UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

CHEMICAL DATA AND VARIATION DIAGRAMS OF IGNEOUS ROCKS FROM THE TIMBER MOUNTAIN-OASIS VALLEY CALDERA COMPLEX SOUTHERN NEVADA

Open-file Report 77-724
1977

Prepared Under
Memorandum of Understanding E(29-2)-474
for the
Nevada Operations Office
U.S. Energy Research and Development Administration

Open-file Report 77-724

Open-file Report 77-724

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

CHEMICAL DATA AND VARIATION DIAGRAMS OF IGNEOUS ROCKS FROM THE TIMBER MOUNTAIN-OASIS VALLEY CALDERA COMPLEX SOUTHERN NEVADA

By

W. D. Quinlivan and F. M. Byers, Jr.

CONTENTS

Page

Abstract-- 1

Introduction-- 1

Major oxide variation-- 2

Alkali-lime index-- 5

Minor elements-- 7

References cited-- 8

ILLUSTRATIONS

Page

Figure 1.--Map showing Timber Mountain-Oasis caldera complex----------------- 3

2.--Map showing location of analyzed samples tabulated in this report--[in pocket]

3.--Weight percent variation diagrams of major oxides in rocks--------[in pocket]

4.--Synoptic silica variation diagrams of lime, total alkalis, and total iron oxides in igneous rocks--------------------------[in pocket]

5.--Synoptic silica variation diagrams for selected minor elements---[in pocket]

TABLES

Page

Table 1.--Analyses of rocks related to Sleeping Butte caldera and biotite-hornblende rhyolite lava from Silent Canyon caldera------[in pocket]

2.--Analyses of rhyolite lavas of Area 20 in Silent Canyon caldera and Stockade Wash Tuff-----------------------------------[in pocket]

3.--Analyses of Pah Canyon and Yucca Mountain Members and tuff of Pinyon Pass of the Paintbrush Tuff, Nye County, Nevada-----------[in pocket]

4.--Analyses of Tiva Canyon Member and tuff of Chocolate Mountain of Paintbrush Tuff--------------------------------------[in pocket]

5.--Analyses of rhyolite lavas intercalated with Pah Canyon and Yucca Mountain Members of Paintbrush Tuff and Rainier Mesa Member of Timber Mountain Tuff-----------------------------------[in pocket]

6.--Analyses of Rainier Mesa Member of Timber Mountain Tuff------------[in pocket]

7.--Analyses of extracaldera specimens of Ammonia Tanks Member of Timber Mountain Tuff---[in pocket]

8.--Analyses of intracaldera specimens of Ammonia Tanks Member and tuff of Buttonhook Wash of Timber Mountain Tuff--------------[in pocket]

TABLES (Continued)

Page

Table 9.--Analyses of pre-Ammonia Tanks lavas in Timber Mountain caldera moat, intrusive rocks on Timber Mountain dome, and younger intracaldera lavas and tuffs in Timber Mountain and Oasis Valley calderas--------------------------------[in pocket]

10.--Analyses of rhyolite lavas of Fortymile Canyon and feeder dikes---[in pocket]

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

CHEMICAL DATA AND VARIATION DIAGRAMS OF IGNEOUS ROCKS FROM THE TIMBER MOUNTAIN-OASIS VALLEY CALDERA COMPLEX SOUTHERN NEVADA

By

W. D. Quinlivan and F. M. Byers, Jr.

ABSTRACT

Silica variation diagrams presented here are based on 162 chemical analyses of tuffs, lavas, and intrusives, representative of volcanic centers of the Timber Mountain-Oasis Valley caldera complex and cogenetic rocks of the Silent Canyon caldera. Most of the volcanic units sampled are shown on the U.S. Geological Survey geologic map of the Timber Mountain caldera area (I-891) and are described in U.S. Geological Survey Professional Paper 919. Early effusives of the complex, although slightly altered, are probably chemically, and petrographically, more like the calc-alkalic Fraction Tuff (Miocene) of the northern Nellis Air Force Base Bombing and Gunnery Range to the north, whereas effusives of later Miocene age, such as the Paintbrush and Timber Mountain Tuffs, are alkali-calcic.

INTRODUCTION

The upper Tertiary Timber Mountain-Oasis Valley caldera complex comprises at least four overlapping cauldron subsidence centers and related volcanic rocks that are petrochemically distinct from those of adjacent and nearby centers of the southwestern Nevada volcanic field (fig. 1; Christiansen and others, 1965, 1966, and 1977). Geologic maps of the Timber Mountain caldera (Byers, Carr, Christiansen, and others, 1976) and adjacent areas (Orkild and others, 1969; Sargent and Orkild, 1973; P. P. Orkild, K. A. Sargent, and R. L. Christiansen, written commun., 1972) are available. The geology, petrography, and geologic history of the Timber Mountain-Oasis Valley caldera complex are discussed by Byers, Carr, Orkild, Quinlivan, and Sargent (1976); petrogenesis and tectonic setting of the complex are presented by Christiansen, Lipman, Carr, Byers, Orkild, and Sargent (1977).

The Silent Canyon caldera has not been included in the Timber Mountain-Oasis Valley caldera complex because its effusives are dominantly of peralkaline composition (Sargent and others, 1965; Noble and others, 1968; Orkild and others, 1969; Byers, Carr, Orkild, and others, 1976, p. 16). The calc-alkalic effusives from Silent Canyon caldera, herein comprising the biotite-hornblende rhyolite lavas west of Split Ridge, Stockade Wash Tuff (Miocene), and the tuffs and rhyolite lavas of Area 20 (Orkild and others, 1969), intertongue with the peralkaline effusives but are generally younger. The calc-alkalic representatives from the Silent Canyon caldera are included here because they are chemically somewhat similar to the rocks of Timber Mountain-Oasis Valley caldera complex and are not likely to be treated elsewhere.

This report presents 149 chemical analyses of rocks from the Timber Mountain-Oasis Valley caldera complex and 13 analyses of related rocks from Silent Canyon caldera. The data are plotted on variation diagrams to show chemical differences in time and between volcanic centers. Basic chemical, spectrographic, normative, and modal data are contained in tables 1-10. In each table the data are grouped according to age and source. Modal analyses were mostly by the authors using the Leitz modification of the Chayes point counter (Chayes, 1949). A few samples were lost and therefore not modally or spectrographically analyzed. The analyzed specimens were collected by many geologists during the period 1960-1970, thus accounting for some imbalance in the number of analyses per stratigraphic unit.

Locations of the analyzed specimens are shown in figure 2.

Potassium-argon ages (Marvin and others, 1970) are included, where appropriate, for added geologic setting and perspective. Some units for which chemical analyses are available were not dated isotopically, but their ages are bracketed by dated units.

MAJOR OXIDE VARIATION

Standard silica-variation diagrams of major oxides are grouped according to volcanic source and stratigraphic position on figure 3. Chemical comparison of the different centers is shown by transposing the curves determined by oxide plots of one center one column to the right. The curves of the different centers are identified by different line symbols. Column 4 contains no curves fit to its data points, as plots of the post-Timber Mountain caldera rocks, including tuffs and lavas in Oasis Valley caldera segment, are essentially on the curves determined by the Timber Mountain caldera rocks. The variation curves in figure 3 were constructed visually and the most widely divergent data points were rejected. The aberrance of such data points is in part due to analytical error, alteration, or unrecognized geologic factors. Data points that show considerable scatter, particularly those of the oldest rocks, are fitted to a straight line as a conservative approach. Points having less scatter appear, with few exceptions, to define curvilinear trends.

Analyses of rocks from the oldest two centers, Sleeping Butte and Silent Canyon calderas, are plotted in column 1 of figure 3. We had originally thought that rocks of these two centers would be chemically similar, inasmuch as they are similar petrographically (Byers, Carr, Orkild, and others, 1976, p. 12-13). However, chemical differences between the suites are apparent, the younger, Silent Canyon suite showing strong curvilinearity. The oxide plots of the older, Sleeping Butte suite, show considerable scatter, owing to varying degrees of hydrothermal alteration, and no attempt has been made on figure 3 to adjust the curves to include plots of the unaltered or least altered rocks. In this report, oxide plots that control curves of the Silent Canyon caldera include those of the biotite-hornblende rhyolite lava west of Split Ridge (column 14, table 1), because it is chemically similar to tuffs and rhyolites of Area 20 of the Silent Canyon suite and geographically is close to the Silent Canyon caldera (Byers, Carr, Orkild, and others, 1976, fig. 4). This rock had been considered a late representative of the Sleeping Butte caldera suite (Byers, Carr, Orkild, and others, 1976, p. 12-13, 15-16) because of petrographic similarities.

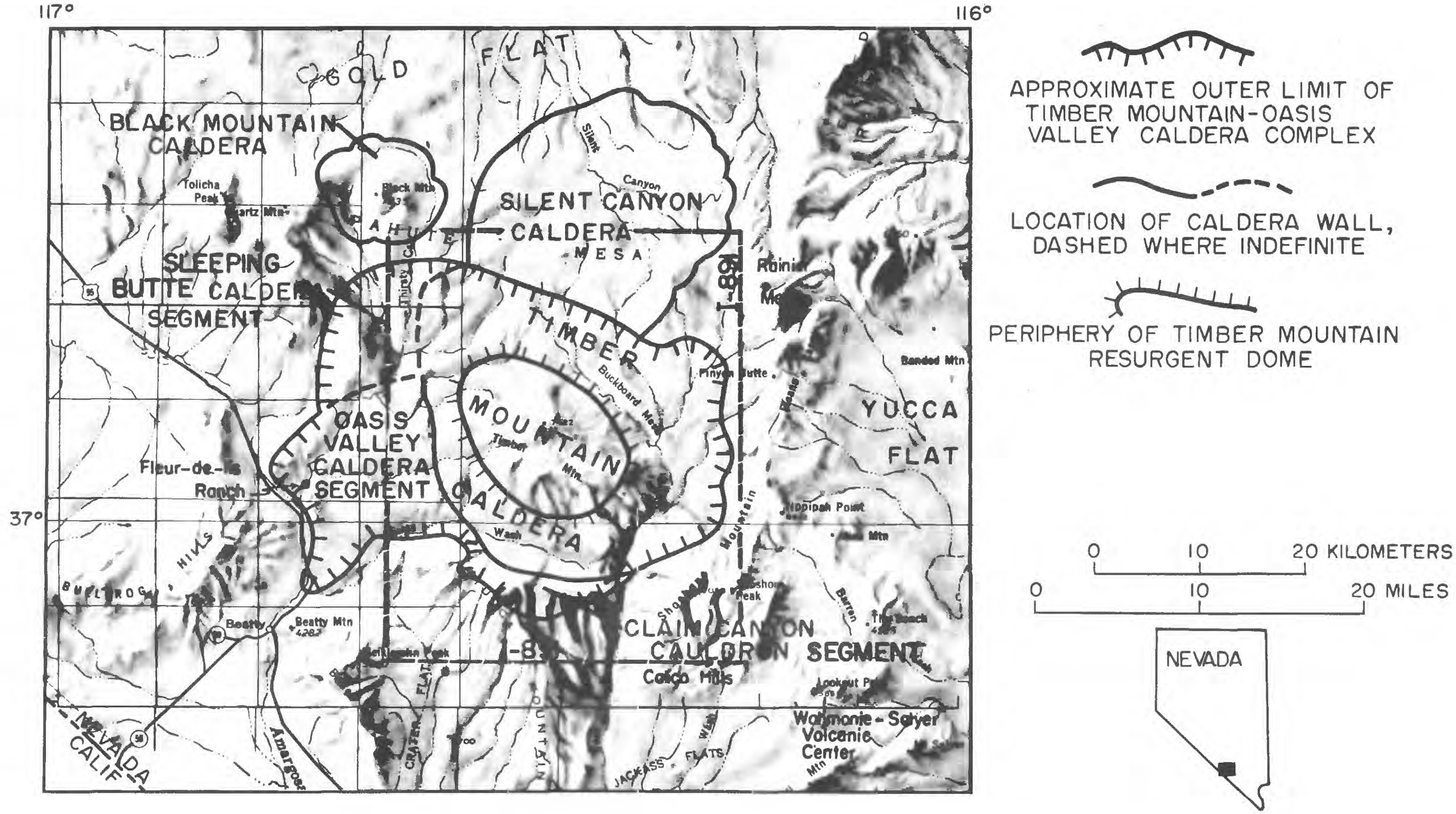

Figure 1.--Timber Mountain-Oasis Valley caldera complex and its relation to adjacent calderas of the southwestern Nevada volcanic field. Heavy dashed rectangle encloses area of U.S. Geological Survey map I-891 (Byers, Carr, Christiansen, and others, 1976).

Both the Sleeping Butte suite of the Timber Mountain-Oasis Valley caldera complex and the Silent Canyon calc-alkalic suite include high-silica rhyolite lavas and water-free SiO_2 plots which are in the range of 78.2 to 79.2 percent (fig. 3). Bowen (1928, p. 131) and others, including the present authors, have noted that high-silica rhyolites that are rapidly chilled at the surface are generally limited to maxima between 77 and 78 percent SiO_2 (peralkaline comendities, 76 and 77 percent SiO_2, because of high iron content). We cannot account for these high SiO_2 contents above 78 percent, as shown on figure 3, except to note that these very high silica rhyolites are all devitrified. Glassy analogs of these same rhyolites range from 75 to 77 percent SiO_2 (Byers, Carr, Orkild, and others, 1976, p. 13).

Some differences exist between variation trends established by calc-alkalic rocks of the older centers, mainly those of the Silent Canyon center, and the alkali-calcic rocks of the Claim Canyon and younger centers (note especially column 2, fig. 3). The Al_2O_3/silica plot of the older centers is slightly steeper than similar plots for rocks of the Claim Canyon and Timber Mountain centers. The Na_2O curve of the older centers is about ±1/2 percent lower at a given silica concentration than that of the younger centers. K_2O of the Silent Canyon center increases markedly through the 72-78 percent silica range in contrast to decreasing K_2O through that range in the Timber Mountain and Claim Canyon rocks. The CaO, MgO, TiO_2, and FeO curves of the Silent Canyon center rise more rapidly at the low silica end than similar curves of the Claim Canyon-Timber Mountain centers. The P_2O_5 curves of the older centers differ slightly from that of the Claim Canyon center, but the difference may not be significant, owing to resorption of apatite in the older rocks.

The strong curvilinearity of the plots of calc-alkalic rocks of the Silent Canyon center is perhaps an enigma and no petrologic interpretation is attempted. The curvilinear trend is established mainly by the one analysis of rhyolite lava at the low silica end. The lava appears unaltered in thin section and is also from the oldest, phenocryst-rich flows (column 2, table 2). The analyzed sample, however, came from a drill hole at a depth of 1,383 meters (4,536 feet) and may have undergone subtle chemical change not detectable in thin section.

A slight curvilinearity in the alkali, lime, and total iron trend lines of the Claim Canyon and Timber Mountain centers is apparent. The curvilinearity, if real, could result from a greater compositional range (66-77 percent SiO_2) spanned by the younger rocks than by the older (72-77 percent SiO_2). That such curvilinearity for the Claim Canyon-Timber Mountain curves may reflect a degree of magmatic differentiation (Bowen, 1928, p. 99-110; Wilcox, 1954) not apparent for the older rocks is consistent with numerous field observations of reversely zoned ash-flow sheets from the younger (Lipman and others, 1966) but not the older centers.

Variation curves of oxide plots of the Claim Canyon (13 to about 12 m.y.) and Timber Mountain (12 to 11 m.y.) centers are superposed in the third column of figure 3. Curves of the two suites obviously are closely similar except those for K_2O, P_2O_5, and possibly MgO. K_2O for the Claim Canyon rocks runs about 1/2 percent high at the low silica ends of the curves for silica contents less than 72 percent; P_2O_5 is about 1/2 percent lower through much of the silica range below 74 percent. MgO is seemingly 1/4 to 1/2 percent lower in the same compositional range; however, the difference is probably insignificant owing to scatter of the data.

Plots of post-Timber Mountain rocks (11 to about 8 m.y.) occur in the fourth column of figure 3. These rocks were erupted either from the Timber Mountain caldera or from the Oasis Valley caldera segment. Their analyses were plotted separately from those of Timber Mountain caldera rocks to investigate differences between the two assemblages, but no significant differences are apparent.

ALKALI-LIME INDEX

The Timber Mountain-Oasis Valley caldera complex has no associated mafic or intermediate eruptives until very late in its history when as much as 275 meters (900 feet) of trachybasalt and trachyandesite (Luft, 1964) were, in places, extruded in the moat of the Timber Mountain caldera between 9.5 and 7.5 m.y. ago. These mafic and intermediate lavas intertongue with the uppermost lavas of the Timber Mountain center, the rhyolite lavas of Fortymile Canyon (Christiansen and Lipman, 1966). Inasmuch as the mafic and intermediate lavas are associated at least spatially and temporally with the Timber Mountain caldera, they are used as control to establish an approximate alkali-lime index (Peacock, 1931).

Lime, total alkalis, and total iron oxide curves of the Timber Mountain-Claim Canyon volcanic suite (including the above mentioned mafic and intermediate lavas) are displayed in figure 4. The total iron-oxide curve is broken and, unlike the lime and total alkalis curves, cannot be drawn smoothly without a sharp inflection between the curve determined by the silicic Timber Mountain-Claim Canyon volcanic suite and that determined by the late mafic and intermediate lavas. This required inflection suggests that the mafic/intermediate lavas perhaps are not true representatives of the low silica end of a Timber Mountain-Claim Canyon differentiation series and should not be used to establish an alkali-lime index. However, if one chooses to use these lavas to establish an index, the series lies barely within the alkali-calcic suite, having an index of just less than 56 (fig. 4).

Included in figure 4 for comparison with the Timber Mountain-Claim Canyon data are variation curves determined for the Fraction Tuff (17.8-15.7 m.y.) and underlying cogenetic intermediate lavas (21-18 m.y.), which are widespread in south-central Nye County (Ekren and others, 1971). In northern Pahute Mesa about 1,200 meters (4,000 feet) of the intermediate lavas was penetrated by drill hole PM2 which bottomed in a chemically similar intrusive granodiorite. Ash flows of the Fraction Tuff extend south into Yucca Flat, and, where present, lie at or near the base of the Tertiary volcanic sequence there. The variation curves for these rocks establish an alkali-lime index of nearly 60 (Anderson and Ekren, 1968), well within Peacock's calc-alkalic suite (fig. 4).

Total alkali and lime plots of four unaltered rocks of the Sleeping Butte caldera suite are joined by a nearly straight line, shown as a queried dashed curve in figure 4. Analyses of these unaltered rocks are shown in columns 3, 4, 7, and 8, table 1, and include two analyses each of the Bullfrog Member of the Crater Flat Tuff (Miocene) and a petrographically similar overlying lava flow. Nearly all the other analyzed rocks (table 1) from the Sleeping Butte caldera are slightly sericitized, resulting in higher potash and lower lime than the unaltered rock. The total alkali curve from 72 to 79 percent (queried dashed curve, fig. 4) is about 1 percent lower than the average total alkalis of the Paintbrush and Timber Mountain Tuffs, and the lime curve is about half a percent higher than the swarm of plots representing lime in the Paintbrush and Timber Mountain Tuffs. If these queried curves are projected toward the mafic end of the variation diagram but parallel to the solid curves representing the Paintbrush and Timber Mountain volcanic suites, the total alkali and lime projected curves would intersect at 58.0 percent silica, well within the calc-alkalic field.

The Redrock Valley and Crater Flat Tuffs, the principal ash-flow tuffs erupted from the Sleeping Butte center (Byers, Carr, Orkild, and others, 1976, p. 7-15), differ in compositional zoning in the field from the four main ash flows of the Paintbrush and Timber Mountain Tuffs. Compositional trends in the latter are upward from high silica rhyolite to quartz latite. Trends in the older rocks from the Sleeping Butte center are either azonal or slightly gradational upward from low silica rhyolite in lowermost parts to higher silica rhyolite (about 76 percent SiO_2) in uppermost parts. Petrographically these old tuffs are characterized mainly by hornblende, like the calc-alkalic Fraction Tuff, rather than by clinopyroxene as in the alkali-calcic Paintbrush and Timber Mountain Tuffs.

The calc-alkalic Silent Canyon caldera suite, as opposed to its peralkaline suite, is represented mainly by the tuffs and rhyolite lavas of Area 20 inside Silent Canyon caldera. The oldest intracaldera lavas and tuffs are phenocryst-rich, low-silica rhyolites that contain hornblende and allanite (Byers, Carr, Orkild, and others, 1976, fig. 5, table 2). These are overlain by lavas and tuffs that grade upward to phenocryst-poor, high-silica rhyolite. The lowermost welded tuff, penetrated in a drill hole at 1,829 meters (6,000 feet) depth is hornblende allanite bearing with about equal amounts of quartz, sanidine, and plagioclase phenocrysts and was first thought to be the Fraction Tuff before Silent Canyon caldera was recognized. This tuff was not chemically analyzed because of slight alteration, but the overlying genetically related lava flow was (table 2, column 2) and is represented by the lime and total alkali plots at the low silica rhyolite end of the light-dashed curves in figure 4. If these curves are projected only a short distance toward the low silica end of figure 4, they would intersect at about 70 percent SiO_2, which would make the Silent Canyon suite highly calcic, according to the Peacock (1931) classification. This seems unreasonable and we are forced to conclude that either the chemical analysis is in error or there is a subtle type of chemical alteration that escaped the eye of the petrographer.

In summary, we conclude that from field and petrographic similarities to the calc-alkalic Fraction Tuff, the volcanic suites from the Sleeping Butte and Silent Canyon calderas (excluding the peralkaline rocks) are probably calc-alkalic. The limited lime and alkali variation curves, though strictly limited by data only at the high silica end of figure 4, are certainly permissive to this conclusion. The similar curves and plots of the alkali-calcic Paintbrush and Timber Mountain volcanic suites are significantly higher in total alkalis and lower in lime than the older suites (fig. 4), and these chemical differences strongly suggest the calc-alkalic character of the older suites of the Timber Mountain-Oasis

Valley complex, inasmuch as the younger Paintbrush and Timber Mountain volcanic suites are barely into the alkali-calcic field (fig. 4).

MINOR ELEMENTS

Most specimens submitted for major-element analyses from the Timber Mountain-Oasis Valley caldera complex were also analyzed semiquantitatively for minor elements; a few specimens from the Beatty area (Cornwall, 1962) were analyzed quantitatively. Plots of eight minor elements that show consistent variations with silica content are shown on figure 5. Also included on this illustration are previously unpublished data from six trachybasalts and one trachyandesite from the Timber Mountain caldera moat area (S. J. Luft, written commun., 1964).

Most minor elements, notably Mn, B, Ce, Co, Cr, Cu, Ga, Mo, Nb, Nd, Ni, Pb, Y, and Yb, are omitted from figure 5. Plots of these elements show little variation and considerable scatter in the 65-78 percent silica range, or are below threshold limits of detectability. Mn, Nb, Nd, Ga, Y, and Yb show minimum change throughout the 48-78 percent silica range. B and Mo show slightly higher, but relatively constant, values in the 65-78 percent range than in the 48-60 percent range. Cr is predictably higher in mafic than in rhyolitic specimens but, interestingly, is nearly an order of magnitude higher in vitrophyres of the Sleeping Butte and Silent Canyon centers than in vitrophyres of the Claim Canyon and Timber Mountain centers. This near lack of Cr in the younger vitrophyres corroborates other observations that rhyolites of these centers are more highly differentiated than those of the older centers of the Timber Mountain-Oasis Valley complex.

The following minor element relations with respect to silica are shown on figure 5:

1. Ba has a maximum concentration in the mediosilicic rocks at about 68 percent silica. Like K, for which it substitutes, Ba is present in higher concentrations in rocks of the Claim Canyon and Timber Mountain centers than in older rocks of the Sleeping Butte and Silent Canyon centers over the range 72-76 percent silica.

2. Be shows a slight enrichment in the silicic rocks, with possibly slight maxima at 71 percent and 77 percent silica. Two unusually high values of 0.0015 weight percent Be in a trachybasalt and a quartz latite may reflect errors in reporting of the data.

3. Ce shows an apparent zero concentration at the high silica end of the range, owing to a high threshold value of 0.02 weight percent. The element is more abundant in the older, Sleeping Butte and Silent Canyon rocks than in the younger rocks of the complex.

4. The remaining elements plotted against silica show compositional trends but no significant enrichment in rocks of any of the caldera centers. La decreases slightly in rocks of the mediosilicic to highly silicic range. Sc, Sr, and V decreases with increasing silica, as in other volcanic suites. Zr decreases away in both directions from mediosilicic compositions.

REFERENCES CITED

Anderson, R. E., and Ekren, E. B., 1968, Widespread Miocene igneous rocks of intermediate composition, southern Nye County, Nevada, in E. B. Eckel, Nevada Test Site: Geol. Soc. America Mem. 110, p. 57-63.

Bowen, N. L., 1928, The evolution of the igneous rocks: Princeton University Press, 332 p.

Byers, F. M., Jr., Carr, W. J., Christiansen, R. L., Lipman, P. W., Orkild, P. P., and Quinlivan, W. D., 1976, Geologic map of the Timber Mountain caldera area, Nye County, Nevada: U.S. Geol. Survey Misc. Inv. Ser. Map I-891.

Byers, F. M., Jr., Carr, W. J., Orkild, P. P., Quinlivan, W. D., and Sargent, K. A., 1976, Volcanic suites and related cauldrons of Timber Mountain-Oasis Valley caldera complex, southern Nevada: U.S. Geol. Survey Prof. Paper 919, 70 p.

Chayes, F., 1949, A simple point counter for thin-section analysis: Am. Mineralogist, v. 34, p. 1-11.

Christiansen, R. L., and Lipman, P. W., 1966, Emplacement and thermal history of a rhyolite lava flow near Fortymile Canyon, southern Nevada: Geol. Soc. America Bull., v. 77, p. 671-684.

Christiansen, R. L., Lipman, P. W., Carr, W. J., Byers, F. M., Jr., Orkild, P. P., and Sargent, K. A., 1977, The Timber Mountain-Oasis Valley caldera complex of southern Nevada: Geol. Soc. America Bull., v. 88, p. 943-959.

Christiansen, R. L., Lipman, P. W., Orkild, P. P., and Byers, F. M., Jr., 1965, Structure of the Timber Mountain caldera, southern Nevada, and its relation to basin-range structure, in Geological Survey Research 1965: U.S. Geol. Survey Prof. Paper 525B, p. B43-B48.

Christiansen, R. L., Noble, D. C., Orkild, P. P., and Sargent, K. A., 1966, Cogenetic sequences and source areas in silicic volcanic terranes: Geol. Soc. America Spec. Paper 101 (Abstracts for 1966), p. 39.

Cornwall, H. R., 1962, Calderas and associated volcanic rocks near Beatty, Nye County, Nevada, in Petrologic Studies--A volume in honor of A. F. Buddington: New York, Geological Society of America, p. 357-371.

Ekren, E. B., Anderson, R. E., Rogers, C. L., and Noble, D. C., 1971, Geology of northern Nellis Air Force Base Bombing and Gunnery Range, Nye County, Nevada: U.S. Geol. Survey Prof. Paper 651, 91 p.

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

Luft, S. J., 1964, Mafic lavas of Dome Mountain, Timber Mountain caldera, southern Nevada: U.S. Geol. Survey Prof. Paper 501-D, p. D14-D21.

Marvin, R. F., Byers, F. M., Jr., Mehnert, H. H., Orkild, P. P., and Stern, T. W., 1970, Radiometric ages and stratigraphic sequence of volcanic and plutonic rocks, southern Nye and western Lincoln Counties, Nevada: Geol. Soc. America Bull., v. 81, p. 2657-2676.

Noble, D. C., Sargent, K. A., Mehnert, H. H., Ekren, E. B., and Byers, F. M., Jr., 1968, Silent Canyon volcanic center, in E. B. Eckel, Nevada Test Site: Geol. Soc. America Mem. 110, p. 65-75.

Orkild, P. P., Sargent, K. A., and Snyder, R. P., 1969, Geologic map of Pahute Mesa, Nevada Test Site and vicinity, Nye County, Nevada: U.S. Geol. Survey Misc. Geol. Inv. Map I-567.

Peacock, M. A., 1931, Classification of igneous rock series: Jour. Geology, v. 39, p. 54-67.

Sargent, K. A., Noble, D. C., and Ekren, E. B., 1965, Belted Range Tuff of Nye and Lincoln Counties, Nevada: U.S. Geol. Survey Bull. 1224-A, p. A32-A36.

Sargent, K. A., and Orkild, P. P., 1973, Geologic map of the Wheelbarrow Peak-Rainier Mesa area, Nye County, Nevada: U.S. Geol. Survey Misc. Geol. Inv. Map I-754.

Wilcox, R. E., 1954, Petrology of Paricutin Volcano, Mexico: U.S. Geol. Survey Bull. 965-C, p. 281-353.