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Utilization of Indian Asbestos: Part I—Analytical Data

A. K. CHATTERJI & K. D. DHARIYAL
Central Building Research Institute, Roorkee

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Chemical, X-ray and differential thermal analysis data are presented for some asbestos minerals from Indian sources. The minerals can be identified from X-ray diffraction patterns by the three most intense lines: (i) chrysotiles (Cuddapah, Andhra), 7·31, 3·67 and 1·53 A.; and (ii) tremolites (Mysore), 3·18, 8·57 and 2·71 A. Lines at 8·21, 3·21 and 3·04 A. help to identify anthophyllites; the absence of a strong line at 2·71 A. helps to distinguish anthophyllites from tremolites. Differential thermal analysis curve for Cuddapah chrysotile does not show the exothermic peak at 800°C. as shown by Canadian chrysotile. Thermograms of tremolite and anthophyllite asbestos from Mysore show no peaks, whereas the thermogram for anthophyllite from Bihar shows only an endothermic peak and that for Rajasthan anthophyllite shows two peaks.

DATA on the physical and chemical characteristics of asbestos minerals like chrysotile, tremolite and anthophyllite from several countries are available in literature. But no work seems to have been carried out on these minerals from Indian sources. The present paper reports the chemical, X-ray and differential thermal analysis (DTA) data on a few asbestos minerals from different parts of the country.

Materials and methods

The asbestos samples examined were: chrysotile from Cuddapah (Andhra), tremolite from Mysore, and anthophyllites from Mysore, Bihar and Rajasthan (Table 1). For comparison, X-ray diffraction study of an asbestos sample of South African origin and DTA of a Canadian sample were also made.

X-ray diffraction patterns were taken with samples in both powder and fibre form. For powder diagrams, samples, freed from extraneous matter, were powdered and the portions passing 200 mesh were packed in quartz tubes. For patterns of asbestos in fibre form, thin pencils of fibres were separated from the bulk and attached to the centre of the camera with the fibre axis perpendicular to the X-ray beam. The patterns obtained are referred to as fibre diagrams though these are zero layer lines of rotation diagrams.

Copper radiation with a nickel filter was used in these experiments. Photographs were taken with a 114·6 mm. diam. Hilger's general purpose camera. Exposure time was 8 hr in each case with the X-ray unit running at 50 kV. and 400 microamperes.

Differential thermal analysis — This was carried out on untreated asbestos samples. The temperature

TABLE 1 — DESCRIPTION OF SAMPLES

Source	Colour	Lustre	Feel		Identification
			Bulk	Fibre	
Mysore I	Light brown	High pearly	Slight, waxy	Stiff needles or short thread-like soft needles, brittle	Tremolite
Mysore II	Brownish white	Dull	Slight, waxy	Thread-like, slight stiff, brittle	Anthophyllite
Bihar	White with greenish tinge	Silky	Soft	Soft, thread-like, very brittle	do
Rajasthan	Brownish white	Dull, earthy	Hard, rough	Stiff, needle-like, brittle	do
Cuddapah	Yellowish white	High, silky	Soft	Silky threads, strong, flexible	Chrysotile

of the furnace was raised uniformly at the rate of 10°C./min. using a Leeds and Northrup programme controller triggered by a chromel-alumel thermocouple, placed outside the specimen block. The ceramic specimen block was of Grinshaw and Roberts' pattern. The differential thermocouple made of chromel-alumel was connected to a sensitive galvanometer, and readings were taken manually. The reference temperature was recorded by means of a thermocouple placed in the inert sample, α-Al_2O_3.

Mysore II, Bihar and Rajasthan samples were confirmed as anthophyllites by petrological examination by the Geological Laboratory of the Oil and Natural Gas Commission, Dehra Dun. Petrological examination of other samples was not carried out as these did not present any difficulty in identification.

Results and discussion

Chemical analysis — The results of chemical analysis of the minerals are given in Table 2.

X-ray data

X-ray diffraction data of Cuddapah, South African, Mysore I, Mysore II, Bihar and Rajasthan samples, calculated from fibre patterns, are given in Tables 3-5.

(i) *General nature of the patterns* — Lines in powder patterns from chrysotile were strong but broad; those from amphiboles were relatively sharper but weak.

TABLE 2 — CHEMICAL ANALYSIS OF INDIAN ASBESTOS SAMPLES

Source	SiO_2 %	R_2O_3 %	CaO %	MgO %	Loss on ignition %
Mysore I	56·70	12·04	1·88	27·80	nil
Mysore II	57·77	8·93	11·98	18·72	3·84
Bihar	55·87	9·65	14·33	18·33	nil
Rajasthan	57·32	7·68	7·05	29·73	nil
Cuddapah	39·54	6·92	—	38·84	14·25

TABLE 3 — X-RAY DATA FOR CHRYSOTILES

Sl No.	Cuddapah sample		South African sample	
	Int.	*d*	Int.	*d*
1	—	—	VVW	$9·56_1$
2	VS	$7·31_3$	VS	$7·31_3$
3	W	$4·40_8$	MS	$4·46_4$
4	VVW	$4·02_3$	VVW	$4·00_2$
5	VS	$3·67_3$	VS	$3·64_4$
6	—	—	VVW	$3·34_7$
7	W	$2·43_5$	MS	$2·43_1$
8	VVW	$1·82_4$	MS	$1·80_8$
9	S	$1·53_2$	S	$1·52_9$
10	VVW	$1·45_8$	W	$1·45_8$
11	VVW	$1·21_4$	VW	$1·21_5$
12	—	—	VVW	$1·04_1$

VS, very strong; MS, moderately strong; S, strong; W, weak; VW, very weak; VVW, very very weak; Int., intensity.

Background scattering in patterns of fibres was much less than in that from powders. This brought out weaker lines which are difficult to recognize in powder patterns. Because of this and as the lines in fibre patterns could be unambiguously attributed to asbestos, measurements were made with fibre patterns only.

The pattern from chrysotile (Cuddapah) consists of (rather broad) spots with little or no arcing. Patterns from amphiboles show large arcs. These indicate that the fibres in this chrysotile variety are more or less parallel to the axis of the pencil whereas in amphiboles the fibres are randomly oriented about the axis.

In the sample from South Africa, a small fraction of the fibres is randomly oriented.

Chrysotiles — The *d* values and intensities in the patterns obtained from Cuddapah and the South African sample are given in Table 3. These compare well with data provided by Warren and Bragg[1]. The *d* values and intensity relations as well as the general character of the patterns agree fairly well. There are two extra spots in the pattern for Cuddapah sample at 4·41 and 4·02 A. and three in the pattern from South African sample at 9·56, 4·46 and 4·00 A.; the lines with *d* values 4·5 and 4·0 A. have been observed by Beatty[2] in the pattern of chrysotile from Richmond, Canada.

The line $d = 9·56$ A. was not given in the data provided by Beatty or by Warren and Bragg[1].

TABLE 4 — X-RAY DATA FOR MYSORE I SAMPLE OF TREMOLITE

Sl No.	Int.	*d*	Sl No.	Int.	*d*
1	W	$9·33_0$	28	VS	$1·60_4$
2	S	$8·57_2$	29	S	$1·53_4$
3	S	$7·92_1$	30	VW	$1·51_3$
4	W	$4·92_2$	31	VVS	$1·49_4$
5	W	$4·56_9$	32	S	$1·45_3$
6	MS	$4·42_3$	33	VVW	$1·35_1$
7	W	$4·19_4$	34	S	$1·31_4$
8	MS	$4·04_2$	35	W	$1·28_3$
9	VVW	$3·52_7$	36	W	$1·26_3$
10	VVW	$3·32_3$	37	MS	$1·25_4$
11	VW	$3·22_8$	38	W	$1·22_4$
12	VS	$3·17_6$	39	W	$1·17_3$
13	MS	$3·07_8$	40	MS	$1·15_4$
14	VS	$2·99_8$	41	VVW	$1·14_4$
15	S	$2·71_1$	42	VVW	$1·13_3$
16	W	$2·49_2$	43	W	$1·11_3$
17	VVW	$2·45_7$	44	VW	$1·10_3$
18	VVW	$2·39_1$	45	S	$1·10_3$
19	MS	$2·31_9$	46	VW	$1·09_3$
20	MS	$2·22_8$	47	VVW	$1·07_3$
21	W	$2·04_2$	48	VVW	$1·07_4$
22	MS	$2·00_9$	49	S	$1·02_3$
23	W	$1·96_1$	50	W	$1·02_4$
24	W	$1·93_9$	51	W	$1·00_3$
25	S	$1·82_9$	52	MS	$0·95_3$
26	MS	$1·76_4$	53	MS	$0·92_3$
27	VVW	$1·65_2$	54	VW	$0·92_3$

TABLE 5 — X-RAY DATA FOR ANTHOPHYLLITES

Sl No.	Mysore II sample		Bihar sample		Rajasthan sample	
	Int.	d	Int.	d	Int.	d
1	MS	$14{\cdot}46_5$	VVW	$13{\cdot}14_0$	—	—
2	—	—	—	—	W	$9{\cdot}16_6$
3	S	$9{\cdot}02_8$	S	$9{\cdot}04_8$	S	$8{\cdot}92_3$
4	VVS	$8{\cdot}38_0$	VS	$8{\cdot}37_0$	VS	$8{\cdot}21_0$
5	MS	$5{\cdot}08_9$	MS	$5{\cdot}07_9$	W	$5{\cdot}00_3$
6	VVW	$4{\cdot}75_0$	VW	$4{\cdot}73_9$	VVW	$4{\cdot}64_8$
7	VS	$4{\cdot}50_6$	VS	$4{\cdot}50_7$	VS	$4{\cdot}48_6$
8	MS	$4{\cdot}17_4$	MS	$4{\cdot}20_1$	MS	$4{\cdot}10_2$
9	—	—	—	—	—	—
10	VVW	$3{\cdot}63_2$	VVW	$3{\cdot}61_5$	W	$3{\cdot}55_8$
11	VVW	$3{\cdot}44_2$	VVW	$3{\cdot}44_3$	W	$3{\cdot}35_2$
12	VVS	$3{\cdot}33_0$	VS	$3{\cdot}27_1$	VS	$3{\cdot}20_6$
13	—	—	—	—	W	$3{\cdot}11_0$
14	VVS	$3{\cdot}11_1$	VVS	$3{\cdot}12_1$	VVS	$3{\cdot}03_8$
15	—	—	—	—	—	—
16	—	—	—	—	—	—
17	VS	$2{\cdot}80_5$	S	$2{\cdot}80_3$	VS	$2{\cdot}73_7$
18	VVW	$2{\cdot}59_2$	—	—	VVW	$2{\cdot}54_9$
19	—	—	—	—	W	$2{\cdot}50_7$
20	—	—	—	—	VVW	$2{\cdot}46_7$
21	—	—	—	—	VVW	$2{\cdot}40_5$
22	S	$2{\cdot}38_0$	S	$2{\cdot}38_1$	W	$2{\cdot}33_5$
23	—	—	—	—	VVW	$2{\cdot}30_4$
24	—	—	—	—	—	—
25	—	—	—	—	W	$2{\cdot}23_7$
26	—	—	—	—	—	—
27	VVW	$2{\cdot}16_2$	—	—	—	—
28	—	—	—	—	VVW	$2{\cdot}04_5$
29	VS	$1{\cdot}99_7$	S	$1{\cdot}99_6$	W	$2{\cdot}01_6$
30	MS	$1{\cdot}96_1$	MS	$1{\cdot}96_1$	W	$1{\cdot}96_6$
31	—	—	—	—	W	$1{\cdot}94_8$
32	VS	$1{\cdot}89_1$	S	$1{\cdot}88_6$	—	—
33	—	—	—	—	VVW	$1{\cdot}86_5$
34	S	$1{\cdot}80_9$	S	$1{\cdot}81_0$	S	$1{\cdot}79_5$
35	—	—	—	—	VVW	$1{\cdot}79_3$
36	—	—	—	—	MS	$1{\cdot}76_4$
37	—	—	VVW	$1{\cdot}68_9$	—	—
38	—	—	VVW	$1{\cdot}66_2$	—	—
39	S	$1{\cdot}63_4$	MS	$1{\cdot}63_6$	VVW	$1{\cdot}65_3$
40	VS	$1{\cdot}61_5$	VS	$1{\cdot}61_6$	VS	$1{\cdot}60_6$
41	S	$1{\cdot}58_3$	MS	$1{\cdot}58_6$	S	$1{\cdot}54_0$
42	—	—	VVW	$1{\cdot}56_1$	—	—
43	—	—	VVW	$1{\cdot}53_1$	VW	$1{\cdot}52_1$
44	VS	$1{\cdot}50_3$	VS	$1{\cdot}50_4$	VVS	$1{\cdot}49_4$
45	W	$1{\cdot}45_6$	S	$1{\cdot}45_7$	S	$1{\cdot}44_1$
46	MS	$1{\cdot}43_7$	W	$1{\cdot}43_6$	—	—
47	W	$1{\cdot}35_5$	W	$1{\cdot}35_6$	VVW	$1{\cdot}35_3$
48	VVW	$1{\cdot}32_7$	VVW	$1{\cdot}32_5$	S	$1{\cdot}31_8$
49	VVW	$1{\cdot}30_2$	VW	$1{\cdot}29_8$	VW	$1{\cdot}29_0$
50	VVW	$1{\cdot}28_5$	—	—	VVW	$1{\cdot}28_0$
51	—	—	VW	$1{\cdot}27_2$	VW	$1{\cdot}27_1$
52	—	—	VVW	$1{\cdot}24_4$	W	$1{\cdot}25_7$
53	—	—	—	—	W	$1{\cdot}22_4$
54	VW	$1{\cdot}18_9$	W	$1{\cdot}19_0$	VVW	$1{\cdot}19_0$
55	—	—	—	—	VW	$1{\cdot}17_3$
56	—	—	—	—	W	$1{\cdot}15_5$
57	W	$1{\cdot}12_5$	MS	$1{\cdot}12_6$	VVW	$1{\cdot}11_8$
58	—	—	—	—	VW	$1{\cdot}10_6$
59	—	—	—	—	VW	$1{\cdot}10_1$
60	—	—	—	—	VVW	$1{\cdot}09_9$
61	—	—	—	—	VVW	$1{\cdot}09_0$
62	—	—	—	—	VVW	$1{\cdot}07_7$
63	—	—	—	—	VVW	$1{\cdot}07_4$
64	MS	$1{\cdot}04_7$	S	$1{\cdot}04_7$	—	—
65	VVW	$1{\cdot}02_9$	—	—	S	$1{\cdot}02_8$
66	—	—	—	—	W	$1{\cdot}02_4$
67	VVW	$1{\cdot}01_8$	W	$1{\cdot}02_0$	—	—
68	—	—	VW	$0{\cdot}98_0$	W	$1{\cdot}00_5$
69	—	—	VVW	$0{\cdot}97_1$	W	$0{\cdot}95_8$
70	—	—	VVW	$0{\cdot}95_3$	VVW	$0{\cdot}95_3$
71	—	—	VVW	$0{\cdot}93_4$	W	$0{\cdot}92_5$
72	—	—	—	—	VVW	$0{\cdot}92_3$

Tremolite — The d values and intensities of the lines for Mysore tremolite are given in Table 4. (These data are comparable with those of Labrador tremolite[1,3], and a natural grammatite[3].) There is a large variation in the interplanar spacings and intensities of lines in these patterns. The structure of Mysore tremolite seems to be more complex.

Three strong lines characteristic of grammatite[3], 3·13, 2·71 and 8·41 A., can be recognized as (3·18 and 3·08 A.), 2·71 A., and (8·57 and 7·92 A.) in the pattern for Mysore tremolite. The lines 3·13 and 8·14 A. seem to have been resolved.

Anthophyllites — The X-ray data for Mysore II, Bihar and Rajasthan anthophyllites are given in Table 5. Patterns from Indian anthophyllites are richer in lines than in those of other varieties. There are considerable variations in both intensities and d values of the lines from one sample to another. Mysore II and Bihar samples show two lines with large interplanar spacings; these do not seem to have been reported earlier.

Three strong lines with d values of 8·21, 3·21 and 3·04 A. help to identify anthophyllites and the absence of a strong line with $d = 2{\cdot}71$ A. often helps to distinguish anthophyllites from tremolites.

Differential thermal analysis

Chrysotiles — DTA curve for chrysotile (serpentine) is known[4] to show endothermic peak at 105°C. (very small), 635°C. (large), 800°C. (small), and an exothermic peak at 850°C. (medium).

These peaks can be identified in curve 1 (Fig. 1) for the Canadian chrysotile. The large endothermic peak at *c.* 675°C. is due to the removal of OH groups from the structure of chrysotile.

Tremolites — DTA curves for tremolites poor in sesquioxide (about 0·1 per cent) are known[5] to show an exothermic peak at 825°C. and an endothermic peak at about 1000°C. The presence of FeO, CaO, MnO and Na_2O is known not to prevent or hinder the changes, shown by the peaks, from taking place[5]. The absence of peaks in curves 3 and 4 (Fig. 1) for raw and processed* Mysore I tremolite is probably due to the large amount of sesquioxide present in the sample.

Anthophyllites — Anthophyllites with relatively low sesquioxide content show in their DTA curve peaks at 825° and 1000°C. similar to those observed in the curves for tremolites mentioned above[5].

Curve 7 (Fig. 1), for Rajasthan asbestos, shows two peaks at 800° and 950°C. The sample has lowest R_2O_3 content. Increase in R_2O_3 content in Mysore II and Bihar samples may be the reason for the suppression of the peak at 800°C. in curves 5 and 6.

*Processing is done by immersing raw asbestos in 10 per cent NaCl solution for 24-48 hr. The sticks are then crushed under rollers, repeatedly washed and dried.

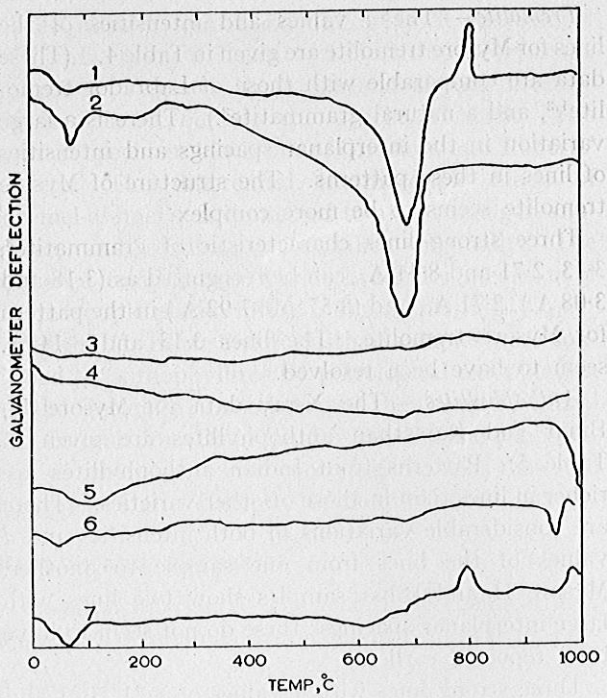

Fig. 1 — Thermograms for some asbestos samples [1, Canadian chrysotile; 2, Cuddapah chrysotile; 3, Mysore I tremolite (raw); 4, Mysore I tremolite (processed); 5, Mysore II anthophyllite; 6, Bihar anthophyllite; and 7, Rajasthan anthophyllite]

Sesquioxides seem to have a pronounced effect on the phase transitions. Further investigation is needed for understanding the various discrepancies observed.

Conclusions

X-ray diffraction patterns of Indian asbestos minerals vary considerably from the patterns of those from foreign sources and possess characteristic features which help in their identification.

Chrysotile (Cuddapah, Andhra) and tremolite (Mysore) can be identified by the presence of the three most intense lines: (i) with d values 7·31, 3·67 and 1·53 A.; (ii) 3·18, 8·57 and 2·71 A. respectively. In the case of anthophyllites, there is considerable variation in the d values of the most intense lines among the samples examined; the lines at about 8·21, 3·21 and 3·04 A. help to identify them and absence of a strong line with $d = 2{\cdot}71$ A. often helps to distinguish anthophyllites from tremolites.

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References

1. Warren, B. E. & Bragg, W. L., cf. Beatty, S. van D., *Amer. Min.*, **35** (1950), 579.
2. Beatty, S. van D., *Amer. Min.*, **35** (1950), 579.
3. Comferro, J. E. & Eitel, W., *Amer. Min.*, **36** (1951), 368.
4. Searle, A. B. & Grimshaw, R. W., *The Chemistry and Physics of Clays* (E. Benn Ltd, London), 1959, 894.
5. Wittels, M., *Amer. Min.*, **36** (1951), 851.