALC-ALKALIC (MIYASHIRO,1974)
THE ROCK IS HIGH ALUMINA (KUNO,1966)
THE ROCK IS KOMATIITIC (NALDRETT & ARNDT,1976)


ACCORDING TO THE IUGS CLASSIFICATION THE ROCK IS A
GRANITE (3B)  OR RHYOLITE
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$$******$$$$$******$$$$$******$$$$$******$$$$$******$$$$$
SAMPLE NUMBER  STEAMBOAT HILLS 3327

** INPUT DATA **
SIO2 55.07      AL2O3 19.36     FE2O3 7.93      FEO 0
MGO  2.15       CAO   6.52      NA2O  4.43      K2O 2.31
TIO2 1.42       P2O5  .5301     MNO   .1358
MODIFIED FE2O3=  2.92
MODIFIED FEO=    4.508
SUM OF OXIDES 99.3539
** NORMALIZED OXIDE VALUES **
SIO2 55.4281    AL2O3 19.4859   FE2O3 2.93899   FEO 4.53731
MGO  2.16398    CAO   6.5624    NA2O  4.45881   K2O 2.32502
TIO2 1.42923    P2O5  .533547   MNO   .136683

** MOLE NUMBERS **
SI .922572      AL .191113      FE+3 1.84043E-2
FE+2 6.31498E-2
MG 5.36835E-2   CA .117019      NA 7.19395E-2   K 2.46818E-2
TI 1.78878E-2   P 3.75896E-3    MN 1.92674E-3

** NIGGLI NUMBERS **
AL 34.1071      FM  27.7656
C  20.8838      ALK 17.2435     SI 164.647
K  .255449      MG  .345054
TI 3.19235      P   .670845

** ATOMIC WEIGHT PERCENTS **
SI 25.9071      AL 10.3139      FE+3 2.05553    FE+2 3.52685
MG 1.30531      CA 4.69015      NA   3.30799    K     1.93
TI .856826      P  .23284       MN 8.63701E-2   O     45.7871

** OXIDE-SILICA RATIOS **
AL2O3/SIO2         .351553
FE2O3/SIO2         5.30234E-2
FEO/SIO2           8.18594E-2
FEO*/SIO2          .12957
MGO/SIO2           3.90412E-2
CAO/SIO2           .118395
NA2O/SIO2          8.04431E-2
K2O/SIO2           4.19466E-2

** OTHER OXIDE RATIOS **
NA2O/K2O           1.91775
K2O/NA2O           .521445
FEO*               7.18182
FEO*/MGO           3.3188
NA2O + K2O         6.78383
A:F:M=             42.0582  44.5256  13.4162
NA2O:K2O:CAO       33.4087  17.4208  49.1704

MGO:AL2O3:(CAO+NA2O+K2O)     (MOLE PROP.)
 11.7101  41.688  46.6018

A:C:F =    32.3787  33.5609  34.0604

1/3SIO2+K2O-MGO-CAO-FEO (LARSEN,1938)= 4.86602
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**** NORMATIVE MINERALS ****

QUARTZ 3.68792
ORTHOCLASE 13.7389
ALBITE 37.7265
ANORTHITE 26.2877
DIOPSIDE 2.27769
HYPERSTHENE 8.0718
MAGNETITE 4.26134
ILMENITE 2.71447
APATITE 1.23546
SUM 100.002

WOLLASTONITE(DIOPSIDE) 1.16268
ENSTATITE(DIOPSIDE) .654106
FERROSILITE(DIOPSIDE) .460912
ENSTATITE(HYPERSTHENE) 4.73518
FERROSILITE(HYPERSTHENE) 3.33662

** NORMATIVE RATIOS - CIPW **
OR:AB:AN     17.6699  48.5209  33.8092
Q:OR:AB      6.68668  24.9103  68.403
Q:OR:AB+AN      4.52834  16.8697  78.6019
LC+NE+KS:OR:AB+AN    0  17.6699  82.3301
NORMATIVE PLAGIOCLASE CONTENT= AN 41.0654
NORMATIVE COLOR INDEX=      17.3253

** PETROCHEMICAL INDICES **
ALKALI INDEX     34.273
FELSIC INDEX     50.8296
MAFIC INDEX      77.5527
SOLIDIFICATION INDEX          13.4162
DIFFERENTIATION INDEX         55.1533
CRYSTALLIZATION INDEX         31.0172
WEATHERING INDEX (PARKER,1970)            83.5082
ALTERATION INDEX (ISHIKAWA ETAL,1976)  28.9422
PERALUMINOUS INDEX            -11.7871
THETA INDEX (SUGIMURA,1968)       39.0655
S INDEX (RITTMAN,1960)            3.70292

THE ROCK IS METALUMINOUS (SHAND,1945)
THE ROCK IS ALKALIC (IRVINE & BARAGAR,1971)
THE ROCK IS THOLEIITIC (MIYASHIRO,1974)
THE ROCK IS ALKALIC (KUNO,1966)
THE ROCK IS ALKALIC (MACDONALD & KATSURA,1964)
THE ROCK IS THOLEIITIC (MACDONALD & KATSURA,1964)
THE ROCK IS KOMATIITIC (NALDRETT & ARNDT,1976)


ACCORDING TO THE IUGS CLASSIFICATION THE ROCK IS A
MONZODIORITE
OR  ANDESITE
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$$$$$*****$$$$$*****$$$$$*****$$$$$*****$$$$$*****$$$$$
SAMPLE NUMBER  STEAMBOAT HILLS 3330

** INPUT DATA **
SIO2 55.52      AL2O3 18.95     FE2O3 8.49      FEO 0
MGO  1.87       CAO   6.55      NA2O  3.92      K2O 2.32
TIO2 1.63       P2O5  .5021     MNO   .1015
MODIFIED FE2O3=  3.13
MODIFIED FEO=    4.82293
SUM OF OXIDES 99.3165
** NORMALIZED OXIDE VALUES **
SIO2 55.9021    AL2O3 19.0804   FE2O3 3.15154   FEO 4.85612
MGO  1.88287    CAO   6.59508   NA2O  3.94698   K2O 2.33597
TIO2 1.64122    P2O5  .505555   MNO   .102198

** MOLE NUMBERS **
SI .930461      AL .187136      FE+3 1.97354E-2
FE+2 6.75869E-2
MG 4.67097E-2   CA .117601      NA 6.36815E-2   K 2.47979E-2
TI 2.05409E-2   P 3.56175E-3    MN 1.44063E-3

** NIGGLI NUMBERS **
AL 34.1218      FM  28.3022
C  21.443       ALK 16.133      SI 169.657
K  .280268      MG  .300926
TI 3.74535      P   .649438

** ATOMIC WEIGHT PERCENTS **
SI 26.1286      AL 10.0993      FE+3 2.20419    FE+2 3.77466
MG 1.13575      CA 4.7135       NA   2.92826    K    1.93909
TI .98391       P  .220624      MN 6.45792E-2   O    45.8076

** OXIDE-SILICA RATIOS **
AL2O3/SIO2        .341318
FE2O3/SIO2        5.63761E-2
FEO/SIO2          8.68683E-2
FEO*/SIO2         .137595
MGO/SIO2          3.36816E-2
CAO/SIO2          .117976
NA2O/SIO2         7.06052E-2
K2O/SIO2          4.17867E-2

** OTHER OXIDE RATIOS **
NA2O/K2O          1.68966
K2O/NA2O          .591837
FEO*              7.69187
FEO*/MGO          4.08519
NA2O + K2O        6.28294
A:F:M=            39.6208  48.5057  11.8735
NA2O:K2O:CAO      30.6489  18.1392  51.2119

MGO:AL2O3:(CAO+NA2O+K2O)      (MOLE PROP.)
 10.6176  42.5381  46.8443

A:C:F =    33.6599  33.435  32.9051

1/3SIO2+K2O-MGO-CAO-FEO (LARSEN,1938)= 4.81659
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**** NORMATIVE MINERALS ****

QUARTZ 7.19313
ORTHOCLASE 13.8035
ALBITE 33.3958
ANORTHITE 27.4463
DIOPSIDE 1.61911
HYPERSTHENE 7.68608
MAGNETITE 4.56953
ILMENITE 3.11708
APATITE 1.17064
SUM 100.001

WOLLASTONITE(DIOPSIDE) .822846
ENSTATITE(DIOPSIDE) .440187
FERROSILITE(DIOPSIDE) .356074
ENSTATITE(HYPERSTHENE) 4.249
FERROSILITE(HYPERSTHENE) 3.43708

** NORMATIVE RATIOS - CIPW **
OR:AB:AN        18.4921  44.7391  36.7688
Q:OR:AB         13.2245  25.3776  61.3979
Q:OR:AB+AN        8.78939  16.8667  74.3439
LC+NE+KS:OR:AB+AN    0  18.4921  81.5079
NORMATIVE PLAGIOCLASE CONTENT= AN 45.1107
NORMATIVE COLOR INDEX=        16.9918

** PETROCHEMICAL INDICES **
ALKALI INDEX        37.1795
FELSIC INDEX        48.7881
MAFIC INDEX         80.9629
SOLIDIFICATION INDEX        11.8735
DIFFERENTIATION INDEX       54.3925
CRYSTALLIZATION INDEX       31.3737
WEATHERING INDEX (PARKER,1970)            78.1936
ALTERATION INDEX (ISHIKAWA ETAL,1976)  28.5812
PERALUMINOUS INDEX          -10.1233
THETA INDEX (SUGIMURA,1968)       40.4256
S INDEX (RITTMAN,1960)            3.05961

THE ROCK IS METALUMINOUS (SHAND,1945)
THE ROCK IS SUBALKALIC (IRVINE & BARAGAR,1971)
THE ROCK IS CALC-ALKALIC (IRVINE & BARAGAR,1971)
THE ROCK IS THOLEIITIC (MIYASHIRO,1974)
THE ROCK IS ALKALIC (KUNO,1966)
THE ROCK IS ALKALIC (MACDONALD & KATSURA,1964)
THE ROCK IS THOLEIITIC (MACDONALD & KATSURA,1964)
THE ROCK IS KOMATIITIC (NALDRETT & ARNDT,1976)


ACCORDING TO THE IUGS CLASSIFICATION THE ROCK IS A
QUARTZ MONZODIORITE
OR  QUARTZ ANDESITE
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SAMPLE NUMBER  STEAMBOAT HILLS 3333

** INPUT DATA **
SIO2 54.72      AL2O3 18.74     FE2O3 8.33      FEO 0
MGO  2.74       CAO   6.69      NA2O  4.24      K2O 2.27
TIO2 1.51       P2O5  .4873     MNO   .1351
MODIFIED FE2O3=  3.01
MODIFIED FEO=    4.78694
SUM OF OXIDES 99.3293
** NORMALIZED OXIDE VALUES **
SIO2 55.0895    AL2O3 18.8665   FE2O3 3.03032   FEO 4.81926
MGO  2.7585     CAO   6.73517   NA2O  4.26863   K2O 2.28533
TIO2 1.5202     P2O5  .49059    MNO   .136012

** MOLE NUMBERS **
SI .916935      AL .185029      FE+3 1.89763E-2
FE+2 6.70739E-2
MG 6.84322E-2   CA .120099      NA 6.88711E-2   K 2.42604E-2
TI 1.90262E-2   P 3.45632E-3    MN 1.91728E-3

** NIGGLI NUMBERS **
AL 32.256       FM  30.5736
C  20.9357      ALK 16.2347     SI 159.84
K  .260496      MG  .390177
TI 3.31666      P   .602507

** ATOMIC WEIGHT PERCENTS **
SI 25.7488      AL 9.98605      FE+3 2.11941    FE+2 3.74601
MG 1.66393      CA 4.81363      NA   3.1669     K    1.89705
TI .911357      P  .214094      MN 8.59461E-2   O    45.6468

** OXIDE-SILICA RATIOS **
AL2O3/SIO2          .342471
FE2O3/SIO2          5.50073E-2
FEO/SIO2            8.74806E-2
FEO*/SIO2           .136976
MGO/SIO2            5.00731E-2
CAO/SIO2            .122259
NA2O/SIO2           7.74854E-2
K2O/SIO2            4.14839E-2

** OTHER OXIDE RATIOS **
NA2O/K2O            1.86784
K2O/NA2O            .535377
FEO*                7.54594
FEO*/MGO            2.73552
NA2O + K2O          6.55396
A:F:M=              38.8765  44.7607  16.3628
NA2O:K2O:CAO        32.1212  17.197   50.6818

MGO:AL2O3:(CAO+NA2O+K2O)      (MOLE PROP.)
 14.6629  39.6482  45.6889

A:C:F =   30.0982  32.5997  37.3021

1/3SIO2+K2O-MGO-CAO-FEO (LARSEN,1938)= 3.55514
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**** NORMATIVE MINERALS ****

QUARTZ 3.49839
ORTHOCLASE 13.5043
ALBITE 36.1174
ANORTHITE 25.5686
DIOPSIDE 3.77663
HYPERSTHENE 9.11946
MAGNETITE 4.39377
ILMENITE 2.88723
APATITE 1.13599
SUM 100.002

WOLLASTONITE(DIOPSIDE) 1.93786
ENSTATITE(DIOPSIDE) 1.15276
FERROSILITE(DIOPSIDE) .686015
ENSTATITE(HYPERSTHENE) 5.71715
FERROSILITE(HYPERSTHENE) 3.40232

** NORMATIVE RATIOS - CIPW **
OR:AB:AN      17.9602  48.0347  34.0052
Q:OR:AB       6.58582  25.4222  67.992
Q:OR:AB+AN       4.44587  17.1617  78.3924
LC+NE+KS:OR:AB+AN    0  17.9602  82.0398
NORMATIVE PLAGIOCLASE CONTENT= AN 41.4496
NORMATIVE COLOR INDEX=     20.1771

** PETROCHEMICAL INDICES **
ALKALI INDEX     34.8694
FELSIC INDEX     49.3182
MAFIC INDEX      73.9962
SOLIDIFICATION INDEX        16.3628
DIFFERENTIATION INDEX       53.12
CRYSTALLIZATION INDEX       32.0619
WEATHERING INDEX (PARKER,1970)            83.4973
ALTERATION INDEX (ISHIKAWA ETAL,1976)     31.4304
PERALUMINOUS INDEX          -15.2359
THETA INDEX (SUGIMURA,1968)      38.7624
S INDEX (RITTMAN,1960)           3.55304

THE ROCK IS METALUMINOUS (SHAND,1945)
THE ROCK IS ALKALIC (IRVINE & BARAGAR,1971)
THE ROCK IS THOLEIITIC (MIYASHIRO,1974)
THE ROCK IS ALKALIC (KUNO,1966)
THE ROCK IS ALKALIC (MACDONALD & KATSURA,1964)
THE ROCK IS THOLEIITIC (MACDONALD & KATSURA,1964)
THE ROCK IS KOMATIITIC (NALDRETT & ARNDT,1976)


ACCORDING TO THE IUGS CLASSIFICATION THE ROCK IS A
MONZODIORITE
OR  ANDESITE
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$$$$$*****$$$$$*****$$$$$*****$$$$$*****$$$$$*****$$$$$
SAMPLE NUMBER  CARSON CITY 3339

** INPUT DATA **
SIO2 54.69     AL2O3 17.07    FE2O3 9.58     FEO 0
MGO  3.08      CAO   6.99     NA2O  4.16     K2O 1.98
TIO2 1.65      P2O5  .526     MNO   .1574
MODIFIED FE2O3=  3.15
MODIFIED FEO=    5.78571
SUM OF OXIDES 99.2391
** NORMALIZED OXIDE VALUES **
SIO2 55.1093   AL2O3 17.2009  FE2O3 3.17415  FEO 5.83007
MGO  3.10361   CAO   7.04359  NA2O  4.1919   K2O 1.99518
TIO2 1.66265   P2O5  .530033  MNO   .158607

** MOLE NUMBERS **
SI .917266     AL .168702     FE+3 .019877
FE+2 8.11423E-2
MG 7.69937E-2  CA .125599     NA .067633     K 2.11803E-2
TI 2.08091E-2  P 3.73420E-3   MN 2.23579E-3

** NIGGLI NUMBERS **
AL 28.9243     FM  34.3143
C  21.5342     ALK 15.2272    SI 157.267
K  .238481     MG  .3847
TI 3.56777     P   .640236

** ATOMIC WEIGHT PERCENTS **
SI 25.7581     AL 9.10443     FE+3 2.22      FE+2 4.53172
MG 1.8721      CA 5.03406     NA   3.10997   K    1.6562
TI .996759     P  .231306     MN .100224     O    45.3851

** OXIDE-SILICA RATIOS **
AL2O3/SIO2       .312123
FE2O3/SIO2       5.75974E-2
FEO/SIO2         .105791
FEO*/SIO2        .157617
MGO/SIO2         5.63174E-2
CAO/SIO2         .127811
NA2O/SIO2        7.60651E-2
K2O/SIO2         3.62041E-2

** OTHER OXIDE RATIOS **
NA2O/K2O         2.10101
K2O/NA2O         .475962
FEO*             8.68618
FEO*/MGO         2.79873
NA2O + K2O       6.18708
A:F:M=           34.4169  48.3186  17.2645
NA2O:K2O:CAO     31.6832  15.08  53.2369

MGO:AL2O3:(CAO+NA2O+K2O)     (MOLE PROP.)
 16.7338  36.6658  46.6004

A:C:F =   25.8637  32.5608  41.5755

1/3SIO2+K2O-MGO-CAO-FEO (LARSEN,1938)= 1.40832
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**** NORMATIVE MINERALS ****

QUARTZ 4.30456
ORTHOCLASE 11.7898
ALBITE 35.4681
ANORTHITE 22.2251
DIOPSIDE 7.5801
HYPERSTHENE 9.64689
MAGNETITE 4.60231
ILMENITE 3.15779
APATITE 1.22732
SUM 100.002

WOLLASTONITE(DIOPSIDE) 3.86525
ENSTATITE(DIOPSIDE) 2.14894
FERROSILITE(DIOPSIDE) 1.56592
ENSTATITE(HYPERSTHENE) 5.58046
FERROSILITE(HYPERSTHENE) 4.06644

** NORMATIVE RATIOS - CIPW **
OR:AB:AN      16.9679  51.0457  31.9864
Q:OR:AB       8.34824  22.8651  68.7867
Q:OR:AB+AN       5.83372  15.978  78.1883
LC+NE+KS:OR:AB+AN    0  16.9679  83.0321
NORMATIVE PLAGIOCLASE CONTENT= AN 38.5229
NORMATIVE COLOR INDEX=     24.9871

** PETROCHEMICAL INDICES **
ALKALI INDEX     32.2476
FELSIC INDEX     46.7631
MAFIC INDEX      74.3669
SOLIDIFICATION INDEX       17.2645
DIFFERENTIATION INDEX      51.5625
CRYSTALLIZATION INDEX      30.7714
WEATHERING INDEX (PARKER,1970)          82.0628
ALTERATION INDEX (ISHIKAWA ETAL,1976)  31.2153
PERALUMINOUS INDEX        -27.0951
THETA INDEX (SUGIMURA,1968)     38.2036
S INDEX (RITTMAN,1960)          3.16119

THE ROCK IS METALUMINOUS (SHAND,1945)
THE ROCK IS SUBALKALIC (IRVINE & BARAGAR,1971)
THE ROCK IS CALC-ALKALIC (IRVINE & BARAGAR,1971)
THE ROCK IS THOLEIITIC (MIYASHIRO,1974)
THE ROCK IS ALKALIC (KUNO,1966)
THE ROCK IS ALKALIC (MACDONALD & KATSURA,1964)
THE ROCK IS THOLEIITIC (MACDONALD & KATSURA,1964)
THE ROCK IS KOMATIITIC (NALDRETT & ARNDT,1976)


ACCORDING TO THE IUGS CLASSIFICATION THE ROCK IS A
QUARTZ MONZODIORITE
OR  QUARTZ ANDESITE
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SAMPLE NUMBER  CARSON CITY 3340

** INPUT DATA **
SIO2 57.35      AL203 18.34     FE203 8.49      FEO 0
MGO  1.62       CAO   6.04      NA20  4.26      K20 1.88
TIO2 1.28       P205   .465     MNO    .143
MODIFIED FE203=  2.78
MODIFIED FEO=    5.13786
SUM OF OXIDES 99.2959
** NORMALIZED OXIDE VALUES **
SIO2 57.7567    AL203 18.4701   FE203 2.79971   FEO 5.17429
MGO  1.63149    CAO   6.08283   NA20  4.29021   K20 1.89333
TIO2 1.28908    P205  .468297   MNO    .144014

** MOLE NUMBERS **
SI .96133       AL .18115       FE+3 1.75322E-2
FE+2 7.20152E-2
MG 4.04735E-2  CA .108467       NA 6.92193E-2  K 2.00991E-2
TI 1.61336E-2  P 3.29926E-3     MN 2.03008E-3

** NIGGLI NUMBERS **
AL 34.2743      FM  28.304
C  20.5224      ALK 16.8994     SI 181.887
K  .225027      MG  .270553
TI 3.05254      P   .624233

** ATOMIC WEIGHT PERCENTS **
SI 26.9955      AL 9.7762       FE+3 1.95812    FE+2 4.02198
MG .984114      CA 4.3474       NA   3.18291    K    1.57165
TI .772802      P  .204365      MN 9.10025E-2   O    46.094

** OXIDE-SILICA RATIOS **
AL203/SIO2          .319791
FE203/SIO2          4.84743E-2
FEO/SIO2            8.95878E-2
FEO*/SIO2           .133205
MGO/SIO2            2.82476E-2
CAO/SIO2            .105318
NA20/SIO2           7.42807E-2
K20/SIO2            3.27812E-2

** OTHER OXIDE RATIOS **
NA20/K20            2.26596
K20/NA20            .441315
FEO*                7.69347
FEO*/MGO            4.71562
NA20 + K20          6.18354
A:F:M=              39.8719  49.6081  10.52
NA20:K20:CAO        34.9754  15.4351  49.5895

MGO:AL203:(CAO+NA20+K20)      (MOLE PROP.)
 9.65014  43.1917  47.1581

A:C:F =   32.9063  32.6364  34.4573

1/3SIO2+K20-MGO-CAO-FEO (LARSEN,1938)= 5.71012
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**** NORMATIVE MINERALS ****

QUARTZ 9.3277
ORTHOCLASE 11.1879
ALBITE 36.3
ANORTHITE 25.5476
DIOPSIDE 1.31222
HYPERSTHENE 8.73434
MAGNETITE 4.0594
ILMENITE 2.44828
APATITE 1.08437
SUM 100.002

WOLLASTONITE(DIOPSIDE) .656164
ENSTATITE(DIOPSIDE) .283871
FERROSILITE(DIOPSIDE) .372189
ENSTATITE(HYPERSTHENE) 3.77927
FERROSILITE(HYPERSTHENE) 4.95508

** NORMATIVE RATIOS - CIPW **
OR:AB:AN      15.3185  49.7018  34.9797
Q:OR:AB       16.4175  19.6917  63.8908
Q:OR:AB+AN       11.3251  13.5837  75.0912
LC+NE+KS:OR:AB+AN    0  15.3185  84.6815
NORMATIVE PLAGIOCLASE CONTENT= AN 41.3073
NORMATIVE COLOR INDEX=      16.5542

** PETROCHEMICAL INDICES **
ALKALI INDEX      30.6189
FELSIC INDEX      50.4105
MAFIC INDEX       83.0151
SOLIDIFICATION INDEX        10.52
DIFFERENTIATION INDEX       56.8156
CRYSTALLIZATION INDEX       28.8086
WEATHERING INDEX (PARKER,1970)            75.5994
ALTERATION INDEX (ISHIKAWA ETAL,1976)  25.3623
PERALUMINOUS INDEX          -9.18319
THETA INDEX (SUGIMURA,1968)      42.0217
S INDEX (RITTMAN,1960)           2.59111

THE ROCK IS METALUMINOUS (SHAND,1945)
THE ROCK IS SUBALKALIC (IRVINE & BARAGAR,1971)
THE ROCK IS CALC-ALKALIC (IRVINE & BARAGAR,1971)
THE ROCK IS THOLEIITIC (MIYASHIRO,1974)
THE ROCK IS HIGH ALUMINA (KUNO,1966)
THE ROCK IS KOMATIITIC (NALDRETT & ARNDT,1976)


ACCORDING TO THE IUGS CLASSIFICATION THE ROCK IS A
QUARTZ MONZODIORITE
OR  QUARTZ ANDESITE
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SAMPLE NUMBER  TABLE MOUNTAIN 3344

** INPUT DATA **
SIO2 57.1       AL2O3 19.33     FE2O3 7.17      FEO 0
MGO  2.36       CAO   7.79      NA2O  3.83      K2O 1.12
TIO2 .7752      P2O5  .3278     MNO   .1364
MODIFIED FE2O3=  2.2752
MODIFIED FEO=    4.40434
SUM OF OXIDES 99.4489
** NORMALIZED OXIDE VALUES **
SIO2 57.4164    AL2O3 19.4371   FE2O3 2.28781   FEO 4.42875
MGO  2.37308    CAO   7.83317   NA2O  3.85122   K2O 1.12621
TIO2 .779495    P2O5  .329616   MNO   .137156

** MOLE NUMBERS **
SI .955666      AL .190635      FE+3 1.43266E-2
FE+2 6.16388E-2
MG 5.88707E-2   CA .139678      NA 6.21365E-2   K 1.19555E-2
TI 9.75589E-3   P 2.32222E-3    MN 1.93341E-3

** NIGGLI NUMBERS **
AL 34.317       FM  27.2013
C  25.1441      ALK 13.3376     SI 172.033
K  .16136       MG  .389598
TI 1.7562       P   .418033

** ATOMIC WEIGHT PERCENTS **
SI 26.8364      AL 10.2881      FE+3 1.60009    FE+2 3.44246
MG 1.43144      CA 5.59836      NA   2.85722    K     .934864
TI .467308      P  .143845      MN 8.66688E-2   O     46.3132

** OXIDE-SILICA RATIOS **
AL2O3/SIO2        .338529
FE2O3/SIO2        3.98459E-2
FEO/SIO2          7.71338E-2
FEO*/SIO2         .112987
MGO/SIO2          .041331
CAO/SIO2          .136427
NA2O/SIO2         6.70753E-2
K2O/SIO2          1.96147E-2

** OTHER OXIDE RATIOS **
NA2O/K2O          3.41964
K2O/NA2O          .292428
FEO*              6.48731
FEO*/MGO          2.73371
NA2O + K2O        4.97743
A:F:M=            35.9697  46.881  17.1492
NA2O:K2O:CAO      30.0628  8.79121  61.146

MGO:AL2O3:(CAO+NA2O+K2O)      (MOLE PROP.)
 12.7075  41.1493  46.1432

A:C:F =   33.3009  35.5424  31.1567

1/3SIO2+K2O-MGO-CAO-FEO (LARSEN,1938)= 3.48088
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**** NORMATIVE MINERALS ****

QUARTZ 9.86905
ORTHOCLASE 6.6549
ALBITE 32.5856
ANORTHITE 32.4222
DIOPSIDE 3.53051
HYPERSTHENE 9.37859
MAGNETITE 3.31717
ILMENITE 1.48046
APATITE .763245
SUM 100.002

WOLLASTONITE(DIOPSIDE) 1.78918
ENSTATITE(DIOPSIDE) .925482
FERROSILITE(DIOPSIDE) .815842
ENSTATITE(HYPERSTHENE) 4.98455
FERROSILITE(HYPERSTHENE) 4.39404

** NORMATIVE RATIOS - CIPW **
OR:AB:AN       9.28642  45.4709  45.2427
Q:OR:AB        20.096  13.5511  66.3529
Q:OR:AB+AN        12.1046  8.16234  79.7331
LC+NE+KS:OR:AB+AN    0  9.28642  90.7136
NORMATIVE PLAGIOCLASE CONTENT= AN 49.8743
NORMATIVE COLOR INDEX=      17.7067

** PETROCHEMICAL INDICES **
ALKALI INDEX      22.6263
FELSIC INDEX      38.854
MAFIC INDEX       73.8925
SOLIDIFICATION INDEX        17.1492
DIFFERENTIATION INDEX       49.1096
CRYSTALLIZATION INDEX       37.9118
WEATHERING INDEX (PARKER,1970)            71.5413
ALTERATION INDEX (ISHIKAWA ETAL,1976)  23.0464
PERALUMINOUS INDEX          -12.1362
THETA INDEX (SUGIMURA,1968)      45.3807
S INDEX (RITTMAN,1960)           1.71851

THE ROCK IS METALUMINOUS (SHAND,1945)
THE ROCK IS SUBALKALIC (IRVINE & BARAGAR,1971)
THE ROCK IS CALC-ALKALIC (IRVINE & BARAGAR,1971)
THE ROCK IS THOLEIITIC (MIYASHIRO,1974)
THE ROCK IS HIGH ALUMINA (KUNO,1966)
THE ROCK IS KOMATIITIC (NALDRETT & ARNDT,1976)


ACCORDING TO THE IUGS CLASSIFICATION THE ROCK IS A
QUARTZ DIORITE
OR  QUARTZ ANDESITE
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SAMPLE NUMBER  SILVER SPRINGS 3345

** INPUT DATA **
SI02 56.64      AL203 18.52     FE203 8.4       FEO 0
MGO  2.09       CAO   6.86      NA20  4         K20 1.75
TI02 1.17       P205  .3258     MNO   .1357
MODIFIED FE203=  2.67
MODIFIED FEO=    5.15585
SUM OF OXIDES 99.3174
** NORMALIZED OXIDE VALUES **
SI02 57.0293    AL203 18.6473   FE203 2.68835   FEO 5.19129
MGO  2.10437    CAO   6.90715   NA20  4.02749   K20 1.76203
TI02 1.17804    P205  .328039   MNO   .136633

** MOLE NUMBERS **
SI .949223      AL .182888      FE+3 1.68348E-2
FE+2 7.22518E-2
MG 5.22045E-2   CA .123166      NA 6.49805E-2   K 1.87052E-2
TI .014744      P 2.31111E-3    MN 1.92603E-3

** NIGGLI NUMBERS **
AL 33.2643      FM  29.1129
C  22.4018      ALK 15.221      SI 172.647
K  .223517      MG  .326148
TI 2.68167      P   .420352

** ATOMIC WEIGHT PERCENTS **
SI 26.6555      AL 9.87001      FE+3 1.88023    FE+2 4.03519
MG 1.26935      CA 4.93654      NA   2.988      K    1.46266
TI .706236      P  .143156      MN 8.63382E-2   O    45.9668

** OXIDE-SILICA RATIOS **
AL203/SI02          .326977
FE203/SI02          4.71398E-2
FEO/SI02            9.10285E-2
FEO*/SI02           .133445
MGO/SI02            3.68997E-2
CAO/SI02            .121116
NA20/SI02           7.06215E-2
K20/SI02            3.08969E-2

** OTHER OXIDE RATIOS **
NA20/K20            2.28571
K20/NA20            .4375
FEO*                7.61027
FEO*/MGO            3.61642
NA20 + K20          5.78952
A:F:M=              37.3417  49.0854  13.5729
NA20:K20:CAO        31.7209  13.8779  54.4013

MGO:AL203:(CAO+NA20+K20)      (MOLE PROP.)
 11.8125  41.3826  46.8049

A:C:F =    31.7401  33.69  34.5698

1/3SI02+K20-MGO-CAO-FEO (LARSEN,1938)= 4.08592
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**** NORMATIVE MINERALS ****

QUARTZ 8.26895
ORTHOCLASE 10.4121
ALBITE 34.0771
ANORTHITE 27.5982
DIOPSIDE 3.75325
HYPERSTHENE 8.99728
MAGNETITE 3.89793
ILMENITE 2.23739
APATITE .759593
SUM 100.002

WOLLASTONITE(DIOPSIDE) 1.88962
ENSTATITE(DIOPSIDE) .899275
FERROSILITE(DIOPSIDE) .964356
ENSTATITE(HYPERSTHENE) 4.34154
FERROSILITE(HYPERSTHENE) 4.65574

** NORMATIVE RATIOS - CIPW **
OR:AB:AN     14.4437  47.272  38.2844
Q:OR:AB      15.6733  19.7355  64.5912
Q:OR:AB+AN      10.2904  12.9574  76.7523
LC+NE+KS:OR:AB+AN    0  14.4437  85.5563
NORMATIVE PLAGIOCLASE CONTENT= AN 44.7476
NORMATIVE COLOR INDEX=      18.8859

** PETROCHEMICAL INDICES **
ALKALI INDEX     30.4348
FELSIC INDEX     45.5987
MAFIC INDEX      78.9226
SOLIDIFICATION INDEX        13.5729
DIFFERENTIATION INDEX       52.7581
CRYSTALLIZATION INDEX       32.5806
WEATHERING INDEX (PARKER,1970)              75.4664
ALTERATION INDEX (ISHIKAWA ETAL,1976)  26.1224
PERALUMINOUS INDEX          -13.1028
THETA INDEX (SUGIMURA,1968)      42.437
S INDEX (RITTMAN,1960)           2.38918

THE ROCK IS METALUMINOUS (SHAND,1945)
THE ROCK IS SUBALKALIC (IRVINE & BARAGAR,1971)
THE ROCK IS CALC-ALKALIC (IRVINE & BARAGAR,1971)
THE ROCK IS THOLEIITIC (MIYASHIRO,1974)
THE ROCK IS HIGH ALUMINA (KUNO,1966)
THE ROCK IS KOMATIITIC (NALDRETT & ARNDT,1976)


ACCORDING TO THE IUGS CLASSIFICATION THE ROCK IS A
QUARTZ MONZODIORITE
OR  QUARTZ ANDESITE
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$$$$$*****$$$$$*****$$$$$*****$$$$$*****$$$$$*****$$$$$
SAMPLE NUMBER  MCCLELLAN PEAK 3346

** INPUT DATA **
SIO2 49.24      AL2O3 14.91     FE2O3 8.66      FEO 0
MGO  10.28      CAO    9.7      NA2O  3.11      K2O 1.74
TIO2 1.55       P2O5  .5714     MNO   .1372
MODIFIED FE2O3=  1.59344
MODIFIED FEO=     6.3651
SUM OF OXIDES 99.1971
** NORMALIZED OXIDE VALUES **
SIO2 49.6385    AL2O3 15.0307   FE2O3 1.60634   FEO 6.41662
MGO  10.3632    CAO    9.77851  NA2O  3.13517   K2O 1.75408
TIO2 1.56255    P2O5  .576025   MNO    .13831

** MOLE NUMBERS **
SI .826207      AL .147417      FE+3 1.00591E-2
FE+2 8.93057E-2
MG .257088      CA .174367      NA 5.05836E-2  K 1.86208E-2
TI 1.95563E-2  P 4.05823E-3     MN 1.94968E-3

** NIGGLI NUMBERS **
AL 19.4107      FM  48.5178
C  22.9592      ALK 9.11227     SI 108.788
K  .26907       MG  .697707
TI 2.57501      P   .534354

** ATOMIC WEIGHT PERCENTS **
SI 23.201       AL 7.95574      FE+3 1.12347   FE+2 4.98764
MG 6.25108      CA 6.9887       NA   2.32598   K     1.45606
TI .936746      P  .251377      MN 8.73984E-2  O     44.4348

** OXIDE-SILICA RATIOS **
AL2O3/SIO2        .302803
FE2O3/SIO2        3.23607E-2
FEO/SIO2          .129267
FEO*/SIO2         .158385
MGO/SIO2          .208773
CAO/SIO2          .196994
NA2O/SIO2         .06316
K2O/SIO2          3.53371E-2

** OTHER OXIDE RATIOS **
NA2O/K2O          1.78736
K2O/NA2O          .559486
FEO*              7.862
FEO*/MGO          .758646
NA2O + K2O        4.88925
A:F:M=            21.1524  34.0133  44.8343
NA2O:K2O:CAO      21.3746  11.9588  66.6667

MGO:AL2O3:(CAO+NA2O+K2O)      (MOLE PROP.)
 39.6693  22.7469  37.5838

A:C:F =    14.4476  28.5388  57.0136

1/3SIO2+K2O-MGO-CAO-FEO (LARSEN,1938)=-10.0734
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**** NORMATIVE MINERALS ****

ORTHOCLASE 10.3651
ALBITE 22.7552
ANORTHITE 21.7588
NEPHELINE 2.04336
DIOPSIDE 18.3998
OLIVINE 18.0488
MAGNETITE 2.32908
ILMENITE 2.96766
APATITE 1.33382
SUM 100.002

WOLLASTONITE(DIOPSIDE) 9.59949
ENSTATITE(DIOPSIDE) 6.69181
FERROSILITE(DIOPSIDE) 2.10852
FORSTERITE(OLIVINE) 13.3967
FAYALITE(OLIVINE) 4.65208

** NORMATIVE RATIOS - CIPW **
OR:AB:AN     18.8871  41.4642  39.6486
Q:OR:AB      0  31.2953  68.7047
Q:OR:AB+AN     0  18.8871  81.1129
LC+NE+KS:OR:AB+AN    3.58971  18.2091  78.2011
NORMATIVE PLAGIOCLASE CONTENT= AN 45.4069
NORMATIVE COLOR INDEX=     41.7454

** PETROCHEMICAL INDICES **
ALKALI INDEX      35.8763
FELSIC INDEX      33.3333
MAFIC INDEX       43.6358
SOLIDIFICATION INDEX        44.8343
DIFFERENTIATION INDEX       35.1637
CRYSTALLIZATION INDEX       49.5898
WEATHERING INDEX (PARKER,1970)          97.2517
ALTERATION INDEX (ISHIKAWA ETAL,1976)  48.4092
PERALUMINOUS INDEX          -65.2258
THETA INDEX (SUGIMURA,1968)      34.3501
S INDEX (RITTMAN,1960)           3.60092

THE ROCK IS METALUMINOUS (SHAND,1945)
THE ROCK IS ALKALIC (IRVINE & BARAGAR,1971)
THE ROCK IS CALC-ALKALIC (MIYASHIRO,1974)
THE ROCK IS ALKALIC (KUNO,1966)
THE ROCK IS ALKALIC (MACDONALD & KATSURA,1964)
THE ROCK IS THOLEIITIC (MACDONALD & KATSURA,1964)
THE ROCK IS KOMATIITIC (NALDRETT & ARNDT,1976)


ACCORDING TO THE IUGS CLASSIFICATION THE ROCK IS A
FOID-BEARING MONZODIORITE
OR  FOID-BEARING BASALT
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$$$$$*****$$$$$*****$$$$$*****$$$$$*****$$$$$*****$$$$$
SAMPLE NUMBER  CHURCHILL BUTTE 3347

** INPUT DATA **
SIO2 58.83      AL2O3 19.26     FE2O3 6.58      FEO 0
MGO  1.58       CAO   6.8       NA2O  4.14      K2O 1.54
TIO2 .8153      P2O5  .2565     MNO   .1189
MODIFIED FE2O3=  2.3153
MODIFIED FEO=    3.83738
SUM OF OXIDES 99.4934
** NORMALIZED OXIDE VALUES **
SIO2 59.1296    AL2O3 19.3581   FE2O3 2.32709   FEO 3.85692
MGO  1.58805    CAO   6.83463   NA2O  4.16108   K2O 1.54784
TIO2 .819452    P2O5  .257806   MNO   .119505

** MOLE NUMBERS **
SI .98418       AL .189859      FE+3 1.45725E-2
FE+2 5.36801E-2
MG 3.93958E-2   CA .121873      NA 6.71359E-2   K 1.64314E-2
TI .010256      P 1.81630E-3    MN 1.68460E-3

** NIGGLI NUMBERS **
AL 36.5667      FM  23.8658
C  23.4725      ALK 16.0949     SI 189.552
K  .196625      MG  .317926
TI 1.97528      P   .349818

** ATOMIC WEIGHT PERCENTS **
SI 27.6372      AL 10.2462      FE+3 1.62757    FE+2 2.99798
MG .957909      CA 4.88471      NA   3.08711    K     1.28486
TI .491261      P  .112507      MN 7.55155E-2   O     46.5972

** OXIDE-SILICA RATIOS **
AL2O3/SIO2         .327384
FE2O3/SIO2         3.93558E-2
FEO/SIO2           6.52282E-2
FEO*/SIO2          .100641
MGO/SIO2           .026857
CAO/SIO2           .115587
NA2O/SIO2          7.03723E-2
K2O/SIO2           2.61771E-2

** OTHER OXIDE RATIOS **
NA2O/K2O           2.68831
K2O/NA2O           .371981
FEO*               5.95083
FEO*/MGO           3.74727
NA2O + K2O         5.70892
A:F:M=             43.0934  44.9194  11.9872
NA2O:K2O:CAO       33.1731  12.3397  54.4872

MGO:AL2O3:(CAO+NA2O+K2O)     (MOLE PROP.)
 9.06286  43.6764  47.2607

A:C:F =    35.812  36.1107  28.0774

1/3SIO2+K2O-MGO-CAO-FEO (LARSEN,1938)= 6.85451
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**** NORMATIVE MINERALS ****

QUARTZ 11.4589
ORTHOCLASE 9.1464
ALBITE 35.2074
ANORTHITE 29.5705
DIOPSIDE 2.1955
HYPERSTHENE 6.89536
MAGNETITE 3.37413
ILMENITE 1.55634
APATITE .596964
SUM 100.002

WOLLASTONITE(DIOPSIDE) 1.10727
ENSTATITE(DIOPSIDE) .539092
FERROSILITE(DIOPSIDE) .549138
ENSTATITE(HYPERSTHENE) 3.41585
FERROSILITE(HYPERSTHENE) 3.47951

** NORMATIVE RATIOS - CIPW **
OR:AB:AN     12.3727  47.6263  40.001
Q:OR:AB      20.531  16.3877  63.0813
Q:OR:AB+AN      13.4206  10.7122  75.8672
LC+NE+KS:OR:AB+AN    0  12.3727  87.6273
NORMATIVE PLAGIOCLASE CONTENT= AN 45.649
NORMATIVE COLOR INDEX=      14.0213

** PETROCHEMICAL INDICES **
ALKALI INDEX       27.1127
FELSIC INDEX       45.5128
MAFIC INDEX        79.5672
SOLIDIFICATION INDEX          11.9872
DIFFERENTIATION INDEX         55.8127
CRYSTALLIZATION INDEX         33.1273
WEATHERING INDEX (PARKER,1970)            73.2705
ALTERATION INDEX (ISHIKAWA ETAL,1976)  22.1906
PERALUMINOUS INDEX          -8.20639
THETA INDEX (SUGIMURA,1968)      45.2687
S INDEX (RITTMAN,1960)           2.02062

THE ROCK IS METALUMINOUS (SHAND,1945)
THE ROCK IS SUBALKALIC (IRVINE & BARAGAR,1971)
THE ROCK IS CALC-ALKALIC (IRVINE & BARAGAR,1971)
THE ROCK IS THOLEIITIC (MIYASHIRO,1974)
THE ROCK IS HIGH ALUMINA (KUNO,1966)
THE ROCK IS KOMATIITIC (NALDRETT & ARNDT,1976)

ACCORDING TO THE IUGS CLASSIFICATION THE ROCK IS A
QUARTZ MONZODIORITE
OR  QUARTZ ANDESITE
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$$XXXXXX$$$$$XXXXXXX$$$$$XXXXXXX$$$$$XXXXXX$$$$$XXXXXXX$$$$$
SAMPLE NUMBER  CLEAVER PEAK 3348

** INPUT DATA **
SIO2 55.94      AL2O3 17.96     FE2O3 8.45      FEO 0
MGO  2.82       CAO    7.71     NA2O  3.79      K2O 1.63
TIO2 1.09       P2O5   .3471    MNO    .1319
MODIFIED FE2O3•  2.59
MODIFIED FEO•     5.27283
SUM OF OXIDES 99.2818
** NORMALIZED OXIDE VALUES **
SIO2 56.3447    AL2O3 18.0899   FE2O3 2.60874   FEO 5.31097
MGO  2.8404     CAO    7.76577  NA2O  3.81742   K2O 1.64179
TIO2 1.09788    P2O5   .349611  MNO    .132854

** MOLE NUMBERS **
SI .937827      AL .177422      FE+3 1.63362E-2
FE+2 7.39175E-2
MG 7.04639E-2   CA .138477      NA 6.15911E-2   K 1.74288E-2
TI 1.37407E-2   P 2.46309E-3    MN 1.87277E-3

** NIGGLI NUMBERS **
AL 30.9174      FM  31.1818
C  24.1309      ALK 13.77       SI 163.425
K   .220562     MG   .393787
TI 2.39445      P    .429216

** ATOMIC WEIGHT PERCENTS **
SI 26.3355      AL 9.57499      FE+3 1.82455    FE+2 4.12822
MG 1.71333      CA 5.5502       NA   2.83214    K     1.36285
TI .658182      P   .15257      MN 8.39505E-2   O     45.7835

** OXIDE-SILICA RATIOS **
AL2O3/SIO2          .321058
FE2O3/SIO2          4.62996E-2
FEO/SIO2            9.42586E-2
FEO*/SIO2           .135919
MGO/SIO2            5.04112E-2
CAO/SIO2            .137826
NA2O/SIO2           6.77512E-2
K2O/SIO2            2.91384E-2

** OTHER OXIDE RATIOS **
NA2O/K2O            2.32515
K2O/NA2O            .430079
FEO*                7.65831
FEO*/MGO            2.69621
NA2O + K2O          5.45921
A:F:M•              34.21  47.9907  17.7993
NA2O:K2O:CAO        28.8652  12.4143  58.7205

MGO:AL2O3:(CAO+NA2O+K2O)      (MOLE PROP.)
 15.1411  38.1239  46.735

A:C:F •    28.7227  34.6652  36.6121

1/3SIO2+K2O-MGO-CAO-FEO (LARSEN,1938)• 2.06123
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**** NORMATIVE MINERALS ****

QUARTZ 7.14077
ORTHOCLASE 9.70155
ALBITE 32.2996
ANORTHITE 27.3754
DIOPSIDE 7.29759
HYPERSTHENE 9.50956
MAGNETITE 3.78249
ILMENITE 2.08516
APATITE .809543
SUM 100.002

WOLLASTONITE(DIOPSIDE) 3.70234
ENSTATITE(DIOPSIDE) 1.94069
FERROSILITE(DIOPSIDE) 1.65457
ENSTATITE(HYPERSTHENE) 5.13318
FERROSILITE(HYPERSTHENE) 4.37638

** NORMATIVE RATIOS - CIPW **
OR:AB:AN       13.9839  46.5569  39.4591
Q:OR:AB        14.5309  19.7419  65.7272
Q:OR:AB+AN       9.33223  12.6789  77.9889
LC+NE+KS:OR:AB+AN     0  13.9839  86.0161
NORMATIVE PLAGIOCLASE CONTENT• AN 45.8741
NORMATIVE COLOR INDEX•      22.6748

** PETROCHEMICAL INDICES **
ALKALI INDEX       30.0738
FELSIC INDEX       41.2795
MAFIC INDEX        73.6025
SOLIDIFICATION INDEX          17.7993
DIFFERENTIATION INDEX         49.1419
CRYSTALLIZATION INDEX         35.159
WEATHERING INDEX (PARKER,1970)            76.725
ALTERATION INDEX (ISHIKAWA ETAL,1976)  27.8997
PERALUMINOUS INDEX            -22.5873
THETA INDEX (SUGIMURA,1968)      42.1609
S INDEX (RITTMAN,1960)           2.23332

THE ROCK IS METALUMINOUS (SHAND,1945)
THE ROCK IS SUBALKALIC (IRVINE & BARAGAR,1971)
THE ROCK IS CALC-ALKALIC (IRVINE & BARAGAR,1971)
THE ROCK IS THOLEIITIC (MIYASHIRO,1974)
THE ROCK IS HIGH ALUMINA (KUNO,1966)
THE ROCK IS KOMATIITIC (NALDRETT & ARNDT,1976)


ACCORDING TO THE IUGS CLASSIFICATION THE ROCK IS A
QUARTZ MONZODIORITE
OR  QUARTZ ANDESITE
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$$$$$*****$$$$$*****$$$$$*****$$$$$*****$$$$$*****$$$$$*****$$$$$
SAMPLE NUMBER  RATTLESNAKE HILL 3350

** INPUT DATA **
SIO2 53.61      AL2O3 18.94     FE2O3 7.76      FEO 0
MGO  2.46       CAO   7.42      NA2O  4.25      K2O 2.82
TIO2 1.69       P2O5  .7962     MNO   .1339
MODIFIED FE2O3=  3.19
MODIFIED FEO=    4.11209
SUM OF OXIDES 99.4222
** NORMALIZED OXIDE VALUES **
SIO2 53.9216    AL2O3 19.0501   FE2O3 3.20854   FEO 4.13598
MGO  2.4743     CAO   7.46312   NA2O  4.2747    K2O 2.83639
TIO2 1.69982    P2O5  .800827   MNO   .134678

** MOLE NUMBERS **
SI .897496      AL .186839      FE+3 2.00923E-2
FE+2 5.75642E-2
MG 6.13817E-2   CA .13308       NA .068969      K 3.01103E-2
TI 2.12744E-2   P 5.64201E-3    MN 1.89848E-3

** NIGGLI NUMBERS **
AL 32.2115      FM  27.7636
C  22.9433      ALK 17.0815     SI 154.731
K  .303901      MG  .381159
TI 3.66776      P   .972698

** ATOMIC WEIGHT PERCENTS **
SI 25.2029      AL 10.0832      FE+3 2.24405    FE+2 3.2149
MG 1.4925       CA 5.33389      NA   3.1714     K    2.35449
TI 1.01904      P  .349481      MN 8.51031E-2   O    45.449

** OXIDE-SILICA RATIOS **
AL2O3/SIO2        .353292
FE2O3/SIO2        5.95038E-2
FEO/SIO2          7.67037E-2
FEO*/SIO2         .130245
MGO/SIO2          .045887
CAO/SIO2          .138407
NA2O/SIO2         7.92763E-2
K2O/SIO2          5.26021E-2

** OTHER OXIDE RATIOS **
NA2O/K2O          1.50709
K2O/NA2O          .663529
FEO*              7.02303
FEO*/MGO          2.83839
NA2O + K2O        7.11109
A:F:M=            42.8162  42.286  14.8979
NA2O:K2O:CAO      29.3306  19.4617  51.2077

MGO:AL2O3:(CAO+NA2O+K2O)      (MOLE PROP.)
 12.7778  38.894  48.3283

A:C:F =    29.8117  36.7852  33.4031

1/3SIO2+K2O-MGO-CAO-FEO (LARSEN,1938)= 3.82301
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**** NORMATIVE MINERALS ****

QUARTZ 1.29119
ORTHOCLASE 16.7606
ALBITE 36.1687
ANORTHITE 24.4147
DIOPSIDE 5.93618
HYPERSTHENE 5.69536
MAGNETITE 4.65217
ILMENITE 3.22838
APATITE 1.85436
SUM 100.002

WOLLASTONITE(DIOPSIDE) 3.08203
ENSTATITE(DIOPSIDE) 2.05714
FERROSILITE(DIOPSIDE) .797004
ENSTATITE(HYPERSTHENE) 4.10497
FERROSILITE(HYPERSTHENE) 1.5904

** NORMATIVE RATIOS - CIPW **
OR:AB:AN      21.6702  46.7635  31.5663
Q:OR:AB       2.38137  30.9119  66.7067
Q:OR:AB+AN      1.642  21.3144  77.0436
LC+NE+KS:OR:AB+AN    0  21.6702  78.3298
NORMATIVE PLAGIOCLASE CONTENT= AN 40.2993
NORMATIVE COLOR INDEX=      19.5121

** PETROCHEMICAL INDICES **
ALKALI INDEX      39.8868
FELSIC INDEX      48.7923
MAFIC INDEX       74.8005
SOLIDIFICATION INDEX          14.8979
DIFFERENTIATION INDEX         54.2205
CRYSTALLIZATION INDEX         31.7288
WEATHERING INDEX (PARKER,1970)            89.3043
ALTERATION INDEX (ISHIKAWA ETAL,1976)  31.1504
PERALUMINOUS INDEX            -24.2565
THETA INDEX (SUGIMURA,1968)      36.3772
S INDEX (RITTMAN,1960)           4.63007

THE ROCK IS METALUMINOUS (SHAND,1945)
THE ROCK IS ALKALIC (IRVINE & BARAGAR,1971)
THE ROCK IS THOLEIITIC (MIYASHIRO,1974)
THE ROCK IS ALKALIC (KUNO,1966)
THE ROCK IS ALKALIC (MACDONALD & KATSURA,1964)
THE ROCK IS THOLEIITIC (MACDONALD & KATSURA,1964)
THE ROCK IS KOMATIITIC (NALDRETT & ARNDT,1976)


ACCORDING TO THE IUGS CLASSIFICATION THE ROCK IS A
MONZODIORITE
OR  ANDESITE
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***$$$$$******$$$$$******$$$$$******$$$$$******$$$$$
SAMPLE NUMBER  UPSAL HOGBACK 3352

** INPUT DATA **
SIO2 70.32      AL2O3 14.72     FE2O3 2.97      FEO 0
MGO  .5866      CAO   1.36      NA2O  4.61      K2O 4.76
TIO2 .427       P2O5  .078      MNO   .042
MODIFIED FE2O3=  1.927
MODIFIED FEO=    .938491
SUM OF OXIDES 99.7691
** NORMALIZED OXIDE VALUES **
SIO2 70.4828    AL2O3 14.7541   FE2O3 1.93146   FEO .940663
MGO  .587958    CAO   1.36315   NA2O  4.62067   K2O 4.77102
TIO2 .427988    P2O5  7.81805E-2                MNO   4.20972E-2

** MOLE NUMBERS **
SI 1.17315      AL .144704      FE+3 1.20951E-2
FE+2 .013092
MG 1.45859E-2   CA 2.43072E-2   NA .074551      K 5.06477E-2
TI 5.35655E-3   P 5.50800E-4    MN 5.93420E-4

** NIGGLI NUMBERS **
AL 41.7406      FM  15.1337
C  7.01152      ALK 36.1141     SI 338.4
K  .404539      MG  .278013
TI 1.54512      P   .158881

** ATOMIC WEIGHT PERCENTS **
SI 32.9436      AL 7.80933      FE+3 1.35086    FE+2 .731178
MG .354656      CA .974242      NA   3.42807    K     3.96042
TI .256579      P  .034118      MN 2.66012E-2   O     48.1303

** OXIDE-SILICA RATIOS **
AL2O3/SIO2        .209329
FE2O3/SIO2        2.74033E-2
FEO/SIO2          .013346
FEO*/SIO2         3.80035E-2
MGO/SIO2          8.34187E-3
CAO/SIO2          1.93402E-2
NA2O/SIO2         6.55575E-2
K2O/SIO2          6.76906E-2

** OTHER OXIDE RATIOS **
NA2O/K2O          .968487
K2O/NA2O          1.03254
FEO*              2.67859
FEO*/MGO          4.55576
NA2O + K2O        9.39169
A:F:M=            74.1943  21.1609  4.64486
NA2O:K2O:CAO      42.9637  44.3616  12.6747

MGO:AL2O3:(CAO+NA2O+K2O)      (MOLE PROP.)
 4.72347  46.8608  48.4157

A:C:F =   37.5399  28.8755  33.5847

1/3SIO2+K2O-MGO-CAO-FEO (LARSEN,1938)= 23.7597
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**** NORMATIVE MINERALS ****

QUARTZ 21.9527
ORTHOCLASE 28.1926
ALBITE 39.096
ANORTHITE 5.4265
DIOPSIDE .642562
HYPERSTHENE 1.16639
MAGNETITE 1.92848
HEMATITE .601415
ILMENITE .812856
APATITE .181031
SUM 100.001

WOLLASTONITE(DIOPSIDE) .344678
ENSTATITE(DIOPSIDE) .297884
ENSTATITE(HYPERSTHENE) 1.16639

** NORMATIVE RATIOS - CIPW **
OR:AB:AN       38.7713  53.766  7.46269
Q:OR:AB        24.5993  31.5914  43.8093
Q:OR:AB+AN         23.1892  29.7805  47.0303
LC+NE+KS:OR:AB+AN     0  38.7713  61.2287
NORMATIVE PLAGIOCLASE CONTENT= AN 12.1882
NORMATIVE COLOR INDEX=      5.15171

** PETROCHEMICAL INDICES **
ALKALI INDEX       50.8004
FELSIC INDEX       87.3253
MAFIC INDEX        83.0074
SOLIDIFICATION INDEX         4.64486
DIFFERENTIATION INDEX        89.2413
CRYSTALLIZATION INDEX        6.8865
WEATHERING INDEX (PARKER,1970)          88.1874
ALTERATION INDEX (ISHIKAWA ETAL,1976)  47.2456
PERALUMINOUS INDEX          -3.3181
THETA INDEX (SUGIMURA,1968)      40.565
S INDEX (RITTMAN,1960)           3.20942

THE ROCK IS METALUMINOUS (SHAND,1945)
THE ROCK IS SUBALKALIC (IRVINE & BARAGAR,1971)
THE ROCK IS CALC-ALKALIC (IRVINE & BARAGAR,1971)
THE ROCK IS THOLEIITIC (MIYASHIRO,1974)
THE ROCK IS ALKALIC (KUNO,1966)
THE ROCK IS KOMATIITIC (NALDRETT & ARNDT,1976)


ACCORDING TO THE IUGS CLASSIFICATION THE ROCK IS A
GRANITE (3B)  OR RHYOLITE
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$$$$$*****$$$$$*****$$$$$*****$$$$$*****$$$$$*****$$$$$
SAMPLE NUMBER  UPSAL HOGBACK 3354

** INPUT DATA **
SIO2 47.1       AL2O3 14.65     FE2O3 10.7      FEO 0
MGO  11.5       CAO   9.48      NA2O  3.01      K2O 1.23
TIO2 1.66       P2O5  .4241     MNO   .1663
MODIFIED FE2O3=  1.9688
MODIFIED FEO=    7.8645
SUM OF OXIDES 99.0537
** NORMALIZED OXIDE VALUES **
SIO2 47.55      AL2O3 14.79     FE2O3 1.98761   FEO 7.93963
MGO  11.6099    CAO   9.57057   NA2O  3.03876   K2O 1.24175
TIO2 1.67586    P2O5  .428152   MNO   .167889

** MOLE NUMBERS **
SI .791444      AL .145056      FE+3 1.24467E-2
FE+2 .110503
MG .288014      CA .170659      NA .049028      K 1.31821E-2
TI 2.09745E-2   P 3.01643E-3    MN 2.36663E-3

** NIGGLI NUMBERS **
AL 18.0481      FM  52.9779
C  21.2337      ALK 7.74027     SI 98.4726
K  .211896      MG  .676417
TI 2.60967      P   .375308

** ATOMIC WEIGHT PERCENTS **
SI 22.2249      AL 7.82832      FE+3 1.39013    FE+2 6.17148
MG 7.00307      CA 6.84008      NA   2.25445    K    1.03078
TI 1.00468      P  .186845      MN .106089      O    43.9592

** OXIDE-SILICA RATIOS **
AL2O3/SIO2       .31104
FE2O3/SIO2       4.18004E-2
FEO/SIO2         .166975
FEO*/SIO2        .204587
MGO/SIO2         .244161
CAO/SIO2         .201274
NA2O/SIO2        6.39066E-2
K2O/SIO2         2.61146E-2

** OTHER OXIDE RATIOS **
NA2O/K2O         2.44715
K2O/NA2O         .408638
FEO*             9.72808
FEO*/MGO         .837915
NA2O + K2O       4.28051
A:F:M=           16.7087  37.973  45.3184
NA2O:K2O:CAO     21.9388  8.96501  69.0962

MGO:AL2O3:(CAO+NA2O+K2O)      (MOLE PROP.)
 43.2493  21.7822  34.9685

A:C:F =   14.2903  25.5924  60.1173

1/3SIO2+K2O-MGO-CAO-FEO (LARSEN,1938)=-14.3143
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**** NORMATIVE MINERALS ****

ORTHOCLASE 7.33767
ALBITE 19.4323
ANORTHITE 23.0479
NEPHELINE 3.40157
DIOPSIDE 17.371
OLIVINE 22.3555
MAGNETITE 2.8819
ILMENITE 3.18287
APATITE .991409
SUM 100.002

WOLLASTONITE(DIOPSIDE) 9.03354
ENSTATITE(DIOPSIDE) 6.11917
FERROSILITE(DIOPSIDE) 2.21828
FORSTERITE(OLIVINE) 15.9737
FAYALITE(OLIVINE) 6.38181

** NORMATIVE RATIOS - CIPW **
OR:AB:AN      14.729  39.0067  46.2643
Q:OR:AB       0  27.4101  72.5899
Q:OR:AB+AN      0  14.729  85.271
LC+NE+KS:OR:AB+AN    6.3916  13.7876  79.8208
NORMATIVE PLAGIOCLASE CONTENT= AN 47.8673
NORMATIVE COLOR INDEX=      45.7913

** PETROCHEMICAL INDICES **
ALKALI INDEX      29.0094
FELSIC INDEX      30.9038
MAFIC INDEX       46.0937
SOLIDIFICATION INDEX        45.3184
DIFFERENTIATION INDEX       30.1715
CRYSTALLIZATION INDEX       52.2206
WEATHERING INDEX (PARKER,1970)            94.9183
ALTERATION INDEX (ISHIKAWA ETAL,1976)  50.4758
PERALUMINOUS INDEX          -60.537
THETA INDEX (SUGIMURA,1968)      33.9472
S INDEX (RITTMAN,1960)           4.02701

THE ROCK IS METALUMINOUS (SHAND,1945)
THE ROCK IS ALKALIC (IRVINE & BARAGAR,1971)
THE ROCK IS THOLEIITIC (MIYASHIRO,1974)
THE ROCK IS ALKALIC (KUNO,1966)
THE ROCK IS ALKALIC (MACDONALD & KATSURA,1964)
THE ROCK IS THOLEIITIC (MACDONALD & KATSURA,1964)
THE ROCK IS KOMATIITIC (NALDRETT & ARNDT,1976)


ACCORDING TO THE IUGS CLASSIFICATION THE ROCK IS A
FOID-BEARING MONZODIORITE
OR  FOID-BEARING BASALT
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$$*****$$$$$*****$$$$$*****$$$$$*****$$$$$*****$$$$$
SAMPLE NUMBER  SODA LAKE 3356

** INPUT DATA **
SIO2 51.55      AL2O3 15.62     FE2O3 10.59     FEO 0
MGO  6.07       CAO   8.12      NA2O  3.15      K2O 1.94
TIO2 1.81       P2O5  .5159     MNO   .172
MODIFIED FE2O3=  1.94856
MODIFIED FEO=    7.78365
SUM OF OXIDES 98.6801
** NORMALIZED OXIDE VALUES **
SIO2 52.2395    AL2O3 15.8289   FE2O3 1.97462   FEO 7.88776
MGO  6.15119    CAO   8.22861   NA2O  3.19213   K2O 1.96595
TIO2 1.83421    P2O5  .5228     MNO   .174301

** MOLE NUMBERS **
SI .869499      AL .155246      FE+3 1.23654E-2
FE+2 .109781
MG .152597      CA .14673       NA 5.15026E-2  K 2.08699E-2
TI 2.29563E-2   P 3.68325E-3    MN 2.45701E-3

** NIGGLI NUMBERS **
AL 23.3829      FM  43.6163
C  22.1001      ALK 10.9006     SI 130.962
K  .288368      MG  .526955
TI 3.45763      P   .554764

** ATOMIC WEIGHT PERCENTS **
SI 24.4167      AL 8.37825      FE+3 1.38105    FE+2 6.13116
MG 3.7104       CA 5.88099      NA   2.36824    K    1.63193
TI 1.09961      P  .22815       MN .110141      O    44.6633

** OXIDE-SILICA RATIOS **
AL2O3/SIO2       .303007
FE2O3/SIO2       3.77994E-2
FEO/SIO2         .150992
FEO*/SIO2        .185004
MGO/SIO2         .11775
CAO/SIO2         .157517
NA2O/SIO2        6.11057E-2
K2O/SIO2         3.76334E-2

** OTHER OXIDE RATIOS **
NA2O/K2O         1.62371
K2O/NA2O         .615873
FEO*             9.66453
FEO*/MGO         1.57116
NA2O + K2O       5.15808
A:F:M=           24.593  46.079  29.328
NA2O:K2O:CAO     23.8456  14.6858  61.4686

MGO:AL2O3:(CAO+NA2O+K2O)      (MOLE PROP.)
 28.9588  29.4615  41.5797

A:C:F =    18.7921  28.952  52.2559

1/3SIO2+K2O-MGO-CAO-FEO (LARSEN,1938)=-4.96639
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**** NORMATIVE MINERALS ****

ORTHOCLASE 11.617
ALBITE 27.009
ANORTHITE 23.0555
DIOPSIDE 11.7173
HYPERSTHENE 17.1706
OLIVINE 1.87542
MAGNETITE 2.86307
ILMENITE 3.48362
APATITE 1.21057
SUM 100.002

WOLLASTONITE(DIOPSIDE) 5.99278
ENSTATITE(DIOPSIDE) 3.4435
FERROSILITE(DIOPSIDE) 2.281
ENSTATITE(HYPERSTHENE) 10.3288
FERROSILITE(HYPERSTHENE) 6.84186
FORSTERITE(OLIVINE) 1.08404
FAYALITE(OLIVINE) .791381

** NORMATIVE RATIOS - CIPW **
OR:AB:AN       18.8339  43.7878  37.3783
Q:OR:AB        0  30.0757  69.9243
Q:OR:AB+AN        0  18.8339  81.1661
LC+NE+KS:OR:AB+AN    0  18.8339  81.1661
NORMATIVE PLAGIOCLASE CONTENT= AN 46.0516
NORMATIVE COLOR INDEX=      37.11

** PETROCHEMICAL INDICES **
ALKALI INDEX      38.1139
FELSIC INDEX      38.5314
MAFIC INDEX       61.5877
SOLIDIFICATION INDEX          29.328
DIFFERENTIATION INDEX         38.626
CRYSTALLIZATION INDEX         38.806
WEATHERING INDEX (PARKER,1970)            84.0201
ALTERATION INDEX (ISHIKAWA ETAL,1976)  41.5456
PERALUMINOUS INDEX              -41.132
THETA INDEX (SUGIMURA,1968)       36.9239
S INDEX (RITTMAN,1960)            2.87957

THE ROCK IS METALUMINOUS (SHAND,1945)
THE ROCK IS SUBALKALIC (IRVINE & BARAGAR,1971)
THE ROCK IS CALC-ALKALIC (IRVINE & BARAGAR,1971)
THE ROCK IS THOLEIITIC (MIYASHIRO,1974)
THE ROCK IS ALKALIC (KUNO,1966)
THE ROCK IS ALKALIC (MACDONALD & KATSURA,1964)
THE ROCK IS THOLEIITIC (MACDONALD & KATSURA,1964)
THE ROCK IS KOMATIITIC (NALDRETT & ARNDT,1976)


ACCORDING TO THE IUGS CLASSIFICATION THE ROCK IS A
FOID-BEARING MONZODIORITE
OR  FOID-BEARING ANDESITE
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$$$$$XXXXX$$$$$XXXXX$$$$$XXXXX$$$$$XXXXX$$$$$XXXXX$$$$$XXXXX$$$$$
SAMPLE NUMBER  DESERT PEAK 3357

** INPUT DATA **
SIO2 68.91      AL2O3 15.83     FE2O3 2.67      FEO 0
MGO  .6055      CAO    1.83     NA2O  5.05      K2O 4.24
TIO2 .4352      P2O5   .159     MNO    .1353
MODIFIED FE2O3=  1.9352
MODIFIED FEO=     .661173
SUM OF OXIDES 99.7914
** NORMALIZED OXIDE VALUES **
SIO2 69.0541    AL2O3 15.8631   FE2O3 1.93925   FEO .662555
MGO  .606766    CAO    1.83383  NA2O  5.06056   K2O 4.24886
TIO2 .43611     P2O5   .159332  MNO    .135583

** MOLE NUMBERS **
SI 1.14937      AL .155582      FE+3 1.21438E-2
FE+2 9.22137E-3
MG 1.50525E-2   CA 3.27002E-2   NA 8.16482E-2   K 4.51047E-2
TI 5.45820E-3   P 1.12253E-3    MN 1.91123E-3

** NIGGLI NUMBERS **
AL 42.5656      FM  13.8096
C  8.94645      ALK 34.6784     SI 314.456
K  .355847      MG  .298214
TI 1.49331      P   .307114

** ATOMIC WEIGHT PERCENTS **
SI 32.2759      AL 8.39634      FE+3 1.35631    FE+2 .515004
MG .366001      CA 1.31064      NA   3.75443    K    3.52698
TI .261448      P  6.95327E-2   MN 8.56748E-2   O    48.0818

** OXIDE-SILICA RATIOS **
AL2O3/SIO2        .22972
FE2O3/SIO2        .028083
FEO/SIO2          9.59473E-3
FEO*/SIO2         3.48638E-2
MGO/SIO2          8.78682E-3
CAO/SIO2          2.65564E-2
NA2O/SIO2         .073284
K2O/SIO2          6.15295E-2

** OTHER OXIDE RATIOS **
NA2O/K2O          1.19104
K2O/NA2O          .839604
FEO*              2.40749
FEO*/MGO          3.96774
NA2O + K2O        9.30942
A:F:M=            75.5409  19.5355  4.92358
NA2O:K2O:CAO      45.4137  38.1295  16.4568

MGO:AL2O3:(CAO+NA2O+K2O)     (MOLE PROP.)
 4.56016  47.1335  48.3064

A:C:F =   41.0308  32.7468  26.2224

1/3SIO2+K2O-MGO-CAO-FEO (LARSEN,1938)= 22.4606
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**** NORMATIVE MINERALS ****

QUARTZ 18.9857
ORTHOCLASE 25.1071
ALBITE 42.818
ANORTHITE 8.02012
DIOPSIDE 2.89188E-2
HYPERSTHENE 1.49771
MAGNETITE 1.31385
HEMATITE 1.0331
ILMENITE .828281
APATITE .368943
SUM 100.002

WOLLASTONITE(DIOPSIDE) 1.55124E-2
ENSTATITE(DIOPSIDE) 1.34064E-2
ENSTATITE(HYPERSTHENE) 1.49771

** NORMATIVE RATIOS - CIPW **
OR:AB:AN      33.0595  56.3801  10.5604
Q:OR:AB       21.8451  28.8883  49.2666
Q:OR:AB+AN       19.9995  26.4477  53.5527
LC+NE+KS:OR:AB+AN    0  33.0595  66.9405
NORMATIVE PLAGIOCLASE CONTENT= AN 15.7758
NORMATIVE COLOR INDEX=     4.70186

** PETROCHEMICAL INDICES **
ALKALI INDEX      45.6405
FELSIC INDEX      83.5432
MAFIC INDEX       81.0892
SOLIDIFICATION INDEX         4.92358
DIFFERENTIATION INDEX        86.9108
CRYSTALLIZATION INDEX        9.09869
WEATHERING INDEX (PARKER,1970)           89.0566
ALTERATION INDEX (ISHIKAWA ETAL,1976)   41.3245
PERALUMINOUS INDEX           -2.48846
THETA INDEX (SUGIMURA,1968)       41.4716
S INDEX (RITTMAN,1960)            3.32637

THE ROCK IS METALUMINOUS (SHAND,1945)
THE ROCK IS ALKALIC (IRVINE & BARAGAR,1971)
THE ROCK IS CALC-ALKALIC (MIYASHIRO,1974)
THE ROCK IS ALKALIC (KUNO,1966)
THE ROCK IS KOMATIITIC (NALDRETT & ARNDT,1976)


ACCORDING TO THE IUGS CLASSIFICATION THE ROCK IS A
QUARTZ MONZODIORITE
OR  QUARTZ ANDESITE
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SAMPLE NUMBER  UPSAL HOGBACK 3358

** INPUT DATA **
SIO2 50.54       AL2O3 15.66     FE2O3 10.75     FEO 0
MGO  4.9         CAO   10.3      NA2O  3.46      K2O 1.61
TIO2 2           P2O5  .5144     MNO   .1746
MODIFIED FE2O3=  1.978
MODIFIED FEO=    7.90125
SUM OF OXIDES 99.0382
** NORMALIZED OXIDE VALUES **
SIO2 51.0308     AL2O3 15.8121   FE2O3 1.99721   FEO 7.97798
MGO  4.94758     CAO   10.4      NA2O  3.4936    K2O 1.62563
TIO2 2.01942     P2O5  .519395   MNO   .176296

** MOLE NUMBERS **
SI .849381       AL .155081      FE+3 1.25068E-2
FE+2 .111037
MG .122738       CA .18545       NA 5.63666E-2  K 1.72573E-2
TI 2.52744E-2    P 3.65926E-3    MN 2.48514E-3

** NIGGLI NUMBERS **
AL 22.9598       FM  38.6842
C  27.4559       ALK 10.9        SI 125.751
K  .234398       MG  .469739
TI 3.74188       P   .541755

** ATOMIC WEIGHT PERCENTS **
SI 23.8518       AL 8.36933      FE+3 1.39685    FE+2 6.20128
MG 2.98438       CA 7.4329       NA   2.5919     K    1.34944
TI 1.21064       P  .226664      MN .111401      O    44.2734

** OXIDE-SILICA RATIOS **
AL2O3/SIO2         .309854
FE2O3/SIO2         3.91373E-2
FEO/SIO2           .156337
FEO*/SIO2          .191552
MGO/SIO2           9.69529E-2
CAO/SIO2           .203799
NA2O/SIO2          6.84606E-2
K2O/SIO2           .031856

** OTHER OXIDE RATIOS **
NA2O/K2O           2.14907
K2O/NA2O           .465318
FEO*               9.77507
FEO*/MGO           1.97573
NA2O + K2O         5.11923
A:F:M=             25.8001  49.2648  24.935
NA2O:K2O:CAO       22.5114  10.475  67.0137

MGO:AL2O3:(CAO+NA2O+K2O)       (MOLE PROP.)
 22.8609  28.8849  48.2542

A:C:F =   18.2216  35.9626  45.8158

1/3SIO2+K2O-MGO-CAO-FEO (LARSEN,1938)=-6.85071
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**** NORMATIVE MINERALS ****

ORTHOCLASE 9.60609
ALBITE 29.5598
ANORTHITE 22.6614
DIOPSIDE 20.9858
HYPERSTHENE 1.74775
OLIVINE 7.50749
MAGNETITE 2.89582
ILMENITE 3.83538
APATITE 1.20269
SUM 100.002

WOLLASTONITE(DIOPSIDE) 10.6643
ENSTATITE(DIOPSIDE) 5.69945
FERROSILITE(DIOPSIDE) 4.62204
ENSTATITE(HYPERSTHENE) .965093
FERROSILITE(HYPERSTHENE) .782656
FORSTERITE(OLIVINE) 3.96435
FAYALITE(OLIVINE) 3.54314

** NORMATIVE RATIOS - CIPW **
OR:AB:AN     15.537  47.8102  36.6528
Q:OR:AB     0  24.5267  75.4733
Q:OR:AB+AN     0  15.537  84.463
LC+NE+KS:OR:AB+AN    0  15.537  84.463
NORMATIVE PLAGIOCLASE CONTENT= AN 43.3951
NORMATIVE COLOR INDEX=      36.9723

** PETROCHEMICAL INDICES **
ALKALI INDEX      31.7554
FELSIC INDEX      32.9863
MAFIC INDEX       66.8454
SOLIDIFICATION INDEX         24.935
DIFFERENTIATION INDEX        39.1658
CRYSTALLIZATION INDEX        39.5959
WEATHERING INDEX (PARKER,1970)           86.1209
ALTERATION INDEX (ISHIKAWA ETAL,1976)  32.1164
PERALUMINOUS INDEX           -67.0568
THETA INDEX (SUGIMURA,1968)       35.8143
S INDEX (RITTMAN,1960)            3.26326

THE ROCK IS METALUMINOUS (SHAND,1945)
THE ROCK IS ALKALIC (IRVINE & BARAGAR,1971)
THE ROCK IS THOLEIITIC (MIYASHIRO,1974)
THE ROCK IS ALKALIC (KUNO,1966)
THE ROCK IS ALKALIC (MACDONALD & KATSURA,1964)
THE ROCK IS THOLEIITIC (MACDONALD & KATSURA,1964)
THE ROCK IS KOMATIITIC (NALDRETT & ARNDT,1976)


ACCORDING TO THE IUGS CLASSIFICATION THE ROCK IS A
FOID-BEARING MONZODIORITE
OR  FOID-BEARING BASALT
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$$$$$*****$$$$$*****$$$$$*****$$$$$*****$$$$$*****$$$$$
SAMPLE NUMBER  DESERT PEAK 3360

** INPUT DATA **
SIO2 54.68      AL2O3 17.62     FE2O3 9.2       FEO 0
MGO  2.93       CAO   7.37      NA2O  4.07      K2O 1.79
TIO2 1.5        P2O5  .6674     MNO   .1548
MODIFIED FE2O3=  3
MODIFIED FEO=    5.57876
SUM OF OXIDES 99.361
** NORMALIZED OXIDE VALUES **
SIO2 55.0317    AL2O3 17.7333   FE2O3 3.01929   FEO 5.61464
MGO  2.94884    CAO   7.4174    NA2O  4.09618   K2O 1.80151
TIO2 1.50965    P2O5  .671692   MNO   .155796

** MOLE NUMBERS **
SI .915973      AL .173924      FE+3 1.89072E-2
FE+2 7.81439E-2
MG 7.31542E-2   CA .132265      NA 6.60887E-2   K 1.91243E-2
TI 1.88942E-2   P 4.73223E-3    MN 2.19616E-3

** NIGGLI NUMBERS **
AL 29.8468      FM  32.8323
C  22.6976      ALK 14.6232     SI 157.188
K  .22443       MG  .382362
TI 3.24239      P   .812087

** ATOMIC WEIGHT PERCENTS **
SI 25.7218      AL 9.38625      FE+3 2.11169    FE+2 4.36426
MG 1.77874      CA 5.30122      NA   3.03895    K    1.49544
TI .905034      P  .293127      MN 9.84472E-2   O    45.505

** OXIDE-SILICA RATIOS **
AL2O3/SIO2        .322238
FE2O3/SIO2        5.48647E-2
FEO/SIO2          .102026
FEO*/SIO2         .151393
MGO/SIO2          5.35845E-2
CAO/SIO2          .134784
NA2O/SIO2         7.44331E-2
K2O/SIO2          3.27359E-2

** OTHER OXIDE RATIOS **
NA2O/K2O          2.27374
K2O/NA2O          .439803
FEO*              8.3314
FEO*/MGO          2.82531
NA2O + K2O        5.89769
A:F:M=            34.3329  48.5006  17.1665
NA2O:K2O:CAO      30.7634  13.5299  55.7067

MGO:AL2O3:(CAO+NA2O+K2O)     (MOLE PROP.)
 15.7471  37.4388  46.8141

A:C:F =   27.3576  33.6228  39.0196

1/3SIO2+K2O-MGO-CAO-FEO (LARSEN,1938)= 1.32487
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**** NORMATIVE MINERALS ****

QUARTZ 5.03379
ORTHOCLASE 10.6454
ALBITE 34.6582
ANORTHITE 24.6795
DIOPSIDE 6.34134
HYPERSTHENE 9.84339
MAGNETITE 4.37778
ILMENITE 2.8672
APATITE 1.55534
SUM 100.002

WOLLASTONITE(DIOPSIDE) 3.22867
ENSTATITE(DIOPSIDE) 1.76437
FERROSILITE(DIOPSIDE) 1.3483
ENSTATITE(HYPERSTHENE) 5.57958
FERROSILITE(HYPERSTHENE) 4.26382

** NORMATIVE RATIOS - CIPW **
OR:AB:AN      15.2113  49.5237  35.2649
Q:OR:AB       10.0001  21.148  68.8519
Q:OR:AB+AN       6.71021  14.1906  79.0992
LC+NE+KS:OR:AB+AN    0  15.2113  84.7887
NORMATIVE PLAGIOCLASE CONTENT= AN 41.5916
NORMATIVE COLOR INDEX=     23.4297

** PETROCHEMICAL INDICES **
ALKALI INDEX      30.5461
FELSIC INDEX      44.2933
MAFIC INDEX       74.5411
SOLIDIFICATION INDEX        17.1665
DIFFERENTIATION INDEX       50.3374
CRYSTALLIZATION INDEX       32.3956
WEATHERING INDEX (PARKER,1970)             80.0615
ALTERATION INDEX (ISHIKAWA ETAL,1976)  29.2079
PERALUMINOUS INDEX          -25.0415
THETA INDEX (SUGIMURA,1968)      39.4006
S INDEX (RITTMAN,1960)           2.89093

THE ROCK IS METALUMINOUS (SHAND,1945)
THE ROCK IS SUBALKALIC (IRVINE & BARAGAR,1971)
THE ROCK IS CALC-ALKALIC (IRVINE & BARAGAR,1971)
THE ROCK IS THOLEIITIC (MIYASHIRO,1974)
THE ROCK IS ALKALIC (KUNO,1966)
THE ROCK IS KOMATIITIC (NALDRETT & ARNDT,1976)


ACCORDING TO THE IUGS CLASSIFICATION THE ROCK IS A
QUARTZ MONZODIORITE
OR  QUARTZ ANDESITE
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$$$$$******$$$$$******$$$$$******$$$$$******$$$$$******$$$$$
SAMPLE NUMBER  DESERT PEAK 2A - 2

** INPUT DATA **
SIO2 69.84      AL2O3 15.34     FE2O3 3.08      FEO 0
MGO  .3836      CAO   1.34      NA2O  5.23      K2O 4.09
TIO2 .3759      P2O5  .0678     MNO    .1109
MODIFIED FE2O3=  1.8759
MODIFIED FEO=    1.08345
SUM OF OXIDES 99.7375
** NORMALIZED OXIDE VALUES **
SIO2 70.0238    AL2O3 15.3804   FE2O3 1.88084   FEO 1.0863
MGO  .384609    CAO   1.34353   NA2O  5.24376   K2O 4.10076
TIO2 .376889    P2O5  6.79784E-2                MNO   .111192

** MOLE NUMBERS **
SI 1.16551      AL .150847      FE+3 .011778
FE+2 .015119
MG 9.54129E-3   CA 2.39573E-2   NA 8.46041E-2   K 4.35325E-2
TI 4.71701E-3   P 4.78924E-4    MN 1.56741E-3

** NIGGLI NUMBERS **
AL 42.7658      FM  14.1149
C  6.792        ALK 36.3273     SI 330.427
K  .339735      MG  .191641
TI 1.33729      P   .135777

** ATOMIC WEIGHT PERCENTS **
SI 32.7291      AL 8.14083      FE+3 1.31546    FE+2 .844381
MG .231996      CA .960218      NA   3.89035    K    3.40404
TI .225945      P  2.96658E-2   MN 7.02621E-2   O    48.1577

** OXIDE-SILICA RATIOS **
AL2O3/SIO2         .219645
FE2O3/SIO2         .02686
FEO/SIO2           1.55133E-2
FEO*/SIO2          3.96819E-2
MGO/SIO2           5.49255E-3
CAO/SIO2           1.91867E-2
NA2O/SIO2          7.48855E-2
K2O/SIO2           5.85624E-2

** OTHER OXIDE RATIOS **
NA2O/K2O           1.27873
K2O/NA2O           .782027
FEO*               2.77868
FEO*/MGO           7.22467
NA2O + K2O         9.34452
A:F:M=             74.7095  22.2155  3.07495
NA2O:K2O:CAO       49.0619  38.3677  12.5704

MGO:AL2O3:(CAO+NA2O+K2O)     (MOLE PROP.)
 3.05339  48.2738  48.6728

A:C:F =    40.7311  28.2938  30.9751

1/3SIO2+K2O-MGO-CAO-FEO (LARSEN,1938)= 22.9695
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**** NORMATIVE MINERALS ****

QUARTZ 20.5613
CORUNDUM 3.54766E-2
ORTHOCLASE 24.2319
ALBITE 44.3681
ANORTHITE 6.22125
HYPERSTHENE .983095
MAGNETITE 2.72709
ILMENITE .715806
APATITE .157408
SUM 100.001

ENSTATITE(HYPERSTHENE) .95785
FERROSILITE(HYPERSTHENE) 2.52448E-2

** NORMATIVE RATIOS - CIPW **
OR:AB:AN      32.3864  59.2988  8.31481
Q:OR:AB       23.0608  27.1776  49.7616
Q:OR:AB+AN       21.5566  25.405  53.0384
LC+NE+KS:OR:AB+AN    0  32.3864  67.6136
NORMATIVE PLAGIOCLASE CONTENT= AN 12.2975
NORMATIVE COLOR INDEX=     4.42599

** PETROCHEMICAL INDICES **
ALKALI INDEX      43.8841
FELSIC INDEX      87.4296
MAFIC INDEX       88.5251
SOLIDIFICATION INDEX         3.07495
DIFFERENTIATION INDEX        89.1613
CRYSTALLIZATION INDEX        6.89255
WEATHERING INDEX (PARKER,1970)            87.6257
ALTERATION INDEX (ISHIKAWA ETAL,1976)  40.5085
PERALUMINOUS INDEX           -.826579
THETA INDEX (SUGIMURA,1968)      41.4684
S INDEX (RITTMAN,1960)           3.23123

THE ROCK IS METALUMINOUS (SHAND,1945)
THE ROCK IS SUBALKALIC (IRVINE & BARAGAR,1971)
THE ROCK IS CALC-ALKALIC (IRVINE & BARAGAR,1971)
THE ROCK IS THOLEIITIC (MIYASHIRO,1974)
THE ROCK IS ALKALIC (KUNO,1966)
THE ROCK IS THOLEIITIC (NALDRETT & ARNDT,1976)


ACCORDING TO THE IUGS CLASSIFICATION THE ROCK IS A
GRANODIORITE  OR DACITE
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$$$$$*****$$$$$*****$$$$$*****$$$$$*****$$$$$*****$$$$$
SAMPLE NUMBER  DESERT PEAK 3 - 3

** INPUT DATA **
SIO2 70.24      AL2O3 15.13     FE2O3 2.34      FEO 0
MGO  .4557      CAO   1.81      NA2O  5.32      K2O 3.88
TIO2 .4382      P2O5  .142      MNO   .1175
MODIFIED FE2O3=  1.9382
MODIFIED FEO=    .36154
SUM OF OXIDES 99.8331
** NORMALIZED OXIDE VALUES **
SIO2 70.3574    AL2O3 15.1553   FE2O3 1.94144   FEO .362144
MGO  .456462    CAO   1.81303   NA2O  5.32889   K2O 3.88649
TIO2 .438932    P2O5  .142237   MNO   .117696

** MOLE NUMBERS **
SI 1.17106      AL .14864       FE+3 1.21576E-2
FE+2 5.04028E-3
MG 1.13238E-2   CA 3.23293E-2   NA 8.59776E-2   K 4.12578E-2
TI 5.49352E-3   P 1.00209E-3    MN 1.65910E-3

** NIGGLI NUMBERS **
AL 42.4024      FM  12.0785
C  9.22258      ALK 36.2965     SI 334.069
K  .324264      MG  .267446
TI 1.56714      P   .285868

** ATOMIC WEIGHT PERCENTS **
SI 32.885       AL 8.02169      FE+3 1.35784    FE+2 .281494
MG .275338      CA 1.29577      NA   3.9535     K    3.22617
TI .26314       P  6.20724E-2   MN 7.43723E-2   O    48.3036

** OXIDE-SILICA RATIOS **
AL2O3/SIO2        .215404
FE2O3/SIO2        .027594
FEO/SIO2          5.14720E-3
FEO*/SIO2         2.99763E-2
MGO/SIO2          6.48776E-3
CAO/SIO2          2.57688E-2
NA2O/SIO2         7.57403E-2
K2O/SIO2          5.52392E-2

** OTHER OXIDE RATIOS **
NA2O/K2O          1.37113
K2O/NA2O          .729323
FEO*              2.10905
FEO*/MGO          4.62043
NA2O + K2O        9.21538
A:F:M=            78.2231  17.9023  3.87459
NA2O:K2O:CAO      48.3197  35.2407  16.4396

MGO:AL2O3:(CAO+NA2O+K2O)      (MOLE PROP.)
 3.54391  46.5185  49.9376

A:C:F =   39.9953  38.5266  21.4781

1/3SIO2+K2O-MGO-CAO-FEO (LARSEN,1938)= 23.0213
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**** NORMATIVE MINERALS ****

QUARTZ 20.7834
ORTHOCLASE 22.9657
ALBITE 45.0884
ANORTHITE 5.95463
DIOPSIDE 1.64321
HYPERSTHENE .37502
MAGNETITE .279203
HEMATITE 1.74888
ILMENITE .833642
APATITE .329359
SUM 100.001

WOLLASTONITE(DIOPSIDE) .881439
ENSTATITE(DIOPSIDE) .761774
ENSTATITE(HYPERSTHENE) .37502

** NORMATIVE RATIOS - CIPW **
OR:AB:AN      31.0311  60.923  8.04585
Q:OR:AB       23.3949  25.8514  50.7537
Q:OR:AB+AN      21.9253  24.2275  53.8473
LC+NE+KS:OR:AB+AN    0  31.0311  68.9689
NORMATIVE PLAGIOCLASE CONTENT= AN 11.6659
NORMATIVE COLOR INDEX=      4.87996

** PETROCHEMICAL INDICES **
ALKALI INDEX      42.1739
FELSIC INDEX      83.5604
MAFIC INDEX       83.4618
SOLIDIFICATION INDEX        3.87459
DIFFERENTIATION INDEX       88.8375
CRYSTALLIZATION INDEX       7.86061
WEATHERING INDEX (PARKER,1970)          87.9841
ALTERATION INDEX (ISHIKAWA ETAL,1976)  37.8145
PERALUMINOUS INDEX          -7.35008
THETA INDEX (SUGIMURA,1968)     41.7784
S INDEX (RITTMAN,1960)          3.10421

THE ROCK IS METALUMINOUS (SHAND,1945)
THE ROCK IS SUBALKALIC (IRVINE & BARAGAR,1971)
THE ROCK IS CALC-ALKALIC (IRVINE & BARAGAR,1971)
THE ROCK IS THOLEIITIC (MIYASHIRO,1974)
THE ROCK IS ALKALIC (KUNO,1966)
THE ROCK IS KOMATIITIC (NALDRETT & ARNDT,1976)


ACCORDING TO THE IUGS CLASSIFICATION THE ROCK IS A
GRANODIORITE  OR DACITE
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$$$$$*****$$$$$*****$$$$$*****$$$$$*****$$$$$*****$$$$$
SAMPLE NUMBER  DESERT PEAK 5 - 5

** INPUT DATA **
SIO2 62.91       AL2O3 16.68      FE2O3 5.68       FEO 0
MGO  1.72        CAO   4.17       NA2O  4.31       K2O 3.13
TIO2 .8927       P2O5  .2433      MNO   .1353
MODIFIED FE2O3=  2.3927
MODIFIED FEO=    2.95791
SUM OF OXIDES 99.5419
** NORMALIZED OXIDE VALUES **
SIO2 63.1995     AL2O3 16.7568    FE2O3 2.40371    FEO 2.97152
MGO  1.72792     CAO   4.18919    NA2O  4.32983    K2O 3.1444
TIO2 .896808     P2O5  .24442     MNO   .135923

** MOLE NUMBERS **
SI 1.05192       AL .164346       FE+3 1.50524E-2
FE+2 4.13573E-2
MG 4.28657E-2    CA 7.47003E-2    NA 6.98586E-2    K 3.33801E-2
TI 1.12241E-2    P 1.72199E-3     MN 1.91602E-3

** NIGGLI NUMBERS **
AL 35.8415       FM  25.3527
C  16.291        ALK 22.5148      SI 229.409
K  .323329       MG  .368733
TI 2.44782       P   .375541

** ATOMIC WEIGHT PERCENTS **
SI 29.5395       AL 8.86935       FE+3 1.68116     FE+2 2.30977
MG 1.04228       CA 2.99401       NA   3.2123      K    2.61017
TI .537636       P  .106665       MN 8.58895E-2    O    47.0113

** OXIDE-SILICA RATIOS **
AL2O3/SIO2        .265141
FE2O3/SIO2        3.80337E-2
FEO/SIO2          4.70182E-2
FEO*/SIO2         8.12409E-2
MGO/SIO2          2.73406E-2
CAO/SIO2          6.62852E-2
NA2O/SIO2         6.85106E-2
K2O/SIO2          4.97536E-2

** OTHER OXIDE RATIOS **
NA2O/K2O          1.377
K2O/NA2O          .726218
FEO*              5.13438
FEO*/MGO          2.97143
NA2O + K2O        7.47424
A:F:M=            52.1342  35.8133  12.0525
NA2O:K2O:CAO      37.1232  26.9595  35.9173

MGO:AL2O3:(CAO+NA2O+K2O)     (MOLE PROP.)
 11.1296  42.6706  46.1998

A:C:F =   32.1352  31.5192  36.3457

1/3SIO2+K2O-MGO-CAO-FEO (LARSEN,1938)= 13.206
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**** NORMATIVE MINERALS ****

QUARTZ 14.5727
ORTHOCLASE 18.5807
ALBITE 36.6352
ANORTHITE 17.0002
DIOPSIDE 1.77208
HYPERSTHENE 5.68642
MAGNETITE 3.48522
ILMENITE 1.70326
APATITE .565967
SUM 100.002

WOLLASTONITE(DIOPSIDE) .912816
ENSTATITE(DIOPSIDE) .5649
FERROSILITE(DIOPSIDE) .294363
ENSTATITE(HYPERSTHENE) 3.73839
FERROSILITE(HYPERSTHENE) 1.94803

** NORMATIVE RATIOS - CIPW **
OR:AB:AN       25.7293  50.73  23.5407
Q:OR:AB        20.8812  26.6243  52.4946
Q:OR:AB+AN        16.791  21.4091  61.7999
LC+NE+KS:OR:AB+AN    0  25.7293  74.2707
NORMATIVE PLAGIOCLASE CONTENT= AN 31.6958
NORMATIVE COLOR INDEX=      12.647

** PETROCHEMICAL INDICES **
ALKALI INDEX       42.0699
FELSIC INDEX       64.0827
MAFIC INDEX        75.674
SOLIDIFICATION INDEX        12.0525
DIFFERENTIATION INDEX       69.7886
CRYSTALLIZATION INDEX       20.8387
WEATHERING INDEX (PARKER,1970)          82.0325
ALTERATION INDEX (ISHIKAWA ETAL,1976)  36.3841
PERALUMINOUS INDEX          -8.27064
THETA INDEX (SUGIMURA,1968)      42.2355
S INDEX (RITTMAN,1960)           2.76562

THE ROCK IS METALUMINOUS (SHAND,1945)
THE ROCK IS SUBALKALIC (IRVINE & BARAGAR,1971)
THE ROCK IS CALC-ALKALIC (IRVINE & BARAGAR,1971)
THE ROCK IS CALC-ALKALIC (MIYASHIRO,1974)
THE ROCK IS ALKALIC (KUNO,1966)
THE ROCK IS KOMATIITIC (NALDRETT & ARNDT,1976)


ACCORDING TO THE IUGS CLASSIFICATION THE ROCK IS A
QUARTZ MONZODIORITE
OR  QUARTZ ANDESITE
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APPENDIX F

Microprobe Data

Sample No. 3304 Crystal feldspar 3-b

ANALYSIS NO.	Na_2O	K_2O	MnO	MgO	SiO_2	FeO	CaO	Al_2O_3	SUM	*	An	Ab	Or
177	8.88	0.63	ND	ND	60.87	0.09	6.37	23.20	100*	Core	16	83	1.3
178	6.63	0.57	ND	0.02	60.30	0.11	6.45	25.92	100*		35	65	1.2
179	7.67	0.58	ND	0.03	60.53	0.09	6.35	24.78	100*		31	68	1.2
180	8.22	0.61	ND	ND	61.46	0.12	6.41	22.86	100*		24	75	1.3
181	8.07	0.62	ND	ND	62.32	0.12	6.22	23.47	100.79		26	73	1.3
183	4.66	1.22	ND	0.01	56.30	0.64	9.95	27.41	100.15	Cellular Zone	54	46	2.6
185	4.87	0.50	0.02	0.06	54.48	0.73	11.57	27.76	100*		55	45	1.0
186	4.56	0.54	ND	0.09	51.69	0.58	11.46	31.11	100*	Rim	57	43	1.1
187	4.85	0.38	0.04	0.07	56.44	0.71	10.72	27.39	100.61		55	45	.8
189	4.16	0.32	ND	0.10	53.52	0.49	12.58	28.87	100*		61	39	.7
190	4.21	0.22	ND	0.11	52.73	0.58	13.16	28.98	100*		61	39	.4

*Normalized to 100 percent.
ND = Not Detected

Sample No. 3304 Crystal feldspar 3-c

ANALYSIS NO.	Na_2O	K_2O	MnO	MgO	SiO_2	FeO	CaO	Al_2O_3	SUM	*	An	Ab	Or
216	8.26	0.75	0.02	0.01	59.76	0.11	5.89	25.48	100*	Core	21	78	1.6
218	7.97	0.91	ND	0.02	61.73	0.14	6.07	23.16	100*		26	74	1.9
219	7.87	0.63	0.04	ND	62.59	0.13	5.98	22.77	100*		26	74	1.3
220	7.21	0.70	1.72	0.08	60.95	0.67	6.04	22.62	100*	Cellular Zone	32	68	1.5
221	8.08	1.08	0.00	0.03	60.56	0.13	6.10	24.01	100*		23	77	2.3
222	6.05	0.63	0.00	0.01	57.79	0.61	9.52	25.41	100*		43	57	1.3
225	5.02	0.47	ND	0.01	53.19	0.61	11.94	28.80	100*		53	47	1.0
226	4.20	0.37	0.03	0.04	53.01	0.60	12.27	29.49	100*		62	38	.8
227	4.49	1.03	0.05	0.08	55.32	0.85	11.69	26.49	100*		55	45	2.2
228	4.45	0.56	ND	0.11	53.08	0.80	12.33	28.70	100*	Rim	59	41	1.2
229	3.51	0.28	0.02	0.04	53.56	0.53	12.98	28.16	99.07		66	34	.6
230	3.38	0.25	ND	0.07	50.29	0.65	13.67	31.69	100*		69	31	.5
231	5.49	0.40	0.01	0.16	55.49	0.89	10.67	26.90	100*		49	51	.8

*Normalized to 100 percent.

Sample No. 3304 Crystal feldspar av

ANALYSIS NO.	Na_2O	K_2O	MnO	MgO	SiO_2	FeO	CaO	Al_2O_3	SUM	*	An	Ab	Or
257	7.17	0.31	0.05	0.05	58.42	0.36	9.30	24.32	100*	Core	34	66	.6
259	5.92	0.32	0.01	0.04	57.08	0.23	9.13	26.85	99.58		46	54	.7
260	6.92	0.86	0.00	0.01	60.07	0.33	6.80	24.19	99.20		33	67	1.8
261	4.78	0.31	ND	0.00	55.39	0.26	9.95	29.31	100*		54	46	.7
262	6.86	0.26	0.01	ND	58.18	0.22	9.24	25.25	100.*		38	62	.5
263	6.05	0.31	0.02	0.03	56.70	0.21	9.32	26.72	99.35		46	54	.6
264	4.92	0.36	ND	0.00	59.97	0.29	8.16	26.32	100*		48	52	.7
265	7.43	0.59	ND	0.03	60.47	0.19	6.40	24.43	99.51		32	68	1.2
266	6.71	0.99	0.03	0.03	60.00	0.43	7.43	24.39	100*	Cellular Zone	36	64	2.1
269	5.96	1.23	ND	0.16	58.66	0.76	8.30	24.95	100*		41	59	2.6
271	3.62	0.25	0.03	0.08	52.44	0.67	12.66	30.25	100*	Rim	66	34	.5
272	3.70	0.32	0.00	0.15	50.97	0.73	12.62	31.50	100*		65	35	.7

*Normalized to 100 percent.

Sample No. 3304 Crystal feldspar 1-a traverse

ANALYSIS NO.	Na_2O	K_2O	MnO	MgO	SiO_2	FeO	CaO	Al_2O_3	SUM	*	An	Ab	Or
236	8.26	1.21	0.01	0.02	62.60	0.04	4.29	23.57	100*	Core	22	78	2.6
237	8.29	0.86	ND	ND	62.43	0.06	4.75	23.66	100*		24	76	1.8
238	8.68	0.91	0.02	0.01	63.15	0.04	4.34	23.06	100.21		22	78	1.9
239	7.90	0.77	0.04	ND	62.25	0.10	4.61	24.33	100*		25	75	1.6
240	8.59	0.72	ND	0.01	61.67	0.09	4.80	24.15	100*		21	79	1.5
241	8.31	0.62	0.00	ND	62.92	0.06	4.92	23.16	100*		25	75	1.3
242	8.89	0.59	ND	0.02	62.44	0.06	4.64	23.36	100*	Cellular Zone	20	80	1.2
243	7.64	0.56	0.03	0.00	62.16	0.07	4.87	23.82	99.15		19	81	.7
245	4.07	0.35	0.04	0.13	52.63	0.85	12.50	29.44	100*	Rim	63	37	.7

*Normalized to 100 percent.

Sample No. 3304 Crystal feldspar 3-c

ANALYSIS NO.	Na_2O	K_2O	MnO	MgO	SiO_2	FeO	CaO	Al_2O_3	SUM	*	An	Ab	Or
155	6.82	0.62	0.01	0.05	61.00	0.07	6.06	25.37	100*	Core	33	67	1.3
156	7.72	0.59	ND	0.01	61.01	0.06	5.81	24.82	100*		29	70	1.2
157	6.77	0.61	0.04	ND	62.61	0.07	6.08	24.57	100.72		33	67	1.3
158	7.97	0.61	0.04	ND	61.92	0.08	5.76	23.65	100*		28	71	1.3
160	8.40	0.61	0.02	0.03	60.56	0.09	6.03	24.70	100*		22	77	1.2
161	6.79	0.59	ND	0.03	61.99	0.20	6.50	23.95	100*		34	65	1.2
162	8.51	0.75	ND	0.03	59.59	0.14	6.72	24.24	100*		18	82	1.6
166	5.86	0.62	ND	0.07	57.68	0.74	9.13	25.92	100*	Cellular Zone	44	55	1.3
168	5.13	0.49	0.00	0.06	54.15	0.82	11.12	28.22	100*		53	46	1.0
172	4.06	0.27	0.01	0.04	53.98	0.54	13.02	28.09	100*	Rim	61	38	.6
173	3.93	0.24	0.01	0.10	52.07	0.66	12.83	29.67	99.52		64	35	.5
174	4.88	0.39	ND	0.16	53.22	0.72	11.51	29.10	100*		55	44	.8

*Normalized to 100 percent.

Sample No. 3312   Crystal feldspar

ANALYSIS NO.	Na_2O	K_2O	MnO	MgO	SiO_2	FeO	CaO	Al_2O_3	SUM	*	An	Ab	Or
416 lath	5.18	0.52	ND	0.09	54.35	0.91	11.17	27.79	100*		52	48	1.1
417 lath	4.56	0.47	ND	0.16	53.89	0.82	11.48	28.63	100*		58	42	1.0
420	7.66	0.65	0.01	0.01	61.16	0.09	6.34	24.07	100*	Core	31	69	1.4
421	7.76	0.53	0.02	ND	60.62	0.08	6.35	24.65	100*		31	69	1.1
422	7.56	0.60	ND	0.08	59.55	0.72	6.58	24.92	100*		31	69	1.3
423	7.46	0.53	0.03	0.04	62.13	0.10	6.11	23.35	99.75		31	69	1.1
424	7.73	0.56	0.01	0.00	59.85	0.07	6.54	25.24	100*		30	70	1.2
425	7.32	1.03	0.01	0.03	61.09	0.14	6.40	23.97	100*		33	67	2.2
427	7.35	1.03	0.01	0.02	60.02	0.11	6.39	25.06	100*		33	68	2.2
428	5.66	0.77	0.00	0.15	57.07	0.90	9.46	25.99	100*	Cellular Zone	46	54	1.6
429	5.65	0.54	ND	0.17	54.05	0.82	10.67	28.13	100*		47	53	1.1
430	3.96	0.37	0.00	0.09	52.64	0.58	12.81	29.55	100*	Rim	64	36	.8
431	4.32	0.31	ND	0.09	53.49	0.77	12.18	28.83	100*		61	39	.6
432	5.01	0.48	0.00	0.13	54.41	0.89	10.98	28.10	100*		54	46	1.0

*Normalized to 100 percent.

Sample No. 3354a   Crystal large feldspar

ANALYSIS NO.	Na_2O	K_2O	MnO	MgO	SiO_2	FeO	CaO	Al_2O_3	SUM	*	An	Ab	Or
215	5.40	0.50	0.04	0.10	54.07	0.32	11.23	28.34	100*		50	50	1.0
216	5.55	0.63	0.02	0.10	56.05	0.29	10.32	27.07	100*		49	51	1.3
217	5.36	0.74	ND	0.07	56.18	0.43	9.94	27.28	100*		51	49	1.5
218	5.65	0.64	0.02	0.09	56.39	0.37	9.55	27.28	100*		48	52	1.3
225	5.56	0.67	ND	0.05	55.76	0.35	10.19	27.69	100.25	Core + Cellular Zone	49	51	1.4
226	6.45	0.76	0.02	0.07	57.87	0.38	9.62	25.17	100.35		39	61	1.6
227	5.63	0.68	ND	0.05	56.17	0.31	9.94	27.24	100*		48	52	1.4
228	5.84	0.75	ND	0.09	55.21	0.34	10.84	26.96	100*		45	55	1.6
229	3.76	0.45	ND	0.15	51.15	0.44	13.52	30.55	100*	Rim	65	35	.9
230	3.89	0.30	0.05	0.11	51.78	0.40	14.06	29.54	100.15		64	36	.6
231	2.78	0.20	0.02	0.16	48.24	0.50	15.34	32.71	99.96		75	25	.4

*Normalized to 100 percent.

Sample No. 3356   Crystal feldspar traverse

ANALYSIS NO.	Na_2O	K_2O	MnO	MgO	SiO_2	FeO	CaO	Al_2O_3	SUM	*	An	Ab	Or
426	7.72	1.06	0.04	0.03	59.50	0.29	7.39	23.99	100*	Core	26	73	2.2
428	5.83	0.99	0.01	0.02	60.12	0.32	7.29	25.44	100*		40	59	2.1
429	6.60	1.00	ND	0.04	60.13	0.39	7.67	24.17	100*		36	64	2.1
430	8.36	1.05	ND	0.01	60.92	0.26	7.37	22.05	100*		20	80	2.2
434	4.40	0.38	ND	0.17	51.34	0.52	13.35	29.88	100*		59	41	.8
436	4.73	0.93	0.02	0.26	52.78	0.69	12.32	28.24	100*		54	46	1.9
438	3.63	0.32	0.04	0.12	51.62	0.67	13.99	29.61	100*		66	34	.7
441	5.77	1.36	ND	0.16	57.29	0.57	10.66	24.21	100*	Cellular Zone	41	59	2.9
442	4.50	0.47	ND	0.51	52.69	0.79	12.84	28.20	100*		58	46	1.0
449	3.71	0.29	ND	0.12	52.40	0.57	13.82	29.09	100*	Rim	65	35	.6
450	3.46	0.35	0.01	0.16	50.05	0.59	14.35	31.01	100*		68	31	.7

*Normalized to 100 percent.

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