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Montana Talc; Problems in Physical Properties

E. C. Armstrong

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MONTANA TALC:
PROBLEMS IN PHYSICAL PROPERTIES

by

E. C. ARMSTRONG

A Thesis
Submitted to the Department of Geology
in partial fulfillment of the
Requirements for the degree of
Bachelor of Science in Geological Engineering

MONTANA SCHOOL OF MINES
BUTTE, MONTANA
June, 1950
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ABSTRACT

General information on talc, including foreign and United States occurrences, origin, and uses is covered. Montana deposits are discussed in greater detail as to location, geology, mineralogy, and mining. Studies of talc by petrographic and x-ray methods and an experiment to determine the porosity are described and discussed. The conclusion is reached that porosity and permeability are important factors in determining the behavior of talc when fired.

INTRODUCTION

Why does the firing of talc result in high breakage in one grade and low breakage in another? What property is it that makes one grade of talc 20 to 25 times as valuable as another? These questions have arisen in the past few years--since the discovery of the fact that massive talc, called steatite or lava talc, makes an ideal electrical insulator in vacuum tubes and in other places where precision insulators are required.

This writer, in attempting to answer the above questions, conducted some experiments to try to discover differences in the physical properties, because chemical composition
in the physical properties, because chemical composition seems to have no effect on the behavior of talc under firing. X-ray spectrograms and thin sections were made, and experiments were performed to determine the amount of water absorption of each grade.

**TALC IN GENERAL**

**Composition**

Talc is a hydrous magnesium silicate having the formula, Mg$_3$Si$_4$O$_{10}$(OH)$_2$, and the theoretical composition of MgO, 31.7%; SiO$_2$, 63.5%; and H$_2$O, 4.8%. However, according to Spence (8,1), the composition may differ considerably; magnesium to silica ratios may range from 1:1 to 4:3. In 99 analyses tabulated by Spence, magnesia ranges from 22.68% to 34.01%, silica from 33.68% to 64.06%, and water from 0.28% to 12.95%. The wide range in silica and water may be due to the presence of impurities in the samples.

**Types**

Talc is divided into three grades, ceramic, cosmetic, and lava. Ceramic grade is common talc, and most of the world production of talc is of this grade. Cosmetic talc is a pure material of light color. Lava talc, or steatite, is the most valuable grade. It is usually more earthy in appearance than either ceramic or cosmetic grades, and does not change in shape or size to any considerable extent upon firing.
Soapstone is a mixture of talc and other minerals, usually mostly dolomite. Industrial usage of the terms talc and soapstone differ; ground soapstone may be called talc or sawed talc may be called soapstone. The colors of the three types range from white to gray or green in hand specimens, but most talcs grind to a white or nearly white powder.

Occurrence

Talc is widely distributed throughout the world, but its use is largely confined to the more advanced countries. Talc is produced in the United States, Manchukuo, France, Italy, Norway, India, Germany, Canada, Sweden, Sardinia, Russia, South Africa, China, Japan, Australia, Egypt, Finland, Greece, Morocco, Rumania, and Spain. In the United States, talc is mined in New York, Vermont, Massachusetts, Rhode Island, New Jersey, Pennsylvania, Maryland, Virginia, North Carolina, Georgia, California, Washington, Nevada, and Montana.

The geologic distribution of talc is much more limited than the geographical distribution. Ultrabasic igneous rocks, metamorphosed dolomites and dolomitic limestones, schists, and gneisses are the source rocks. Talc is most commonly found in old rocks, generally pre-Cambrian in age, although the finest French and Italian talcs are found in rocks of Jurassic age.
Vermont deposits are in altered ultrabasic rocks which intruded schists and gneisses. Other deposits resulting from ultrabasics are in Virginia, Massachusetts, Pennsylvania, Maryland, North Carolina, and Georgia. Deposits in metamorphosed dolomites and dolomitic limestone are found in New York, North Carolina, Georgia, California, Nevada, and Montana.

Talc deposits may occur as lenses, beds, or veinlike masses. The lenticular deposits are the most common. Because talc is a metamorphic mineral, it is usually found in disturbed regions, where the dip commonly approaches 90°.

Minerals commonly associated with talc are serpentine, tremolite, chlorite, anthophyllite, diopside, quartz, prehnite, actinolite, tourmaline, biotite, apatite, magnetite, titanite, pyrrhotite, dolomite, calcite, and pyrite. These are essentially minerals of metamorphosed rocks.

Origin

It is generally agreed that talc results from the hydrothermal alteration of basic and ultrabasic igneous rocks and dolomites. In his discussion of the Vermont talc deposits, Gillson (3) brings forth the following points: (1) the talc occurs in serpentine rock where it was formed after the process of serpentinization was complete, (2) talc replaced the serpentine either directly or after an intermediate chlorite stage, and (3) dolomite is always associated with
the talc. He considers that "the Vermont talc lenses are a kind of contact metamorphic deposit, formed by hot alkaline solutions, low in silica, and toward the last rich in magnesia and carbon dioxide, which were given off by a large igneous body... at a time soon after the intrusion and serpentinization of the exposed plugs of basic igneous rock" (p.275). He points out that the large igneous body may have been either basic magma or granite.

Hess (4), after studying alteration in 150 ultrabasic intrusions, came to the conclusion that talc was formed later than serpentine by "hot, dilute, aqueous solutions usually carbonate-bearing" (p.643). He disagreed with Gilison's description of the solutions, because solutions of so complex a nature would not be likely to be widespread. Hess believes that the only change in the solutions from serpentine to talc was cooling.

Both Hess and Gilison agree that the paragenesis of talc is original rock, amphibole, serpentine or chlorite, and talc. Both of these writers believe that dynamic stress was not active during the formation of talc.

An older idea is that of C. H. Smyth, Jr., who, according to Ladoo (5,5), believed that the talc found in dolomites resulted from the alteration of silicate impurities in the dolomite to tremolite, and the subsequent change of tremolite to talc through the action of ground water containing carbon dioxide. No mention is made of the agent which was
active in the formation of the tremolite. Most authors, however, believe that hydrothermal solutions were responsible for the talc in dolomites. The association of igneous bodies with most talc deposits seems to substantiate this theory.

Uses

Ladoo (5, 66-67) lists more than 120 uses of talc, but he points out that substitutes may be employed in most of the uses. The paint industry, using about 25 per cent of the United States consumption, is the leading user of talc. Other important uses of talc are in ceramics, roofing, paper, rubber, toilet articles, and foundry facings. Some of the uses listed by Ladoo include textile manufacture, soap manufacture, lubricants, electrical insulation, rope and twine manufacture, leather manufacture, glass industry, cleaning and polishing grains and seeds, veterinary surgery, candy and chewing gum manufacture, crayons and pencils, casting molds, refractories, and polishing agents.

Powdered talc is used as a filler and a pigment in paints, and is especially important in cold water paints. As a filler in paper, talc is better than clay. In the ceramics industry, talc is used in glazes and as a body material. It is also used in sagger bodies and kiln furniture.

In the roofing industry, talc is used in asphalt roll roofing and in shingles as a filler, as granules, and as a
dusting preparation to prevent sticking. Most of the minor uses are for filler or anti-sticking duster. The oil absorbing properties of talc are utilized in many industries such as leather manufacture.

Most talc is used ground, the size being dependent upon the use. Ladoo says, "The most important commercial grades of ground talc are generally sold as 200-mesh products, but wide variations occur in the products actually delivered by mills" (5, 87). Eight sizing tests recorded by Ladoo show more than 90 per cent minus 300-mesh for all but one sample. Only three ran less than 95 per cent minus 300-mesh.

Cosmetic talc is usually selected for good white color and is used in toilet powders, creams and lotions. Sizing through silk bolting rolls is practiced in the toiletries industry.

Lava talc is formed into insulators by machining, and is fired at about 1100°C. The finished material is harder than glass and has a high strength. The compressive strength is from 20,000 to 30,000 pounds per square inch, and the dielectric strength is from 75 to 250 volts per thousandth of an inch (5, 80). Shrinkage during firing is negligible; the finished shapes being accurate to 0.0005 inch (8, 10). Lyden (6, 21), quoting Carl (2) and data from the American Lava Corporation, Chattanooga, Tennessee, states that breakage during firing ranges from about 50 per cent for non-lava
talcs to about 6 per cent for lava talc.

Synthetic lava talc is made from ground talc and a bonding agent such as lithium or boric oxide. Synthetic material is satisfactory for many uses, but it is not as adaptable to forming into precision shapes. Breakage during firing is also higher than for natural talc.

In the United States, only California and Montana produce talc suitable for use in steatite ceramics (9, 159).

**TALC IN MONTANA**

Talc of all three grades is produced in Montana, but, by volume, ceramic grade leads. Deposits are known at several places in southwestern Montana; Perry (7, Plate 2) shows 9 deposits in the region from Blacktail Deer Creek south of Dillon to the Madison River south of Ennis. He also states that numerous small, non-commercial occurrences of talc are known in this region. Only two deposits, Axes Creek and Johnny Gulch, have been worked in recent years, and now only the Axes Creek deposit is being worked. A talc deposit was once worked near Helena, but it was worked out about 1936.

The talc of southwestern Montana is in pre-Cambrian marble of the Cherry Creek series, whereas the Helena talc is in the Cambrian Pilgrim formation.
Axes Creek Deposit

The mine on Axes Creek is called the Smith-Dillon mine, and is operated by the Tri State Minerals Company of Los Angeles, California. The deposit was previously worked both from an open pit and an adit, but the underground workings have caved, so that now only the pit is in operation. This deposit is about 11 miles southeast of Dillon.

The deposit is in coarsely crystalline dolomitic marble of the pre-Cambrian Cherry Creek series. Talc of ceramic grade occurs in an irregular body elongated roughly parallel to the strike of the marble (7, 4). The talc is fine to coarsely crystalline, granular, or massive, and in color it ranges from nearly white to dark green. In places, masses of calcite with crystals as much as two inches on a side may be found in the talc body.

Johnny Gulch Deposits

Ceramic, cosmetic, and lava talcs are obtained from the deposits at Johnny Gulch 20 miles south of Ennis. These deposits consist of large, irregular masses and small vein-like bodies in the Cherry Creek marbles. The talc ranges in color from white to dark gray, but greens are common. Of the specimens studied by the writer, the ceramic talc was gray, the cosmetic pale green, and the lava white with dendrites of manganese oxide.
The cosmetic talc occurs as concretion-like masses up to 6 or 8 inches in diameter contained in the ceramic talc. The nodules have a radiating structure apparently caused by radial fracturing. The cryptocrystalline nature of the talc seems to preclude the possibility of crystal growth as the cause of the radial structure. The exterior of these nodules is commonly darker than the interior and may have a more greasy appearance. A faint banded appearance may be seen in some specimens.

The ceramic talc is usually gray and commonly mottled or banded. Both the ceramic and cosmetic talcs are badly cracked and checked. Large and apparently sound pieces of ceramic talc may be crumbled with the fingers after standing in the laboratory for a long period of time.

The lava talc is white on a fresh surface, but it turns tan with age. All of the lava talc studied by the writer had dendritic patterns caused by manganese dioxide extending into the mass from fracture surfaces, which usually have a darkened, weathered appearance. The lava talc usually has a dull, earthy appearance, whereas the ceramic and cosmetic grades have a more waxy luster. During the last war, Johnny Gulch was the principal domestic source of lava talc for use in the electronics industry. According to Thurnauer (9, 159), Johnny Gulch is the only deposit of lava grade talc in the United States, although it has been reported to be present in other parts of the country.
"The lava grade talc... is associated with much powdery and compact iron oxide and some manganese oxide in a thick mantle of soil and weathered rock. Solution cavities containing oxide material extend downward into the marble. It appears that the development of this type of talc is related to intense conditions of weathering since the original talc deposition, and it is possible that the presence of the iron and manganese oxides have some bearing on its development" (7, 9).

EXPERIMENTATION BY OTHERS

A great amount of work has been done on talc by ceramists, chemists, mineralogists, and geologists, but as far as is known no one has determined exactly what makes lava talc different. This writer was unable to find in the literature any report on comparative study of physical properties of raw talcs. Most of the work on lava talc has been on the effect of firing, and many authors have written on the occurrence and origin of talc in this country and abroad. The works of Gillson (3) and Hess (4) present clear, essentially similar views on the origin of talc. Ladoo (5), in 1923, wrote an excellent report in which he discusses uses, mining, milling, and many individual talc properties. A paper by Spence (8) is more modern, but it is primarily concerned with the occurrence of Canadian deposits. Thurnauer and Rodriguez (10) studied, by microscopic and x-ray methods, the effects of firing on steatite bodies.
Their review of the literature abstracts the experiments of others in the same line. In 1946, Lyden (6) carried out experiments to determine the losses in weight and volume at various temperatures for the three grades of talc as found in Montana. Thurnauer and Rodriguez worked with bodies made from ground talc, whereas Lyden used solid samples of Montana talc. In 1945, Carl (2) studied the firing of domestic talcs, especially the losses due to breakage during and after firing.

The work of Thurnauer and Rodriguez, dealing with the firing of talc, disclosed two crystal modifications of magnesium metasilicate, the unstable protoenstatite and the stable clinoenstatite. It is the belief of these authors that the protoenstatite formed through reactions in the solid state at about 850°C, whereas clinoenstatite formed in the liquid state. The liquid phase is apparently the result of fusion of the edges of crystals in the presence of a flux. Pure talc having no flux showed only protoenstatite. These two forms of magnesium metasilicate, along with others, were recognized earlier by different authors. The crystal modification present under various conditions is controversial, although it seems to be generally agreed that firing converts talc to clinoenstatite at temperatures above 1200°C.

Thurnauer and Rodriguez used bodies made of various proportions of California talc, feldspar, flint, barium carbonate, and kaolin. The ingredients were dry ground and pressed
into thin disks or wedges. The bodies were fired one, two, three, and four times, and the structural changes were studied by means of microscope and x-ray diffraction patterns. The pieces were tested for vitrification by immersion in fuchsine dye-alcohol solution under pressure. Moisture absorption was determined after boiling the pieces for four hours in water.

Although all of the pieces were vitrified and nonabsorbent immediately after being removed from the kiln, many samples became absorbent after boiling. It was believed that boiling weakened the structure and thereby increased porosity.

X-ray diffraction patterns and microscopic methods showed an increase in crystal size with additional firings for all specimens. The specimens showed a slight increase in absorption as the crystal diameter increased up to 7 microns, and a sharp increase above 7 microns. Cristobalite lines showed on the diffraction patterns of all specimens, and tridymite lines showed on some.

These authors found that pulverizing the samples for 1½ hours caused a transformation of one crystal form to another. They believe that the crystal forms are closely related, and that one form could go to another by gliding of planes caused by the shear stress in grinding.
Lyden's experiments were based on the assumption that the breaking of the talc bodies under firing resulted from loss of water and reduction in volume. Cubes of talc 0.8 inch on a side were heated in an electric furnace. The samples were held at the desired temperatures for 20 hours and then measured for weight and volume. The object of the work was to determine the temperature at which greatest loss in weight and volume occurred. The temperatures used were 220°C, 420°C, 620°C, 830°C, and 1030°C.

Lyden plotted his results in graphical form, and at the final temperature of the experiment all of the reductions were increasing rapidly. It would be interesting but not particularly enlightening to carry the temperatures to the point where the percentage of reduction decreases to zero.

The curves showing percentage of reduction in weight for each of the three grades are roughly parallel, and show an increase, a decrease, and finally an increase in relation to the final temperature. The loss in weight does not exceed 1 per cent until a temperature of about 700°C is reached. According to the outline of procedure, about 70 hours were required to bring the furnace to 700°C.

Lyden (p.20) says that Carl (2) explains the first decrease in weight as resulting from the loss of loosely held water. The following increase in weight was explained by Lyden as the result of the conversion of ferrous iron to ferric iron.
This explanation accounts for only about 60 per cent of the increase, and the remaining 40 per cent is unexplained.

Lyden's graph (Plate VIII) showing percentage of reduction in volume contains curves which are extremely irregular and have several changes of slope. Ceramic and cosmetic talc both have erratic behavior, but the curves are approximately parallel and very close in values. Lava talc, according to Lyden, shows a more regular reduction in volume, and the percentage of reduction is slightly greater than for ceramic and cosmetic grades. Reduction for the three grades is less than 2 per cent up to temperatures from 700°C to 900°C. Rearrangement of the molecules was suggested by Lyden as an explanation for the erratic expansion and contraction of the samples.

**EXPERIMENTAL WORK**

**Petrography**

Eleven thin sections were made of material from the Dillon deposit to study the minerals and their relationships. Eight of these thin sections were made of samples at the contact of small masses of talc with the limestone, two were made of the limestone which showed no talc to the unaided eye, and one was made with samples of two grades of talc.
The eight thin sections cut to show both talc and limestone were made primarily to show the relationships of the talc and the limestone, but they also served for determination of the associated minerals. Two of the eight were from one hand sample, and six were from another sample. Five of the eight slides showed only talc and calcite and no unusual relationships. One contained several small grains of greenish brown biotite. One slide showed talc contained within grains of calcite, whereas in most specimens the talc and calcite grains were adjacent to one another. The third slide showed what appeared to be reaction rims around some of the calcite grains.

The two thin sections made from the limestone in which the talc is found were apparently barren when examined with the unaided eye or with a hand lens. However, the microscope revealed grains of talc disseminated in both specimens. Material which to the unaided eye was only dark lines and patches in the white limestone showed up under the microscope as minute flakes of graphite.

The slide with samples of two types of talc was prepared to study them comparatively. The slide was originally made with samples of all three grades, but one sample, the ceramic grade, was lost in grinding the specimens to the proper dimensions. Because of the radially fibrous fracture of the cosmetic talc, two pieces of that grade were mounted.
One piece was mounted with the fracture lines at right angles to the slide, and another with the fracture lines parallel to the slide. The two thin sections were cut at right angles to each other.

The thin sections were made by standard methods of cutting and grinding. Lakeside cement was used to mount the rock slices, and Canada balsam to mount the cover glasses. The absence of quartz made the estimation of thickness difficult, but with a little experience, the writer was able to use talc effectively.

X-ray Spectrograms

The x-ray apparatus used was a Hayes 60 kv machine. Copper radiation with a nickel filter was used on all samples. Sample 1 is cosmetic talc, 2 is ceramic, and 3 is lava.

To prepare the samples for analysis, the writer scraped powder from a sample with a knife blade. The powder was caught on a clean piece of tracing cloth and transferred to cork-stoppered glass vials. This powder was then ground in an agate mortar to reduce any large fragments. The material was not sized. Ordinary library paste thinned with tap water was used as a binder and an adhesive to hold the talc on the fine glass rod used as a mount.

The camera used is a circular camera with diameter of 14 cm. All pictures were taken with the motor on for full rotation,
and a circular aperture about 1 mm in diameter was used.

The spectrograms were all made with copper radiation, through a nickel filter, at 40kv. Sample 1 was run at 15 milliamperes for 1½ hours; samples 2 and 3 at 20 milliamperes for 1 hour.

Water Absorption

When work was started on this problem, Dr. Perry suggested to the writer that porosity or permeability in lava talc may be at least part of the answer. Mr. Buckvich, of the petroleum department, was consulted concerning the possibility of using the mercury porosimeter and permeameter in his department. However, these instruments, while sufficient for the needs of the petroleum department, are not capable of measuring values as low as those anticipated in talc. A decision was therefore reached to attempt to measure the amount of liquid absorbed by talc, and in that way obtain a measure of the combined permeability and porosity. A preliminary test was made by weighing a piece of talc before and after boiling in water for a few minutes. The weight of the sample was determined only approximately on a pulp balance, but the test was sufficiently successful to warrant further experimentation.

Water was chosen as the most suitable liquid because of its high surface tension, low viscosity, and availability. The
properties of several liquids were examined before choosing water. Because any openings in the talc would probably be of capillary size, the writer felt that surface tension was the most important property of the liquid to be used. The surface tension of water is about 72 dynes per centimeter, nearly twice as great as that of the liquid second highest in value.

Penetration of the water into the talc was hastened by placing the sample in water in a closed vessel and evacuating the air above the water. The sample was covered with tap water in a wide mouthed bottle which was sealed with a rubber stopper having two holes. A vacuum pump was attached to a glass tube in one hole, while an open-type mercury manometer was connected to the other hole. The vacuum pump, an electrically powered oil-tank pump, was run for from 20 to 30 minutes for each test. About 10 minutes were required for the pump to acquire its maximum vacuum of 600 mm. of mercury.

When the samples were removed from the water, the surface was quickly dried outwardly, and they were weighed on an analytical balance. The samples were allowed to dry in air for about 20 hours, then they were dried on a warm hot plate for \( \frac{1}{2} \) hour, after which they were again weighed on the same balance.
The decrease in weight between the two weighings was assumed to be the result of loss of water after drying. This loss in weight was divided by the weight of the dry sample to determine the weight percentage of water absorbed.

Because of the highly fractured and cracked nature of the cosmetic talc, three small pieces were used rather than one large piece. Several pieces were examined under a binocular microscope to find that material which was solid. The presence of cracks would cause inaccurate results by increasing the apparent permeability and porosity.

RESULTS OF EXPERIMENTATION

Mineralogy of Dillon Ore

Only five minerals were found in the material from the Dillon deposit. They are talc, calcite, graphite, biotite, and limonite.

The talc ranges in color from pale to dark green and in grain size from coarse to microscopic. Most of the talc is finely micaceous.

The calcite may be white or yellowish to brown from iron stains. The crystals in the limestone are anhedral and are about 0.2 mm or 0.3 mm in diameter, but much coarse-grained material may be found at the mine. Pockets of calcite are encountered in which the crystals may be 2 inches on a side.

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The calcite may occur in small veinlets or in pockets.

Fine-grained graphite is found disseminated through some of the talc and calcite. No regular orientation of the graphite grains is apparent. Even a small percentage of included graphite is harmful in talc.

Biotite was identified in three thin sections, and folded veinlets of biotite were found in places in the northwest side of the pit. The vein biotite is a pale brown, translucent variety. Most of it was highly weathered and rotten.

Much of the limestone is stained with limonite, some of which appears to be transported and other that appears to be the result of the oxidation of pyrite grains in place. One specimen supplied by Dr. Perry looked like a limonite boxwork.

**Petrography of Dillon Ore**

A general discussion of the thin sections was given previously, but a more detailed description of the thin sections follows.

Most of the talc examined in thin sections was cryptocrystalline, but some material was in fairly large grains. Much of the calcite has so much very fine talc scattered through it that it has the appearance of sericitized orthoclase. However, most of the talc-calcite boundaries are
smooth and abrupt. Very little embaying of calcite by talc was noted. Fibrous talc, coarser grained than the average, was found around some calcite grains. The talc fibers were disposed at right angles to the edge of the calcite grain. This coarser talc, when viewed under low power magnification, had the appearance of reaction rims around the calcite.

The country rock when viewed in thin section shows up as being composed of anhedral calcite grains, many of which show fine examples of twinning. Many grains show two sets of twinning planes oriented at angles of about 70° to each other. The diameter of the calcite grains was estimated to be about 0.2 mm. The limestone, which to the unaided eye appears to be barren, under the microscope is seen to contain perhaps 1 per cent of talc. The talc in these sections seems to have replaced certain grains of the limestone completely while not attaching other adjacent grains. Boundaries are usually smooth and abrupt. Something about the composition of the replaced grains may have influenced the ease with which they were replaced. None of the grains showed signs of the squeezing or crowding which may have resulted had the talc been deposited between the calcite grains.

The slide prepared with two grades of talc showed no difference in the two grades. Both were cryptocrystalline and apparently identical.
X-ray Data

X-ray spectrograms made of the three grades of talc are in the pocket inside the rear cover of this report. Values of the distances from the center to the spectrum lines are shown in Table I. The values for each spectrogram are arranged in order of decreasing intensity of the lines. The values of \(d\) are calculated on the same basis and are shown in Table II.

<table>
<thead>
<tr>
<th>Sample Number</th>
<th>Grade Talc</th>
<th>Line No.1</th>
<th>Line No.2</th>
<th>Line No.3</th>
<th>Line No.4</th>
<th>Line No.5</th>
<th>Line No.6</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Cosm</td>
<td>1.19</td>
<td>3.42</td>
<td>7.42</td>
<td>1.08</td>
<td>4.44</td>
<td>2.45</td>
</tr>
<tr>
<td>2</td>
<td>Ceram</td>
<td>1.16</td>
<td>3.42</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>3</td>
<td>Lava</td>
<td>1.20</td>
<td>3.54</td>
<td>7.43</td>
<td>1.08</td>
<td>4.44</td>
<td>2.53</td>
</tr>
</tbody>
</table>

Table I. Distance (cm) from center of spectrograms to spectrum lines. Values arranged according to decreasing intensity of lines.

<table>
<thead>
<tr>
<th>Sample Number</th>
<th>Grade Talc</th>
<th>(d_1)</th>
<th>(d_2)</th>
<th>(d_3)</th>
<th>(d_4)</th>
<th>(d_5)</th>
<th>(d_6)</th>
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<td>Cosm</td>
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<td>3.2</td>
<td>1.53</td>
<td>10.05</td>
<td>2.48</td>
<td>4.44</td>
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<td>2</td>
<td>Ceram</td>
<td>9.32</td>
<td>3.14</td>
<td>--</td>
<td>--</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>3</td>
<td>Lava</td>
<td>9.0</td>
<td>3.08</td>
<td>1.52</td>
<td>10.05</td>
<td>2.48</td>
<td>5.95</td>
</tr>
</tbody>
</table>

Table II. Distances in Angstrom units between atomic planes in talcs.

The distance \(d\) between adjacent atomic planes is calculated from the formula, \(n \lambda = 2d \sin \theta\), where \(n=1\), \(\lambda =1.5412\), and \(\theta\) = angle of incidence of the x-ray beam. \(\theta\) in radians is found by dividing the distance from the center of the
spectrogram to the lines by the diameter of the camera (14 cm). The sine may be determined for radians, or the angle may be converted to degrees.

The difference between number 1 and numbers 2 and 3 may be because of the difference in operating procedure, or it may be the result of impurities in 2 and 3. The second possibility seems more reasonable, because the change in the procedure was relatively slight.

The calculated values of d for this experiment agree very closely with the values of talc as listed in a standard reference (1) for x-ray spectrograms. However, in the order of the listing, the first two values in the report are reversed from the standard. No explanation is offered for this variation. The three types of Montana talc showed values of d within 0.5 Angstrom units, which is considered to be a good agreement.

Liquid Absorption Test

The experiment on water absorption gave data more interesting, and perhaps more valuable, than the other work performed. This experimentation was undertaken with the hope of verifying the suggestion of Lyden and Dr. Perry that a porosity or permeability in lava talc is at least partly responsible for the low breakage rate when firing.
The theory is that enclosed water or molecular water, when heated with no passages for escape, must build up a steam pressure which causes breakage. If the talc is permeable enough to allow the steam to escape easily, the breakage should be low.

The procedure was discussed earlier, so that only the results will be covered here. In this experiment, it was assumed that the increase in weight from the second weighing to the first weighing was entirely the result of loss of water. The temperature at which the samples were dried, although not measured, was not high enough to cause any transformation in the structure of the talc.

The data and results are shown in Table III, in which the percentage of water (column 4) was determined by dividing the difference (column 3) by the dry weight (column 2) and multiplying by 100.

<table>
<thead>
<tr>
<th>Talc</th>
<th>Wet Weight</th>
<th>Dry Weight</th>
<th>Difference</th>
<th>% Water</th>
<th>Porosity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ceramic</td>
<td>16.1726</td>
<td>16.1000</td>
<td>0.0726</td>
<td>0.45</td>
<td>1.24</td>
</tr>
<tr>
<td>Cosmetic</td>
<td>8.8535</td>
<td>8.8280</td>
<td>0.0255</td>
<td>0.29</td>
<td>0.80</td>
</tr>
<tr>
<td>Lava</td>
<td>16.0102</td>
<td>15.4770</td>
<td>0.5332</td>
<td>3.45</td>
<td>9.50</td>
</tr>
</tbody>
</table>

Table III Results of water absorption test. Weights in grams.

Because of limited time, only one test was made on each grade of talc. If many tests could be made, more reliable and more useful results may be determined. As it is, the
results here may be true only for those particular samples used.

The weight percentage of water in Table III is not porosity, but it is directly proportional to the porosity. This value may be converted to porosity by multiplying it by the average specific gravity of talc. The average specific gravity of talc is 2.75. Porosities are shown in column 5 of Table III.

No direct value of permeability can be determined from the above data, but the fact that the talc absorbed water is an indication of some permeability which should be measurable.

Conclusions

Petrographic and x-ray methods of examination showed no differences in the physical properties of the three grades of talc. Water absorption experiments to determine the porosity of the three grades showed lava talc to be about 12 times as porous as cosmetic talc and 7.5 times as porous as ceramic talc. The single test showed lava talc to have a porosity of 9.5 per cent. These data seem to indicate that porosity and an associated permeability in lava talc may be the answer to the question of why lava talc has a lower breakage rate than either ceramic or cosmetic grades. The greater porosity and permeability of lava talc would allow steam to escape easily rather than causing disrupting pressures to build up as it would in ceramic or cosmetic talc.
A. Nodules of cosmetic talc in a matrix of earthy talc.

B. Nodules in A showing radiating structure.

C. Radiating structure in large "concretion" of cosmetic talc.
Dendritic talc (lava grade) from Johnny Gulch.

Vacuum pump and manometer apparatus used in water absorption test.
BIBLIOGRAPHY

1. Alphabetical Index of X-ray Diffraction Patterns

2. Carl, Howard F., "Studies of Firing Failures in Massive Talcs"
   Rept. of Investgn. 3800
   U. S. B. M.

3. Gillson, L. L., "Origin of the Vermont Talc Deposits, with a discussion on the formation of talc in general"
   Econ. Geol. vol. 22, no. 3, pp 246 - 287 (1927)

   Econ. Geol., vol. 28, pp 634 - 657 (1933)

5. Ladoo, R. B., "Talc & Soapstone; their mining, milling, products, and uses"
   U. S. B. M., Bull. 213 (1923)

   B. S. Thesis, Mont. School of Mines (1946)

7. Perry, E. S., "Talc, Graphite, Vermiculite, and Asbestos in Montana"
   Mont. Bur. Mines and Geol., Memoir No. 27 (1948)

8. Spence, H. S., "Talc, Steatite, and Soapstone; Pyrophyllite"

9. Thurnauer, Hans, "High Frequency Insulation"

    Am. Cer. Soc., Jour. vol. 25, no. 15, Nov. 1, 1942, pp 443 - 450