

NOTES – NOTISER

A Study of Zoned Beryl from Rajasthan

M. W. CHAUDHARI

Chaudhari, M. W.: A study of zoned beryl from Rajasthan. *Norsk Geologisk Tidsskrift*, Vol. 51, pp. 187–190. Oslo 1971.

A beryl from Mewar (Rajasthan) shows two zones; the outer yellowish green border zone and the inner yellow core. The refractive index and cell dimensions of beryl increase from the core to the border. This increase seems to be due to the slightly higher $\text{FeO} + \text{Fe}_2\text{O}_3$ content of the border. It is proposed that the zoning is due to the isomorphous solid solution series between Al beryl and Fe beryl.

M. W. Chaudhari, University Department of Geology, Udaipur, Rajasthan, India.

Introduction

Zoning in beryl is not an uncommon phenomenon. A detailed study of zoned beryl was made by Hurlbut & Wenden (1951), and since then no detailed investigations on zoned beryls, except for the work of Watters (1963), seem to have been carried out. This paper describes preliminary study on zoned beryl from Rajasthan.

Beryls from Rajasthan pegmatites often show zoning. The Shikarwadi pegmatite yielded a good crop of such beryls of various sizes. Unfortunately this pegmatite could not be studied at first hand as it has been long abandoned and rendered unfit for any observations. The beryls so far studied invariably showed two zones only; the outer border zone and the inner core. The border zone is invariably a shade greener or more bluish than the core. It is also comparatively more translucent than the inner zone, the colour of which is usually in the shade of yellow. A detailed study of the inclusions in beryl (Chaudhari 1968), indicates a possibility of one more zone; the innermost core in beryl. But so far no such beryl has been obtained.

Examination of beryl

A thin slice of a zoned beryl with yellowish green border and yellow core was cut parallel to the basal pinacoid and samples from four spots were taken out for the optical, X-ray and chemical investigations (Fig. 1). The refractive index ω shows very small variations between the adjacent samples well within the experimental errors. A *single* measurement of ω can thus often be mis-

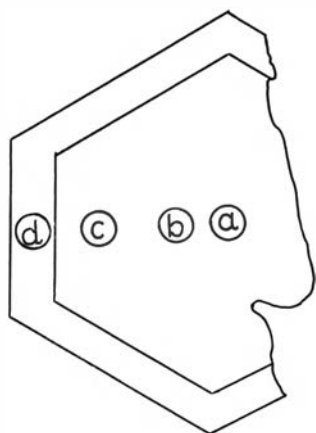


Fig. 1. Schematic diagram of zoning in beryl. Circled letters indicate sample location. Natural size.

leading. The refractive indices for sodium light were therefore measured for 10 different grains from each sample. The average values of these measurements are given in Table 1.

The cell dimensions of beryl obtained from the core and the border were determined from the diffractograms of the cavity mount samples using quartz as an internal standard. The average measurements of two diffractometer charts were taken to calculate the a and c axial lengths. The values of a and c (Table 1) show interesting variations. Both a and c show slight increase in the border zone. It is, however, more pronounced in the a axis. A partial chemical analysis shows an increase of 10% in the total ($\text{FeO} + \text{Fe}_2\text{O}_3$) in the border zone over the total ($\text{FeO} + \text{Fe}_2\text{O}_3$) content of the core. The increase in the refractive index and cell lengths thus seems to be due to the increase in the total iron content in the border zone.

Crystal chemistry of beryl

It is now known that the entry of Fe^{3+} , Mn^{3+} , Sc^{3+} etc. in beryl lattice increases its a axis length (Fron del & Ito 1968). This increase is roughly proportional to the size of the trivalent ion. These substitutions in the octahedral

Table 1. Properties of zoned beryl.

Sample location (See Fig. 1)	Refractive index ω (average of 10 measurements)	$\text{FeO} + \text{Fe}_2\text{O}_3$	$a(\text{\AA})$	$c(\text{\AA})$	c/a
<i>a</i>	1.583	1.00	9.193	9.190	0.9989
<i>b</i>	1.583	—	—	—	—
<i>c</i>	1.582	—	—	—	—
<i>d</i>	1.588	1.10	9.199	9.195	0.9999

site leave the length of the c axis practically unaffected or slightly decreased. In view of these considerations the slight increase in c axis in the border zone seems anomalous.

The compositional complexities in beryl are now fairly well known. Both Fe^{3+} and Fe^{2+} occur in appreciable amounts in natural beryls. A comparative study of a large number of beryl analyses indicates that the Fe_2O_3 content of natural beryls is usually slightly more than the FeO content (Chaudhari 1956). Beryls are known to contain as much as 3.4% Fe_2O_3 (Watters 1963). After a critical study of a large number of beryl analyses Schaller et al. (1962), postulated a basic Femag molecule, $(\text{Na}, \text{K}, \text{Sc}) \text{Be}_3\text{R}^{3+}\text{R}^{2+}\text{Si}_6\text{O}_{18}$ to account for the iron magnesium content of beryls. In this formula R^{3+} and R^{2+} represent Al, Fe^{3+} , Sc, Cr and Fe^{2+} , Mn^{2+} , Mg, respectively. Subsequent synthetic work of Frondel & Ito (1968) has confirmed the essential validity of this postulate. They were unable to synthesize pure $\text{Be}_3\text{Fe}^{3+}_2\text{Si}_6\text{O}_{18}$ beryl. Yet in the presence of scandium $\text{Be}_3\text{Sc Fe}^{3+}\text{Si}_6\text{O}_{18}$ beryl, containing a large amount of Fe_2O_3 , could be synthesized.

Discussion

The thermal stability relations in beryls with $(\text{R}^{3+}\text{O}_6)$ octahedra in the structure are imperfectly known. However, from the data given by Frondel and Ito (1968) they can be worked out reasonably well. $\text{Be}_3\text{Sc}_2\text{Si}_6\text{O}_{18}$ is stable up to 450°C at 2 kbar pressure. This stability temperature rises up to 650°C when half of Sc is replaced by Fe^{3+} . Al beryl is synthesized at 680°C . The thermal stability is thus apparently controlled by the ionic radii and ionization potential of the ions in the $(\text{R}^{3+}\text{O}_6)$ groups (Table 2). The melting relations between various beryls may, therefore, be given in the order:



Once the series between Al and Fe beryl, with a lower formation temperature for Fe beryl, is accepted, the occurrence of Fe rich border zone becomes understandable. The pale yellow green rim then represents the last stage of deposition of Fe rich beryl around earlier formed cores of Fe poor

Table 2. Thermal stability relations of different beryls, correlated with the chemical properties of R^{3+} ion.

Beryl composition	Temp. $^\circ\text{C}$	Trivalent ion	Ionic radius	Ionization potential
$\text{Be}_3\text{Sc}_2\text{Si}_6\text{O}_{18}$	450°	Sc	0.81	3.70
$\text{Be}_3\text{Sc Fe}^{3+}\text{Si}_6\text{O}_{18}$	650°	Fe^{3+}	0.64	4.69
$\text{Be}_3\text{Al}_2\text{Si}_6\text{O}_{18}$	680°	Al	0.51	5.88

beryl. And since this represents the last act in the crystallogenesis of beryl it is likely that it may get slightly enriched in the larger alkali ions with respect to the core. A slight increase in the *c* axis in the border zone may be due to this cause. The chemical and lattice dimensional differences between the core and the rim are indeed very small. It is, therefore, remarkable that they should be differentiated at all and preserved in the form of zoning. Special conditions of temperature, particularly the cooling history, must have been responsible for it.

8 June 1969

REFERENCES

- Chaudhari, M. W. 1956: Unpublished Ph.D. Thesis. University of Rajasthan, India.
- Chaudhari, M. W. 1968: A Study of Beryls from Rajasthan. Symposium on Geology and Mineralogy of Atomic Mineral Deposits and their Development for Use in the Nuclear Power Programme in India. National Institute of Sciences of India.
- Fronzel, C. & Ito, J. 1968: Synthesis of the scandium analogue of beryl. *Am. Mineralogist* 53, 943–953.
- Hurlbut, C. S. & Wenden, H. E. 1951: Beryl at Mount Mica Maine. *Am. Mineralogist* 36, 751–759.
- Schaller, W. T., Stevens, R. E. & Jahns, R. H. 1962: An unusual beryl from Arizona. *Am. Mineralogist* 47, 672–699.
- Watters, W. A. 1963: Zoned blue beryl from the Canaan region New Zealand. *N. Z. Jour. of Geol. & Geophysics* 6, 715.