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SOME MINERALOGICAL, GEOCHEMICAL AND ECONOMIC ASPECTS OF LITHIUM PEGMATITES FROM THE KARIBIB - CAPE CROSS PEGMATITE FIELD IN SOUTH WEST AFRICA/NAMIBIA

by

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ABSTRACT

In the area around Karibib, Usakos and Cape Cross, an important pegmatite field is situated, measuring about 200 x 100 km. The pegmatites are of late Damaran age; many are well mineralised and important sources of Li, Cs, Be, Sn, Nb, Ta and Bi minerals, ceramic feldspar and quartz, and a few contain gem tourmalines. The majority may be considered as Li pegmatites, but there are also Be and Sn pegmatites.

The nature of Li pegmatites is discussed in detail; they may be subdivided in amblygonite, spodumene, petalite and complex Li pegmatites. A number of minerals included in those pegmatites is also described.

UITTREKSEL

In die gebied rondom Karibib, Usakos en Kaap Kruis is ‘n belangrike pegmatietveld geleë wat oor ongeveer 200 x 100 km strek. Die pegmatiete is van laat-Damara ouderdom; baie is goed gemineraliseer en belangrike bronne van Li, Cs, Be, Sn, Nb, Ta en Bi minerale, keramiese veldspaat en kwarts en sommige bevat toermalyne van edelsteen-gehalte.

Die geaardheid van die pegmatiete word in detail bespreek; hulle kan in ambligoniet-, spodumeen-, petaliet- en komplekse Li pegmatiete onderverdeel word. ‘n Aantal van Li, Be en Sn minerale wat in die pegmatiete voorkom, word ook beskryf.

1. INTRODUCTION

In the Karibib-Usakos-Cape Cross areas numerous mineralized pegmatites have been known for many years as important sources of Li, Cs, Be, Sn, Nb, Ta and Bi minerals, ceramic feldspar and quartz - and for some spectacular finds of gem tourmaline. This pegmatite field is some 200 km long and up to 100 km wide, and is comparable to the most extensive pegmatite fields in other parts of the world. The pegmatites are apparently connected with latekinematic granites of the Salem Suite that have intruded a variety of metasediments of the Damara Sequence.

The pegmatites vary to some extent in their internal structure and mineral composition, but most have a common geochemical pattern where Li, Na and K phases are well developed. Among the major mineral constituents, lepidolite, petalite, amblygonite, various Li-Mn-Fe phosphates, microcline, albite (cleavelandite), muscovite, beryl and tourmaline are of common occurrence. Although the majority of the deposits may be considered as Li-Be pegmatites, there are a great number of important Sn pegmatites as well.

2. MINERALOGY OF LITHIUM PEGMATITES

From a mineralogical point of view the Li pegmatites of the Karibib area in particular are unique in that the major Li-mineral in most of them is petalite and not spodumene, which is a more common Li-mineral in other pegmatite provinces of the world.

Lithium is one of the characteristic elements of granite pegmatites, where it is concentrated to varying degrees and pegmatites containing appreciable amounts of Li-minerals are termed Li-pegmatites. Normally, within an extensive pegmatite field only a few distinct Li-pegmatites may be found but in some pegmatitic terrains, especially in parts of Central and Southern Africa, Madagascar, Central Asia (including Afghanistan), U.S.A. and Canada distinct geochemical provinces of Li can be established where Li pegmatites predominate.

On a purely mineralogical basis, the following Li pegmatites may be distinguished:

Amblygonite pegmatites, essentially quartz-microcline-albite-muscovite pegmatites with development of amblygonite, or rather montebrasite, in or around the quartz core, with or without some Li-Mn-Fe phosphates or smaller amounts of lithian mica. Major economic minerals: ceramic feldspar, muscovite, amblygonite, beryl and smaller amounts of Nb-Ta and Sb minerals. Occasionally important sources of gem tourmaline.

Spodumene pegmatites, either generally quartz-microcline-albite-muscovite pegmatites with spodumene confined either to the dominant quartz core, the intermediate zone, or both. In these pegmatites, the spodumene is frequently kaolinized or replaced by cleavelandite, fine-grained muscovite-quartz or occasionally by an albite-eucryptite intergrowth. Economic minerals: spodumene, beryl, Sb, Nb-Ta and Bi minerals;

or essentially spodumene pegmatites with variable amounts of microcline, albite, muscovite, quartz, accessory manganoan apatite and garnet, with or without

Li-Mn-Fe phosphates. They are typically marginal or exterior pegmatites occurring regionally in dyke-like or lenticular bodies, most of which are poorly zoned. These pegmatites constitute the major lithium deposits in the world. Additional economic minerals: amblygonite, beryl and abundant cassiterite with smaller amounts of Nb-Ta minerals;

Petalite pegmatites, generally quartz-microcline-albite (cleavelandite)-muscovite pegmatites with or without lithian micas and Li-Mn-Fe phosphates; some containing minor spodumene. Economic minerals: petalite, amblygonite, eucryptite, Be, Sn, Nb-Ta and Bi minerals;

Complex Li-pegmatites, displaying well developed zoning with dominant quartz cores, and contain a large variety of Li minerals belonging to one or several specific Li-Na-F phases of mineralization. They include important Li, Cs, Be, Ta-Nb, Bi and occasionally gemstone pegmatites containing multicoloured alkali beryl (aquamarine, morganite) and tourmaline (rubellite, verdelite, indigolite), this mineral often displaying colour zones.

2.1 Lithium Minerals

The most common independent Li minerals occurring in Li pegmatites are the major Li-Al silicates eucryptite, $LiAlSiO_4$, spodumene, $LiAlSi_2O_6$, petalite, $LiAlSi_4O_{10}$, a variety of lithian micas including lepidolite, the phosphates amblygonite-montebrasite, $LiAlPO_4(F,OH)$, and lithiophilite-triphylite, Li $(MnFe)PO_4$.

Apart from eucryptite and spodumene which are rather rare in the present area and only found in a few occurrences, petalite and lithian micas are well represented and constitute important ores of Li.

Petalite ($LiAlSi_4O_{10}$), the major Li component in many of the Karibib pegmatites, occurs in large masses, at many places together with blocky microcline and albite (cleavelandite). Occasionally giant tabular crystals or aggregates of petalite are seen associated with large pods of saccharoidal albite as at the Rubicon mine on Okongava Ost 72. Here, as at the Helicon mine, the mineral is altered to varying degrees. Quensel (1956) describes a similar alteration of petalite from the Varutrask pegmatite in northern Sweden and attributes it to an initial hydrothermal and a subsequent supergene alteration. At Rubicon the alteration of petalite has proceeded in stages and may have started with the introduction of late-stage cleavelandite, thus coinciding with the hydrothermal replacement processes and supporting Quensel's and earlier writers views regarding both spodumene and petalite alteration.

The stability fields of eucryptite, spodumene and petalite are well documented experimentally in the system $LiAlSiO_4 + SiO_2$ (London and Burt, 1982). Thus the stability of eucryptite is restricted to low pressure and temperature, spodumene is stable at relatively high pressure and moderate temperature, whereas petalite is stable at moderate pressure and high temperature. The effect of acidic volatiles, P and F during the hydrothermal stage is such, that eucryptite and petalite, in particular, are easily altered or modified (London and Burt, loc. cit.). Analyses of petalite and its alteration product are given in Table 1.

Spodumene, $LiAlSi_2O_6$, the most common LiAl-silicate, is rare in the present area and appears to be restricted to a series of smaller pegmatites south of Brandberg. Here it occurs as bladed crystals together with quartz and muscovite - and in some pegmatites together with amblygonite, petalite and eucryptite.

In the Karibib area a small amount of acicular spodumene was noted at the Dernburg 1 pegmatite on Navachab 58.

Occasionally spodumene has been seen as clayey pseudomorphs in the quartz cores of a number of pegmatites.

Outside the present pegmatite field, a large amount of spodumene has been observed in the Tantalite Valley pegmatites, south of Warmbad (Karasburg District).

Eucryptite, $LiAlSiO_4$, is the rarest of the Li-Al-silicates and has not been previously described from SWA/Namibia. Apart from an exceptional occurrence at Bikita and some other smaller pegmatites in Zimbabwe, eucryptite is rather rare in other lithium pegmatite fields of the world. Fresh eucryptite, however, resembles quartz so much that it may have been overlooked in many Li pegmatites - eucryptite means "well concealed"! The diagnostic features of eucryptite are its alteration, especially along the margins, to a brittle or often clayey crust and pink to crimson fluorescence in short-wave ultraviolet light.

In SWA/Namibia eucryptite has been noted in two occurrences - in the so-called "Petalite" pegmatite in the Strathmore Sn pegmatite area east of Cape Cross, and in some smaller pegmatites south of Brandberg. In

	1	2	3	4
SiO_2	78.36	77.30	56.35	52.65%
TiO_2	n.d.	n.d.	n.d.	n.d.
Al_2O_3	17.06	17.68	19.26	22.30%
Fe_2O_3	0.04	0.02	0.03	0.02%
FeO	-	-	-	-
MnO	n.d.	0.03	0.17	0.38%
M_sO	n.d.	tr.	3.03	2.76%
CaO	n.d.	tr.	2.06	2.19%
Nc_2O	0.07	0.09	0.33	0.25%
K_2O	0.06	0.18	0.24	0.12%
Li_2O	4.56	4.40	tr.	tr.
H_2O+	0.05	0.34	9.00	9.80%
H_2O-	0.05	0.26	9.59	9.72%
P_2O_5	n.d.	n.d.	n.d.	n.d.
	100.25	100.30	100.06	100.19%

Table 1: Chemical composition of petalite and its alteration product. Locality: Rubicon Mine on Okongava Ost 72.

1. White, clear petalite.
2. Pink petalite.
3. Montmorillonite (light pink).
4. Montmorillonite (dark pink).

Analyst: Erna Padget.

LOCALITY	Li_2O	Na_2O	K_2O	Fe_2O_3	MnO	F	
Petalite pegmatite, Strathmore near Cape Cross	4,03	1,56	0,25	0,03	0,08	0,02	%
Petalite pegmatite, south of Brandberg	4,15	0,68	0	0,03	0	0,01	%

Table 2: Chemical composition (partial analyses) of eurcryptite-quartz intergrowths.

both cases the eucryptite is nodular or concretionary in habit and porcellaneous in appearance. It is intimately intergrown with quartz, having apparently formed by replacement of petalite as follows: $LiAlSi_4O_{10} \rightarrow LiAlSiO_4 + 3\ SiO_2$.

Partial analyses of eucryptite are given in Table 2.

Lithian micas, pink to purple and occasionally grey to brown are a group of striking minerals typically associated with Li pegmatites, and in most cases they are also indicative of the complex group of these deposits. They commonly form separate core units and are intergrown with variable amounts of quartz and albite (cleavelandite).

The lithian mica occurrences are not only important for their Li, Rb and Cs contents but, being formed late in the crystallization sequence of pegmatites, they are highly fractionated and may contain a variety of enclosed accessory rare-element minerals, such as caesian beryl, cassiterite, hafnian zircon, a great variety of niobium- and particularly tantalum minerals, e.g. manganotantalite, varieties of microlite, simpsonite, stibio- and bismutotantalite, etc. Although there are numerous compositional and structural varieties of Li micas, chemically they are essentially similar to muscovite but due to Li-substitution their Al-content is lower and that of silicon higher. In addition, they are much richer in F and poorer in Fe than the pegmatitic muscovites. There is an apparent correlation between Li and F (see Table 2); moreover, the F-rich lithian micas are commonly associated with other F-bearing minerals such as topaz and fluorite, e.g. in pegmatites at Etiro 50, Okongava Ost 72, Okakaora 43, Okatjimukuju 55.

Manganese is responsible for the pink to purple colour of lithian micas - when the Fe content is minimal, Mn imparts a pink to purple colour to the lithian micas; with increasing Fe content, however, the micas turn grey or yellow and when both Fe and Mn are relatively high, the micas are usually brown.

The partial analyses of some micas shown in Table 3 were essentially done in order to study the relationship between the composition of the lithian micas and the rare-element mineralisation in the pegmatites - the results show that the Li and F-rich micas indicate in most cases a more varied and intense rare-element mineralization.

Members of the ***amblygonite-montebrasite series***, $LiAlPO_4$ (F,OH), are rather common minerals in most of the Li pegmatites in the present pegmatite field, and they are in many instances the only Li minerals to form in pegmatites. Their position in a pegmatite body is commonly within the quartz core or along the quartz core margin but often they are also found in the intermediate zone. At the Rubicon pegmatite on Okongava Ost 72, for instance, amblygonite occurs with petalite and lepidolite on each side of the quartz core.

Amblygonite, an important economic mineral of Li, is stable and rather resistant and may be used as an indicator mineral of Li pegmatites, especially in areas with intensive weathering. When amblygonite weathers, a protective crust is formed which impedes further weathering, and boulders of amblygonite are commonly found together with quartz float on the surface, indicating a Li pegmatite. The composition of amblygonite-montebrasite varies to some extent although the variations are rather small and the Li_2O-content is rather constant between 8 and 9 per cent (Table 4). The F content is generally from 5 to 7 per cent, indicating that the mineral is montebrasite rather than amblygonite (the name generally applied to the series) which has been observed only at Etiro pegmatite north of Karibib. There seems to be a substitution of Li for Na and Ca, but the Na-rich variety natromontebrasite has not been observed.

The mineral generally forms rounded nodules of varying size and occasionally larger aggregates up to a few tons may be found. The colour is mostly creamy white or grey but locally purplish varieties occur, indicating higher contents of F than at Etiro 50.

Apart from marginal alteration of amblygonite to various clay minerals, a number of replacements have been observed. Thus amblygonite-montebrasite may be partially replaced to apatite, crandallite, eosphorite, wavellite, triplite, lazulite, scorzalite, brazilianite and morinite, in addition to a number of other secondary phosphate minerals. Brazilianite has been observed at Okatjimukuju 55 and brazilianite, morinite and eosphorite have been noted on amblygonite from Etiro 50.

Members of the ***lithiophilite-triphylite series***, $Li(Mn,Fe)PO_4$, are commonly observed in Li pegmatites, and like amblygonite-montebrasite, they are usually confined to the quartz core unit, forming smaller or larger nodules or aggregates sometimes up to several tons in weight. Frequently they are of rusty appearance and smaller nodules may be completely altered to Mn and Fe oxides. In a number of cases, however, a large amount of colourful secondary phosphates is present and these constitute an intriguing research material for mineralogists who maintain a keen interest in pegmatite phosphates. In the lithiophilite from Rubicon on Okongava Ost 72, the following secondary minerals have been observed: heterosite, sicklerite, hureaulite, tavorite, barbosalite, frondelite, strengite, phosphosiderite, bermanite and stewartite.

	Li_2O	Na_2O	K_2O	Fe_2O_3	MnO	F	
1.	4.13	0.32	11.37	0.01	0.56	5.11 %	Rubicon Mine, Okongava Ost 72
2.	3.96	0.31	10.68	0.01	0.12	5.25 %	Rubicon Mine, Okongava Ost 72
3.	1.71	0.54	10.38	6.97	1.16	3.29 %	Rubicon Mine, Okongava Ost 72
4.	3.22	0.29	10.96	1.89	0.45	4.71 %	Helicon 2 pegm., Okongava Ost 72
5.	5.57	0.43	10.61	0.04	1.18	7.17 %	Microlite pegm., Okongava Ost 72
6.	3.78	0.49	10.87	0.04	0.51	5.16 %	Microlite pegm., Okongava Ost 72
7.	4.13	0.37	11.23	0.07	0.30	5.59 %	Purple mica, Okatjimukuju 55
8.	3.97	0.40	10.95	2.14	0.49	5.56 %	Grey mica, Okatjimukuju 55
9.	5.34	0.46	11.09	0.11	0.57	7.55 %	Cassiterite pegm., Okatjimukuju 55
10.	5.42	0.36	11.06	0.02	0.24	7.26 %	Microlite pegm., Okakoara 43
11.	4.76	0.38	10.93	0.07	0.41	6.30 %	Gem tourmaline pegm., Neuschwaben 73
12.	4.75	0.60	10.87	0.02	0.24	6.35 %	Petalite pegm., Daheim 106
13.	6.45	0.50	10.91	0.06	0.22	8.37 %	Microlite pegm., Okawayo 46
14.	6.20	0.42	11.10	0.03	1.57	8.12 %	Etiro 50
15.	6.98	0.51	11.04	0.05	1.51	8.44 %	Etiro 50
16.	6.06	0.40	10.77	0.22	1.74	8.32 %	Etiro 50
17.	6.18	0.34	11.11	0.16	1.63	8.37 %	Etiro 50
18.	6.04	0.35	10.91	0.15	1.62	8.07 %	Etiro 50
19.	4.41	0.35	10.66	4.83	2.10	6.86 %	Etiro 50
20.	4.33	0.22	10.86	0.11	0.27	5.84 %	Cassiterite pegm., Sandamap, 64, Damaraland
21.	3.50	0.50	10.62	0.03	0.23	4.54 %	Tantalite Valley, Umeis 110, Karasburg District
22.	2.15	0.46	10.99	0.19	1.42	3.20 %	Tantalite Valley, Umeis 110, Karasburg
23.	2.58	0.48	10.77	2.42	1.72	4.08 %	Tantalite Valley, Umeis 110, Karasburg
24.	0.48	0.31	11.08	4.96	0.77	1.05 %	Tantalite Valley, Umeis 110, Karasburg

Table 3: Chemical composition (partial analyses) of lithian micas from pegmatites in the Karibib District, Damaraland and the Karasburg District.

In the pegmatites of Okatjimukuju 55 numerous phosphates, mostly of secondary origin, have been identified, e.g. sicklerite, heterosite, triploidite, phosphoferrite, hureaulite, eosphorite, childrenite, vivianite, tavorite, barbosalite, frondelite, strengite, phosphosiderite, bermanite, jahnsite, stewardite, strunzite, mitridatite, zwieselite, apatite and collinsite.

2.2 Rubidium and Caesium Minerals

The bulk of the rare alkali elements Rb and Cs is generally camouflaged in the K minerals, e.g. orthoclase, microcline and in micas. The lithian micas, in particular, may have a substantial concentration of these elements. So far, there are no independent minerals known of Rb, and Cs forms only one -

Pollucite $(Na,Cs)Al_2Si_2O_6.H_2O$, a characteristic, although rather rare, constituent of complex Li pegmatites. It is often confined to the intermediate zone and particularly to the marginal parts of the quartz core. Pollucite is one of those unique minerals peculiar to pegmatites once a trace element, in this case Cs, is concentrated to such an extent that it forms a mineral of its own.

In the present pegmatite field only three pegmatites are known to contain pollucite, namely Helicon 1 and 2 and a highly fractionated Li pegmatite north of Rubicon mine, all within Okongava Ost 72. In all three occurrences pollucite is of nodular appearance, locally forming larger aggregates. It is grey to pinkish in colour, of glassy appearance, and has great similarity to quartz, although it is much heavier, having a specific gravity of around 2,9. When enclosed in quartz, it shows an alteration rim at the contacts and contains, in addition, numerous thin veinlets of grey to purplish lithian mica, which intersect the entire pollucite, forming parallel or mesh-like structures.

At Rubicon a highly altered bluish-green pollucite was seen - this mineral may correspond to the caesian analcime described by Černỳ (1982).

Pollucite may be altered to varying degrees - the alteration products being usually clay minerals or clay minerals and quartz. This alteration process, initiated during the late hydrothermal stage of crystallization and

	LiO_2	Na_2O	K_2O	CaO	Fe_2O_3	MnO	F	
Becker's pegmatite, Otjua 37	9,49	0,44	0,01	0,43	0,03	0,01	5,94	%
Rubicon Mine, Okongava Ost 72	9,15	0,40	0,12	-	-	-	6,22	%
Cement dam, Okongava Ost 72	9,54	0,17	0,13	1,41	0,15	0,43	6,36	%
Neuschwaben 73	7,53	1,18	0,02	3,49	0,08	0,04	4,78	%
Ptn. Ricksburg of Okakoara 43	8,77	1,47	0,15	0,36	0,23	0,09	6,80	%
Dernburg pegmatite, Karibib 54	9,00	9,90	0,25	-	-	-	5,34	%
Dobbelsberg 99	8,28	1,24	0,29	-	-	-	5,08	%
Etiro 50	9,26	0,88	0,02	0,11	0,11	0,01	7,77	%
Tantalite Valley, Umeis 110, Karasburg District	8,09	3,03	0,17	0,44	0,44	0,03	5,83	%

Table 4: Partial analyses of montebrasite - amblygonite series $LiAlPO_4(OH,F)$. All locations besides Tantalite Valley are in the Karibib District.

subsequently completed during weathering, may explain the apparent paucity of pollucite in many pegmatite occurrences.

2.3 Beryllium Minerals

Beryllium is one of the characteristic trace elements associated with granite pegmatites, and beryl is by far the commonest and economically the most important Be mineral. Among rare Be minerals found in African pegmatites are the following: chrysoberyl, bertrandite, bavenite, euclase, phenakite, milarite, helvine, genthelvine, beryllian margarite, bityite, rhodizite, hambergite, herderite, hurlbutite, moraesite and faheyite. Apart from chrysoberyl and bertrandite, which are relatively common, most of the other minerals are very rare and have only been recorded from a few localities.

In SWA/Namibia the following Be minerals apart from beryl are known to occur: chrysoberyl, bertrandite, bavenite, phenakite, milarite, herderite and moraesite. However, most Be minerals are difficult to recognize and may be easily overlooked. Apart from chrysoberyl many of the rarer Be minerals are of secondary origin formed by various alteration and replacement processes from primary beryl during a late hydrothermal stage of crystallisation.

Among the many varieties of ***beryl*** $Be_3A1_2Si_6O_{18}$, the greenish-grey to greenish-yellow or common beryl is found in almost all mineralised pegmatites and often in large quantities, whereas the glassy, coloured varieties are usually confined to Li pegmatites - chemically they are also distinct in that they contain significant amounts of water and alkalies, including Li, Na and frequently Cs. Within this group of glassy beryls, the important gem varieties are to be found e.g. the greenish-blue to blue aquamarine, pink morganite and the greenish-yellow heliodor. The zonal position of beryl within a pegmatite is variable but most commonly it is located at the quartz core margin together with microcline-perthite, albite (cleavelandite), muscovite, lepidolite or amblygonite. Occasionally large masses of beryl may be confined to the quartz core and there may be also specific zones or pockets of beryl in the intermediate units of the larger pegmatites. At times beryl is found in the border zone of Li pegmatites, e.g. Dernburg 3 pegmatite on Karibib 54, where small crystals of aquamarine occur in the contact zone with the surrounding quartzite.

Another form of beryl mineralization is its sporadic occurrence in some pegmatitic granites or migmatites, e.g. the pegmatitic granite on Okongava Ost 72.

In general, the typical beryl-bearing pegmatites vary to certain extent in their internal structure and composition but most have prominent quartz cores, distinct zoning and well developed Li and/or Na phases.

The following is an analysis of a pink alkali beryl from the Etiro Mine on Etiro 50:

Li_2O	Na_2O	K_2O ppm	Rb_2O ppm	Cs_2O	Fe_2O_3 ppm	MnO	H_2O+	H_2O-	F ppm
0,69	0,79	200	424	1,59	5	40	1,47	0,02	<20%

Chrysoberyl, $BeAl_2O_4$, has been observed in considerable amounts in a non-Li pegmatite in the Kuduberge on Neuschwaben 73, where it is associated with bluish (aquamarine) beryl. This black tourmaline rich pegmatite has a distinct quartz core which is partly rose-coloured, and an intermediate zone with large amounts of microcline, some muscovite and quartz. Larger beryl crystals are found in the quartz core, whereas aggregates of chrysoberyl and beryl are confined to the intermediate zone. This particular pegmatite cuts across a basic rock, which may explain the formation and stability of chrysoberyl in this environment.

Phenakite, $BeSiO_4$, and ***bertrandite***, $Be_4Si_2O_7(OH)_2$, are known from the Spitzkoppe pocket pegmatites and phenakite has also been observed in the Nainais Tin pegmatites. Bertrandite is a common breakdown product of primary beryl and has been noted in a number of localities, occasionally together with phenakite.

Milarite, $K_2Ca_4Al_2Be_4Si_{24}O_{60}.H_2O$, is one of the rarer Be minerals, first discovered as a fissure mineral in the Swiss Alps. In recent years it has been recorded from pegmatites in Bohemia and from a number of localities in the USSR. In SWA/Namibia, milarite occurs in an amazonite-bearing pegmatite near Rössing Mountains. The mineral is found in well-developed, greenish-yellow hexagonal prisms with terminations. The largest crystals are up to 2.5 cm long and 0.5 cm across and many are of gem quality. A chemical analysis gave:

SiO_2	GeO	Al_2O_3	MnO	MgO	CaO	Na_2O	K_2O	H_2O+	$H_2O¬$	
72,17	5,87	3,37	0,15	trace	11,2	0,51	5,1	1,38	0,02	%

Among secondary beryllium minerals ***herderite***, $CaBe(PO_4)(OH,F)$, has been noted as an alteration product of beryl in a pegmatite south of Rubicon, on Okongava Ost 55. It occurs as small spheroidal aggregates in cavities of partly altered beryl.

Outside the present pegmatite field at Tantalite Valley, south of Warm bad, the rare, secondary beryllium minerals ***bavenite*** $Ca_4Be_2Al_2Si_9O_{26}(OH)_2$ and ***moraesite*** $Be_2(PO_4(OH).4H_2O$ have been found as fracture fillings in the lithian mica unit of a pegmatite.

2.4 Tin Minerals

Pegmatitic Sn occurrences are widespread on the African continent, especially south of the equator along the Kibaran orogenic belt extending from Uganda through Rwanda and the Kivu province of Zaire. Moreover, Sn is ubiquitous in the gigantic spodumene pegmatites at Manono in the Shaba province of Zaire and at Kamativi in Zimbabwe.

In the present pegmatitic field Sn is of great importance and a large number of pegmatites have been mined exclusively for cassiterite in the past. In most cases Sn is associated with mineralized pegmatites and, although it is not always apparent, the majority of the Sn bearing pegmatites show a characteristic Li-Na-F phase of mineralization. Within the present pegmatite field the Sn-bearing pegmatites can be tentatively grouped as follows:

scattered Sn pegmatites in the Karibib area;

numerous Sn pegmatites in the neighbourhood of the Erongo complex;

a large concentration of Sn pegmatites in the Brandberg

- Cape Cross area.

An isolated Sn occurrence situated at Trekkopje is connected with sulphide-bearing hydrothermal quartz veins, and does not seem to be of pegmatitic origin.

Tin is a typical element of late magmatic differentiation, and tetravalent Sn with ionic radius 0.71 a can readily substitute for a number of elements and in the granitic rocks, in particular, Sn may be accommodated in the structures of micas, amphiboles, garnets, sphene and other accessory minerals.

Cassiterite, SnO_2, is by far the most common mineral of Sn. It is heavy and extremely resistant to weathering, and the bulk of the world's tin is mined from alluvial deposits in SE-Asia.

Occasionally, cassiterite is found as an accessory in certain mineralized alkali granitic rocks e.g. in Niger, Nigeria, Egypt and Uganda, but more often it occurs in pegmatites with some Li mineralization and in micaceous quartz veins (greisens), some of them of pegmatitic character.

In pegmatites, Sn is commonly associated with typical pegmatitic lithopile elements, e.g. Li, Be, B, Nb and Ta, but according to its position in the periodic system, Sn is also chalcophile in character and may be found in hydrothermal sulphide ore deposits forming a number of rare independent sulphide minerals or is incorporated in other more common sulphides.

Occasionally, minerals of the stannite group, ***stannite***, Cu_2FeSnS_4, ***kesterite***, Cu_2ZnSnS_4, and ***černýite***, Cu_2CdSnS_4, may be formed in Sn-bearing pegmatites when the amount of S is sufficiently high and Cu, Zn and Cd are present. Although cassiterite is often regarded as a relatively pure mineral, corresponding to the chemical formula SnO_2, earlier spectrographic and recent microprobe analyses have shown that cassiterite can accommodate a variety of elements e.g. Ti, Mn, Fe, Nb, Ta and W in trace and minor amounts in its structure. Frequently exsolutions of columbite-tantalite, microlite and tapiolite are also seen in the cassiterite grains of these minor elements. Ta may be present in considerable amounts and is often recovered from the tin slags.

Cassiterite from four occurrences in the present pegmatite field has been analysed by microprobe and the results are shown in Table 5.

The Ta content of the cassiterite from a small Li pegmatite at Okatjimukuju 55, (Table 5, analysis 1), is particularly high and it appears as if most of the Ta present has been incorporated in the cassiterite, since no other Ta minerals apart from trace amounts of microlite were observed in this particular pegmatite. More often, however, the reverse is true, in that the Nb-Ta minerals incorporate Sn in their structures as indicated by another adjacent pegmatite in the area, where only the high Sn bearing Ta minerals wodginite was noted.

No inclusions or exsolution phases of Ta minerals could be detected in the Karibib specimens; in the cassiterites from Sandamap and Uis, however, minute columbite inclusions (20-50 μ across) with an approximate composition of 50 per cent Nb_2O_5, 32 per cent Ta_2O_5 and 15 per cent FeO, were seen.

3. REFERENCES

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	1		2			3			4			
SnO_2	92.72	93.98	96.49	98.29	94.04	95.77	98.51	94.89	96.27	92.82	95.04	%
TiO_2	0.04	0.02	0.29	0.07	-	0.21	0.05	0.14	-	-	0.01	%
MnO	n.d.	n.d.	0.13	0.03	0.09	-	0.03	-	0.02	0.12	0.05	%
FeO	0.26	0.22	0.39	0.03	0.63	0.63	0.06	0.85	0.37	0.74	0.46	%
Nb_2O_5	0.44	0.29	1.47	-	2.06	2.17	0.38	2.11	1.91	2.26	2.04	%
Ta_2O_5	6.44	4.99	1.32	1.33	2.10	1.89	0.56	2.19	1.04	3.36	1.65	%
WO_3	0.00	0.00	0.20	0.55	0.94	-	-	-	0.28	0.01	0.20	%
	99.90	99.50	100.29	100.30	99.86	100.67	99.59	100.18	99.89	99.31	99.45	%

1. Cassiterite from lepidolite mica, rich in topaz, Okatjimukuju 55, Karibib District
2. Cassiterite from a muscovite greisen, Sandamap 64, Damaraland
3. Cassiterite from a micaceous unit, Uis Tin Mine, Damaraland
4. Cassiterite from micaceous unit K 5, Uis Tin Mine, Damaraland

Table 5: Microprobe analyses of cassiterites from Okatjimukuju, Sanda map and Uis.