KAOLINITE AFTER BERYL FROM ALTO DO GIZ, BRAZIL

PAUL F. KERR, *Columbia University, New York City.*

ABSTRACT

A large pseudomorph of kaolinite after a cesium-bearing beryl from Alto do Giz, Brazil, is described. The beryl has been replaced to the extent of about 28.3 per cent kaolinite by weight. Although weathering appears to have been a dominant alteration feature of the deposit there is reason to believe that the pseudomorph could have been produced by hydrothermal action.

INTRODUCTION

On a recent trip to Brazil, Dr. Frederick H. Pough of The American Museum of Natural History collected an unusual pseudomorph of kaolinite after beryl from Alto do Giz, Rio Grande do Norte. Before removing samples for study and analysis, the crystal measured over six inches in length and nearly four inches across. The pseudomorph shown in Fig. 1, has the form of a typical beryl crystal consisting of the hexagonal prism and pinacoid. It is yellowish to dull white in color and superficially appears to have been largely, but not completely, kaolinized. The color of the prism faces and the two ends in contrast to the interior suggests that kaolinization in the outer portion has been more complete than on the inside.

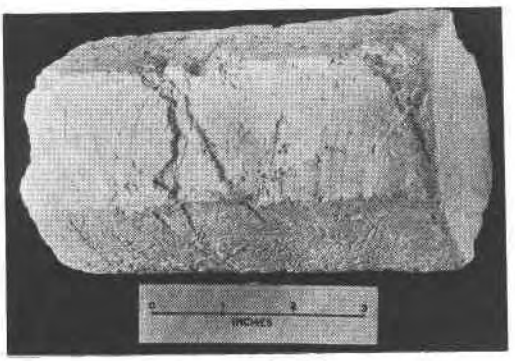

FIG. 1. Pseudomorph of kaolinite after beryl, Alto do Giz, Brazil.

It was decided that the information to be gained warranted the removal and destruction of a considerable portion of the crystal for study. Hence, one end of the specimen was sacrificed in order to provide samples for chemical analysis, chips for thin sections, and material for optical and x-ray examinations.

Nature of the Replacement

In determining the extent of replacement a sample weighing 225 grams was allowed to disintegrate in water. The clay was washed out, decanted, and allowed to settle in large beakers, about 2.67 per cent of material being unrecovered. The residue of beryl was collected after being washed free from clay. The amount of clay collected was 28.3 per cent of the total residue by weight, while the beryl amounted to 71.7 per cent.

The minerals in the pseudomorph are chiefly beryl, and kaolinite. Muscovite is present in small amounts and occasional grains of quartz may be observed under the microscope. There are small amounts of limonitic stain. Identifications of the beryl and kaolinite have been confirmed by *x*-ray diffraction (Fig. 2) and optical examination.

No evidence of kaolin minerals other than kaolinite could be observed even in photographs with the electron microscope (Fig. 3). At a magnification of 16,000 diameters irregular plates and groups of plates may be observed with occasional individuals showing a pseudohexagonal outline characteristic of kaolinite. Elongate forms suggesting halloysite did not appear in the photographs available. The photograph reproduced in Fig. 3 at a magnification of 8000 diameters was furnished through the courtesy of the Palmerton Research Laboratory of the New Jersey Zinc Co.

Several thin sections distributed through the crystal in different positions and orientation were cut from the pseudomorph. These included sections cut normal to the *c*-axis from the central core and from the outer zone, as well as sections cut parallel to prism faces.

In all sections beryl could be observed in various stages of replacement. Beryl in basal thin sections yields uniaxial negative interference figures, notwithstanding the division of the beryl into isolated portions by kaolinite. The beryl in sections cut parallel to the prism yields maximum birefringence. It is assumed that the original crystal was either an individual unit of beryl or was made up of closely parallel crystals.

Although the beryl pseudomorph was found in a pegmatite at Alto do Giz, no evidence of feldspar either in residual fragments or relict forms could be observed in thin sections. Infiltration of the kaolinite through the beryl appears to have taken place by direct replacement first along incipient fractures, later followed by mass invasion.

The penetration of the solutions responsible for the replacement of the beryl by kaolinite appears to have been aided materially by the widespread distribution of microscopic cavities throughout the beryl. These are observable in thin section and vary in sectional pattern with orienta-

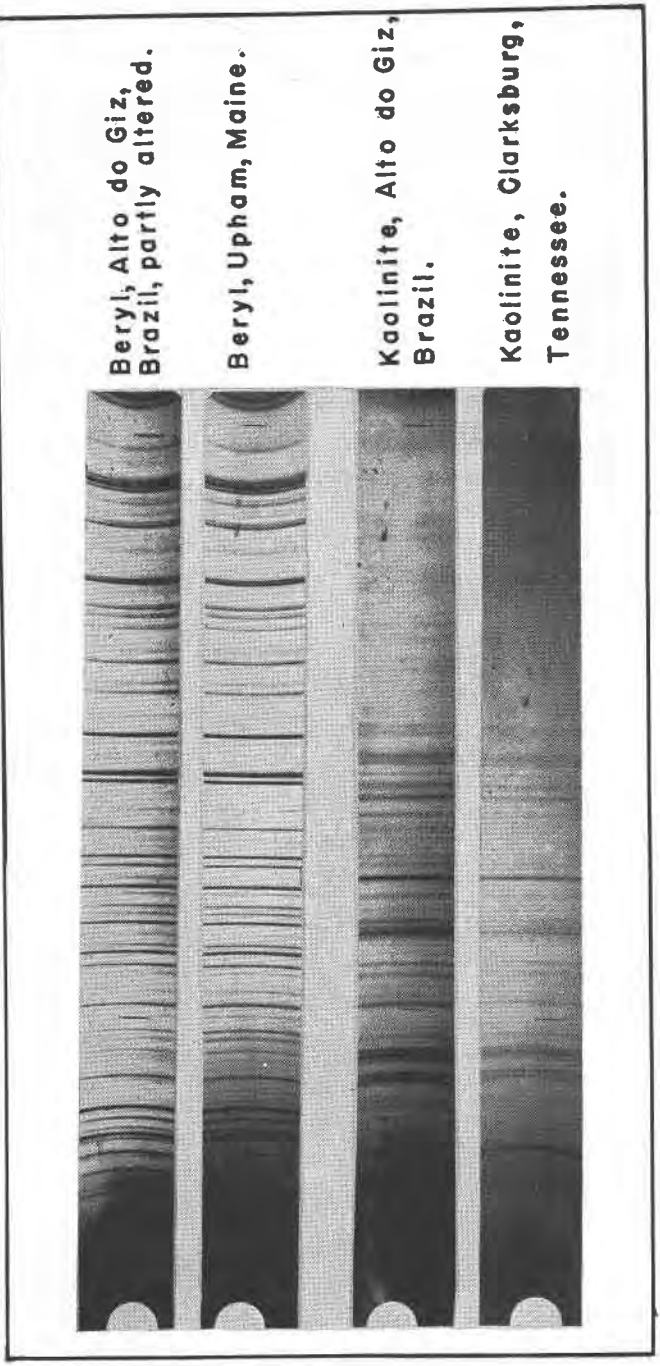

FIG. 2. Comparison of *x*-ray diffraction patterns of beryl and kaolinite with reference patterns.

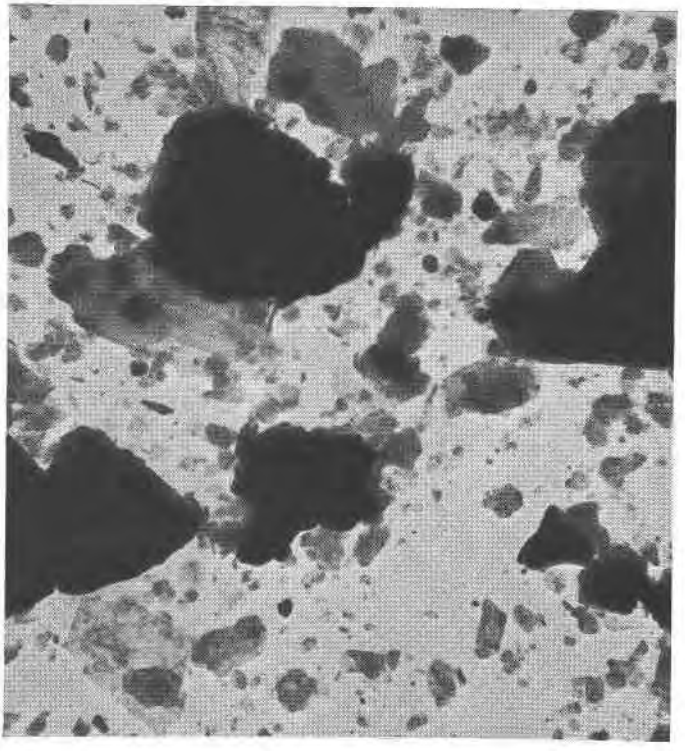

FIG. 3. Electron micrograph of kaolinite from Alto do Giz, Brazil. Magnification 8,000×.

tion. In basal sections the cavities frequently exhibit hexagonal outlines varying from about 5 to 40 microns across. The hexagonal cavities may be interspersed with round or irregular cavities devoid of symmetry. In vertical sections patterns are not hexagonal, but assume elongate shapes frequently suggesting the cross section of a flat hexagonal cavity. Such sections may be about 2 or 3 microns thick and as much as 40 microns in length. In places, these cavities are enlarged into angular shapes resembling the cross sections of pyramidal protuberances. Some are round or irregular.

No evidence of fluids could be observed in the cavities. On the other hand, incipient alteration to kaolinite is common. Cavities in various stages of alteration by kaolinite may be seen, from the first stages in which a few small kaolinite specks line the walls of a cavity, to completely kaolinized cavities or relict outlines of cavities dispersed through areas of kaolinite. Apparently the cavities provide points of weakness where kaolinization has progressed more rapidly than in solid areas.

Chemical Analyses

Chemical analyses of both altered and unaltered beryl and kaolinite from Alto do Giz have been made (Table 1). The original beryl (analysis no. 2) represents a clear transparent crystal which is free from alteration aside from a few scattered inclusions of mica distributed along the walls of cavities. The material selected for analysis was free from these inclusions. The Brazilian crystal agrees reasonably well with an analysis of cesium beryl from Hebron, Maine, by H. L. Wells, reported by Dana (1892, p. 407, no. 10). The two are shown for comparison in Table 1.

Table 1. Analyses of Beryl and Alteration

	Hebron, Maine	Alto do Giz, Brazil* Original Beryl	Intermediate stages*—		Kaolinized Residue*
	(1)	(2)	(3)†	(4)†	(5)
SiO_2	62.44	62.90	58.55	54.97	44.98
Al_2O_3	17.74	18.88	25.51	28.03	36.84
Fe_2O_3	0.40	.18	.90	2.86	2.09
FeO		.00	.05		.10
MgO		.00	.15	.15	.11
CaO		.00	.01	.01	.00
Na_2O	1.13	1.01	.28	.28	.24
K_2O		.40	.42	.42	.65
H_2O+	2.03	2.15	5.44	(8.42)‡	13.53
H_2O-		.03	.31		.78
TiO_2		.02	.13		.20
P_2O_5		.02	.09	.09	.17
Li_2O	1.60	1.00	.05		.05
Cs_2O	3.60	2.18	.05		.08
BeO	11.36	11.00	8.01	4.54	.24
	100.30	99.77	99.95	99.77	100.06

* Analyses by Dr. Lee C. Peck, Rock Analysis Laboratory, University of Minnesota.

† Sample No. 3 was used for the minor constituents of No. 4 (MgO, CaO, Na_2O, K_2O and P_2O_5). Sample No. 3 was supplied as a duplicate of No. 4 but proved to represent a less advanced stage of alteration.

‡ Loss on ignition.

Analyses numbered 3 and 4 represent partially replaced beryl from the Alto do Giz pseudomorph. The residue from repeated washing to remove the kaolinite was submitted for analysis. The analyses exhibit significant decreases in SiO_2, Na_2O Li_2O, Cs_2O, and BeO with correspondingly significant increases in Al_2O_3, Fe_2O_3, H_2O and TiO_2.

The kaolinite fraction separated from the beryl remaining in the pseudomorph has been analyzed as shown in number 5. The analysis of the kaolinite residue, Table 2, has been recast to eliminate beryl, potash and soda micas, and limonite. Aside from a small excess of Al_2O_3 and H_2O the remainder agrees reasonably well with the analysis for normal kaolinite. The TiO_2, H_2O and P_2O_5 were unassigned in the recast. Since the amounts due to these constitutents are small their elimination only slightly affects the total.

TABLE 2

	Kaolinite Residue	Beryl	Micas		Limonite	Remainder	Kaolinite Analysis	Kaolinite Theoretical $Al_2O_3:SiO_2=1:2$
			Potash	Soda				
SiO_2	44.98	1.15	2.49	1.40		39.94	*46.48*	46.5
Al_2O_3	36.84	0.33	2.12	1.19		33.20	*38.64*	39.5
Fe_2O_3	2.08				2.08			
FeO	0.10							
MgO	0.11							
CaO	0.00							
Na_2O	0.24			0.24				
K_2O	0.65		0.65					
H_2O+	13.53		0.25	0.14	0.35	12.79	*14.88*	14.0
H_2O-	0.78							
TiO_2	0.20							
P_2O_5	0.17							
Li_2O	0.05							
Cs_2O	0.08							
BeO	0.24	0.24						
	100.05	1.72	5.51	2.97	2.43	85.93	100.00	100.00

The analyses offer no indication of concentration of either cesium or beryllium in the kaolinite fraction. The kaolinite contains little beryllium and cesium and is apparently in no way unusual in composition. It would appear that the solution which removed portions of the beryl crystal to make room for the deposition of kaolinite carried away the two elements in question. There appears to be no evidence from the study of the pseudomorph to indicate the final site of deposition of the dissolved cesium and beryllium.

Optical Properties

The indices of refraction for the unaltered beryl of analysis number 1 are $n_\omega = 1.590$; $n_\epsilon = 1.581 \pm .001$. The indices of refraction of beryl from the central core of the pseudomorph are $n_\omega = 1.576$; $n_\epsilon = 1.568 \pm .001$. Although the difference between the two sets of values is perceptible, both values lie within the normal range for beryl. Although the altered material has lower indices of refraction insufficient data are available to attach much significance to this fact.

The indices of refraction of the kaolinite are higher than kaolinite reported from other localities, having the values $n_\gamma = 1.577$; $n_\alpha = 1.571 \pm .002$, but the Debye type x-ray diffraction pattern agrees with similar patterns of other samples of kaolinite available for comparison.

Alteration Problem

The conditions under which alteration occurred are not clearly indicated. The locality has been described by Pough (1945). Kaolinization of feldspar is reported to be a prominent feature of the pegmatite in which the beryl pseudomorph was found. This has been attributed to weathering (Pough, p. 507). Although the possibility exists that the alteration is not the result of weathering, nothing was observed in the pegmatite other than the depth of alteration, to indicate that hydrothermal activity caused the kaolinization.

Clean cut cavities and microscopic inclusions were observed in a clear transparent beryl crystal from the same locality. Cavities, in the case of a resistant silicate such as beryl, would seem to indicate a form of thermal solution. One would expect weathering to affect the surface of the crystal and would be more of a surficial phenomenon. On the other hand, it is not clear whether the kaolinization accompanied the thermal solution or represented later activity. Johnson (1945, p. 1024) points out that pegmatites in the northeastern Brazilian area which lie on an old peneplain have little or no topographic expression and in many of them the feldspars have weathered to kaolin. Since the cavities are unfilled except by kaolinite it is reasonable to relate the introduction of the kaolinite to the etching phase. Under such circumstances, the kaolinite could have been hydrothermal in origin. Unfortunately, more information on this interesting feature does not appear to be available.

Acknowledgments

The writer wishes to thank Dr. Frederick H. Pough and The American Museum of Natural History for furnishing the material upon which this description has been based. He is also grateful to Dr. Lee C. Peck of the Rock Analysis Laboratory of the University of Minnesota for his co-operation in connection with the chemical analyses. The support of the Administration of Columbia University in furnishing funds for research is also gratefully acknowledged.

References

Dana, J. D., 1892, *System of Mineralogy*, pub. by John Wiley and Sons, Inc., p. 407.

Johnson, Jr., W. D., 1945, Beryl-tantalite pegmatites of northeastern Brazil; *Bull. Geol. Soc. Am.*, **56**, no. 11, 1071–1078.

Pough, F. H., 1945, Simpsonite, and the northern Brazilian pegmatite region: *Bull. Geol. Soc. Am.*, **56**, 505–514.