

CENOSITE FROM COTOPAXI, COLORADO<sup>1</sup>

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ABSTRACT

Cenosite, the first found in the United States, occurs as a rare accessory in a replacement unit in a granite pegmatite near Cotopaxi, Colorado. Associated species are albite, muscovite, fluorite, monazite, cyrtolite, euxenite and doverite. Properties are: pale rose, H 5, G 3.41, two cleavages at 90°;  $\alpha=1.662$ ,  $\beta=1.686$ ,  $\gamma=1.692$ ,  $(-)$   $2V=40^\circ$ ,  $r < v$  distinct. From a new analysis the formula is:  $\text{Ca}_4(\text{Y, etc.})_4\text{Si}_8\text{O}_{23}(\text{CO}_3)_3 \cdot 3\text{H}_2\text{O}$ . The RE are mainly Y, with lesser Yb, Dy and Er.

INTRODUCTION

*General.* During the summer of 1958, while engaged on a reconnaissance examination of the Precambrian area north of Cotopaxi, Colorado, the senior author revisited the Henry pegmatite and found on the dump a small specimen of an unusual mineral which could not be identified. Subsequent optical studies suggested that it was the rare carbonate-silicate of calcium and rare earths, cenosite, which was confirmed by x-ray powder data. The pegmatite was further studied and mapped by Salotti in 1959, but no more cenosite was discovered. The analysis was completed by Borup at the Central Laboratory of the Dow Chemical Company, Freeport, Texas. The writers are grateful to the Company and to Dr. E. R. Wright for their cooperation and for permission to publish the results of the study. We also thank the following for gifts and loans of specimens: Paul E. Desautels, Smithsonian Institution, J. A. Mandarino, the Royal Ontario Museum, S. C. Robinson, Geological Survey of Canada, and Cyril Holland, Bicroft Uranium Mines, Ltd.; for suggestions, information and assistance: A. A. Levinson and J. A. Greear, The Dow Chemical Company, E. B. Gross, The University of Michigan, and Louis Moyd, New York City. Some of the field work and part of the laboratory studies were supported by a grant from Michigan Memorial Phoenix Project, No. 204.

*History of cenosite.* Cenosite (kainosite) was described first by Nordenskiöld in 1886 from Igeltjern, on Hitterö Island, Norway. In 1897 Sjögren recorded a second occurrence at the Ko mine, Nordmark, Sweden. The mineral was next found in Ontario, Canada on lot 8, concession V, Noth Burgess township (Graham and Ellsworth, 1930; Ells-

<sup>1</sup> Contribution No. 240 from the Department of Mineralogy, The University of Michigan, and Mineralogical Publication from the Dow Chemical Co., No. 62841.

worth, 1932). A second Canadian discovery was made in the late 1950's at the Bicroft Uranium Mines, Ltd., 10 miles west of Bancroft, Ontario (Holland, written comm.). The mineral also has "... been reported in traces ... in the nearby Greyhawk Mine" (Robinson, written comm., see also, Robinson, 1960). Dr. Robinson has undertaken a complete mineralogical study of the Bicroft cenosite.

Four occurrences of very limited numbers of tiny crystals have been reported from Switzerland in the Grimsel region (Parker and de Quervain, 1940, 1956; Beck, 1956).

The Colorado cenosite thus apparently represents the tenth recorded occurrence of the mineral and the first in the United States.

#### THE HENRY PEGMATITE

*General.* The geology of the Cotopaxi region has been studied by Salotti (1960). The Henry pegmatite (previously also known as the Colorado Feldspar pegmatite) lies across the boundary between sections 7 and 8 near their southern ends, in T.48 N., R.12 E., about  $3\frac{1}{2}$  miles north-northeast of Cotopaxi, Fremont County, Colorado. The dike has been intruded in part along the contact between Pikes Peak granite and a body of Precambrian biotite gneiss which appears to be a roof pendant in the batholith. The gneissic structure in the pendant trends generally northerly with gentle eastward dips. Near the pegmatite body, however, the foliation strikes nearly east-west, dipping northward  $40-46^\circ$ . The dike, which cuts across both the foliation and the granite-gneiss contact, trends west-northwest and appears to dip northeastward at a moderate angle.

The pegmatite has been mined and explored by means of several small cuts, pits and trenches (Fig. 1) and is poorly exposed. The deposit was quarried first in 1939 by the Colorado Feldspar Company of Canon City, Colorado. Prospecting in the replacement unit was carried on in the late 1950's by Robert Benton of Cotopaxi.

*Geology.* The internal structure of the pegmatite is indistinctly developed. The wall zone, which makes up most of the body, consists of an intergrowth of quartz, microcline, oligoclase and minor biotite and magnetite. The intermediate zone, weakly developed along the northwest end of the core, contains chiefly a coarse graphic intergrowth of quartz and microcline. The centrally placed quartz core dips  $60^\circ$  north.

The rarer minerals are confined to a small unit localized along the hanging-wall contact between the core and the intermediate zone. The quartz of the core directly beneath this unit is strongly fractured. Its irregular contacts and the included remnants of graphic granite indicate this unit has formed by means of replacement, largely of intermediate

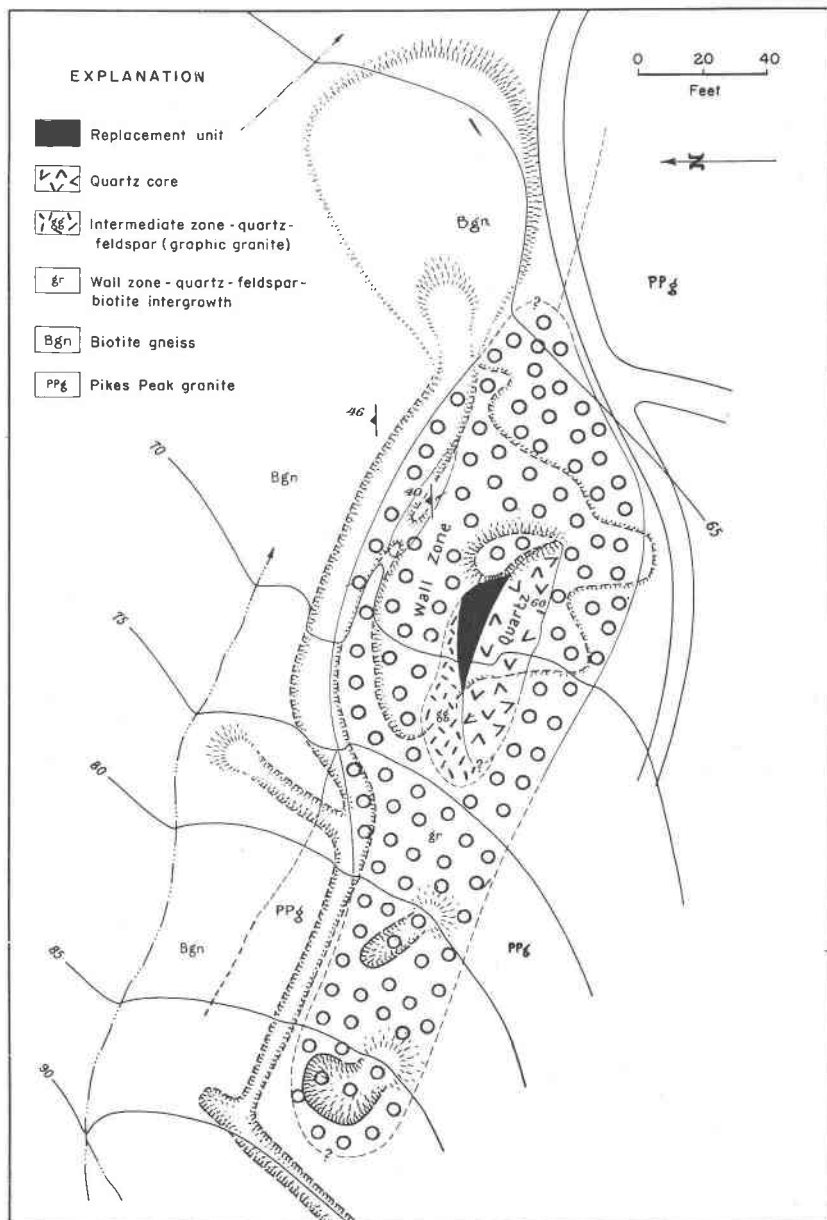


FIG. 1. Map of the Henry pegmatite, Cotopaxi, Colorado, with surface geology restored. Mapped by Salotti by means of tape and Brunton compass. Contour interval 5 ft.

zone rock, by solutions moving upward through the fracture zone in the core.

This replacement pod, which measures about 10×35 feet in plan, consists chiefly of white albite-oligoclase, quartz, and local concentrations of chloritized biotite in blades as wide as 3–6 inches and as long as a foot. Other widely distributed minerals in this unit are microcline, muscovite, fluorite and specular hematite. Rare constituents are euxenite, cyrtolite, monazite, allanite, cenosite, calcite and a rare-earth fluocarbo-nate mineral.

*Rare minerals.* Gray, white, pale blue or pale green fluorite formed as irregular masses as much as three inches across, replacing chiefly microcline. Some of this fluorite is purple, especially near inclusions of radioactive rare-earth minerals. The fluorite contains scattered blebs and tablets of a uniaxial, positive, calcium-rare-earth fluorocarbonate mineral whose powder *x*-ray spacings correspond closely to those of synchysite but are distinctly shifted (Levinson, written comm.). Preliminary studies of the composition of this fluocarbonate indicate, however, that yttrium rather than cerium earths predominate. A complete study of this mineral has been undertaken by A. A. Levinson and R. A. Borup.

Closely associated with the fluorite pods are small aggregates of monazite, a few scattered crystals of largely metamict allanite, and pods and radial blades of euxenite. One mass of euxenite found in the 1930's is reported to have weighed 75 pounds. Cyrtolite occurs as hemispherical clusters of radiating crystals, some of which are 1½ inches long in four-inch groups. It is strongly radioactive and contains 11.2% Hf, and 32.4% Zr; also present are: Fe, Y, Yb, Th, U.

Because of the small number of specimens available the paragenesis of the rare minerals cannot be accurately determined. Several general stages in the development of the replacement unit can be distinguished:

- I. Quartz-microcline (residual)
- II. Albite-oligoclase, biotite, allanite
- III. Fluorite, RE carbonate, monazite, cyrtolite, euxenite, cenosite
- IV. Corrosion, formation of small vugs, fracturing
- V. Hematite, muscovite, quartz (including quartz crystals as much as two inches long).

#### CENOSITE

*Description.* Only one specimen of cenosite was found. It measured about 2×4 inches and was 1–1½ inches thick. About half of this piece was cenosite, the remainder being mainly iron-stained feldspar, and subordinate purple fluorite and specular hematite. The fine-grained hematite locally fringes the cenosite and appears to replace it. A thin section of the specimen reveals the cenosite contains scattered clusters of hematite

plates and is partly altered to a very fine-grained turbid to brownish carbonate mineral (doverite) and subordinate sericite. A few grains of quartz and a few of beryl (?) also are present.

The properties of the Cotopaxi cenosite are:

Color	pale rose to light red
Streak	colorless to very pale pink
Luster	greasy
Hardness	5
Specific Gravity	3.41
Cleavage	two at 90°
Radioactivity	none
Fluorescence	none under either short- or long-wave ultraviolet
Effervesces slowly in cold, dilute HCl.	

TABLE 1. OPTICAL PROPERTIES OF CENOSITE

	Cotopaxi	Sweden	N. Burgess, Ont.	Switzerland
Color	rose to lt. red	yellow brown to dk. chestnut brown	lt. rose	lt. brown
Pleochroism	none	—	none	—
$\alpha$	1.662	1.667	1.664	1.658 (Na)
$\beta$	1.686	1.681	1.689	1.682
$\gamma$	1.692	1.683	1.691	1.687
Sign, 2V	(-) 40°	(-) medium	(-) 39°59'	(-) 40°
Dispersion	$r < v$ distinct	—	$r < v$ strong	$r < v$ weak

The uneven color of the specimen results in part from variations in the amount of included hematite. Some crushed grains are cleavage fragments, and some of these also show edges that are cleavage faces. Such grains show an eccentric Bxa figure. On the Norwegian material one distinct cleavage direction was reported with two others indistinct, 90° apart. (Nordenskiöld, 1886). The optic plane is (010) and  $\alpha = a$  (following axes transformation) (Graham and Ellsworth, 1930).

*Paragenesis.* Table 4 compares the occurrences and associated minerals of cenosite. This summary indicates the cenosite is a hydrothermal mineral formed 1) in cavities of veins, of replacement deposits, or of pegmatites or 2) in replacement units of pegmatites.

### Composition

#### (a) Analytical procedures

The sample as received for analysis was a fine powder, of grain size less than 200 mesh. It was divided into two portions: one for analysis by

TABLE 2. X-RAY POWDER DATA ON CENOSITE  
 Filtered Cu radiation

Cotopaxi		Hitterö, Norway		Burgess Twsp., Ontario		Bancroft, Ontario	
d Å	I	d Å	I	d Å	I	d Å	I
9.00	mw						
7.1	mw	7.1	vvw	7.1	w	7.1	vw
6.50	vs	6.6	vs	6.50	vs	6.56	vs
5.5	vw			5.54	vvw	5.5	vvw
4.80	ms	4.8	w	4.80	w	4.6	w
						3.65	vvw
3.55	w	3.55	vvw			3.54	vw
3.44	s	3.46	vw	3.45	w	3.45	ms
3.28	s	3.29	ms	3.29	s	3.29	s
3.19	s	3.20	m	3.19	m	3.20	m
3.12	vw			3.15	vw	3.13	vw
3.03	w	3.05	vvw			3.04	vw
2.75	vs	2.77	s	2.76	s	2.76	s
2.62	vw						
2.55	m	2.56	w	2.55	w	2.55	w
						2.50	vvw
2.39-2.44	w(b)	2.4-2.44	w(b)			2.44	w
						2.39	w
2.16	ms	2.17	m	2.17	m	2.17	m
2.10	m	2.12	m	2.10	w	2.12	w
1.95	w	1.98	vw	1.95	vvw	1.96	w
1.92	m	1.93	m	1.93	vw	1.92	w
1.88	vw(b)						
1.778	vw						
1.72	w			1.73	vvw	1.73	vw
1.70	vw						
1.67	w					1.67	vvw
1.58-1.66	(5)vw						
1.45	vvw						
1.255	vvw					1.26	vvw
						1.22	vvw

means of *x*-ray fluorescence techniques and the other for analysis by means of wet chemical procedures.

The *x*-ray equipment, sample preparation methods, and techniques used were essentially the same as described by Heinrich, *et al.* (1960). Calcium and the rare-earth elements were determined by *x*-ray fluorescence. The wet chemical methods employed in the determination of H<sub>2</sub>O, CO<sub>2</sub>, Fe<sub>2</sub>O<sub>3</sub>, Al<sub>2</sub>O<sub>3</sub> and SiO<sub>2</sub> are well proven conventional procedures and need no elaboration.

## (b) Analysis and formula

The results obtained from the combination of  $x$ -ray and wet chemical analytical methods are given in Table 3 along with previous analyses of cenosite for comparison.

The elements reported as "estimated maximum" are present in the sample, but no measurement has been made to determine the amount of each. According to the  $x$ -ray data, the distribution of the trace rare-earths appears to be  $Ce > Nd > Sm > La$ , with Ho, Tm, and Tb present in about equal amounts. Thus the rare-earth elements in Cotopaxi cenosite consist mainly of the yttrium subgroup, with only a small amount of the cerium (or lanthanum) subgroup. No determinations for either magnesium or sodium were made; both may be present in trace amounts.

The following simplest formula that can be calculated from this analysis is:

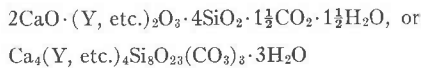


TABLE 3. ANALYSES OF CENOSITE

	1	2	3	4	5
SiO <sub>2</sub>	34.66	34.05	35.21	31.7	29.6
(Ce, La, Dy) <sub>2</sub> O <sub>3</sub>	3.22	tr	tr	—	—
(Y, Er) <sub>2</sub> O <sub>3</sub>	35.46	38.00	37.34	35.9	—
CaO	16.72	16.10	15.80	16.5	15.7
SrO	0.31	—	—	—	—
Al <sub>2</sub> O <sub>3</sub>	0.22	—	—	—	0.9
Fe <sub>2</sub> O <sub>3</sub>	—	—	—	2.9	0.9
FeO	—	0.29	0.22	—	—
MgO	0.19	0.04	0.03	1.4	—
MnO	0.02	—	—	—	—
Na <sub>2</sub> O	0.27	0.38	—	3.6	—
K <sub>2</sub> O	tr	—	0.43	—	—
CO <sub>2</sub>	6.58	5.54	6.25	[5.1]	10.1
SO <sub>3</sub>	0.04	—	—	—	—
H <sub>2</sub> O	2.58	[5.60]	4.92	2.9	3.8
				Y <sub>2</sub> O <sub>3</sub>	29.0
				Yb <sub>2</sub> O <sub>3</sub>	2.3
				Dy <sub>2</sub> O <sub>3</sub>	2.6
				Er <sub>2</sub> O <sub>3</sub>	2.3
				Gd <sub>2</sub> O <sub>3</sub>	0.5 (est. max.)
				(La, Ce, Nd, Sm) <sub>2</sub> O <sub>3</sub>	0.5 (est. max.)
				(Ho, Tm, Tb) <sub>2</sub> O <sub>3</sub>	0.5 (est. max.)
Total	100.23	100.00	100.20	100.00	99.7

1. North Burgess, Ont. (Graham and Ellsworth, 1930).

2. and 3. Hitterö, Norway (Nordenskiöld, 1886).

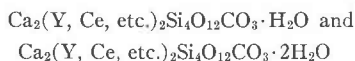
4. Nordmark, Sweden (Sjögren, 1897).

5. Cotopaxi, Colorado.

TABLE 4. PARAGENESIS OF CENOSITE

	Occurrence	Associated Minerals
Hitterö, Norway	Granite pegmatite	Gadolinite, allanite, beryl, microcline, muscovite, quartz.
Ko mine, Nordmark, Sweden	In vugs in fine-grained magnetite ore	Magnetite, diopside, clinocllore, apatite; cenosite is youngest.
North Burgess twsp., Lanark Co., Ont., Canada	In solution cavities in vein (?) of calcite, apatite, phlogopite and minor sphalerite	Vugs contain sequence: (1) Quartz, (2) calcite, (3) aegirine and chalcopyrite, (4) cenosite, (5) celestite.
Grimsel region, Switzerland	Alpine cleft veins in altered granite	(1) Quartz crystals, chlorite, albite, sphalerite (2) Hematite roses, quartz crystals, chlorite, albite, apatite, pyrite (3) Brookite, monazite, calcite (4) Ankerite, monazite
Bicroft mine, Bancroft, Ont., Canada	In vug in biotite-granite pegmatite	Quartz, calcite, fluorite, pyrite and sphalerite crystals, chlorite.
Cotopaxi, Colorado	In core-margin replacement unit in granite pegmatite	Fluorite, doverite, monazite, cyrtolite, euxenite.

This compares well with the formulae calculated by Graham and Ellsworth (1930):



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*Manuscript received, June 1, 1961.*