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Economic Talc Deposits of Montana and Related Firing Problems

Charles J. Lyden

ECONOMIC TALC DEPOSITS OF MONTANA AND RELATED FIRING PROBLEMS

BY

Charles J. Lyden

A Thesis
Submitted to the Department of Geology
in Partial Fulfillment of the
Requirements for the Degree of
Bachelor of Science in Geological Engineering

Monta na School of Mines
Butte, Monta na
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Illustrations

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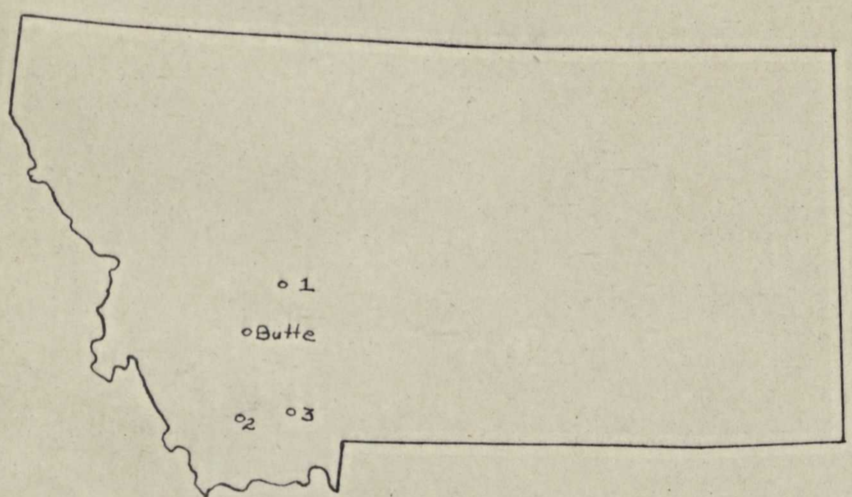
INTRODUCTION

Montana is world famous for its metallic products, however little attention has been given to its many non-metallic materials, some of which promise a profit-producing future. One of these non-metallic materials,



Location of Montana Talc Deposits

Figure 1. The Montana talc production is derived from the deposits located on the map of Montana above: (1) the Helena deposit, (2) the Dillon deposit, (3) the Johnny Gulch (Ennis) deposit.

recently being worked on an economic scale, is talc.

This thesis has to do with a study of the production of talc in Montana, describing the local geology of each deposit, and a description of the laboratory tests that were made on various grades of Montana talc in an attempt to determine why some grades of talc can be burned in solid forms while others must be ground, mixed with a binder, and molded before they can be burned.

The areas of Montana that are now producing, or have produced recently, talc on a commercial scale are the Helena area, one mile south of Helena, the Johnny gulch area about three miles south of Ennis, and an area about eight miles south-southeast of Dillon. Although there are other talc deposits scattered about the southwest portion of the state none has produced talc on a commercial scale.

All three deposits have produced ceramic and cosmetic talc and during World War II the Johnny Gulch deposits have produced some lava talc. This lava talc was produced at a very small margin of profit due to the cost of mining and hand sorting the lava grade talc from the gangue and other grades of talc.

The geology of these three deposits is in general similar. They all appear to have been formed by the alteration of dolomite of Cambrian or pre-Cambrian age and in each area there is evidence of igneous activity which could have furnished the solutions for hydrothermal alteration of these dolomites.

Of the three deposits considered the Dillon and the Johnny Gulch areas are producing ceramic talc at the present time. The Helena deposit has not been worked for several years.

The writer wishes to thank Dr. E. S. Perry of the Geology Department of the School of Mines for his guidance in preparing this thesis and for the great

volume of information he has provided concerning the talc deposits of Montana.

Professor J. P. Spielman of the Metallurgy Department of the school was most accomodating in making available much of the equipment that made the research possible and he also gave considerable time and advice in developing a workable burning technique.

Dr. A. E. Koenig of the Chemistry Department of the school gave much assistance in interpreting the results of some of the research.

GENERAL CONSIDERATIONS OF TALC

Occurrence

Ford[1] describes talc as an acid metasilicate of magnesium having a chemical formula of $H_2Mg_3(SiO_3)_4$ or $H_2O \cdot 3MgO \cdot 4SiO_2$. The theoretical percentage composition is given as follows:

Silica	63.5%
Magnesia	31.7%
Water	4.8%
	100.0%

Talc is usually foliated massive, but it is also found as granular massive, fibrous, compact, or cryptocrystalline. It has a greasy feel. The hardness of talc is between 1 and 1.5, and the specific gravity ranges from 2.7 and 2.8.

As presented in the literature, talc is generally considered to have been formed by the hydrothermal alteration of basic igneous rocks such as gabbro, pyroxenite, peridotite and horneblende,[2-3-4] or by the hydrothermal alteration of limestone or dolomite.[2-4]

Spence[5] states that "The formation of talc on a major scale usually takes place either (a) under conditions of intense dynamic disturbance, where the magnesian host rock has suffered severe deformation and squeezing by tectonic agencies, with attendant heat and pressure or (b) where such rock has been subjected to contact metamorphism thru the agency of igneous intrusions.

"Where the host rock is an older crystalline dolomite, or other similar carbonate rock, the first stage often appears to have been the formation, by silicification, of a lime-magnesia silicate, such as tremolite, which finally alters to talc. In such case, particularly where alteration has remained incomplete, the talc may contain considerable residual silicate, as in the deposits of fibrous talc of the Gouverneur district, New York. The principal impurities in talcs of such origin are usually dolomite, quartz, and various residual silicate minerals.

"The finest and highest priced commercial talcs are found in deposits in younger bedded dolomites that have suffered relatively little metamorphism, or recrystallization. Recrystallization, especially under conditions of contact metamorphism, is usually attended with the introduction of foreign mineral elements, resulting in the formation of the varied range of secondary silicates common in the older pre-Cambrian carbonate rocks and also in the talc deposits associated with them. In the younger and less highly altered dolomites, talc appears to have been formed by a direct process of silicification of the magnesia constituent, the lime being removed in solution. ....

"In the narrower mineralogical sense, the term "steatite" is generally applied to massive, compact, cryptocrystalline talc, without visible grain, and usually of a pale yellow or cream color. Such talc is generally derived from the alteration (silicification) of carbonate rocks, such as dolomite or magnesite, having a negligible iron content.

"Steatite is a much rarer material than ordinary talc, and commercial deposits that will yield sound material suitable for sawing and forming into lava articles are scarce."

Uses of Talc

Ladoo[6] lists over sixty uses for ground talc including its use as a filler and pigment in paints, filler in paper, kiln furniture, dusting of rubber vulcanizing molds and cosmetics.

Altho the uses he lists represent consumption of the majority of the talc produced, the steatite or lava talc was so vital to the electrical and electronic industries that it was listed as a most critical material during the war.

H. F. Carl[7] states: "Talc also occurs, altho much less frequently, in massive, fine grained, fairly homogeneous bodies; the impure varieties are the familiar soapstones, and the purer form is frequently called steatite. Because of certain properties, the purer grades of this massive variety have a monetary value about twenty times that of ground talc.

"One desirable property of this massive talc is its amenability to accurate cutting, machining, and working in many ways, similar to a hard wood or a soft metal, and then firing without warping or appreciable shrinkage into a hard, refractory, ceramic body. Consequently, shapes that cannot be formed conveniently by molding and pressing can be produced readily with ordinary machine tools. When talc is fired to 1000°C. it is converted to a ceramic body with certain very desirable physical properties. This fired material has a hardness and a toughness frequently superior to steel. It is a refractory and an exceptionally good electrical insulator. When formed from a high grade talc essentially free from iron, it has unusually low dielectric losses, even at very high frequencies.

"Recently this use alone has consumed about one million dollars worth of finished products per year. Altho substitutes are being developed and are used to some extent, no completely satisfactory one has been made for certain of the most essential uses."

Talc Production of the World

In 1937, the last year for which complete data is available, the world production of talc and soapstone is tabulated as follows:[8]

	Metric Tons
Argentina	80
Australia	1,570
Austria	14,098
Canada	11,301
Egypt	2,266
Finland	881
France	56,300
Germany	7,790
Greece	1,838
India	13,249
Indo-China	428
Italy	45,714
Manchukuo	111,140
Morocco (French)	841
Norway	24,701
Roumania	1,976
Spain	3,021
Sweden	7,937
South Africa	376
United States (sales)	208,650
Uruguay	437

Talc Production of the United States

Talc, pyrophyllite and ground soapstone sold in the United States during 1941 are listed as follows:[8]

State	Short Tons	Value
California	59,203	$811,793.00
Georgia	28,511	346,550.00
Maryland	15,628	105,363.00
Nevada	13,178	126,433.00
New York	153,560	1,917,732.00
North Carolina	64,783	567,921.00
Vermont	57,248	663,468.00
Washington	6	2,426.00
Montana, Pennsylvania and Virginia	24,252	142,196.00
Total	416,369	$4,701,892.00

Carl[7] says that: "The present domestic production of the high-grade "critical" block talc has been extremely sporadic, amounting to only a few tons per year. As a result, practically all high grade talc of this type has to be imported. In 1943 the demand amounted to about 55 tons per month. The price of imported material, in rough lump form, has ranged from $100 to $150 per ton, depending on size and grade, and the domestic rough lump is valued at about $160 per ton. Sawed prisms of acceptable size from any source bring $200 per ton."

Microscopic Character of Talc

In writing about the optical properties of talc L. H. Berkelhamer[9] states that it is either monoclinic or orthorhombic, alpha = 1.539, beta = 1.589 and gamma = 1.589, biaxial negative with small axial angle (av = 6-30°, 2E = 9-48°) appearing almost uniaxial at times. The cleavage is perfect in one direction (001) and the talc particles colorless to transparent green under the microscope. Talc as observed microscopically occurs in plate, shred, or prismatic-acicular form.

Samples of massive ceramic, cosmetic, and lava (steatite) talc were all prepared in thin section and studied under a petrographic microscope. As far as could be determined by standard proceedure there was no difference between the various types. Grain size was identical, and all three were of a platy structure. No well-formed crystals were observed. The largest grains observed had a maximum diameter of .029 inches and a minimum diameter of .010 inches. The average grains were .0015 inches long and .0005± inches wide.

MONTANA TALC DEPOSITS

The Helena Deposit

The talc deposit in the Helena area is about one half mile southwest of the Helena city limits, and is in an area that in past years has produced considerable limestone for burning to lime. The talc deposit is exposed on the quarry faces and has been developed by adits driven along the long axis of the deposit.

The formations in the immediate vicinity of the deposit are all Paleozoic in age and the talc occurs in the Cambrian Pilgrim dolomite.

The area is one of general folding and faulting and the talc producing area is along the axis of a northwest striking syncline. The talc carrying formation is faulted just to the southwest of the quarries by a right-throw fault.

On the accompanying map of this district a north-striking fault is easily determined by areal mapping, but the system of faults that produced the sequence of beds; Pilgrim, Dry Creek, Jefferson, Meagher, and Flathead has not been worked out at present. For convenience a south-southeasterly striking fault has been postulated to branch from the main fault in about the center of section 36.

The talc of this deposit was apparently produced by the alteration of the Pilgrim dolomite, and was of the massive pure white type that is required for use as a filler for high grade paper and as a base for cosmetics.

GEOLOGIC MAP
OF
HELENA TALC DEPOSIT
AND
IMMEDIATE SURROUNDING AREA

Dr. E.S. Perry

Anderson[12] describes the main talc body as being roughly lenticular with the long axis oriented a little west of south. It has a nearly vertical dip, and does not seem to follow any definite path such as a bedding plane or a fault zone.

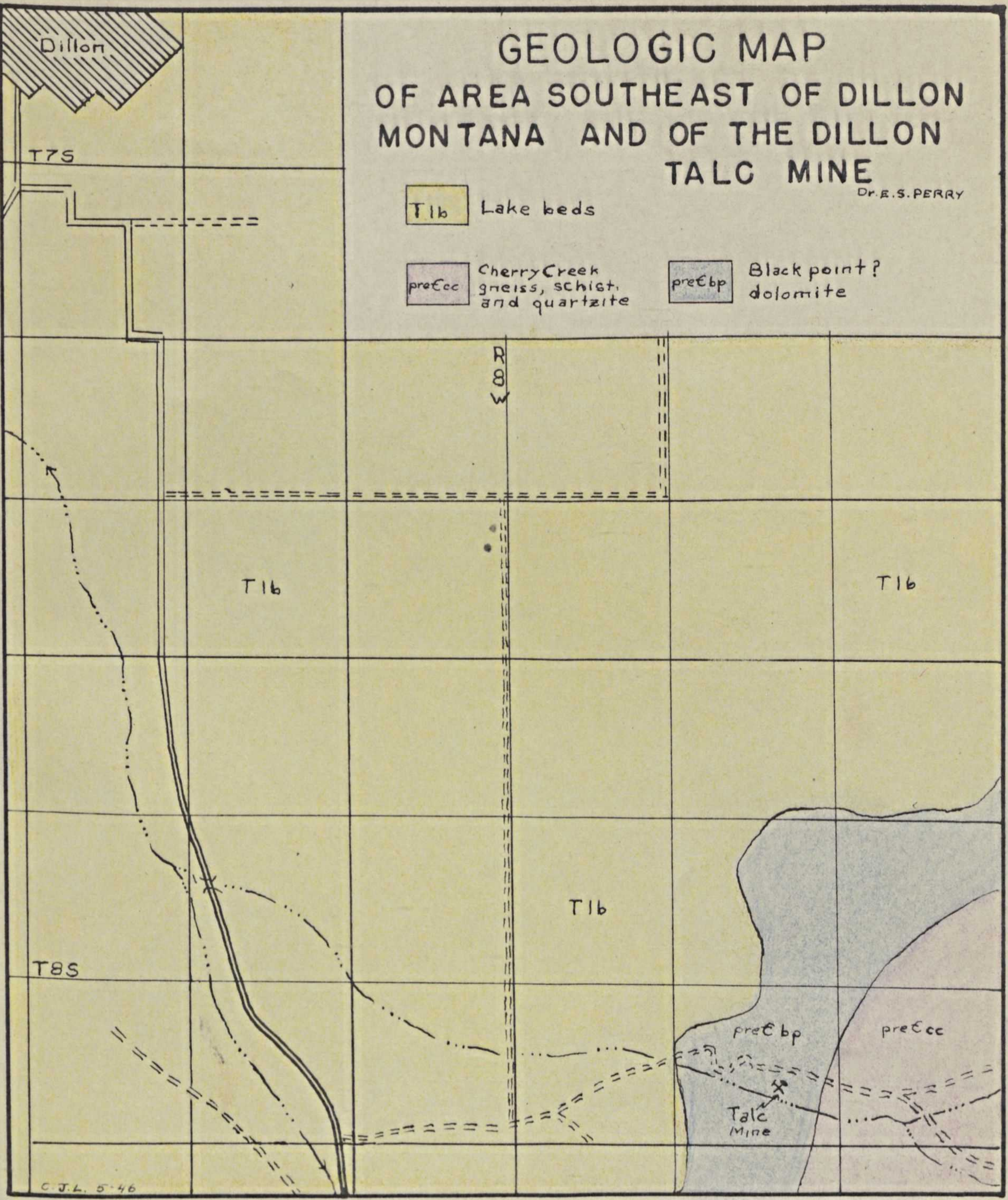
The deposit has the general appearance of a fissure vein, and was probably developed by alteration spreading laterally into the walls of a minor fissure through which hydrothermal solutions passed.

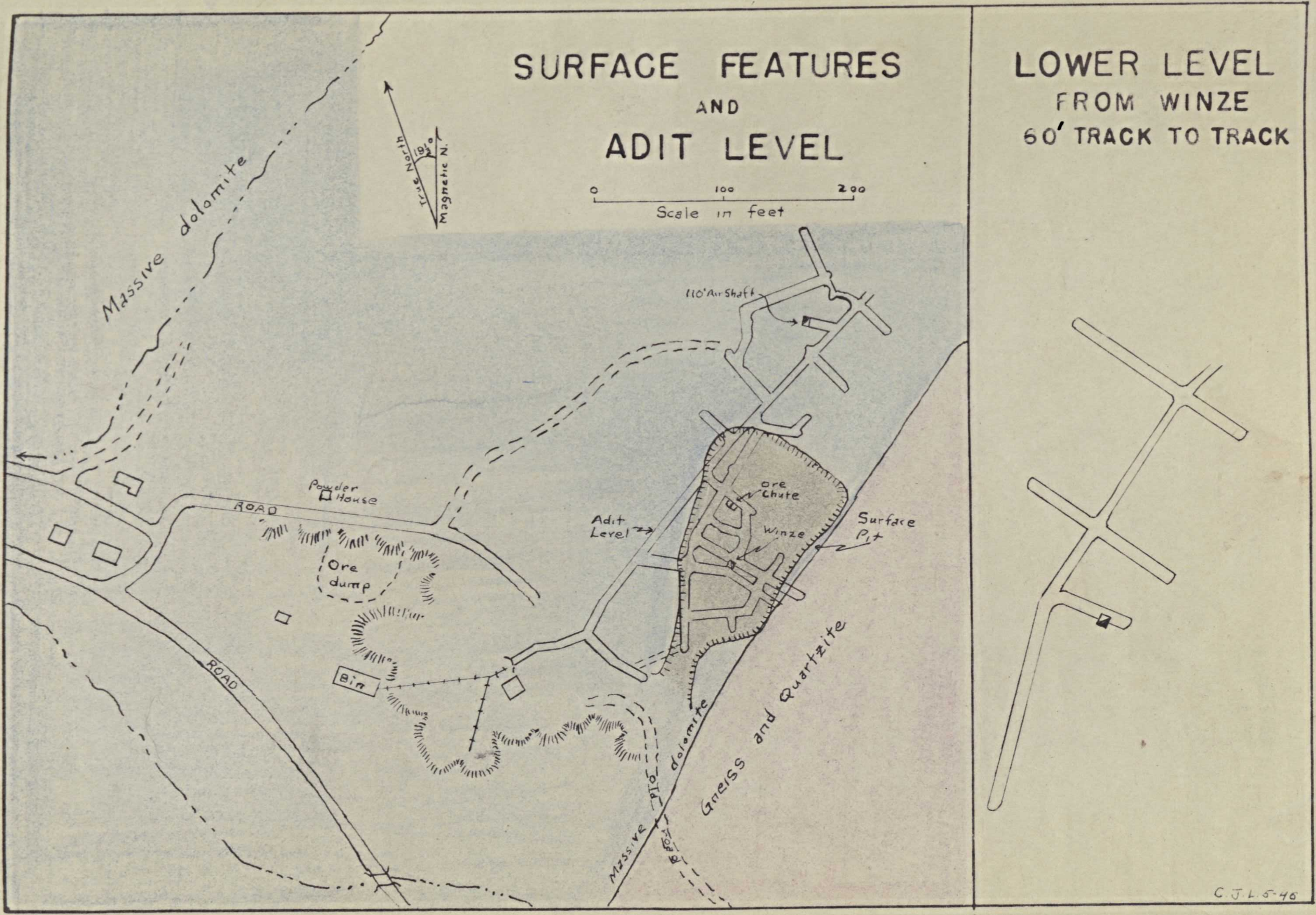
The Dillon Deposit

The talc deposit southeast of Dillon, Montana, produces a ceramic grade talc and is operated by the Tri-State Minerals Company, a California firm.

This deposit was first developed by an open pit and then by two underground levels. The upper level is a series of drifts and crosscuts driven from an adit. The lower level constitutes a drift with crosscuts driven from it at various intervals to block out the ore. The lower level is serviced through a winze, and is sixty feet below the upper level, track to track.

The talc occurs in a massive gray dolomite that has been tenatively identified as equivalent to the Black Point dolomite of the Johnny Gulch area by Dr. E. S. Perry. The talc body has an irregular boundary where it is in contact with the dolomite, and conforms to the plane of a fault separating the dolomite from the gneiss, schist and quartzite, where the talc is


GEOLOGIC MAP
OF AREA SOUTHEAST OF DILLON
MONTANA AND OF THE DILLON
TALC MINE
Dr. E. S. PERRY
Tlb
Lake beds
pre€cc
Cherry Creek gneiss, schist, and quartzite
pre€bp
Black point? dolomite
Dillon
T7S
T8S
R 8 W
Tlb
Tlb
Tlb
pre€bp
pre€cc
Talc Mine
C. J. L. 5-46



TALC MINE 8 MILES SOUTHEAST OF DILLON, MONT.

in contact with the fault.

The portion of the talc deposit that has been developed measures approximately 300 feet long and 150 feet wide. It has not been prospected below the lower level; but on this level, which is at a maximum depth of about 170 feet, good ceramic talc has been blocked out along the drift and most of the crosscuts. It is extimated that this single deposit contained between one quarter and one half a million tons of talc of various grades.

The talc is considered to be a product of hydrothermal alteration, as are the other Montana deposits. In the talc there are sometimes found "horses" or bodies of dolomite, as large as twenty feet in diameter, that are probably unaltered portions of the country rock.

The Johnny Gulch Deposits

The talc deposits at Johnny Gulch, three miles south of Ennis, Montana, are all found in dolomite that has been identified as pre-Cambrian Black Point dolomite. Dr. E. S. Perry describes it as being very similar over the entire area of the deposit except for suggestions of schistosity and massiveness that does vary from place to place. On a fresh break it is of a light to medium gray color with a fine to medium grain. Its surfaces weather to a chocolate brown color and it is sufficiently resistant to erosion to form ridges. The schistosity conforms to the bedding of the dolomite. The strike of the bedding varies from N10°E to N35°E and the dip from NW70° to vertical.

At present four main talc bodies have been developed. There are possibly two other large bodies of talc yet undeveloped, one northeast and one northwest of upper No. 5 pit.

The main talc bodies are irregular, locally crushed and broken, and may contain "ribs" of dolomite through them. They are fifteen to thirty feet wide, and fifty to one hundred feet long, with the long axis parallel to the bedding of the dolomite. This does not apply to the body developed in upper No. 5 pit which strikes at a slight angle to the strike of bedding.

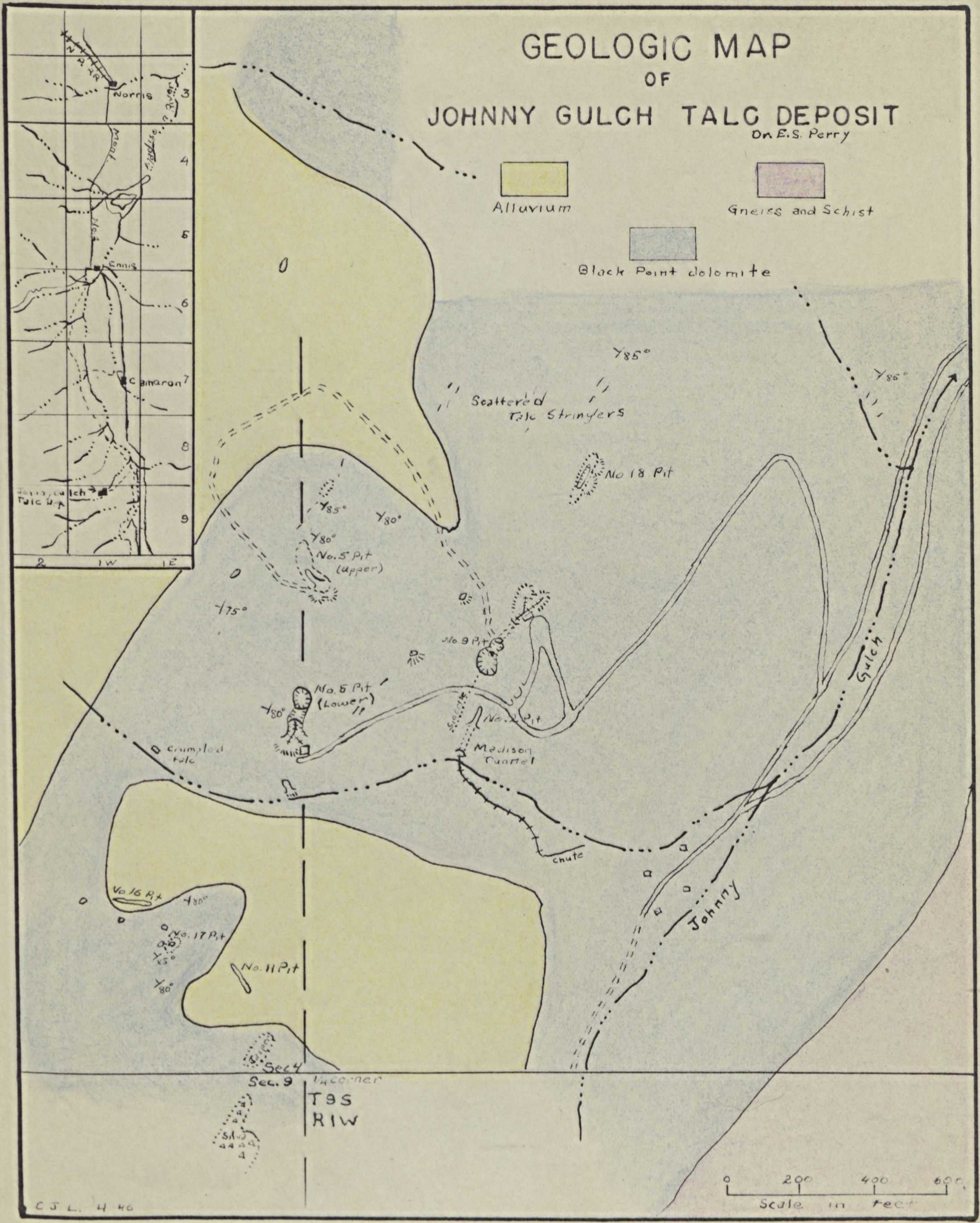
The talc bodies pinch out against the dolomite in length, and along the sides and ends of the bodies there are numerous stringers of talc in the dolomite.

Numerous small lenses and vein-like bodies of talc are found scattered throughout the dolomite.

During the recent war, pit No. 9 attracted much of the attention of the Bureau of Mines, because this body produced about ninety per cent of the lava grade talc mined at Johnny Gulch. In this pit the talc appears to have been subjected to considerable movement and blocks of talc up to a foot in diameter are found in a matrix of clay and associated with MnO_2, Fe_2O_3, and some brown and blue jasper.

Pits No. 2 and 9 and an area of jasper eleven hundred feet southwest of No. 2 pit are apparently related altho the connection between them is obscure.

The transition from dolomite to talc is not apparent


GEOLOGIC MAP
OF
JOHNNY GULCH TALC DEPOSIT
Dr. E.S. Perry
Alluvium
Gneiss and Schist
Black Point dolomite
Norris
Ennis
Cimarron
Scattered Talc Stringers
No 18 Pit
No. 5 Pit (upper)
No 9 Pit
No. 5 Pit (Lower)
Crumpled talc
Medison Tunnel
chute
Gulch
Johnny
No 16 Pit
No. 17 Pit
No. 11 Pit
Sec 4
Sec. 9
1/4 corner
T9S
R1W
Scale in feet
C J L. 4 46

in the field, the talc stopping abruptly against clean dolomite. The talc bodies commonly protrude into the dolomite in bowl-like depressions.

Altho the contacts between the talc and the dolomite appear to be clean cut the talc probably was produced by hydrothermal alteration. In support of this contention are the rounded fingers of dolomite extending into the talc in No. 5 pit and the occasional small fragments of partially altered calcareous rock that are found in the talc.

Minerals such a barite, jasper and siderite which occur with the talc in varying quantities also point to the presence of hydrothermal solutions.

The United States Bureau of Mines[13] in 1943 estimated that there were 35,000 tons of ceramic grade talc developed in No. 5 pit alone. With a planned system of prospecting and development it should be possible to block out many times this tonnage in the other pits and the potential areas.

LABORATORY TESTS ON MONTANA TALC

As the problems of this thesis were originally laid out it was intended to try to determine why talc coming from the same small area, and produced from the same country rock would be of at least three different types. It was also hoped that it might be possible to determine how massive ceramic or cosmetic talc could be beneficated so that it could be machined and burned in solid blocks as is done with lava talc.

Due to the limitations of time, and equipment available, it was only possible to work on one problem that seemed to stand out as being the first problem to be solved, namely: Why do some types of talc have a 50% loss due to firing failures (checks or cracks) while others have only a 5 - 6% loss?

The only reasons which seemed to partially explain the cracking were the loss of water and reduction of volume, both of which may go on in such a way during burning that internal strains would result.

To determine where, during the burning, the water was driven off and the volume of the blocks began to reduce the following tests were developed:

Prisms of massive ceramic, cosmetic, and lava talc about 0.8 inch on each dimension were cut out with a diamond saw. These blocks were thoroughly scrubbed with water and then examined for cracks. If satisfactory they were dried for twenty-four hours in an electric furnace at 50°C. They were then weighed and their displacement volume measured in a Russel volumeter. The weights were accurate to 1/10,000 grams and the volumes within $0.05^{\pm}$ cc.

The blocks were then placed on a bed of dried bone ash, each in an individual three inch scorifying dish and then covered with bone ash to a minimum depth of one-half inch. This bone ash bed and cover was found to be necessary because the type electric furnace used had a loosely fitting door in front and a

3/4" opening to the atmosphere at the back making it impossible to maintain an even temperature over the entire bottom surface of the muffel. By trial and error it was found, by covering the blocks with bone ash and keeping them in scorifying dishes, reproducable and consistant results could be obtained.

The furnace used was a Hevi-Duty Electric Furnace, Type HD96 of the muffel type. Its temperature range is 220°C to 1050°C and the temperature is controlled in increments of 20°C.

For a full test burn, five blocks of each type of talc to be tested were used. The capacity of the furnace being fifteen small scorifying dishes generally three types were tested on each burn. All the blocks were placed in the cold furnace and the furnace heated to 220°C. This temperature was held for about twenty hours and then the first blocks of each type of talc were removed and allowed to cool for twenty-four hours. After cooling the blocks were brushed well to remove any adhering bone ash and then weighed and displacement volume measured. As soon as the first set of blocks were withdrawn the temperature was increased to 420°C and this held for about twenty hours. The next set of blocks were then removed, cooled, weighed and volume taken. This was repeated at 620°C, 830°C and 1030°C.

The data obtained from these tests was plotted on semi-logrithmic paper with the increase in temperature on the arithmetic scale plotted against per cent reduction of volume and per cent reduction of weight on the logrithmic scale. This is shown on Plates I, II, and III.

Plate IV shows the relation of the three reduction of volume curves and Plate V the relation of the three reduction of weight curves to each other.

Study of these plates brings out two interesting details, one is the decrease and then the increase followed by another decrease in weight of all three types of talc as they pass from room temperature to above 420°C. The first decrease in weight is explained by Carl[7] as due to the removal of loosely held water in excess of the one molecule present as part of the talc structure. The gradual increase of weight between 220°C and 420°C is thought to be partially explained by the change of ferrous to ferric iron which is an impurity present in all these talc samples. This oxidation of iron accounts for about sixty per cent of the increase in weight and at present the remaining increase is unexplained.

The first reaction upon seeing these weight-loss curves is to dismiss them as improbable, but several sets of blocks were run thru the temperature range from room temperature to 520°C and within the limits of accuracy used the curves obtained were similar.

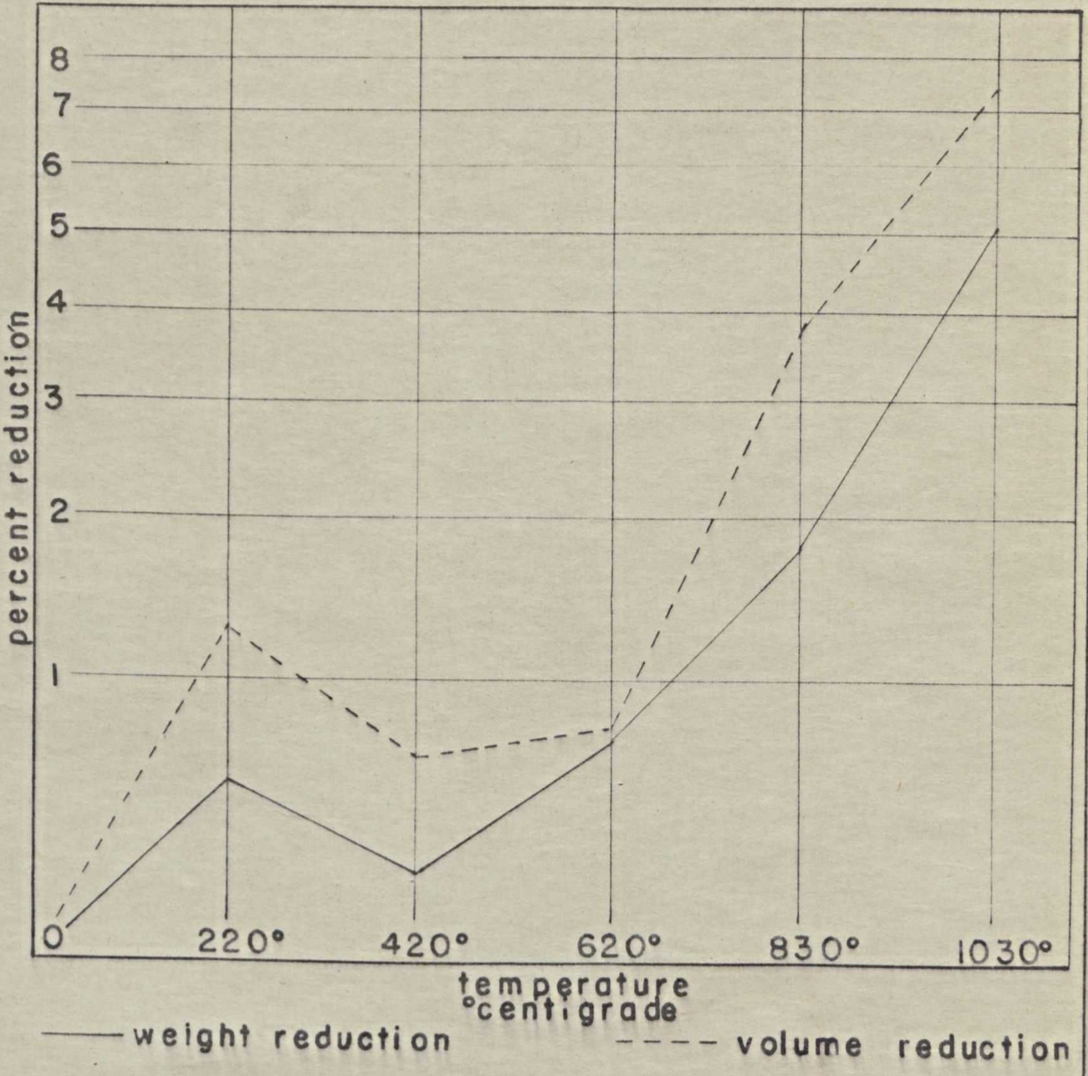
Plate V shows a striking similarity of behavior of all three types of talc.

The other interesting and, as far as this report is concerned, the most important fact that study of these curves brings out is the erratic shrinkage and swelling of the blocks as the temperature increases. This is explained by Dr. Koenig[10] as probably being due to rearrangement of the molecules of the talc as water is driven off and by the molecules changed in physical form by the heat.

It is considered probable that the massive ceramic talc and the nodular cosmetic talc have a much higher frequency of breakage (about 50% according to Carl[7]) than the lava-steatite talc (that had a frequency of breakage of 6% when tested by the American Lava Corporation[11]) due to this erratic behavior. This shrinking and swelling would set up strains within the blocks that as the hardening of the material progresses would result in cracking. The lava talc shows the most nearly regular curve of the three types tested while the poorest burning talc, the cosmetic talc, shows the most irregular curve.

Altho Carl[7] states that the proper burning temperature for talc is 1100°C the American Lava Corporation burns their talc at 1010°C in a hydrogen atmosphere.[11] With the equipment that was available it was not possible to burn the material in a hydrogen atmosphere. The reason this is done commercially is to prevent the iron present from changing to ferric iron and staining the block. The closest temperature that could be maintained, comparable to that used by the American Lava

PLATE V

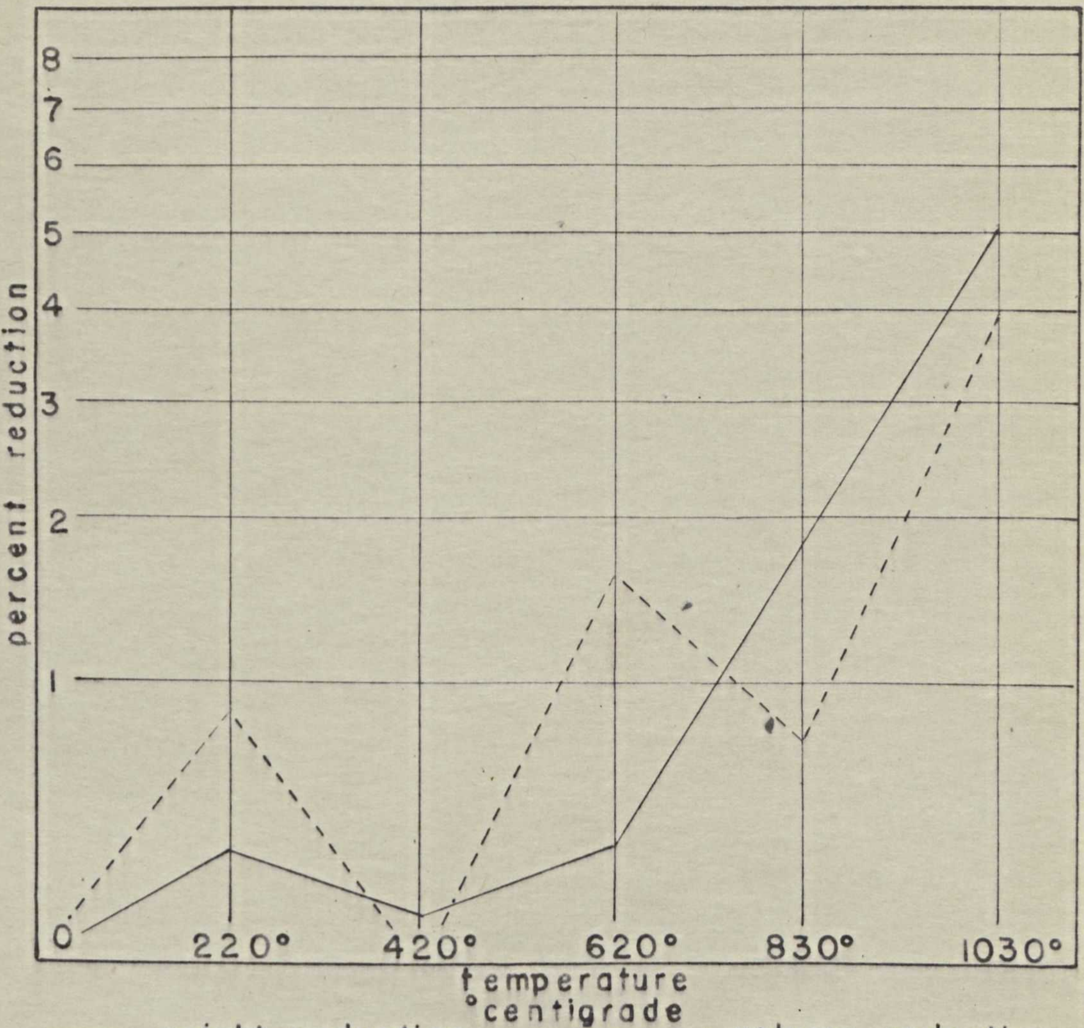


LAVA (STEATITE) TALC

Graphs illustrating the percentage reduction of volume and weight of lava talc upon being burned at various temperatures up to 1030°C.

C.J.L. 4-45

PLATE VI



—— weight reduction ----- volume reduction

COSMETIC TALC

Graphs illustrating the percetage reduction of volume and weight of cosmetic talc upon being burned at various temperatures up to 1030°C.

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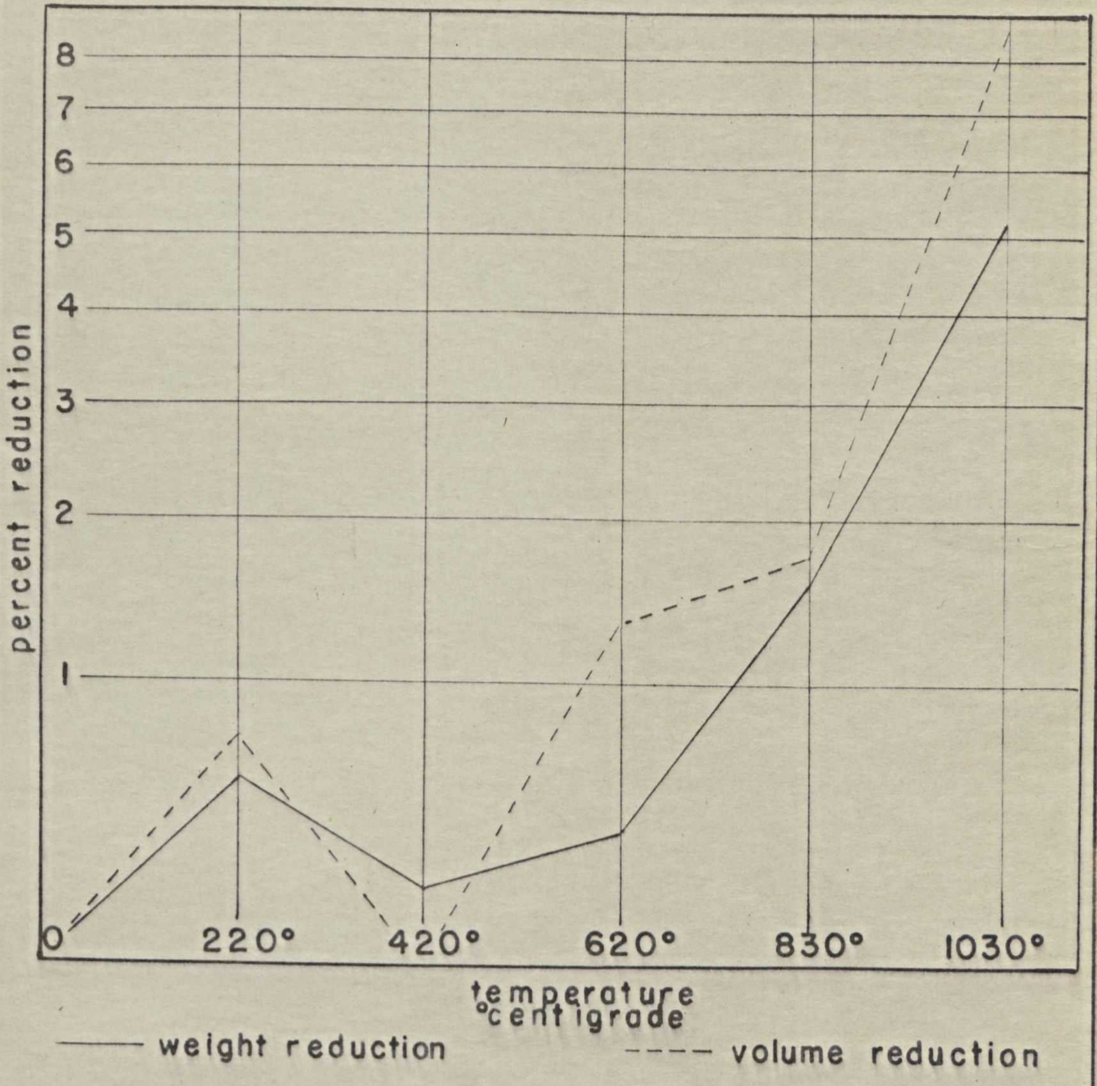
PLATE VII

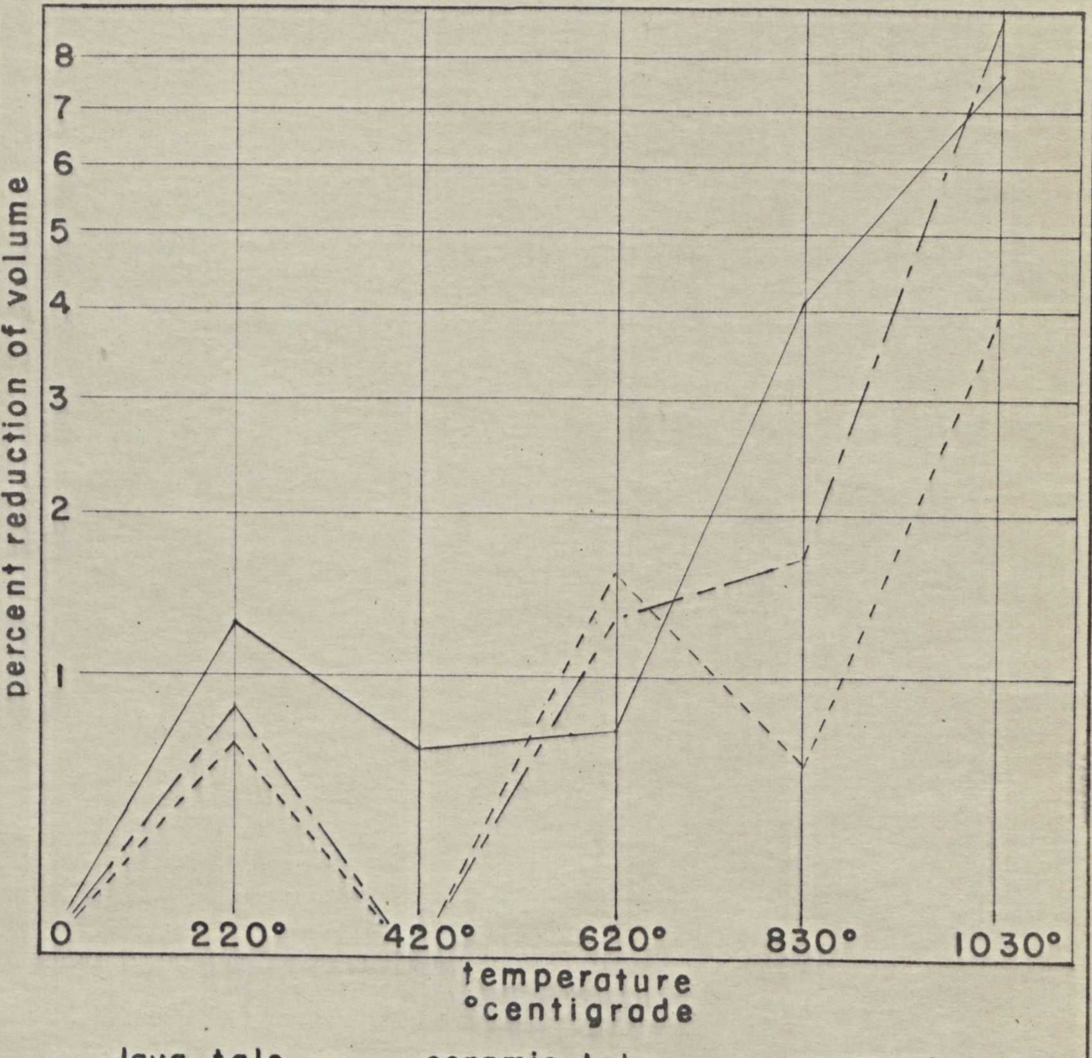


CERAMIC TALC

Graphs illustrating the percentage reduction of volume and weight of ceramic talc upon being burned at various temperatures up to 1030°C.

C.J.L. 4-46

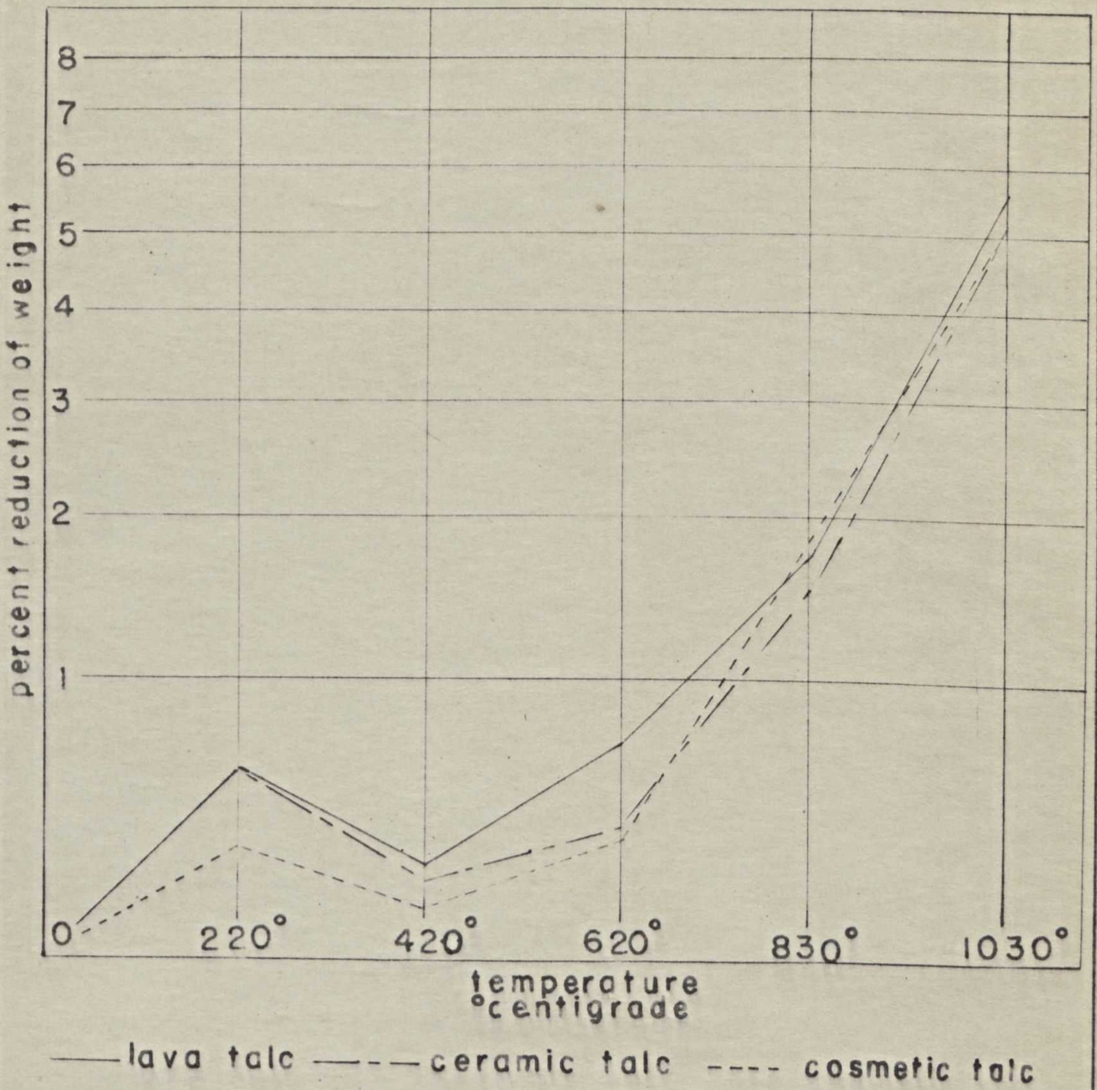
PLATE VIII



Composite graph showing reduction of volume of lava, ceramic, and cosmetic talc samples upon being burned at various temperatures up to 1030°C.

C.J.L. 4-46

PLATE IX



Composite graph showing reduction of weight of lava, ceramic, and cosmetic talc samples upon being burned at various temperatures up to 1030°C.

G.J.L. 4-46

Corporation was 1030°C and this was used as a final temperature in all the tests.

The maximum rate of increase of temperature that could be obtained with the furnace used in these experiments was about 80°C per hour and cracking of all types of talc except lava talc was observed. Carl[7] states that in his tests a maximum rise of 150°C per hour was used thru the 500°C and 900°C phases of the burning and an increase of 500°C per hour was used from room temperature to 1100°C exclusive of the two phases noted above. His experiments yielded about 50% crack free specimens. He considers these good results and attributes them to the slow rise thru the two critical temperatures. With even a slower rise the writer did not obtain even 50% crack free specimens from non-lava talcs.

CONCLUSIONS

Of the three comercial deposits of talc that have been developed in Montana up to this time the Johnny Gulch and the Dillon deposits are still in production while the Helena deposit has been exhausted for several years.

At Johnny Gulch a good grade of ceramic talc is produced and some lava grade talc is available although it is difficult to produce the latter at a profit due to the high cost of mining and sorting. However, this deposit still contains a considerable quantity of talc that can be produced if the market for this material is maintained.

The Dillon deposit still contains a large quantity of proved, probable, and possible ceramic grade talc but no lava grade talc that can be produced commercially.

In the general Dillon-Ennis area there are many smaller deposits of talc that are not definitely known to be of sufficient size to permit exploitation but there may be other, yet undiscovered deposits in this area that would rival any of the three discussed in this paper.

The problem of producing sufficient lava grade talc to satisfy the radio and electronic industries during times when foreign imports are sharply curtailed will have to be solved along one or more of three lines: (1) develop a process to beneficate extruded talc so that it will have the desired minimum dielectric loss and maximum resistance to heat, (2) perfect a burning technique that will permit burning of solid pieces of ceramic grade talc that is machineable, or (3) produce more lava grade talc.

Since the last alternative is subject to the whims of nature it appears that it is up to industry to solve its problems, and to do it before our supply of foreign talc is again cut off.

BIBLEOGRAPHY

1. Ford, William E.
Dana's Textbook of Mineralogy, 4th Edition, 1932
John Wiley and Sons Inc., New York.

2. Keith, Arthur
Talc Deposits of North Carolina
United States Geological Survey Bulletin 213.

3. Hess, H. H.
Origin of Talc and Soapstone
Economic Geology, Volume 28, pages 634-657, 1933.

4. Berkelhamer, L. H.
Petrographic Study of Domestic Talcs
American Ceramic Society Bulletin
Volume 22, Number 7, July 15, 1943.

5. Spence, Hugh S.
Talc, Steatite, and Soapstone; Pyrophyllite
Canada Department of Mines and Resources
Mines and Geology Branch Report No. 803, 1940.

6. Ladoo, R. B.
Talc and Soapstone, Mining, Milling, Products and Uses
United States Bureau of Mines Bulletin No. 213, 1923.

7. Carl, Howard F.
Study of Firing Failure in Massive Talc
United States Bureau of Mines
Report of Investigation Number 3800
February, 1945.

8. Roush, G. A.
The Mineral Industry During 1941, Volume 50
McGraw Hill Book Company, 1942.

9. Berkelhamer, L. H.
Petrographic Study of Domestic Talcs
American Ceramic Society Bulletin, July 15, 1943
Volume 22, Number 7, pages 227-230.

10. Conversations with Dr. A. E. Koenig, professor of chemistry, Montana School of Mines.

11. Thurnauer, Hans (American Lava Corp.)
Report on Crude Talc Samples from Teutsch (Johnny Gulch) Property
Personal report to L. F. Teutsch from the American Lava Corporation, Chattanooga, Tennessee
December 7, 1942.

12. Anderson, H. N.
Helena and Ennis Talc Deposits
Senior Thesis submitted to Department of Geology,
Montana School of Mines, May, 1942.

13. War Minerals Report 178, May 1943
United States Bureau of Mines.