TERUGGITE, $4CaO \cdot MgO \cdot 6B_2O_3 \cdot As_2O_5 \cdot 18H_2O$, A NEW MINERAL FROM JUJUY, ARGENTINA

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Abstract

The new mineral, teruggite, $4CaO \cdot MgO \cdot 6B_2O_3 \cdot As_2O_5 \cdot 18H_2O$, was collected at the Loma Blanca borate deposit, province of Jujuy, Argentina. It occurs in white cauliflower-shaped nodules associated with inyoite, calcite, ulexite, aragonite and realgar, in a spring deposit. These minerals are irregularly distributed through a local valley fill and are mostly epigenetic but partially contemporaneous. The deposit is Recent in age and genetically related to dacitic effusions from nearby volcanos. Teruggite is monoclinic, $2/m$; space group $P2_1/a$; $a=15.68$, $b=19.90$, $c=6.25$ Å, $\beta=100°05'$; $a:b:c=0.7879:1:0.3141$; volume 1920 Å³; $Z=2$. Colorless, well-formed, acicular crystals of 110 μm maximum length are elongated on [001]. Faces of 10 forms are present; the dominant are: p {110}, c {001} and D {$\bar{1}$01}.

Strongest lines in the X-ray powder photographs are, in Å: 12.13 (100), 2.785 (30), 9.98 (22), 3.577 (22), 4.65 (21), 8.37 (20), 3.851 (17), 3.245 (17).

The new mineral is optically biaxial $(+)$; $\alpha=1.526$, $\beta=1.528$, $\gamma=1.551$; $2V=33°$; $r>v$ weak; $Z=b$, $X \wedge c=-26°$. The hardness is $2\frac{1}{2}$; density 2.149 (meas.); 2.139 g/cm³ (calc.). Cleavage: {001} good and {110} fair. The chemical analysis yields: CaO 17.51, MgO 3.16, B_2O_3 32.76, As_2O_5 17.93, $H_2O+110°C$ 25.48, $H_2O-110°C$ 2.81, SiO_2 0.29 Total 99.94. Interpretation of the analysis gives the empirical formula: $Ca_{3.98}Mg_{1.00}B_{12.00}As_{1.99}O_{27.96}$ 18.04 H_2O. DTA shows endothermic peaks at 200°, 305°, 440°, and 655° and exothermic peaks at 740°, 795°, 950° and 1040°C.

Teruggite is named in honor of Mario E. Teruggi, Professor in the Department of Geology, Universidad Nacional La Plata, Argentina.

Introduction

Teruggite, a new borate mineral, was collected in June, 1967, during a field study of Argentine borates. It was found in the deposit known as Loma Blanca in the Departamento Susques, Jujuy Province, approximately 80 kilometers east of the point where Argentina, Bolivia and Chile meet. Maps of the area are poor and thus it is difficult to give a precise location. However, the deposit is located approximately 8 kilometers in a straight line SW of the village of Coranzulí.

A small borate mine is owned and operated by the Compañía Borax Argentina, S.A. at Loma Blanca. It is located in a minor east–west valley 1.5 kilometers east of the junction with a north–south valley known as Cueva Blanca. The locality lies at an elevation of approximately 4100 meters above sea level on the eastern flank of a group of volcanos rising from the high plateau, Puna de Atacama. The mine can be reached by car following Route 9, 166 kilometers north from Olacapato Station on the G.M. Belgrano Railway.

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[1] Mineralogical contribution No. 458, Harvard University.

Teruggite[1] is named in honor of Mario E. Teruggi, Professor in the Department of Geology, Universidad Nacional de la Plata, Argentina, in recognition of his numerous contributions to the sedimentology and petrology of his country. Equally important has been his work as a dedicated teacher, for under trying circumstances he has for the past twenty years helped move Argentina toward modern scientific and cultural goals.

GEOLOGIC SETTING

A group of high volcanos (Coyaguaima, Coyambaya, Niño, Supisaino) west of Loma Blanca and aligned in a north–south direction, forms the most striking morphological feature of the landscape. Related to them are extensive flows and tuffs of dacitic composition that make up the major geologic units of the area.

Because of the genetic relationship of volcanism to important mineral deposits of the Puna, the age of the volcanic rocks is of particular interest. Sgrosso (1943) considered the volcanics of the area as Miocene-Pliocene, although he stated that they extended into the Pleistocene (p. 27). Ahlfeld (1948a, p. 138) described volcanic cones of the region as Pleistocene. A Lower Quaternary age has been assigned by Vilela (1953) to similar dacites and tuffs about 80 kilometers to the south and by Turner (1964) to the zone of the Nevado de Cachi still further south. However, based on a study of fossil diatoms, Pratt (1961) concluded that the age of folded continental sandstones, older than the volcanic rocks, is Pleistocene or younger. Thus the dacites would be, at least in part, Recent.

About 10 kilometers north of Loma Blanca are schists and quartzites considered to be Cambro-Ordovician by Sgrosso (1939, p. 88) and Ordovician by Ahlfeld (1948b, p. 271). Overlying these rocks are yellow and red sandstones and conglomerates that according to Ahlfeld (1948b) are Upper Tertiary in age but according to Pratt's work could be younger. At the Loma Blanca mine Recent fluvial and pyroclastic sediments form a local valley fill.

Related to the large volcanic system of the area are several borate spring and playa deposits. The spring deposits represent the latest cycle of borate deposition while those of the playas are related, in general, to earlier phases of regional volcanic activity. The spring deposits are of special interest because of their similarity to the one at which teruggite was found. In addition to Loma Blanca, two other deposits of this type

[1] The name and the mineral, teruggite (pronounced, té roo gite) has been approved by the Commission of New Minerals and New Mineral Names, IMA.

are known in the area. The Coyaguaima (or Coyahuima), located at the eastern fringe of the cone of the homonymous volcano, was described by Catalano (1930) and Ahlfeld (1948b). Here a cap of ulexite (now removed by mining) was deposited over layered travertine. According to Blosser[1] a layer of borax was originally above the ulexite indicating a change of the composition of the spring water from calcium to sodium and from carbonate to borate. The deposit is located along the fault that follows the Coyaguaima River; and, because of its relationship to morainal material, Ahlfeld (1948b, p. 276) suggests a post-glacial age for it although borates may have existed there earlier. Small amounts of water may be seen today bubbling from the springs' mouths.

The second borate spring deposit of the area is located in the Quebrada del Alumbrio, southeast of the volcano Supsaino; according to Barnabé (1915) it contains "calcium borate" which, because of the local terminology of the time, (Reichert, 1907, p. 9) is interpreted as ulexite.

OCCURRENCE

Teruggite occurs at Loma Blanca, the third spring deposit of the area. Here, the borates are embedded in a local valley fill composed of tuffs, sandstones and conglomerates that reach a thickness of about 25 meters.

The pyroclastic rock is a light-gray dacitic tuff composed of approximately two-thirds phenocrysts and one-third matrix with few voids. A few small fragments of volcanic rocks are also present. The phenocrysts are zoned andesine (55%), quartz (30%), biotite (12%) and sanidine (3%); the matrix is composed of the same minerals plus glass and iron oxide. The phenocrysts present no marked orientation, are very fresh and range in size from one to four millimeters. They are predominantly angular broken fragments but many are subhedral.

The sandstones are formed by the same minerals that compose the phenocrysts of the dacitic tuff, partially altered and sorted by a short transport. They are friable, being only poorly cemented by calcite. The conglomerate is coarse, containing pebbles and cobbles of volcanic rocks and a calcareous cement.

Loma Blanca, as far as explored, is of relatively small dimensions with a low borate content. Figure 1 shows the south wall of the valley with terrace sediments invaded by borates. There are two areas of impregnation suggesting two spring mouths developed along an E–W fault. Each area is approximately 100 meters long. The borates and other minerals precipitated from the spring waters are irregularly distributed in the partially cemented sediments of the valley fill with textures

[1] Personal communication from B. Blosser (1967), former mining engineer for the company that exploited the deposit.

FIG. 1. Loma Blanca mine. Photograph showing the two principal areas of mineralization in the south side of the valley, taken from a point a few meters above the place where teruggite was found.

characteristic of epigenetic deposition. But locally there is a much greater concentration in small bodies that, in cross section, are 1–2 meters high and 3–4 meters wide, the lower parts of which are concave upward suggesting deposition from small streams that flowed toward the valley bottom. The concordance of these bodies with the enclosing sediments indicates some contemporaneous deposition of borates. On the north valley wall the distribution of borates is in general similar to that of the south wall.

The formation of the deposit must have begun during Recent times and continued almost to the present day. It is thus a final manifestation of the last cycle of the effusion of the near-by volcanos. Obviously much of the boron of the spring waters was contributed to the stream system and thus became incorporated in the playa deposits.

MINERALOGY OF THE DEPOSIT

Teruggite was found at Loma Blanca in the north wall of the valley at a point approximately 2 meters above the stream bed and 300 meters downstream from the only house of the mine. It is found in cauliflower-shaped nodules (Fig. 2) ranging from 2 to 6 cm in diameter. Each nodule is composed of countless minute euhedral crystals which give the interior a pure-white appearance. An estimated two percent of impurities is present as hydrobiotite and montmorillonite confined to small veinlets or nodules of gray color. The exterior is light brown because of adhering fragments of biotite, feldspar and quartz.
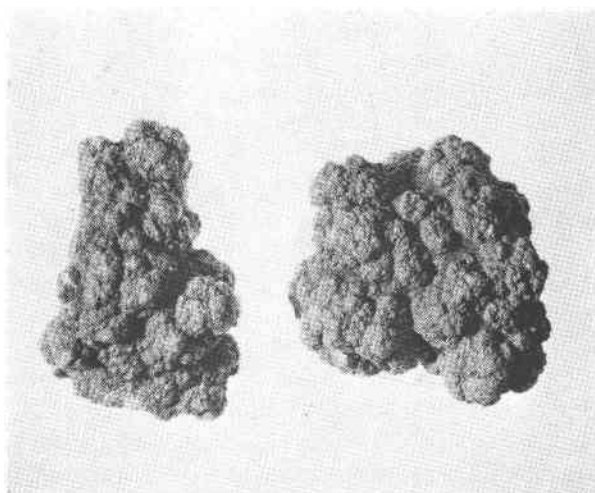
Fig. 2. Teruggite nodules showing the characteristic cauliflower shape.
Approximately $\frac{1}{2}$ actual size.

The principal minerals found in the deposit associated with teruggite as precipitates from spring waters are inyoite, calcite, ulexite, aragonite and realgar. Only the first two are abundant, ulexite is scarce, and the others, including teruggite are rare.

The occurrence of inyoite ($Ca_2B_6O_{11} \cdot 13H_2O$) is irregular, forming subhorizontal veinlets or groups of 2 or 3 crystals having a spotty distribution (Fig. 3) through the sandstone. Inyoite show two distinct
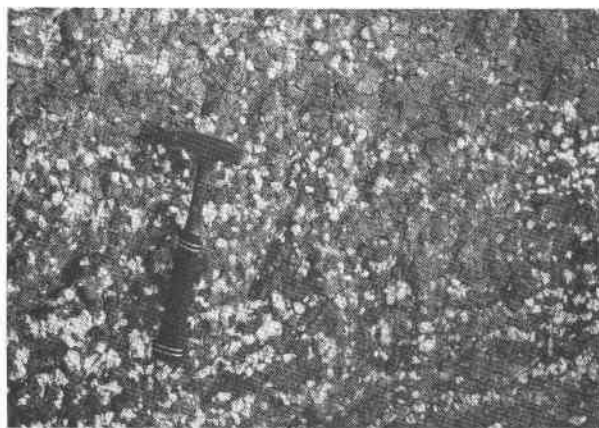

Fig. 3. Inyoite crystals in sandstone entirely replaced by ulexite as seen in a vertical cut in the north wall of the valley.

habits. In one, euhedral crystals, tabular parallel to {001}, have a diamond-shaped outline resulting from the presence of {110}. These crystals are relatively uniform in size measuring 2 to 3 centimeters parallel to the *b* axis. They are slightly brownish because of clays incorporated during growth, but show no trace of alteration. In the second type, fresh acicular crystals are arranged in parallel orientation to form tabular aggregates.

Ulexite ($NaCaB_5O_9 \cdot 8H_2O$) occurs scattered through the deposit in typical "cotton-balls" but also in a very unusual way; that is, completely replacing euhedral crystals of inyoite. (Fig. 3). Individual crystals are fibers (10×1000 μ) but arranged in parallel aggregates they form stream-like patterns randomly oriented in relation to the replaced mineral. This replacement obviously indicates a change of the spring waters towards a more sodic composition. This pseudomorphous ulexite is in a single body (2.5×1 m.) very near the place where teruggite was found and represents a local alteration. For the body is enclosed in an otherwise uniform sandstone with inyoite crystals regularly distributed through it.

Aragonite forms dense nodules somewhat similar in external appearance to those of teruggite that reach 6 centimeters in diameter. The nodules, made up of well formed but randomly oriented crystals 2–3 mm long, are incrusted with microcrystals of the same mineral.

Although realgar is rare, it is conspicuous because it coats the surface of pseudomorphous ulexite forming thin and incomplete orange-red films. This occurrence of realgar shows the presence of arsenic, at least during the late stages, in the evolution of the solutions.

Calcite is very abundant as the cementing material of the conglomerate and sandstone and in addition forms subhorizontal thin layers with banded texture.

The presence of inyoite in this deposit is of particular interest because this mineral is here primary without question. Foshag (1921) in discussing the origin of colemanite deposits of California, concluded that calcium borates are not formed in playa environments. However, Catalano (1926, p. 35, 51; 1964, p. 77) reported calcium borates from three *salars* in Argentina: Pastos Grandes, Cauchari and Hombre Muerto. Later Muessig (1958, 1959) described primary inyoite in a playa deposit near a hot spring at Laguna Salinas, Perú. The occurrence of primary inyoite at Loma Blanca reaffirms the assertion of Catalano and Muessig that this mineral can form under surface conditions.

MORPHOLOGY

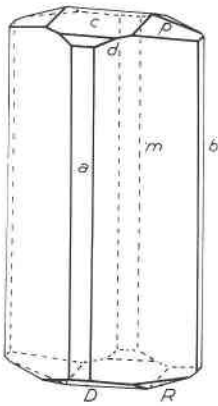The crystals of teruggite are greatly elongated on the *c* axis with

FIG. 4. Idealized teruggite crystal. The thickness is increased relative to the length in order to show better the terminal faces.
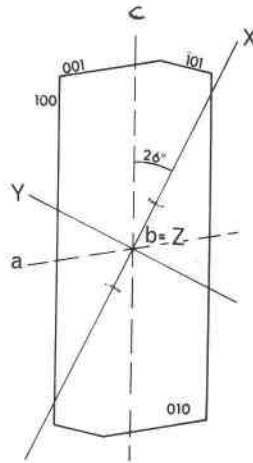
FIG. 5. Optical orientation of teruggite.

rhomboidal cross-section perpendicular to this direction. Most crystals measure between 30 and 60 μm in length, but an occasional one is as long as 110 μm. The average dimensions across the length is 5 to 7 μm; the maximum is 20 μm. The general length to thickness ratio 7:1 gives the crystals an acicular habit. In Figure 4 the thickness is increased relatively to the length in order to show better the terminal faces.

Ten crystals were measured on the two-circle optical goniometer. The faces of the $\{hk0\}$ forms gave fair to poor signals but some terminal faces were seen only as points of light. For this reason the axial ratios and angles given in the angle table (Table 1) were calculated from X-ray measurements.

The ϕ and ρ angles obtained from morphological measurements differ no more than $2\frac{1}{2}°$ from the calculated values. The habit of all crystals is similar with $\{110\}$, $\{001\}$ and $\{\overline{1}01\}$ the dominant forms. Although present on all crystals. $\{100\}$ and $\{010\}$ occur only as line faces and $\{\overline{1}11\}$ and $\{021\}$ as little more than points. Faces of the forms $\{130\}$ and $\{101\}$ are only occasionally present. Equal development of faces at the positive and negative ends of the b axis suggest the crystal class $2/m$, which is confirmed by X-ray study.

OPTICAL AND PHYSICAL PROPERTIES

The optical orientation of teruggite is shown in Figure 5 with $b = Z$ and $X \wedge c = -26°$. However, since $\{001\}$ and $\{\overline{1}01\}$ are equally well de-

TABLE 1. TERUGGITE ANGLE TABLE MONOCLINIC; PRISMATIC—$2/m$
$a:b:c=0.7879:1:0.3141$; $\beta=100°05'$; $p_0:q_0:r_0=0.3986:0.3092:1$;
$r_2:p_2:q_2=3.2340:1.2890:1$; $\mu=79°55'$; $p_0'\ 0.4049$, $q_0'\ 0.3141$; $x_0'\ 0.1778$

	Forms	ϕ	ρ	ϕ_2	$\rho_2=B$	C	A
c	001	90°00′	10°05′	79°55′	90°00′	0°00′	79°55′
b	010	00 00	90 00	—	0 00	90 00	90 00
a	100	90 00	90 00	0 00	90 00	79 55	0 00
k	130	23 15	90 00	0 00	23 15	86 02	66 45
m	110	52 48	90 00	0 00	52 48	81 59	37 12
p	011	29 31	19 51	79 55	72 49	17 11	80 22
q	021	15 49	33 08	79 55	58 15	31 45	81 26
d	101	90 00	30 14	59 46	90 00	20 09	59 46
D	$\overline{1}$01	−90 00	12 47	102 47	90 00	22 52	102 47
R	$\overline{1}$11	−35 52	21 11	102 47	72 58	28 14	102 14

veloped with rho values differing by less than 3°, it is extremely difficult, because of the small size of the crystals, to distinguish them under the microscope. For these reasons it is impossible to unequivocally establish the relation between the goniometric and microscopic observations. To fix the optical indicatrix it was assumed that the cleavage parallel to the b axis is {001}.

The optical properties of teruggite are:

$\alpha = 1.526$ Na light   Opt (+) $X \wedge c = -26°$
$\beta = 1.528$ ± 0.001 $2V = 33°$ $Z = b$
$\gamma = 1.551$ $r > v$ weak

Teruggite shows two cleavages: {001} good and {110} fair. The crystals are brittle and tend to break across the length on the {001} cleavage; they are colorless and transparent with vitreous luster. However, as aggregates in the nodules they have a powdery white appearance. The hardness is 2 1/2. The specific gravity measured by the pycnometer method described by Fahey (1961), when corrected for adsorbed water, is 2.149; the calculated density is 2.139 g/cm³ for the theoretical formula. That the measured value is greater than the calculated is attributed to a small amount of impurities. The mineral does not fluoresce under ultraviolet light.

X-RAY STUDY

The cell dimensions of teruggite (Table 2) were determined from precession photographs (Mo/Zr) with b as precession axis, and Weissen-

TABLE 2. UNIT-CELL DATA FOR TERUGGITE

$a = 15.68$ ⎫	Space group $P2_1/a$
$b = 19.90$ ⎬ ± 0.01 Å	Measured specific gravity,
$c = 6.25$ ⎭	2.149 $\pm$ 0.005
	Calculated density,
	2.139 g/cm³
$\beta = 100°05' \pm 10'$	Cell content:
$a:b:c = 0.7879:1:0.3141$	$2[4CaO \cdot MgO \cdot 6B_2O_3 \cdot As_2O_5 \cdot 18H_2O]$
$V = 1920.08$ Å³ $Z = 2$	

berg photographs (Cu/Ni) with c the rotation axis. Values were refined with X-ray powder data. Extinctions in the single crystal photographs uniquely determine the space group as $P2_1/a$.

The spacings given in Table 3 were derived from powder photographs (Cu/Ni) but with intensities obtained from diffractometer charts. Charts obtained using a mixture of mineral and ground glass (40%), to avoid preferred orientation, showed only minor changes in the relative intensities of the peaks compared with those obtained using the mineral alone.

CHEMICAL COMPOSITION

A two-gram sample was selected for chemical analysis from the interior of a nodule to avoid any inclusion of surficial impurities. Microscopic examination showed it to have less than one percent extraneous minerals, chiefly hydromicas. The results of a wet chemical analysis carried out by Mr. Hisayoshi Ichihara of the Toshiba, Central Research Laboratory, Kawasaki, Japan, are given in column 1 of Table 4. In column 4, Table 4, are given the atomic proportions that result using boron equal to 12. These values yield the empirical formula: $Ca_{3.98}Mg_{1.00}$ $B_{12.00}As_{1.99}O_{27.96}18.04$ H_2O; which is remarkably close to an ideal formula: $4CaO \cdot MgO \cdot 6B_2O_3 \cdot As_2O_5 \cdot 18H_2O$.

The above formula was obtained disregarding the $-110°C$ water. If this water is included a similar formula results but with almost exactly 20 H_2O. Although the DTA curve (Fig. 7) and TGA show no clear distinction between adsorbed and structural water, the authors prefer 18 H_2O for two reasons. First, X-ray diffraction charts obtained using samples heated for one hour to 110°C show no difference from charts obtained with the unheated sample. Second, there is a better agreement between measured specific gravity (2.149) and calculated density. For the theoretical formula the calculated density using 20 H_2O is 2.201 gm/cm³; using 18 H_2O, it is 2.139 gm/cm³. The molecular weight for the empirical formula is 1235. The molecular weight calculated

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TABLE 3. X-RAY POWDER DATA FOR TERUGGITE
(CuKα = 1.54178; CuKα₁ = 1.54051; Ni filter)
Camera diameter 114.59 mm

I^a	d(obs)	d(calc)[b]	hkl[b]	I^a	d(obs)	d(calc)[b]	hkl[b]	I^a	d(obs)	d(calc)[b]	hkl[b]
100b	12.13	12.198	110	5b	3.051	3.051	510			2.090	$\bar{7}$31
						3.049	440			2.088	072
22b	9.98	9.950	020	13b	2.947	2.949	520	5	2.051	2.051	003
20b	8.37	8.363	120			2.944	$\bar{5}$11	4	2.015	2.016	740
4	7.72	7.719	200			2.941	341			2.015	661
2	7.21	7.196	210	12b	2.907	2.906	421			2.014	741
11b	6.13	6.153	001	7	2.838	2.842	$\bar{3}$12	7b	1.984	1.986	$\bar{1}$33
		6.099	220	30	2.785	2.788	360	4b	1.926	1.927	$\bar{7}$51
		6.095	130	3	2.765	2.769	$\bar{2}$32			1.925	$\bar{7}$22–481
10	5.88	5.879	011			2.763	431	8	1.892	1.893	$\bar{6}$71–213
15	5.22	5.234	021	2	2.704	2.700	202	8b	1.838	1.840	$\bar{2}$53
		5.212	111	6	2.625	2.623	540	3	1.796	1.796	$\bar{5}$33
7b	4.97	4.982	310	5	2.575	2.576	$\bar{1}$71	3	1.766	1.765	751
		4.975	040			2.573	600	2	1.741	1.741	$\bar{7}$71
8	4.73	4.735	140	5	2.519	2.519	142	2	1.702	1.702	$\bar{6}$33
21b	4.65	4.666	$\bar{2}$21			2.517	$\bar{6}$11	2	1.668	1.669	423
17	4.571	4.571	320			2.516	171			1.668	860
						2.515	460	4	1.622	1.626	$\bar{8}$52
11	4.071	4.066	330	5	2.450	2.454	$\bar{4}$32			1.619	771
7	3.966	3.977	$\bar{3}$21			2.453	361	1	1.582		
17b	3.853	3.859	$\bar{4}$00	2	2.421	2.420	$\bar{2}$52	1	1.564		
		3.854	$\bar{1}$41–150	4	2.368	2.370	$\bar{6}$31	1	1.545		
12	3.662	3.659	141			2.368	280	1	1.525		
22b	3.577	3.598	420	3	2.324	2.329	$\bar{3}$52	1	1.512		
		3.586	$\bar{3}$11	8b	2.252	2.256	062	1	1.459		
		3.577	340			2.251	$\bar{2}$81	1	1.437		
		3.562	$\bar{4}$01	5	2.194	2.192	162–710	2	1.434		
3	3.325	3.336	430	7	2.155	2.157	$\bar{6}$12				
		3.317	060			2.153	720				
		3.316	241	5	2.136	2.139	$\bar{6}$51				
17b	3.245	3.243	160	4	2.091	2.091	480		Plus 40 additional lines		
2	3.141	3.138	$\bar{4}$31								
1	3.081	3.086	$\bar{1}$12								
		3.077	002								

[a] The line intensities were derived from a diffractometer chart obtained with Cu radiation.

[b] The calculated d were obtained and indexed with an IBM 7094 Computer using a program for calculations of all possible spacings.

TABLE 4. CHEMICAL ANALYSIS OF TERUGGITE[a]

| | Wt. % | Wt. % recalculated | | Atomic proportions | |
	1	2		3	4 (B=12)
CaO	17.51	18.08	Ca	0.322	3.982
MgO	3.16	3.26	Mg	0.081	1.000
B_2O_3	32.76	33.83	B	0.972	12.000
As_2O_5	17.93	18.52	As	0.161	1.990
$H_2O+110°C$	25.48	26.31	H	2.921	36.076
$H_2O-110°C$	2.81		O	3.724	45.996
SiO_2	0.29				
Total	99.94	100.00			

[a] A spectrographic analysis by the Jarrell-Ash Company, Waltham, Massachusetts, showed traces of Al, K, Ti, Sr and very faint traces of Cr, Mn, Fe, Cu, Bi.

1. Mr. Hisayoshi Ichihara, analyst.

2. Analysis recalculated to 100 percent disregarding $H_2O-110°C$ and SiO_2

using the measured cell volume and specific gravity is 1242.5, with two formula weights in the unit cell.

Teruggite is only slightly soluble in warm water but readily soluble in hydrochloric acid. When heated before the blowpipe it gives the green boron flame and fuses to a clear glass bead. When heated on charcoal, it yields the characteristic garlic-like odor of arsenic.

DIFFERENTIAL THERMAL ANALYSIS

A differential thermal analysis of teruggite was made in air at one atmosphere from room temperature to 1100°C. The resulting pattern is shown in Figure 6.

There are 4 endothermic peaks at 200°, 305°, 440° and 655°C and four exothermic peaks at 740°, 795°, 950° and 1040°C. The first endothermic reaction apparently starts at 90°C, because of adsorbed water, and ends at 405°C producing a very large peak with maximum at 305°C and a small shoulder at 200°C. The next endothermic peak at 440°C is small and is superimposed on the high temperature branch of the first. The shoulder and the two peaks are interpreted as resulting from the loss of water and suggest that this component is lost in three stages, which are also indicated by thermogravimetric curves.

The mineral was heated in 50°C stages from 200° to 750° and diffractometer runs made on the resulting products. At 200°C the pattern showed a slight resemblance to that obtained on the original material but the others indicated the products are amorphous. Although amor-
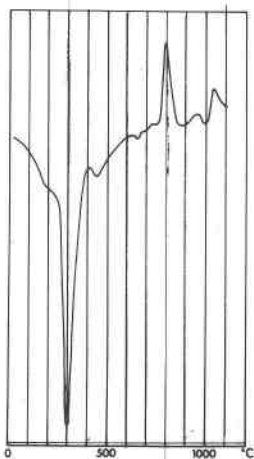
Fig. 6. DTA curve of teruggite. Rate of heating 20°/min. reference junction 0°C; thermocouple Pt/Pt+10% Rh; reference material burned kaolin.

phous, microscopic examination shows that the particles do not lose the euhedral shape of the teruggite crystals until heated above 550°C.

Samples air-quenched after heating to 850°C show tiny equidemensional crystals embedded in a glass $(n=1.61)$. The second exothermic peak (795°C) seems to be related to the formation of these crystals whose principal spacings in Å are: 2.95 (100), 2.70 (73), 4.52 (46), 5.35 (39), 3.31 (39) and 1.76 (32). The same two phases are present in samples heated to 1000°C but at 1100°C a new crystalline phase is found embedded in the glass $(n=1.61)$. The exothermic peak at 1040°C probably results from the formation of these crystals whose principal spacings in Å are: 2.075 (100), 1.596 (100), 2.536 (86), 3.450 (63), 1.732 (49), 2.365 (38) and 1.369 (38).

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