OCCURRENCES OF SHALES PARTIALLY ALTERED TO PYROPHYLLITE

by

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ABSTRACT

Examination of samples from shale outcrops on the periphery of the Utah Valley graben has revealed an unusual association of disseminated pyrophyllite with various clay minerals. Numerous samples were obtained from exposures in brick clay pits located in the Manning Canyon formation of Mississippian–Pennsylvanian age and from the Long Trail member of the Great Blue formation of Mississippian age. Associated clay minerals in these beds include illite, illite–montmorillonite mixed-layer clays, 7 Å chlorite, 14Å chlorite, kaolinite and sericite. Associated nonclay minerals include quartz, calcite, and small amounts of dolomite. Associated secondary minerals are calcite, aragonite, jarosite, gibbsite and gypsum.

Three possible explanations of genesis have been considered in the present study: deposition of detrital pyrophyllite, surface weathering under special conditions, and hydrothermal or pneumatolytic activity. The third alternative explanation, hydrothermal or pneumatolytic activity, is believed to be the most acceptable. It is hypothesized that magnesium, iron, and interlayer cations have been removed from some of the original 2 : 1 layer clays in the shale by solutions localized along fault zones.

INTRODUCTION

The shale beds in the Manning Canyon formation and the Long Trail member of the Great Blue formation bordering the Utah Valley furnish most of the brick clay used in the Salt Lake City area. Examination of samples from many of the clay pits in these formations has revealed the presence of pyrophyllite, sometimes in large quantities. The unexpected occurrence of this mineral, and the areal extent of the occurrences, present interesting mineralogical problems. Occurrences over wide areas and as far apart as 35 miles indicate a different paragenesis for pyrophyllite in shales than that reported in other occurrences (Stuckey, 1928; Buddington, 1916).

The lithology of the Mississippian–Pennsylvanian Manning Canyon formation in this vicinity is approximately 85 percent black shale, the remainder being thin dark limestones and sandstones. The Long Trail member of the Mississippian Great Blue formation is entirely a black shale bed in this area.

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LOCATION AND GEOLOGY

The locations of the exposures sampled for this study are shown in Fig. 1. All exposures numbered on the map contain pyrophyllite in varying amounts.

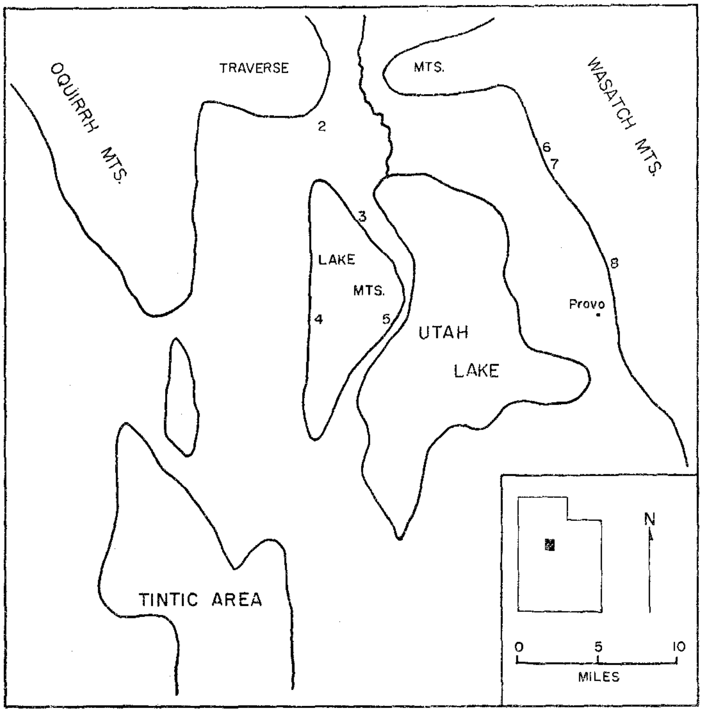

FIGURE 1.—Generalized map showing exposures sampled for this study. (1) Soldier Canyon (Manning Canyon formation), (2) Clinton Pit (Manning Canyon formation), (3) Interstate Pit (Manning Canyon formation), (4) Western Pit (Manning Canyon formation), (5) Cedarstrom Pit (Manning Canyon formation), (6) Wadley Pit (Long Trail member), (7) McFarland Pit (Long Trail member), (8) Stubbs Pit (Long Trail member).

Utah Valley is located between the Wasatch Mountains on the east and the Lake Mountains on the west. It is believed to be an area affected by Basin and Range faulting. The largest number of samples was taken in the Lake Mountain area. The Lake Mountains are a large synclinal block of Paleozoic beds protruding through the sediments of the Salt Lake group. The beds are well exposed on the eastern and western sides of the mountains and dip into the center of the range. Figure 2 is a view of one of the Lake Mountain clay pits (number 3 on the index map) in the Manning Canyon formation. The picture is taken directly down dip, which is about 30 degrees. The resistant bed lying immediately over the clay is a fine-grained black limestone—a type which is common in the Manning Canyon formation. The limestone bed lies below the unconformity with the lake sediments of the Cenozoic Salt Lake group.

OCCURRENCE OF THE PYROPHYLLITE

Typical x-ray diffraction patterns of bulk samples from this study and a standard North Carolina pyrophyllite are shown in Fig. 3. Peaks at 7.14 and 10 Å indicate impurities of kaolinite and mica in the standard. The patterns indicate that all shales under study contain well-crystallized pyrophyllite. The associated clays indicated by these patterns will be discussed later.

Figure 4 is a typical photomicrograph of Manning Canyon shale from the Clinton pit. The light colored ovals are pyrophyllite. Many of the pyrophyllite ovals show sharp points on opposite ends similar to the augen structure of metamorphic rocks. A photomicrograph of the texture of the pyrophyllite in the Manning Canyon shale from Soldier Canyon is seen in Fig. 5. The veins seen in this photomicrograph are chlorite; the pyrophyllite again shows the typical "augen" structure.

Examination of thin sections and insoluble residues shows that the pyrophyllite is also found in lesser amounts in the fine-grained black limestone that overlies the shale bed in the Interstate pit (Fig. 2). This pyrophyllite, however, is restricted to a distance of approximately three feet from the contact with the shale.

There is strong indication that the pyrophyllite is localized along fault zones. This is shown best in the section sampled at Soldier Canyon (number 1 on the index map) in the Oquirrh Mountains. Figure 6 shows the grouping of the pyrophyllite in the vicinity of a readily apparent fault in the Manning Canyon formation. As indicated at the top of the column, it is 276 ft to the overlying Oquirrh formation. Also noted, at the bottom of the column, is the distance to the underlying Great Blue formation, 584 ft. No pyrophyllite was found in any samples from this stratigraphic section except those noted here.

ASSOCIATED MINERALS

The clay minerals associated with the pyrophyllite in the Long Trail member of the Great Blue formation and in the Manning Canyon formation include a number of species. The samples from the Manning Canyon formation range from almost pure pyrophyllite to apparently unaltered shale and reflect varying intensities of alteration of the original shale. The Long Trail member, however, has relatively constant mineralogy in the area studied.

FIGURE 2.—The Interstate pit located in the Manning Canyon formation on the northeast side of the Lake Mountains.

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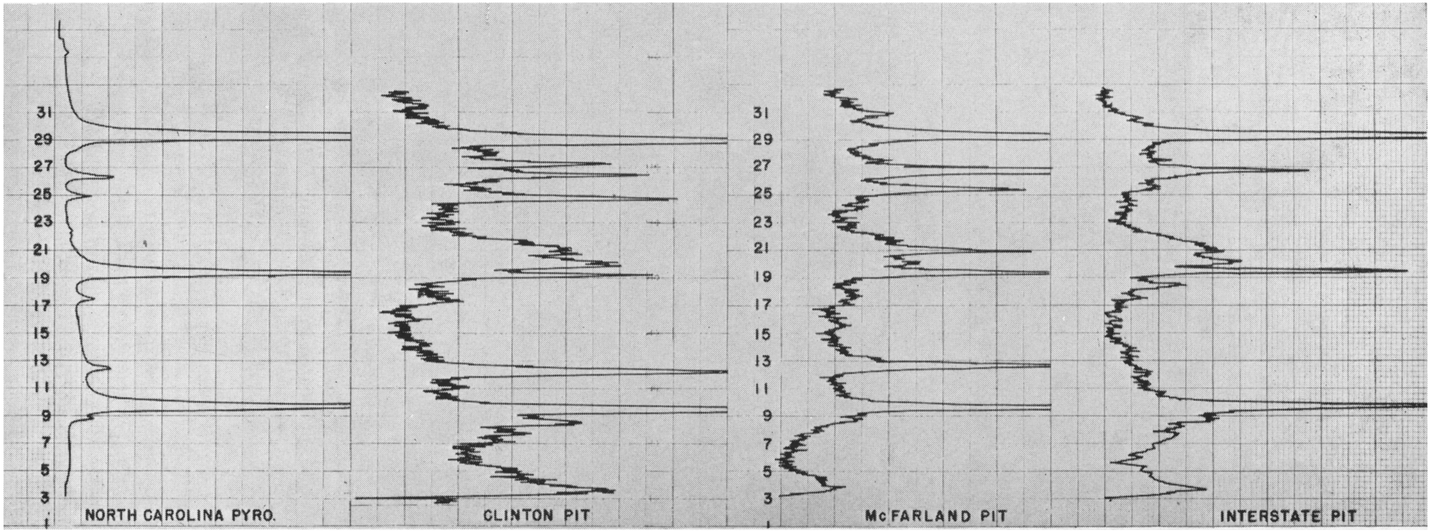

FIGURE 3.—Typical x-ray diffraction patterns of samples from this study and a standard North Caroline pyrophyllite. Ni-filtered, CuK$_\alpha$ radiation Values in degrees 2θ.

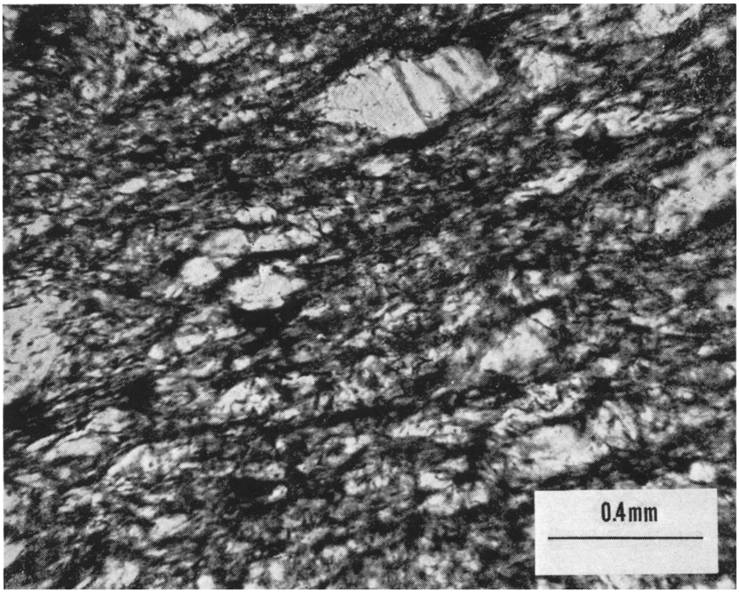

FIGURE 4.—Photomicrograph of Manning Canyon shale from the Clinton pit showing light colored patches of pyrophyllite. Unpolarized transmitted light.

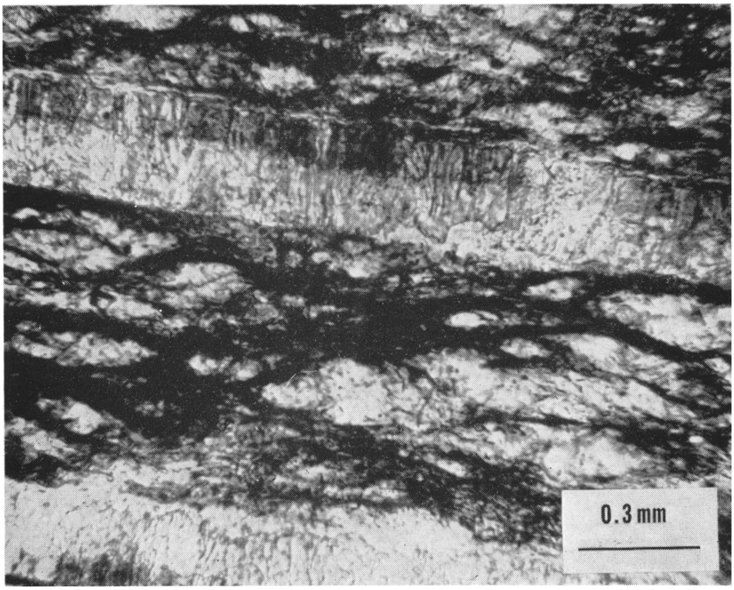

Figure 5.—Photomicrograph of Manning Canyon shale from Soldier Canyon showing patches of pyrophyllite and chlorite veins. Unpolarized transmitted light.

Illite was ever present in the samples from the Manning Canyon formation and the Long Trail member. On the x-ray patterns the 10 Å peak commonly is skewed to the low-angle side indicating random interlayers of montmorillonite. After vapor glycolation treatment, some patterns showed basal peaks

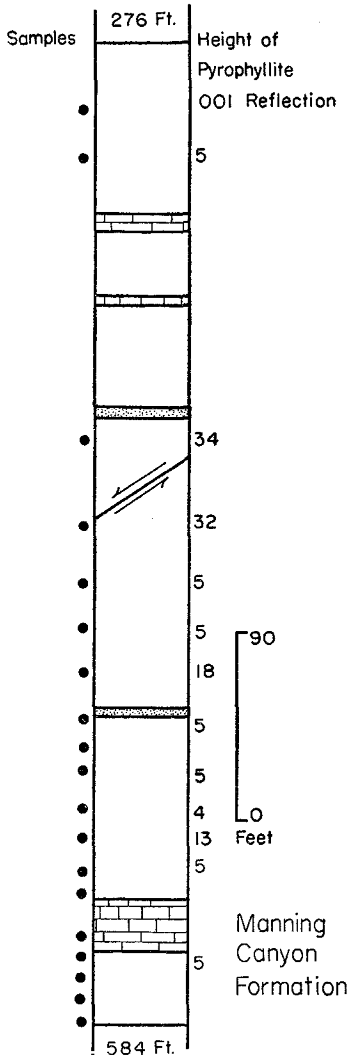

FIGURE 6.—An idealized section of a part of the Manning Canyon formation at Soldier Canyon. Numbers at the top and bottom of the section indicate distances to overlying and underlying carbonate formations. Peak height is expressed in arbitrary units from x-ray diffraction patterns.

with spacings as large as 13.8 Å, indicating a maximum of 35 percent of interlayer montmorillonite using Weaver's curves (1956).

The Long Trail member is characterized by the presence of 7 Å chlorite (Fig. 3, McFarland pattern), although small amounts of 14 Å chlorite are present in a few samples. The 7 Å chlorite was distinguished from kaolinite by reflections at 7.0 Å and 3.50 Å, definitely lower than the 001 and 002 reflections of kaolinite. Use of Nelson and Roy's (1954) curves relating basal spacing to aluminum content indicates that this chlorite is a high-aluminum variety similar to amesite. Some Manning Canyon shale samples contained 14 Å chlorite although chlorite generally is not found in the more altered samples.

Kaolinite is not found in the Long Trail member and is identified in the Manning Canyon formation only in samples from the Clinton pit (Fig. 3, Clinton pattern).

Small sericite veins, one to two centimeters thick, are found in the Manning Canyon formation in the Clinton pit.

Primary nonclay minerals in the shales are quartz, calcite, and small amounts of dolomite. Associated secondary minerals are calcite, aragonite, jarosite, gibbsite and gypsum.

PARAGENESIS

The area in which the pyrophyllite occurs contains no high-temperature mineralization, and only manganese deposits, usually attributed in this vicinity to hot spring activity, are found (Crawford and Buranek, 1945). The area generally is considered to be a barren district lying in the triangle of the mineralized Tintic, Bingham and Cottonwood mining districts.

In explaining this occurrence of pyrophyllite, deposition of detrital pyrophyllite is dismissed as a possible mode of genesis because of size and textural relations noted in thin sections (Figs. 4 and 5). In addition, great stratigraphic thicknesses contain pyrophyllite; a source area of a type to supply this quantity of pyrophyllite is difficult to hypothesize. The remote possibility that this pyrophyllite is a product of surface leaching is dismissed because of the occurrences of pyrophyllite disseminated in black shales and limestones as well as in the light surface clays.

The explanation of genesis which is supported by phase data, field relations, and petrographic examination is that of hydrothermal or pneumatolytic alteration. Not so apparent is the temperature or composition of the solutions. The genesis proposed for massive replacements in acid igneous rocks by pyrophyllite, such as those found in North Carolina (Stuckey, 1928), probably is not applicable to this disseminated occurrence in shale beds. It is believed that in the present occurrences, leaching solutions at elevated temperature have removed the iron, magnesium, and interlayer cations from originally deposited 2 to 1 layer clays, thus forming pyrophyllite. Hydrothermal syntheses by Roy and Osborn (1954) in excess water systems under equilibrium conditions indicate that a temperature of 420°C is required for the formation of pyrophyllite, whereas Al-montmorillonite is formed below that temperature. Roy and Osborn, however, have mentioned the possible formation of pyrophyllite at temperatures as low as 275 degrees because of field occurrences of pyrophyllite with diaspore. Occurrence of diaspore and pyrophyllite together, however, is not necessarily evidence for low-temperature formation because pyrophyllite and diaspore could have formed at higher temperatures. Studies by Gruner (1944) indicate that pyrophyllite forms from the alteration of feldspars in acid systems at temperatures as low as 300°C.

On the basis of the available data it appears that the solutions causing the alteration had a temperature of at least 300°C and were probably of an acid nature.

REFERENCES

Buddington, A. F. (1916) Pyrophyllitization, pinitization, and silicification of rocks around Conception Bay, Newfoundland : *J. Geol.*, v. 24, pp. 130–152.

Crawford, A. L. and Buranek, A. M. (1945) A reconnaissance of the geology and mineral deposits of the Lake Mountains, Utah ; *Utah Geol. & Mineral. Survey*, Circ. 35.

Gruner, J. W. (1944) The hydrothermal alteration of feldspars in acid solutions between 300° and 400°C : *Econ. Geol.*, v. 39, pp. 578–589.

Nelson, B. W. and Roy, R. (1954) New data on the composition and identification of chlorites : in *Clays and Clay Minerals*, National Academy of Sciences—National Research Council pub. 327, pp. 335–346.

Roy, R. and Osborn, E. F. (1954) The system Al_2O_3–SiO_2–H_2O : *Amer. Min.*, v. 39, pp. 853–885.

Stuckey, J. L. (1928) The pyrophyllite deposits of North Carolina with a more detailed account of the geology of the Deep River region : *North Carolina Dept. Conservation and Development, Bull.* 37, 62 pp.

Weaver, C. E. (1956) The distribution and identification of mixed-layer clays in sedimentary rocks : *Amer. Min.*, v. 41, pp. 202–221.