

Solution Studies of Chrysotile, Lizardite and Antigorite

GEOLOGICAL SURVEY PROFESSIONAL PAPER 384-B



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By GEORGE T. FAUST and BARTHOLOMEW S. NAGY

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 $\text{MgO-SiO}_2\text{-H}_2\text{O}$ AND THE SYSTEMS CONTAINING THE
CONGENERS OF MAGNESIUM

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*Reevaluation of the differential
solution method for
serpentine-group minerals*



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SOLUTION STUDIES OF CHRYSOTILE, LIZARDITE, AND ANTIGORITE

By GEORGE T. FAUST and BARTHOLOMEW S. NAGY¹

ABSTRACT

A reevaluation of the differential-solution method for discriminating among chrysotile, lizardite, and antigorite was made in the light of the studies reported by E. J. W. Whittaker and Jack Zussman in 1958. The solvent used is 1*N* hydrochloric acid. The stability of lizardite under the conditions of the test was reaffirmed and accordingly five of the samples previously studied by Nagy and Faust in 1956 were reexamined for lizardite. The method was critically examined both qualitatively and quantitatively on four natural admixtures of clinochrysotile and lizardite and on the lizardite from the type locality, Kennack Cove, The Lizard, Cornwall, England. The solution test differentiates quantitatively between chrysotile and the pair of platy phases lizardite-antigorite. The identity of the platy phase must be determined by X-ray methods. Early work on solution studies of serpentine-group minerals is reviewed and interpreted.

INTRODUCTION

EARLY INVESTIGATIONS

The use of solution and solubility studies as an aid in the identification of minerals has had a long and successful qualitative application in blowpipe analysis and chemical mineralogy. Mineral chemists of an earlier period also made quantitative studies of the effects of acids, alkalis, and salt solutions on minerals. Typical of such studies was the work of Clarke and Schneider (1890). These scientists made a particular study of the solution and decomposition relations of a group of magnesium silicates—olivine, talc, serpentine, chlorite, vermiculite, and phlogopite. Their work on the serpentine-group minerals is of special interest to us.

They investigated the stability relations of the serpentine-group minerals under the following conditions:

1. Heating the mineral in dry gaseous hydrochloric acid at 383°–412°C for periods ranging from 41 to 78 hours, and at 498°–527°C for 18 hours.

2. Heating the mineral in aqueous hydrochloric acid, 1.12 specific gravity (7.32*N*), to dryness, extracting with weak acid, and weighing the residue. (The temperature reached in the vessel over the steam-bath was approximately 90°C and the evaporation probably required about 1 or 2 hours.)
3. Treating the sample as in 2 but using weak hydrochloric acid as the solvent.

The five specimens studied were:

- A, Dull green serpentine (alteration product of pyroxene) from Montville, Morris County, N.J.
- B, Dark-green serpentine from the well-known locality at Newburyport, Mass.
- C, Silky, fibrous chrysotile from Montville, N.J.
- D, Grayish-green picrolite from Buck Creek, N.C.
- E, A grayish-green serpentine from Corundum Hill, N.C.

Our studies on similar materials from these localities suggest the following identifications:

- A, Chiefly lizardite, with some chrysotile.
- C, Chiefly chrysotile, possibly with some lizardite.
- D, Chiefly antigorite, with some chrysotile.

Clarke and Schneider's data and our interpretations thereof are summarized in table 1.

Bearing in mind the experimental conditions—the strength of the acid, the duration of the heating process, and the subsequent extraction of the decomposed residue by weak acid—the results of these experiments do show a pattern of stability. The data obtained using very dilute hydrochloric acid indicate that specimen D, chiefly antigorite, is the most stable sample. The stability of sample A, lizardite, is also indicated. The results of the stability test in which the sample is heated in dry gaseous hydrochloric acid suggests that the fibrous structure of the chrysotile, sample C, may actually increase the resistance of the mineral to chemical

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TABLE 1.—*Chemical studies of serpentine-group minerals by Clarke and Schneider (1890)*

Mineral sample	Interpretation of Faust and Nagy	Result of heating sample in dry, gaseous HCl at—				Result of heating sample in 7.32 N HCl at about 90°C to dryness followed by treatment with—	
		383°–412°C		498°–527°C		Dilute HCl ¹	Very dilute HCl ¹
		MgO extracted (percent)	Time (hours)	MgO extracted (percent)	Time (hours)		
A. Dull green serpentine, Montville, Morris County, N.J.	Chiefly lizardite, with some chrysotile.	10.14	54	10.83	18	Completely decomposed.	Partially decomposed.
B. Dark-green serpentine, Newburyport, Essex County, Mass.	(²)	16.73	68	14.28	18	-----do-----	
C. Silky, fibrous chrysotile Montville, Morris County, N.J.	Chiefly chrysotile, but some lizardite. (See also Nagy and Faust, 1956, p. 828, fig. 4.)	9.98	54	-----	-----	-----do-----	Do.
D. Grayish-green picrolite, Culakenee mine, Buck Creek, Clay County, N.C.	Chiefly antigorite, with some chrysotile.	11.38	78	-----	-----	-----do-----	Partially decomposed; most stable.
E. Grayish-green serpentine, Corundum Hill, Macon County, N.C.	-----	15.25	41	-----	-----	-----do-----	

¹ Not defined by the authors; based on the value of 7.32N given above, the dilute HCl was probably 3.6N (1:1) and the very dilute HCl 0.7N (1:10) (W. T. Schaller, oral commun. 1964).

² Selfridge (1936) examined similar material, and his data suggests lizardite probably admixed with chrysotile.

attack from vapor phase reactions by armoring it with a less pervious coating of silica.

Solution studies of the stability of serpentine-group minerals in hydrochloric acid, bromine, ammonium chloride solution, acetic acid, potassium hydroxide solution, and sodium carbonate solutions were made by Lindner (1893). He repeated the work of Clarke and Schneider (1890) in an attempt to determine the structural formulas of these minerals. Terreil (1885) noted that in boiling acids the compact serpentine rocks decompose slowly, the lamellar and fibrous varieties, more rapidly, and the finely fibrous chrysotiles from Canada and the Tyrol, almost immediately.

RECENT STUDIES

Nagy and Bates (1952) made preliminary studies of the stability of chrysotile asbestos. This work was further refined and standardized by Nagy (1953). Using purified sample materials—a chrysotile from Thetford, Quebec, and an antigorite from Val Antigorio, Italy—a solution test was devised which differentiated between the two minerals on the basis of their resistance to acid treatment. The specimens were placed in 1N hydrochloric acid, and the temperature was held at 95°C for 1 hour. Chrysotile was decomposed by this treatment, and antigorite was unaffected. The destruction of the crystal structure of chrysotile by hydrochloric acid was measured by means of the X-ray diffractometer using the intensity of the (002) reflection at $2\theta = 12.02^\circ \pm$ (Cu/K $\alpha = 1.5418$ Å Ni filtered) as a standard.

The method was then applied to a suite of serpentine-group minerals, and the results were reported by Nagy and Faust (1956). The results of the solution tests were interpreted on the basis of chrysotile and antigorite being the only phases present. Chief reliance was placed on the electron microscope examinations of the specimens studied which showed two types of material; one fibrous (tubular), the other irregular or flaky.

Whittaker and Zussman (1958) questioned the reliability of the interpretation that all flaky particles are antigorite and showed that the polymorph lizardite, which has a platy structure, could have been easily mistaken, in some of the samples, for antigorite. They further investigated the solution behavior of one of their specimens of lizardite under the identical conditions used by Nagy and Faust (1956) and found that its powder diffraction pattern is only slightly weakened. (Treatment with somewhat stronger acid destroys the lizardite structure while still not affecting that of antigorite.)

ACKNOWLEDGMENTS

We wish to acknowledge the help of Brian J. Skinner and Dora von Limbach, both of the U.S. Geological Survey, who prepared the diffractometer patterns for this study. Professors Thomas F. Bates and O. F. Tuttle of the Department of Mineralogy, Pennsylvania State University, very kindly arranged to have us supplied with fragments of the minerals from the Frederick A. Genth Collection, which are similar to those

previously studied at that institution. Dr. George Switzer, Curator of Mineral Sciences, U.S. National Museum, supplied us with a specimen of lizardite from the type locality at The Lizard, Cornwall, England.

REEXAMINATION OF SERPENTINE-GROUP MINERALS

Recognizing the validity of the doubts expressed by Whittaker and Zussman (1958), we have reexamined some of the samples studied previously and have found that some of the flaky and platy phases actually are lizardite and not antigorite.

We have used X-ray powder diffraction methods to examine five of the specimens on which we previously reported and which we considered, on the basis of the studies of Whittaker and Zussman (1958), to contain lizardite. The data are given in table 2 and figure 43. The specimens studied here were taken from the same hand specimen as the previously studied samples, but they are not necessarily identical. All samples examined with the X-ray diffractometer were prepared as smear mounts on glass.

Photomicrographs of serpentine-group minerals similar to those studied previously by Nagy and Faust (1956) and reinvestigated in this study are shown in figure 44. The photomicrographs illustrate the structural complexity of the natural mixtures. Material

that exhibits a smearlike appearance and stringy character yields X-ray powder diffraction patterns having broad and diffuse bands and lines.

The original specimens used in the previous study by Nagy and Faust (1956) were taken from the Genth Collection at the College of Mineral Industries, Pennsylvania State University. Professor O. F. Tuttle of the Department of Mineralogy very kindly arranged to have these specimens resampled for us. Representative, but not necessarily identical, samples were obtained for four of the minerals. We were unable, however, to get sufficiently pure specimens of No. 14, aphrodite from Grenville, Canada, which contained calcite, talc, and probably a trace of clinochrysotile, and of No. 16, marmolite from Blandford, Mass., which contained magnesite, chlorite, and quartz.

We have added the data on the clinochrysotile from Thetford, Canada, to table 2 to record the absence of both antigorite and lizardite from this sample.

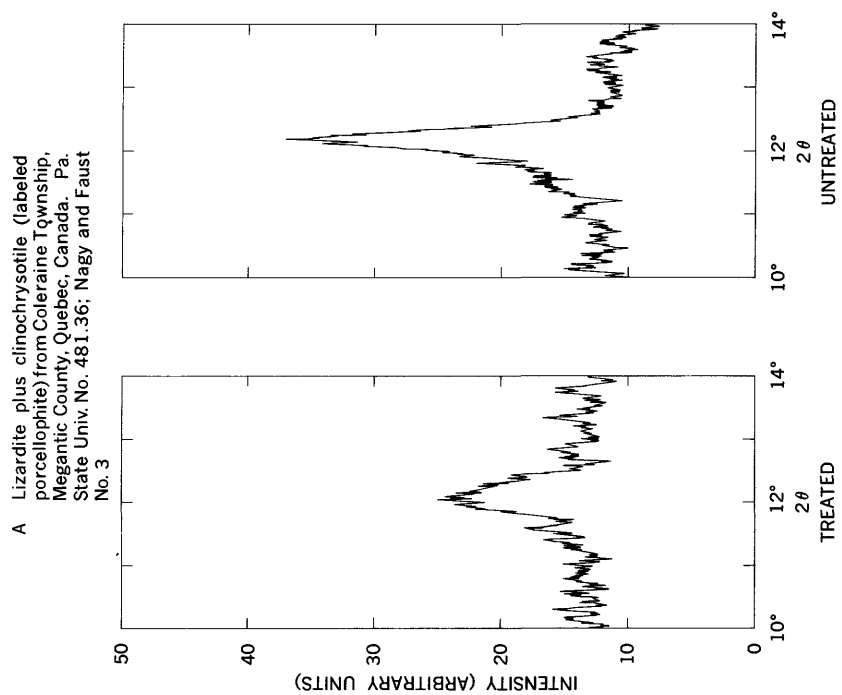
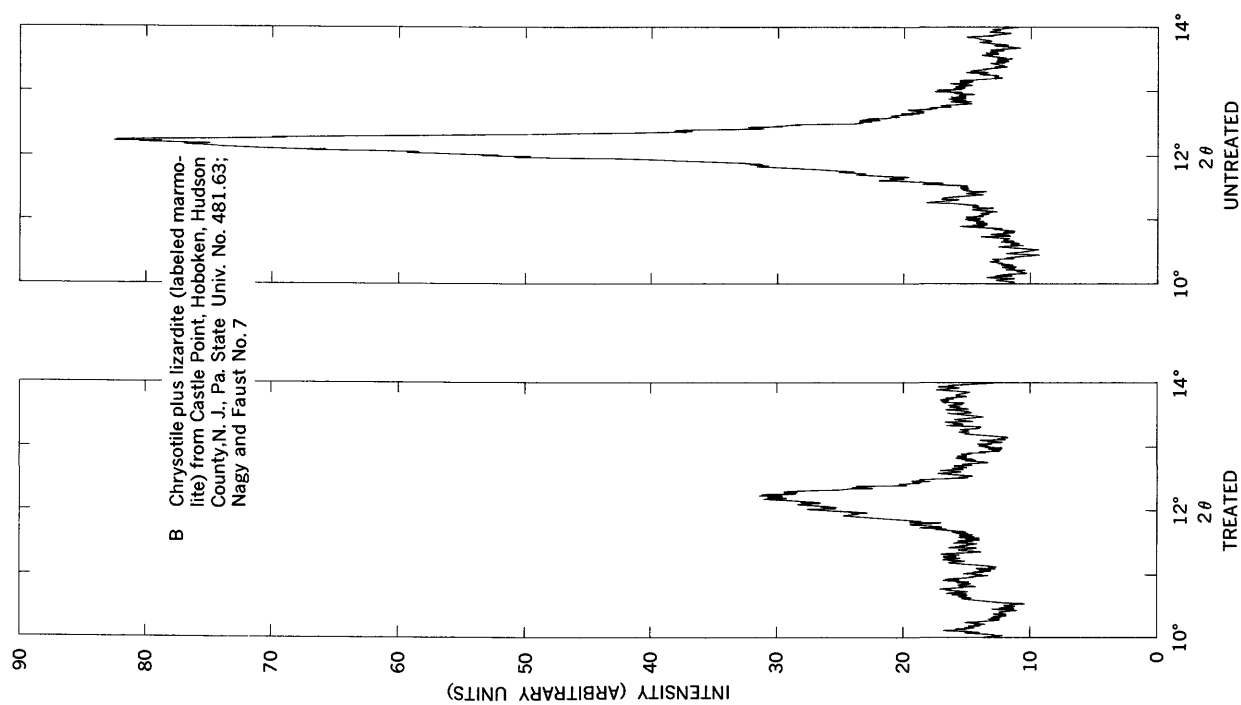
The data in table 2 show that an unequivocal determination of the polymorph which constitutes the platy phase in these natural admixtures is necessary for the interpretation of the results of the solution study. The differences between some of the quantitative results obtained in the two studies can be explained only by the demonstrated heterogeneous nature of the hand specimens.

TABLE 2.—X-ray diffraction studies of some serpentine-group minerals previously examined by Nagy and Faust (1956)

Sample	Sample label	Locality	Physical character	X-ray determination		
				Mineralogy of untreated sample	Mineralogy of acid-treated sample	Lizardite content (percent) (remainder is chrysotile)
3-----	Porcellophite, Pa. State Univ. No. 481.36.	Coleraine Township, Megantic County, Quebec, Canada.	Massive-----	Lizardite, chrysotile and dolomite.	Lizardite-----	48
4-----	Chrysotile-----	Near Montville, Morris County, N.J.	Fibrous (see Nagy and Faust, 1956, fig. 4, p. 828).	Chrysotile and lizardite.	-----do-----	50
7-----	Marmolite, Pa. State Univ. No. 481.63.	Castle Point, Hoboken, Hudson County, N.J.	Massive-----	Lizardite and chrysotile.	-----do-----	23
9-----	Antillite, Pa. State Univ. No. 481.25.	Havana, Havana Province, Cuba.	Massive (showing a few flakes).	-----do-----	-----do-----	56
10-----	Antillite, Pa. State Univ. No. 481.26.	-----do-----	-----do-----	-----do. ¹ -----	-----do-----	46
	Chrysotile-----	Near Thetford, Megantic County, Quebec, Canada.	White bundles of fibers.	Clinochrysotile and a little magnetite.	Dehydrated silica gel with a few protected fibers of clinochrysotile in the larger bundles. ²	0

¹ Weak lines at 2.10 Å± and 1.61 Å± suggest corundum.

² Trace of clinochrysotile indicated by faint lines of the (002) and (004) reflections.



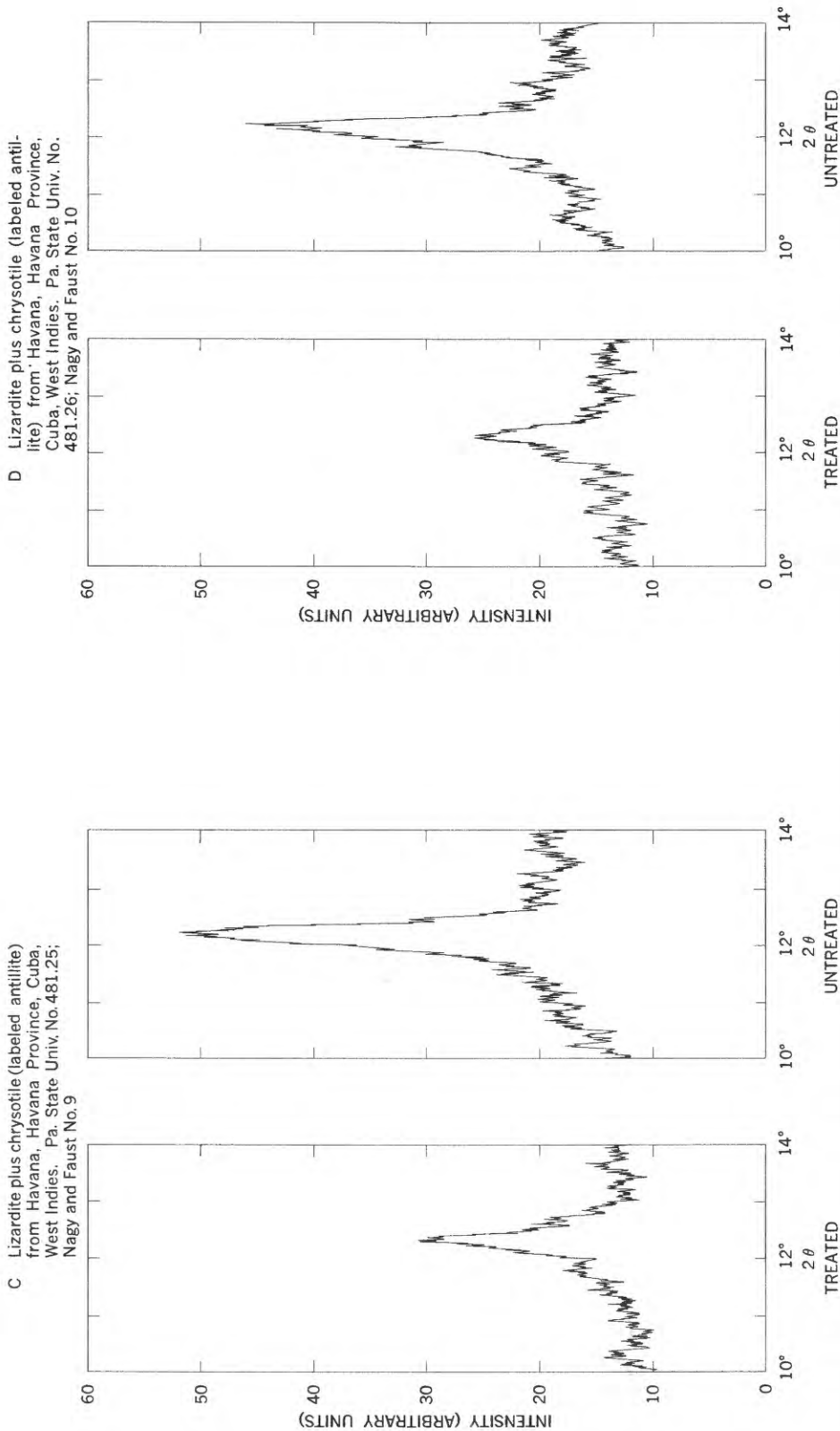
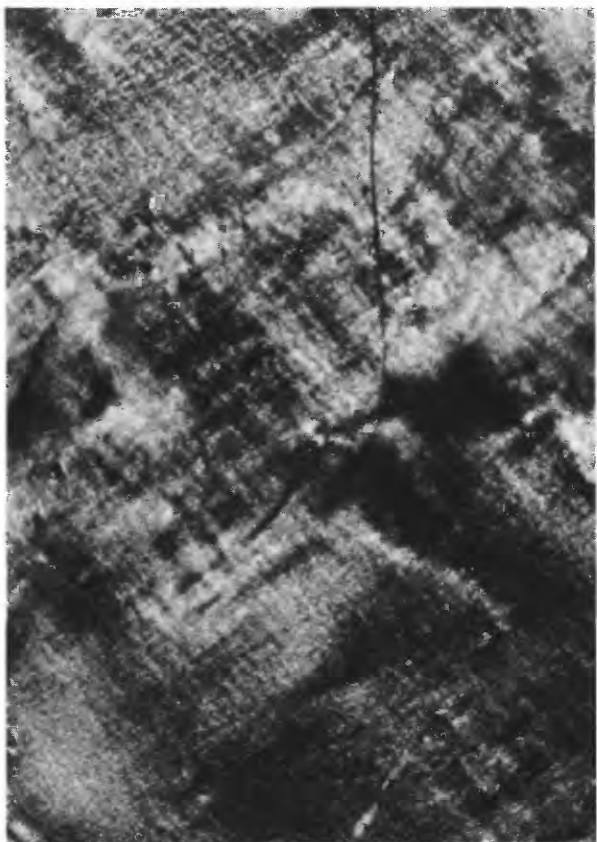
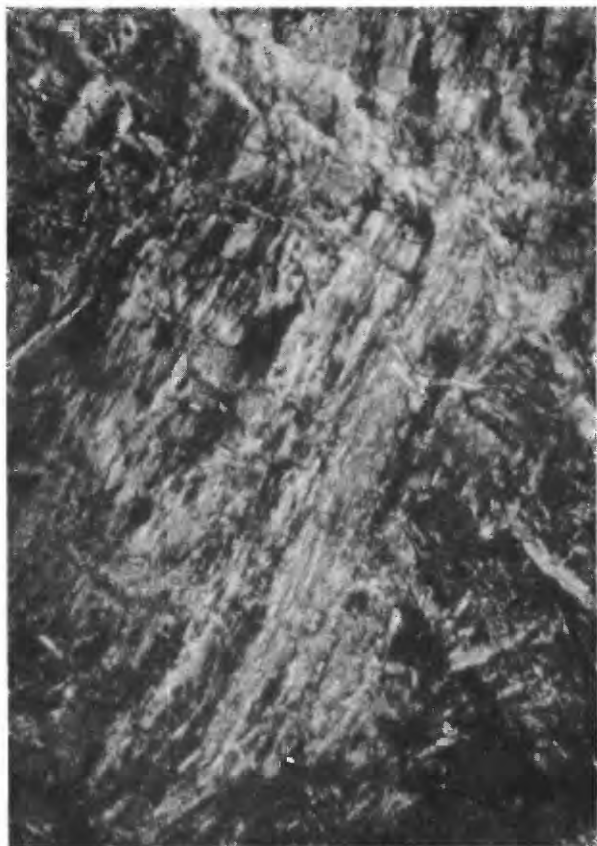
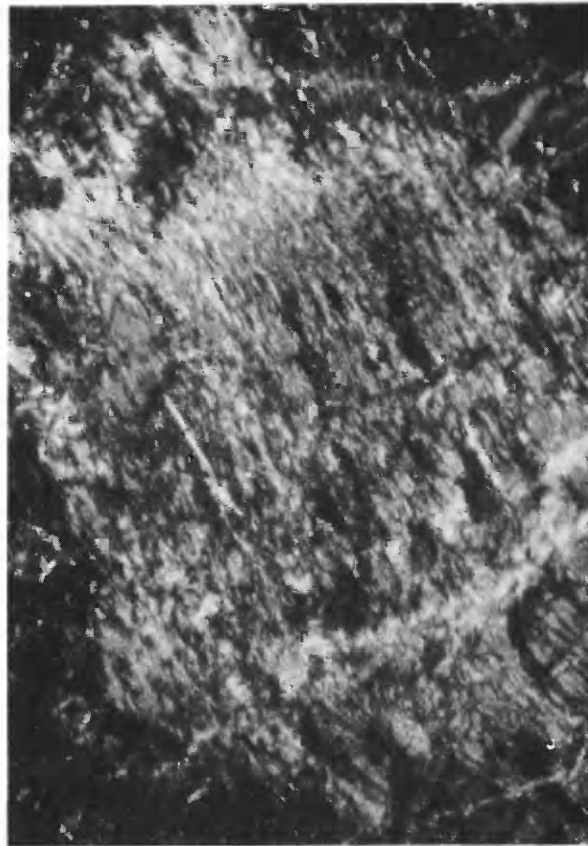


FIGURE 43.—Tracings of X-ray diffractometer patterns of the (002) reflections of natural and 1N hydrochloric acid treated specimens of serpentine-group minerals.

*A**B**C**D*

1 cm

THE SOLUTION PROCESS

The extent of the reaction between hydrochloric acid and the serpentine-group minerals depends on the following factors:

Concentration of the acid.—In their studies, Clarke and Schneider (1890) and others noted that too strong a concentration may cause such rapid attack as to armor the undecomposed material with silica and thus effectively remove it from reaction. An acid concentration that is too weak, however, requires inordinate time for the reaction process. Nagy and Bates (1952) and Nagy (1953) found that 1*N* hydrochloric acid was suitably concentrated.

Temperature of the reaction.—Nagy and Bates (1952) and Nagy (1953) found that $95^{\circ}\pm 1^{\circ}\text{C}$ was a suitable and convenient temperature, and that it permitted the reaction to proceed at a speed sufficient for a practical laboratory test.

Duration of the chemical process.—Nagy and Bates (1952), Bates (1952), and Nagy (1953) found, by trial and error, that 1 hour was an optimum time limit. This was confirmed in the present investigation. If the sample, consisting only of serpentine-group minerals, is attacked by the acid, the color of the solution at the end of the run will in general be greenish yellow because of the entry of iron and other ions into the solution.

Grain size.—The differential solution rate of the serpentine-group minerals is strictly valid only if the specific areas of the samples are similar. Nagy and Bates (1952) measured the surface area of the chrysotile from Thetford, Quebec, and the antigorite from Val Antigorio, Italy, using the Brunauer-Emmett-Teller gas adsorption method and found the values to be 7.24 m² per g and 11.40 m² per g, respectively. These were the standard samples used in their original work. In the present study most of the samples were ground to pass 65-mesh bolting cloth. We tested, for several samples, the nature of the residue left after the acid treatment to see if texture or intimacy of association in the natural admixtures perceptibly slowed down the decomposition of the chrysotile. We did not find any significant evidence of such behavior. Microscopic, X-ray powder diffraction, or differential thermal analysis methods can be used to confirm such a relationship if there is any suspicion that textural control fortui-

tously protects the chrysotile from attack. Differential thermal analysis and X-ray studies by Nagy (1953) have also shown the efficacy of the acid attack. That very small amounts of chrysotile may be protected from reaction is always a possibility, and when realized it means that the solution value for chrysotile is minimal.

The solution method is independent of the common impurities in serpentines because it is specifically adjusted to bring about the destruction of the clinochrysotile structure. Thus brucite, stevensite, the carbonates, and talc do not interfere because there is no coincidence with the (002) spacing of chrysotile at 7.36 Å. If a member of the 14 Å chlorite group is present as an impurity, a correction may have to be made to the area at the base of the (002) peak on the high-angle side. The pyrogenic minerals olivine, enstatite, and magnetite also do not interfere with X-ray measurements. Some of these impurities, if present with either the chrysotile-lizardite assemblage or the chrysotile-antigorite assemblage, may, however, because of their solubility, help to color the acid solution so that even if the attack on the antigorite or lizardite is slight, the color of the solution may be misleading.

The solution process is differential, and therefore it is necessary to recognize the fact that lizardite and antigorite are also slightly attacked by the acid solution, particularly in the exceedingly fine grain sizes, whereas the crystal structure of the chrysotile is completely destroyed. It is this disparity in stability that makes the method practical.

CRITICAL EXAMINATION OF THE EXPERIMENTAL PROCEDURES

DESCRIPTION OF THE MATERIAL SELECTED FOR STUDY

To check on the stability of lizardite we used a specimen from the type locality, Kennack Cove, Cornwall, England (U.S. Natl. Mus. No. 114569). This sample contains about 5–10 percent talc. To prepare the lizardite for study it was gently crushed, inspected under the binocular microscope so that obvious grains of impurities could be removed, and then sieved through 65-mesh bolting cloth. Most of the sample consists of pseudohexagonal plates. A diffractometer trace of this sample shows a peak for talc at 9.3 Å.

Four mixtures of the polymorphs lizardite and clinochrysotile were examined qualitatively, quantitatively,

FIGURE 44.—Photomicrographs of serpentine-group minerals similar to some of those studied in this research and illustrating the complexity of the mixtures. A, Lizardite plus chrysotile (porcellophite), from Middletown, Delaware County, Pa., U.S. National Museum No. R4645. Fabriclike aspect interrupted by areas of discontinuity. Crossed polars. Material is similar to Nagy and Faust (1956) No. 3. B, Chrysotile plus lizardite C>L. From underground workings, New Almaden mine, Santa Clara County, Calif. Crossed polars. Material is similar to that reported in table 3. C, Chrysotile plus lizardite (antillite), from Havana, Havana Province, Cuba, West Indies. U.S. National Museum No. 46265. Shows distorted character of poorly crystallized and stringy serpentine group minerals. Crossed polars. Material is similar to Nagy and Faust (1956) No. 10. D, Chrysotile plus lizardite (antillite). Same thin section shown in C, but shows a slightly different orientation of the fibers and plates. Material gives very poor X-ray powder diffraction patterns. Crossed polars.

or by a combination of the two methods. These samples are described as follows:

1. Lizardite plus clinochrysotile, from Snarum, Modum Canton, Parish of Buskerud, Norway.
2. Clinochrysotile plus lizardite, from the New Almaden mine, Santa Clara County, Calif.
3. Lizardite plus clinochrysotile, from near Forest Hill, Harford County, Md.
4. Lizardite plus clinochrysotile, from the campus of the Stevens Institute of Technology, Castle Point, Hoboken, Hudson County, N.J.

QUALITATIVE EXAMINATION

In the course of mineralogical and petrological studies of suites of specimens it is often desirable and sometimes necessary to treat the samples with a 1:1 hydrochloric acid solution (6.1*N*) at room temperature to eliminate iron oxide coatings, large amounts of carbonates, and other acid-soluble minerals to effect a concentration of certain other minerals. If serpentine-group minerals are present in such assemblages it is

necessary to get some idea of the damage done to them by the acid treatment.

Three samples of the lizardite-clinochrysotile mixtures were treated with 1:1 hydrochloric acid at room temperature for periods of time generally ranging from 15 minutes to 1 hour. Results for samples treated for 1 hour are shown in table 3 and figure 45. The X-ray powder pattern shows that clinochrysotile is significantly destroyed and may be completely removed by the ordinary treatment for the purification and concentration of mineral grain fractions. Therefore, when effecting separations by acid treatment, the presence of serpentine-group polymorphs should be checked to assess the probable damage.

QUANTITATIVE EXAMINATION

Whittaker and Zussman (1958) found that the platy polymorph lizardite was stable in the solution technique used by Nagy and Faust (1956) and reported as follows: "We have treated green massive serpentine (which had been identified as lizardite by X-ray diffraction)

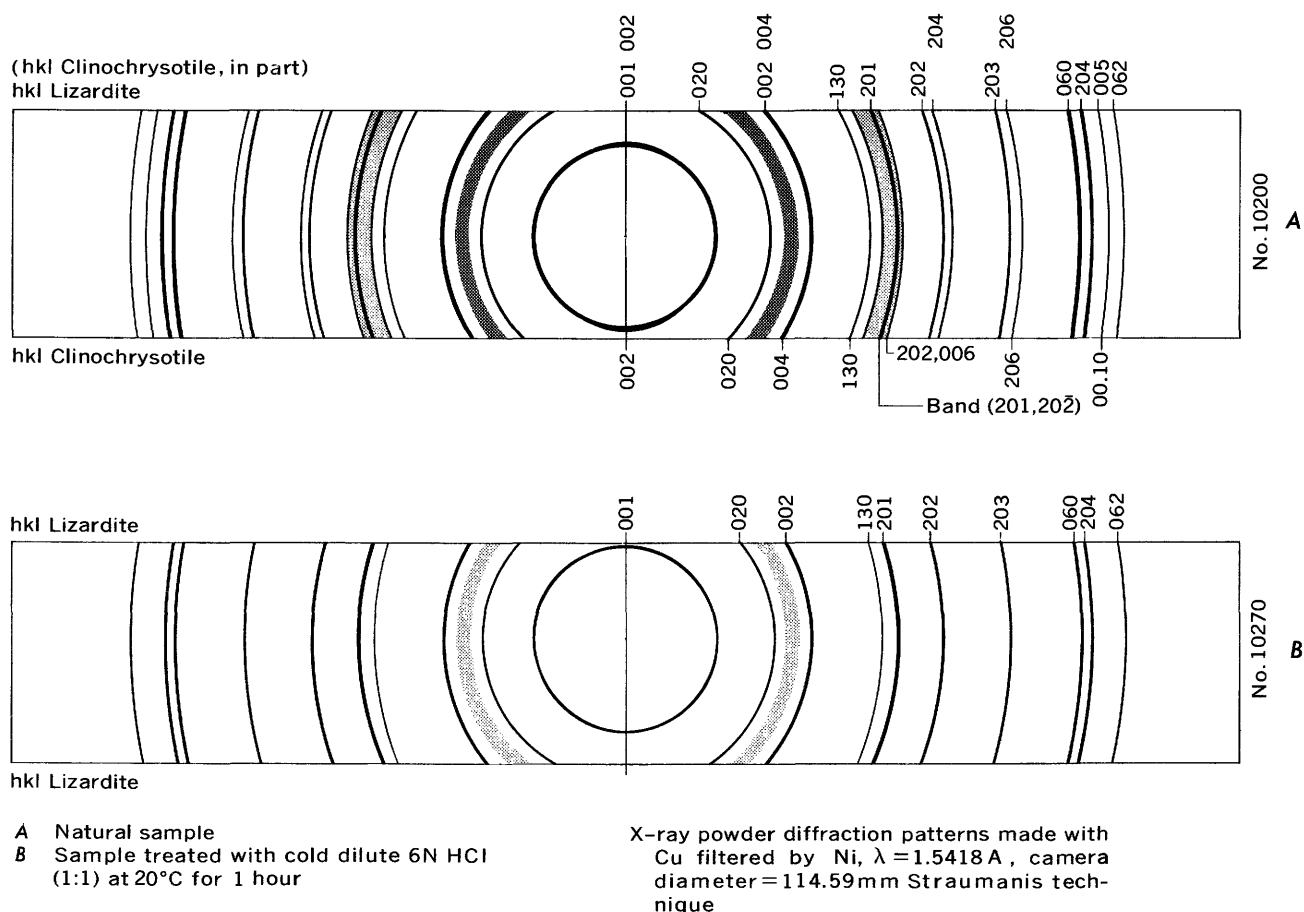


FIGURE 45.—A graphic representation of a selected portion of the X-ray powder diffraction pattern of a natural mixture of lizardite and clinochrysotile from Snarum, Modum Canton, Parish of Buskerud, Norway.

TABLE 3.—*Effect of treatment with cold (20°C) dilute hydrochloric acid (1:1) for 1 hour on the appearance of selected lines in the X-ray powder diffraction pattern of clinochrysotile*

Untreated clinochrysotile data (of Whittaker and Zussman, 1958)			Acid treated		
hkl	d _{obs}	I	Lizardite plus clinochrysotile from—		Chrysotile plus lizardite from New Almaden mine, Santa Clara County, Calif.
			Snarum, Norway	Campus of Stevens Inst. of Technology, Hoboken, N.J.	
130-----	2.66	Medium weak.	} Band almost completely removed. Faint line----- Band greatly reduced in intensity, almost removed. Faint line-----	Band present but weak-----	Band present but faint.
202, 006--	2.456	Strong-----		Very weak-----	Faint suggestion of line.
204-----	2.096	Medium-----		Band very weak-----	Do.
206-----	1.748	do-----		Very weak-----	Do.
00.10-----	1.465	Weak-----			

with one normal HCl at 95°C for one hour as prescribed by Nagy and Faust, and have found that its powder diffraction pattern is only slightly weakened. (Treatment with somewhat stronger acids destroys the lizardite structure while still not affecting that of antigorite)."

We have further investigated this stability using lizardite from the type locality at The Lizard, Cornwall, England, described by Midgley (1951) and natural admixtures of lizardite and clinochrysotile from Snarum, Parish of Buskerud, Norway, from New Almaden mine, Santa Clara County, Calif., and from Forest Hills, Hartford County, Md. The results are shown in table 4 and figure 46. Our studies confirm the work of Whittaker and Zussman (1958) on the stability of the polymorph lizardite under the conditions of the differential solution test.

With this knowledge we can see that the stability of lizardite is also suggested by Nagy and Faust's graph

TABLE 4.—*X-ray diffraction studies of acid-treated lizardite and mixtures of chrysotile and lizardite*

Name	Locality	Physical character	Lizardite content (in percent) as determined by the X-ray method (remainder is chrysotile)
Lizardite plus clinochrysotile, L>C.	Snarum, Modum Canton, Parish of Buskerud, Norway.	Massive, yellow-----	72
Chrysotile plus lizardite, C>L.	New Almaden mine, Santa Clara County, Calif.	Massive, green-----	26
Clinochrysotile plus lizardite.	Forest Hills, Hartford County, Md.	Massive, flesh colored.	10
Lizardite and talc----	Kennack Cove, The Lizard, Cornwall, England.	Aggregates of small white crystals of lizardite with a small amount of talc.	100

(1956, fig. 6, p. 835) showing the relationship of the intensity of the (001) [now the (002)] reflection to the

antigorite content, if the abscissa is corrected to read "percent antigorite or lizardite."

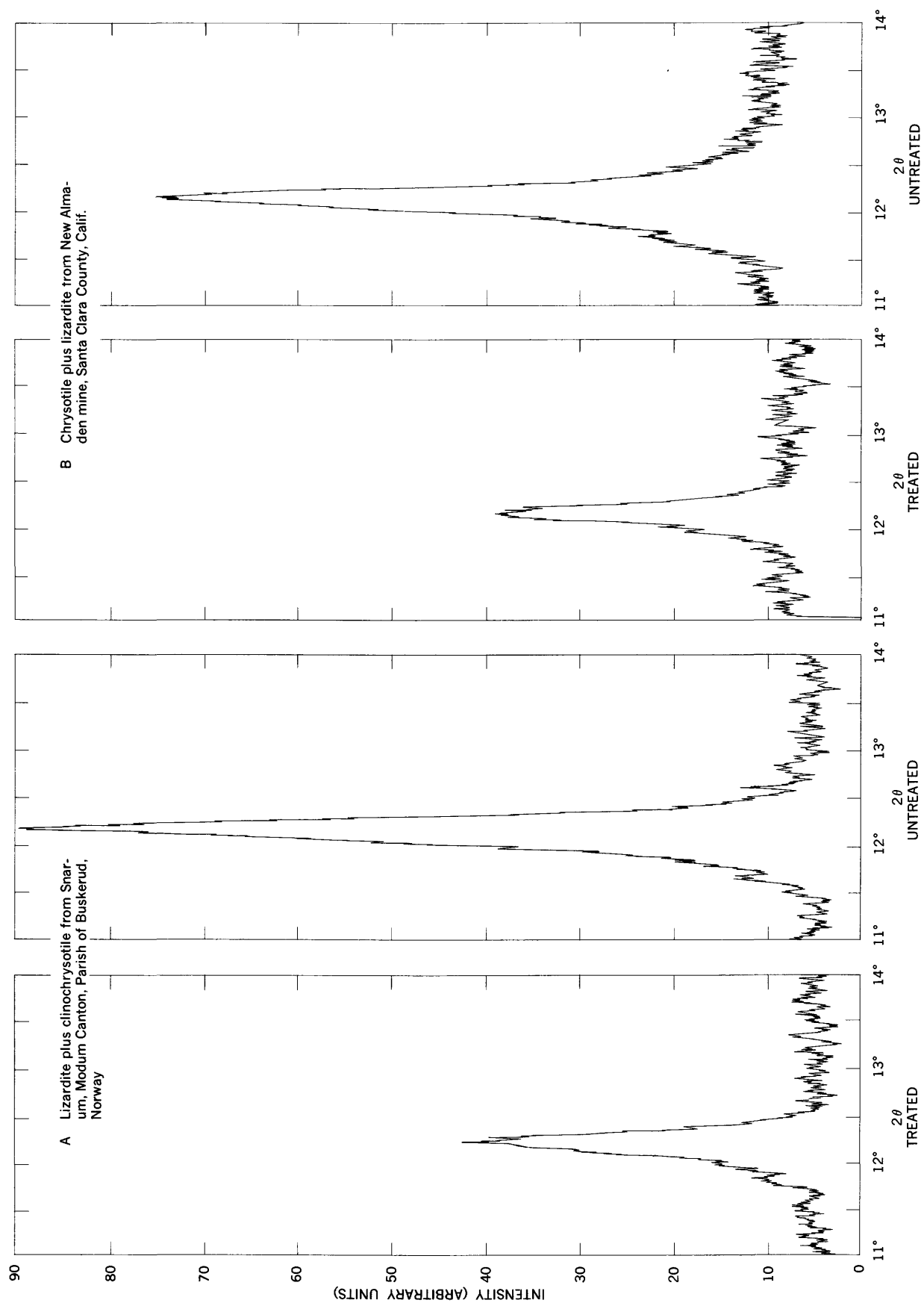
The electron micrograph of chrysotile No. 4 (Nagy and Faust, 1956, fig. 4) from the Montville area, Morris County, N.J., shows it to be a mixture of clinochrysotile fibers and plates. The results of the present study show that it is actually a mixture of clinochrysotile and lizardite. The same admixture was found in a sample studied by Faust and Fahey (1962, p. 10). The solution test shows it to be a mixture of 50 percent clinochrysotile and 50 percent lizardite. A differential thermal analysis record of this acid-treated mixture shows that the residue exhibits the high-temperature endothermic trough of the undecomposed lizardite (Nagy, 1953, fig. 3).

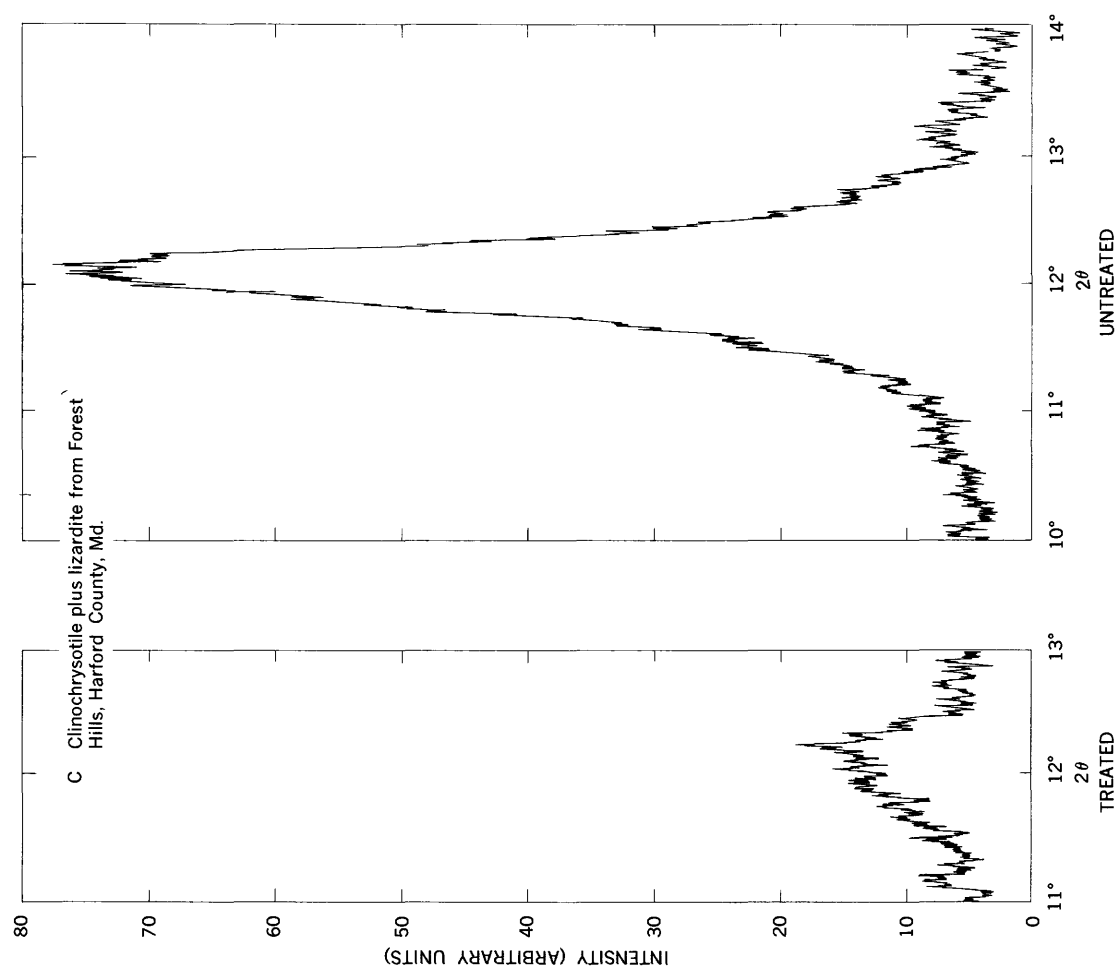
Ruotsala, Pflugger, and Dow (1964) have successfully used the differential solution technique in a study of iron-rich serpentine and chamosite from Ely, Minn. They used the method to determine the amounts of antigorite and clinochrysotile in mixtures.

CONCLUSION

We have investigated the stability of lizardite samples using the solution test of Nagy (1953). Our results confirm the observations of Whittaker and Zussman (1958) that lizardite is stable under the conditions of the test. A reexamination of five of the specimens reported by Nagy and Faust (1956) as mixtures of chrysotile and antigorite in the light of the studies of Whittaker and Zussman has confirmed their opinion that some of the flaky or platy phases are actually lizardite and not antigorite. In the paper by Nagy and Faust (1956), table 5 (p. 834, 835) should be corrected for the specimens reported here. In figure 6 (p. 835), the abscissa should read "% antigorite or lizardite"; and figure 4 (p. 828) should read "a natural mixture of chrysotile fibers and lizardite flakes."

The importance of the acid strength (1*N* hydrochloric acid), the time of the reaction (1 hour), and the temperature of the reaction (95°C), stressed by





The patterns for A, B, and C were obtained under the following conditions

Cu filtered by Ni
 KVP = 35
 Receiving slit = 1°
 Multiplier = 1
 Scanning speed = 1/2° per min
 Chart scale = 1° per inch
 $\lambda = 1.5418 \text{ \AA}$
 MA = 20
 Scale factor = 2
 Time constant = 4 sec

FIGURE 46.—Tracings of X-ray diffractometer patterns of the (002) reflections of natural and 1N hydrochloric acid treated specimens of serpentine-group minerals. Part D on next page.

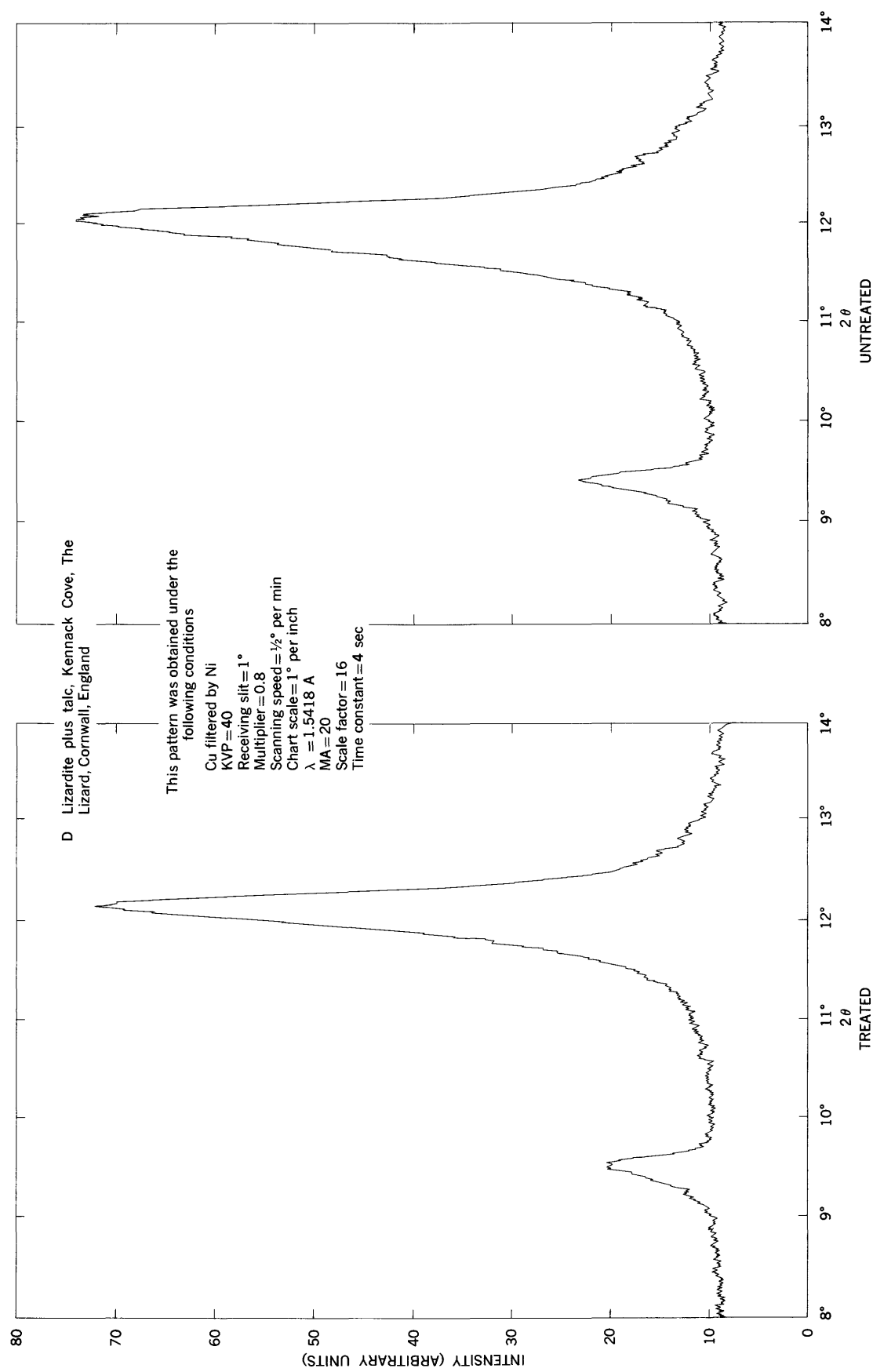


FIGURE 46.—Tracings of X-ray diffractometer patterns of the (002) reflections of natural and 1N hydrochloric acid treated specimens of serpentine-group minerals—Continued.

Nagy and Bates (1952) and reiterated by Whittaker and Zussman (1958), has been reaffirmed here.

The common use of dilute hydrochloric acid for the removal of carbonates or iron oxides from mineral separates may destroy most or all of the clinochrysotile. The X-ray powder diffraction patterns of acid-treated specimens show a weakening in the intensity of the lines arising from the presence of clinochrysotile. This particular X-ray technique is very sensitive to intensity changes of the X-ray diffraction lines even though they are broad and diffuse.

The differential solution method was used to test the stability of lizardite from the type locality, The Lizard, Cornwall, England, and in three natural admixtures with clinochrysotile. Its relative stability under the conditions of the test was confirmed. The samples

studied in this research included specimens whose structures were flaky, fibrous, and lamellar; crystalline aggregates; and massive material. For each type the stability of the lizardite in the admixture was observed.

An examination of the data of the previous solution studies on serpentine-group minerals by Clarke and Schneider (1890) and Terreil (1885) also shows the same pattern of stability of lizardite and antigorite and the instability of chrysotile. The parallel stability relations of iron-rich serpentine-group minerals studied by Ruotsala, Pfluger, and Dow (1964) is noted.

In Professional Paper 384-A, "The serpentine-group minerals," by G. T. Faust and J. J. Fahey (1962 and 1964 editions), the following corrections should be made:

Page 2, column 2, line 35 from top.	In the formula $[\text{Mg}_{5.0}\text{Ni}_{0.5}\text{Fe}^{2+}_{0.5}]\text{Si}_4\text{O}_{10}(\text{OH})_8$ the Si_4 should read Si_4 .
Page 39, figure 19	In the tetrahedral scale, the spacing between 4.80 and 5.00 is incorrect. When corrected the points F-26 and F-48 will lie closer to the line.
Page 40, column 2	The formula for 95 per cent serpentine and 5 per cent Fe_2O_3 should be $[\text{Mg}_{5.77}\text{Fe}^{3+}_{.35}][\text{Si}_{3.85}\text{O}_{10}(\text{OH})_8]$.
Page 43, figure 21	Serpentine of Strunz in the lower right hand corner should be deleted.
Page 46, figure 23	In the graph for the Val Antigorio serpentine, the octahedral scale should run from 6.00 to 5.80 instead of 6.40 to 6.20.
Page 58, figure 30	C-187 should be C-817.
Page 88, insert after Delesse the following reference.	Dienemann, Wilhelm and Burre, Otto, 1929, <i>Die Nutzbaren Gesteine Deutschlands</i> : Stuttgart, Verlag von Enke, Band 2, xvi+485.

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