

CLAY MINERALS IN ROCKS OF THE LOWER PART OF THE OQUIRRH FORMATION, UTAH¹

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ABSTRACT

An association between clay minerals and rock type is recognized in the rocks of an inter-layered sequence of fossiliferous shaly, sandy bioclastic, and cherty limestone, dolomitic limestone, calcareous and dolomitic quartzite, and quartzite that form a portion of the lower part (Pennsylvanian age) of the Oquirrh formation in the northern Oquirrh Range, Utah. These sedimentary rocks are largely of clastic origin and range from fine- to coarse-grained. In part they are cross-bedded, and fossils are locally abundant. Calcite-rich rocks predominate (78 percent) over dolomite- and quartz-rich rocks (17 and 5 percent, respectively). Clay minerals constitute less than one percent in quartzite and range from one to five percent in some limestones.

Clay minerals and rock types are commonly observed in the following associations: Illite and chlorite occur in limestone; illite, chlorite, and mixed-layer clay occur in cherty, bioclastic, and sandy limestone and in calcareous quartzite; chlorite and illite commonly are present in dolomitic quartzite; chlorite, illite, and mixed-layer clay are found in dolomitic limestone; and kaolinite, illite and chlorite are typically present in quartzite. The mixed-layer clay has a lattice spacing of 29.4 Å that expands to 31.0 Å when glycolated and contracts irregularly to 13.2 Å when heated to 500 °C; the clay is assumed to consist of 14 Å chloritic and 15 Å montmorillonitic material. Chlorite or mixed-layer clay, or both, generally are associated with rocks containing dolomite.

INTRODUCTION

The clay minerals in carbonate and quartzite rocks of the lower part of the Oquirrh formation were studied by X-ray diffraction, chemical, and petrographic methods to determine the relationship of clay mineral assemblages to rock type. This progress report is part of a comprehensive study of the Oquirrh formation in the Bingham mining district (Fig. 1) being carried on by the U.S. Geological Survey. The Oquirrh formation is the host rock of the porphyry and related copper and base metal deposits of the Bingham district. The samples studied were collected about 15 miles north of the

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district, presumably outside of the halos of contact metamorphism and hydrothermal alteration that surround the district.

Weaver (1959) compiled data that showed that Pennsylvanian rocks in the central and eastern United States contain complex clay mineral suites. In general an illite, chlorite, kaolinite, montmorillonite, and random mixed-layer illite-montmorillonite assemblage characterizes Upper Pennsylvanian

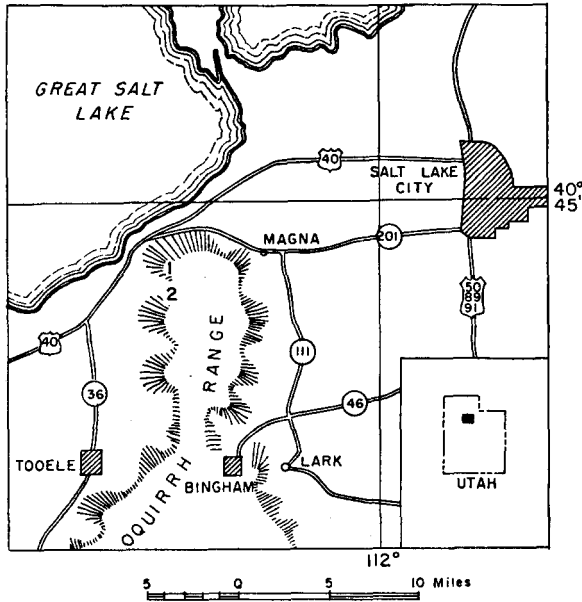


FIGURE 1.—Index map showing the sample areas in the northern Oquirrh Range and the Bingham mining district, Utah. (1) Rogers Canyon, (2) Big Canyon.

limestones in Illinois, and illite and kaolinite characterize sandstone and quartzite. Similar complex clay mineral assemblages occur in the Oquirrh rocks, but the assemblage also includes a regular mixed-layer montmorillonite-chlorite clay mineral as a significant phase in some rocks.

Assistance in the laboratory by James Berkland, who determined the content of calcite and dolomite, is acknowledged. Ralph J. Roberts aided in measuring stratigraphic sections and in sampling the rocks.

FIELD AND LABORATORY METHODS

Forty samples, representative of individual beds in part of a measured section (Fig. 2) of the lower part of the Oquirrh formation, were collected. Modal analyses were made from thin sections cut from these rocks. The rocks were crushed and ground in the spectrographic laboratory of the

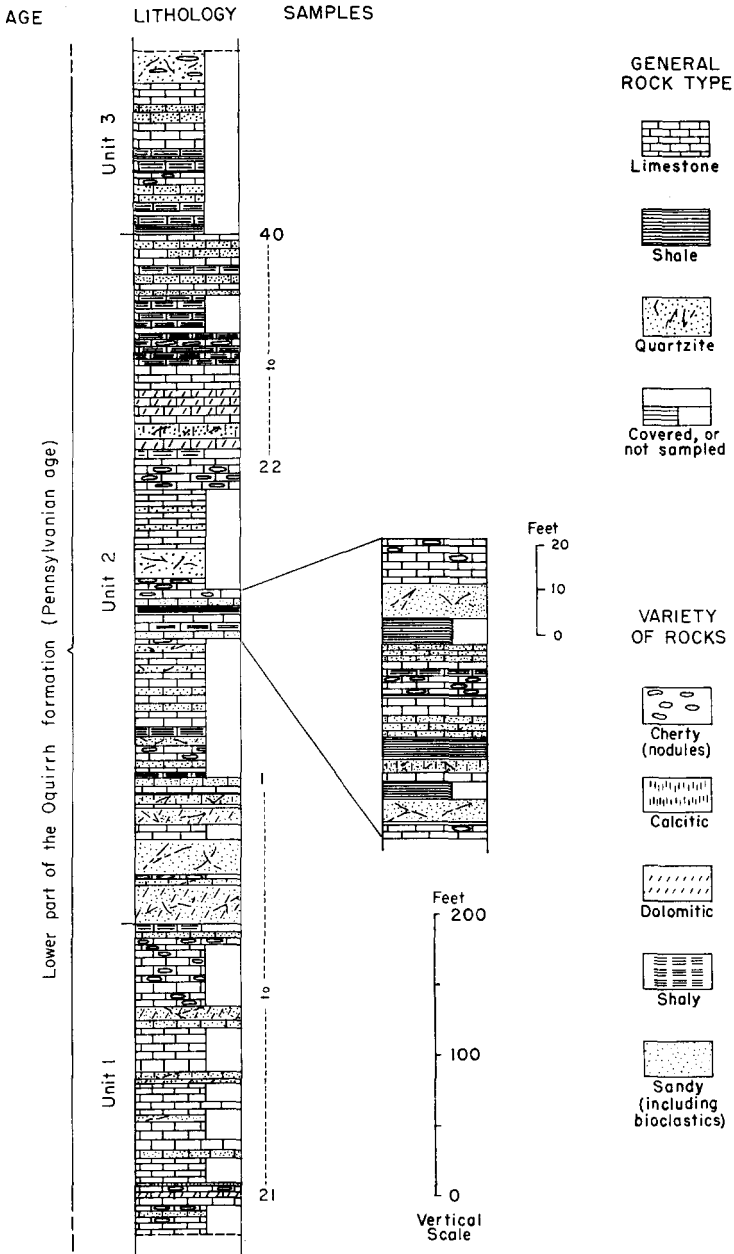


FIGURE 2.—Composite columnar section showing the general character of the rocks sampled in the lower part of the Oquirrh formation.

Geological Survey for spectrographic and chemical analysis and mineralogical study. A $<2\ \mu$, $>0.2\ \mu$ size fraction from each sample, which was previously ground to pass the 325-mesh screen, was obtained in a centrifuge according to methods described by Hathaway (1956). This sample included quartz, carbonate minerals, and a few grains of feldspar as well as clay minerals; air-dried oriented aggregates were prepared on glass slides for X-ray examination on a Philips-Norelco diffractometer using nickel-filtered copper radiation, a linear range of 320 cps, and a scan of $2^\circ\ 2\theta$ per min. The samples also were X-rayed following treatment by ethylene glycol using the vapor-pressure method (Brunton, 1955), and then heated at 500°C in an electric muffle furnace for 1–2 hr.

Clay minerals are sparse in most samples, and the diffractometer data are poor. The clays are characterized and roughly grouped on the basis of the diffraction data. Illite produces an identifiable $10\ \text{\AA}$ diffraction maximum that is unaffected by glycolation and heat treatment. Montmorillonite (in mixed-layer clay) is generally the $15\ \text{\AA}$ variety that expands to $17\ \text{\AA}$ when glycolated and contracts to $9.7\ \text{\AA}$ when heated. Chlorite has a $14\ \text{\AA}$ basal spacing that is unaffected by glycolation and whose intensity is enhanced as it contracts to $13.2\ \text{\AA}$ on heat treatment. Kaolinite diffraction peaks at $7.2\ \text{\AA}$ and $3.5\ \text{\AA}$ are not affected by glycolation but are destroyed by heat treatment. The regular mixed-layer clay basal spacing at $29.4\ \text{\AA}$ expands to $31.5\ \text{\AA}$ when glycolated and contracts to about $13\ \text{\AA}$ when heated. This may be a 002 peak, but no higher-order peaks were observed. Random mixtures of illite and montmorillonite, also present, are sparse and poorly defined. Nonclay mineral component diffraction peaks at 4.27 , 3.35 , 2.45 , and $2.28\ \text{\AA}$ for quartz, at 3.84 , 3.03 , and $2.49\ \text{\AA}$ for calcite, and at $4.19\ \text{\AA}$ for K-feldspar are not modified by treatment, but carbonate is readily removed by dilute HCl; the $2.88\ \text{\AA}$ peak for dolomite is not present following heat treatment. Calcite and dolomite proportions in the rocks were determined by the X-ray method of Tennant and Berger (1957).

GEOLOGIC SETTING

The northern Oquirrh Range, in north-central Utah in the eastern part of the Great Basin, is underlain by folded rocks of the Oquirrh formation (Gilluly, 1928; Nygreen, 1958; Bissell, 1959). Seven units that total more than 11,000 ft were mapped in the area under study (Fig. 1); these include interbedded limestone, sandstone, quartzite, shale, and dolomite. Clastic limestone, commonly with abundant fossils, is the principal rock type in the lower part; quartzite is dominant in the middle part, and quartzite, sandstone, and dolomite predominate in the upper part. Only samples collected from the lower part were studied during this investigation.

LITHOLOGY

Rocks in units one and two at the base of the Oquirrh formation are predominantly carbonate-rich clastic sediments. Unit one is 2390 ft thick and consists of limestone and subordinate interlayered shale and sandy limestone; about 200 ft of the upper part of unit one were sampled. Unit two, 490 ft thick, is composed mostly of cyclic sequences of sandy limestone, quartzite, shale, and limestone (Fig. 2).

The rocks studied are grouped into seven general types shown in Fig. 3 on the basis of their chemistry and mineralogy. General lithologic features

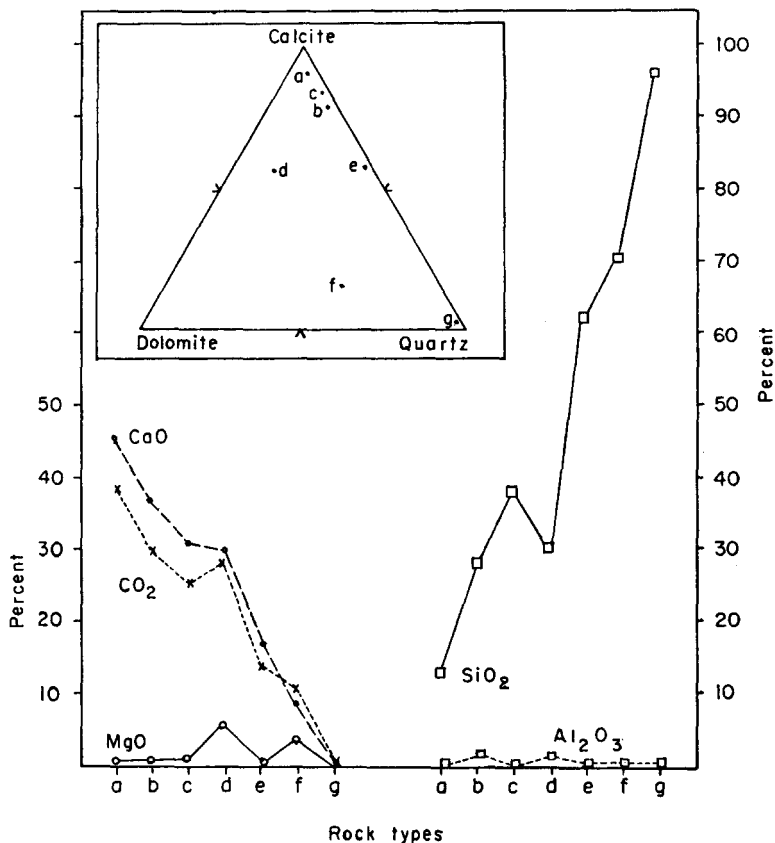


FIGURE 3.—Average variations in major oxide constituents in chemically analyzed rocks, and in the inset, average mineral composition of the rocks estimated from thin section mode and X-ray diffraction data: *a*, limestone (10); *b*, cherty limestone (3); *c*, sandy limestone (12); *d*, dolomitic limestone (6); *e*, calcareous quartzite (6); *f*, dolomitic quartzite (2); and *g*, quartzite (1). Number of samples averaged are in parentheses. Analysts for original "rapid" chemical analyses are P. L. D. Elmore, S. D. Botts, and Leonard Shapiro.

TABLE 1.—GENERAL LITHOLOGIC FEATURES OF THE OQUIRH FORMATION ROCKS STUDIED

Rock Type	Approximate Percent of Section Sampled	Mineral Composition and Grain Size	Groundmass	Structures and Textures
Fossiliferous limestone	16	Carbonate and quartz sand and carbonate fossil fragments partly silicified. Fine grained to sandy. Plate 1, <i>a</i>	Carbonate and sparse clay minerals	Carbonate grains well rounded, quartz subrounded
Cherty limestone	10	Carbonate and sparse quartz grains, carbonate fossil fragments and chert nodules. Fine grained	Carbonate and sparse clay minerals	Nodules, lenses and discontinuous layers of chert
Sandy limestone	23	Carbonate and quartz sand grains average 0.2 mm. Plate 1, <i>b</i> (is finer grained than average)	Carbonate and sparse clay minerals	Crossbedding common; rocks may grade into quartzite types
Dolomitic limestone	15	Quartz and carbonate grains average 0.02 mm to 0.1 mm. Carbonate fossil fragments. Plate 1, <i>c</i>	Carbonate and moderate clay minerals	
Calcareous quartzite	11	Quartz and calcite sand grains 0.01 to 0.2 mm. Plate 1, <i>d</i>	Carbonate and moderate clay minerals	Dense and hard with conchoidal fracture; grains well sized in any one layer
Dolomitic quartzite	6	Quartz and dolomite and calcite grains. Fine grained and sandy. Plate 1, <i>e</i>	Carbonate and sparse clay minerals	Hard with conchoidal fracture
Quartzite	9	Sutured quartz grains 0.1 mm average size. Plate 1, <i>f</i>	Silica and only sparse clay mineral	Massive beds, very hard and pure with conchoidal fracture

of these rocks are given in Table 1. In the Bingham mining district any coarse clastic bed in the Oquirrh formation is called quartzite without implying that the rocks are cemented only by silica; some have carbonate cement (Gilluly, 1932, p. 34). The term is used here to include rocks that are hard and dense, break with conchoidal fracture, and are nearly pure quartz, or may contain varied amounts of calcite or dolomite or both, in addition to quartz sand grains or cement. Shales are omitted because representative samples were not available for this study.

RELATIONSHIP OF CLAY MINERALS TO LITHOLOGY

The clay mineral content in rocks of the lower part of the Oquirrh formation ranges from 1 percent or less in the quartzite to as much as 5 percent in some limestones. As the clay minerals are relatively sparse and are intimately mixed with cementing material such as carbonate and quartz, it was impossible to obtain a pure clay mineral fraction. Carbonate (and some clay minerals) were eliminated by acid treatment, but quartz remained in the fraction.

The clay mineral assemblages are clearly related to the kind of rock studied (Table 2): limestone contains illite, subordinate chlorite, and other unresolved mineral phases (Fig. 4, *a*); sandy and cherty limestones contain illite as well as smaller amounts of regular mixed-layer clay; dolomitic limestone contains chlorite and illite (Fig. 4, *b*); dolomitic quartzite contains chlorite and illite (Fig. 4, *c*); and quartzite contains sparse kaolinite and subordinate illite and chlorite (Fig. 4, *d*). In Plate 1, *a-e*, the grains and fossil fragments of quartz are white, of calcite are gray, and the groundmass of carbonate, quartz, and clay minerals is dark gray and black. Plate 1, *f* contains nearly 100 percent quartz. The clay minerals in Fig. 4, *a* are from a clay-rich limestone; most X-ray traces of clay minerals in limestone show only a broad indistinct band on both sides of the much lower-intensity 10 Å peak. The regular mixed-layer chlorite-montmorillonite clay mineral in Fig. 4, *b* is considered a regular 1:1 mixture of chlorite and montmorillonite that produces an integral series of basal spacings beginning at 29.4 Å. This mineral occurs both in fine and sandy sediments but is somewhat restricted to rocks in which moderate amounts of dolomite also occur in the carbonate fraction.

In summary, illite is a common clay mineral in all the Oquirrh rocks studied. It is dominant in the limestones and less abundant in dolomitic limestone and quartzite. Regular mixed-layer chlorite-montmorillonite is most common in dolomitic limestone and calcareous quartzite (which also contains some dolomite) and is less common in clastic and cherty limestone. Chlorite is the dominant clay mineral in dolomitic quartzite and is subordinate in limestone and quartzite. Kaolinite was found only in quartzite, and a separate montmorillonite phase was not found in any of the rocks.

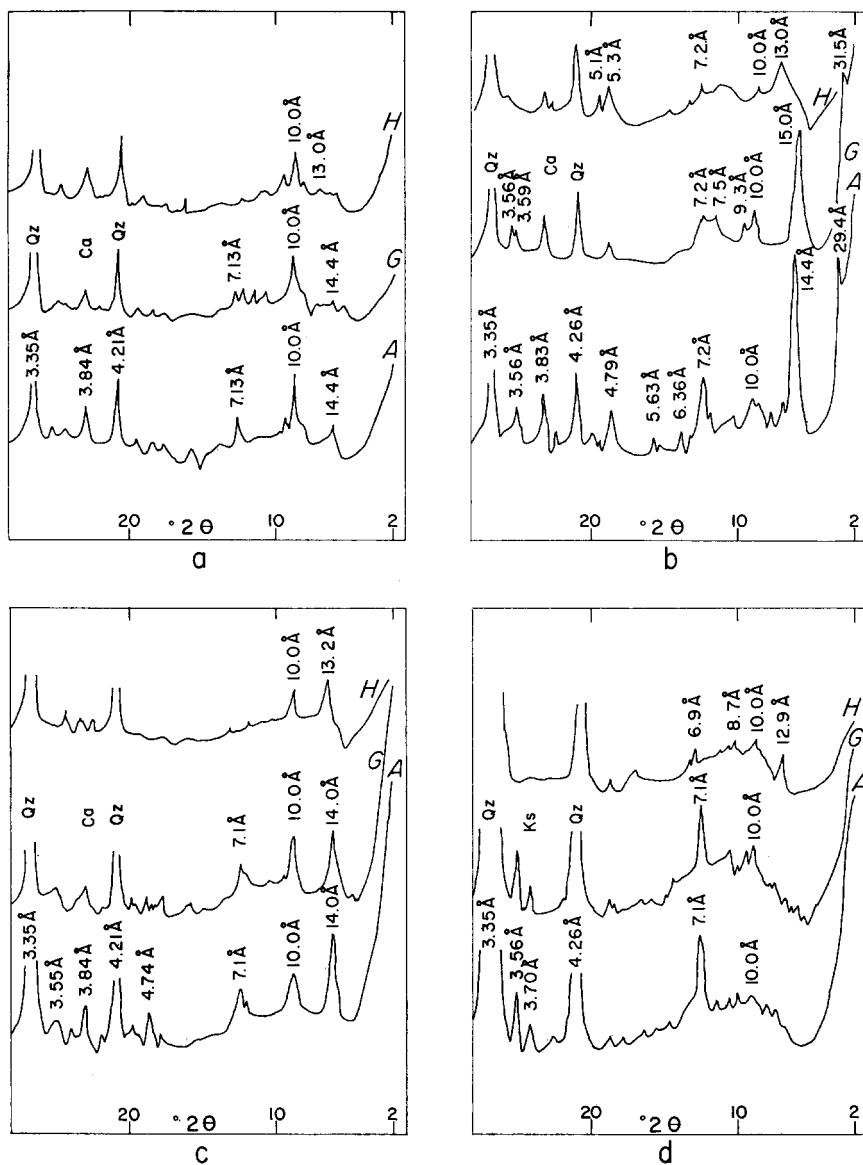


FIGURE 4.—Typical smoothed X-ray traces show the most abundant phases that occur in the complex clay mineral assemblages commonly found in rocks in the lower part of the Oquirrh formation: *a*, illite and chlorite from limestone; *b*, regular mixed-layer chlorite-montmorillonite and illite from dolomitic limestone; *c*, chlorite and illite from dolomitic quartzite; and *d*, kaolinite, illite, and chlorite from quartzite. Minor amounts of mixed-layer clay (in *a*), montmorillonite (in *a* and *c*), and perhaps kaolinite (in *c*) also appear in these traces. *A*, untreated sample; *G*, glycolated sample; *H*, heat-treated (500 °C) sample. Qz = quartz, Ca = calcite, Ks = K-feldspar.

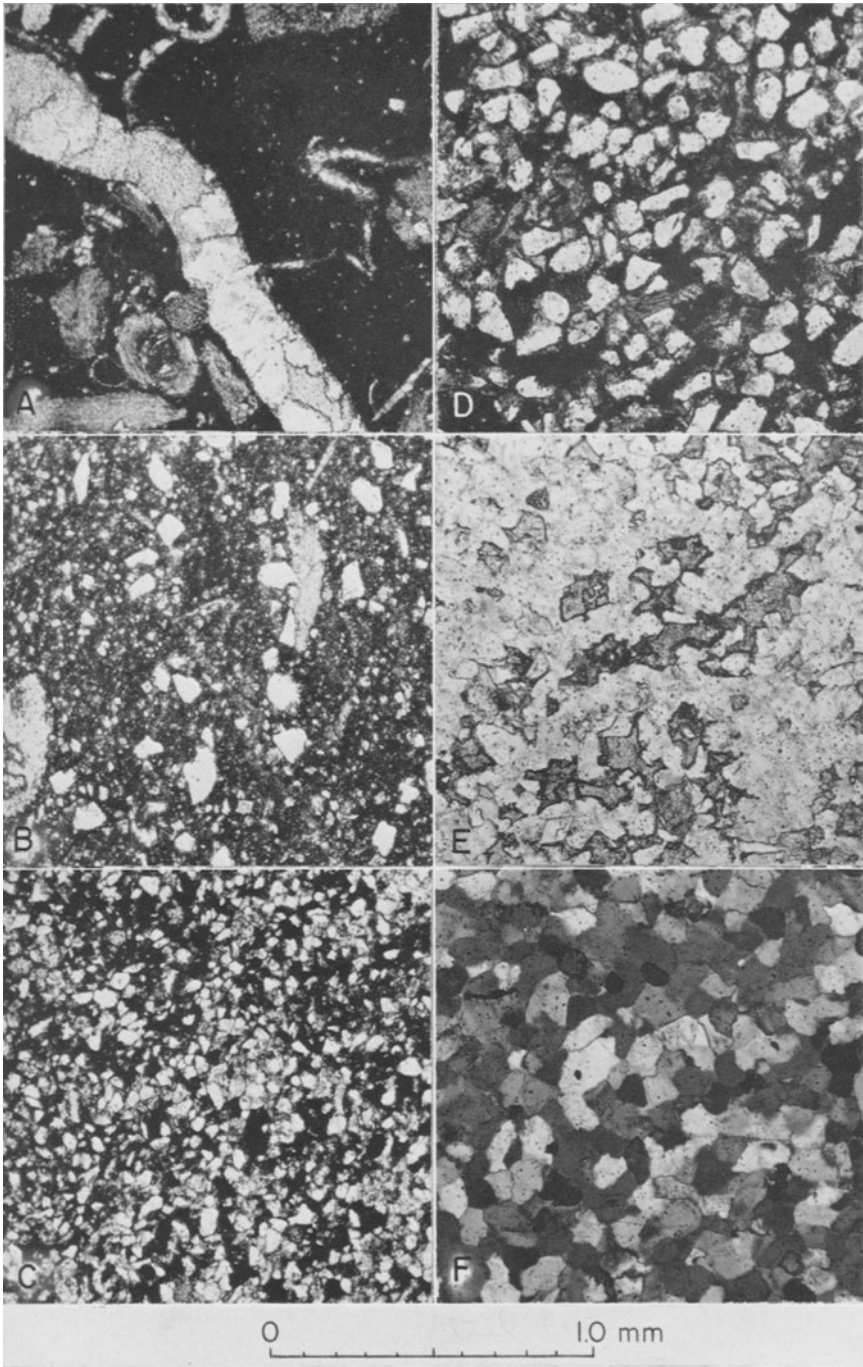


PLATE 1.—Photomicrographs showing characteristic rock textures. *a*, Fossiliferous limestone; *b*, sandy limestone; *c*, dolomitic limestone; *d*, calcareous quartzite; *e*, dolomitic quartzite; and *f*, quartzite. (*a–e*, plane polarized light, *f*, crossed nicols).

These results in general correspond with Weaver's (1959) survey of clay mineral-lithology relationships. He reported the occurrence of montmorillonite and random mixed-layer montmorillonite-illite clay but not a regular mixed-layer clay mineral constituent in the carbonate rocks of Pennsylvanian age in the midcontinent region. The Upper Permian Yates formation

TABLE 2.—SUMMARY OF THE TYPE AND ABUNDANCE OF CLAY MINERALS IN ROCKS FROM THE LOWER PART OF THE OQUIRRH FORMATION

Rock	Clay Minerals	Percent of Clay Minerals
Fossiliferous limestone	Illite, chlorite	<1
Sandy limestone	Illite, regular mixed-layer clay	<1
Cherty limestone	Illite, regular mixed-layer clay	1
Dolomitic limestone	Chlorite, regular mixed-layer clay, illite	1-3
Calcareous quartzite	Regular mixed-layer clay, illite	1-3
Dolomitic quartzite	Chlorite, illite	1
Quartzite	Kaolinite, chlorite, illite	<<1

in west Texas (Earley, Brindley, McVeagh and Van den Heuvel, 1956), however, yields a regular mixed-layer montmorillonite-chlorite clay that resembles the Oquirrh type. The Yates clay occurs in a poorly cemented siltstone that contains quartz, clay and carbonaceous matter, dolomite, and mica in order of abundance.

Finally these data suggest that because specific clay mineral assemblages occur with specific rock types, and at random in the stratigraphic sequence, the clay minerals favored are those that were in equilibrium with the major constituents of the rock in the sedimentation or diagenesis environment.

In the small part of the Oquirrh basin studied, we find that different types of carbonate-rich rocks contain a varied assemblage of clay minerals. It remains to be determined if these characteristics hold throughout the whole Oquirrh Range and basin areas.

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