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BLUE ASBESTOS FROM LUSAKA, NORTHERN RHODESIA, AND ITS BEARING ON THE GENESIS AND CLASSIFICATION OF THIS TYPE OF ASBESTOS*

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Abstract

An occurrence of blue asbestos near Lusaka was investigated and proved to consist of an anastomosing stockwork of predominantly slip-fiber veins in a semi-calcareous host rock. The host rock is probably lenticular and occurs in a strongly deformed dolomite formation. Chemical analysis of the asbestos shows that it is magnesioriebeckite according to the classification of Miyashiro (1957); the geological evidence strongly suggests that it is of metasomatic origin. A similar occurrence has been described from Bolivia (Ahlfeld 1943), and both are in strong contrast to the normal South African and Australian occurrences, where the asbestos is of riebeckite composition and probably of purely metamorphic origin. The name crocidolite has been widely used to describe blue asbestos, but as it applies only to fibrous varieties of riebeckite and magnesioriebeckite, it should not be applied as a mineral name.

Introduction

Blue asbestos was discovered four and a half miles south-west of Lusaka during the excavation of several shallow pits. The occurrence was investigated by trenching and augering as there were no surface outcrops. The water-table lies within a few inches of the surface and consequently the whole exposure including the asbestos had a very weathered appearance.

Field Relations

The predominant rock-type of the area is a creamy, dolomitic limestone striking east-west and dipping vertically. One hundred yards from the asbestos occurrence, thin-bedded dolomite is seen to be tightly folded, and some of the more competent bands display boudinage structure. The strike of the axial planes of the folds is 70° east of north and the pitch steeply westwards. This single exposure displays the only indications of structure in the immediate vicinity.

The host rock of the asbestos appears to be a lenticular body enclosed in Lusaka Dolomite, as it is not traceable along strike for more than approximately 100 yards. Within this lenticle, the asbestos occurs as an anastomosing complex of veins forming an irregular stockwork. There is no tendency for these veins to be parallel to each other or to the bedding, as in South African and Australian occurrences. The seams average half

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an inch in thickness and are usually separated by three to four inches of country rock. The fibers are commonly parallel to the walls of the vein, i.e. slip-fiber, and vary greatly in length. Examples up to two inches are common, particularly where two or more veins coalesce, but the bulk of the fiber is less than half an inch long. Some small veinlets are of cross-fiber type. Persistent veinlets of quartz, talc and calcite are common in the host rock and the dolomite.

Petrology of the Country Rocks

The rock adjacent to the asbestos-bearing body is a very weathered, brownish, coarse-grained dolomite with porphyroblasts of albite and dolomite. The latter are characterized by a brownish outer zone clouded with dust-like inclusions, and the former are conspicuous in hand specimen as irregular white crystals. The matrix of the rock consists of fine-grained calcite with occasional quartz grains, some of which are rounded and appear detrital, while others are idioblastic or grouped together interstitially.

The host rock of the asbestos veins is a very altered, fine-grained sediment. Fragments of this rock, seen adhering to the asbestos in thin sections, contain carbonate, highly altered mica, tourmaline, albite, and occasional irregular sections of blue amphibole. A heavy mineral separation contained a high proportion of tourmaline, apatite, monazite and blue amphibole together with red-brown rutile, yellow-green epidote, kyanite and iron oxides. The tourmaline is present in three different forms: (a) predominantly as stubby, reddish-brown crystals exhibiting strong pleochroism, (b) an uncommon olive-green type, and (c) a rare, colorless or pale-yellow variety. The cleavage flakes of blue amphibole, which are length-fast, exhibit almost straight extinction (0° to 3°); i.e. $X = c$. Pleochroism is from blue parallel to X, to violet. These properties are similar to those of riebeckite. The abundant prismatic crystals of apatite are an important constituent. Some are markedly elongated but the larger ones are stouter and contain many minute inclusions, including tourmaline. Monazite occurs as irregular, occasionally euhedral crystals, sometimes showing pleochroism in shades of yellow.

The host rock as seen elsewhere in the trenches is micaceous in some parts and tourmaline-rich in others. The micaceous rock was identified in thin section as a medium-grained quartz-biotite-schist showing obvious signs of metasomatism, including porphyroblasts of irregular, clouded and zoned albite crystals with many inclusions, and the presence of strongly pleochroic (reddish-brown to black) subhedral tourmaline crystals up to 1.2 mm. long. The tourmaline-rich rock consists of corroded grains of quartz and irregular albite porphyroblasts both containing tourmaline crystals, the presence of which suggests that the boron metasomatism preceded the introduction of soda. The matrix consists almost exclusively of minute, granular, brown tourmaline crystals.

MINERALOGY OF THE ASBESTOS

South African crocidolite is generally accepted as an asbestiform variety of the soda-amphibole riebeckite with the formula $Na_2Fe_2'''Fe_3''Si_8O_{22}(OH)_2$ but, as in the riebeckite-glaucophane series, Mg can proxy for Fe'' and Al for Fe''', the two substitutions being independent of one another.

TABLE I. ANALYSES OF CROCIDOLITE

	1	2	3	4	5	6A	6B	7A	7B
SiO_2	51.86%	50.50%	51.94%	59.40%	51.58%	54.68%	55.16%	56.10%	55.38%
Al_2O_3	0.03	—	0.20	—	—	3.90	3.10	4.51	3.87
Fe_2O_3	20.26	20.20	18.64	14.40	16.90	13.98	14.02	13.67	15.69
FeO	14.84	15.40	19.39	15.10	21.22	7.40	7.93	1.77*	1.19*
MnO	0.01	—	—	—	—	0.21	0.09	0.02	0.02
MgO	3.26	3.65	1.37	3.40	0.15	12.25	11.78	10.40	12.11
CaO	0.49	0.80	0.19	0.55	—	1.27	0.98	0.48	0.57
Na_2O	6.12	4.40	6.07	4.05	6.33	5.55	5.92	4.95	5.58
K_2O	0.28	—	0.04	—	—	0.46	0.60	0.23	0.27
H_2O^+	1.97	4.15	2.58	3.25	3.79	0.72	1.07	5.18†	3.61
H_2O-	0.68	1.05	0.31	0.10				2.74	1.84
TiO_2	0.03	—	—	—	—	—	—	0.29	0.14
CO_2	0.02	—	—	—	—	—	—	0.08	0.05
P_2O_5	0.05	—	—	—	—	—	—	0.07	0.07
	99.90	100.15	100.73	100.25	99.97	100.42	100.65	100.49	100.39

* The low ferrous iron percentages are probably the result of oxidation of the asbestos.

† Calculated from loss on ignition. (Tests on the two Lusaka samples showed that no fluorine was present.)

1. Mount Margaret, Western Australia. Analyst, J. N. Grace. (Finucane 1939)
2. Kunuman, Bechuanaland. Analyst, J. Macrae. (Finucane 1939)
3. Kliphuis, North-West Cape. Analyst, H. E. Vasser. (Hall 1930)
4. Pietersburg Asbestos Ltd. East of Malips River, Transvaal. Analyst, Govt. Lab. Jo'burg. (Hall 1930)
5. Average of two samples, Cumberland, Rhode Island, U.S.A. Analyst, Chester. (Peacock 1928)

6A. Philadelphia Mine, Cristalmayu, Bolivia. (coarse fiber). Analyst, W. Brendler. (Ahlfeld 1943)
6B. Philadelphia Mine, Cristalmayu, Bolivia. (fine fiber). Analyst, W. Brendler. (Ahlfeld 1943)
7A. Lusaka, Northern Rhodesia. Analyst, E. W. Fowler } Independent analyses on separate samples
7B. Lusaka, Northern Rhodesia. Analyst, W. Hesom

Analyses of typical examples of crocidolite from various localities are given in Table I, together with two independent analyses of different samples from Lusaka. The first five analyses have much in common, and contrast strongly with the Bolivian and Lusaka examples, which are far richer in Al_2O_3 and MgO. Although the Bolivian and Lusaka examples are broadly similar, they differ in that the former is richer in FeO and CaO. The marked differences between the analyses of the two Lusaka samples, especially when they are recalculated as atomic proportions, indicate that the samples are not completely unweathered. It would appear that the ferrous iron content has been to a large extent oxidized, probably by circulating ground-water. According to the classification of Miyashiro (1957), the South African, Australian and American examples are of riebeckite composition, whereas the Bolivian and Lusaka examples fall within the magnesioriebeckite field. The name crocidolite has been applied to all the varieties of blue asbestos as a term descriptive of habit, distinguishing the fibrous varieties of riebeckite and magnesioriebeckite. It is therefore not a true mineral name.

The Lusaka asbestos is a pale, powder-blue, fluffy variety, soft and silky to the touch. At the deepest part of the excavations, the fiber is deeper blue in color and harsher in texture. Red iron-staining occurs in places. In thin section, it is seen as bundles of fibers, usually orientated sub-parallel to the vein. Pleochroism is from blue-gray parallel to the length of the fibers, to pale-violet perpendicular thereto. The fibers are length-fast and since they are probably elongated parallel to *c*, it is likely that $X=c$. The asbestos fibers penetrate albite porphyroblasts.

GENESIS AND COMPARISON WITH OTHER OCCURRENCES

From the foregoing description, it is evident that the fiber occurs in a metasomatized and metamorphosed semicalcareous horizon within the Lusaka Dolomite. It is probable that any competent horizon within this dolomite will display boudinage structures as a result of intense folding. Thus, from the exposures available, the host-rock of the asbestos could be regarded as a vertically orientated lens and might well be one of a series of such lenses aligned along an east-west strike.

The origin of South African crocidolite is discussed by Peacock (1928), Hall (1930) and Du Toit (1945), and the remarkably similar Australian examples by Finucane (1939) and Miles (1942). At all the localities, the crocidolite is present as cross-fiber veins parallel to the bedding of thin-bedded ironstone associated with dolomite. The South African crocidolite is of remarkably similar composition to the ironstone, the former being richer only in Na and Mg. The fiber is believed to have formed from constituents already present in the ironstone during a prolonged period of metamorphism caused by burial at depth. Both Peacock (1928) and Hall (1930) favor the possibility that the soda was originally uniformly distributed throughout the ironstone, and was subsequently concentrated in certain bands. Du Toit (1945) has suggested that the MgO has behaved in a similar manner. There is no evidence in any of the South African or Australian occurrences to suggest that a basic magma is in any way essential for the formation of crocidolite. "Crocidolization is conceived as a mild, static, non-additive metamorphic process, resulting in the chemical union, along soda-rich bedding planes of the necessary constituents *in situ*" (Peacock 1928, p. 283).

The Lusaka occurrence differs from the characteristic South African and Australian examples in several respects and the above hypothesis cannot be directly applied. The veins of fiber form an irregular stockwork—thus, their distribution cannot be controlled by pre-existing soda-rich horizons; rather, the soda would appear to have been introduced metasomatically, the veins marking the paths of migrating soda-rich solutions. The nearby dolomite may have been the source of any MgO required for the formation of the fiber but the presence of the talc veinlets could indicate that MgO was also introduced. The occurrence of abundant albite porphyroblasts in the host rock and the dolomite is strong evidence supporting the hypothesis of soda metasomatism, and the presence of large amounts of tourmaline (up to 50% of the rock) proves that some metasomatic process was operative. From the evidence of thin sections, it would appear that tourmaline was the first metasomatic mineral to form and was followed by albite and magnesioriebeckite. The last two minerals are probably genetically associated, but the significance of the tourmaline, monazite and apatite, representing phases of boron and phosphate metasomatism, remains an enigma.

It is interesting to note that recent experiments have shown that both tourmaline (Frondel and Collette 1957) and monazite (Anthony 1957) can be synthesized at comparatively low temperatures and high water vapor pressures, and that tourmaline fails to form in the presence of alkali-rich minerals including glaucophane. This evidence supports the hypothesis that the boron metasomatism preceded the formation of albite and magnesioriebeckite. Again, there is no evidence that basic magma is essential for the formation of blue asbestos, although the source of the introduced material is a matter for speculation. The presence of tourmaline, apatite, and monazite could be taken as an indication that a magma of acid rather than basic affinities was involved, but this assumes that all the metasomatic processes were genetically associated. Another striking difference is that the Lusaka example consists predominantly of slip-fiber, whereas the South African and Australian deposits are characterized by well developed cross-fiber structure. Hall (1930) suggests that slip-fiber occurs where differential movement has taken place, but as there is no evidence of shearing in the Lusaka exposures, it can only be assumed that the conditions under which the fiber formed were different from those which operated elsewhere. That is, metasomatic instead of a metamorphic environment in some way inhibited an exclusive development of cross-fiber.

Of all the deposits of blue asbestos, the only other example which

TABLE II. COMPARISON BETWEEN METAMORPHIC AND METASOMATIC BLUE ASBESTOS

	Metamorphic type	*Metasomatic type*
Typical occurrences	S. Africa and Australia	Bolivia and N. Rhodesia
Form of deposit	Veins parallel to bedding	Stockwork
Typical composition	Riebeckite	Magnesioriebeckite
Predominant fiber	Cross-fiber	Slip-fiber
Tensile strength	Medium to high	Low
Color	Blue	Pale-blue
Associated minerals	—	Metasomatic minerals—e.g., talc and tourmaline
Country-rock	Ironstone and dolomite	Variable

bears any marked resemblance to that of Lusaka occurs in Bolivia. This occurrence, described in detail by Ahlfeld (1943) and summarized by Ahlfeld and Reyes (1955), is more extensive than that of Lusaka but shows the following points of similarity:

1. The asbestos occurs as a stockwork of veins following irregular fracture planes and bedding planes.
2. It is predominantly slip-fiber.
3. It is of magnesioriebeckite composition and pale-blue in color.
4. It has a low tensile strength.
   (Frankel (1953) has suggested that both the color and the tensile strength of blue asbestos vary with the ferrous iron content, which is low in both the Lusaka and Bolivian occurrences.)
5. Associated minerals include quartz, talc and pyrite, and a nearby horizon of dolomite contains various borosilicates including tourmaline and danburite.
6. The fiber is believed to have formed during a period of dynamometamorphism associated with the metasomatic introduction of Ca, Mg, Fe, and Na.

The main difference between the two areas is in regard to host rocks, those of Bolivia being slate and sandstone, and those at Lusaka being semicalcareous; since the asbestos seems to be of metasomatic origin this is of no great significance. Otherwise, these two deposits are similar in all major respects, and contrast strongly with the South African and Australian type of occurrence, as shown in Table II.

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