The Facer Formation, a New Early Proterozoic Unit in Northern Utah

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By MAX D. CRITTENDEN, JR., *and* MARTIN L. SORENSEN

CONTRIBUTIONS TO STRATIGRAPHY

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THE FACER FORMATION, A NEW EARLY PROTEROZOIC UNIT IN NORTHERN UTAH

By MAX D. CRITTENDEN, JR., and MARTIN L. SORENSEN

ABSTRACT

The new name Facer Formation is given to a sequence of quartzite, pelitic schist, and sparse limestone exposed in the northern Wasatch Mountains of Utah. The unit is distinguished by the presence of three nearly unique lithologies; green fuchsite-bearing quartzite, quartz-hematite schist, and amphibolite. K/Ar and Rb/Sr dating show it to be of late Proterozoic X age. The sequence rests on the Willard thrust and in the type area, south of Brigham City, has no known base. It is overlain unconformably by diamictite and related rocks of the Huntsville sequence of Proterozoic Z and Early Cambrian age. Complex thrust structure precludes measurement of a complete section, but partial sections aggregating about 750 m are known. Muscovite from both schist and pegmatite has yielded K/Ar ages of 1.4 b.y. (billion years) and Rb/Sr ages of 1.6 to 1.7 b.y. The Facer Formation is tentatively correlated with a similar sequence of rocks in the Raft River Mountains and Albion Range of northwestern Utah and adjoining Idaho. These rocks, beginning with the Elba Quartzite, contain the same series of distinctive lithologies, and are believed to occupy a similar stratigraphic position. In that area, however, they are largely autochthonous and rest unconformably on a metamorphic and intrusive basement that is at least 2.2 b.y old.

INTRODUCTION

Detailed mapping and stratigraphic study of the rocks adjoining the Willard thrust east of Hunsville, Utah, was begin in 1965 (Crittenden, 1968). Since that time work has been extended westward to include the Wasatch Mountains approximately from Ogden Canyon to Brigham City (Crittenden, 1972a, Sorensen and Crittenden, 1972, 1976, 1980)

The principal objectives of this study were to develop an understanding of the stratigraphy and paleogeography of late Precambrian rocks and to use that information to aid in unraveling the structural history of this segment of the Sevier orogenic belt. It was evident early in the investigation that the area included an unusually thick and readily decipherable section of rocks of Proterozoic Z and Early Cambrian age. These rocks, informally referred to as the Huntsville sequence (Crittenden, Schaeffer, Trimble, and Woodward, 1971), were found to rest on an older unit, one that had been recognized previously, but not formally named, by Eardley and Hatch (1940, p.

816). Preliminary age determinations by McKee and Peterman (Crittenden, McKee, and Peterman, 1971) suggested that the unnamed unit was older than the Belt Supergroup of Montana, Idaho, and Washington and the Big Cottonwood Formation and Uinta Mountain Group of Utah and Colorado. The purpose of the present paper is to name and describe this unit, and to suggest its provisional correlation and tectonic significance.

NAME

This distinctive unit is here named the Facer Formation for Facer Creek, a steep canyon draining the west face of the Wasatch Mountains, midway between Perry Canyon (Threemile Creek) and Willard Canyon, about 7 km south of Brigham City, Utah (fig. 1).

TYPE AND REFERENCE SECTIONS

The type area is in the headwaters of Facer Creek and over the ridge to the south on the north slopes of Willard Canyon (fig. 1). The type section begins at the foot of the steep cliffs north of Willard Canyon (fig. 2) near the center of the N½ sec. 19, T. 8 N., R. 1 W. and continues up the ridge diagonally northeastward, to the point marked 8186 feet on the topographic map of the Mantua quadrangle, in the SE¼ sec. 18, T. 8 N., R. 1 W. Excellent exposures that extend across the crest of Willard Peak in sec. 32, T. 8 N., R. 1 W. are designated a reference section (see section B).

Although many exposures appear structurally uncomplicated at a distance, they are invariably folded and repeated by faulting; even those of the type section do not represent the original stratigraphic sequence.

DISTRIBUTION

The Facer Formation crops out sporadically above the trace of the Willard thrust from its intersection with the mountain front south of Brigham City to the point where it crosses Ogden Canyon near Pineview Reservoir (fig. 1). The largest areas of exposure are those in the type area, noted above, and on the ridge east of Willard Canyon. These rest on an upper strand of the Willard thrust. A second set of exposures begins as a thin wedge along the lower strand of the thrust on the ridge north of Willard City Spring and extends with minor interruption southeast to Willard Peak. Farther south along this strand of the fault only thin faulted slices are present except for a lenticular wedge near Lewis Peak. The southernmost exposures consist only of a sheared lens of dark-blue-purple and green phyllite exposed in the roadcut and a prospect adit about 750 m northeast of Pineview dam. It is notable that the thickest exposures are to the north and west, indicating that the Willard thrust cuts upward to the east through the Precambrian section.

LOWER AND UPPER CONTACTS

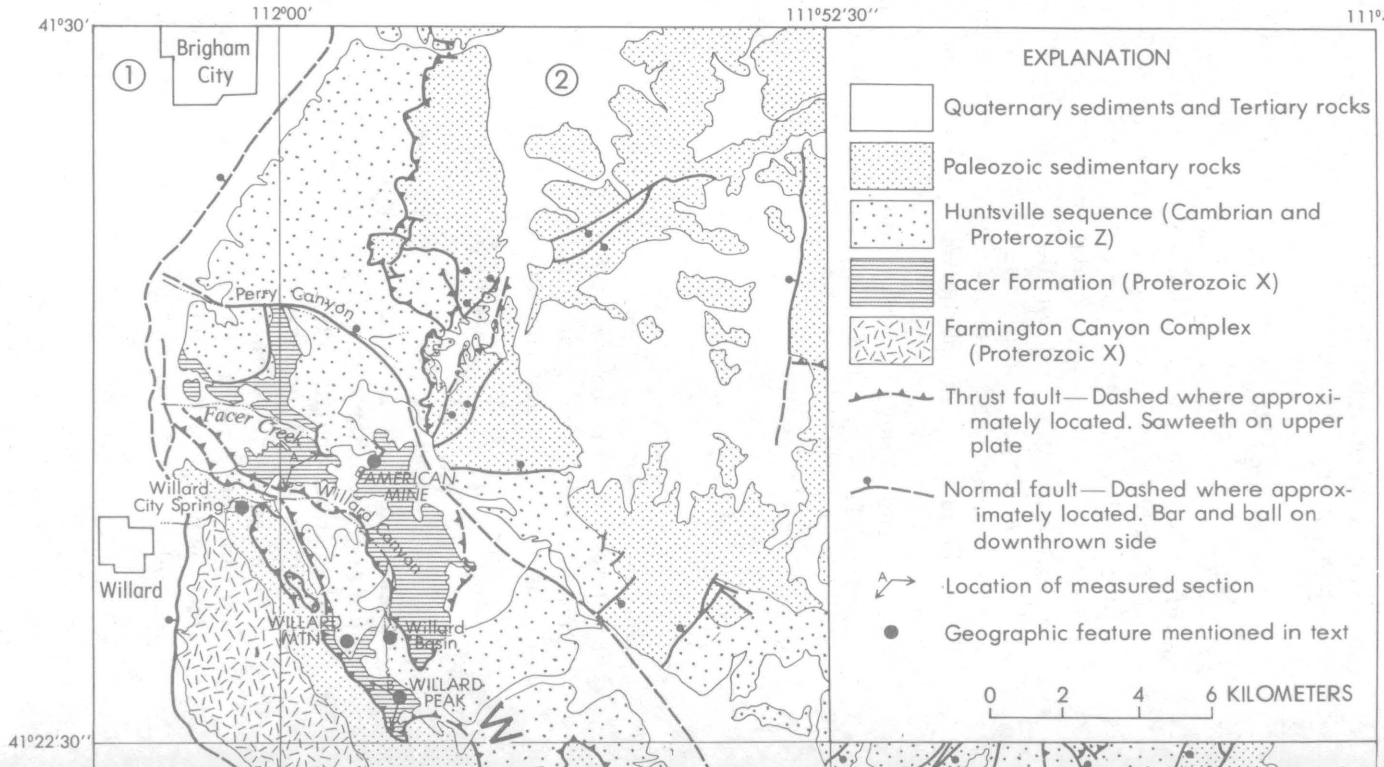
The base of the Facer Formation is everywhere a thrust fault; its stratigraphic relations to older rocks are therefore unknown in this area. Possibly correlative rocks in northwestern Utah, however, rest unconformably on a still older crystalline basement (see section on "Correlation"), and it is inferred that the Facer originally occupied a similar stratigraphic position, but was sheared off during thrusting.

Wherever the upper contact is visible it is an unconformity at the base of the overlying Huntsville sequence. In the structural block just above the lower strand of the Willard thrust, the basal beds of the Huntsville sequence consist of a few meters of grit or fine pebble conglomerate, grading upward into rusty-weathering black pyritic mudstone. These are most readily seen on the narrow ridge along the west rim of Willard Basin, about 250 m southeast of the scenic outlook on Willard Mountain (1,100 m northwest of the bench mark on Willard Peak). Excellent exposures, although repeated by faulting, also are to be seen along the ridge that extends northwest from Willard Mountain. Similar grits are present at the base of the Huntsville sequence above the upper strand of the Willard thrust a few meters south of the creek in Perry Canyon, at an elevation of 5400 m on the line betwee secs. 6 and 7, T. 8 N., R. 1 W. (Mantua quadrangle). At several other places in this block the Facer Formation is overlain unconformably by diamictite.

METAMORPHISM

The Facer Formation was subjected to low-grade regional metamorphism before the deposition of the overlying Proterozoic Z and Early Cambrian Huntsville sequence. During this time the Facer was folded, its fine-grained sedimentary rocks were metamorphosed to phyllite, semischist, and schist, and small bodies of pegmatite, gabbro, and diorite were emplaced within it. K/Ar and Rb/Sr age determinations on muscovite from both the pegmatite and muscovite schist, as will as a K/Ar age determination in hornblende from diorite, indicate that this metamorphism occured at least 1.7 b.y. ago (see table 2).

A second period of low-grade regional metamorphism affected the Facer Formation after the deposition of the overlying Huntsville sequence and before or during its emplacement on the Willard thrust. The clearest evidence of this metamorphic event is the presence of abundant porphyroblasts of chloritoid in both the pelitic schist of the


41°30′
112°00′
111°52′30″
111°45′
41°22′30″
①
②
Brigham City
Willard
Willard City Spring
Perry Canyon
Facer Creek
Willard Canyon
AMERICAN MINE
WILLARD MTN
Willard Basin
WILLARD PEAK
EXPLANATION
Quaternary sediments and Tertiary rocks
Paleozoic sedimentary rocks
Huntsville sequence (Cambrian and Proterozoic Z)
Facer Formation (Proterozoic X)
Farmington Canyon Complex (Proterozoic X)
Thrust fault—Dashed where approximately located. Sawteeth on upper plate
Normal fault—Dashed where approximately located. Bar and ball on downthrown side
Location of measured section
Geographic feature mentioned in text
0 2 4 6 KILOMETERS

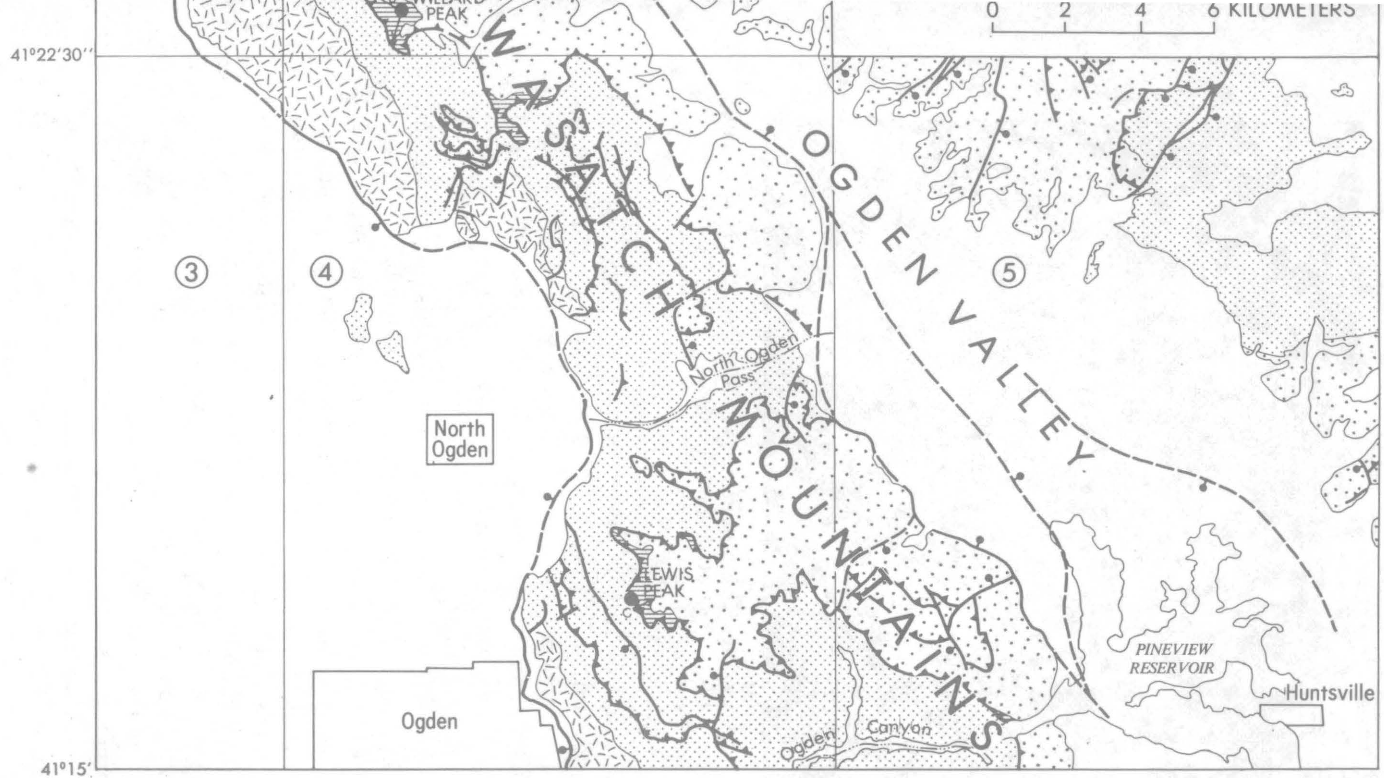


FIGURE 1.—Generalized geologic map of the Wasatch Mountains between Brigham City and Ogden, Utah. Quadrangles (7½ minute) designated by number: 1, Willard; 2, Mantua; 3, Plain City; 4, North Ogden; 5, Huntsville.

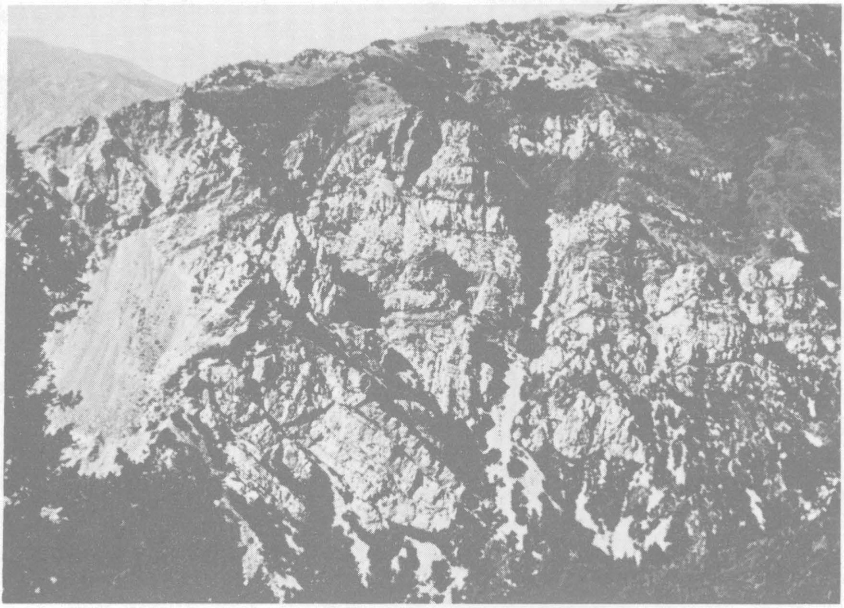


FIGURE 2.—Part of type section of Facer Formation in cliffs on north slope of Willard Canyon.

Facer Formation (fig. 5) and in pelites of the overlying Huntsville sequence. The new minerals that resulted are mainly sericite, chlorite, and chloritoid, and in most of the area these represent the highest grade attained. In one small area in the upper plate of the Willard thrust between Perry and Willard Canyons, poorly formed fine-grained biotite occurs in quartz-rich siltstone at the base of the Huntsville sequence. Biotite has been found near this locality in the Facer Formation also, indicating that these rocks briefly and locally reached pressures and temperatures in which biotite was stable. The existence of biotite in this one locality at the west edge of the mapped area, and in an upper thrust plate, presumably derived from farther west, is consistent with the gradual westward increase in metamorphic grade seen throughout this edge of the Cache allochthon (Crittenden, 1972b). By contrast, metamorphism is entirely absent in siltstone and limestone of the underlying autochthon. A notable feature of the rocks of the Facer Formation in this area is that in spite of mild regional metamorphism sufficient to produce chloritoid, they still yield Precambrian K/Ar ages indicative of only moderate loss of argon. This is in striking contrast to similar rocks throughout much of western Utah, which commonly yield K/Ar dates of 20 to 50 m.y. regardless of their actual age (Armstrong and Hansen, 1966, p. 120).

LITHOLOGY

The principal rocks composing the Facer Formation are, in order of decreasing abundance, quartzite, pelitic schist or phyllite, quartz-muscovite schist, amphibolite, gneiss, limestone, and conglomerate. In addition, fuchsite-bearing green quartzite and quartz-hematite schist, although present in minor amounts, are unusual and characterizing rock types that distinguish this unit from all others in the area. Chemical analyses of typical lithologies are listed in table 1.

QUARTZITE

Quartzite is the most obvious rock in the Facer Formation, both because of its abundance and because of its resistance to erosion. It forms massive cliffs and ledges, and supports the highest peaks in the area. Viewed from a distance, these ledges range from white to pale rusty brown. Most are highly jointed to badly shattered. Bedding is usually obscure and can only be distinguished from the myriad joints by a characteristic rolling or undulating character plus a veneer of muscovite or sericite that follows the irregular bedding surfaces. In thickness, beds range from on the order of 10 m to as little as 2 m. In a few places thin 10- to 20-cm beds of quartzite are intercalated with pelitic schist or phyllite.

In hand specimen the quartzite is white to very pale gray, pure, extremely dense, vitreous and translucent, and commonly without visible granular texture. In this respect, it contrasts strongly with quartzite of the Huntsville sequence or the Tintic Quartzite, in which original grains and grain boundaries are clearly visible. In thin section, quartzite of the Facer Formation characteristically shows intricately mosaicked grain boundaries (fig. 3) and a significant degree of grain flattening and orientation. Most samples contain minor amounts of sericite or muscovite and occasionally chlorite.

A distinctive and characteristic variant of the quartzite is an apple-green variety, colored by small amounts of fuchsite (chromian mica). This striking rock occurs in layers 1 to 2 m thick that follow bedding in a general way, as if the chromium were syngenetic. In detail, however, the green color follows low-angle faults that are close to bedding but not exactly parallel. These relations are most clearly displayed at the type locality in the cliffs on the north slope of Willard Canyon (fig. 2) where the green beds are offset by several high-angle faults. Green quartzite also appears in the structurally more chaotic outcrops to the east, about a kilometer south of the American Mine, but cannot be traced farther because of complex faulting. In these exposures the fuchsite clearly transgresses bedding, and has been

TABLE 1.—*Chemical analyses of rocks from the Facer Formation*

	Quartz-chlorite-chloritoid schist	Quartz-muscovite schist	Hornblende diorite	Gneissic meta-arkose	Quartz-hematite schist
Lab. No.	M122277W	M122278W	M122279W	M122280W	M112090
Field No.	66–MC–16	69–MC–41	72–MC–130c	72–MC–124	69–MC–50
SiO_2	57.2	69.3	51.2	75.1	66.8
Al_2O_3	18.4	15.7	15.3	12.6	6.6
Fe_2O_3	1.6	3.4	2.4	.32	21.0
FeO	10.0	1.6	8.5	.44	.76
MgO	2.8	2.0	7.4	.31	.09
CaO	.30	.17	6.4	.16	.45
Na_2O	.24	.29	3.2	1.9	.12
K_2O	2.1	4.2	2.1	6.9	1.8
H_2O+	4.5	2.9	2.0	.55	1.0
H_2O-	.33	.26	.05	.01	.05
TiO_2	.76	.21	.41	.12	.34
P_2O_5	.11	.06	.09	.04	.39
MnO	.19	.03	.22	.02	.00
CO_2	.03	.01	.02	.03	$<.05$
Total	99	100	99	99	99

Chemical analyses by Lowell Artis using single solution method described by Shapiro, 1967.

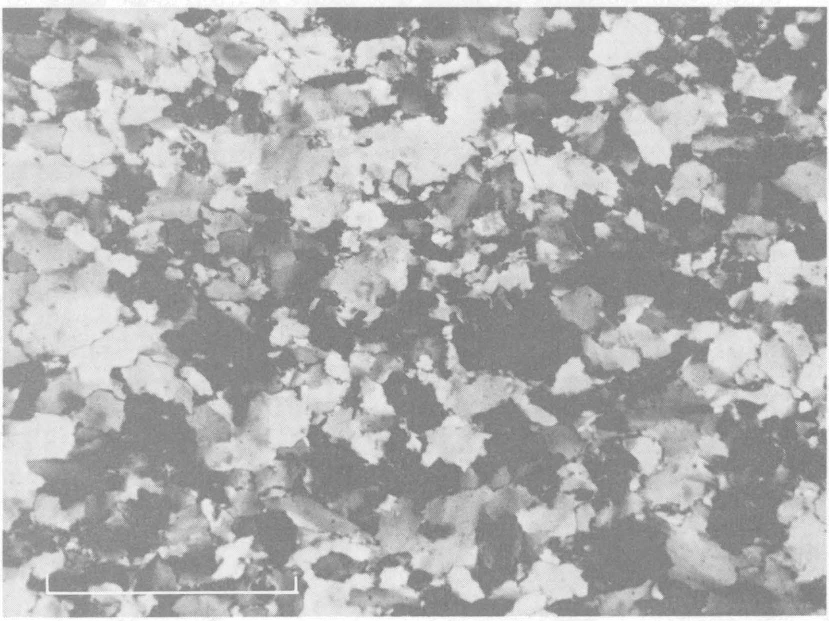


FIGURE 3.—Photomicrograph of quartzite of Facer Formation showing interlocking mosaic structure. Rock includes very minor chlorite and muscovite. Sample 70–MC–88, white quartzite. Crossed nicols. Scale bar indicates 1 mm.

introduced along inconspicuous minor faults. These tend to follow bedding in some blocks, but locally diverge from it by 20° to 30°. The chromian mica forms minute pale-green plates dispersed through the quartzite. Locally the mica forms thin coatings associated with minute quartz crystals lining an irregular fracture usually less than 1 cm wide. Quartzite adjoining these fractures contains enough fuchsite to color it green to distances of 1–2 m on either side. Spectrographic analysis (lab No. M112091W) shows that a typical sample of massive quartzite contains about 150 ppm of Cr and 7,000 ppm Al. Assuming that all the Cr and Al are contained in mica, this would be equivalent to 3.5 percent muscovite with a chromium content of 4,300 ppm, a value comparable with other fuchsites.

A second characterizing rock type, also apparently a variant of quartzite, is lustrous deep-reddish-black quartz-hematite schist. This rock is best exposed on the south slopes of Willard Peak, where it occurs in one or more beds up to a meter thick, intercalated with quartz-chlorite-sericite schist and intruded by sills of gabbro (now amphibolite).

In hand specimen the quartz-hematite schist shows a finely granular texture and strong foliation, commonly forming wavy crenulated lustrous surfaces at a marked angle to bedding (fig. 4). Although the rocks are dark in color, the maximum hematite content is only about 20 percent (table 1) and is commonly less. In a typical thin section, quartz is seen to make up 60 to 70 percent of the rock, specular hematite 10 to 20 percent. Sericite, chlorite, and epidote are minor

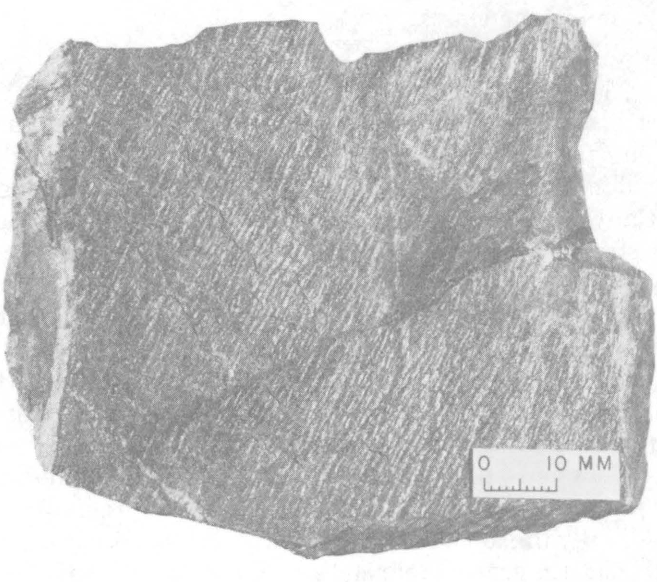


FIGURE 4.—Quartz-hematite schist of Facer Formation showing finely crenulated foliation surface. Angle between bedding and schistosity is approximately 35°. Sample 69–MC–50.

constituents. Quartz grains (typically 0.1 × 0.4 mm) were probably originally detrital, although they now show considerable recrystallization and form sutured domains in each original clast. Hematite forms thin plates, typically 0.03 × 0.3 mm, wrapping around the quartz grains, as if formed from a high-iron interstitial matrix. A few rounded grains of deep-blue tourmaline, sphene(?), and rare zircon reinforce the impression of a clastic origin.

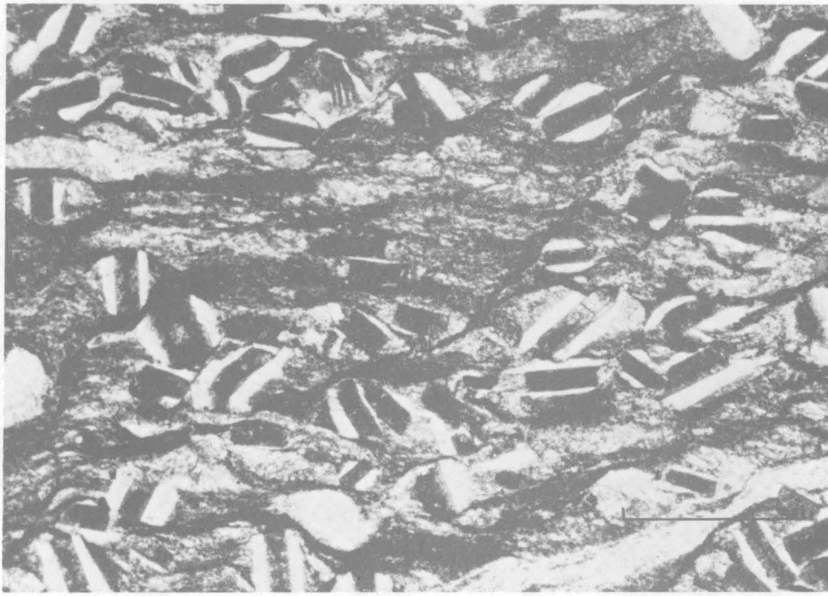
PELITIC SCHIST AND PHYLLITE

Pelitic schist of several varieties is among the most abundant and readily recognizable rocks of this formation. The commonest is pale grayish green (10GY5/2 to 5G7/2) or grayish purple (5R5/2 to 5RP3/2), a color combination not found in any other rock unit. It ranges in grain size from claystone to coarse siltstone, and in metamorphic grade from lustrous fine-grained phyllite to finely spotted schist. The color variation is due to the relative dominance of either chlorite or hematite, and is suspected to be inherited from the oxidation state of iron in the original sediment. A recurring variant is the coarsely spotted chlorite-chloritoid schist (fig. 5). This appears to have originated as a coarse siltstone containing numerous mudflakes or pellets which were stretched and flattened during later metamorphism. Chloritoid has formed in the silty matrix, but only chlorite has developed in the mudstone clasts.

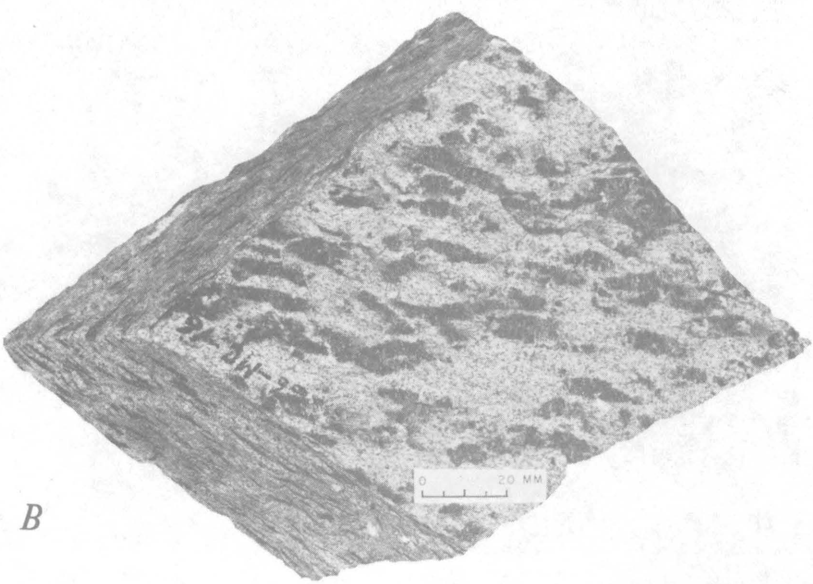
QUARTZ-MUSCOVITE SCHIST

Another distinctive rock, though of somewhat uncertain origin, is lustrous quartz-sericite or quartz-muscovite schist. This rock type is most abundant in the upper part of the section on the north slope of Willard Canyon, where it forms moderate slopes and poor outcrops above the steep quartzite cliffs. It is also readily observable where the road crosses the ridge crest northeast of Willard Basin, as it forms the roadbed directly in front of the sign describing early soil conservation efforts. These rocks commonly show wavy or strongly folded foliation and range widely in grain size, 0.1 mm to 5 mm. In thin section the texture of the quartz-muscovite schist ranges from coarse grained and nearly equigranular (fig. 6) to very fine grained and strongly sheared. The latter shows strong flattening of quartz grains (commonly 5:1 to 10:1) and pervasive strain shadows. Both quartz and muscovite layers are folded locally (fig. 6). Garnet, apatite, and zircon occur in rounded, apparently clastic grains; tourmaline, zircon, and apatite occur in minute euhedral grains enclosed in quartz.

The origin of these rocks is somewhat obscure because most have been recrystallized sufficiently to destroy original textures. The com-



A



B

FIGURE 5.—Chlorite-chloritoid schist of Facer Formation. *A*, Photomicrograph showing randomly oriented porphyroblasts of chloritoid, flanked by quartz, set in a pelitic matrix. Sample 67–MC–13. Plane-polarized light. Scale bar indicates 1 mm. *B*, Hand specimen of the schist. Sample 66–MC–16.

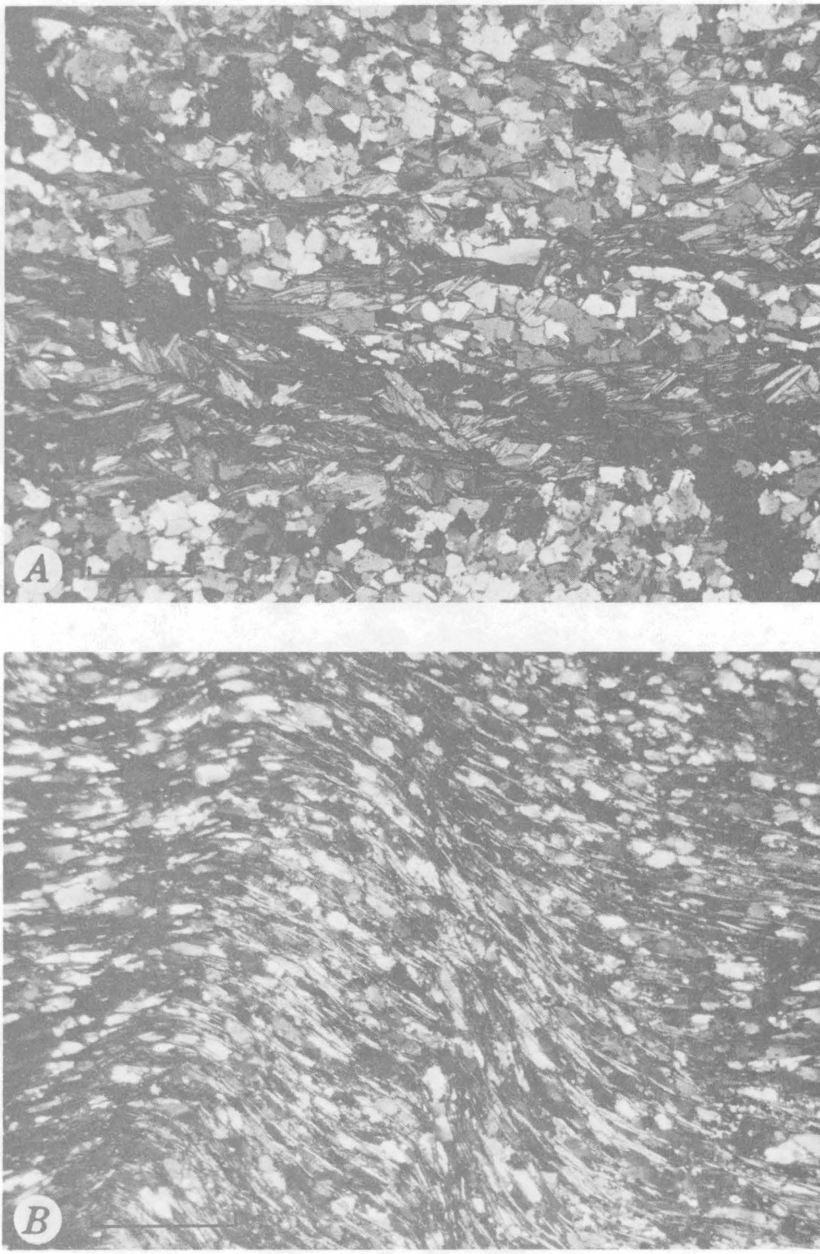


FIGURE 6.—Photomicrographs of quartz-muscovite schist of Facer Formation. Partly crossed nicols. Scale bars indicate 1 mm. *A*, Coarse grained and nearly equigranular. Sample 67–MC–82. *B*, Microfolds in the schist. Sample 69–MC–41.

position (table 1) is compatible with either a vitric tuff or an unusually iron-free clay shale. The former appears more probable. Muscovite from these rocks on the ridge east of Willard Canyon yielded a K/Ar age of 1.4 b.y. and Rb/Sr ages of 1.6 b.y. (table 2).

CARBONATE ROCKS

Two distinctive and strongly contrasting varieties of carbonate rock are present in outcrops of the Facer Formation south of North Ogden Pass. One is pink, pinkish-tan to cream-colored, very fine grained, streaky, badly sheared and folded limestone that is intimately interbedded with greenish-gray or grayish-red phyllite (siltstone). Excellent exposures of these rocks are present in small scale recumbent folds on Lewis Peak (fig. 7), and badly sheared remnants are present immediately above the Willard thrust at several other places nearby. Intense deformation has obscured most features diagnostic of origin, but the fine grain size and intimate mixture with fine-grained clastic material is suggestive of chemical deposition.

A second and thicker carbonate unit, also seen near Lewis Peak, is pale-gray massive limestone in which possible organic structures are poorly and locally preserved. These consist of medium-gray masses of crystalline calcite, arranged in rodlike bodies 10 to 20 cm long and 1 to 2 cm in diameter, set in a finer grained pale-gray matrix. On bedding surfaces the darker rods are irregular in outline (fig. 8) and contain light- to dark-tan centers that appear to have been cavity fillings. Gross morphology and structural details have been obscured by recrystallization, but they resemble rodlike structures in giant stromatolites described by Knight (1968, fig. 3) in his Nash Formation, Wyoming, and present evidence suggests they are of about the same age. They also resemble tube fillings in giant stromatolites in the Noonday Dolomite (Cloud and others, 1974), though the latter are considerably younger (less than 1.3 b.y.). In any case, laminae subparallel to bedding are conspicuously absent and an organic origin is probably dubious at best.

In addition to the carbonate rocks described above that are clearly of sedimentary origin, dolomite of possible hydrothermal origin is present at several localities near Willard Peak, above the upper strand of the Willard thrust. The largest outcrops are lcated on the east side of the main ridge 800 m northeast of Willard Peak, where the dolomite forms thick lenses along the thrust contact with the underlying Huntsville sequence. The dolomite here is typically massive, coarse to very coarse grained, light to dark brown on weathered surfaces, and dark gray on fresh surfaces. The coarsely crystalline character and absence of bedding in many outcrops suggest a hy-

TABLE 2.—*Analytical data and K/Ar and Rb/Sr ages for minerals from the Facer Formation, Utah*

[Potassium analyses by Lois B. Schlocker, Argon by E. H. McKee, U.S.G.S., Menlo Park, Calif. Methods described by Dalrymple and Lanphere (1969) Rubidium-strontium age determinations by Zell Peterman, U.S.G.S., Denver, Colo. Methods described in Peterman and Hedge (1967)]

Mineral and Field No.	Lat (N)	Long (W)	K_2O (percent)	^{40}Ar rad (mol/gr)	^{40}Ar rad (percent)	Age (10^6 yr)
Muscovite from schist (67–MC–82)	41°25′18″	111°58′23″	10.47; 10.47	3.00×10^{-8}	98.5	1342 ± 10
Muscovite from pegmatite (67–MC–84)	41°25′25″	111°58′23″	10.47; 10.47	3.05×10^{-8}	88.7	1357 ± 10
Hornblende from diorite (72–MC–130c)	41°25′57″	111°59′52″	0.564; 0.564	2.26×10^{-9}	89.7	1681 ± 12

	Mineral	Rb (ppm)	Sr_{η} (ppm)	Rb^{87}/Sr^{86}	Sr^{87}/Sr^{86}	Age ($\times 10^6$ yr)
Muscovite from schist (67–MC–82)		491	37.0	38.4	1.628	1660 ± 50
Muscovite from pegmatite		943	29.1	93.7	2.835	1580 ± 50

Constants used: $\lambda_\beta = 4.963 \times 10^{-10}yr^{-1}$, $\lambda_\epsilon = 0.572 \times 10^{-10}yr^{-1}$, $\lambda_\epsilon' = 8.78 \times 10^{-13}yr^{-1}$, $^{40}K/K_{total} = 1.167 \times 10^{-4}$gm/gm; ^{87}Rb decay constant = $1.42 \times 10^{-11}yr^{-1}$.

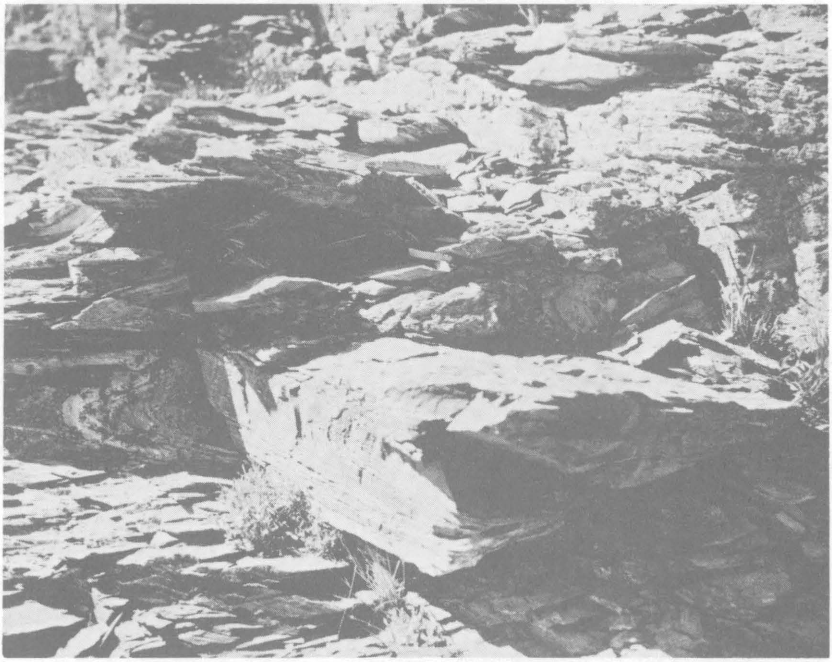


FIGURE 7.—Folded thin-bedded limestone intercalated with greenish and bluish phyllitic siltstone. Facer Formation on Lewis Peak, North Ogden quadrangle, Utah.

drothermal origin for at least some of the dolomite. Small pods and lenses of ankeritic carbonate also are present as inclusions in nearby exposures of green and gray schist of the Facer Formation, but these appear to be original concretions.

CONGLOMERATE

Another distinctive though minor rock within the Facer Formation is sheared pale-gray quartzose conglomerate. The best exposures are in the cirque wall at the head of Willard Basin (section at locality B, fig. 1), but it also can be seen in 1- to 3-m blocks that are probably snowslide talus in the basin above the road and along the trail leading to the small lake immediately north of Willard Peak. This is a massive unit, 5–10 m thick, consisting mainly of cobble- to boulder-size clasts (range 1 cm to 1½ m). At least 80 percent of the clasts are white to pale-gray quartzite; the remainder includes dark-gray quartzite, hematitic schist, purple to greenish phyllite, and rare green fuchsitic quartzite. The almost total dominance of rock types indigenous to the Facer itself suggests that the conglomerate was locally derived and implies the existence of a local hiatus within the Facer Formation. Many of the loose talus blocks in the center of Willard Basin are so strongly sheared that they have the appearance of a tectonic breccia, but rounded clasts are unmistakable in places.

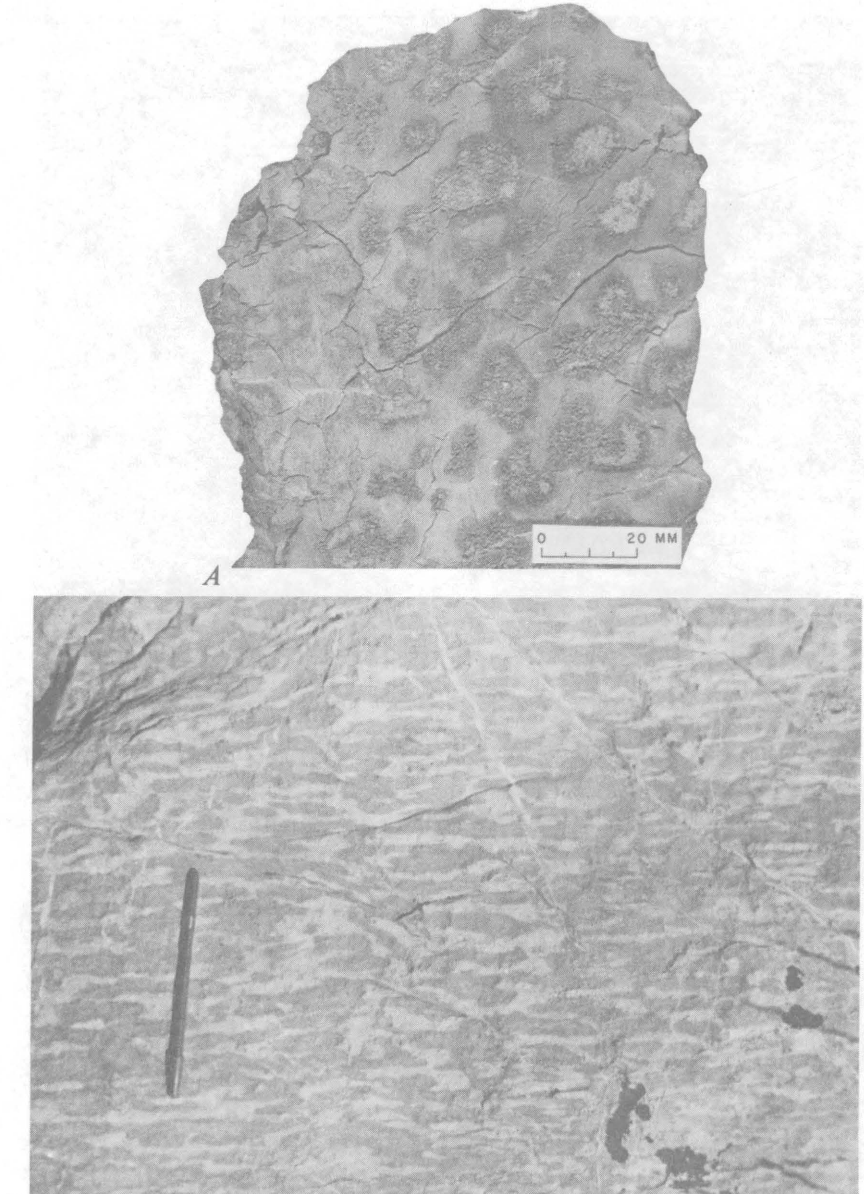


FIGURE 8.—Possible organic structures preserved in pale-gray massive limestone of Facer Formation. *A*, Hand specimen from near Lewis Peak showing possible tube fillings. *B*, View at right angles to bedding showing deformed and recrystallized structures resembling tube fillings. 18-cm pen for scale.

GNEISS

Massive creamy-white leucocratic gneiss occupies a considerable area in the head of Facer Creek, where it is locally intercalated with thin-bedded quartz-muscovite schist. In the field, the origin of the gneiss is obscure. In thin section (fig. 9) it is seen to consist of about equal quantities of quartz and microcline, with minor amounts of sericite and chlorite. Although grain boundaries are moderately sutured, occasional well-rounded grains of both quartz and feldspar are to be found. This, together with the almost complete absence of mafic minerals, indicates that these rocks are meta-arkose, not orthogneiss.

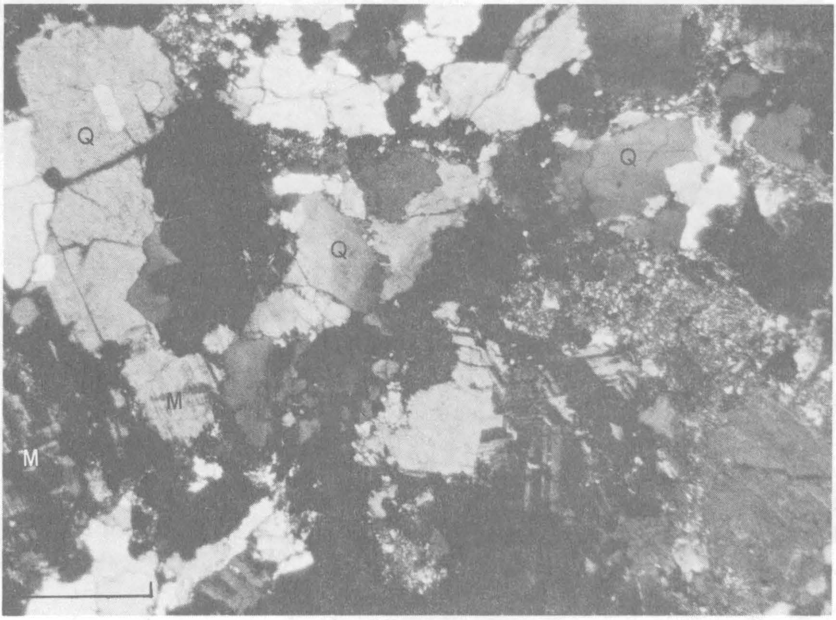


FIGURE 9.—Photomicrograph of leucocratic gneiss of Facer Formation showing quartz (Q) and microcline (M) in matrix of chlorite and sericite. Sample 72–MC–126. Crossed nicols. Scale bar indicated 1 mm.

AMPHIBOLITE

A widespread and characterizing component of the Facer Formation is dark-green to greenish-black amphibolite. It occurs in more or less concordant sills commonly a meter to a few meters thick. These vary widely in the degree of shearing and recrystallization; where least affected, original igneous textures and relics of amphibole and feldspar are preserved; elsewhere they are strongly sheared and consist mainly of chlorite, shreddy pale-green amphibole, sericite, and carbonate. The least altered rocks were apparently mafic gabbro or diabase. An unusual variant exposed near the head of Facer Creek is a fine-grained diorite (fig. 10) in which both original hornblende and feldspar are preserved. This rock is more highly discordant than most, and its relations to the more abundant amphibolite is uncertain. Hornblende from this rock yielded a K/Ar date of 1.7 b.y. (table 2).

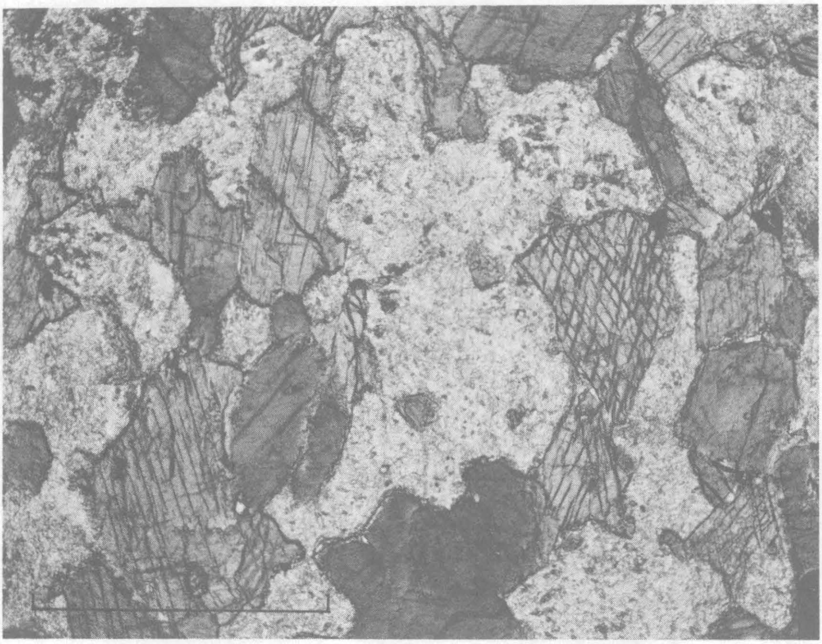


FIGURE 10.—Photomicrograph of diorite from Facer Formation showing hornblende phenocrysts in groundmass of altered feldspar. Sample 72–MC–130c. Collected near head of Facer Creek. Partially crossed nicols. Scale bar indicated 1 mm.

PEGMATITE

In addition to the gabbro-diorite group of intrusive rocks noted above, the Facer Formation contains a few small bodies of moderately coarse grained pegmatite. So far as known these are restricted to the thicker and slightly higher grade part of the formation above the upper strand of the Willard thrust. They appear as irregular lenses or pods a fraction of a meter wide and a few meters long. Most are highly discordant and are associated with coarser phases of the quartz-muscovite schist described above. The most common components are quartz, pale-creamy-white microcline, and muscovite in books typically 1–2 cm, rarely as much as 5 cm across. Black tourmaline crystals up to 5 cm long are present locally. Muscovite from one such lens on the ridge east of Willard Canyon yielded a K-Ar date of 1.35 b.y. and a Rb-Sr date of 1.6 b.y. (table 2).

STRATIGRAPHY

Although no complete section of the Facer Formation is exposed in the Wasatch Mountains, several partial sections have been measured and demonstrate the typical relations between the lithologic types described previously. All sections begin at the Willard thrust so are without a normal stratigraphic base. All thicknesses are approximate, those of thicker units having been estimated from maps and cross sections rather than from unit-by-unit measurements. Locations are shown on figure 1.

Section A exposes the greatest thickness and is designated the type section. It is exposed on the north slope of Willard Creek and in the head of adjoining Facer Creek. Section B is designated a reference section. Although it is not as thick or as complete lithologically as section A, it appears to be considerably less deformed, particularly by low-angle faults. Units 1 through 11 of this reference section form a continuous sequence along the ridge south of Willard Peak and across the crest. Units 12 through 14 are exposed in Willard Basin immediately north of the peak and extend onto the ridge to the northwest. A third partial section, section C, on Lewis Peak about 13 km south of Willard Peak is thin but distinctive in that it contains two carbonate units not exposed in the sections to the north. Correlation with those sections depends largely on the characteristic blue or greenish-gray pelitic schists.

SECTION A, TYPE SECTION OF FACER FORMATION

Begins on north slope Willard Canyon in N½ sec. 19, T. 8 N., R. 1 W., ends in head of Facer Creek, SE¼ sec. 18, T. 18 N., R. 1 W., Mantua quadrangle.

Unit	Description	Thickness (meters)
	Base of Huntsville sequence (Formation of Perry Canyon)	
19.	Thin quartzose grit grading up into black mudstone diamictive.	
	Unconformity	
	Facer Formation	
18.	Arkose?	?
17.	Quartzite	175
16.	Schist, sericite-quartz	300
15.	Quartzite, includes thin beds of quartz-hematite schist	60
14.	Schist, muscovite-quartz, fine- to coarse-grained	120?
13.	Schist, quartz-chlorite-sericite, blue-gray, with some thin-bedded quartzite and hematitic schist	10?
12.	Quartzite, white, rusty weathering, forms top of cliffs	30

11. Amphibolite sill	3–4
10. Quartzite, white, rusty weathering. Includes 1–2 m pale-green fuchsite quartzite near middle	20
9. Amphibolite sill	3
8. Quartzite, massive, white	8–10
7. Schist, quartz-chlorite, and thin-bedded quartzite	15
6. Quartzite, massive, white	6
5. Schist, bluish-gray, fine-grained, intercalated with thin-bedded quartzite. Includes two beds quartz-hematite schist, each 1½–2 m thick. Entire interval weathers rusty brown	15
4. Quartzite, vitreous, pure white at base, rusty stained at top, ripple marks on upper surfaces trend N. 60° W.	75
3. Schist, quartz-sericite-chlorite, bluish-gray, fine-grained; probable fault at base	50–120
2. Quartzite, white, vitreous, fine-grained, strongly foliated	30
1. Schist, quartz-sericite, pale-greenish-gray; strongly foliated	30
Approximate total	1,000

Fault, Willard thrust (upper strand)
Formation of Perry Canyon, (Proterozoic Z)
Black phyllite with graded beds.

SECTION B, REFERENCE SECTION OF FACER FORMATION

Partial section extending along ridge of Willard Peak. Begins just above trail 100 m S of N edge of section, in NE¼, sec. 5, T. 7 N., R. 4 W. and ends near center of sec. 32, T. 8 N., R. 1 W., Mantua quadrangle.

Unit Description	Thickness (meters)
Base of Huntsville sequence	
16. Thin grit, overlain by brown-weathering black schist (formation of Perry Canyon)	?
Unconformity	
Facer Formation	
15. Missing inverval, unknown thickness.	
14. Schist, mainly blue-gray	100
13. Conglomerate, boulder to cobble, locally strongly sheared and stretched or brecciated	6–10
12. Schist, mainly grayish-green quartz-chlorite (originally siltstone)	150
Fault, stratigraphic separation unknown	

11. Quartzite, white, vitreous, thick-bedded, rusty weathering, intensely joined. Forms main mass of Willard Peak	150
10. Quartzite, white, thin-bedded, intercalated with gray sericite schist, unit folded	15
9. Schist, quartz-sericite, bluish-gray, locally hematitic	20
8. Amphibolite sill, originally diabase or gabbro	3
7. Quartzite, white, rusty weathering	2–3
6. Schist, bluish-gray, locally includes a 1- to 2-m bed, dense black, fine-grained quartz-hematite schist	20
5. Quartzite, white, rusty weathering	30
4. Amphibolite sill, locally with diabasic texture	10–15
3. Quartzite, as unit 5, in 3- to 4-m beds separated by amphibolite sills	10–12
2. Schist, quartz-muscovite, pale-greenish-gray, possible metatuff	15
1. Schist, quartz chlorite, locally contains chloritoid. Lower part blue gray, medial part grayish green, uppermost 20 m blue gray	70
Approximate total	600

Willard thrust

Tintic Quartzite (Cambrian)

Rusty-weathering buff quartzite.

SECTION C, PARTIAL SECTION OF FACER FORMATION ON LEWIS PEAK

SW¼ sec. 2, T. 6 N., R. 1 W., North Ogden quadrangle.

Unit Description	Thickness (meters)
Base of Huntsville sequence	
8. Diamictite (formation of Perry Canyon)	?
Unconformity	
Facer Formation	
7. Phyllite, quartz-chlorite, dark-blue at base (3 m), brown above	30
6. Schist, quartz-chlorite, chloritoid, dark-greenish-gray	15
5. Phyllite, olive-drab, fine-grained	2
4. Limestone, pale-gray, massive, coarse rodlike structures (?) (fig. 10)	10
3. Arkose, tan to pale-brown, well-sorted, fine-grained	40
2. Limestone, pinkish-buff, fine-grained, impure, very thin bedded, intimately intercalated with grayish-red to grayish-green phyllitic siltstone	6
1. Phyllite, blue-gray and greenish-gray, strongly sheared	15

Approximate total 120

Willard thrust

Tintic Quartzite (Cambrian)

Rusty-weathering tan quartzite.

AGE

The sedimentation age of the Facer Formation has not been determined precisely, though it can be placed within broad limits of 1.7 to 2.5 b.y. The younger limit of 1.6 to 1.7 b.y. is set by the Rb/Sr ages of muscovite in both schist and pegmatite (table 2), which indicates that the unit underwent an episode of mild regional metamorphism and local pegmatite injection at that time. This metamorphic age is corroborated by the K/Ar date of 1.68 b.y. obtained on hornblende from a body of diorite by which the unit was intruded. It is clear therefore that the Facer is at least as old as late Proterozoic X age (1,600–2,500 m.y.). It seems unlikely however, that the Facer is much older than its igneous and metamorphic components indicate, inasmuch as it has undergone only low-grade metamorphism. An older limit of approximately 2.5 b.y. is indicated indirectly by the age of igneous and metamorphic rocks that underlie similar rocks in the Raft River-Grouse Creek areas of northwestern Utah, with which the Facer Formation is provisionally correlated.

CORRELATION

The nearest occurrences of Precambrian units that contain the unique combination of rock types that characterize the Facer Formation are in the Raft River Mountains of northwestern Utah. The section in that area (section B, fig. 11) consists of six units of quartzite, feldspathic quartzite, and schist (originally pelite) resting unconformably on an older metamorphic and igneous terrane at least 2.2 b.y. old (Compton and others, 1977). The oldest unit is a locally conglomeratic quartzite (Elba Quartzite) that is overlain by a series of alternating schist and quartzite units (schist of the Upper Narrows, quartzite of Yost, schist of Stevens Spring, quartzite of Clarks Basin, and schist of Mahogany Peaks). The two lower quartzites (Elba and Yost) contain bright green quartzite, hematitic schist, and amphibolite identical in appearance with rocks in the Facer Formation. The uppermost unit is overlain by metamorphosed limestone assigned to the Ordovician Pogonip Group (Compton, 1972, 1977). These rocks were included by Felix (1956) in Unit B of his Precambrian Harrison(?) Series, and all but the Elba were included by Stringham on the Geologic Map of Northwestern Utah (Stokes, 1963) in his upper(?) Precambrian Dove Creek Formation. In the nearby Albion Range, these rocks were divided into the Elba Quartzite and overlying Conner Creek Formation by Armstrong (1968), who considered the Elba to be Cambrian(?) and the Conner Creek to be Cambrian or Ordovician. Compton (1972) designated the lower part of the sequence, including the Elba, as Precambrian(?) and the uppermost units (quartzite of Clarks Basin and schist of Mahogany Peaks) as Cambrian(?). Compton and others (1977) now recognize these same units throughout much of the Grouse Creek and Raft River Mountains and the Albion Range.

Although the characterizing rock types (green quartzite, hematitic schist, and amphibolite) are present in both the Wasatch and Raft River Mountains, complex folding and faulting make it impossible to be certain whether the differences between the two sections represent original variation, or result from plastic thinning and tectonic removal within the Raft River sections or folding and repetition of the sections within the Wasatch Mountains. In any case, certain units (limestone) are entirely absent in possible Facer equivalents within the Raft River Mountains, although they may perhaps be found in less faulted and attenuated sections within the Albion Range.

These uncertainties make it impossible to establish a correlation unequivocally between the Facer Formation and similar rocks in the Raft River Mountains beginning with the Elba Quartzite. On the other hand, the occurrence of the distinguishing rock types in both units is highly suggestive, and is consistent with the concept of eastward tectonic transport on the Willard thrust, derived from regional studies of other stratigraphic units (Crittenden, 1961). More significantly, if this correlation is correct, the stratigraphic relations in the two areas (Wasatch and Raft River Mountains) complement each other and make possible the reconstruction of a complete stratigraphic section for northwestern Utah (fig. 11).

According to this concept, the Facer Formation is inferred to be equivalent to that part of the Raft River section above the pre-Elba unconformity and below the base of the Pogonip. Because it is clearly impossible for a unit of Proterozoic X age to be interbedded with Ordovician rocks, this implies the existence at the base of the Pogonip of a major plane of detachment (shown as an inferred thrust on fig. 11) that has been concealed by subsequent metamorphism (Crittenden, 1979). In spite of careful search, however, Compton and Todd (1979) have been unable to recognize this structure. If it exists, structural relations to the Immigrant Pass pluton at the south end of the Grouse Creek Mountains (Compton and others, 1977) suggest that this tectonic contact developed before 38 m.y. age. These proposed correlations imply that the Facer was originally deposited somewhere in western Utah on a basement like that of the ±2.5-b.y.-old rocks of the Raft River Mountains (Compton and others, 1977) but has been de-

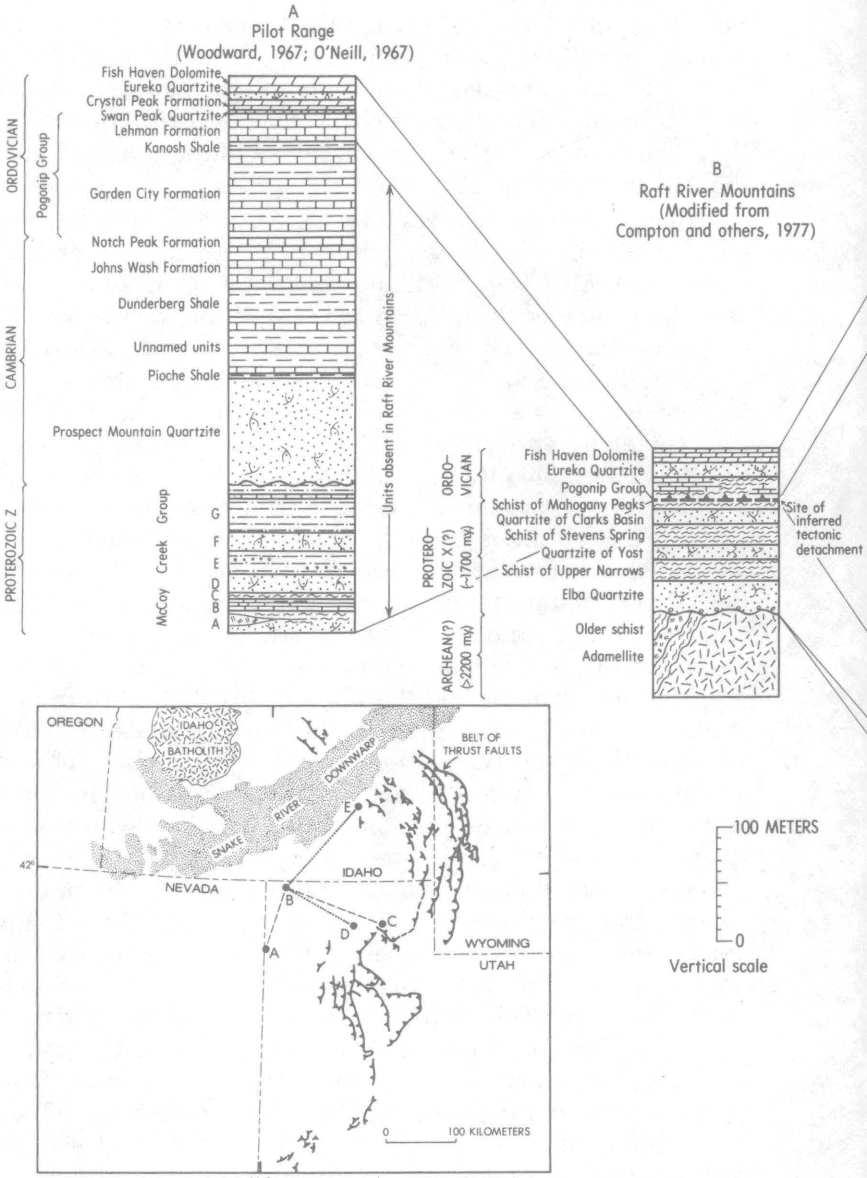
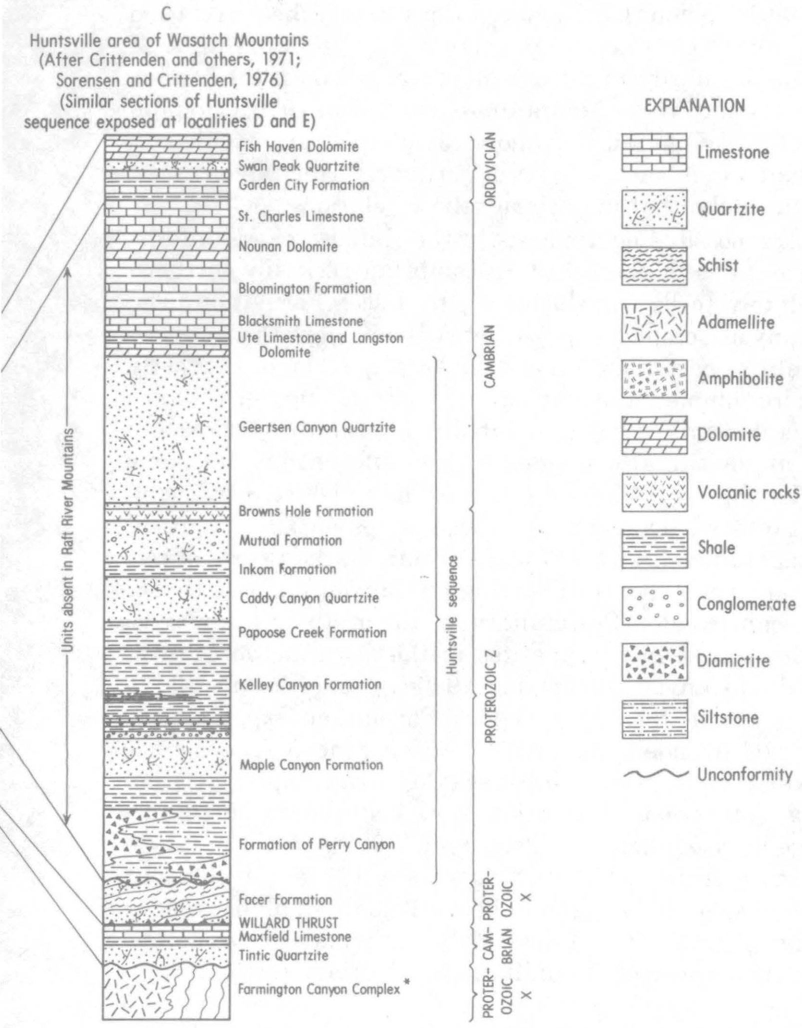


FIGURE 11.—Inferred correlation of Facer Formation and overlying units with Precambrian rocks in Raft River Mountains and nearby areas in northwestern Utah. Location of sections shown on inset. Horizon of inferred tectonic detachment shown by thrust fault symbol in Raft River section (column B).



* Now known to include rocks of Archean age (see text)

tached from that basement by thrusting. Conversely, the correlation implies that the thick (5,000 m) section of the Proterozoic Z Huntsville sequence has been tectonically removed from the section now exposed in the Raft River Mountains (Crittenden, 1979; Compton and others, 1977). It is hoped that more complete stratigraphic sections may be found in adjoining parts of northwestern Utah or in the Albion Range in Idaho that may clarify these relations.

Aside from the possible equivalents in the Raft River Mountains described above, none of the other Precambrian rocks in northern Utah appear likely to be correlative of the Facer Formation. The Farmington Canyon Complex exposed below the Willard thrust in the Wasatch Mountains east of Ogden and on Antelope Island is a vastly thicker and more complex unit, including extensive gneissic plutons. Its original metamorphic grade (amphibolite to granulite facies) and abundance of migmatite also suggest a very different metamorphic history. The Farmington Canyon Complex has yielded Rb/Sr and K/Ar ages of 1.6 to 1.7 b.y. Although these are essentially identical with the dates obtained from the Facer Formation, the extent of retrogressive metamorphism in the Farmington Canyon suggests that it could be significantly older. Preliminary results of Rb/Sr study by C. E. Hedge indicate that the migmatites in the Farmington Canyon Complex in Wilbur Canyon are 2,600 to 2,900 m.y. old (Bryant, 1979).

One additional unit, the Little Willow Formation, exposed near Salt Lake City, (Crittenden and others, 1952) is conceivably correlative of the Facer Formation only because of its stratigraphic position below the Big Cottonwood Formation, now believed to be of Proterozoic Y age (Crittenden and Peterman, 1975). But the Little Willow contains neither of the distinctive sedimentary rocks that characterize the Facer, and in general bears little resemblance to it in lithology or appearance. The Little Willow Formation cannot be dated isotopically because of proximity to the Tertiary Little Cottonwood stock.

Inasmuch as the Facer Formation is unconformably overlain by the Huntsville sequence, it is clearly older than all the units in western Utah with which that sequence, mainly of Proterozoic Z age, is correlated (Crittenden, Schaeffer, Trimble and Woodward, 1971). This includes the Precambrian sections at Pocatello, Idaho (loc. E, fig. 11), on Promontory Point (loc. D, fig. 11) (Olson, 1956), in the Pilot Range (section A, Fig. 11) (Woodward, 1967), the Canyon Range (Christiansen, 1952), the Sheeprock and Simpson Mountains, and the Wah Wah Mountains of central Utah.

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