

## NOTES ON ASBESTOS AND ASBESTIFORM MINERALS.

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The investigations detailed below are an outgrowth of an attempt at classifying and labeling the "asbestos" collections in the economic series of the geological department of the National Museum. The results seem of sufficient interest to warrant immediate publication, as the final handbook<sup>1</sup> of which they were designed to form a part may yet be delayed some months.

Without going too deeply into a discussion of the origin of the name "asbestos," and the causes which led to its present loosely-defined mineralogical significance,<sup>2</sup> it may be said that as commercially used the name now covers at least four distinct minerals, having in common only a fibrous structure and more or less fire- and acid-proof properties. These minerals are (1) monoclinic amphibole (tremolite), (2) serpentine (amianthus), (3) anthophyllite, and (4) erocidolite. Of these, tremolite and serpentine have long been recognized in fibrous forms, and are as a rule readily distinguishable from one another by the silky fiber and greater flexibility of the last named. Asbestiform erocidolite is well known to most mineralogists, though, so far as the present writer is aware, the South African locality is the only source of the mineral in commercial quantities. That the fibrous form of anthophyllite is also sufficiently common to be commercially used as asbestos, seems not so well understood, though the leading text-books on the subject<sup>3</sup> all mention the mineral as sometimes occurring in fibrous forms resembling asbestos. That a lack of discrimination between fibrous anthophyllite and the true tremolite asbestos should exist is not strange, since to the unaided eye they are often in every way alike, and it is only by microscopic or chemical means that the true nature of the mineral can be made out.

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<sup>1</sup>The Nonmetallic Minerals, now in process of preparation.

<sup>2</sup>See "Some Misconceptions concerning Asbestos," by J. T. Donald and A. H. Chester, in the Eng. and Min. Journal for March 18, April 1, and June 10, 1893.

<sup>3</sup>See Dana's System of Mineralogy, latest edition, and Hintze's Handbuch der Mineralogie.

In the accompanying table (pages 291 and 292) I have brought together all the analyses of the above noted asbestiform minerals that have been made either by R. L. Packard or myself in the department laboratory, as well as such others as can be compiled from available literature. It will be seen that out of the 24 analyses made by ourselves, 12 are anthophyllite, 7 asbestiform tremolite, and 2 uralitic augite. This statement must not, however, be accepted as conveying the idea that anything like the same proportions would hold in another series, since only such samples were selected for our analyses as had not been already satisfactorily determined. In all cases the optical and chemical determinations agree, the mineral giving extinctions parallel with the axis of elongation proving to be anthophyllite, and that with inclined extinctions, tremolite (asbestos) or uralitic augite. This result was not wholly expected, since it was thought that possibly some might be amphibole anthophyllite, *i. e.*, a mineral with the composition of anthophyllite, but monoclinic in crystallization. The angle of extinction given, is that obtained by measuring against the axis of elongation of the fibers, which is doubtless the vertical crystallographic axis.

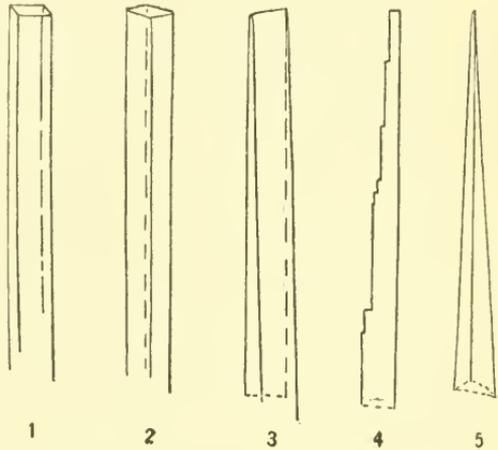
The size and shape of the fibers in both asbestos proper and anthophyllite is found to be quite variable, but I can not discover that there is any constant difference. The Salls Mountain material (No. 61357, U. S. N. M.) occurs in the form of a massive aggregate of bundles of short radiating fibers, rarely 20 mm. in length. The mineral is soft, of a somewhat brittle nature, but in small fibers very flexible, though scarcely elastic. Under the microscope the interference colors are very faint, scarcely discernible in the smaller fibers: extinction is always parallel with the axis of elongation. The composition is that of a hydrated anthophyllite.

The Nacoochee (White County) material (No. 60842, U. S. N. M.) is of a beautiful snow-white color in the mass, but colorless in single fibers. The fibers are long, smooth, of very uniform diameter throughout, flexible, but breaking with rectangular cross fractures. The fibers not infrequently show a cross parting at right angles to the axis of elongation. The mineral is not at all pleochroic, and the fibers always extinguish parallel with the axis of elongation. The outline of the fiber is polygonal. Other materials from Cleveland, in this same county, are precisely similar, both in physical and chemical properties. The Rabun County (Georgia) material (No. 56351, U. S. N. M.) is colored brownish by oxidation, and, on casual inspection, is coarse-fibered. The fibers are long, somewhat stiff, but flexible, though not elastic. The ultimate product of fibrillation, obtained by rolling the material between the thumb and fingers, has a somewhat splintery look under the microscope, the thin fibers, some 0.002 mm. in diameter, running out to a point at the end. Extinction parallel with axis of elongation.

The material from Alberton, Maryland (No. 62604, U. S. N. M.), is quite similar in general appearance to that from Cleveland, occurring in the form of fibrous bundles 12 to 18 inches in length. The individual fibers are very smooth and polygonal in outline, and give parallel extinctions. The ultimate composition, it will be observed, is essentially the same as that of Nacoochee. Another variety, occurring in the limestone just above Alberton, is pure white in color, finely fibrous, and when wet is easily reduced to a condition that can only be described as *pulpy*, like wet paper. The fibers extinguish always parallel with the axis of elongation, but its exact mineral nature has not been as yet worked out (see Analysis 40 in accompanying table).

The Carbon County (Wyoming) material (No. 62090, U. S. N. M.) is of the same general nature as No. 62604. The material from Mitchell County, North Carolina (No. 50876, U. S. N. M.), is in the form of bundles

of parallel-lying, long, soft and silky fibers, white in color, and easily reduced to a fine, silky powder, without appreciable grit, by rubbing between the thumb and finger. The extinction colors are very faint, but always parallel with the axis of elongation. No appreciable pleochroism. The fibers show occasional cross partings, causing them to break with sharp, straight fractures. The actual size of the fibers—that is, the diameter—is indefinite, since there seems no limit to further sub-



ASBESTOS FIBERS  
Enlarged

division. The smallest actually measured was 0.002 mm. Down to a diameter of 0.004 mm. the fibers are of quite uniform diameter throughout their length and in the form of square or slightly compressed prisms (see Figs. 1 and 2). The smaller sizes frequently taper off to wedge-shaped forms, as shown in Fig. 3. All show extinctions and plane of optic axis parallel with the axis of elongation.

Two samples were examined, labeled as from Franklin County, North Carolina. The first, from the Brush collection at New Haven, kindly submitted by S. L. Penfield, was in the form of somewhat stiff and brittle bundles of a slight brownish color. The material was easily reduced to fibrous form by thumb and fingers, but the fibers were quite brittle. Its composition is that of normal anthophyllite, closely resembling that of Mitchell County, above noted. The second sample (No. 44232, U. S. N. M.), concerning the identity of which there at first seemed some doubt, proved microscopically identical and was not analyzed.

A sample marked as from Tallapoosa County (?), Alabama, was received from Prof. Albert H. Chester, of Rutgers College, New Jersey. It resembles very closely that of Mitchell County, North Carolina, and occurs in fibrous bundles ten or more inches in length. This is also anthophyllite, as shown by its chemical and optical properties. Material received from Warrenton, Warren County, the same State, is of pure white color, excepting where stained externally by iron oxide. It is reduced readily by the thumb and fingers to fine, soft and silky fibers, which do not differ materially from others mentioned.

The San Diego material occurs in the form of hard, compact bundles, somewhat difficult to reduce to a fibrous condition, but capable of almost indefinite subdivision. Under the microscope the fibers, either singly or in bundles, give parallel extinctions. The bundles, even though containing thousands of individual fibers, conduct themselves as crystal units, the entire bundle behaving optically as a single fiber. The larger fibers, although clear and compact, without indication of having in themselves a fibrous structure, yet manifest their capability of further subdivision by steplike ends, as in Fig. 4, where the rise of each step represents the diameter of a fiber which has been separated from it.

As above noted, I fail to find any certain means of discrimination between the anthophyllite and asbestos fibers by their shape alone. Optically there is, of course, a well-defined distinction, the asbestos fibers giving extinction angles from  $0^{\circ}$  to  $20^{\circ}$ , according to their orientation. These fibers, like those of anthophyllite, are angular in outline, often compressed, at times of a very uniform diameter throughout their entire length, or again tapering very gradually to a triangular point, as shown in Fig. 5, which is drawn from a fiber of asbestos (No. 62550, U. S. N. M.) found in the "soapstone" quarries of Alberene, Virginia. The asbestos from Chester, South Carolina (No. 73462, U. S. N. M.), is of a gray color, short-fibered, and rather brittle. The individual fibers often show the cross partings, but have frequently acute terminations and a splintery appearance. The material in Analysis 20 (see accompanying table), marked as from Cow Flats, New South Wales, it will be observed, differs radically from that of the "asbest-forming mineral" from the same locality as given by Hintze (Analysis 26). Our material is of a beautiful white, silky appearance, very finely fibered, and showing under the microscope clear, colorless, straight fibers of very uniform size throughout, ranging from 0.008 down to 0.002 mm. or even smaller, and giving extinction angles varying from  $0^{\circ}$  to  $17^{\circ}$ . The Corsican material is very similar, as is also that of Pylesville, in Harford County, Maryland (noted later), excepting that the last is a trifle more brittle and of a grayish hue.

That from Aston, Delaware County (obtained from the Boston Society of Natural History, through the kindness of Prof. W. O. Crosby), occurs in short, beautifully silky forms, sometimes almost feltlike, or

again in the form of compact bundles of flat fibers of a grayish hue, several inches in length. The larger bundles found at this locality frequently show rude cross partings, indicative of a rupturing through shearing agencies, the clefts thus formed being filled by other secondary minerals. The significance of this fact is noted later. The material from Idaho (Analysis 32) can scarcely be considered a true mineral species, being partially decomposed by cold dilute hydrochloric acid, the solution reacting for alumina and magnesia, while the insoluble residue consists of pure white, brittle fibers, in the form of flat bundles, showing to the naked eye a peculiar crimping extending diagonally across the plates. The two samples from Nahant and Malden, Massachusetts, received from Prof. W. O. Crosby, occur in diabase, the fibers running oblique or parallel with the walls of the "vein." That from Nahant is a dull, light-green-gray, platy mineral, shredding up readily into flattened bundles of fibers which lie with their greatest diameters in one general plane. The fibers, under the microscope, are very uneven in diameter and splinterlike, terminating in acute points. There seems almost no limit to fibrillation, bundles not over 0.004 mm. in diameter being made up of a large number of short, splinterlike fibers, with free ends frequently projecting like the broken strands in an old rope. Fibers were measured down to 0.001 mm. in diameter, but smaller exist. Small flattened fibers, the fraction of a millimeter in diameter, give extinction angles, measured against the edge, of  $7^{\circ}$ , and show indistinctly the emergence of a bisectrix a little to one side, facts at once suggestive of cleavage splinters parallel to the prismatic faces. Measurements on a number of small individual fibers show extinction angles ranging from  $0^{\circ}$  to  $17^{\circ}$ . The Malden material is very similar, but the fibers are longer and more uniform in diameter. The composition and optical properties of both are such as to relegate them to the "uralites" rather than to true asbestos, though their fibrous structure is none the less suggestive from our present standpoint.

A platy, dull greenish, soft, and rather brittle mineral found at Roxbury, Massachusetts, under similar conditions, shows under the microscope stout, faintly yellowish, and pleochroic columns, with frequent cross partings which give extinction angles as high as  $22^{\circ}$ . The material is doubtless actinolite, and was not analyzed.

Concerning the possible cause of the fibrous structure of these minerals, existing literature is strangely silent, though there are numerous references to the occurrence of asbestos as a secondary mineral. Thus Blum describes<sup>1</sup> the conversion ("umwandlung") of an augite from Pitkaranda, in the Ladoga-See, into an asbestos-like hornblende, the process being evidently akin to uralitization. He finds also a fibrous intermediate product having the following composition:  $\text{SiO}_2$ , 45.57 per cent;  $\text{Al}_2\text{O}_3$ , 3.00 per cent;  $\text{Fe}_2\text{O}_3$ , 19.73 per cent;  $\text{CaO}$ , 4.40 per cent;  $\text{MgO}$ , 23.40 per cent;  $\text{H}_2\text{O}$ , 2.00 per cent. In the augites from the Brozza-

<sup>1</sup> Die Pseudomorphosen des Mineralreiches, 1843.

Thal of Piedmont he also finds all transition stages between compact augite and asbestos. The first stages of the transformation are indicated by a tissue of fine fibrous material on the terminal planes, whereby the crystal form becomes obscured, the whole ultimately becoming converted into a bundle of flexible fibers with a silky luster. Unfortunately he gives no analyses to show how this "asbestos" differs, if at all, from the original augite. E. Schumacher also describes<sup>1</sup> the alteration of diopside into asbestos in a manner quite analogous to that of augite into uralite. The secondary asbestos thus sometimes forms parallel-lying fibers a decimeter in length, or "verworren faserigen" masses. The material occurs in a granular limestone. No analyses are given, the determinations being based on optical properties; nor is there given any suggestion as to the cause of the transformation.

Before going further, the writer should state that the idea that the fibrous structure might be but an extreme phase of uralitization, produced by shearing, was adopted very early in the work of this investigation, and in perusing the literature and making his own observation, it has always been with this in mind. Both literature and observation support this idea to a limited extent, as will be noted as we proceed.

In his work on the Mineralogy of Scotland, Professor Heddle describes<sup>2</sup> an "amianthus" of unusual if not unrivaled excellence as occurring in the deep-cut "goes" on the eastern coast of the Balta Sound, in the Shetland Islands. The length of the fiber varies from 4 to 12 inches, and the mineral is sufficiently soft to be readily rubbed down to an unctuous pulp between the thumb and fingers. It occurs in thin rifts in gabbro, and though not definitely so stated, the descriptions are such as to lead one to infer that the fibration may be but a phase of schistosity. Indeed, he describes a highly fissile schistose mineral of essentially the same chemical composition, which is convertible into a fibrous form by beating, and which passes into the asbestos on exposure, or, as he expresses it, the "amianthus" seems to "grow out of the solid and fissile stone." This is almost precisely the relative condition of the fibrous and compact anthophyllite at Alberton, Maryland, to be described later. The composition of this "amianthus" is given in Analysis 34, showing it to be a true asbestos. A second occurrence at Portsoy, described by this same authority, is of interest as showing the mineral in veins an inch in width in a gabbro passing into serpentine, and with fibers lying transversely to the veins, an unusual thing, he says, "as regards asbestos." Although occurring in serpentinous rocks, this also is a true asbestos, as indicated by Analysis 36. The "hydrous anthophyllite" first noted by Jameson, and afterwards by Professor Heddle, as occurring at the Free Church of Milltown, in Glen Urquhart, Scotland, is described as an alteration product after asbestos. The

<sup>1</sup> Zeit. der Deutschen Geol. Gesell., XI, 1878, p. 494.

<sup>2</sup> Mineralogical Magazine, II, 1878; also Trans. Royal Society of Edinburgh, XXVIII, 1877-78, p. 502.

fibers were some 4 or 5 inches in length, of a green-brown color, silky luster, and great toughness. These also ran transversely to the walls of the vein. The mineral was subsequently shown by Lacroix to be monoclinic in crystallization, and hence tremolite, rather than anthophyllite, although the analysis as given<sup>1</sup> (No. 33) shows it to be very low in lime. F. von Sandberger describes<sup>2</sup> asbestos and epidote, so associated as to indicate that they result from the alteration of hornblende and augite, in South Tyrol, in Nassau near Hof, and in Pribram.

The above enumerated observations, it will be observed, throw little light upon the subject, other than indicating that the mineral is a secondary product after augite or hornblende. My own observations in the field are limited to three localities, in all of which indications as to the secondary nature of the mineral, as well as to the probable efficacy of shearing, were unmistakable. These localities are at the well-known "soapstone" quarries of Alberene, in Albemarle County, Virginia, and near Alberton, in Howard County, Maryland.

The "soapstone" at the first-named locality is not a pure steatite, but rather an admixture of various alteration products, among which a colorless tremolite and light-green talc are most conspicuous.<sup>3</sup> What the original rock may have been is not apparent from a study of thin sections, but the appearance in the field is such as to suggest it to have been a pyroxenite. It occurs in the form of a broad dike or sheet, parallel and dipping with the gneiss (?) in which it is inclosed, and, as displayed in the quarry opening, is traversed by numerous irregular veins of coarsely crystalline calcite. The rock is very massive, in general appearance eminently suggestive of an eruptive pyroxenite which has undergone extensive hydration and carbonatization, whereby a considerable portion of its calcium has separated out in the form of calcite. As is almost invariably the case in rocks of this class, the mass is traversed by numerous joint planes, some of which are pronouncedly slickensided. Asbestos, as found, is always along these slickensided zones, with fibers parallel to line of movement. The material is, as a rule, in the form of thin plates or sheets, rarely over 10 mm. in thickness, but perhaps several feet in breadth, which bear every evidence of compression, accompanied by a shearing movement whereby the material is drawn out into a series of laminae and the laminae again into fibers. In one instance the material was fibrous (asbestiform) only where it had been subjected to a sharp crimping process, such as would result from the impinging of the end of one block against another at a considerable angle, accompanied by a slight lateral movement. The physical and chemical properties of the fibrous mineral are those of true asbestos (Analysis 12).

<sup>1</sup>Trans. Royal Society of Edinburgh, XXVIII, 1877-78, p. 531.

<sup>2</sup>Neues Jahrb. für Min., etc., 1888, I, pt. 3, p. 208.

<sup>3</sup>A chemical analysis of the stone, by R. L. Packard, yielded SiO<sub>2</sub>, 39.06 per cent; Al<sub>2</sub>O<sub>3</sub>, 12.84 per cent; FeO, 12.93 per cent; CaO, 5.98 per cent; MgO, 22.76 per cent; ignition, 6.56 per cent. Total, 100.13. All iron calculated as FeO.

At the second locality above mentioned, the asbestos (fibrous anthophyllite, Analysis 9) occurs along a slickensided zone between a schistose actinolite rock on the north, and a dark, massive, impure serpentine on the south. Soil and decomposition products obscure the outcrops, so that observations are limited to an abandoned shaft and a few shallow prospect holes. The evidences of movement are everywhere abundant in the form of slickensided, pinched-out masses of serpentine, sometimes more or less fibrous. The anthophyllite occurs only along the line of disturbance, and in two forms—the one fibrous, asbestos-like, and of a white color; the other also fibrous, but in compact masses, with sharp cross fracture, so that the material as taken out bears a striking resemblance to a fine-grained hard wood, sawed and split for the fire. The color of this variety is a dull yellowish brown; translucent. By beating, it is readily reduced to a fibrous condition, though the fibers are brittle. On weathering it appears to undergo a spontaneous fibrillation quite suggestive of the Balta "amianthus" described by Professor Heddle (*ante*, p. 286). What the origin of this serpentinous rock may have been, is not here apparent, but from its locality it seems safe to assume it to be an altered form of the gabbros or peridotites described by Williams.<sup>1</sup> This being the case, the closing remark made by Dr. Williams in his paper, though referring to a different locality, is at least suggestive. He says: "It seems possible that the asbestos deposits of Baltimore County (*e. g.*, like the one near Elysville) may likewise be the results of the alteration of original pyroxenic masses."

Just below the western edge of the lower bridge of the Baltimore and Ohio Railroad across the Patapsco, at this same place, is another, the third deposit, which has come under the writer's observation. This, though small, offers some interesting distinctive features.

The rock here is a granular, micaceous, magnesian limestone, occurring in narrow beds intercalated in the gneiss, and standing nearly on edge, with an approximately east and west strike. As exposed, the rock is locally traversed at varying angles across the bedding with sharp joint planes, in some cases so fine as to be scarcely distinguishable, the walls being in almost perfect contact, or again separated from one another by a slight space, so far as observed never exceeding an inch, and usually much less. The walls of these joint planes are vertically grooved and striated, indicative of a relative movement in this direction, which was, however, presumably slight. In nearly every case noted, the walls of these joint planes are sporadically coated with thin films of a pure white asbestos-like mineral, which fills the entire space, and is always arranged with its fibers lying in a direction parallel with the striations, or line of movement. Optical examination shows the mineral to be orthorhombic. Chemical analysis (No. 40) shows it to be a mineral of somewhat anomalous composition, and

<sup>1</sup> Bull. No. 28, U. S. Geol. Survey, 1889, p. 59.

needing more study. It is mentioned here only on account of its bearing upon the subject in hand.

The writer has elsewhere noted<sup>1</sup> the efficacy of pressure and shearing in the production of fibrous serpentine (as well as calcite). The fibrous serpentine used as asbestos occurs, however, under such conditions as to preclude any such possibility of origin. As is well known, this mineral is found in what are simply cracks rather than true veins, with fibers standing at right angles with the walls, and under such conditions that any lateral movement on the part of the walls themselves was simply impossible. The material is doubtless a reproduction on a large scale of the process so frequently seen in thin sections, where olivines and other magnesian silicates undergo serpentinization. The remarks made here have only a slight bearing upon this mineral.

*Résumé.*—The points brought out in this paper and the suggestions advanced are (1) that a very considerable proportion of the mineral in commercial use, and labeled as asbestos in mineral cabinets, is in reality anthophyllite,<sup>2</sup> and (2) that the fibrous structure in this case, and that of the true asbestos as well, is due, in many instances at least, to a process of shearing—is, in fact, an exaggerated form of the process of uralitization. The fibers are drawn out along the plane of the vertical axis only, the parting or line of separation between individual fibers taking place mainly along cleavage lines, each one being, therefore, an elongated prism bounded by cleavage faces, but with form somewhat compressed or otherwise distorted by pressure. The broad faces on the fibers will therefore correspond to the faces of the unit prism.<sup>3</sup> The fact that the fibers do not in all cases run even approximately parallel to the walls of the inclosing rock is not necessarily opposed to the view. Owing to a lack of homogeneity in a rock mass subjected to a compressive force, there may be developed at an early stage, a series of short, step-like folds bordering closely upon, or perhaps passing into faults, in which the materials forming the yielding portion of the mass may be ground to powder, crimped, puckered, or even rendered fissile, or fibrous, according to their individual qualities. In such cases, the fibers may stand, relative to the inclosing, more resisting rock masses, in all positions short of at right angles.

<sup>1</sup>On the Serpentine of Montville, New Jersey, Proc. U. S. Nat. Mus., XI, 1888, p. 105.

<sup>2</sup>Pentfield states (Am. Jour. Sci., XL, Nov., 1890, p. 394), in speaking of the occurrence of anthophyllite, "Many specimens which may be seen in collections labeled anthophyllite will be found, when examined with the microscope, to be fine fibrous or radiated varieties of hornblende." My own observations, as here noted, are quite to the contrary, it being much more common to find fibrous anthophyllite labeled asbestos than the reverse.

<sup>3</sup>See description of Nahant material, p. 285.

If the foregoing is correct, it may seem, on first thought, that we should find asbestiform augites, enstatites,<sup>1</sup> and other members of the pyroxene group. This does not necessarily follow, since these minerals, as is well known, are peculiarly subject to alteration under conditions of strain, giving rise to actinolitic, tremolitic, and talcose products. These may or may not be asbestiform, according to local conditions. It is my present belief that the asbestos form is never a result of original crystallization, but is always secondary, the original mineral doubtless being an orthorhombic or monoclinic pyroxene, or perhaps an amphibole. The references made to the works of Blum, Heddle, Sandberger and others, in the earlier parts of this paper, seem to point to this conclusion. It is possible in such cases that the mineral derived from the rhombic magnesian pyroxenes may take the form of anthophyllite, and those from monoclinic lime-magnesian pyroxenes that of tremolite. Such a rule can scarcely be considered as universal, since in many cases the mineral undergoes more or less chemical as well as molecular alteration under these conditions. The absence of appreciable quantities of alumina in the asbestos proper is perhaps the strongest argument against its derivation from augite or other aluminous pyroxenes, though it is doubtless to such an origin that we can trace the uralites from Nahant and Malden.

There is ample field here for further observation, and should this paper be effective in causing collectors to note more carefully than heretofore, not merely where the mineral occurs, but how it occurs and with what associations, it will serve at least one good purpose.

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<sup>1</sup> Dana, on p. 389 of his "System of Mineralogy," latest edition, mentions the possibility that "some asbestos may properly belong to the pyroxene group." It is evident that, with the possible exception of the uralites from Malden and Nahant, none of the samples examined by the writer can be referred to the monoclinic pyroxenes, though on strictly chemical grounds many of those called anthophyllite might equally well be called enstatite.

## Analyses of asbestiform minerals.

No.	Locality.	Mineralogical nature.	Exinction angle.	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	FeO	CaO	MgO	MnO	K <sub>2</sub> O	Na <sub>2</sub> O	Ign.	Totals.	Authority.
1	Salls Mountain, Georgia (61357).	Anthophyllite	0	57.12	0.75		6.36		29.44		*	*	5.47	98.14	R. L. Packard.
2	Nacoochee, Ga. (60842)	do	0	57.73	.72	8.61		0.08	28.77		0.14	0.57	2.52	100.26	Do.
3	Rabun County, Ga. (56351)	do	0	56.52	3.67	10.08		Trace.	27.13		*	*	2.96		Geo. P. Merrill
4	Tallapoosa County (D), Ala.	do	0	55.92	3.69	11.00		.60	26.33		*	*	2.40	98.94	Do.
5	Lenoir, Caldwell County, N. C.	do	0	56.21	2.78	8.58		.82	28.95	Trace.	*	*	2.23	99.31	Do.
6	Warrenton, Warren County, N. C. (62748).	do	0	57.00		10.32		Trace.	29.98		*	*	2.29	99.59	Do.
7	Franklin, N. C. (44232)	do	0	54.79		13.65			28.52		*	*	2.55	99.51	Do.
8	Mitchell County, N. C. (50876).	do	0	59.00	.91		6.09	.45	29.90		.43	.68	2.35	99.81	R. L. Packard.
9	Albertain, Md. (62604)	do	0	56.75	1.54		10.76	.10	27.46	Trace.	*	*	2.88	99.49	Do.
10	Carbon County, Wyo. (62090).	do	0	54.56	1.47		12.39	1.86	23.28		*	*	2.95	99.51	Do.
11	San Diego, Cal. (67001)	do	0	57.31	1.57		7.06		30.24		*	*	2.73	98.91	R. L. Packard.
12	Albemarle County, Va. (62550).	Amphibole, var. asbestos.	0-16	56.26	1.81		6.40	11.98	20.85	Traces.	*	*	2.65	99.95	Do.
13	Parkton, Md. (85326)	do	0-15	56.96	.52		1.12	13.84	23.90		*	*	2.37	98.71	Geo. P. Merrill.
14	Roanoke, Va. (5694)	do	0-15	55.81	1.06		6.81	12.74	21.09		*	*	1.81	99.92	R. L. Packard.
15	Chester, S. C. (73462)	do	0-15	54.66	3.72		6.83	12.81	19.87	Traces.	*	*	2.28	100.17	Geo. P. Merrill.
16	Pylesville, Harford County, Md.	do	0-15	56.76			3.10	12.75	23.85		*	*	2.68	98.94	Do.
17	Aston, Delaware County, Pa. (62754)	do		53.42				13.42	22.85		*	*	4.36	98.65	Do.
18	Staten Island, New York	do		52.50			11.82		30.73				2.25	100	Hintze, p. 1241.
19	Zillertal, Tyrol	do	0-15	55.08	1.64		4.57	14.65	22.56	0.81			2.39	100.4	Hintze, p. 1235 (av of 4 det.).
20	Cow Flats, Bathurst, New South Wales (62450).	do	0-15	54.75	1.21		2.79	13.99	22.93	Traces.	*	*	2.58	98.25	Geo. P. Merrill.
21	Corsica (82259)	do	0-17	56.72	.545		1.73	14.72	23.63	Traces.	*	*	2.33	99.67	Do.
22	Zillertal	Amphibole, var. mountain cork.		57.20			4.37	13.39	22.85		*	*	2.43	100.24	Pana, p. 395.
23	Frankenstein, Silesia	Amphibole, var. asbestos.		57.69			2.46	13.39	23.68	.13		3.14	.17	100.66	Do.
24	Crimdorf, Saxony	do		57.98	.58		6.22	12.95	22.38					100.21	Hintze, p. 1234.
25	Taberg, Sweden	do		59.75			3.95	14.25	21.10	.31	Fl. 1.16			100.52	Hintze, p. 1238.
26	Cow Flats, New South Wales	do		49.45	9.69	16.33	5.15	11.97	Trace.	4.39			3.03	100.91	Hintze, p. 1240.
27	Bolton, Mass.	do		58.80			3.05	16.47	22.23					100.55	Hintze, p. 1242.

\*Not determined.

## Analyses of asbestiform minerals—Continued.

No.	Locality.	Mineralogical nature.	Extinction angle.	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	Fe <sub>2</sub> O <sub>3</sub>	FeO	CaO	MgO	MnO	K <sub>2</sub> O	Na <sub>2</sub> O	Ign.	Totals.	Authority.
28	Malden, Mass.		0-17	48.60	6.64		18.23	12.55	9.52				2.85	98.39	Geo. P. Merrill.
29	Nahant, Mass.		0-17	51.58	1.88		14.99	9.72	16.65				4.98	99.8	R. L. Packard.
30	Mexico.		0-20	55.48	2.01	12.32		10.35	17.23			1.54	1.47	100.40	Banc. Neues Jahrb., Vol. 1, 1882, p. 159.
31	South Africa (50877).	Crocidolite.	0	52.11	1.01	20.62	16.75	None.	1.77			6.16	1.58	99	Dana, p. 400.
32	Idaho (49521).			53.28					22.87				19.53	98.97	Geo. P. Merrill.
33	Glen Urquhart, Scotland.	Amphibole, var. asbestos.		47.721	3.837	1.76	5.741	3.64	28.745	.150	.186	.264	7.648	100.117	M. F. Heddle.
34	The Bala, Scotland.			56.153	1.539	.388	3.111	11.716	22.461	.769	.188	.692	2.5	99.517	Do.
35	Shinness, Sutherland, Scotland.			56.864	.232	.484	2.124	12.535	23.923	.23	.437	.538	2.325	99.866	Do.
36	Portsoy, Scotland.			56.307	.77	.527	2.323	12.578	23.307	.153	.439	.633	2.941	99.978	Do.
37	Italy.	Fibrous serpen- tine, amianthus.	0	40.30		2.27	.87		43.37				12.72	100.53	J. T. Donald.
38	Canada.		0	40.57		.90	2.81		41.50				13.55	99.33	Do.
39	Victoria, British Columbia.		0	41.95		2.81			41.62				14.85	100.23	Geo. P. Merrill.
40	Alberton, Md. (62778).	Hydrous antho- pnyllite. (?)	0	51.84		1.51			24.54	*	0.25	0.45	20.181	98.77	Do.

† H<sub>2</sub>O at 110°, 10.55 per cent; at bright, red heat, an additional loss of 9.63 per cent.

\* Not determined.