# SAPONITE NEAR MILFORD, UTAH

Harold P. Cahoon, *Department of Ceramic Engineering, University of Utah, Salt Lake City, Utah.*

## Abstract

A small deposit of saponite has been found near Milford, Utah, which is apparently a result of hydrothermal replacement of a dolomitic limestone. Differential thermal analysis, optical data, chemical analysis, and *x*-ray analysis all confirm the identification of this mineral as saponite. Electron microscope pictures show this mineral to possess a sheet-like structure as expected.

## Introduction

A new deposit of saponite was found approximately seven miles southwest of Milford, Utah (see Fig. 1), in the Star Mining District. This district is in the most southern part of the area which was described by Butler (1) in 1913. The deposit was found in a small adit located near the Commonwealth mine (see Butler 1913). The area was actively mined for lead, silver, and copper in the 1870's and again around 1909. The present study began in the summer of 1951 for the purpose of positively identifying the mineral.

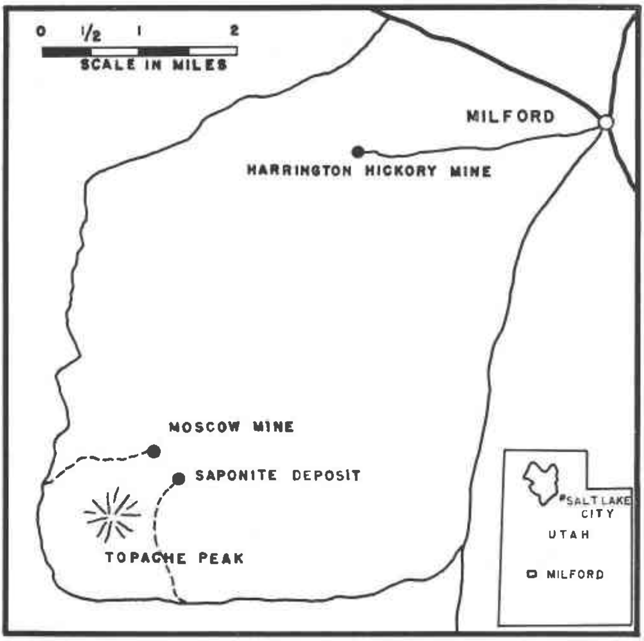

Fig. 1. Index map showing the location of the saponite deposit, Utah.

## GENERAL GEOLOGY

In the Star Mining District the rocks consist mainly of dolomitic limestones, quartzites, and an intrusive quartz monzonite. The beds strike generally north-south and dip approximately east at an angle of 45° to 50°. In general they are broken by a series of nearly parallel fissures which have an east-west strike with a very nearly vertical dip.

The saponite deposit is located in the Topache limestone thought by Butler to be of Mississippian age (1). It is found in a poorly defined vertical fissure of about 3 feet in width. In a hand specimen the clay is snow-white and porcelain-like in appearance, but is soft and has a greasy "feel." Associated with it is considerable siliceous material believed to be chalcedony.

## MINERALOGY OF THE CLAY

### 1. *Microscopic Properties*

The clay mineral was observed to be somewhat fibrous in its over-all appearance when viewed under low magnification, but under high magnification a more or less flaky appearance predominates. The indices of refraction of these flakes, using sodium light and immersion oils that were checked immediately with a refractometer, were found to be $\alpha = 1.511$ and $\gamma = 1.514$. It should be pointed out that due to the small size of the flakes, these indices are at best only approximate.

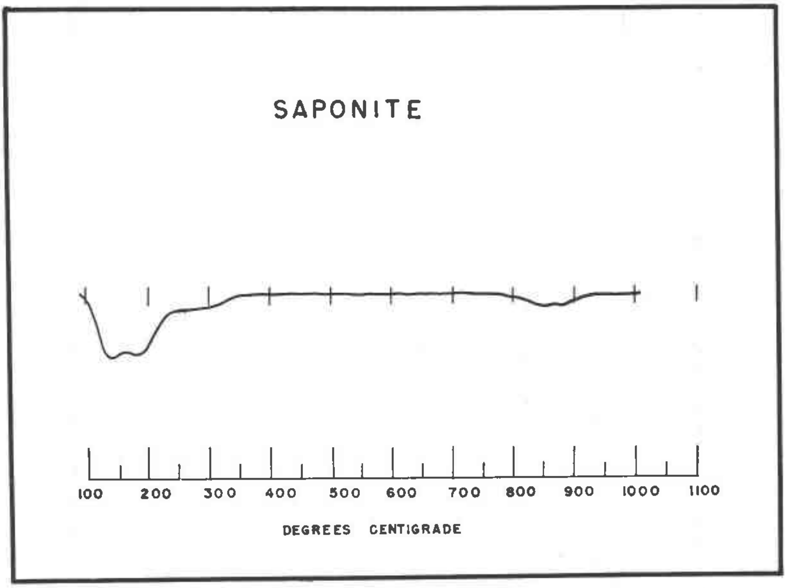

FIG. 2. Differential thermal analysis curve of saponite, Utah.

### 2. *Differential Thermal Analysis*

The apparatus used for this test consisted of a program controller constructed at the University of Utah to increase the temperature of the nichrome furnace at the rate of 10° C. per minute, and a six point, high speed, high sensitivity electronic recorder (Leeds and Northrup "Speedomax"), which recorded both furnace temperature and differential readings.

Figure 2 shows the curve obtained from differential thermal analysis of this mineral. The curves given by Kerr and Kulp (2) for saponite agree well with this curve except for the endothermic reaction at 550° C., which is absent in this case. The curve for saponite from Montreal, Quebec, as shown by Kerr and Kulp, also lacks this reaction.

### 3. *Chemical Analysis*

A spectrographic analysis run by Mr. Harold R. Bradford at the University of Utah gave very high percentages for magnesium and silicon, low percentages for aluminum, calcium and iron, and no lines for potassium, sodium, and a questionable line for lithium. A wet chemical analysis of hand picked material made by Mr. Walter Savournin at the University of Utah gave the following results:

TABLE 1. CHEMICAL ANALYSIS OF SAPONITE FROM MILFORD, UTAH

| | | |
|---|---|---|
| $SiO_2$ | 50.01 | Per cent |
| $Al_2O_3$ | 3.89 | |
| $Fe_2O_3$ | 0.21 | |
| CaO | 1.31 | |
| MgO | 25.61 | |
| $TiO_2$ | less than 0.04 | |
| $H_2O+$ | 12.02 | |
| $H_2O-$ | 7.28 | |

Using these figures, the formula was calculated as 17 $MgO \cdot Al_2O_3 \cdot 22SiO_2 \cdot 6H_2O(CaO)$. Calculations according to the method proposed by Ross and Hendricks (3) gave the structural formula as $(Al_{0.04}Fe_{0.01}Mg_{2.85})(Al_{0.30}Si_{3.70})O_{10}(OH)_2$, which is in agreement with their formulas for saponite.

To form saponite's structure the alumina in the octahedral layer of the montmorillonite structure as given by Norton (4) would be almost completely replaced by magnesia. Therefore, the only difference in the structure for saponite would be a slightly thicker unit cell due to the substitution of the larger magnesium ions.

## 4. *X-ray Analysis*

An *x*-ray powder pattern was taken of the mineral after it had been exposed to room atmosphere for several days. The *d* values obtained are presented in Table 2. These values agree with the values given by MacEwan (5).

TABLE 2. *X*-RAY DATA OF SAPONITE, UTAH

| Line Number | *d* Values | Indices | $I/I_1$ | Line Shape |
|---|---|---|---|---|
| 1 | 16.6 | 001 | 1.0 VS | Vbr |
|  | 13.0 |  |  |  |
| 2 | 4.94 | 001* | .2 | Sh |
| 3 | 4.51 | 110, 020‡ | .8 | Sh |
| 4 | 3.70 | ? | .4 | Br |
| 5 | 3.21 | 002* | .1 V |  |
| 6 | 2.89 | 121* | .4 | Br |
| 7 | 2.58 | 130, 200‡ | .5 | Vbr[1] |
| 8 | 2.26 | 220, 040‡ | .1 V |  |
| 9 | 2.06 | 003* | .1 V |  |
| 10 | 1.72 | 310, 150,‡ 240 | .3 | Sh |
| 11 | 1.52 | 330, 060‡ | .9 | Sh |
| 12 | 1.31 | 260, 400‡ | .5 | Br |
| 13 | 1.26 | 350, 170,‡ 420 | .1 V |  |
| 14 | 1.05 | 370, 280,‡ 510 | .1 V |  |
| 15 | .99 | 190, 530,‡ 460 | .3 | Br |
| 16 | .88 | 390, 600‡ | .4 | Sh |

*d* = Spacings in angstroms.
$I/I_1$ = Compared in tensities
V = Just visible
VS = Very strong
Vbr = Very broad
Br = Broad
Sh = Sharp
1. = A sharp inner edge
* = Indices from Winkler *x*-ray Identifications and Structure of Clay Minerals, p. 126 (1951).
‡ = Indices from D. M. C. MacEwan *X*-ray Identification and Structure of Clay Minerals (1951), Table facing p. 124.

The mineral was also heated up to 1000° F. in intervals of 100 degrees with an *x*-ray photograph being taken after each interval. One photograph was taken of the mineral after it had been allowed to hydrate by placing it in a sealed jar containing water. It is interesting to note that the *hk*0 spacings, in agreement with the findings of MacEwan (5), did not change with hydration or dehydration, but that the 00*l* spacings changed distinctly. This shift should be kept in mind when evaluating *x*-ray patterns of minerals of the montmorillonite type. The broadness of the $00l$ reflection can well be explained by the thickness of the particles. Line broadening is first noticeable when the mean thickness is about 1000 Å and is very strongly effective when the mean thickness reaches 300 Å.

### 5. *Electron Micrographs*

Samples were prepared for observation under the electron microscope by placing about 10 grams of mineral which had not been crushed in 100 cc. of distilled water. The container was thoroughly shaken once a day for a week. It was hoped by this method that the particles would separate from each other without disintegrating. Preparing the sample in this manner proved highly successful.

Figure 3 is an electron micrograph which shows a booklet of saponite in which part of the book has slid off the main particle. Several thin sheets are clearly visible. The flaw in the lower left hand corner of each sheet proves that they are all from the same booklet. It is possible to

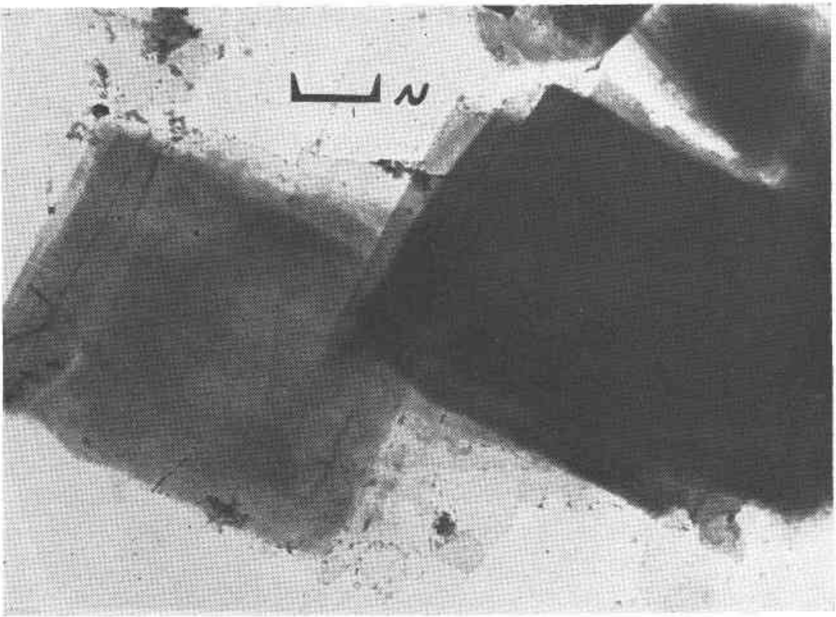

FIG. 3. Electron microscope photograph showing the book-like structure of saponite. Notice the flaws in the sheets proving they are all from the same book. Notice the one or two very thin plates.

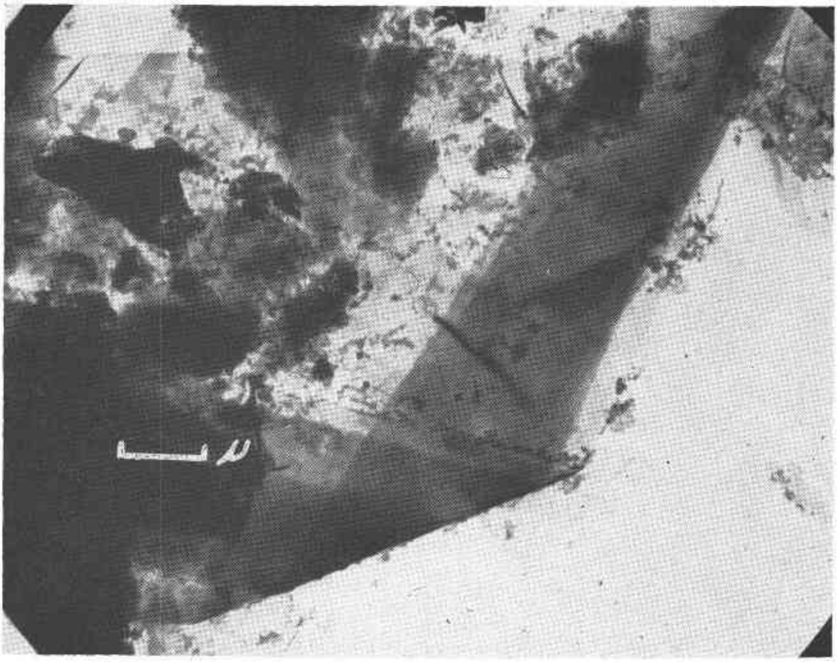

FIG. 4. Electron microscope picture showing a completely folded sheet. Notice that the individual sheets can be traced through the fold. Also note the one large thin sheet.

trace the outline of several of these thin sheets even though they overlie other sheets. Figure 4 shows a large multiple layer which has been folded. Tracing the individual sheets, it is possible to follow the edges through the fold. Also there is one large sheet which is approximately $\frac{3}{4}$ as wide as the field, or about 12 microns in width. No tears or cracks are evident in the folded edge, which indicates that the sheet is pliable enough to withstand folding. The thinnest sheets have been torn in several places as evidenced by the small irregular particles in the field. The thinnest sheets seen in these figures are 50 Å and less in thickness,[*] which is approaching the required thickness of a single unit cell.

The shapes of the particles probably have no significance in identifying this mineral in view of the fact that in all the photographs that have been observed no two particles possessed the same shape. Figure 5 shows

---

[*] According to R. W. G. Wyckoff in his book Electron Microscopy (p. 52), the maximum thickness of objects that can be penetrated at an accelerating voltage of 50 KV is 2000 Å. Using this figure, the accelerating voltage used and the number of sheets observed on top of each other, the number 50 Å was calculated. At the present time experimental work is being done to determine the true thickness of these plates.

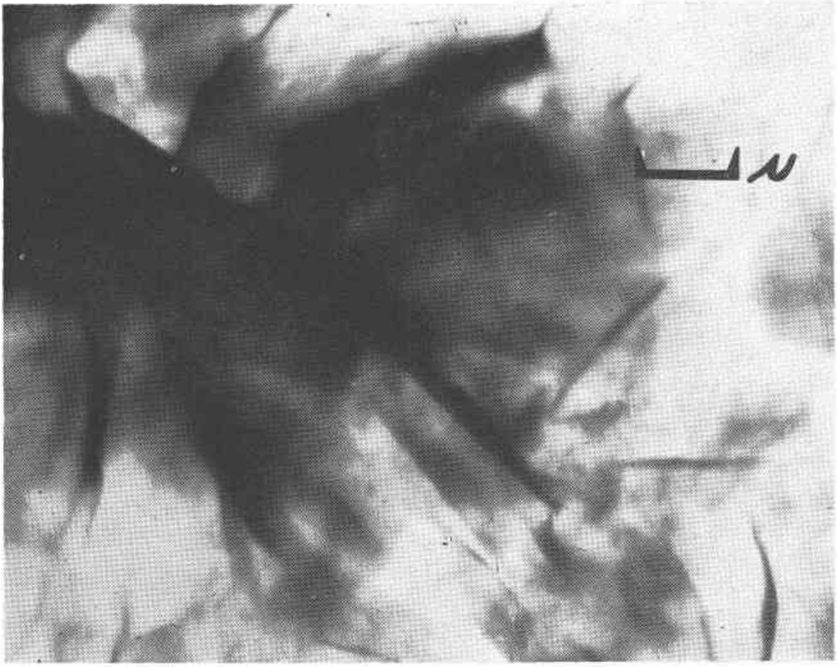

Fig. 5. Electron microscope photograph showing the sheets of saponite crinkled and bent. Most of the particles observed were of this type.

the most commonly observed particles. These particles are thin sheets which have been twisted and folded so that a wavy appearance resulted. Some of this effect no doubt is due to the incomplete dispersion of the particles. When a sample was prepared by the method previously described, except for the addition of three drops of sodium silicate, the sample expanded within a short time so that it was approximately 12 times its original volume. No individual particles were evident by visual inspection after this expansion and the mass became jelly-like in character. The expanded particles when viewed through the electron microscope were very thin and considerably smaller than the untreated particles. As is evident in Fig. 6 very few particles did not expand.

## Origin of the Saponite

The saponite occurs in dolomitic limestone as veins in a zone about three feet in width. In these veins are found nodules composed of a core of dolomitic limestone with a layer of pure white crystallized calcite surrounded by saponite (see Fig. 7). The dolomitic limestone cores are often partially replaced by veins and patches of chalcedony and saponite.

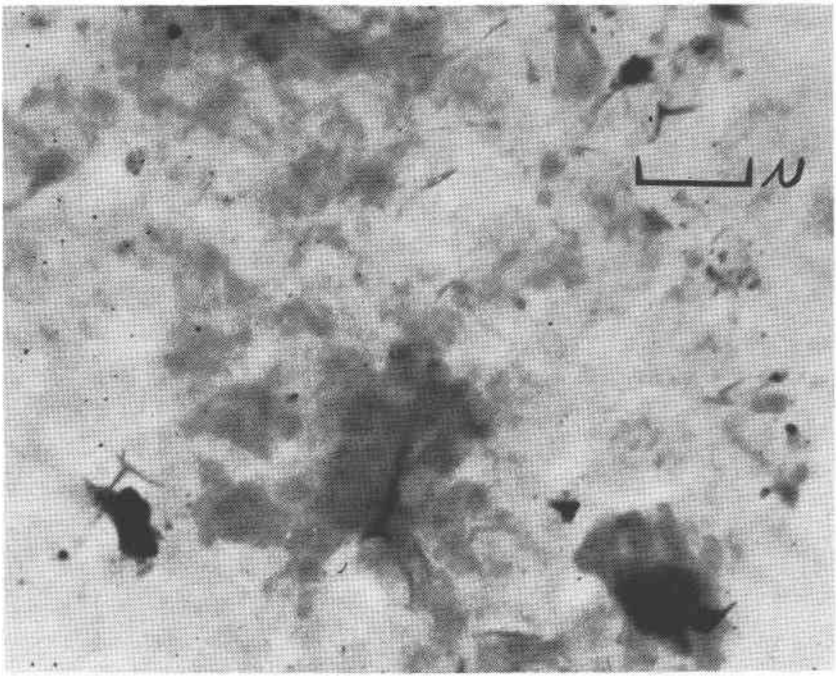

FIG. 6. Electron microscope photograph of the dispersed saponite. Notice that the particles have become very thin and small and are difficult to distinguish.

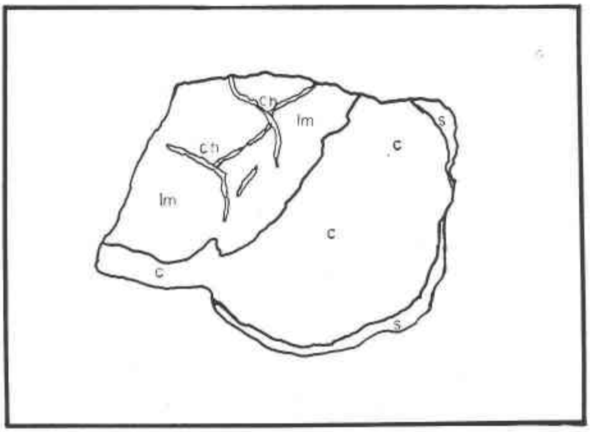

FIG. 7. Line drawing of a polished surface of a nodule showing the relation of limestone (*lm*), calcite (*C*), chalcedony (*Ch*), and saponite (*S*).

Microscopic veinlets of chalcedony, and rarely veinlets of saponite, are observed in the calcite. Occasionally small wheat-size grains of chalcedony are found within the saponite.

Silica-bearing hydrothermal solutions are believed to have formed this mineral by using the magnesium of the dolomitic limestone and depositing it as saponite, with the calcium of the limestone forming the calcite. The small amount of alumina could have been supplied by the clay impurities in the dolomitic limestone.

## Acknowledgments

Appreciation is expressed to the University of Utah Research Fund for financial assistance and to Dr. Bronson Stringham and Dean Carl J. Christensen for their helpful suggestions.

## References

1. Butler, B. S., Geology and ore deposits of the San Francisco and adjacent districts: *Utah Professional Paper* **80,** 35 (1913).
2. Kerr, P. F., and Kulp, J. L., Multiple differential thermal analysis: *Am. Mineral.*, **33,** 387–419 (1948).
3. Ross, C. S., and Hendricks, S. B., Minerals of the montmorillonite group: *Professional Paper* **205–B,** 41–42(1945).
4. Norton, F. H., Elements of Ceramics, p. 11 (1952).
5. MacEwan, D. M. C., *X*-ray Identification and Structure of Clay Minerals, pp. 101–104 (1951).

*Manuscript received Feb. 12, 1953.*