GEOCHEMICAL AND MORPHOLOGICAL FEATURES OF BERYL
FROM THE BIKITA GRANITIC PEGMATITE, ZIMBABWE

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ABSTRACT

The geochemical evolution of beryl in the Bikita rare-element granitic pegmatite, in Zimbabwe, was examined by analyzing this mineral for alkali elements in 23 samples from eight zones in this giant deposit. From the outer to the inner zones of the pegmatite, generally corresponding to the least up to the most evolved ones, the alkali contents of near-homogeneous crystals of primary beryl increase from 0.09 to 1.08 wt.% Li_2O, from 0.39 to 1.56 wt.% Na_2O and from 0.10 to 2.23 wt.% Cs_2O. The entry of Li into the Be-populated tetrahedra is compensated initially by incorporation of Na into the channels of the structure, but in the more evolved samples from the inner zones of the pegmatite body, Cs becomes the main charge-balancing cation. A single sample of subsolidus pinkish beryl, in thin platy crystals flattened parallel to {0001}, with a thickness-to-diameter aspect of up to 1:50, has a general geochemical signature that in part overlaps, in part departs from, that of the primary beryl. Crystals of the late beryl show an alkali-poor core overgrown by alkali-rich outer zones, containing up to 1.15 wt.% Li_2O, 2.01 wt.% Na_2O and 3.48 wt.% Cs_2O. However, the alkali contents generally decrease from the early to the late "generations" of the platy crystals. The extremely platy habit cannot be linked to the alkali content, and the factor that promoted this habit remains unknown.

Keywords: beryl, morphology, lithium, cesium, granitic pegmatite, Bikita, Zimbabwe.

SOMMAIRE

Nous avons examiné l'évolution géochimique du béryl dans la pegmatite granitique à éléments rares de Bikita, au Zimbabwe, au moyen de données sur les teneurs en alcalins dans vingt-trois échantillons de ce minéral, prélevés sur les huit zones de ce massif géant. A partir des zones externes vers les zones internes de la pegmatite, correspondant aux parties les plus primitives vers les parties plus évoluées, les teneurs en alcalins des cristaux presque homogènes de béryl primaire augmentent de 0.09 à 1.08% Li_2O, de 0.39 à 1.56% Na_2O et de 0.10 à 2.23% Cs_2O (poids). L'incorporation du Li dans les tétraèdres hôtes du Be est compensée d'abord par le présence du Na dans les canaux de la structure, mais dans les échantillons plus évolués pris des zones internes de la pegmatite, le Cs devient le cation le plus important dans l'équilibre des charges. Un seul échantillon de béryl subsolidus rosâtre, se présentant en plaquettes minces empilées parallèle à {0001}, avec un rapport épaisseur:diamètre atteignant 1:50, fait preuve de caractéristiques géochimiques en partie parallèles, en partie divergentes, par rapport à celles du béryl primaire. Les plaquettes de béryl tardif possèdent un coeur à faible teneur en alcalins, avec surcroissances de béryl riche en alcalins, atteignant 1.15% Li_2O, 2.01% Na_2O et 3.48% Cs_2O. En général, toutefois, les teneurs en alcalins diminuent des plaquettes précoces aux plaquettes tardives de cet amas. La morphologie inhabituelle de cet échantillon en plaquettes empilées ne dépendrait pas des teneurs en alcalins, mais plutôt d'un autre facteur, qui demeure méconnu.

(Traduit par la Rédaction)

*Mots-clé*s: béryl, morphologie, lithium, césium, pegmatite granitique, Bikita, Zimbabwe.

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INTRODUCTION

The Bikita granitic pegmatite in Zimbabwe constitutes one of the largest deposits of lithium and ceramic petalite, with minor reserves of tin, tantalum and beryllium. Since its discovery in 1911, this pegmatite has been intermittently mined in open pits. Internal zoning of the pegmatite is well documented (Symons 1961, Cooper 1964), but the mineralogy, geochemical characteristics and petrology have been largely neglected. Random individual minerals, such as bikitaite ($LiAlSi_2 O_6 \bullet H_2O$), with notes on associated stilbite, calcite, and allophane (Hurlbut 1957, 1958, Bissert & Liebau 1986), eucryptite (Hurlbut 1962), simpsonite (MacGregor 1946), simpsonite, alumotantite, ferrotapiolite and zirconian hafnon (Ercit 1986, Ercit *et al.* 1992), pollucite (Khalili & von Knorring 1976, Teertstra & Černý 1997), late Rb-rich K-feldspar (Teertstra *et al.* 1998), and zabuyelite in spodumene (Anderson *et al.* 2001), have been described in the literature. Also, chemical compositions of impure mineral concentrates of petalite, eucryptite, lepidolite, "zinnwaldite", pollucite, spodumene + quartz intergrowth, tantalite, microlite, simpsonite and amblygonite were published by Tyndale-Biscoe (1951), Symons (1961), Martin (1964) and Cooper (1964). However, the complete assemblage of minerals in the pegmatite remains unexplored, and even the basic geochemical properties of the rock-forming and accessory minerals remain undocumented.

In 1984, A.J.A. had an opportunity to visit this pegmatite and to collect a suite of beryl samples from different zones in the pegmatite, and a specimen of an unidentified phase, which proved to be an extremely platy variety of late beryl, not observed to date at any other locality. This suite of samples was coupled with specimens forwarded by Mr. J.E. Wegener, former manager of the Bikita mine. In this note, we present the compositional and structural characteristics of the primary and late beryl, as a first systematic contribution to a better understanding of the constitution of the Bikita granitic pegmatite.

THE BIKITA PEGMATITE

The Bikita granitic pegmatite is located about 65 km east–northeast of Fort Victoria in the Victoria schist belt, surrounded by plutons of Archean granitoid rocks of the Zimbabwean craton (Tyndale-Biscoe 1951, Martin 1964). The age of the pegmatite was given as 2650 Ma (Herzog *et al.* 1960: average of four interlaboratory Rb–Sr results on a single sample of lepidolite). The pegmatite body strikes north–northeast and dips moderately to the east, and was emplaced in quartz-bearing amphibolite; it has an exposed length of ~1700 m and a true width variable from 40 to 70 m. Although direct physical connection is not demonstrated, the smaller pegmatites just north of the Bikita body may be branching parts of a single system (Fig. 2 in Tyndale-Biscoe 1951).

The internal zoning of the Bikita pegmatite is quite complex (Table 1). Cooper (1964) distinguished nine to thirteen zones in separate segments of the pegmatite; he subdivided the tabular body into border, upper wall, upper intermediate, core, lower intermediate, and lower wall zones. The internal structure seems to be layered rather than concentric, with distinct vertical asymmetries exhibited particularly in the intermediate zones (Table 1). Nevertheless, Norton (1983) fitted the internal structure at Bikita into his universal scheme of zoning in complex lithium-rich pegmatites. The zoning also varies laterally, with pronounced differences among the intermediate zones between the northern Al Hayat and southern Bikita sectors (the latter in turn subdivided into a central Quarry and southern Southeastern Area sectors) of the pegmatite (Symons 1961, Cooper 1964).

DISTRIBUTION AND SAMPLING OF PRIMARY BERYL

Cooper (1964) reported the presence of beryl in most zones of the Bikita pegmatite. In general, it is concentrated in the Bikita sector, but much less abundant in the Al Hayat segment. In some zones of the Bikita sector, beryl forms masses from tens of kilograms (in the rhythmically banded beryl zone) to a few tonnes (in the lepidolite–quartz shell). In the present study, we have examined twenty-three samples of beryl from eight zones (samples 1 to 10, W1 to W13) from the beryl-enriched Bikita sector. The samples of primary beryl are listed, together with details about general morphology and color in individual zones of the pegmatite, in

TABLE 1. ZONING IN THE BIKITA SECTOR OF THE BIKITA GRANITIC
PEGMATITE* AND DISTRIBUTION OF SAMPLES

	Hanging-wall greenstone	Sample numbers
Border zone	Selvedge (plagioclase, quartz)	
Wall zones	Muscovite band	W1, W2
	Hanging-wall feldspar zone	
Intermediate zones (upper)	Petalite and feldspar	
	Spodumene (i) massive	
	Spodumene (ii) mixed	1, 3, 4
	Pollucite	
	Feldspar–quartz	
	"All-mix" zone	2, 7, W9, W13
Core zones	Massive lepidolite[†] (i) high-grade core	W7, W8
	Massive lepidolite (ii) nearly pure lepidolite	
	Lepidolite–quartz shell (i) lepidolite	W3, W4
	Lepidolite–quartz shell (ii) amblygonite	
Intermediate zones (lower)	"Cobble" zone	
	Feldspathic lepidolite	8, W10
Wall zone	Footwall feldspar zone (i) rhythmically banded beryl zone	5, 6, 9, 10, W11, W12
	Footwall feldspar zone (ii) muscovite band	W5, W6
	Footwall feldspar zone (iii) "spotted dog"	
	Footwall greenstone	

* after Cooper (1964). [†] The name of a series of mineral species.

Tables 1 and 2. Crystals of primary beryl were found to be rather homogeneous in chemical composition.

LATE PLATY BERYL

A specimen of pale pink platy beryl (samples B–1 to B–4), found as a loose fragment in a dump, also was examined; its zonal affiliation is unknown, and the only associated mineral is a single large grain of milky quartz. The specimen, $9 \times 6 \times 4$ cm in size, consists of several "generations" of platy crystals, transitional from the older coarse plates that constitute most of the sample (~30 mm across) to the youngest small crystals that line miarolitic cavities (~6 mm in diameter). The platy crystals and the mode of their fan-shaped aggregation closely resemble "cleavelandite". The size of the platy crystals decreases from contacts with quartz toward the cavities, indicating gradual reduction of size for progressively younger crystals. In this sequence, the crystals were subdivided for descriptive purposes into "generations" 1 to 4, and representative examples extracted for study. The platy crystals are invariably zoned, with a dominant inner zone and subordinate outer zone, which is extremely thin on basal faces ($\leq$6 μm), but well developed along the edges of the crystals (1 to 4 mm).

The cavity-lining crystals display well-developed faces, the interfacial angles of which were measured on a spindle stage under a light microscope. Besides the dominant $\{0001\}$, the dipyramid $\{20\bar{2}1\}$ is substantial, its edges and corners blunted by prismatic faces of $\{10\bar{1}0\}$ and $\{11\bar{2}0\}$, respectively. The thickness-to-diameter aspect of the platy crystals is variable, but generally tends to increase from the oldest to the next-to-youngest platy crystals. In some crystals, this aspect is as low as 1:50.

EXPERIMENTAL

Partial chemical analysis of samples 1 to 10 and W1 to W13 was performed by atomic-absorption spectroscopy for Li, Na, K, Rb, Cs and Ca, using NBS standards. The concentration of lithium was determined by this method also for the zoned B-series samples and for three representative samples otherwise analyzed with a Cameca SX–50 electron microprobe under the following conditions: excitation voltage 15 kV, beam current 20 nA, peak counting time 20 s for Na, Si, Al, 30 s for Cs, and 50 s for K, Rb, Ca, Mg, Fe, Mn and Sc, background determination 10 s. The $K\alpha$ lines were used for all elements sought: Na (albite), Al (kyanite), Si

TABLE 2. CHEMICAL COMPOSITION AND PHYSICAL ATTRIBUTES OF BERYL, BIKITA GRANITIC PEGMATITE

	Li_2O	Na_2O	K_2O	Rb_2O	Cs_2O	CaO		Li_2O	Na_2O	K_2O	Rb_2O	Cs_2O	CaO
	Upper muscovite band (subhedral, greenish)							Rhythmically banded beryl zone (anhedral, greenish to white)					
W1	0.2	0.77	0.03	0.03	0.13	0.01	5	0.41	0.81	0.03	0.05	0.12	0.007
W2	0.11	0.4	0.02	0.02	0.18	0.009	6	0.65	1.25	0.02	0.04	0.28	0.003
							9	0.41	0.84	0.03	0.05	0.11	0.004
	Mixed spodumene zone (anhedral, pale pink)						10	0.47	0.99	0.03	0.04	0.13	0.002
1	0.97	1.04	0.02	0.02	1.04	0.007	W11	0.55	1.07	0.03	0.01	0.22	0.005
3	0.86	1.1	0.02	0.07	1.1	0.003	W12	0.52	1.24	0.04	0.02	0.1	0.003
4	0.75	0.93	0.04	0.1	0.93	0.003							
								Lower muscovite band (anhedral, greenish)					
	"All-mix" zone (subhedral, peach-colored)						W5	0.13	0.54	0.01	0.03	0.09	0.011
2	1.08	1.56	0.03	0.04	2.05	0.007	W6	0.09	0.39	0.03	0.03	0.1	0.012
7	0.9	1.39	0.02	0.08	2.02	0.005							
W9	0.84	1.43	0.02	0.05	2.23	0.008		Late platy beryl (pale pink)*					
W13	0.96	1.4	0.02	0.07	1.86	0.004	B-1a core	0.66	1.75	b.d.l.	b.d.l.	0.56	0.01
							B-1b rim	0.98	2.01	0.01	b.d.l.	2.49	0.1
	Massive lepidolite zone (anhedral, pink)						B-1c core	0.76	1.85	b.d.l.	b.d.l.	0.95	b.d.l.
W7	1.04	1.45	0.03	0.05	1.38	0.003	B-1d rim	1.05	1.92	0.01	b.d.l.	2.66	0.16
W8	0.89	1.41	0.04	0.07	1.51	0.002	B-2a core	0.76	1.6	0.01	b.d.l.	1.09	b.d.l.
							B-2b rim	1.15	1.8	0.02	0.12	3.48	0.37
	Lepidolite–quartz shell (anhedral, peach-colored)						B-2c core	0.85	1.61	0.01	0.02	1.03	0.01
W3	0.76	1.07	0.01	0.06	1.32	0.002	B-2d rim	1.1	1.89	0.02	0.08	3.38	0.26
W4	0.7	1.06	0.02	0.05	1.68	0.002	B-3a core	0.81	1.69	b.d.l.	b.d.l.	1.09	b.d.l.
							B-3b rim	0.85	1.91	0.01	b.d.l.	1.66	b.d.l.
	Feldspathic lepidolite zone (anhedral, pink)						B-3c core	0.69	1.75	0.01	0.04	0.81	b.d.l.
8	0.47	0.91	0.03	0.06	0.26	0.001	B-3d rim	1.03	1.87	b.d.l.	b.d.l.	1.7	0.01
W10	0.46	0.85	0.02	0.04	1.8	0.002	B-4a core	0.76	1.73	b.d.l.	b.d.l.	0.92	0.01
							B-4b rim	0.92	1.82	b.d.l.	0.04	1.79	0.02
							B-4c core	0.83	1.68	0.01	b.d.l.	0.96	0.01
							B-4d rim	1	1.77	0.02	b.d.l.	1.8	0.03

Samples W1, 2, W3, 9 and W6 also contain, respectively, total Fe as FeO 0.15, 0.04, 0.05, 0.08, 0.13 wt.%, and MnO 0.06, 0.13, 0.16, 0.10, 0.08 wt.%. * 1 to 4 mark four platy crystals, representative of "generations" #1 to #4, selected for chemical analysis; *a* and *b,* and *c* and *d* represent two core and rim pairs, each pair separated from a single crystal. The results are quoted in wt.%; b.d.l.: below detection limit.

(quartz), K (orthoclase), Rb (rubidian microcline), Cs (pollucite), Mg (forsterite), Fe (fayalite), Mn (spessartine) and Ca (diopside). The program of Pouchou & Pichoir (1984, 1985) was used for data reduction.

Concentrates of core and rim material of the platy B-series crystals were prepared by soft-cementing the crystals to a hard plastic sheet, covering them with a loose sheet of thin cardboard and tapping them with a small hammer. Fragments of core and rim, preserved in their original location within the crystals, were then hand-picked and cleaned in acetone.

Unit-cell dimensions were refined from X-ray powder-diffraction data collected on a Philips PW 1720 system, with monochromated $CuK\alpha$ radiation and CaF_2 as internal standard (a 5.4620 Å), using a modified version of the Appleman & Evans (1973) least-squares program.

CHEMICAL COMPOSITION AND UNIT-CELL DIMENSIONS

The results of the chemical analyses are given in Tables 2 and 3, and graphically represented in Figures 1 and 2. The alkali contents in general, and those of the rare-alkali elements in particular, generally increase from the outer to the inner zones of the pegmatite, as the color of beryl changes from greenish through white to pink and peach. The Li content increases from 0.09 to 1.08 wt.% Li_2O, from 0.39 to 1.56% Na_2O, and 0.10 to 2.23% Cs_2O. The values of the Na:Li ratio decrease in this direction, accompanied by an initially modest but later very pronounced increase in Cs (Fig. 2C). In the same direction, the few samples analyzed for Fe and Mn show a decrease in the concentration of Fe, but increasing quantities of Mn (Table 2). The traces of Ca vary concomitantly with Fe.

The trends shown by the late platy beryl generally conform to the overall pattern of the primary beryl (Figs. 1, 2), but not necessarily in a sequential manner. Parallel alignment with the trend of primary beryl (Figs. 1A, B) or substantial overlap of ranges (Figs. 1C, D) are observed, and in some cases the primary and late trends are distinctly independent (Figs. 1B and 2B). The sequence from B1 to B4 follows the decreasing relative age of the platy crystals selected for analysis. The results show that the outer zones of the platy crystals are invariably enriched in alkalis relative to their interiors, with up to 1.15 wt.% Li_2O, 2.01% Na_2O, and 3.48% Cs_2O. In general, however, the alkali contents decrease from the oldest to the youngest plates (Table 2, Figs. 1, 2).

The unit-cell dimensions are listed in Table 4. The c parameter increases with the content of the alkali elements in general, and with that of Cs in particular (*cf.* Table 2), whereas a shows only very minor and apparently erratic variations. The correlations would probably be better if single-crystal methods were employed for determination of the cell dimensions: indexing of X-ray powder-diffraction data and selection of non-overlap-

ping diffraction maxima are quite difficult for alkali-poor beryl with $a \approx c$. However, powder data are more representative of the bulk of material used for determination of Li contents.

DISCUSSION

Crystal chemistry

There has been some discussion about the location of the alkalis in the structure of natural beryl from granitic pegmatites, but the current consensus places the three main alkali metals virtually exclusively into three respective sites. Lithium substitutes for Be^{2+} in the tetrahedra linking the six-membered Si_6O_{18} rings, with the charge balance assured by Na^+ and Cs^+ in the channels passing through the centers of the vertically stacked rings. Sodium is accommodated in the centers of the individual rings of tetrahedra, but the larger Cs^+ is located halfway between these centers. Partial overlap of these two channel sites, the second of which also hosts molecular H_2O, results in restrictions on the stoichiometry of these two cation populations (*cf.* Hawthorne & Černý 1977, Sherriff *et al.* 1991, Artioli *et al.* 1993, Hawthorne & Huminicki 2002, Černý 2002).

TABLE 3. CHEMICAL COMPOSITION OF REPRESENTATIVE SAMPLES OF BERYL, BIKITA GRANITIC PEGMATITE

	9	7	B-2b
SiO_2, wt.%	66.01	63.85	62.60
Al_2O_3	18.75	17.96	17.69
FeO*	0.10	0.08	b.d.l.
MnO	0.06	0.06	0.03
MgO	0.02	b.d.l.	b.d.l.
CaO	0.01	0.01	0.01
BeO	13.05	11.42	11.15
Li_2O	0.42	1.06	1.20
Na_2O	0.82	1.63	1.58
K_2O	0.01	0.03	0.03
Rb_2O	0.03	0.03	0.12
Cs_2O	0.09	2.14	3.46
H_2O	0.75	1.05	1.90
total	100.12	99.32	99.77
atomic contents normalized to 18 oxygen atoms			
Si *apfu*	5.990	6.011	5.993
Be	2.845	2.583	2.564
Li	0.153	0.401	0.462
Σ	2.998	2.984	3.026
Al	2.005	1.993	1.996
Fe^{2+}*	0.008	0.006	0.000
Mn	0.005	0.005	0.002
Mg	0.003	0.000	0.000
Σoct.	2.021	2.004	1.998
Ca	0.001	0.001	0.001
Na	0.144	0.298	0.293
K	0.001	0.004	0.004
Rb	0.002	0.002	0.007
Cs	0.003	0.086	0.141
Σchannel	0.151	0.391	0.446
H_2O	0.454	0.659	1.213

* total Fe as FeO; b.d.l.: below detection limit. Samples: 9: greenish beryl from the footwall rhythmically banded beryl zone; 7: pink beryl from the upper intermediate "all-mix" zone; B-2b: rim of a coarse platy beryl. *apfu*: atoms per formula unit.

Data presented for three specimens representative of the greenish alkali-poor beryl from outer zones of the pegmatite (#9), pink beryl from the interior (#7), and the rim of a coarse platy beryl (B–2b) support the above scheme of substitution. The sum of Be + Li equals 3, and the sum of Na + K + Rb + Cs + Ca equals, within the limits of analytical error or better, the number of Li atoms (Table 3). The extent of incorporation of Fe, Mn and Mg in the octahedral site is negligible. In general, the behavior of the Bikita beryl matches that of its Tanco counterpart (Černý & Simpson 1977).

Geochemical evolution of the primary beryl

Geochemically, the alkali contents of the primary Bikita beryl generally conform to the pattern established for beryl from rare-element pegmatites by Beus (1960) and quantified by Černý (1975): from primitive to evolved pegmatites, and from apparently early to late zones within individual bodies of pegmatite, the gradual

increase of Li is initially compensated mainly by Na but, at a more advanced stage, dominantly by Cs (Figs. 1, 2). The turning point from the Na-dominant to the Cs-dominant compensation is commonly attained at the Na/Li (wt.) value of 4 to 2 (Figs. 1 to 4 in Černý 1975). The Bikita data show some scatter in the Na *versus* Cs and Li *versus* Cs diagrams (Fig. 1), but the general trend of the plots is well defined. All the trends are close to those observed in beryl from complex pegmatites of the same highly evolved category: Mongolian Altai #3 (Solodov 1962, Wang *et al.* 1981, Shmakin 1992) and Tanco (Černý & Simpson 1977), although at Bikita the enrichment in Cs does not attain the same level as in the Tanco beryl (see also Černý 1975). In keeping with the compositional characteristics of beryl from these pegmatites, the contents of Ca, Mn and Fe of the Bikita samples are very low (Table 2). In less evolved pegmatites, these elements are distictly enriched (*e.g.*, up to 1.25 wt.% total Fe as Fe_2O_3 in beryl of the Greer Lake pegmatite group in Manitoba; Černý & Turnock 1975).
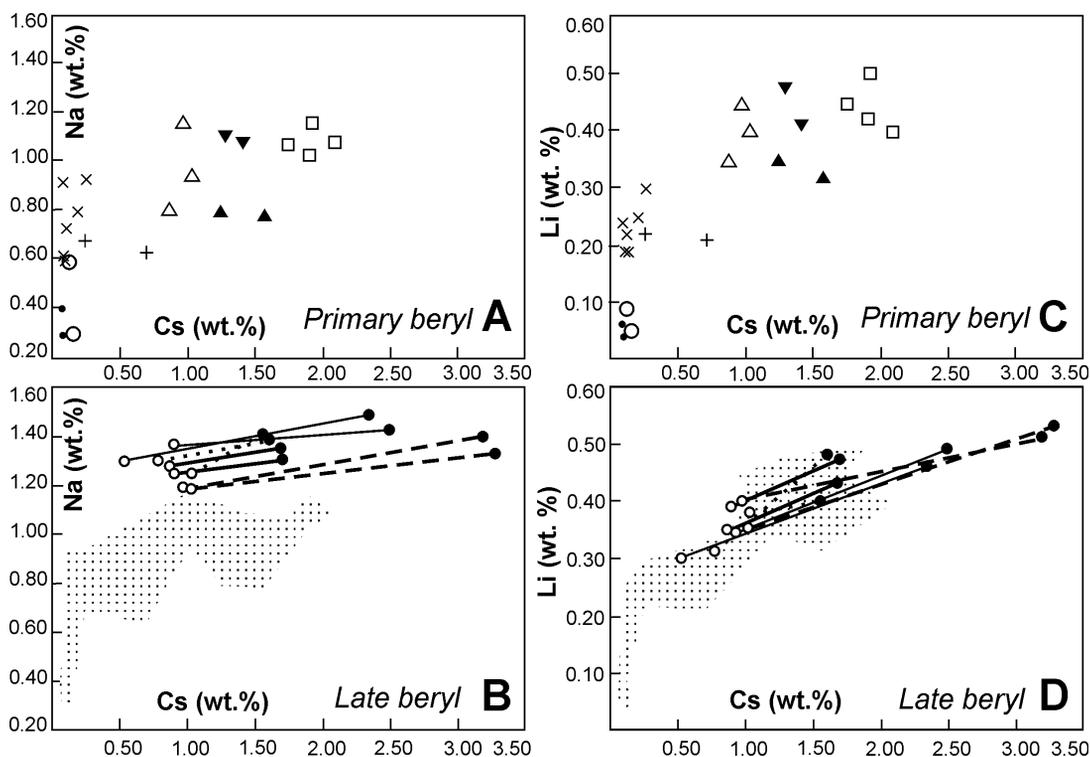

Fig. 1. The Na *versus* Cs (A, B) and Li *versus* Cs (C, D) diagrams for the primary (A, C) and late (B, D) beryl from the Bikita pegmatite. Primary beryl is distinguished by its parent zones: o upper muscovite band, △ mixed spodumene zone, □ "all-mix" zone, ▼ massive lepidolite, ▲ lepidolite–quartz shell, + feldspathic lepidolite zone, X rhythmically banded beryl zone, ● lower muscovite band. Tielines designate four analyzed crystals of platy beryl, from early to late: thin solid: 1, dashed: 2, dotted: 3, thick solid: 4. The dotted area in B and D marks the compositional fields of the primary beryl from A and C, for direct comparison with the late variety. Note the parallel but non-overlapping trends in A and B, and the sequential overlap of trends in D and C.
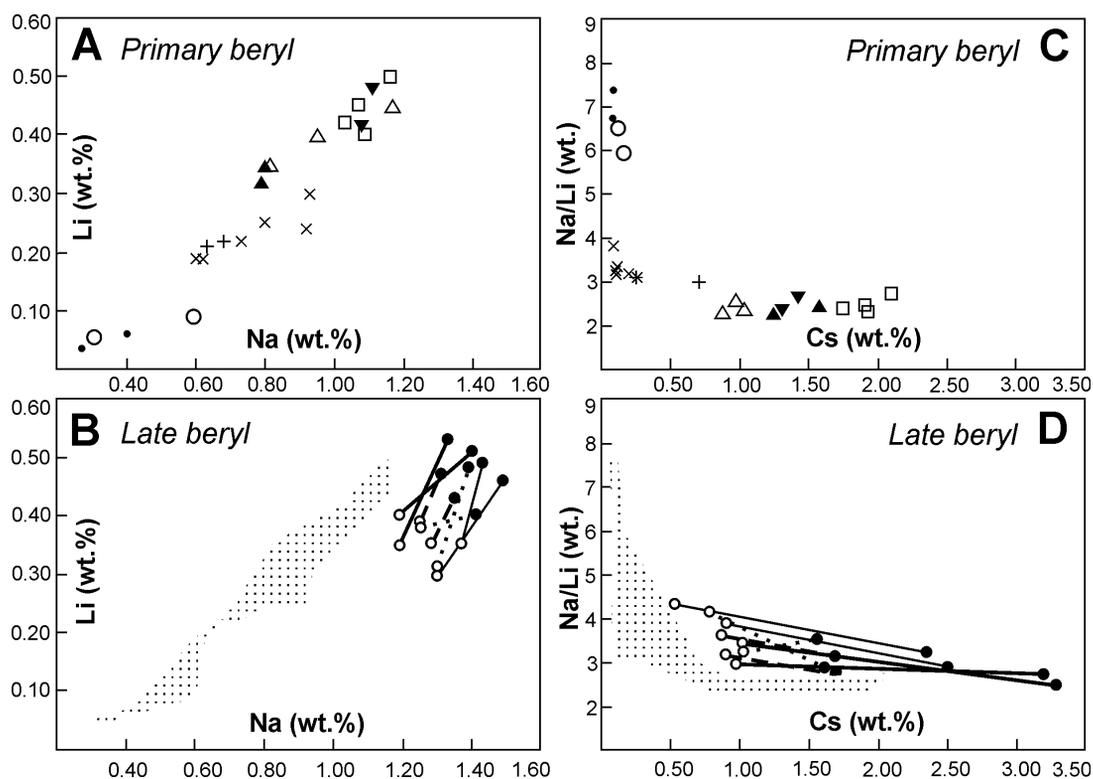
FIG. 2.   The Li *versus* Na (A, B) and Na/Li *versus* Cs (C, D) diagrams for the primary (A, C) and late (B, D) beryl from the Bikita pegmatite. See Figure 1 for explanation of the graphic symbols. Note the separation of trends in A and B, and the parallel alignment of the D trend, at a higher average Na/Li, with the Cs-enriched part of the C trend.

The distribution of alkalis in primary beryl across the zoning of the Bikita sector of the Bikita pegmatite shows a general increase toward the central parts of the pegmatite (Fig. 3), *i.e.,* toward zones that probably consolidated late in the history of the pegmatite solidification. In this respect, the location of the pollucite zone and of the main lepidolite-rich zones strongly suggests such a concentric inward pattern of crystallization (Table 1). However, the above trends are neither smooth nor symmetrical. They are probably influenced by the compositions of competing coexisting phases, such as micas and feldspars, for which there are no data available. It is noteworthy that the highest alkali contents in general, and those of Cs in particular, are recorded for beryl from the "all-mix" zone closely adjacent to the pollucite zone (Table 1, Fig. 3).

Further complications can be expected considering the volume of the Bikita pegmatite: it shows distinct vertical asymmetry along dip, from a feldspathic keel to petalite-rich crest, with lepidolite and pollucite accumulated in the upper central parts (Cooper 1964, Martin 1964). Differences can be expected in the chemical composition of beryl within individual zones of the pegmatite; this aspect of the geochemistry of beryl was, however, beyond the scope of our study.

Late platy beryl

The pattern of the alkali distribution in the late secondary beryl does not sequentially follow the trends defined by the primary beryl. This is understandable in view of the inevitable difference in the mineral-forming environment between the magmatic medium (which generates the primary beryl in massive pegmatite zones), to the supercritical to hydrothermal milieu of subsolidus processes (which produces the tabular and platy varieties of beryl in vugs and along fractures). Within individual platy crystals of the Bikita sample, the alkali contents show a sharp increase from the core to the outer zones, in keeping with the usual trend observed in primary as well as late beryl from granitic pegmatites (*e.g.,* Hurlbut & Wenden 1951, Černý & Turnock 1975, Černý & Simpson 1977). However, the general level of alkali concentration decreases from the early coarse plates of

the late beryl to the late fine crystals lining cavities in the platy aggregates. This decline in alkali substitution is rather unique among the beryl sequences examined to date, except for a similar reversal observed in the Mongolian Altai #3 pegmatite by Solodov (1962), Wang *et al.* (1981) and Shmakin (1992): the Li and Cs contents surprisingly but distinctly decrease in primary beryl from the core–margin zone, which is most enriched in lepidolite and pollucite.

The most peculiar aspect of the platy beryl is its habit. The general tendency of early alkali-poor beryl to form columnar crystals that gradually become stumpy grading to tabular with increasing alkali contents in late generations is well known. However, the thickness-to-diameter aspect of the tabular crystals usually varies from ~1:3 to ~1:5, rarely attaining values close to 1:10 (Figs. 9–14 in Sinkankas 1989). Feklitchev (1964) advanced a complicated and unconvincing argument that the tabular habit is favored by alkali substitution in the

linking Be-tetrahedra (in an allegedly Be-deficient environment), which is supposed to increase the rate of lateral growth. Were this the case, the varieties of beryl most enriched in alkalis would be expected to be extremely platy: this is evidently not the case, as the most alkali-rich beryl crystals examined to date are columnar (Evans & Mrose 1968, Černý 1972), and the platy beryl examined here does not rank with specimens most enriched in alkalis (*cf.* Beus 1960, Feklitchev 1964, Bakakin *et al.* 1969, Černý & Simpson 1977, Aurisicchio *et al.* 1988). Thus another reason for the extremely thin platy habit of the late Bikita beryl must be sought.

TABLE 4. UNIT-CELL DIMENSIONS OF BERYL, BIKITA PEGMATITE

Sample #	a (Å)	c (Å)	c/a
1	9.213(3)	9.224(5)	1.0012
7	9.210(2)	9.231(4)	1.0023
W8	9.211(2)	9.228(4)	1.0008
9	9.221(3)	9.226(6)	1.0005
W5	9.222(4)	9.218(7)	0.9996
B-1b	9.210(1)	9.251(5)	1.0045
B-2d	9.213(1)	9.249(4)	1.0039
B-3b	9.213(3)	9.234(8)	1.0023
B-4b	9.211(1)	9.241(6)	1.0033

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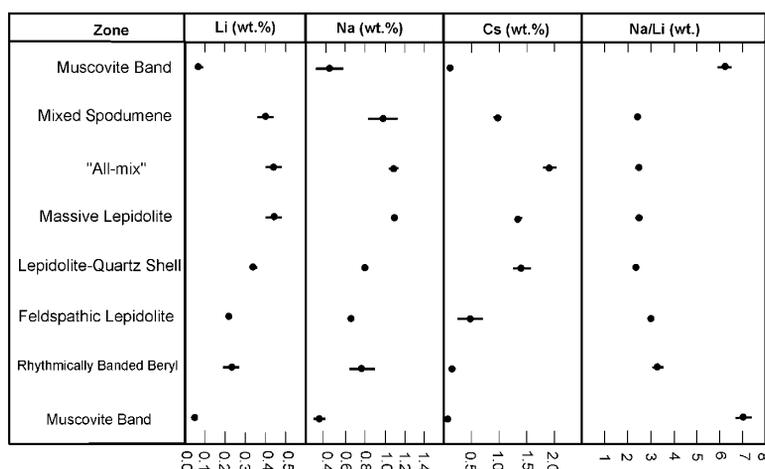

FIG. 3. Vertical variations in alkali contents of the primary Bikita beryl; zone designations and vertical sequence as in Table 1. Note the general but irregular increase in the alkali contents toward the central parts of the pegmatite.

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