THE GEOLOGICAL SURVEY OF WYOMING

Daniel N. Miller, Jr., State Geologist

PRELIMINARY REPORT No. 17

PETROGRAPHY OF SELECTED ROCK SAMPLES AND A DISCUSSION OF STRUCTURAL FABRIC, NORTHERN SALT RIVER RANGE, LINCOLN COUNTY, WYOMING

By

David R. Lageson

LARAMIE, WYOMING

1978

First printing of 1500 copies, May, 1978

Additional copies of this report may be obtained from

The Geological Survey of Wyoming
Box 3008 University Station
Laramie, Wyoming 82071

Front cover. *Photomicrograph of Giraffe Creek Member of Twin Creek Limestone. Average ooid diameter 0.3 mm (medium sand size).*

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ABSTRACT

The descriptive petrography of selected rock samples from formations exposed in the Stewart Peak quadrangle, northern Salt River Range, is presented.

The Stewart Peak quadrangle is a structurally important part of the Wyoming thrust belt, being situated on the structural culmination of the Absaroka-St. Johns thrust complex. Paleozoic rocks ranging in age from Middle Cambrian to Mississippian are exposed through a complex array of imbricate thrust faults.

Deformation associated with large-scale horizontal thrust plate translation has imprinted the rocks with characteristic fabric elements. These include stylolitization, increased grain compaction and suturing, dolomitization, microfracturing, deformation lamellae, and general cataclasis.

INTRODUCTION

Generalized hand-sample descriptions of various rock units in the Wyoming-Idaho thrust belt are available from numerous sources (e.g., Boeckerman and Eardley, 1956; Eyer, 1969; Kummel, 1954; Mansfield, 1927; Olson, 1977; Pattison, 1977; Sando, 1977, and Wanless and others, 1955). In addition, there are excellent sources for detailed petrography of specific formations from place to place throughout the thrust belt (e.g., Furer, 1970; Holm and others, 1977; Kamis, 1977; Middleton and others, 1976; Pacht, 1977; and Picard, 1977). However, there is no single publication which provides detailed petrographic information for the entire stratigraphic section.

This report is a preliminary attempt to present petrographic data for Paleozoic and Mesozoic rocks exposed in the Stewart Peak 7.5 minute topographic quadrangle, northern Salt River Range, Lincoln County, Wyoming (Fig. 2).[1]

In addition to presenting petrographic data, aspects of structural fabric are discussed as they relate to foreland thrust deformation in the quadrangle.

ACKNOWLEDGMENTS

I am indebted to Drs. J.D. Love of the U.S. Geological Survey, and to D.L. Blackstone, Jr., of the University of Wyoming, for the guidance and assistance they have provided in my thrust belt studies. I thank Larry T. Middleton for reviewing this report.

METHODS OF INVESTIGATION

Representative rock samples of Paleozoic and Mesozoic formations exposed in the Stewart Peak quadrangle were collected from hanging wall and footwall sections of the Absaroka and St. John thrusts (Fig. 3). Samples of Paleozoic formations were collected from hanging wall sections, while those of Mesozoic formations were collected from footwall sections east of the main crest of the range (Table 1). Imbricate thrust faults and other structural complexities have precluded measurement of complete stratigraphic sections at many localities in the quadrangle. In addition, certain upper Paleozoic and lower Mesozoic formations are absent at the surface in the quadrangle due to several combined factors, including erosion, thrust cutoffs, and Recent normal faulting.

Rock samples were collected during the 1977 field season. Standard size thin sections were made of selected samples, and a Zeiss petrographic microscope was used for subsequent analysis. Thin sections of sandstone samples were point counted and classified according to Folk (1974, p. 129) (Fig. 4). Limestone samples were classified according to Folk (1959). Petrographic analyses have been standardized to include data on composition, textural relationships, maturity, grain contacts, and diagenesis. For the sake of simplicity and organization, petrographic data are presented in chart form (Plate 1). Photomicrographs are provided for several of the units described (Plates 2 through 10). This format should enable quick and easy reference to the data.

Stratigraphic nomenclature used in this report follows that of Jobin (1972).

[1]This work is not complete or final, but represents preliminary observations made during an ongoing mapping project of the Stewart Peak 7.5 minute topographic quadrangle (43°00′ to 43°07′30″ latitude, 110°52′30″ to 111°00′ longitude).

GENERAL GEOLOGY

The northern Salt River Range is a structurally important area of the Wyoming thrust belt. In particular, the Stewart Peak quadrangle is situated on the structural culmination of the Absaroka and St. John thrusts. Paleozoic rocks, ranging in age from Middle Cambrian to Mississippian, are exposed through a complex array of imbricate thrust faults. Common structural features of the more competent

Table 1. *Sample locations for units described in this report.*

FORMATION NAME	LOCATION	
*Aspen Formation		
Bear River Sandstone	NE ¼ sec.15 and NW ¼ sec.14,	T.36N., R.118W.
Draney & Peterson Limestones	NE ¼ sec.9,	T.36N., R.118W.
Sandstone from Ephraim Conglomerate	center of N ½ sec.9,	T.36N., R.118W.
Ephraim Conglomerate	SE ¼ sec.9,	T.36N., R.118W.
Stump Formation	SE ¼ sec.9,	T.36N., R.118W.
Preuss Formation	SW ¼ sec.17,	T.36N., R.118W.
Twin Creek Limestone	NE ¼ sec.20,	T.36N., R.118W.
Nugget Sandstone	SW ¼ sec.21,	T.36N., R.118W.
Ankareh Formation	SW ¼ sec.21,	T.36N., R.118W.
*Thaynes Formation		
*Woodside Formation		
*Dinwoody Formation		
*Phosphoria Formation		
*Wells Formation		
Mission Canyon Limestone	NW ¼ sec.22,	T.35N., R.118W.
Lodgepole Limestone	SE ¼ sec.8,	T.35N., R.118W.
Darby Formation	NW ¼ sec.22,	T.35N., R.118W.
Bighorn Dolomite	NE ¼ sec.22,	T.35N., R.118W.
Gallatin Limestone	NE ¼ sec.22,	T.35N., R.118W.
Gros Ventre Formation	W ½ sec.23,	T.35N., R.118W.

**These formations are exposed in the Ferry Peak quadrangle, immediately north of the Stewart Peak quadrangle; sample descriptions for these units are from Jobin (1972).*

units include tightly overturned concentric folds and pervasive cataclasis, especially near thrust faults; incompetent units occasionally show axial plane cleavage, but more commonly responded passively to deformation.

The Stewart Peak quadrangle is characterized by rugged mountainous terrain ranging in elevation from 6,000 feet at the base of the range to 10,103 feet at the summit of Stewart Peak. The crest of the Salt River Range trends north-south through the middle of the quadrangle and was extensively glaciated during Pleistocene time. Access to the area is extremely limited.

The quadrangle may be subdivided into three distinct structural and topographic regions. The westernmost part is the downthrown block of the Grand Valley fault and is characterized by gently sloping, treeless alluvial fans. The central and southwest parts are characterized by northwest-trending thrust faults and rocks ranging in age from Middle Cambrian to Mississippian. This is the zone of complex imbricate thrust faulting, folding, and fracturing of allochthonous strata of the Absaroka-St. John thrust complex. The northeast quarter of the quadrangle is composed of Mesozoic strata in the footwall of the Absaroka-St. John thrust complex; tightly overturned anticlines and synclines typify this part of the quadrangle. The Murphey thrust, which trends northwest in the northeast quarter of the quadrangle, has displaced Triassic strata over the Cretaceous Bear River and Aspen Formations.

Major mappable thrust faults in the Stewart Peak quadrangle include, from east to west, the Firetrail, Murphey, Absaroka, St. John, Ferry Peak, Blowout, Star and Stewart thrusts (Boeckerman and Eardley, 1956). The direction of tectonic transport was relatively southwest to northeast. Repetition of the Bighorn Dolomite in the southern part of the quadrangle is a reliable marker for mapping thrust faults; in this regard, the upper Gros Ventre Formation (Park Shale Member) repeatedly serves as a zone of detachment for imbricate thrust faults on the hanging wall of the Absaroka thrust. There is little doubt that the lower shale member of the Gros Ventre Formation (Wolsey Shale Member) is the main zone of detachment or décollement for the Absaroka-St. John thrust complex. To the writer's knowledge, there is no Lower-to-Middle Cambrian Flathead Sandstone exposed anywhere in the Salt River or Snake River Ranges.

Figure 1. *Outcrops of Bighorn, Darby, and Lodgepole formations in a cirque headwall, NW 1/4, T.34N., R.117W., northern Salt River Range, Lincoln County, Wyoming. Photo taken looking southwest. East dip of strata represents limb of overturned anticline on hanging wall of Absaroka thrust. Caribou Range in far distance.*

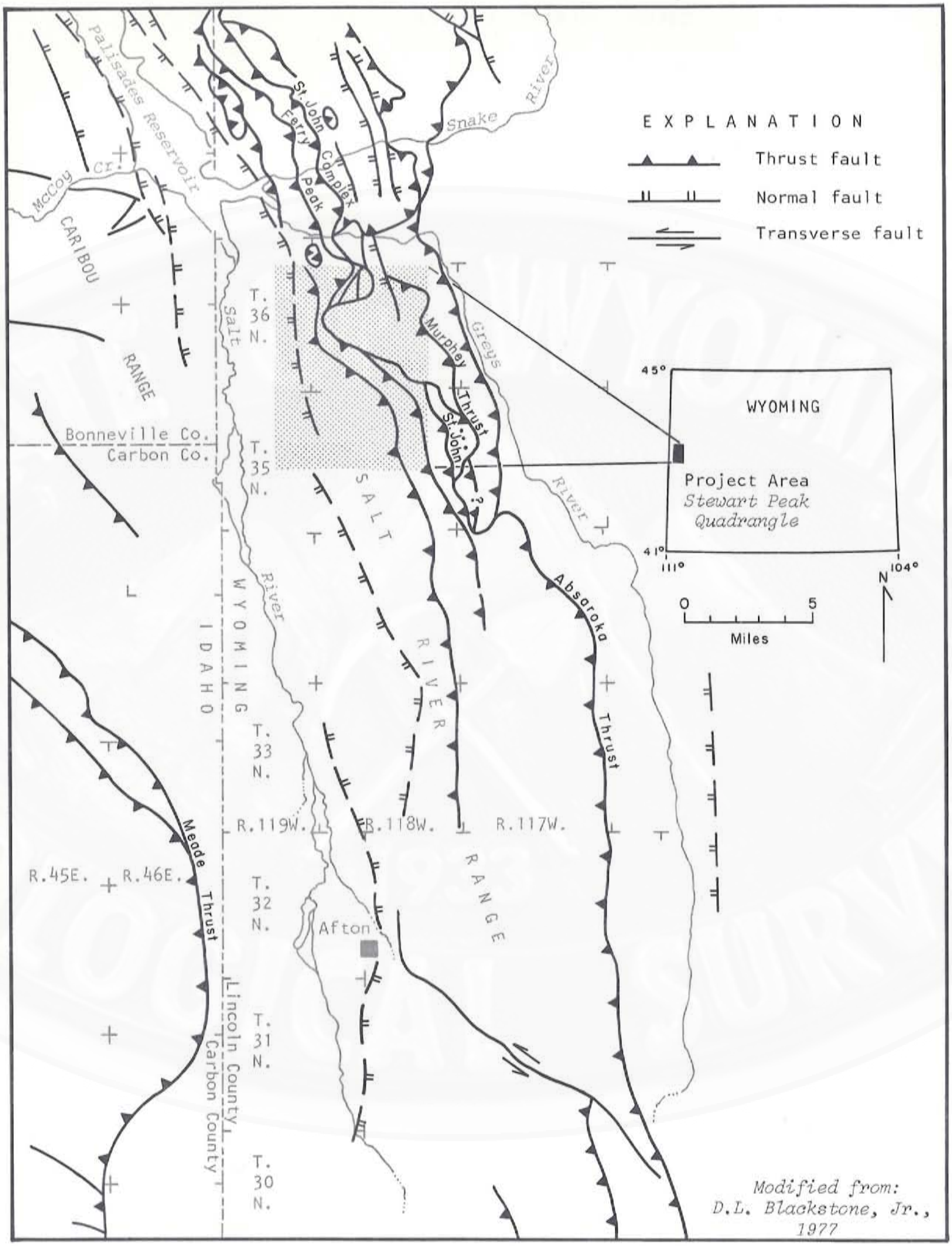
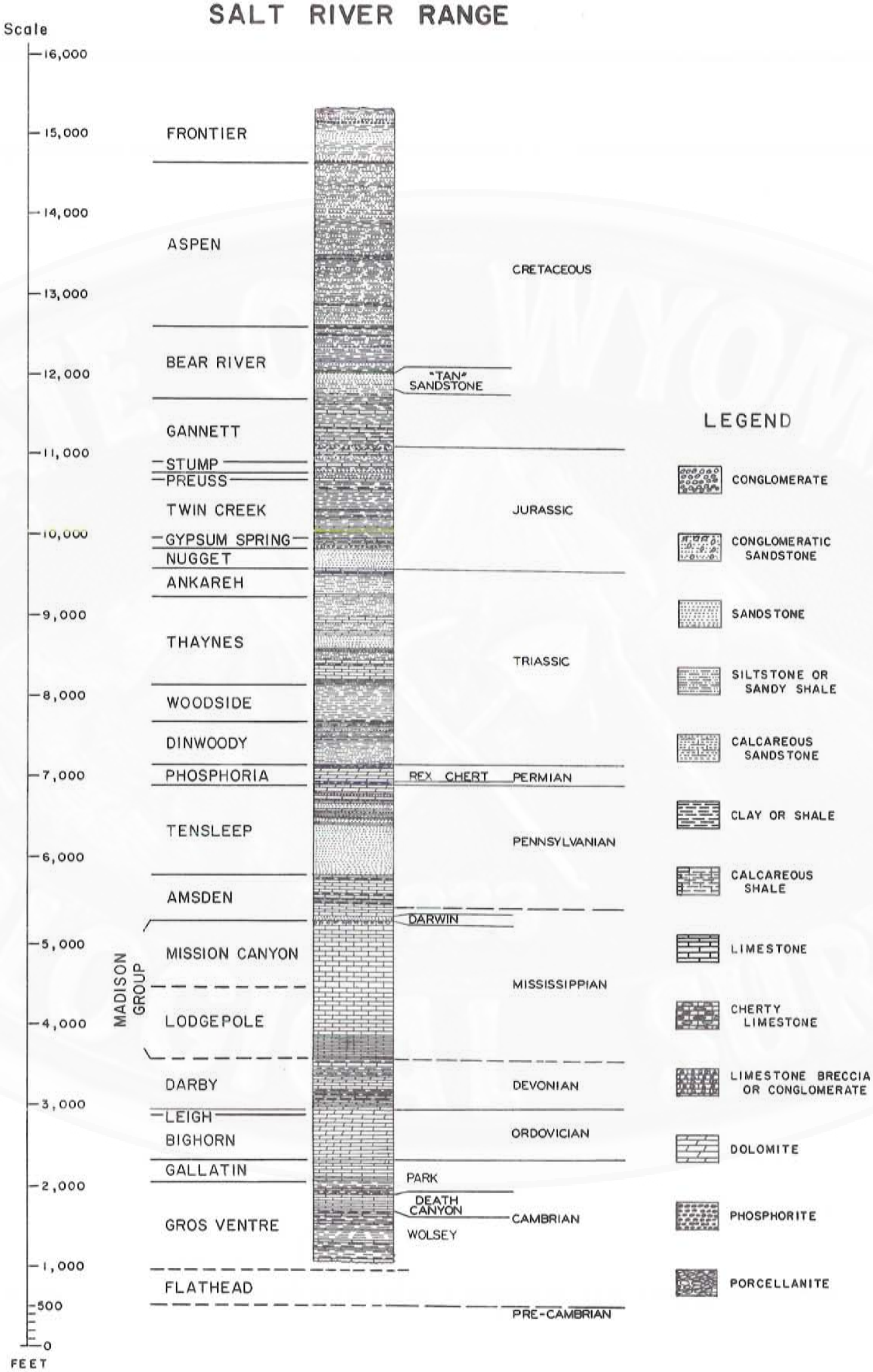


Figure 2. *Map showing area of study, northern Salt River Range, Lincoln County, Wyoming.*

SALT RIVER RANGE



The mapping of thrust faults within thick Cambrian sections or in areas of rapid stratigraphic repetition is more tenuous. This, in addition to locally dense forest cover and rugged terrain, makes mapping of thrust faults and stratigraphic units along strike most difficult. However, subtle lithologic and paleontologic differences between seemingly similar units help to unravel the puzzle.

A small erosional reentrant in the Absaroka-St. John complex occurs in the northern half of the quadrangle (Fig. 2). Exposed footwall rocks are as young as Preuss and dip uniformly southwest at approximately 20°. At present, there is no reason to believe that this reentrant is structurally controlled; it seems to be the result of headward stream erosion by Stewart Creek.

The Grand Valley normal fault borders the Salt River Range on the west and trends north-south through the western part of the Stewart Peak quadrangle. Offset Quaternary sediments in the Bedford NW quadrangle, in addition to faceted spurs and steep totographic relief, suggest that this fault is currently active. Royse and others (1975) have interpreted this fault near Alpine, Wyoming, as a listric normal fault restricted to the hanging wall of the Absaroka thrust. It is postulated that the Grand Valley fault is localized by a major "step" or ramp in the underlying Absaroka thrust; evidence for this interpretation includes the eastward dip of Pliocene strata into the fault and parallel trends of the Grand Valley and Absaroka faults. This interpretation is tentatively favored by the writer.

PETROGRAPHY

The petrographic data presented on Plate 1 are based on hand sample examination of several specimens in the field, in addition to one respresentative thin section, for each unit. For many of the sandstone samples, two or more thin sections were made. Therefore, the data reflect gross lithologies and are not intended to define specific sub-units within a formation. These data may be of most use to the wellsite geologist, where cutting samples are often homogenized and sub-units of a formation are blended together.

Good outcrops of the Aspen and Bear River Formations (Cretaceous) are relatively infrequent in the Stewart Peak quadrangle, although they crop out over a large part of the northeast quarter. The lower part of the Bear River formation crops out as a reddish brown and brownish gray, moderately resistant sandstone. The unit is characterized by carbonaceous partings and bioturbation structures. In thin section, the unit consists of fine-grained, moderately well-sorted, subround grains of quartz and feldspar (Plate 2, A and B). Oil well cutting samples through the Bear River interval would undoubtedly yield an admixture of fine-grained sandstone and splintery black shale fragments.

Figure 3 (opposite). *Composite Paleozoic and Mesozoic columnar section, northern Salt River Range, Lincoln County, Wyoming. Modified from Wanless, et al., 1955, plate 14. Unconformities within the section not shown.*

The Gannett Group, as mapped by Jobin (1972), includes an upper unit of undifferentiated interbedded marly mudstone and gray limestone, red to brown mudstone and interbedded siltstone, and white-weathering, thick-bedded sublithographic limestone. The upper unit is probably equivalent to the Draney Limestone, Bechler Conglomerate, and Peterson Limestone (all Lower Cretaceous) of southeastern Idaho. Representative samples of the Draney and Peterson Limestones have been microscopically examined for this report and appear very similar (Plate 3, A and B). Subtle differences include the fact that the Peterson contains more disseminated grains of feldspar and quartz, is darker (more micritic), and contains intraclasts of rounded micritic mud balls, where the Draney does not.

The lower unit of the Gannett Group, as mapped by Jobin (1972), consists of red sandstone and blue-gray, pebbly conglomerate correlative with the Ephriam Conglomerate (Upper Jurassic to Lower Cretaceous). The conglomerate is very hard (silica cemented) and consists of abundant rounded pebbles of Paleozoic limestone; this unit represents synorogenic sediment derived from the Paris-Willard Thrust system during late Jurassic-early Cretaceous time (Royse and others, 1975). Matrix grains between the lithic clasts consist of fine-grained quartz and feldspar (Plate 4, B). Maroon, cross-bedded, massive sandstones are interbedded with conglomerate and are characterized by well-sorted, fine-grained, subangular to subround grains of quartz and feldspar (Plate 4, A). The sandstone is very hard and, like the conglomerate, is predominantly silica cemented; however, a more recent episode of calcite cement replacement of both framework grains and silica cement has occurred in the sandstone.

The Stump Formation (Upper Jurassic) consists of light green-gray to brown-gray, fine- to medium-grained, thin-bedded, glauconitic calcareous sandstone and sandy limestone. The middle calcareous member was thin sectioned for this report, and consists of ooids and echinoderm fragments, cemented by blocky calcite. The ooids display excellently preserved concentric and radial microstructure; many ooid grain boundaries are sutured. Disseminated pelletal glauconite accounts for approximately 5 percent of all framework grains in the rock. In terms of well cuttings, the oolitic nature of the middle calcareous member may be mistaken for oolitic beds in the Twin Creek Limestone; however, the presence of pelletal glauconite should be a good marker for the Stump Formation.

The Preuss Formation (Upper Jurassic) is a redbed sequence consisting of fine-grained, thin-bedded, clayey sandstone and siltstone. No thin sections were made of Preuss samples.

Samples from the upper and middle parts of the Twin Creek Formation (Upper Jurassic), the Giraffe Creek and Leeds Creek Members, respectively, were thin sectioned for this report. The Giraffe Creek Member consists of yellow-gray oolitic limestone (Plate 5, A). Ooids are medium-grained (up to 0.3mm in diameter) and, as with the middle calcareous member of the Stump Formation, display excellently preserved microstructure. The Leeds Creek Member consists of pale yellow (weathered surfaces) to brown-gray (fresh surfaces), slabby-bedded, micritic limestone (Plate 5, B). Fossils are abundant and include well-preserved *Gryphaea* and *Pentacrinus.* The Twin Creek Formation typically forms prominant white slopes. Well cuttings of the Twin Creek could potentially be confused with the Peterson and Draney Limestone Members of the Gannett Group.

The Nugget Sandstone (Triassic-Jurassic) is a reddish-yellow, extremely hard, noncalcareous, cross-bedded arkosic sandstone (Plate 6, A and B). Quartz and feldspar comprise 90 percent of all framework grains. The framework grains are fine grained, moderately well sorted, subangular to subround, and typically have concavo-convex to sutured grain contacts. Silica overgrowths, chert cement, and hematite have reduced porosity to near zero in the area. The intense grain compaction and nearly complete cementation of the Nugget may be the result of structural deformation.

The Ankareh Formation (Middle-Upper Jurassic) is a sequence of maroon noncalcareous sandstone, siltstone, and shale which typically forms nonresistant outcrops. Sandstone samples of the Ankareh, examined by thin section, are arkosic in composition (Plate 7, A). Although these sandstone samples appear to have low porosity and permeability, there is evidence of dolomite cement replacing earlier calcite cement, which could enhance porosity.

The Thaynes, Woodside, Dinwoody, Phosphoria, and Wells formations were not examined in detail. Current mapping of the Stewart Peak quadrangle by the writer has not yet established the outcrop extent of these units. However, generalized descriptions from Jobin (1972) and Boeckerman and Eardley (1956) are provided on Plate 1.

The Madison Group (Mississippian) crops out in well-sculptured cirques along the crest of the Salt River Range. The two formational subdivisions of the Madison, the Mission Canyon and Lodgepole limestones, are quite distinct in terms of their outcrop appearance. The Mission Canyon is medium to light gray and medium- to thick-bedded; the Lodgepole is darker, blue-gray and thin-bedded. On weathered outcrop surfaces, the Lodgepole is characteristically brown or tan in color and may be easily confused with argillaceous Cambrian strata. Both the Mission Canyon and Lodgepole limestones contain abundant megafossils (Plate 7, B).

The Darby Formation (Devonian) has been subdivided into two mappable units (Jobin, 1972). The upper third of the Darby consists of thin-bedded, yellow-brown siltstone and mudstone; the lower two-thirds consists of dark brown (sooty), nodular, cliff-forming petroliferous limestone (Plate 8, A). Thin section analysis of the Darby was not done for this report.

The Bighorn Dolomite (Ordovician) is a light blue-gray to white, massive, cliff-forming dolomite. Weathered surfaces of the Bighorn are commonly chalky-white and pitted. Although relict fossils were evident in some samples (*Receptaculites*?), the majority of samples analyzed were medium- to coarsely-crystalline diagenetic dolomite (Plate 8, B).

The Gallatin Limestone (Cambrian) is a medium to dark gray, thin- to medium-bedded, cliff-forming limestone with mottled patches of yellow, silty dolomite. Mottled dolomite commonly occurs along bedding planes and stylolites, and in burrows oriented normal to bedding. In thin section, the unit is predominantly microcryptocrystalline, sparry, dolomitic limestone (Plate 9, A). Neomorphic textures and stylolites are common. The Gallatin is virtually identical to the middle limestone member (Death Canyon Limestone) of the Gros Ventre Formation.

The upper shale and middle limestone members of the Gros Ventre Formation (Cambrian) are extensively exposed in the southern and central parts of the Stewart Peak quadrangle. The upper shale member (Park Shale?) consists predominantly of green shale with interbedded, thin, dark-gray limestone beds. Abundant trilobite cephalons may be found on bedding surfaces of some limestone interbeds. Thin section examination of one limestone interbed showed an extensively recystallized dolomitic limestone with remnant bioclastic fragments and widely disseminated quartz grains (Plate 9, B). Many limestone interbeds are composed of flat-pebble conglomerate, algal limestone, and oolitic limestone (Wanless and others, 1955), all of which are suggestive of an inter-subtidal depositional regime. As previously mentioned, the middle limestone member of the Gros Ventre Formation (Death Canyon Limestone?) closely resembles the Gallatin Limestone.

The reader is referred to Plate 1 for more specific information on all units discussed.

DISCUSSION

The Wyoming salient of the Cordilleran fold and thrust belt is characterized by a structural suite which includes low-angle thrust faults, detached concentric folds, transverse tear faults, and listric normal faults (Royse and others, 1975). The complex structural geometry of the northern Salt River Range may be attributed to an array of interleaved imbricate thrust faults associated with the hanging walls of the Absaroka and St. John thrusts. In general, the rocks described in this report represent an allochthonous mass of miogeosynclinal origin which has moved relatively eastward over shelf strata, resulting in an estimated 50% horizontal shortening (Royse and others, 1975). This large-scale deformation has imprinted the rocks with structural fabrics and petrographic characteristics common to nonmetamorphic overthrust terranes.

As used in this report, the term "fabric" includes the spatial and geometric configuration of all components that make up the rock (Hobbs and others, 1976). Penetrative fabric modifications recognized in this study include stylolitization, increased grain compaction and suturing, dolomitization, microfracturing, deformation lamellae, and general cataclasis.

Stylolites form as anastomosing networks of sutures and form boundaries between discrete "blocks" of rock. Stylolites range in scale from macroscopic to microscopic grain sutures. According to Price (1967, p. 43) a stylolite is a surface of pressure solution and defines a unique direction of compression. Stylolitic fractures typically parallel axial planes of folds and, in a regional perspective, are generally perpendicular to direction of tectonic transport. Paleozoic limestones in the field area (e.g., Gallatin Limestone) are pervaded by stylolitic fractures, many of which parallel bedding. Stylolites are a locus for dolomitization and recrystallization, and may significantly alter the ability of hydrocarbons or other fluids to move through the rock.

Greater grain compaction and suturing has been reported for the Nugget Sandstone within the thrust belt relative to adjacent areas (Pacht, 1976). Nugget samples analyzed in this report also show extensive grain compaction and interpenetration (Plate 6); original grain boundaries are often difficult to discern. Pacht (1976) noted that the percentage of framework grains is high relative to cement in Nugget samples from the thrust belt; this may be due to greater compaction, presumably by tectonic pressures. The tight, compacted nature of the Nugget, as well as other sandstones analyzed in this report, supports this observation.

Deformation lamellae are typically seen in tightly compacted sandstones adjacent to sutured or concavo-convex grain boundaries (Plate 6, A and B). Because lamellae diverge from points or surfaces of contact between adjacent grains, they seem to be genetically related to overthrust deformation, rather than having formed in a pre-depositional stressed environment.

Microfracturing and cataclasis are dramatic elements of structural fabric in the study area (Plate 10, A and B). Fracture arrays isolate rock fragments at all scales, within which there has been little or no deformation. Price (1967, p. 43) states that

> fractures obviously represent discrete strain discontinuities, and the bulk deformation may have been somewhat analogous to "cataclastic flow" in a granular or blocky aggregate, in which individual fragments are free to move relative to one another along their bounding surfaces during deformation.

The process of cataclasis involves rotation, fracturing by shear and tension, and grain fragmentation (Spencer, 1969, p. 156). Cataclastic deformation is a common phenomenon in rocks adjacent to thrust faults. According to Higgins' (1971) classification of cataclastic rocks, the deformational regime of these rocks was one of low temperature and pressure where there was no primary cohesion (i.e., the cataclastically deformed rocks had to be secondarily cemented for induration). Cataclasis ranges in scale from microscopic granulation to the isolation and rotation of blocks several meters on a side. In one example (SW ¼ sec. 17, T.36 N., R. 118 W.), a mass of Cambrian limestone on the hanging wall of the St. John thrust complex, measuring approximately 1.4×10^7 cubic meters, has been shattered to such an extent that the entire mountain is composed of unstable and loose talus. More typically, however, cataclasis is developed for only a few 10's of meters above and below the fault plane. Based on field observation in the Stewart Peak quadrangle, cataclastic zones in hanging wall rocks are thicker (although variable) than in footwall rocks; this seems reasonable considering the allochthonous nature of hanging wall rocks. There are no visible fracture trends in either hanging wall or footwall cataclastic zones.

Although cataclasis is normally associated with thrust faults, large-scale cataclastic zones ranging from 100 to 200 meters thick and more may be due to increased fracturing in ramp regions where faults cut up-section in the direction of tectonic transport. In such regions, hanging wall strata are rotated and moved up the ramp via a mechanism involving the propogation of high-angle reverse faults (Morse, 1977). Royse and others (1975) have postulated a major "step" in the Absaroka thrust near Alpine, Wyoming, based on their inferred origin for the Grand Valley fault. This "step" may account for the extensive cataclasis observed in the Stewart Peak quadrangle.

In addition to penetrative fracturing, bedding plane gouge is another cataclastic phenomenon observed in the field. Gouge is formed by granulation due to flexural slip on bedding planes during concentric folding. Gouge zones may be several centimeters thick, but most commonly are 1 to 2 centimeters thick. Gouge is well developed in the regularly-bedded Lodgepole Limestone, especially in areas of tight concentric folding. Bedding plane gouge may hinder vertical hydrocarbon communication through a well-bedded reservoir rock, although fractures may counteract this influence.

In terms of subsurface geology, cataclastic deformation adjacent to thrust faults, especially in "step" or ramp regions, may greatly enhance secondary porosity and perme-

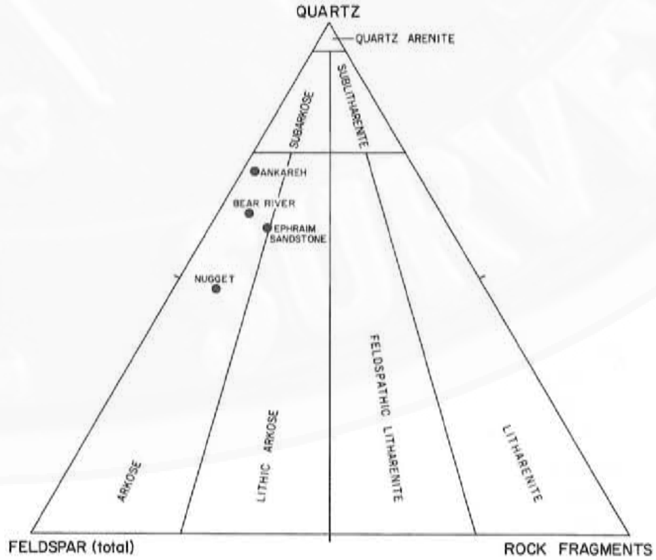


Figure 4. *Ternary diagram (Q-F-R) for selected sandstone samples, northern Salt River Range, Lincoln County, Wyoming. Data based on 500 to 1000 point-counts per sample.*

ability of the rocks. Cataclasis may counteract the detrimental effects of extensive grain suturing and overgrowth development. Predicting areas of intense cataclasis relative to thrust fault ramps or other changes in fault geometry may aid explorationists in their search for petroleum. Thus, the elements of structural fabric are important considerations when analyzing the petrography of highly deformed sedimentary rocks.

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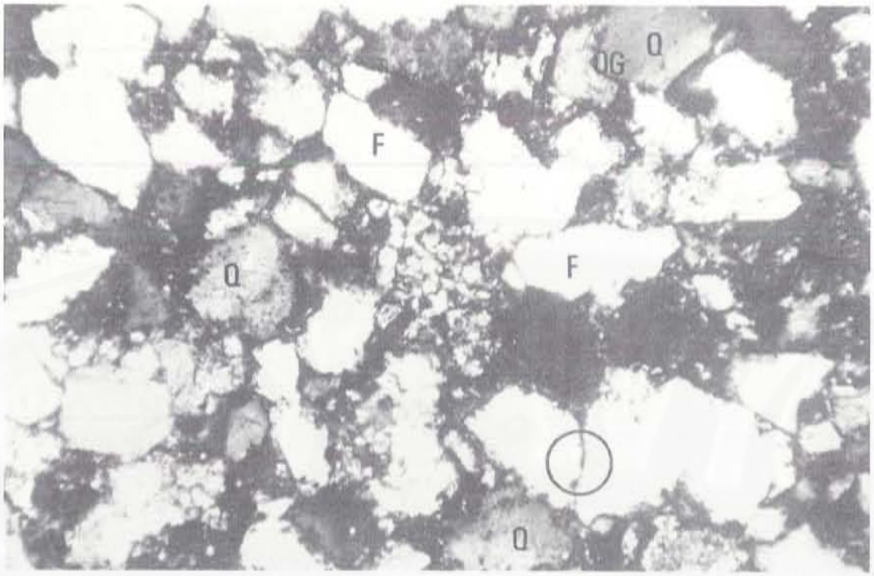
Plates 1-10

(Plate 1 in pocket)



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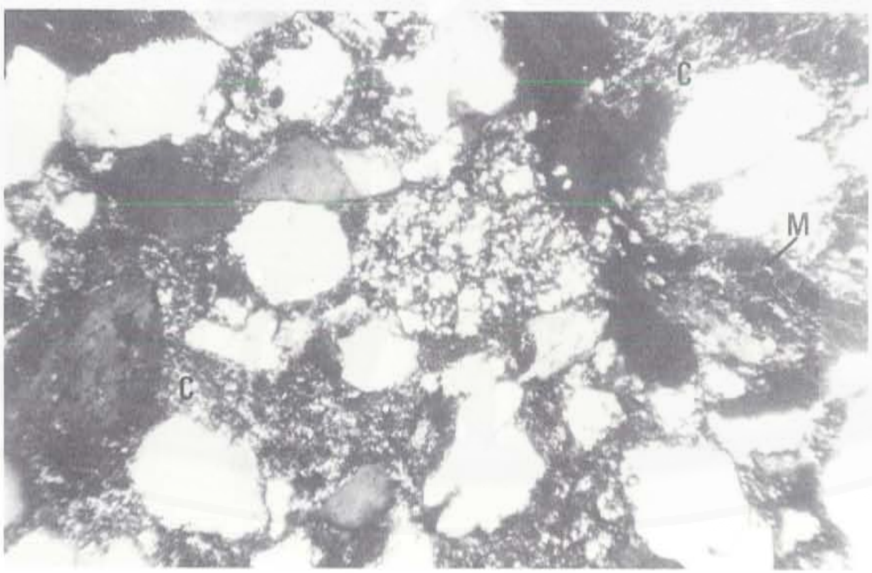
A. *Photomicrograph of Bear River Sandstone. Note large area of silica cement in center. Untwinned feldspars (F) are white, whereas quartz grains (Q) are shades of gray. Angular overgrowths (OG) common. Grain contacts (circled area) long to concavo-convex.*



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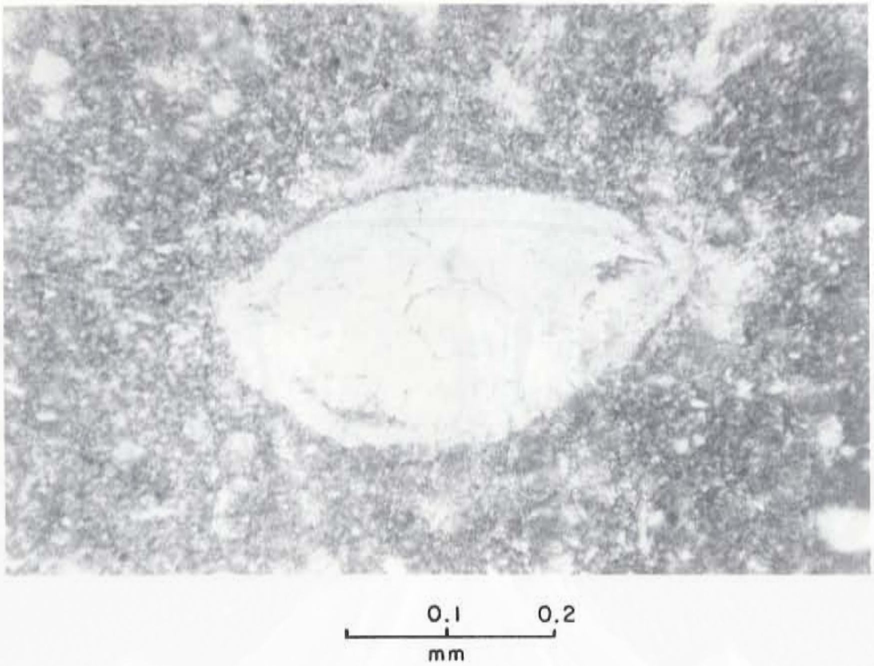
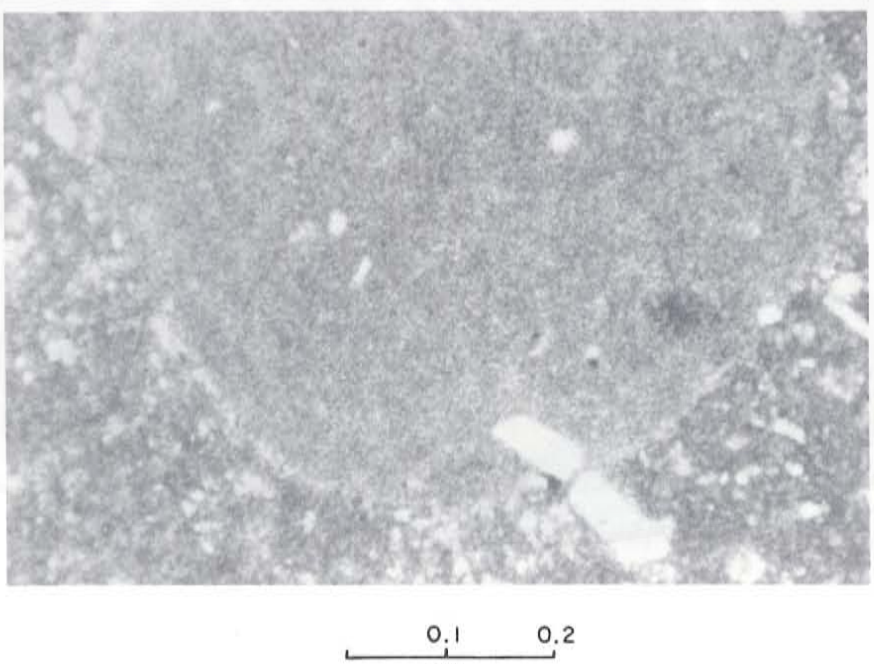
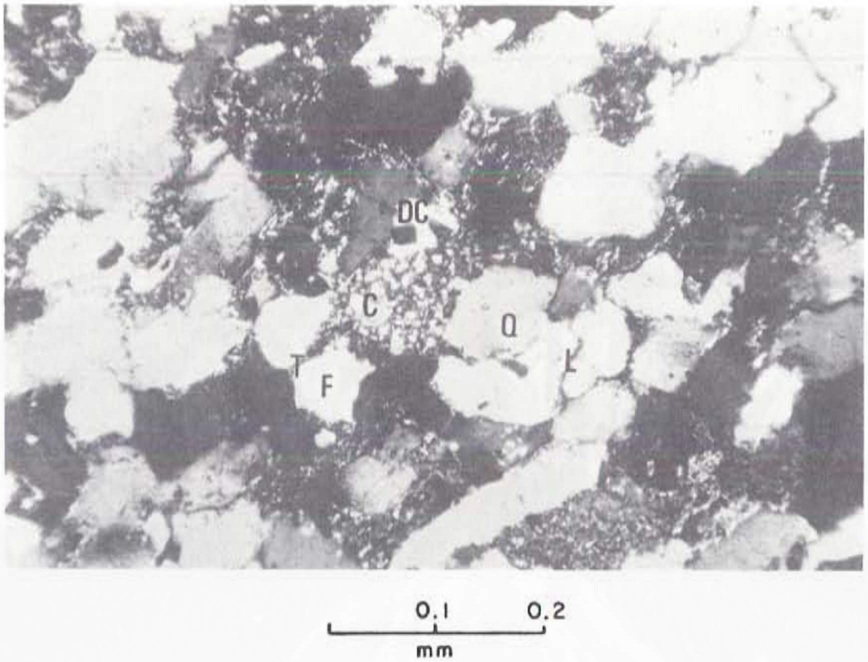
B. *Photomicrograph of Bear River Sandstone. Note large polycrystalline quartz grain in center. Similar to photomicrograph above, but shows more intergrain matrix (M) and cement (C).*



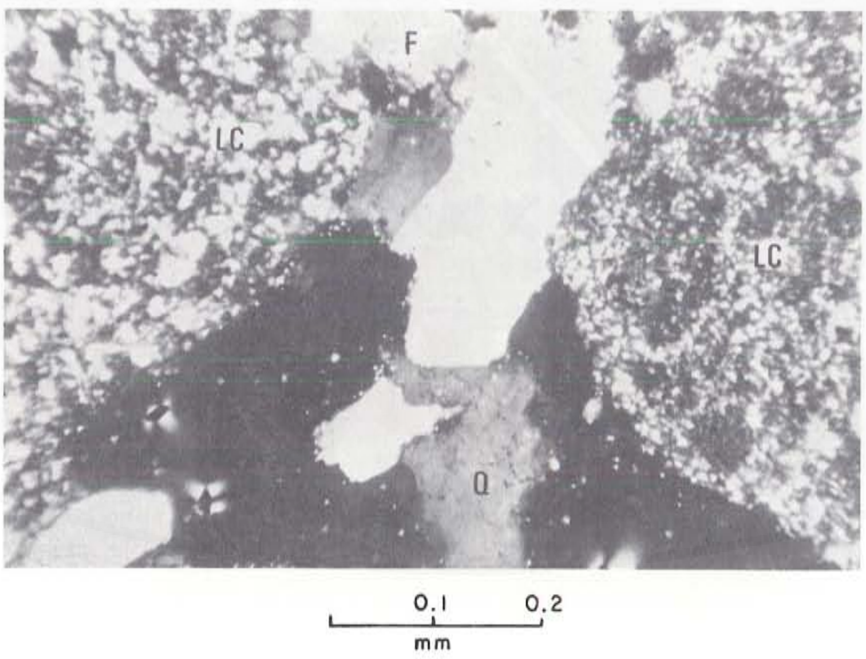
A. *Photomicrograph of Draney Limestone Member of Gannett Group. Longitudinal cross section through ostracode in center: note good preservation of prismatic microstructure of valves. Blocky calcite cement forms interior cast. Micrite surrounding ostracode "speckled" with small spar crystals.*



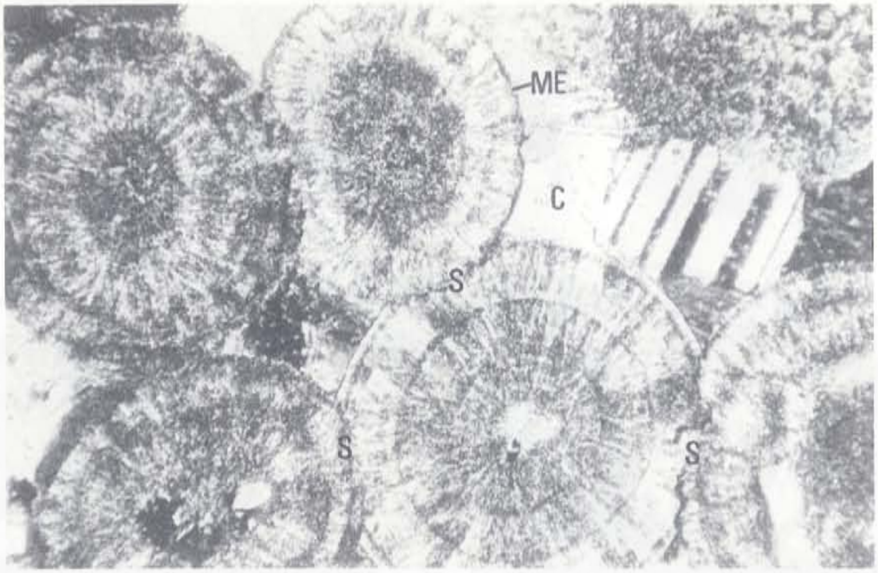
B. *Photomicrograph of Peterson Limestone Member of Gannett Group. Large micritic intraclast occupies upper three-quarters of photomicrograph. Surrounding micrite contains sparry fossil fragments.*



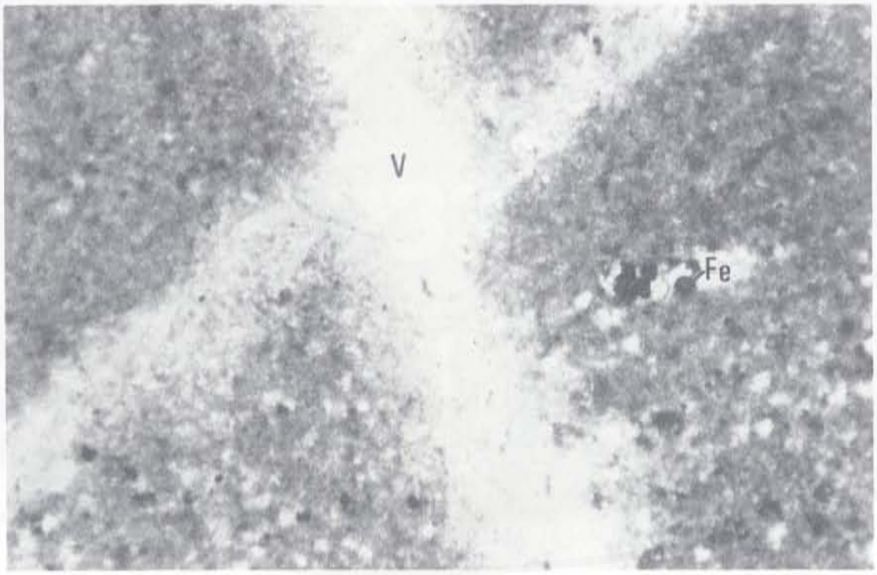
A. *Photomicrograph of sandstone from Ephraim Conglomerate Member of Gannett Group. Note replacement of cherty cement (C) by dolomitic calcite cement (DC) directly north of it. Framework grains quartz (Q) and feldspar (F). Grain contacts tangential (T) to long (L). Very low porosity.*



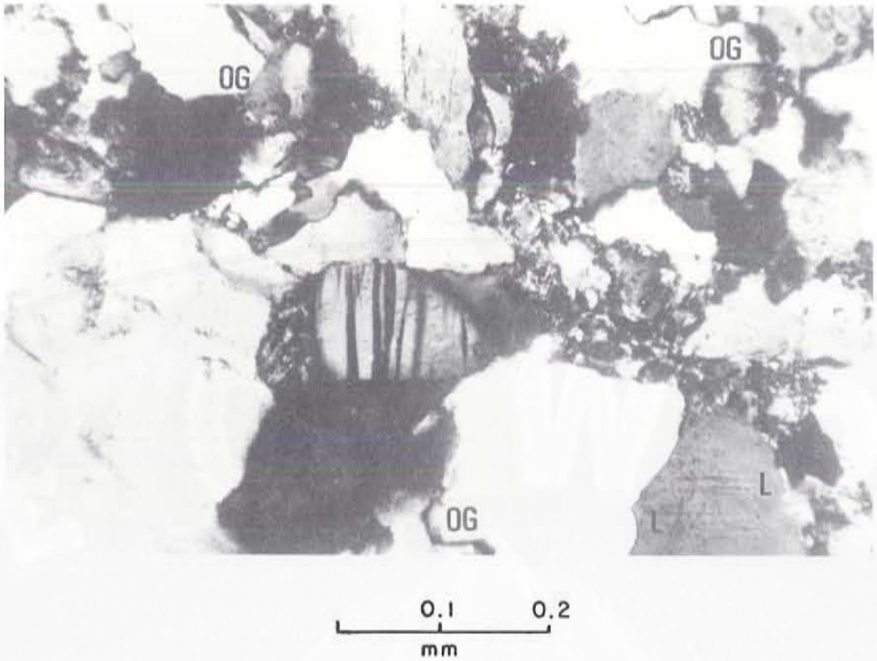
B. *Photomicrograph of pebbly conglomerate from Ephraim Conglomerate Member of Gannett Group. Corners of large lithic clasts (LC) at right and left margins of photomicrograph, with matrix grains of quartz (Q) and feldspar (F) in middle. Lithic clasts are silicified fine-grained sandstone and limestone. Conglomerate cemented with silica and very hard.*



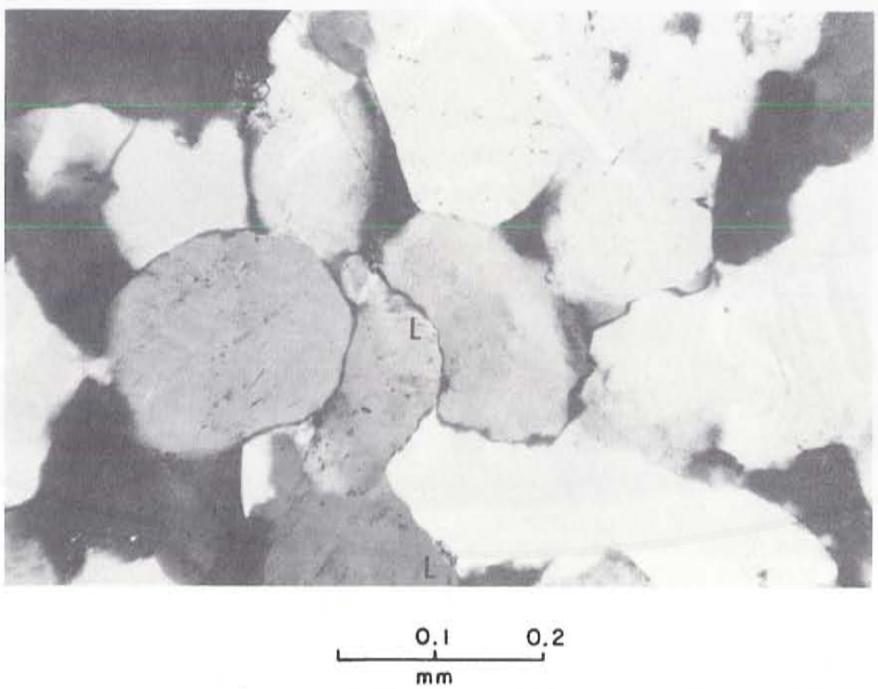
A. *Photomicrograph of Giraffe Creek Member of Twin Creek Limestone. Note beautifully preserved radial and concentric ooid microstructure. Grain boundaries between ooids sutured (S). Micrite envelopes (ME) bound many ooids. Cement (C) blocky calcite. Note twinned calcite cement in upper right (grain is not detrital feldspar, as determined by optical properties).*



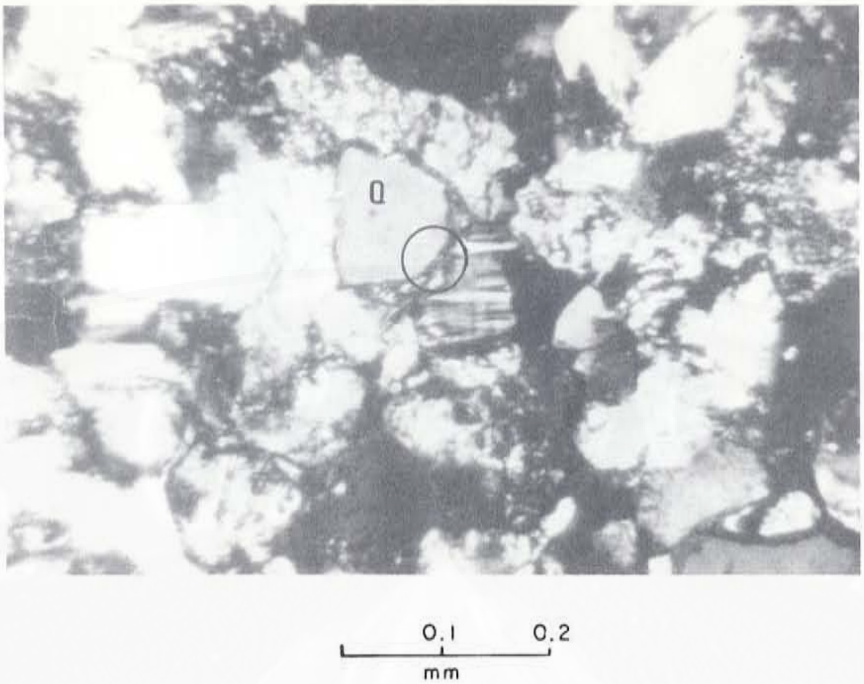
B. *Photomicrograph of Leeds Creek Member of Twin Creek Limestone. Rock dull-looking micrite with occasional "specks" of spar. White bands crossing photo are calcite-filled veins (V). Small patches of diagenetic iron oxide (Fe) visible in right-center.*



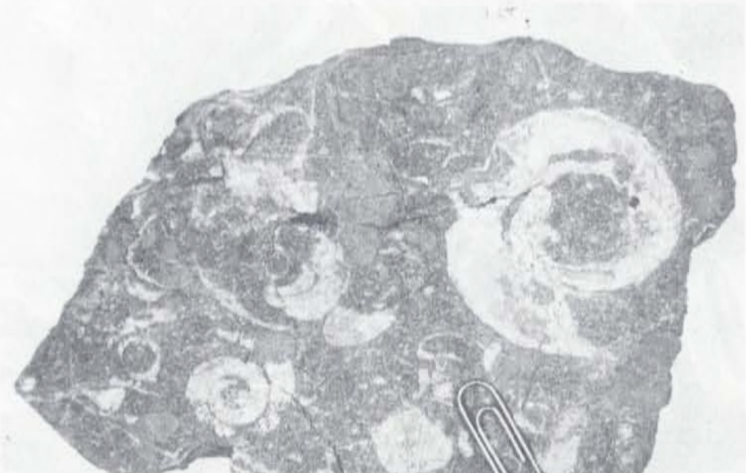
A. *Photomicrograph of Nugget Sandstone. Rounded plagioclase grain in center (pericline twinning). Grain contacts concavo-convex to sutured with abundant overgrowths (OG). Cements include silica (overgrowths plus chert) and minor hematite. Deformation lamellae (L) well developed adjacent to many grain contacts. Very low porosity.*



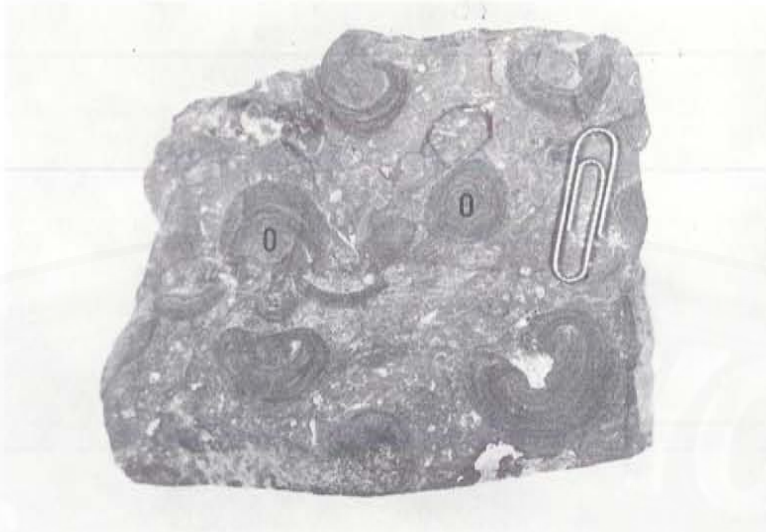
B. *Photomicrograph of Nugget Sandstone. Extensive overgrowth development on quartz and feldsapr grains. Note deformation lamellae (L). Extremely low porosity.*



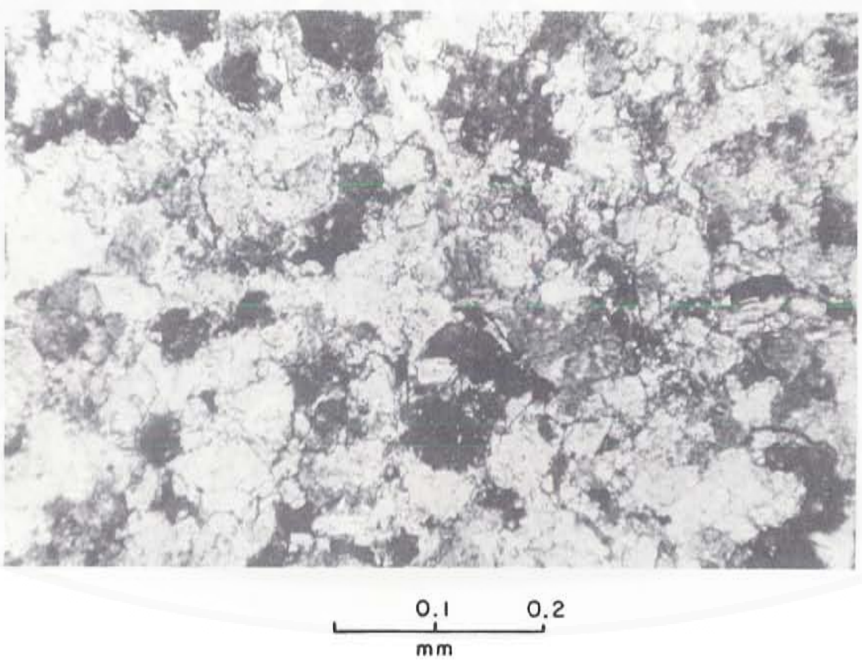
A. *Photomicrograph of sandstone sample from Ankareh Formation. Twinned feldspar in center (microcline) with quartz grain (Q) directly northwest; note long grain contact (circled). Cements include calcite and hematite. Low porosity.*



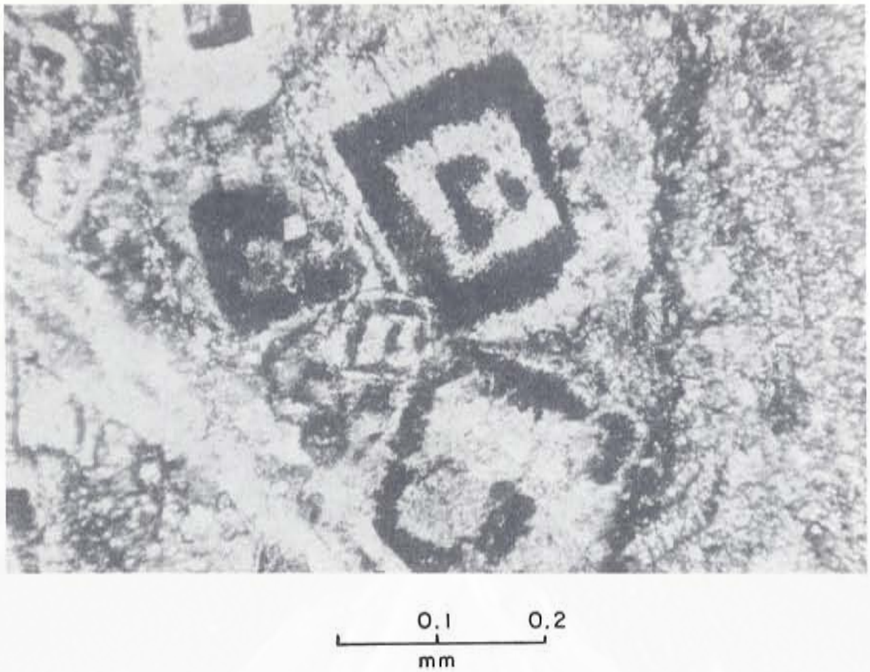
B. *Photograph of Mission Canyon Limestone. Numerous spar-filled casts of gastropods. Paper clip for scale is three cm long.*



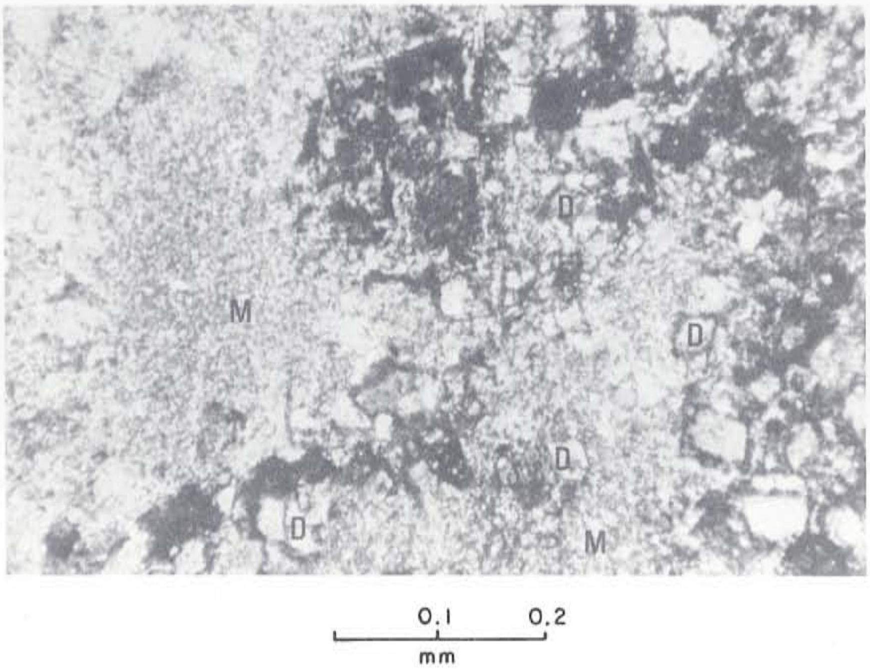
A. *Photograph of Darby Formation (limestone sample from lower part). Unusual algal oncolites (O) in micritic matrix. Paper clip for scale is three cm long.*



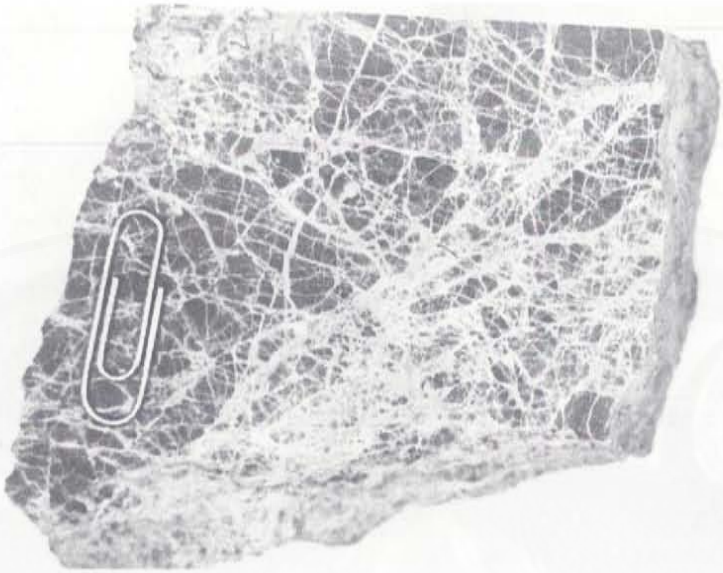
B. *Photomicrograph of Bighorn Dolomite. Subhedral to euhedral dolomite rhombs common. Texture medium to coarsely crystalline. Good potential for porosity development.*



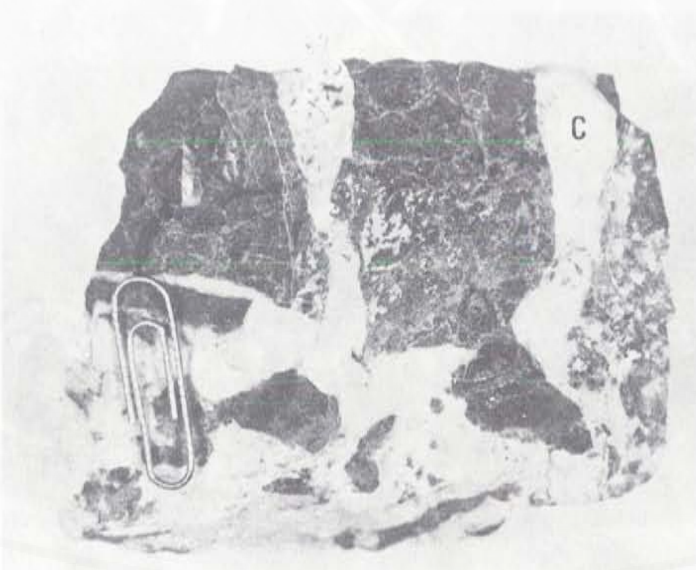
A. *Photomicrograph of Gallatin Limestone. Large zoned dolomite rhombs (center) are part of coarsely crystalline mottled zones in sparsely fossiliferous micritic limestone. Square outline of some dolomite crystals due to plane of the thin section. Calcite vein cuts across lower left corner.*



B. *Photomicrograph of limestone sample from Park Shale Member of Gros Ventre Formation. Micritic limestone (M) mottled with patches of coarser crystalline dolomite (D).*



A. *Photograph of cataclastically deformed sample of Bighorn Dolomite. Sample taken less than 1 centimeter from a thrust plane contact. Note intense fragmentation along a locus of shear in lower right corner. Paper clip for scale is three cm long.*



B. *Photograph of cataclastically deformed sample of Gallatin Limestone. Large angular blocks of limestone have been rotated and displaced in a rubble zone several meters thick adjacent to a thrust fault. Cement (C) sparry calcite. Paper clip for scale is three cm long.*