written $(Ba, K_2, Mg, Ca, Na_2, Co, Ni)Mn^2Mn^4_7O_{16} \cdot nH_2O$, with $Ba:K$ $\sim 8:1$. The amount of essential water, if any, is uncertain; the analysis is close to $2H_2O$.

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## CHEVKINITE IN VOLCANIC ASH*

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Chevkinite, a titano-silicate of the cerium earths, first found as large crystals presumably from a nepheline syenite pegmatite (Rose, 1839), has been found in samples of volcanic ash of rhyolitic composition. Noteworthy are its apparent paragenesis, its trifling abundance and its wide distribution. It occurs as separate phenocrysts embedded in volcanic glass in all the samples, and as inclusions within phenocrysts of fayalite, ferroaugite, and sanidine in several samples. Its abundance is on the order of a thousandth of a per cent; only a few crystals can be concentrated from ten grams of sample. It has been separated from a tuffaceous sand in the Dubose member of the Whitsett formation of Eocene age from Texas, an early Pleistocene ash from Idaho, and from the so-called

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* Publication authorized by the Director, U. S. Geological Survey.

Pearlette ash beds of middle Pleistocene age from Texas, Kansas, Colorado, Nebraska, Wyoming, Utah, and Nevada.[1] The widespread so-called Pearlette ash deposits are thought to represent not more than four separate volcanic eruptions (Powers, *et al.*, 1958).

### PHYSICAL AND OPTICAL PROPERTIES

The prismatic chevkinite crystals are approximately 0.03 by 0.17 mm. They vary from slender elongated forms to short stubby ones, and break conchoidally, showing no cleavage. In reflected oblique light they appear
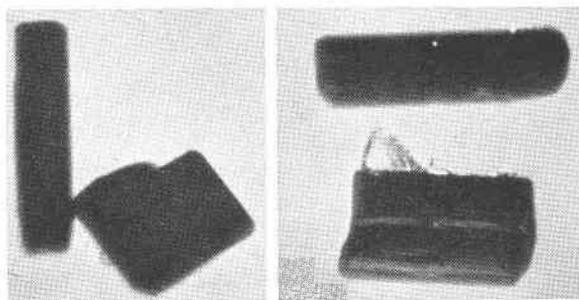


FIG. 1. Photomicrograph of four chevkinite grains from near Mercury, Nevada, taken in plane polarized transmitted light. The short stubby grain with volcanic glass adhering to it is not entirely opaque to transmitted light, showing the property of lesser absorption for $\alpha$. ×130.

black and have a bright splendent luster. In transmitted light (Fig. 1) their most striking diagnostic feature is virtually complete absorption of polarized light for $\beta$ and $\gamma$ so that even the smallest fragments appear opaque in at least one position; $\alpha$ shows least absorption, and is yellow to brown in color.

$\alpha \perp$ elongation, 1.97 to 2.01, moderate absorption (yellow to brown)
$\beta \perp$ elongation, >2.00, virtually complete absorption
$\gamma \parallel$ elongation, >2.00, virtually complete absorption
Birefringence −0.020 to 0.030.

Attempts to obtain the optic sign and 2V with the universal stage failed due to the intense absorption.

Some portions of crushed chevkinite crystals showing refractive indices less than $\alpha$ values suggest alteration or metamictization even in this Pleistocene chevkinite.

The $x$-ray patterns of chevkinite from 3 samples of volcanic ash match

[1] Robert L. Smith of the United States Geological Survey reports (written communication, July 6, 1959) chevkinite from the Bandelier tuff in New Mexico.

the pattern of monoclinic chevkinite from New Hampshire and Arizona (Jaffe *et al.*, 1956). The monoclinic symmetry cannot be confirmed by optical methods because the prismatic crystals are elongated parallel to *b*.

## CHEMICAL

Hydrochloric and nitric acids do not affect chevkinite but hot hydrofluoric acid attacks most of the chevkinite strongly, leaving behind a whitish soft isotropic skeleton which has a refractive index of 1.556 ±0.002. Some of the chevkinite grains appear fresh and unchanged after the treatment, and many grains were only partially altered and still possessed cores of presumably fresh chevkinite.

Radioactivity of a group of several chevkinite grains was measured on a micro-alpha-counter as approximately 7 per cent equivalent Th, which

TABLE 1. SEMIQUANTITATIVE SPECTROGRAPHIC ANALYSIS OF A CHEVKINITE CONCENTRATE FROM PLEISTOCENE VOLCANIC ASH FROM THE LA SAL MOUNTAINS, UTAH

Analyst: John C. Hamilton, U. S. Geological Survey

| Element | | Per cent | Element | | Per cent |
|---|---|---|---|---|---|
| | Si | M | | Mg | 0.7 |
| | K | M | | Y | 0.7 |
| Major | Ti | M | | Nb | 0.7 |
| | Ce | M | | Mn | 0.3 |
| | La | M | | Dy | 0.3 |
| | | | | Er | 0.3 |
| | Fe | 7 | | Gd | 0.3 |
| | Ca | 7 | Trace | Sc | 0.07 |
| | Nd | 7 | | Yb | 0.07 |
| Minor | Al | 3 | | Ba | 0.03 |
| | Pr | 3 | | Cu | 0.015 |
| | Th | 3 | | Mo | 0.015 |
| | Sm | 1.5 | | Cr | 0.007 |
| | Zr | 1.5 | | Sr | 0.003 |

Notes: The chevkinite concentrate consists of the following minerals:

| chevkinite | 50% |
|---|---|
| fayalite | 10% |
| ilmenite | 2–5% |

The remainder is tourmaline, hornblende, ferroaugite, plagioclase.

Figures are reported to the nearest number in the series 7, 3, 1.5, 0.7, 0.3, 0.15, etc. in per cent.

Sixty per cent of the reported results may be expected to agree with the results of quantitative methods.

M = Major constituent—greater than 10 per cent.

agrees with a semiquantitative spectrographic analysis of a 50 per cent chevkinite concentrate shown in Table 1.

The spectrographic analysis was made on only 8 mg. of sample; this was all that was available in one of the samples richest in chevkinite. Major amounts of Ti, Ce, and La and relatively large amounts of several other rare earths confirm the identification of chevkinite. The high content of K may be due to volcanic glass coatings surrounding many of the grains.
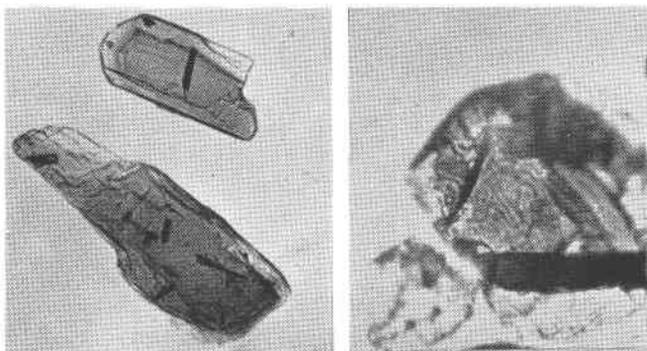


FIG. 2. Photomicrographs of ferroaugite and fayalite with chevkinite inclusions from near Mercury, Nevada, taken in plane polarized transmitted light. (a) the larger ferroaugite grain contains four chevkinite inclusions. The two small nonopaque inclusions in the center of the grain are not chevkinite, and are unidentified. Note that the two chevkinite inclusions in approximately horizontal position show lesser absorption due to $\alpha$ of the chevkinite being transmitted. $\times 100$. (b) The relatively large inclusion of chevkinite in the fayalite is also in position for $\alpha$ to be transmitted and is consequently nonopaque. $\times 330$.

## CHARACTERISTICS OF HOST MATERIALS

In large pumice fragments in a tuff in Forty Mile Canyon near Mercury, Nevada, chevkinite crystals are embedded within phenocrysts of fayalite and ferroaugite (Fig. 2). The inclusions were removed from the host grains and identified by immersion methods.

The fayalite grains are rounded (resorbed) and generally clear yellow in color. Others contain a thin reddish skin presumed to be hematite. Optical data for the fayalite are:

$\alpha = 1.810 \pm 0.01$, $\beta = 1.850 \pm 0.01$, $\gamma = 1.860 \pm 0.01$
Pleochroism is $\alpha = \beta$ pale yellow, $\gamma =$ almost colorless
Absorption formula is $\alpha = \beta > \gamma$, $2V(-) = 48° \pm 2°$ (universal stage).

According to the data of Winchell (1951) the measured 2V would place the mineral almost at the fayalite end of the forsterite-fayalite series. The $\beta$ refractive index would indicate a composition of $Fo_{5-11}$ $Fa_{95-89}$. Using an $x$-ray method of Yoder and Sahama (1957) accurate

measurement of the (130) spacing, which was 2.825 Å, indicates a composition of $Fo_{11}Fa_{89}$. Optical data for the ferroaugite are:

$\alpha = 1.729$, $\beta = 1.735$, $\gamma = 1.762$ ($\pm 0.005$)

$Z \wedge c = 49°$, average (variation from 48°–52°)

$2V(+) = 56°$, average (variation from 54°–67°)

Extinction angles and 2V determined on the universal stage.

Pleochroism is faint with $\alpha = \beta$ green, $\gamma =$ yellowish green.

Using the determinative chart by Hess (1949) the green pyroxene fits in the ferroaugite field and has the following cation ratio: Fe: Ca: Mg = 58:34:8.

The pumice has the following chemical composition (in weight per cent), with and without phenocrysts.

| | Pumice | Pumice (*phenocrysts extracted*) |
|---|---|---|
| | D-1756[1] | D-1757[1] |
| $SiO_2$ | 69.44 | 70.98 |
| $Al_2O_3$ | 12.56 | 12.28 |
| $Fe_2O_3$ | 1.60 | 1.46 |
| FeO | .54 | .53 |
| MgO | .63 | .34 |
| CaO | 1.12 | .78 |
| $Na_2O$ | 3.41 | 3.48 |
| $K_2O$ | 5.24 | 5.35 |
| $H_2O^-$ | 1.16 | .72 |
| $H_2O^+$ | 3.01 | 3.04 |
| $TiO_2$ | .13 | .13 |
| $CO_2$ | .52 | .27 |
| $P_2O_5$ | .01 | .01 |
| F | .14 | .12 |
| MnO | .08 | .07 |
| | 99.59 | 99.56 |
| Less 0 | .06 | .05 |
| | 99.53 | 99.51 |

[1] Analysis number—U. S. Geological Survey, Denver rock analysis laboratory. Analyst, Dorothy F. Powers.

## COMPARATIVE DATA ON THE OCCURRENCES

In this study chevkinite has been identified from 60 samples of silicic volcanic ash from 20 different localities; it is believed, however, that these samples are from the products of not more than six different volcanic eruptions at centers whose location is not yet known. One tuffaceous sand that contains chevkinite is of Eocene age in the Dubose member of the Whitsett formation of Texas; one ash bed from Hagerman, Idaho, is of Early Pleistocene age; the other beds are believed all to be

parts of the so-called Pearlette ash (four separate closely-spaced eruptions) of middle Pleistocene age (Powers *et al.*, 1958). No chevkinite was found in samples of about sixty other ash beds of late Cenozoic age; hence, about 50 per cent of the volcanic ashes examined contained chevkinite. Perhaps chevkinite has been a rare species because its presence has been overlooked, and future mineralogic studies of heavy mineral concentrates may find it to be an expectable accessory constituent of some varieties of igneous rocks. Chevkinite is an early-formed mineral in a magma as shown by its common appearance as inclusions in early-formed ferroaugite and fayalite.

A comparison of several features of some of the chevkinite-bearing ashes is given in Table 2.

TABLE 2. COMPARATIVE DATA ON SOME CHEVKINITE-
BEARING VOLCANIC ASHES

|  | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Chevkinite, $\alpha$ refractive index | 1.99 | 1.99[1] | 1.99[1] | 1.99 | 1.98 | 1.98 | 1.97 |
| Associated phenocryst heavy minerals[2] |  |  |  |  |  |  |  |
| Fayalite |  | x |  | x |  |  |  |
| Augite, $\beta 1.695\pm$ | x |  |  |  |  |  |  |
| Ferroaugite, $\beta 1.736$ |  | x | x | x | x |  |  |
| Hornblende, red-brown |  |  | x | x | x | x | x |
| Hornblende, olive-brown | x |  |  |  | x | x | x |
| Hornblende, blue-green |  |  |  |  | x | x | x |
| Zircon, colorless | x | x | x | x | x | x | x |
| Zircon, pink |  | x | x | x | x | x | x |
| Partial chemical composition of volcanic glass (phenocrysts extracted) |  |  |  |  |  |  |  |
| $SiO_2$, water free | 74.3 | 74.1 | 75.5 | 76.5 | 76.5 | 76.3 | 77.1 |
| $TiO_2$, water free | 0.13 | 0.14 | 0.13 | 0.13 | 0.13 | 0.12 | 0.11 |
| $Na_2O+K_2O$, water free | 9.6 | 9.2 | 8.8 | 8.9 | 8.8 | 8.9 | 9.2 |

1. Ash, Hagerman, Idaho.
2. Pumice blocks from tuff, Forty Mile Canyon, Mercury, Nevada.
3. Ash, Pine Valley, Nevada.
4. Ash, La Sal Mountains, Onion Creek, Utah.
5. Ash, Meade County, Kansas.
6. Ash, Pine Valley, Nevada (probably different from 3).
7. Ash, Valley County, Nebraska.

[1] Identity of chevkinite verified by *x*-ray diffraction.
[2] All samples contain ilmenite and magnetite.

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## AN IMPROVED THERMAL HEAD FOR D.T.A. OF CORROSIVE MATERIALS

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Differential thermal analysis of sulfides and other minerals that corrode metal containers when heated in air was made practical through the development of specially designed receptacles described by Kopp and Kerr (1957). Research on the differential thermal analysis of sulfides supported by the National Science Foundation has recently resulted in the development of apparatus which is a further refinement of this equipment.

The thermal head, shown in Fig. 1, is machined out of 18-8, Cr-Ni stainless steel round stock. Specimen well holes are designed to contain nests of alundum insulator tubing which are supported in the head by a thin transite disc. The nests can be prepared in advance from commercially available stock and are quickly interchanged when thermocouples require replacement. Head temperature is measured by the reference thermocouple using an ordinary triple lead arrangement as described by Mackenzie (1957, p. 36, Fig. II, 4). The writers are indebted to Mr. E. M. Bollin of the mineralogy group at Columbia University for calling this procedure to their attention.

The simplification of the head design permits rapid and inexpensive machining, and facilitates the removal of used specimen wells and cement. The specimen well assemblies are constructed with the aid of brass gauges which have been made in order to insure constant well