BASTNÄSITE*

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ABSTRACT

Bastnäsite, a fluocarbonate of cerium metals $(RF)CO_3$, has been found in the fluorspar deposits in the Gallinas Mountains in central New Mexico. A spectrographic analysis of the mineral has been made; *x*-ray diffraction patterns have been prepared and compared with patterns of bastnäsite from other previously described localities; and the optical properties and specific gravity have been determined. Minerals associated with the bastnäsite are: barite, barytocelestite, calcite, fluorite, goethite, hematite, limonite, orthoclase, pyrite, and quartz.

Bastnäsite from Ruanda-Urundi, Belgian Congo, another new locality, is also described, together with its associated minerals.

For comparison compilations of all the available data on optical properties, chemical composition, mode of occurrence, and associated minerals are given for bastnäsite. The uniformity of optical data for bastnäsite from six localities indicates a constant chemical composition, which agrees with a conclusion arrived at from a consideration of seven chemical analyses of the mineral from various localities. The summary of data also shows that most of the known occurrences of bastnäsite are in contact metamorphic rocks.

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BASTNÄSITE FROM THE GALLINAS MOUNTAINS, LINCOLN COUNTY, NEW MEXICO

INTRODUCTION

Bastnäsite, a fluocarbonate of cerium metals, $(RF)CO_3$, a rare mineral containing about 75% oxides of the cerium group, has been found in the fluorite deposits in the Gallinas Mountains, New Mexico. Bastnäsite was first discovered at Bastnäs, Sweden,[9] more than a century ago, at the same locality where, a few years before, the examination of a new mineral, cerite, led to the discovery of the metal cerium in 1804. Since the discovery of bastnäsite in Sweden, other minor occurrences have been recorded from two places in Colorado, two in Madagascar, and one in the Ural Mountains of Russia. Bastnäsite from the Gallinas Mountains, New Mexico, was identified in the Petrographic Laboratory of the United States Geological Survey, in October, 1943, in the course of mineralogic and petrographic examinations of ore samples, as a part of cooperative investigation of strategic and critical mineral deposits by the Geological Survey and the Bureau of Mines, United States Department of the Interior.

The laboratory study of the specimens, the determination of the optical properties, and the compilation of published data on bastnäsite were made by Jewell J. Glass; and the field geology and collection of specimens are largely the contributions of Robert G. Smalley. Vincent Kelley and other geologists of the Geological Survey, and engineers of the Bureau of Mines contributed valuable field data. The spectrographic examination was made by K. J. Murata, and the *x*-ray work was done by J. M. Axelrod, both of the Geological Survey, to whom the authors are greatly indebted. The authors are also indebted to E. P. Henderson of the United States National Museum, through whose cooperation samples of specimens from other localities were secured for comparison; to Fritiof M. Fryxell of the Geological Survey for his valuable aid in translating data from original Swedish publications; to Dr. C. S. Ross and to Dr. M. Fleischer for critical reading and constructive criticism of the paper.

LOCATION

The Gallinas Mountains comprise a small rugged area elongated northwest and southeast about 10 miles long and 5 miles wide, with a maximum elevation of nearly 9000 feet, situated in the Lincoln National Forest, and almost in the geographical center of the state of New Mexico. The northern end of the mountains is crossed east and west by the county line between Torrance and Lincoln counties. The southeastern end of the mountains in Lincoln County contains mineral deposits. In times

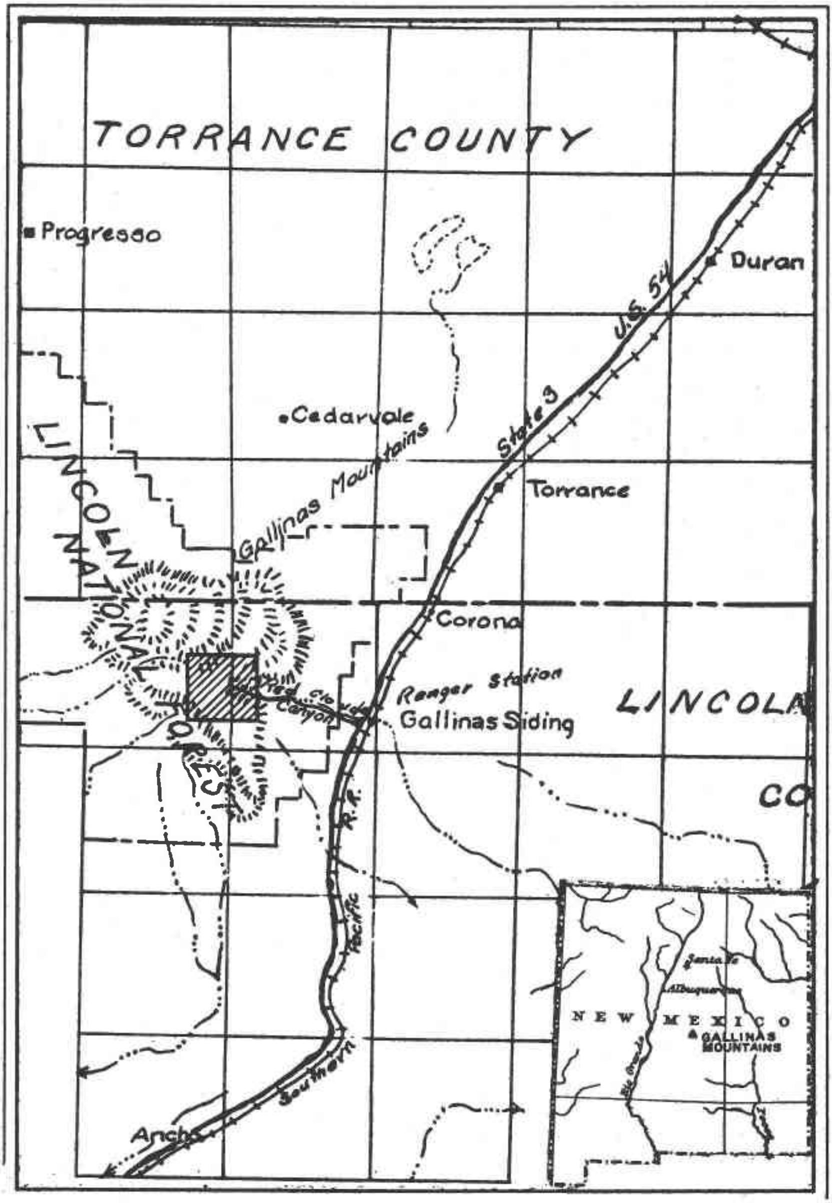

FIG. 1. Map showing the locality of the Gallinas Mountains bastnäsite deposits, Lincoln County, New Mexico.

past the region has been worked for lead and copper; and in 1943 and 1944, the area was explored by the Federal Bureaus for minable deposits of fluorspar and iron ore. The fluorspar district extends over an area of about 1 square mile in the southern part and is accessible by dirt road from the Southern Pacific R. R. and U. S. highway 54, both about eight and a half miles to the east. Carrizozo, the nearest town of any size, is 50 miles south, and Socorro is 70 miles nearly west. The region is forested but water is extremely scarce.

Occurrence

The Gallinas Mountains are characterized by a complex of igneous intrusions which have penetrated pre-Cambrian granites and overlying sediments of Permian age. The principal intrusive rocks are prophyritic quartz-monzonites, rhyolites, and syenites. They occur in large bodies which are discordant with the sedimentary rocks and irregular in outline, and as numerous small sills and dikes. A number of small lamprophyre dikes apparently belong to the same period of igneous activity. The sedimentary rocks are conglomerates, arkoses, and fine-grained sandstones interbedded with some limestones and siltstones overlying the pre-Cambrian granites. These underwent slight metamorphism previous to the igneous intrusions, and were complexly faulted and fractured during and after the intrusions.

The fluorspar deposits which contain the mineral bastnäsite occur along fissures and faults, and in fault breccias and shatter zones, usually largely within the sedimentary rocks, but most of them are near, or along the contacts of, intrusive bodies. The deposits were probably formed by ascending hydrothermal solutions which were apparently related to the igneous activity. Those which contain the largest amounts of bastnäsite occur along faults where extensive movement has taken place, resulting in wide zones of brecciated rock, and thus affording excellent channelways for the mineralizing solutions.

Bastnäsite was first found in a fluorspar deposit in the Red Cloud area, at the southern end of the mineralized district, and later it was identified as a minor constituent of the fluorspar ore in the neighboring areas—the Conqueror prospects which contain more and larger crystals of bastnäsite than most of the others, the Eagles Nest claims, the Eureka mine, and the Buckhorn mine.

The rockmass in which the bastnäsite occurs is composed largely of a purplish or brown stained, porous aggregate of interlocking crystals of barite, bastnäsite, fluorite, quartz and goethite, and hematite pseudomorphs after pyrite. Fresh crystals of bastnäsite are found wedged between altered crystals of barite, and in close association with fine-grained fluorite.

The extreme alteration of the rock in the mineralized zone indicates that it may be the result of repeated periods of hydrothermal action. Pyrite appears to have been deposited at the same time as the barite and older fluorite, at one of the earlier periods of deposition; and at a later period the entire zone was invaded by magmatic emanations rich in fluorine, carbon dioxide, and rare earths, at which time a new generation of fluorite and the bastnäsite were deposited. Bastnäsite appears to have been one of the last minerals to be deposited, and shows no evidence of having been derived from the alteration of a preexisting mineral.

Physical and Optical Properties

Bastnäsite from the Gallinas Mountains occurs in thin, tabular, hexagonal crystals usually about 4 millimeters across, although some crystals are 6 millimeters across, and seldom more than 1 or 2 millimeters thick. Clusters of platy crystals are common; some of the clusters or aggregates are 30 millimeters across. The bastnäsite crystals have a distinctly lamellar structure, each one built up of thin plates stacked one on top of the other, with edges rough and striated horizontally, similar to mica crystals. Prism faces on these thin crystals are narrow bands, or, on some crystals nearly entirely lacking, but pyramid faces are conspicuous.

Cleavage is perfect parallel to $c(0001)$. The thin laminae can be split apart with ease. The bond between the laminae apparently becomes weaker with weathering and planes of separation, or what has been called basal parting, develop. Prismatic cleavage is poor and rarely observed. Fracture uneven. Brittle. H. $=4.5$, scratches fluorite but can be scratched by glass. Sp. Gr. $=4.99$. Luster vitreous, sometimes resinous or waxy. Color honey yellow. Transparent to subtranslucent. Streak colorless. Infusible. Soluble in strong sulphuric acid with effervescence (CO_2) and evolution of hydrofluoric acid.

Optically the mineral is uniaxial positive. Birefringence high. Colorless to pale yellow in thin fragments. Pleochroism very weak, colorless to pale yellow. The indices of refraction measured by the immersion method in white light are: $\omega=1.718$, $\epsilon=1.819$, $B=0.101$.

Bastnäsite described as having a prismatic habit, otherwise corresponding closely in its properties to that found in the same district and described in this paper, has been reported by R. S. Dean[5] of the Bureau of Mines.

No chemical analysis has been made on the bastnäsite from New

Mexico, but a qualitative spectrographic examination of a sample of bastnäsite from the Red Cloud area, Gallinas Mountains, Lincoln County, New Mexico, made by K. J. Murata of the U. S. Geological Survey showed the following results:

Major constituents:	La, Ce, F
Minor constituent:	Ca
Traces	Si, Mg, Al, Fe, Ba

Flourine was detected spectrographically (by means of the CaF^+ band) and chemically (by means of the zirconium-alizarin color test). In making the latter test, the mineral was treated with warm HCl which produced an appreciable effervescence ascribable to carbon dioxide liberated from the mineral.

The specific gravity was determined on the Berman balance by M. Fleischer of the U. S. Geological Survey, on fragments from the same sample on which the spectrogram was made. Nine transparent crystal fragments were carefully selected, and each of three determinations was made on three nearly equidimensional fragments. The results are:

Wt. fragments	*Sp. Gr.*
10.8 mg.	4.989
15.2	4.995
16.8	4.991
Average	4.99

X-ray powder diffraction patterns of bastnäsite from the Gallinas Mountains, New Mexico, and of bastnäsite from West Cheyenne Cañon, near Pike's Peak, Colorado (U.S.N.M. No. 84413); and from Madagascar (U.S.N.M. No. R-2617), were made by J. M. Axelrod in the Geological Survey Laboratories. A comparison of these photographs shows that the pattern is the same for all, and that all of the comparable data coincide with those obtained by Oftedal[16] who has made a detailed study of the crystal structure of bastnäsite.

MINERALS ASSOCIATED WITH BASTNÄSITE IN THE GALLINAS MOUNTAINS

Barite. Barite is one of the most abundant minerals in the bastnäsite-bearing rocks. As much as thirty-seven per cent of the rock mass in some areas is composed of coarse, rough, orthorhombic crystals of barite. Most of the barite is white, but some of it is stained pink from iron oxide; and some is colorless, transparent and glassy. The crystals are short and thick, varying in length from 0.5 millimeter to 6 millimeters. Nearly all of the crystals are etched and dotted with tiny knobs of purple fluorite. Many of the barite crystals, however, have been dissolved away leaving a honeycomb-like skeleton. In the more altered portions of the rocks the barite has disintegrated to a fine, dust-like powder, and where stained by limonite looks like brown clay. In some areas granular barite has been consolidated into what may be called a barite sandstone.

Barytocelestite (celestobarite). A strontium-bearing mineral that has the same physical properties as the barite described above is found in the southern part of the mineralized region. The mineral is optically biaxial positive, $2V=45°$; indices of refraction are: $\alpha=1.628$, $\beta=1.630$, $\gamma=1.639$. The optical properties are nearly midway between those for barite and for celestite. Because chemical data are lacking, and the relationship of the indices of refraction to the intermediate compounds not known, the mineral names which were first applied to barium-strontium sulphates have been retained; by the newer system of nomenclature a barium sulphate containing strontium would have the mineral name strontian barite, likewise, barian celestite.

Calcite. Druses of colorless, glassy calcite are found in cavities in the bastnäsite-bearing rocks, and in places calcite occurs as a constituent of the rock mass. The amount of calcite observed is small.

Fluorite. Fluorite with which the bastnäsite is commonly associated occurs in granular masses composed of aggregates of small, deep violet colored crystals loosely held together, usually by interlocking crystals of barite, quartz, and goethite and hematite pseudomorphs after pyrite. As seen in thin section the color varies in different parts of the same crystal, showing bands of different shades of purple lying parallel to the cube faces. In this respect the fluorite resembles that associated with bastnäsite at Jamestown, Colorado.[7] When heated the fluorite shows thermoluminescence, giving off pale yellow, nearly white light, whereas the thermoluminescence of most fluorites is either green or violet. No fluorescence has been observed. The specific gravity is apparently higher (near 3.3) than that for normal fluorite, probably due to inclusions. The index of refraction is also slightly higher (1.440), but this fluorite developed from solutions containing varying amounts of rare earths and other rare elements, and so slight variations in optical properties are to be expected. Bray[3] found by spectrographic study 20 minor elements in the fluorites from Jamestown, Colorado. No spectrographic study was made of the fluorite from the Gallinas Mountains because so much of the fluorite contains impurities.

Goethite. *X*-ray study and microscopic examination indicate that the pseudomorphs after pyrite so common in the bastnäsite rock are goethite with some hematite. In several samples one-fourth, and in a few, one-half of the rock mass is composed of goethite and hematite pseudomorphs. Well preserved pyrite crystal forms, including pyritohedrons and striated cubes 1 millimeter to 3 millimeters on the edge are common.

Hematite. Hematite is less common than goethite and occurs with goethite in the same crystal in some samples. In others, the pseudomorphs are hematite covered with a thin limonitic film.

Limonitic material. A limonitic material occurs in all of the bastnäsite rocks, and constitutes a large part of the more decomposed rocks. Thin films of iridescent limonite with a metallic luster can be seen also enclosing some of the pseudomorphs.

Orthoclase. A few small grains of orthoclase were found in one sample. The source of the orthoclase is obscure, but it is probable that these grains are relics from the brecciated wall rock.

Pyrite. Pyrite that formed a major constituent of some of the rock during one stage of its history has been acted upon by later oxidizing agents, and what once were pyrite crystals are now goethite and hematite pseudomorphs, some of which are marked by a thin limonitic film with yellow, metallic luster.

Quartz. Small quartz crystals occur commonly scattered in random orientation in the bastnäsite rock. These crystals represent the low-temperature form and show strongly developed prism faces and double terminations. The length of the crystals varies from less than 1 millimeter to 3 millimeters and their length is usually six or eight times their thickness. Most of the crystals are deeply etched, and some are dotted with fluorite crystals.

BASTNÄSITE FROM RUANDA-URUNDI, BELGIAN CONGO

(*U.S.N.M. No. 104097*).

Specimens of bastnäsite from the Belgian Congo in the collections of the United States National Museum have not heretofore been studied and so are here described. They consist of six or more irregular, nodular, waterworn fragments one-half to one inch across, of a dense reddish brown, silicified rock, in which bastnäsite occurs as tabular masses, probably rude crystals, 5 to 8 millimeters long and about 2 milimeters wide, scattered at random through the rock. About one-fourth of the rock mass is bastnäsite; other minerals sparsely distributed through the rock are: transparent quartz grains, pyrite crystals, microcline, biotite, and limonite. The entire rock appears to be secondary, but the original source and the occurrence of this rock are unknown.

Some of the tabular masses of bastnäsite were removed and examined. Basal cleavage is conspicuous. The mineral is honey-yellow; some of the grains are reddish brown from staining by iron oxide. Luster resinous.

Hardness 4 to 4.5. Sp. Gr. near 5 (not accurately determined). Infusible. Dissolves in strong sulphuric acid with evolution of hydrofluoric acid and carbon dioxide.

Optically the mineral is uniaxial, positive. Pleochroism weak, colorless to pale yellow. Indices of refraction are: $\omega=1.722$, $\epsilon=1.823$, $B=0.101$. The optical data agree nearly exactly with those for bastnäsite from Bastnäs, Sweden. Physical and optical data on the mineral from Belgian Congo are in such close agreement with known data for bastnäsite that no further study was necessary for conclusive identification.

OPTICAL PROPERTIES OF BASTNÄSITE

For the purpose of comparing the optical properties of bastnäsite from the Gallinas Mountains, New Mexico, and from the Belgian Congo, with those for bastnäsite from previously described localities, three specimens, one from each of the localities most extensively studied and for which the most complete and reliable data are recorded, Sweden, Colorado (Pike's Peak), and Madagascar, were obtained from the United States National Museum for optical study. A brief description of each specimen together with its optical properties is given below.

Bastnäs, Sweden (*U.S.N.M. No. R-2619*). The specimen from Bastnäs is a small fragment of dark gray, granular rock containing honey-yellow grains of bastnäsite in an intimate mixture of cerite, allanite, fluorite, etc. The bastnäsite grains were separated and studied in grain mounts by the immersion method in white light. The mineral is uniaxial positive. The indices of refraction are: $\omega=1.7220$, $\epsilon=1.8235$. These data are nearly identical with those determined by Geijer[6] (No. 1, Table 1). The optical properties for the material from Belgian Congo and from Bastnäs are essentially the same. The indices for the bastnäsite from the Gallinas Mountains, however, are slightly lower, indicating a small difference in composition (Table 1).

Pike's Peak, Colorado (*U.S.N.M. No. 84413*). The sample from Colorado is a crystalline mass nearly as large as a man's fist. About half of the mass is reddish-brown, laminated bastnäsite, and the rest of the sample is grayish-buff fluocerite (tysonite). The fluocerite (optically uniaxial negative, $\epsilon=1.608$, $\omega=1.613$) appears to occur in parallel growth with the bastnäsite. The optical properties of the bastnäsite are identical with those previously recorded by Larsen (Table 1): Biaxial positive. $\omega=1.717$, $\epsilon=1.818$. The optical data for bastnäsite from New Mexico agree closely with those for bastnäsite from Colorado, but those for the material from Belgian Congo are slightly higher (Table 1).

Madagascar (*U.S.N.M. No. R-2617*). The bastnäsite specimen from Madagascar is a piece of a crystal about one inch across and half an inch thick, and may possibly be some of the pegmatite material described by Lacroix,[12] however, the National Museum has no record of the specific locality or occurrence of the specimen. The color is reddish to yellowish-brown, and with the exception of the typical laminated structure so well developed on this specimen, it might easily be mistaken for monazite, as can be said of most bastnäsite. The mineral is optically uniaxial positive, $\omega=1.717$, $\epsilon=1.818$. These properties agree closely with those for bastnäsite from New Mexico (Table 1).

TABLE 1. COMPARISON OF OPTICAL PROPERTIES OF BASTNÄSITE

Locality	Sweden (Bastnäs)		Colorado			Madagascar		New Mexico (Gallinas Mtns.)	Belgian Congo
			Pike's Peak		Jamestown				
Observer	Geijer[6]	Glass	Larsen[14]	Glass	Glass[7]	Lacroix[12]	Glass	Glass	Glass
Number	1	2	3	4	5	6	7	8	9
$\omega=$	1.7225*	1.7220†	1.717	1.717†	1.716	1.714	1.717†	1.718†	1.722†
$\epsilon=$	1.8242	1.8235	1.818	1.818	1.817		1.818	1.819	1.823
B=	.1017	.1015	.101	.101	.101		.101	.101	.101
Sign	+	+	+	+	+	+	+	+	+

* Indices were determined on prisms cut parallel to the prismatic cleavage.
† Data obtained from recent investigation by the writer.

The optical determinations made on these three specimens, with those determined on bastnäsite from the Gallinas Mountains, New Mexico, and from Belgian Congo, are given in Table 1, together with the data taken from the literature which are included for comparison. Optical determinations by other investigators on material from the previously studied localities, Sweden, Colorado, and Madagascar, are recorded in Table 1, Nos. 1, 3, and 6. Data obtained in the present investigation on material from the same three localities, Nos. 2, 4, and 7, are in close agreement with the recorded data. The uniformity of the optical data for bastnäsite from six localities including the two new ones, New Mexico and Belgian Congo, indicates a nearly constant composition for the mineral, a conclusion arrived at independently from a consideration of the chemical analyses (Table 2).

CHEMICAL COMPOSITION OF BASTNÄSITE

A new cerium-bearing mineral found at Bastnäs, Sweden, and later

Table 2. Compilation of Chemical Analyses of Bastnäsite

	1	2	3	4	5	6	7
Ce_2O_3		28.49	29.94	41.04	37.71	40.50	
$(La, Di)_2O_3$	73.59		75.71	75.80			75.84
or La group		45.77	45.77	34.76	36.29	36.30	
CO_2	19.11	19.50	19.50	20.15	20.03	20.20	
F	5.76	5.23	7.42	n.d.	7.83	6.23	
Fe_2O_3					.22		
Na_2O					.18		
H_2O		1.01			.08		
SiO_2	1.25						
P_2O_5						0.60	
Total	99.71	100.00	102.63		102.34	103.83	
−O=F			3.11		3.30	2.61	
			99.52		99.04	100.22	
Sp. Gr.			4.93	5.18–5.20 (5.19)	5.12	4.948	

1. "Basiskt" (basic) Fluor-Cerium from Bastnäs, Riddarhyttan District, Sweden. Hisinger's old analysis (1838) recalculated by Nordenskiöld, allowing for CO_2 which Hisinger overlooked (1868).
2. "Hamartite" (Bastnäsite) from Bastnäs, Riddarhyttan District, Sweden. Analysis by Nordenskiöld (1868).
3. Bastnäsite from Bastnäs, Riddarhyttan District, Sweden. Nordenskiöld's analysis with values for Ce_2O_3 and F recalculated by Geijer (1921).
4. Bastnäsite from Cheyenne Mountain, near Pike's Peak, Colorado. Analysis by Allen and Comstock (1880).
5. Bastnäsite from Cheyenne Mountain, near Pike's Peak, Colorado. Analysis by Hillebrand (1899).
6. Bastnaesite from east of Ambositra, Madagascar. Analysis by Pisani, quoted by Lacroix (1912).
7. Bastnäsite from Kychtym (Oural), Ural Mountains, Russia. Analysis by Silberminz (1929).

known as bastnäsite was first analyzed by W. Hisinger,[9] in 1838, and designated by him as "Basiskt Fluor-Cerium från Bastnäs."

Hisinger's analysis taken from the original publication of his work is quoted here:

	funnet (determined)	räknadt (calculated)
Cerfluorid (cerium fluoride)	50.150	49.35
Ceroxid (cerium oxide)	36.430	38.65
Vatten (water)	13.413	12.00
Kiselsyra (silica)	0.007	—

Hisinger concluded that the loss on heating consisted of water and some fluorine but he did not take into account the carbon dioxide. A. E. Nordenskiöld[15] later analyzed the mineral and determined its correct composition. He recalculated Hisinger's analysis considering the carbon dioxide and applying necessary corrections for the reduction of cerium oxide to cerium trioxide and found that the results showed close agreement with his own determinations. To this mineral Nordenskiöld gave the name hamartite. Huot,[10] however had previously called the mineral bastnäsite after the locality. Hisinger's corrected analysis (No. 1), and Nordenskiöld's own analysis (No. 2) are given in Table 2. The chemical composition and physical properties of Basiskt Fluss-spatssyradt from Finbo, described by Berzelius,[2] were recognized by Hisinger as being in agreement with those recorded by him for Basiskt Fluo-Cerium from Bastnäs. Berzelius' analysis, made on scanty material, is incomplete and is not included in Table 2.

A compilation of seven recorded analyses of bastnäsite on material from four widely separated localities is shown in Table 2.

The agreement between the results of the different analysts is remarkable, considering the probable changes in analytical methods in the nearly one hundred years between 1838 and 1929, applied to material containing rare earths. The variations in the percentages are notably small. The combined percentages for the cerium groups, where the greatest difference might occur, vary from 73.59% to 76.80%, with a difference of 3.21%; CO_2 from 19.11% to 20.20%, with a difference of 1.09%; and F from 5.23% to 7.83%, with a difference of 2.60%. If, however, only the more recent analyses had been considered the agreement would be even closer.

OCCURRENCES OF BASTNÄSITE AND ITS ASSOCIATED MINERALS

At the original locality for bastnäsite, Bastnäs, in the Riddarhyattan district, province of Västmanland in central Sweden, bastnäsite and other cerium minerals form narrow bands in a silicate zone, "skarn," composed largely of amphiboles, that run parallel and adjacent to the hematite ore belt, in the leptite (granulite) formation, consisting of leptite, mica schists and limestone-dolomite layers. These narrow bands are fine-grained aggregates of bastnäsite, orthite (allanite), cerite, fluocerite, törnebohmite and other minerals, in a contact metamorphic zone.

At Pike's Peak, Colorado, bastnäsite has been found in parallel growth with fluocerite (tysonite) in feldspar in granite pegmatite.

In Madagascar, east of Ambositra in the region of Torendrika-Ifasina, bastnäsite occurs in a contact metamorphic zone with the pegmatite facies of alkali-granites. The bastnäsite is most closely associated with tscheffkinite (Chevkinite). Other minerals present are "torendrikite" (glaucophane), aegirite, biotite, hematite, magnetite, rutile, etc. Lacroix[12] describes bastnäsite as occurring also in pegmatite in Madagascar.

In Russia, in the Kyshtymsk (Kychtym) district, in the Urals, bastnäsite is found with cerite, "lessingite" (britholite), törnebohmite, and more abundant orthite (allanite), in pebbles in auriferous gravels. The source of these pebbles has been traced to the contact zone of alkali-syenites.

At Jamestown, Colorado, bastnäsite occurs with cerite and other cerium-bearing minerals (Table 3) in narrow zones and pod-like areas along the contact between pegmatite-aplite bodies in granite and lens-shaped inclusions of biotite schist in the granite.

Bastnäsite in the Gallinas Mountains, as has already been stated, occurs in a brecciated zone near the contact between metamorphosed sediments and igneous intrusives. The mineral assemblage of the deposit (Table 3) and the occurrence are simlar to those at Bastnäs.

The occurrence of the bastnäsite from Belgian Congo is not known.

A tabulated list of minerals associated with bastnäsite together with its occurrences are given for seven recorded localities in Table 3.

Data on mineral relations is meager for some occurrences of bastnäsite. A summary of the available data, however, indicates that the most frequent and most abundant deposits of this mineral are in contact metamorphic zones where these deposits are the result of hydrothermal replacement of sedimentary rocks by mineralizers rich in rare earths and carbon dioxide and fluorine which were derived from nearby igneous intrusions. The largest and only deposit of cerium minerals that has ever produced commercial ore is the well-known contact metamorphic deposit at Bastnäs, Sweden, where during the period 1875 to 1888, a total of 4465 metric tons of high grade cerium ore were mined.[6]

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TABLE 3. OCCURRENCES OF BASTNÄSITE AND ITS ASSOCIATED MINERALS

Local.	Sweden	Colorado		Madagascar	Russia	New Mexico	Belgian Congo
		Pike's Peak	Jamestown				
Occur.	Contact zone	Pegmatite	Contact	Contact	Contact	Brecciated fault	?
	Actinolite	—	—	—	—	—	—
	—	—	—	Aegirine	—	—	—
	Allanite (orthite)	—	Allanite	—	Allanite	—	—
	—	—	—	—	—	Barite	—
	—	—	—	—	—	Barytocelestite	—
	Bastnäsite	*Bastnäsite*	*Bastnäsite*	*Bastnäsite*	*Bastnäsite*	*Bastnäsite*	*Bastnäsite*
	—	—	—	Biotite	—	—	Biotite
	Bismuthinite	—	—	—	—	—	—
	—	—	—	—	—	Calcite	—
	Cerite	—	Cerite	—	Cerite	—	—
	Chalcopyrite	—	Chalcopyrite	—	—	—	—
	—	—	Epidote (brown)	—	—	—	—
	Fluocerite (Tysonite)	Fluocerite (Tysonite)	—	—	—	—	—
	—	—	Fluorite	—	—	Fluorite	—
	—	—	—	—	—	Goethite	—
	—	—	—	Hematite	—	Hematite	—
	—	—	—	Ilmenite	—	—	—
	Lanthanite	—	—	—	—	—	—
	—	—	—	—	Lessingite	—	—
	—	—	—	—	—	Limonite pseudomorphs	Limonite
	Linnaeite	—	—	—	—	—	—
	Magnetite	—	—	Magnetite	—	—	—
	Molybdenite	—	—	—	—	—	—
	—	—	Monazite	—	—	—	—
	—	—	—	—	—	Orthoclase	Microcline
	—	—	Pyrite	—	—	Pyrite	Pyrite
	—	—	Quartz	—	—	Quartz	Quartz
	—	—	—	Rutile	—	—	—
	Törnebohmite	—	Törnebohmite	—	Törnebohmite	—	—
	—	—	—	Tscheffkinite (Chevkinite)	—	—	—
	—	—	Uraninite	—	—	—	—

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NOTE: * *Dana's System of Mineralogy*, Sixth Edition, page 291, Section 285. BASTNÄSITE: . . . *Afh.* **6**, 64, 1818, should read: *Afh.* **5**, 64, 1818.