

other bats the secretions produced by the follicle cells escape out of the cells and accumulate in the antral cavity so that the great increase in the size of the follicle is due to the enlargement of the antrum. Apparently, the unique histological changes resulting in the hypertrophy of the cumulus cells is a feature characteristic of some of the vespertilionids amongst the bats irrespective of their geographical location and irrespective of whether they undergo a protracted post-copulatory hibernation or not. The Graafian follicles of bats belonging to no other family have been so far shown to

exhibit these modifications of the cells of the discus proligerus.

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MINERALOGY AND CHEMISTRY OF ASBESTOS FROM HOLENARASIPUR SCHIST BELT : MANGALAPUR AREA

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ABSTRACT

Asbestos from the Mangalapur area of Holenarasipur Schist belt has been identified as anthophyllite contrary to the earlier report as tremolite. The serpentines in this area are 6-layer orthoantigorites and the chlorites are 14 Å, 11b polytypes of variable Si/Al ratios. The anthophyllite is derived from the alteration of antigorite, chlorite and talc by the hydrothermal metamorphism of the ultrabasic intrusives.

ASBESTOS, a mineral of wide variety of uses, is found widely scattered in different parts of the Precambrian of Mysore. The difficulty in identifying the types of asbestos has led to erroneous conclusions regarding its geology and genesis. Since the physicochemical methods are the only means by which the asbestos minerals can be identified conclusively, the present series of investigations have been taken up. Amphibole asbestos forms the major exploitable variety in the State. One of the major workable deposits of asbestos is confined to Holenarasipur schist belt, south of 13° latitude and west of 76° 20' E longitude. The asbestos from this area have been differently identified as tremolite-actinolite, anthophyllite and chrysotile. A systematic study of asbestos and the coexisting minerals from the southern limb of the Y-shaped schist belt, south of the river Hemavathi is undertaken. The present report is confined to Mangalapur area, north of the old Holenarasipur-Channarayapatna road and south of the river Hemavathi.

The geology of Holenarasipur schist belt has been repeatedly studied by many in the past¹⁻⁵. The principal rock types are: the metamorphosed ultramafites, kyanite-staurolite schists and hornblende schists. The occurrence of asbestos is confined to the altered ultramafites. The veins in dis-

connected lenses with a general N-S trend occur in them within a span of 30 miles.

In Mangalapur region asbestos are of varying habits, fine as well as massive fibres of differing length (a few inches to 6 feet), varying in colour (grey, brown and white) and also in strength. The massive woody type and its host rock are associated with the asbestos. The minerals coexisting with asbestos are: carbonates such as dolomite, calcite and magnesite; chlorites of flaky, coarse and massive habits; serpentines with magnetite grains. The chlorites are contiguous with the serpentinites and is abundant towards the kyanite-staurolite schists. The asbestos bearing horizons are confined to the vicinity of serpentinite bodies in the field. The lithological features of the schist belt suggest that subsequent to the ultramafic intrusion into the pelitic sediments, the terrain has been subjected to dynamic metamorphism and deformation.

MINERALOGY OF THE ASBESTOS

The chemical analysis of a number of asbestos samples from Mangalapur area showed that they are all anthophyllites as against the reported occurrence of tremolite asbestos^{3,4}. Mountain wood and its host rock are also found to be anthophyllites. The typical analyses of asbestos, mountain wood and its host rock are given in

Table I. The X-ray data show that all the three are orthorhombic confirming the above conclusion.

TABLE I
Chemical composition of asbestos

	Fibrous asbestos	Mountain wood	Massive Anthophyllite
SiO ₂	55.09	58.15	57.20
TiO ₂	0.00	0.00	0.00
Al ₂ O ₃	2.07	2.27	1.32
Fe ₂ O ₃	3.19	6.52	0.61
FeO	13.68	6.41	17.03
MnO	0.19	0.21	0.11
MgO	21.62	21.55	20.79
CaO	0.93	2.22	0.45
Na ₂ O	0.15	0.20	0.12
K ₂ O	0.21	0.00	0.01
H ₂ O ⁺	2.43	2.85	2.35
H ₂ O ⁻	0.34	0.16	0.16
CO ₂	0.21	0.00	0.00
TOTAL	100.11	100.54	100.15
a (Å)	18.53	18.48	18.54
b (Å)	17.98	18.09	17.98
c (Å)	5.31	5.30	5.33
β	90°	90°	90°

Number of ions on the basis of 24(O) atoms

Si	7.785	8.000	7.863	8.000	7.996	8.000
Al	0.215		0.137		0.004	
Al	0.130	6.907	0.224	6.315	0.213	6.715
Ti	0.000		0.000		0.000	
Fe ³⁺	0.343	6.907	0.661	6.315	0.064	6.715
Mg	4.556		4.330		4.332	
Fe ²⁺	1.618	6.907	0.723	6.315	1.991	6.715
Mn	0.023		0.024		0.013	
Na	0.028	6.907	0.052	6.315	0.033	6.715
K	0.058		0.000		0.002	
Ca	0.141	6.907	0.321	6.315	0.067	6.715
(OH)	2.296		2.565		2.193	

The serpentinite boulders occurring close to one of the asbestos pits have been examined. The minerals of the serpentinite have been identified by the optical methods (Fig. 1). The minerals

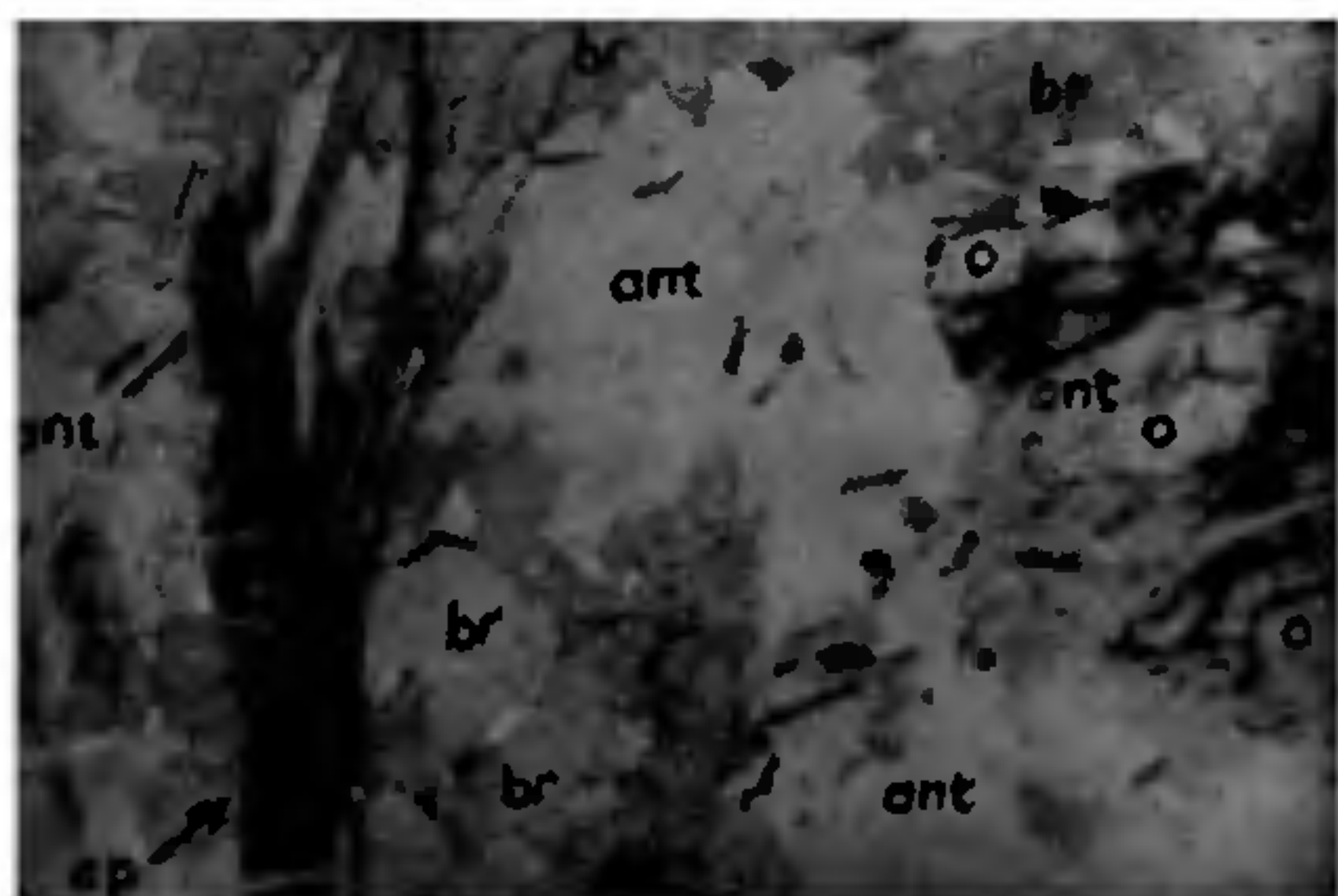


FIG. 1. Serpentinite. ant—antigorite, an—anthophyllite, br—breunnerite, O—Olivine with streaks of magnetite surrounding.

are antigorite, anthophyllite, magnesite, magnetite and relict olivine. The minerals have been separated using magnetic and gravity methods. The analytical data are given in Table II. In the antigorite, there is considerable substitution of Mg by Fe²⁺. The X-ray powder diffraction data given in Table IV show that this is a 6-layer orthoserpentine. All the observed reflections could be indexed as per data furnished by Gillery⁶. In the magnesite also there is substitution of Mg by Fe²⁺ suggesting that it is breunnerite. The substitution is true even in the dolomite (4% by wt. of FeO) occurring separately associated with anthophyllites. The coexistence of anthophyllite with the antigorite and magnesite is very characteristic in this area.

TABLE II

Chemical composition of serpentinite minerals

	Anti-gorite	Breun-nerite	Antho-phyllite	
SiO ₂	41.65	..	54.58	
TiO ₂	0.00	..	0.00	
Al ₂ O ₃	3.80	..	2.53	
Fe ₂ O ₃	0.61	0.00	0.47	
FeO	8.32	9.73	14.76	
MnO	0.08	0.09	0.03	
MgO	33.88	40.15	24.69	
CaO	0.17	0.26	0.56	
Na ₂ O	0.02	0.00	0.18	
K ₂ O	0.01	0.00	0.07	
H ₂ O ⁺	10.98	0.08	1.97	
H ₂ O ⁻	0.32	..	0.08	
CO ₂	0.39	49.82	0.00	
TOTAL	100.18	100.13	99.92	
No. of ions	9(0)	6(0)	24(0)	
atoms		atoms	atoms	
Si	2.025	2.025	7.672	8.000
Al	
Al	0.218	3.051	..	7.020
Ti	0.000		..	
Fe ³⁺	0.022	3.051	0.000	7.020
Fe ²⁺	0.339		0.239	
Mn	0.003	3.051	0.002	7.020
Mg	2.459		1.759	
Ca	0.009	3.051	0.008	7.020
Na	0.002		0.000	
K	0.001	3.051	0.000	7.020
(OH)	1.785		..	
CO ₂	..	1.997

The cell dimensions for the anthophyllite are: a=18.52 Å; b=17.98 Å; c=5.33 Å; β=90°

The chlorites are of variable chemical composition of differing Si/Al ratios. Analyses show that

TABLE III
Chemical composition of chlorites

	Chlorite (Ripidolite)	Talc-chlorite
SiO ₂	26.71	39.20
TiO ₂	0.00	0.00
Al ₂ O ₃	21.85	9.31
Fe ₂ O ₃	0.08	0.00
FeO	14.76	5.75
MnO	0.03	0.04
MgO	24.30	34.27
CaO	0.00	0.28
Na ₂ O	0.08	0.02
K ₂ O	0.01	0.00
H ₂ O ⁺	12.09	11.19
H ₂ O ⁻	0.12	0.00
CO ₂	0.00	00.00
TOTAL	100.03	100.06

Number of ions on the basis of 36 (0) atoms

Si	5.308	} 8.000	7.501	} 8.000
Al	2.692		0.499	
Al	2.422	} 12.110	1.598	} 12.355
Ti	0.000		0.000	
Fe ₃ ⁺	0.012		0.000	
Fe ₂ ⁺	2.451		0.920	
Mn	0.005		0.006	
Mg	7.188		9.763	
Ca	0.000		0.058	
Na	0.031		0.005	
K	0.001		0.000	
(OH)	16.03		14.31	

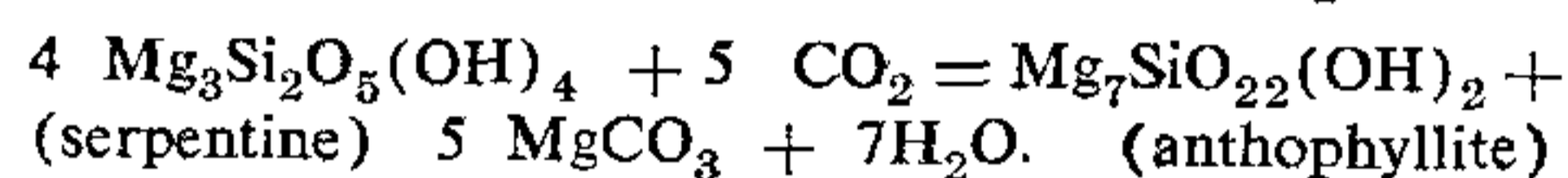
the composition vary from ripidolite-heridanite to talc-chlorite. The data for the two extreme members are presented in Table III. The X-ray data (Table IV) of clinocllore composition show that it is 14Å, II b polytype^{7,10} suggesting that they are not low temperature alteration products. The talc-chlorite (Table III) occurs as nodules within the asbestos veins. Their mode of occurrence strongly suggest that they are the relicts of a reaction that gave rise to anthophyllite asbestos. It may also be mentioned that occasionally talc occurs with dolomite-anthophyllite pair.

GEOCHEMISTRY AND GENESIS

The genesis of asbestos is closely connected with the hydrothermal metamorphism of the ultramafites in the Holenarasipur schist belt. In the normal course, metamorphism of ultramafites gives rise

to serpentines of which chrysotile is one of the polymorphs. In the present instance, instead of chrysotile the anthophyllite asbestos happens to be the final reaction product. This suggests that a separate sequence of reaction must have taken place in this area.

Based on the available experimental data on the stability relations of minerals and hydrothermal synthesis of anthophyllite^{8,9}, the absence of orthopyroxene (particularly enstatite) and cordierites from the host rocks of asbestos and based on the coexisting minerals with the anthophyllites, we postulate the possible sequence of reactions. After the intrusion of ultramafites into the pelitic sediments, the central portion of the intrusive transformed into serpentinite with added water. The peripheral portions, on the other hand, reacted with the alumina rich sediments leading to the formation of chlorites in presence of water. Chlorites of such an origin can have varying Si/Al ratio. The serpentines and the chlorites thus formed underwent a second set of reactions under hydrothermal conditions. The total pressure for such a reaction is built up both by P_{H₂O} and P_{CO₂}, with P_{H₂O} being smaller which is more conducive for the formation of anthophyllite⁸. The serpentine underwent the following reaction in presence of CO₂:



giving rise to anthophyllite and magnesite. Because of the iron-rich conditions in the area, substitution of Mg by Fe²⁺ took place.

The other set of reaction leading to the formation of anthophyllite and talc is by the breakdown of alumina poor chlorites which are known to be unstable under the hydrothermal conditions. The nuclei for the anthophyllite crystallisation are provided by the reaction given above. It is also known that talc can give rise to anthophyllite^{8,9}.

The experimental data show that anthophyllites are formed under restricted P-T conditions (P = 500 to 2000 bars; T = 550 to 760°C) with narrow stability range⁸. The 14 Å chlorites, particularly the II b polytype are stable under the above P-T conditions. This suggests that anthophyllites of variable habits occurring as disconnected lenses replacing the ultramafites, have been derived from the alteration of antigorite, chlorite and talc formed during hydrothermal metamorphism. The deformational features of the rock types also suggest the role of shearing stress in the formation of anthophyllite asbestos.

TABLE IV

X-ray powder diffraction data of antigorite and clinochlore

Antigorite			Clinochlore		
d (Å)	Intensity	hkl	d (Å)	Intensity	hkl
7.08	>100	006	14.09	75	001
4.61	3	020	7.06	100	002
3.86	3	026	4.718	65	003
3.554	>100	0,0,12	3.536	100	004
3.300	5	029	2.825	40	005
3.124	8	0,2,10	2.584	45	20 $\bar{2}$
3.047	10	0,0,14	2.537	80	201
2.647	10	200	2.438	65	20 $\bar{3}$
2.523	70	205	2.376	40	202
2.439	5	207	2.252	35	20 $\bar{4}$
2.399	10	208	2.057	20	20 $\bar{5}$
2.256	3	2,0,10	1.998	50	204
2.207	3	2,0,12	1.876	25	20 $\bar{6}$
2.016	50	2,0,14	1.819	30	205
1.878	5	2,0,16	1.657	15	206
1.775	10	0,0,25	1.562	40	20 $\bar{8}$
1.726	15	310	1.540	50	060
1.704	20	2,0,20	1.502	25	062
1.570	10	2,0,22	1.414	15	0,0,10
1.541	20	060	1.392	35	208
1.525	8	0,0,28	1.208	10	0,4,10
1.502	10	066	1.180	25	0,0,12
1.472	8	068			
1.421	5	0,0,30			
1.322	20	400			
1.290	3	0,6,18			
1.254	5	0,0,34			

$a = 5.29 \text{ \AA}$; $b = 9.25 \text{ \AA}$; $c = 42.66 \text{ \AA}$; $\beta = 90^\circ$
 $D = 2.634$.

$a = 5.32 \text{ \AA}$; $b = 9.24 \text{ \AA}$; $c = 14.27 \text{ \AA}$; $\beta = 97^\circ$;
 $c \sin \beta = 14.06 \text{ \AA}$; $D = 2.804$.

The clinochlore composition corresponds to—
(Al_{1.85} Fe³⁺_{1.18} Fe²⁺_{2.31} Mg_{7.88}) (Si_{5.73} Al_{2.27}) (OH)_{16.1}

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