New Interpretations of Paleozoic Stratigraphy and History in the Northern Laramie Range and Vicinity, Southeast Wyoming

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By WILLIAM J. SANDO *and* CHARLES A. SANDBERG

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A revision of Paleozoic stratigraphy based on biostratigraphic analysis

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By WILLIAM J. SANDO and CHARLES A. SANDBERG

ABSTRACT

The Paleozoic sequence in the northern Laramie Range and vicinity begins with a basal quartzarenite that rests unconformably on Precambrian granite or metamorphic rocks and passes upward into predominantly carbonate rocks of Devonian to Permian age. Quartzarenite formerly regarded as Deadwood Formation (Upper Cambrian and Lower Ordovician) and as basal Guernsey Formation at the base of the sequence is referred to the Fremont Canyon Formation (new) and is correlated with the Parting Formation (Upper Devonian) of central Colorado. The Fremont Canyon Sandstone is succeeded by terrigenous and dolomitic rocks belonging to the Englewood Formation, whose Late Devonian and Early Mississippian age is determined by conodonts. The boundary between the Devonian and Mississippian Systems is a disconformity within the Englewood Formation. The Englewood is conformably overlain by carbonate rocks assigned to the Madison Limestone, which ranges in age from Early Mississippian (Kinderhookian) to Late Mississippian (early Meramecian), based on conodont, foraminifer, and coral data. The Madison Limestone includes, in ascending order, the Big Goose, Little Tongue, and Bull Ridge Members, which were described previously from outcrops in north-central Wyoming. The term "Madison Limestone" is extended into the Hartville uplift area, replacing "Guernsey Formation," which is an outmoded name. The Madison Limestone is overlain disconformably by the Casper Formation or by the Hartville Formation of Pennsylvanian and Permian age. Only the lower 100 feet (30.5 meters) of the Casper or Hartville was examined in this study. The basal unit of the Casper and Hartville consists of quartzarenite assigned to the Darwin Sandstone Member, which is a member of the Amsden Formation in areas west and north of the study area. The Paleozoic sequence from the base of the Fremont Canyon Sandstone into the lower part of the Casper Formation has a maximum thickness of about 625 feet (191 meters).

The area studied was characterized by deposition of quartzarenite (Fremont Canyon Sandstone) derived from the Transcontinental Arch in marginal-marine and peritidal environments during Late Devonian time. These environments gave way to terrigenous and carbonate deposition on intertidal flats and beaches (Englewood Formation) during latest Devonian and earliest Mississippian (early Kinderhookian) time. The Devonian-Mississippian boundary, however, was marked by an interruption in sedimentation. Later Kinderhookian to middle Osagean time was characterized by carbonate deposition in intertidal mud flats and lagoons (Big Goose Member of Madison Limestone). Evaporites were deposited in restricted lagoons (lower solution zone of Little Tongue Member of Madison Limestone) at the end of middle Osagean time or the beginning of the late Osagean, followed by normal-marine offshore carbonate deposition (upper part of Little Tongue Member of Madison Limestone) in the late Osagean. Another episode of restricted lagoonal deposition (upper solution zone of Bull Ridge Member of Madison Limestone) occurred at the end of the Osagean or the beginning of the Meramecian. This was followed in the early Meramecian by a brief return to normal-marine carbonate deposition (upper part of Bull Ridge Member of Madison Limestone), which was succeeded by further shallowing that culminated in uplift, emergence, and karst development during Late Mississippian (Meramecian and Chesterian) time. The sea returned to the area in Pennsylvanian time and reworked sand deposits derived from the Transcontinental Arch (Darwin Sandstone Member of Casper and Hartville Formations), forming beaches and offshore bars. During later Pennsylvanian time (Desmoinesian and later), the area was characterized by alternations of normal-marine offshore carbonate deposition and intertidal or supratidal carbonate-flat deposition, interrupted by pulses of quartz sand deposition in beaches and offshore bars.

INTRODUCTION

Exposures of Paleozoic rocks in the Laramie Range and Hartville uplift of southeast Wyoming occupy a significant geographic position in the regional stratigraphy of the Paleozoic Era in the northern Cordilleran region. This area was located close to the Transcontinental Arch during much of Paleozoic time and may have formed an emergent prong of the arch during part of that time (Sando, 1976b, fig. 1). Consequently, the Paleozoic sequence is composed largely of sedimentary rocks deposited close to ancient shorelines.

The original purposes of this study were to determine the lithology and paleontology of the Mississippian in the northern Laramie Range and adjacent areas (figs. 1, 2) and to correlate this sequence with Mississippian rocks studied previously in other parts of Wyoming. Because rocks at the base of the sequence originally referred to the Cambrian were later assigned tentatively to the Mississippian by some authors

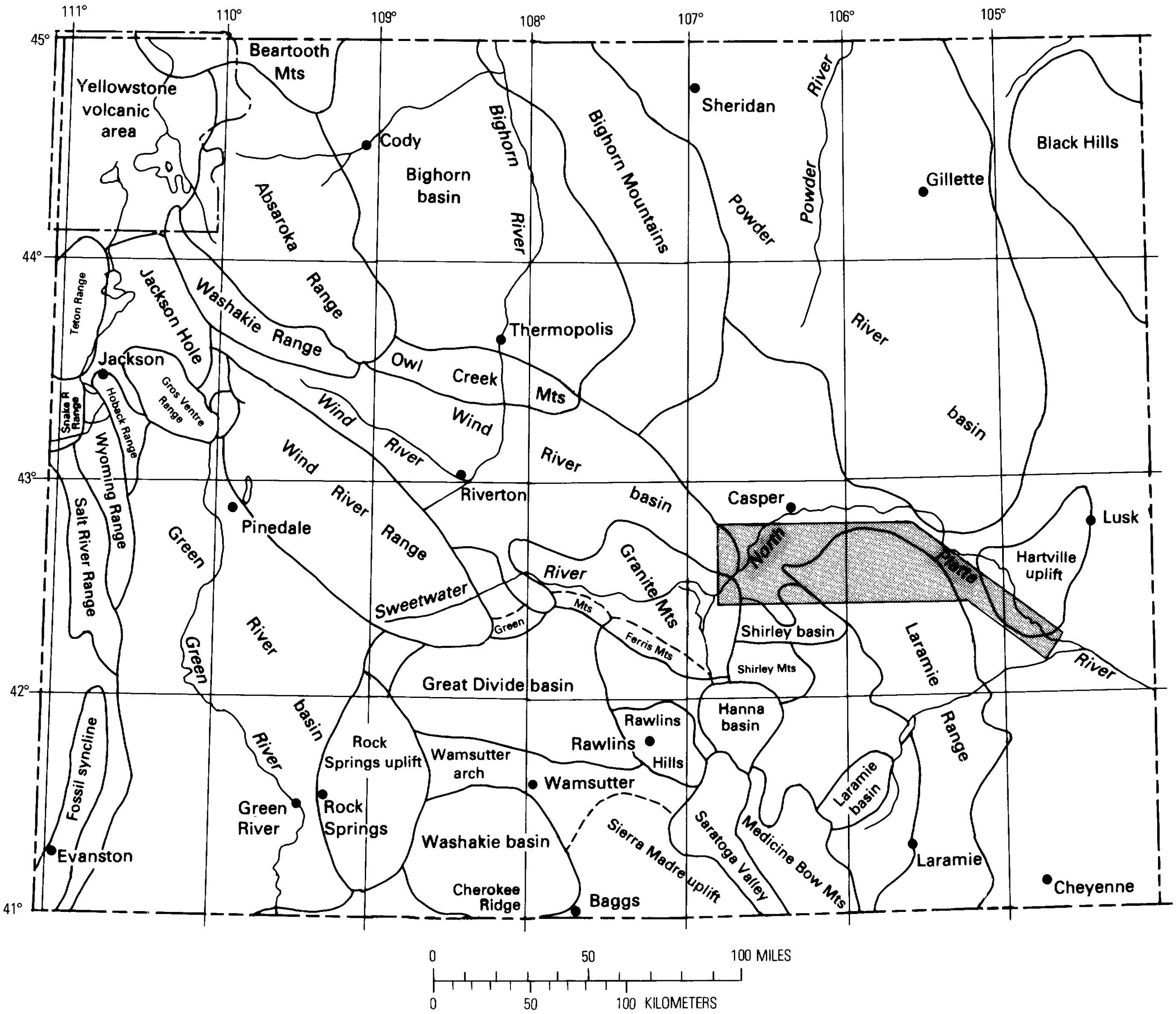


FIGURE 1.—Map of Wyoming showing present structural features (from Welder and McGreevy, 1966) and the area studied (shaded).

(Thomas, 1951; Maughan, 1963), the present study began at the top of the Precambrian. The study also included the lower part of the Casper and Hartville Formations (Pennsylvanian) in order to determine relationships with the Amsden Formation in areas to the north and west of the study area.

E.K. Maughan introduced the senior author to some of the localities studied during fieldwork in 1974. Most of the field studies were made by Sando, assisted by K.R. Moore. Conodont determinations are by Sandberg, foraminifer determinations are by B.L. Mamet of the Université de Montréal, and other faunal determinations are by Sando. Harrison Sheng of the Department of Paleobiology of the Smithsonian Institution advised Sando in heavy mineral identifications. Comments by J.T. Dutro, J.D. Love, J.E. Repetski, M.W. Reynolds, and G.L. Snyder significantly improved the original manuscript.

SUBJACENT ROCKS

The Paleozoic rocks of the northern Laramie Range rest unconformably on Precambrian granite that was not investigated thoroughly in this study. Where observed in the field, the granite is pink-weathering, poorly foliated, and composed mainly of pink orthoclase feldspar, biotite, and quartz in approximately equal

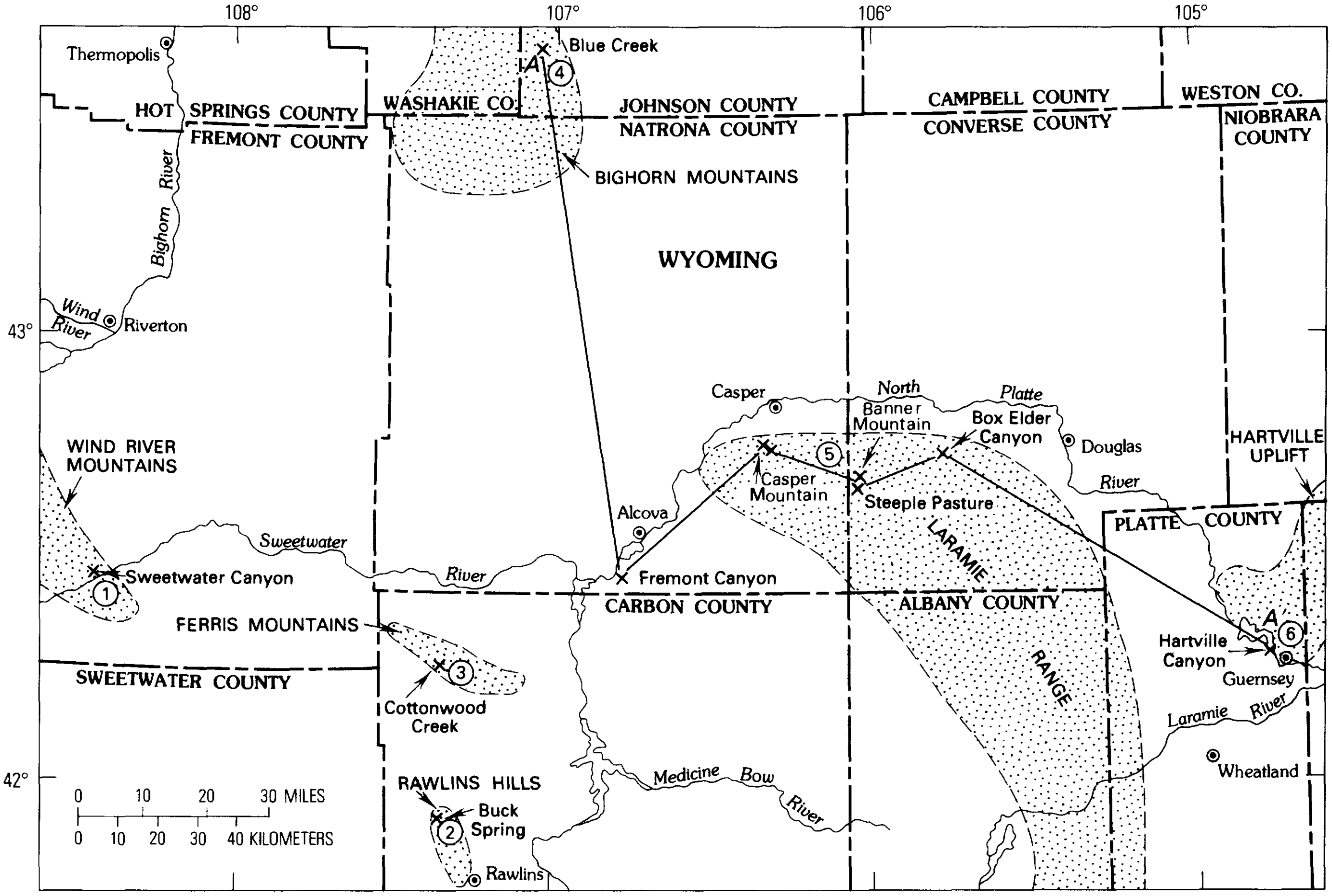


FIGURE 2.—Map of a part of southeast Wyoming showing location of stratigraphic sections discussed in this report. *A–A′* marks cross section illustrated in plate 1. Circled numbers mark locations of stratigraphic sections shown in figure 5.

grains 2–5 mm in diameter. Pegmatite veins are common. The rock commonly forms massive, rounded outcrops. A red weathered zone 1–5 ft (0.3–1.5 m) thick, probably a regolith, is present between the granite and overlying sedimentary rocks at Casper Mountain Road B (see section description).

In the Hartville uplift, the Paleozoic rocks rest unconformably on Precambrian dolomite, schist, and amphibolite, as well as on granite (G.F. Snyder, written commun., 1985). These rocks are assigned to the Late Archean Whalen Group (Smith, 1903; Hofmann and Snyder, 1985).

FREMONT CANYON SANDSTONE

DESCRIPTION

Cliff-forming quartz sandstone and quartzite that overlie the Precambrian granite and underlie the Englewood Formation (pl. 1) are referred to the newly named Fremont Canyon Sandstone (see discussion below regarding nomenclature of this unit). The type section of this formation is at Fremont Canyon at the south end of Alcova Reservoir (see section description).

The basal contact of the Fremont Canyon Sandstone is an unconformity having a local relief of at least 1–2 ft (0.3–0.6 m) in the Laramie Range and as much as 10 ft (3 m) in the Hartville uplift (G.F. Snyder, written commun., 1985). The top of the formation is sharp and without noticeable relief. The formation ranges in thickness from 6 ft (1.8 m) at Hartville Canyon to 186 ft (56.7 m) at Fremont Canyon, but at Steeple Pasture it is absent.

The main body of the Fremont Canyon is classified petrographically as quartzarenite as used by Pettijohn, Potter, and Siever (1972). The rock consists of 95 percent or more of very angular to well-rounded, moderately well sorted quartz grains of predominantly very fine to coarse size. Feldspars, including orthoclase, plagioclase, and microcline, constitute 1 percent or less of the rock. The heavy mineral fraction constitutes 1 percent or less of the rock and consists predominantly of rounded to well-rounded black tourmaline. Other detrital minerals, in order of approximate decreasing abundance, are muscovite; pink, amber, yellow, and green tourmaline; zircon; pyroxene; magnetite; biotite; metamorphic and igneous rock fragments; and various metallic oxide and sulfide minerals. The cement consists predominantly of silica, but hematite and limonite are common as cementing materials.

The quartzarenite is friable to indurated and weathers white, gray, tan, orange, red, and pink. Current ripples and crossbedding in sets 0.1–2 ft (0.03–0.6 m) thick characterize most of the bedding. A distinctive feature is thin interbeds and partings of dessication-cracked, micaceous, silty, sandy clay shale weathering mostly grayish green. The detrital mineral fraction in the shale is essentially the same as that in the quartzarenite.

In the Laramie Range, the lower 3 to 20 ft (0.9–6.1 m) of the formation consists of subarkosic quartz sandstone and sandy conglomerate containing granite pebbles near the base. In the Hartville uplift, the basal beds commonly consist of angular fragments of quartz derived from underlying Precambrian dolomite and cemented by silica and hematite (G.F. Snyder, written commun., 1985). Clastic dikes of this material may extend downward into the Precambrian dolomite commonly tens of feet and locally a hundred feet.

The only fossils observed in the Fremont Canyon Sandstone are linear ichnofossils on bedding planes of shaly partings. Negative results were obtained from 123 samples from throughout the unit processed for conodonts and 12 samples processed for palynomorphs.

AGE AND CORRELATION

PREVIOUS STUDIES

The sandstone in the Laramie Range herein referred to the Fremont Canyon Sandstone was regarded as the Deadwood Formation of Late Cambrian and Early Ordovician age by most previous workers. However, Thomas (1951, p. 32) briefly described the stratigraphy of the Cambrian sandstones southwest of the study area and suggested that the Cambrian rocks pinch out eastward, just east of the Shirley Mountains, before reaching the Laramie Range. He (p. 34) also pointed out localities in the Laramie Range and vicinity where Mississippian fossils were found in or just above a sandstone that rested on the Precambrian granite.

Love, Henbest, and Denson (1953) correlated sandstone underlying the Guernsey Formation and overlying the Precambrian granite with the sandstone in the Laramie Range and assigned it questionably to the Cambrian.

Maughan (1963) compiled evidence for a Mississippian age for thin sandstone overlying Precambrian granite in the Laramie Range south of the study area and questioned the Cambrian age of the sandstone found in the northern Laramie Range and adjacent areas. He included the sandstone of the study area on his isopach map of the basal Mississippian sandstone.

PRESENT ANALYSIS

The nearest possible correlatives to the quartz sandstone at the base of the Paleozoic sequence in the area studied are the Deadwood Formation (Upper Cambrian and Lower Ordovician) of South Dakota, the Sawatch Quartzite (Upper Cambrian) of Colorado, the Harding Sandstone (Middle Ordovician) of Colorado, the Winnipeg Sandstone (Middle Ordovician) of North Dakota, the Lander Sandstone Member of the Bighorn Dolomite (Upper Ordovician) of western and northern Wyoming, and the Parting Formation (Upper Devonian) of Colorado (fig. 3). These are all partly or predominantly supermature, multicyclic quartzarenites distinguished from each other with difficulty in places where stratigraphic position and paleontology are unknown. Each of these sheet sands probably covered an area much larger than that indicated by their present distribution, which resulted from several periods of uplift and erosion prior to the present. In the absence of paleontologic data to determine the age of the sandstone of the study area, physical criteria were used to compare this sandstone to formations previously established in the northern Cordilleran region (table 1.)

The Deadwood Formation has been recognized in a large area that includes parts of western North and South Dakota and eastern Wyoming (fig. 3). Correlation with the Deadwood Formation fails chiefly because of the lack of glauconite in the sandstone of the study area. Pettijohn, Potter, and Siever (1972, p. 229) state that glauconitic sandstones are particularly common in the Cambrian. Thomas (1951, p. 34) noted that the upper part of the Deadwood is commonly glauconitic, and Carlson (1960, p. 33) also described the Deadwood as glauconitic. Thus, it would seem that glauconite is a reliable index to the Deadwood. Moreover, the Deadwood contains invertebrate fossils of Late Cambrian and Early Ordovician age (Meyerhoff and Lochman, 1934, 1935, 1936; Lochman and Duncan, 1950; Müller, 1956; Ross, 1957a; Carlson, 1960) and fish remains (Repetski, 1978), whereas no such fossils were found in the sandstone of the study area. The Deadwood Formation also lacks the dessication cracks and green, micaceous, shaly partings found in the sandstone of the study area. Carbonate interbeds are common in the Deadwood but absent in the unit studied.

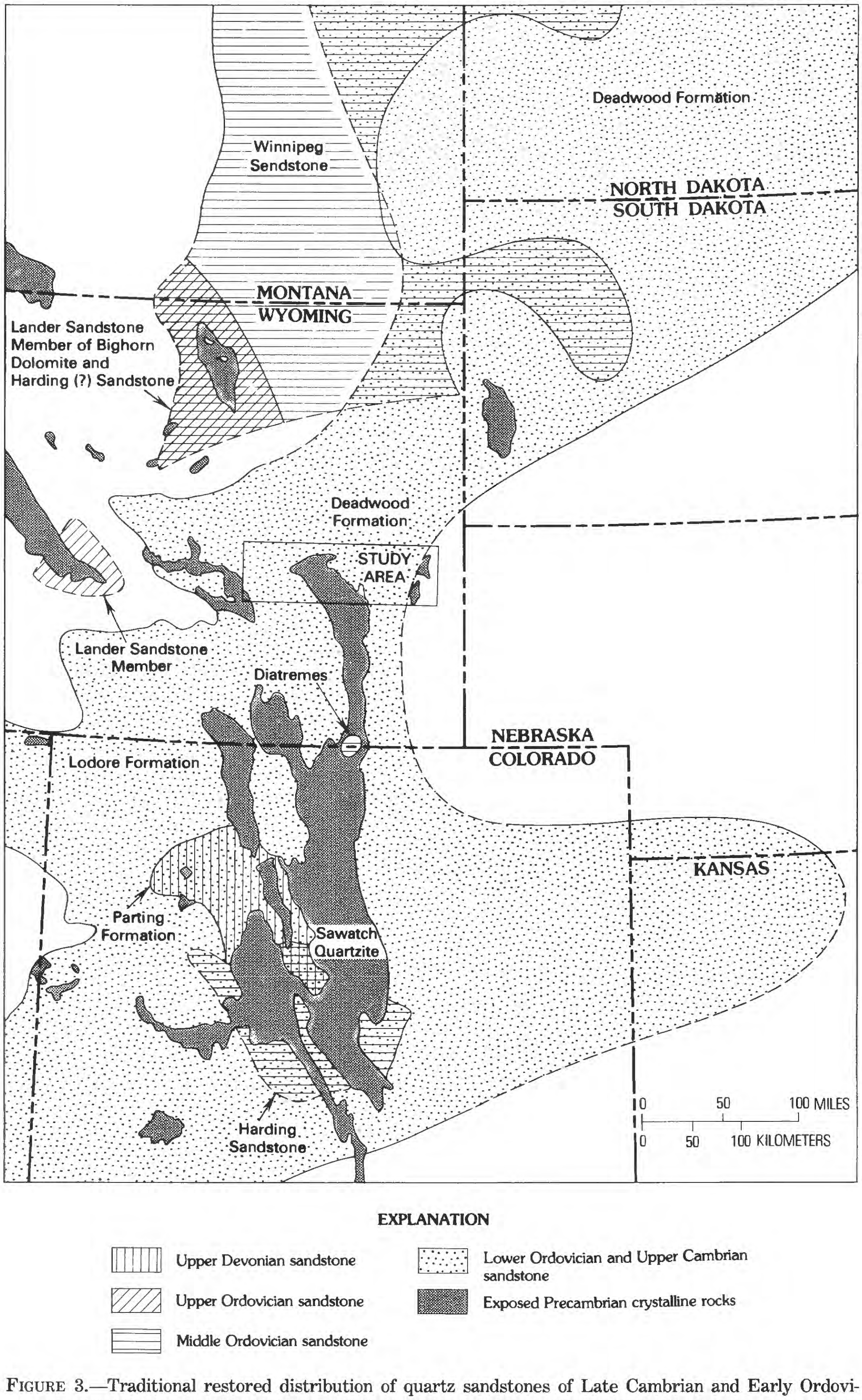


FIGURE 3.—Traditional restored distribution of quartz sandstones of Late Cambrian and Early Ordovician, Middle and Late Ordovician, and Late Devonian ages in the northern Cordilleran region. Data from Richards and Nieschmidt (1957), Ross (1957b), Lochman-Balk (1972), Foster (1972), and Baars (1972).

TABLE 1.—*Characteristics of Cambrian to Devonian quartz sandstones in the northern Cordilleran region*

[References: Deadwood (Thomas, 1949; Block, 1952; Chronic and others, 1969; Carlson, 1960); Harding (Tolgay, 1952; Chronic and others, 1969; J.D. Love, written commun., 1985); Winnipeg (Carlson, 1960); Parting (Campbell, 1970, 1972); Fremont Canyon (this paper)]

Characteristic	Deadwood Formation	Harding Sandstone	Winnipeg Formation	Parting Formation	Fremont Canyon Sandstone
Petrographic classification	?	Orthoquartzite	?	Orthoquartzite-subgraywacke	Quartzarenite
Mean grain size (approximate)	Medium-coarse sand	Very fine sand	Very fine–medium sand	Medium–coarse sand	Very fine–coarse sand
Roundness of sand grains	Well rounded	Well rounded	Rounded	?	Well rounded
Mature heavy mineral suite 1% of rock	?	X	?	X	X
Glauconite	X	-------------	---------------	----------------	------------
Phosphate grains	-------------	X	---------------	----------------	------------
Basal arkosic conglomerate, poorly sorted.	X	-------------	X	----------------	X
Crossbedding	X	X	---------------	X	X
Dessication cracks	-------------	?	---------------	----------------	X
Green, micaceous shale partings	-------------	X	---------------	X	X
Carbonate and (or) shale interbeds	X	X	X	X	------------
Marine invertebrates	X	X	X	----------------	------------
Fish plates	X	X	---------------	X	------------
Ichnofossils	X	X	---------------	X	X

The Harding Sandstone is known mainly from outcrops in central Colorado, but was also described from diatremes at the south end of the Laramie Range (Chronic and others, 1969) and from a few localities in the Bighorn Mountains (Kirk, 1930; Hose, 1955) (fig. 3). The Harding contains Middle Ordovician conodonts (Sweet, 1955) and fish remains (Walcott, 1892; Ørvig, 1958; Chronic and others, 1969), which distinguish it from the barren sandstone of the study area. Phosphate grains, noted by Chronic and others (1969) in the Harding, are also absent from the unit studied. The Harding also contains thick shale interbeds not present in the study area.

The Lander Sandstone Member of the Bighorn Dolomite consists of light-greenish-gray and pinkish-gray sandstone containing shaly streaks, laminae, and nodules. It contains an Ordovician shelly fauna including orthocones, gastropods, and *Receptaculites*. Its open-marine origin is so obvious that its characteristics are not tabulated in table 1.

The Winnipeg Sandstone is recognized in the subsurface of eastern Montana, northeastern Wyoming, and western North and South Dakota and in outcrop in northeastern Wyoming (fig. 3). Like the Harding, the Winnipeg contains a diverse Middle Ordovician conodont fauna (e.g., Carlson, 1960; Sweet, 1982) and considerable amounts of shale, features absent in the sandstone of the study area. Moreover, the Winnipeg Sandstone does not have the crossbedding, dessication cracks, and green micaceous shale partings of the unit studied.

The Parting Formation occupies a relatively small area in central Colorado (fig. 3). It consists of a complex sequence of quartz sandstone, shale, and dolomite (Sandberg and Poole, 1977, fig. 15) but is almost entirely sandstone at some localities (Campbell, 1970). The sandstone includes predominantly medium- to very coarse-grained and conglomeratic orthoquartzite (quartzarenite), protoquartzite, feldspathic sandstone (subarkose), and subgraywacke (Campbell, 1972). The accessory mineral suite includes zircon, tourmaline, muscovite, biotite, and chert grains. Silica is the predominant cement. Interbedded shales are green, micaceous, and arenaceous. The sandstone is crossbedded. The Parting is dated by conodonts as Late Devonian (late Famennian) and contains the Upper *postera* and Lower *expansa* Zones (Sandberg and Dreesen, 1984, fig. 5).

Close petrographic similarity of the sandstone of the study area with the Parting Formation (table 1) and its similar stratigraphic position leads us to the conclusion that the unit studied is probably correlative with and approximately the same age as the Parting. The sandstone in Wyoming cannot be physically traced into the area of the Parting in Colorado, and the absence of diagnostic fossils in the study area precludes precise biostratigraphic correlation. For these reasons, the strata in Wyoming are given a new name.

The lack of an obvious discontinuity between the sandstone unit and the overlying Englewood Formation, which has been dated by conodonts as Late Devonian (Lower to Middle *expansa* Zone) and Early Mississippian in the study area, provides compelling circumstantial evidence for a Late Devonian age for the basal sandstone. Moreover, the upper part of the Parting of Colorado and the basal part of the Englewood of the study area contain conodonts that belong to the same conodont zone. Where the contact is well exposed (e.g., Casper Mountain Road, Banner Mountain, Box Elder Canyon), the plane of contact shows little or no relief and is marked mainly by a general reduction in size of siliceous grains from the Fremont Canyon to the overlying Englewood Formation (pl. 2). Sandstone beds in the Englewood are very similar in grain size, heavy mineral suite, and sedimentary structures to those in the Fremont Canyon Sandstone. Supporting evidence for the Devonian age of this sandstone is supplied by three paleomagnetic pole determinations made by S. Beske-Diehl (written commun., 1975) from samples collected in the Casper Mountain Road B section (see section descriptions). These determinations suggest a pole position closer to that of the Devonian than to Cambrian and Ordovician pole positions.

The areal extent of the Fremont Canyon Sandstone is not completely documented, but sandstone of similar lithology and stratigraphic position has been reported by Thomas (1951) in the Seminoe Mountains, Elk Mountain, and western Laramie Range; by Love, Henbest, and Denson (1953) in the Hartville area (we also recognize it there); by Love, Denson, and Botinelly (1949) in the Glendo area; by Lageson (1977) in the northern Medicine Bow Mountains; by Mytton (1954) in the study area; by Ritzma (1951) in the Washakie basin and the Sierra Madre; and by Maughan (1963) over much of the southeast Wyoming and parts of western Nebraska and northeast Colorado. The occurrence of Mississippian fossils in thin sandstone sequences at some localities in southern Wyoming suggests that some of these beds actually belong to the overlying Englewood Formation, which is not readily distinguishable lithologically from the Fremont Canyon where only a few feet of sandstone is present above the Precambrian. Figure 4 shows a revised interpretation of the distribution of Upper Devonian sandstone based on the present analysis and on relationships with older sandstones in the northern Cordilleran region. The present distribution of Upper Devonian sandstone, like that of older sandstones, is probably only an erosional remnant of a formerly larger areal extent.

ORIGIN

According to Campbell (1970), the sandstone of the Parting Formation in central Colorado represents nearshore marine environments and was derived mostly from the "Front Range highland," an area of moderate relief composed of metamorphic, igneous, and some older Paleozoic sedimentary rocks. Conodonts in the Parting are assigned to the clydagnathid biofacies, which is within the most nearshore of the Devonian facies belts and indicates restricted marine to peritidal environments (Sandberg and Dreesen, 1984). A similar origin is indicated for the Fremont Canyon Sandstone in the area studied. The broad distribution of this sandstone (fig. 4) suggests derivation from the Transcontinental Arch to the east of the area studied.

ENGLEWOOD FORMATION

DESCRIPTION

Poorly resistant terrigenous and dolomitic rocks that ordinarily overlie the Fremont Canyon Sandstone and underlie the Madison Limestone are referred to the Englewood Formation (pls. 1, 2). The basal contact with the Fremont Canyon Sandstone is sharp, without noticeable relief, and is placed at the base of the lowest red siltstone above the quartz sandstone of the Fremont Canyon. However, at Steeple Pasture (see section descriptions), the formation rests unconformably on Precambrian granite. The upper contact with the Big Goose Member of the Madison Limestone is sharp and without noticeable relief. The top of the Englewood is

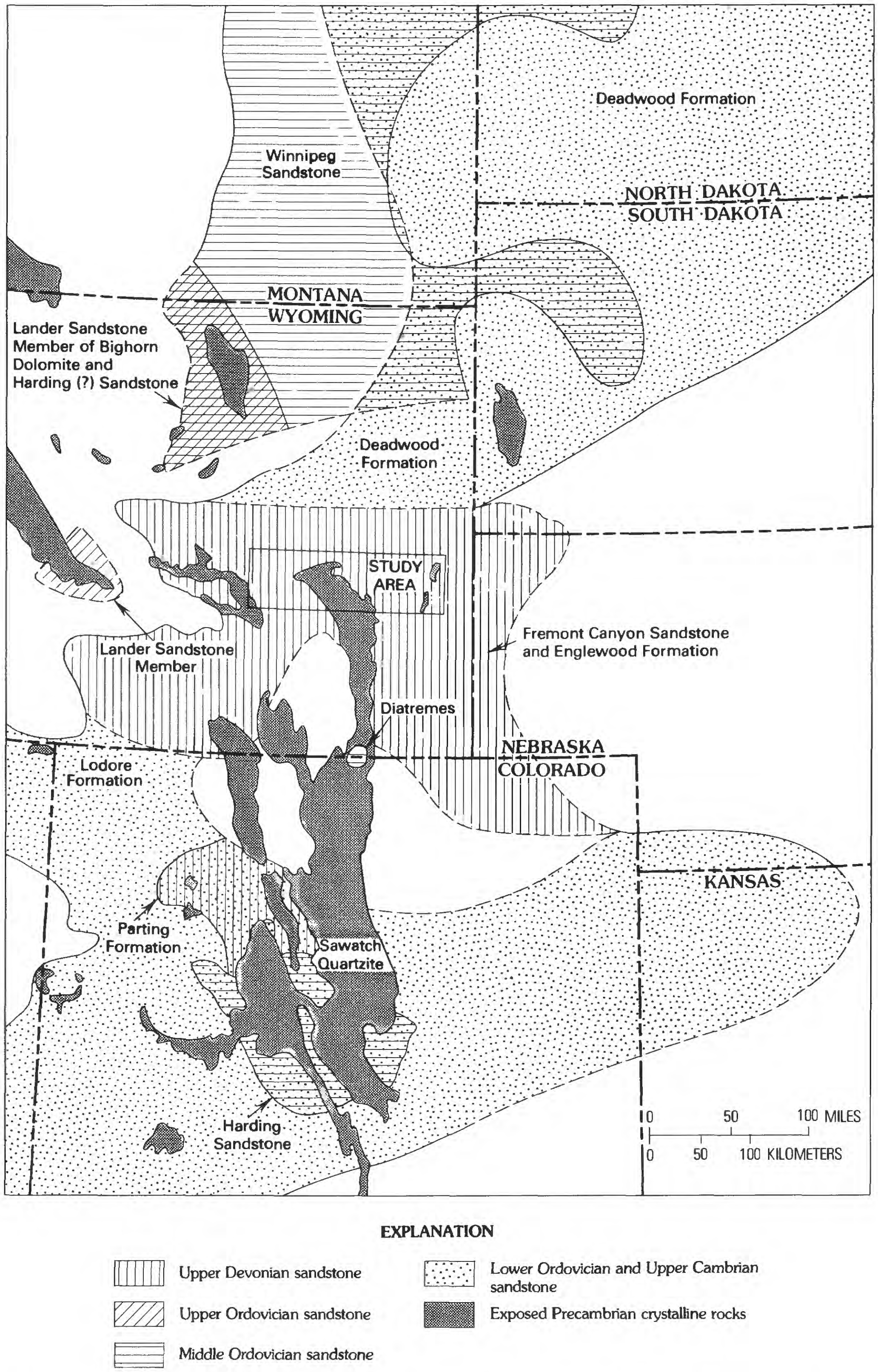


FIGURE 4.—Revised, partly restored distribution of quartz sandstones of Late Cambrian and Early Ordovician, Middle and Late Ordovician, and Late Devonian ages in the northern Cordilleran region based on revised interpretation of sandstones in southeast Wyoming. Maughan's (1963) data were used in areas of southeast Wyoming not studied by the authors.

TABLE 2.—*Diagnostic Devonian and Mississippian conodonts from the Englewood Formation*

[See pl. 2 for positions in measured sections. Numbers are numbers of specimens. X denotes presence only]

Taxon and age	Locality and USGS Upper Paleozoic catalog number (Sandberg collection number)								
	Fremont Canyon		Casper Mountain		Banner Mountain				Box Elder Canyon
	25976–PC	25975–PC	25879–PC	25878–PC	26008–PC	(BAH–3)	(BAH–2)	26006–PC (BAH–1)	26036–PC
Kinderhookian									
Pandorinellina n. sp.	-------	------	-------	-------	------	------	2	-------	------------
Patrognathus andersoni (*crenulata* Zone or younger)	-------	------	1	-------	X	------	-----	-------	------------
Polygnathus inornatus	-------	------	8	3	X	14	38	-------	------------
P. inornatus rostratus	1	------	-------	-------	------	------	-----	-------	------------
P. longiposticus	3	------	-------	-------	X	------	-----	-------	------------
Siphonodella sp.	-------	------	-------	-------	X	2	2	-------	------------
Late Devonian									
Lower or Middle *expansa* Zone	-------	------	-------	-------	------	------	-----	-------	------------
Icriodus costatus?	-------	------	-------	-------	------	------	-----	1	------------
Polygnathus communis carina	-------	------	-------	-------	------	------	X	4	------------
P. experplexus	-------	------	-------	-------	------	------	-----	-------	1
P. semicostatus	-------	------	-------	-------	------	------	-----	1	------------
P. sp.	-------	------	-------	-------	------	------	-----	-------	1
Lower *expansa* Zone									
Clydagnathus ormistoni	-------	8	-------	-------	------	------	-----	-------	------------
Polygnathus semicostatus	-------	1	-------	-------	------	------	-----	-------	------------
Scaphignathus sp.	-------	1	-------	-------	------	------	-----	-------	------------

placed at the top of dolomitic or terrigenous rocks beneath thin-bedded cherty dolomicrite of the Big Goose Member of the Madison (pl. 2). The formation ranges in thickness from 12.7 ft (3.8 m) at Steeple Pasture to 44.8 ft (13.8 m) at Banner Mountain. The Englewood is weakly resistant and ordinarily covered or poorly exposed; the best exposure is in road cuts at the Casper Mountain Road B section.

The Englewood Formation consists predominantly of quartz siltstone, very fine- to fine-grained quartz sandstone, and silty and sandy dolomicrite that weather red, brown, and orange in platy beds 0.1–0.5 ft (0.03–0.15 m) thick and thin interbeds and partings of green-weathering silty and sandy clay shale. The formation also contains beds of medium-grained quartz sandstone that in a few places are conglomeratic and crossbedded, 0.3–1 ft (0.09–0.3 m) thick, and that weather white, brown, and red. Dessication cracks and salt casts also occur rarely.

The sandstone beds are poorly to well-sorted quartzarenites composed of as much as about 95 percent or more very angular to subrounded quartz grains and containing rare detrital grains of plagioclase, orthoclase, microcline, muscovite, tourmaline, and crystalline rock fragments. The cement is silica, calcite, dolomite, and limonite.

FOSSILS, AGE, AND CORRELATION

The Englewood Formation of the area studied is similar in lithology and age to the Englewood Formation of the Black Hills in South Dakota as described by Klapper and Furnish (1962) and by Sandberg (1963, p. C20). Sandberg and Mapel (1967, fig. 10) projected this formation into southeast Wyoming from its principal area of occurrence in the northeast. Beds of similar lithology, age, and stratigraphic position were included in the basal part of the Guernsey Formation in the Glendo and Hartville areas by Smith (1903), Love, Denson, and Botinelly (1949), and Love, Henbest, and Denson (1953).

Conodonts are the only identifiable fossils recovered from the Englewood Formation in the area studied. The conodont assemblages (table 2) are generally meager, of low diversity, and contain elements characteristic of shallow-water faunas. Assemblages of two ages can be recognized in the samples from the Englewood: Kinderhookian assemblages probably correlative with the *duplicata*, *sandbergi*, and Lower *crenulata* Zones (see Sandberg and others, 1978), and Late Devonian assemblages characteristic of the Lower or Middle *expansa* Zone (see Ziegler and Sandberg, 1984).

The top of the Englewood Formation is placed at the base of the lowest cherty, nonsandy dolomicrite in the Big Goose Member of the Madison (pl. 2). This contact is not exposed at Fremont Canyon, Casper Mountain TV Tower, and Box Elder Canyon. However, at Fremont Canyon, Casper Mountain Road B, Banner Mountain, and Steeple Pasture, the highest bed in the Englewood is noncherty, crinoidal, ordinarily sandy biomicrite that contains Kinderhookian conodonts. This bed overlies a disconformity between Kinderhookian and Upper Devonian rocks, except at Banner Mountain, where a 1.3-ft-thick (0.4-m-thick) bed of quartz sandstone occurs between the dolomite and the disconformity, and at Casper Mountain Road B, where a siltstone bed 1.5 ft (0.5 m) thick occurs between the dolomite and the disconformity. Thus, the uppermost part of the Englewood contains Mississippian strata equivalent to the upper tongue of the Cottonwood Canyon Member of the Madison Limestone of north-central Wyoming (see Sandberg and Klapper, 1967, and Sandberg and Mapel, 1967), and the lower part of the Englewood contains strata equivalent to the lower tongue of the Cottonwood Canyon Member.

The Englewood Formation probably has a much wider distribution, although erratic, in southern Wyoming than formerly recognized. An 8-ft (2.4-m) interval of red-weathering quartz siltstone, sandstone, and conglomerate previously included in the basal Madison at Buck Spring in the Rawlins Hills (Sando, 1967, fig. 3; 1979, fig. 3) is now recognized as Englewood Formation (fig. 5, locality 2). Likewise, beds of red-weathering sandstone and sandy limestone in the same stratigraphic position at Cottonwood Creek in the Ferris Mountains (Sando, 1979, fig. 3) are now also placed in the Englewood (fig. 5, locality 3). Conodont samples from the basal 1.5 ft (0.5 m) of the Englewood at Cottonwood Creek collected by M.W. Reynolds yielded large conodont faunas that belong to the *Patrognathus-Pandorinellina* biofacies of the Kinderhookian Lower *crenulata* Zone. Other possible occurrences of the formation are terrigenous rocks resting on the Precambrian granite from which Mississippian fossils were reported by Thomas (1951, p. 34) in the subsurface south of Rawlins, the Seminoe Mountains, and on the west flank of the Laramie Range. The Englewood Formation is probably also present at some of the localities summarized by Maughan (1963) in the Laramie Range and elsewhere in southeast Wyoming. The terrigenous and dolomitic interval included in the basal part of the Guernsey Formation in the Glendo area by Love, Denson, and Botinelly (1949) and in the Hartville uplift by Love, Henbest, and Denson (1953) certainly includes beds that we regard as belonging in the Englewood Formation, particularly that part of the interval from which Devonian fossils were recovered. The upper Famennian conodont *Polygnathus obliquicostatus* Ziegler (identified by B.R. Wardlaw) was recovered from this unit on the north side of Sparks Canyon in the Hartville uplift (G.F. Snyder, written commun., 1985, sample 2225). The Fremont Canyon Sandstone is also present at the base of the interval in much of the Glendo-Hartville area (see our Hartville Canyon section, fig. 5, locality 6, and section descriptions). Differentiation of these two Devonian terrigenous units is difficult where they are both thin, requiring lumping of the two formations in a single map unit in some areas (see geologic maps accompanying section descriptions).

ORIGIN

Similar mineralogy of the sandstone beds in the Englewood Formation and the Fremont Canyon Sandstone suggests similar sources for the detritus. These sandstones had a comparable peritidal origin, probably on beaches. Dessication cracks and salt casts in the siltstones of the Englewood Formation indicate an intertidal or supratidal flat environment.

MADISON LIMESTONE

DESCRIPTION AND DISCUSSION

Carbonate rocks that conformably overlie the Englewood Formation and that are disconformably overlain by the Casper and Hartville Formations are referred to the Madison Limestone (Peale, 1893). In the study area, the Madison is a formation that consists of three members, which are, in ascending order, the Big Goose Member (Sando, 1982; formerly cherty dolomite member of Sando, 1972), the Little Tongue Member (Sando, 1982; formerly cliffy limestone member of Sando, 1972), and the Bull Ridge Member (Sando, 1968). The type section for the lower two members is in the Bighorn Mountains, and the type section for the upper member is in the Wind River Mountains. All three members have been traced over a large area in north-central Wyoming and southern Montana, where they have been studied in the Beartooth Mountains (Sando, 1972), Absaroka Range (Sando, 1975), Washakie Range (Sando, 1967), Gros Ventre Range (Sando, 1977), Wind River Range (Sando, 1967, 1968), Owl Creek Mountains (Sando, 1967), and Bighorn Mountains (Sando, 1976a). Sando (1979) summarized the stratigraphy of the Madison Limestone in Wyoming and recognized the three members of the Madison in the northern Laramie Range.

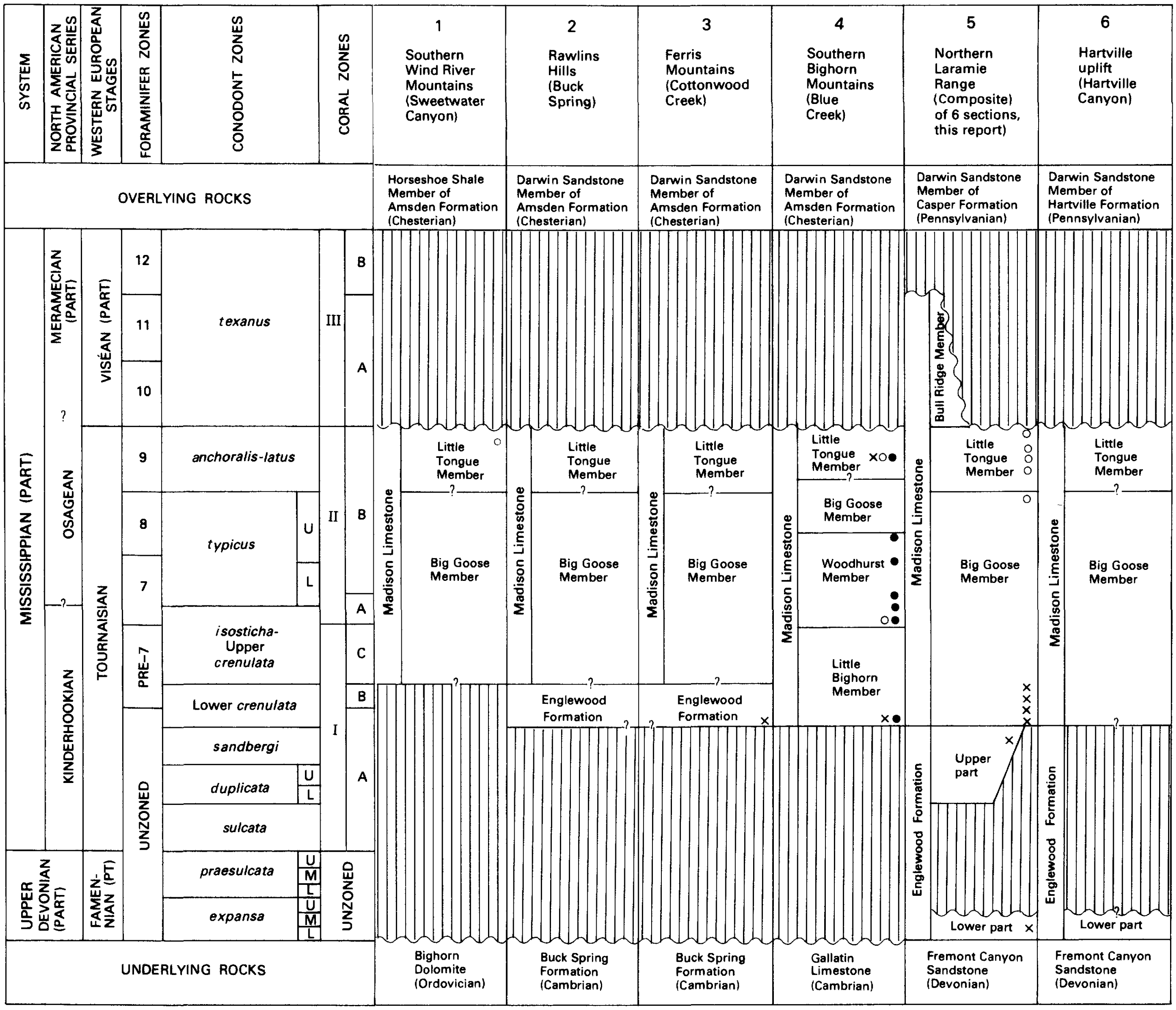


FIGURE 5.—Correlation of Upper Devonian and Mississippian sequences at selected localities in southern Wyoming (see fig. 2 for locations). Conodont zonation slightly modified from Sando, Sandberg, and Gutschick (1981), and Ziegler and Sandberg (1984). Foraminiferal zonation from Mamet in Sando, Mamet, and Dutro (1969). Coral zonation from Sando and Bamber (1985). Fossil collections indicative of corresponding zone at left; open circle, foraminifers; x, conodonts; closed circle, corals.

Throughout most of north-central Wyoming and southern Montana, the Madison includes three additional members beneath the Big Goose Member. These are, in ascending order, the Cottonwood Canyon Member (Sandberg and Klapper, 1967), the Little Bighorn Member (Sando, 1982; formerly lower dolomite member of Sando, 1972), and the Woodhurst Member (Weed, 1899). In the northern Laramie Range and vicinity, time equivalents of these lithologic units are present in the Englewood Formation and the Big Goose Member, whose base is much older than elsewhere in its area of occurrence.

On plate 1, sections in the study area are correlated to the Blue Creek section in the southern Bighorn Mountains to show the stratigraphic relationships of the three members of the Madison that are present in both areas and the time equivalence of the lithologically dissimilar lower part of the Madison. Madison sequences more generally similar in the lower part to that of the northern Laramie Range occur in the southern Wind River Mountains, Ferris Mountains, Rawlins Hills, and Hartville uplift (fig. 5).

STATUS OF GUERNSEY FORMATION

The name "Guernsey Formation" was introduced by Smith (1903, p. 2) to include strata between the Precambrian rocks of the Whalen Group and the Casper Formation (Pennsylvanian and Permian) in the Hartville quadrangle. Smith's nomenclature was perpetuated by Love, Denson, and Botinelly (1949) in their mapping of the Glendo area and by Love, Henbest, and Denson (1953) in the Hartville uplift. Although no type section was designated, Smith briefly described a stratigraphic section measured "near Fairbank" to show "the general character of the beds composing the formation." Our Hartville Canyon section (see pl. 1, fig. 5, and section descriptions) was measured at a location just north of the location shown for the town of Fairbank on Smith's (1903) geologic map and conforms to his description of the lithology of the Guernsey. We consider this section the type section of the Guernsey Formation.

The present investigation indicates clearly that the basal part of the Guernsey, as originally defined, includes beds now assigned elsewhere to the Fremont Canyon Sandstone and the Englewood Formation. The remainder of the type Guernsey is readily classified as Big Goose and Little Tongue Members of the Madison Limestone. Thus, the Guernsey is a superfluous name and is replaced in this report by the Madison Limestone, Englewood Formation, and Fremont Canyon Sandstone.

BIG GOOSE MEMBER

DESCRIPTION

The Big Goose Member is the oldest member of the Madison Limestone in the study area. It generally overlies the Englewood Formation conformably and is conformably overlain by the Little Tongue Member of the Madison, but it rests directly on Precambrian dolomite near Hell Gap in the Hartville uplift (G.F. Snyder, written commun., 1985). The thickness of the Big Goose Member ranges from 87 ft (26.6 m) in the Casper Mountain TV Tower section to 206 ft (63 m) at Steeple Pasture. The member thickens both eastward and westward from Casper Mountain (pl. 1).

The Big Goose Member consists predominantly of cherty, thin-bedded, fine-grained, commonly intensely fractured (but rarely brecciated) dolomite and dolomitic limestone that weather mostly yellowish gray. Petrographically, the dominant rock type is dolomicrite. Chert occurs as brown, gray, and white irregular nodules and stringers that parallel bedding and may constitute 5 to 40 percent of the dolomitic beds in the member. Faint lamination is a common feature in the dolomitic beds, and some of the laminations appear to represent stromatolites. Medium- to coarse-grained, crossbedded, bioclastic (molds and casts) dolomitic limestone and dolomite are present in the lower part of the member at some localities. Gray-weathering, mostly fine-grained, commonly cherty limestone in beds as much as 2 ft (0.6 m) thick is interbedded with the dolomitic beds in the upper part of the member at most localities. The limestone includes fossiliferous and unfossiliferous micrite (commonly laminated), biomicrite, and pelmicrite, and rare pelbiosparite, pelsparite, and intrabiosparite. Some of the limestone beds are partly recrystallized. Stromatolites are rare.

FOSSILS, AGE, AND CORRELATION

Fossils are rare in the Big Goose Member. Algal cysts (calcispheres), stromatolites, crinoid debris, brachiopods, bryozoans, and coral fragments are sporadically distributed throughout the member in the sections studied. *Vesiculophyllum*, a very common Mississippian coral, was found near the middle of the member at Steeple Pasture. Foraminifers and algae of Mamet Zone 8 (near top of zone), indicative of an Early Mississippian (middle Osagean) age, were collected at the top of the member in the Casper Mountain TV Tower section.

Extensive sampling for conodonts resulted in discovery of only five identifiable assemblages from the lower 20 ft (6.1 m) of the member at three localities (table 3, pl. 2). These assemblages are all of Early Mississippian (Kinderhookian) age and represent shallow-water biofacies not readily assignable to standard conodont zones. However, conodonts in USGS 26013–PC belong to the *Patrognathus-Pandorinellina* biofacies and indicate the Lower *crenulata* Zone or the *isosticha*-Upper *crenulata* Zone.

Foraminiferal and conodont data indicate an age range of Kinderhookian to middle Osagean for the Big Goose Member in the study area. This means that most of the member here is older than it is throughout most of north-central Wyoming (see Sando, 1979, fig. 3). In fact, the Big Goose here includes time equivalents of the upper part of the Cottonwood Canyon Member, the Little Bighorn Member, and the Woodhurst Member, which make up the lower part of the Madison Limestone in the Bighorn Mountains, Washakie Range, Absaroka Range, northern Wind River Range, and Gros

Ventre Range. The base of the Big Goose in the study area is also slightly older than it is in the Rawlins Hills, southern Wind River Range, and Ferris Mountains (fig. 5).

ORIGIN

The lithic facies of the Big Goose Member overwhelmingly indicate shallow-water, nearshore, marine environments. The main lithologies are fine-grained dolomite and limestone (dolomicrite and micrite) suggestive of deposition in relatively quiet waters, probably in lagoons or on intertidal mudflats. The presence of stromatolites and the rarity of marine fossils support these conclusions. Although no evaporitic rocks were found in the member, abundant autobrecciation (fracturing) of the dolomites suggests leaching of thin evaporite layers from an evaporitic carbonate sequence, which is consistent with postulated shallow lagoonal environments.

Chronostratigraphy indicates that the Big Goose Member in the northern Laramie Range represents the lower part of an extensive lithosome extending over much of southern Wyoming (fig. 5). This lithosome was marginal to an emergent or near-emergent prong of the Transcontinental Arch now represented by outcropping plutonic and metamorphic rocks of the core of the Laramie Range uplift in southeast Wyoming. The lower part of the Big Goose lithosome extended westward to at least the longitude of the southern Wind River Mountains, eastward for some unknown distance into Nebraska, and northward into the Wind River and Powder River basins. Northward, the lower part of the Big Goose lithosome interfingered with carbonate rocks deposited in slightly deeper waters of the Wyoming Shelf. Exposures of these seaward rocks in the lower part of the Madison Limestone in the Washakie Range, Owl Creek Mountains, and Bighorn Mountains are probably just north of the northern edge of the lower part of the Big Goose lithosome. The Wind River Mountains transect the boundary and provide exposures of it. Later in Osagean time, the Big Goose lithosome extended northward as a tongue into rocks deposited in deeper waters in southern Montana.

TABLE 3.—*Diagnostic Kinderhookian conodonts from the Big Goose Member of the Madison Limestone*

[See pl. 2 for positions in measured sections. Numbers are numbers of specimens]

Taxon	Locality and USGS Upper Paleozoic catalog number				
	Casper Mountain Road B			Banner Mountain	Steeple Pasture
	25883–PC	25882–PC	25880–PC	26009–PC	26013–PC
Bispathodus aculeatus	-------	1	-------	2	-------
B. stabilis	-------	------	-------	------	4
Hindeodus cf. *H. cristulus*	-------	------	-------	------	1
Pandorinellina plumula	-------	------	-------	------	5
P. n. sp.	-------	------	1	------	2
Patrognathus andersoni	1	5	-------	1	9
Polygnathus inornatus	-------	------	-------	1	3
Siphonodella advanced sp.	-------	------	-------	------	1

LITTLE TONGUE MEMBER

DESCRIPTION

The Little Tongue Member conformably overlies the Big Goose Member of the Madison. At Fremont Canyon and Casper Mountain, the Little Tongue Member is overlain conformably by the Bull Ridge Member of the Madison, but at Steeple Pasture and Box Elder Canyon, the Bull Ridge Member was removed by post-Madison, pre-Casper erosion and the Little Tongue is overlain unconformably by the Darwin Sandstone Member of the Casper Formation. At Hartville Canyon, the Little Tongue is overlain unconformably by the Darwin Sandstone Member of the Hartville Formation. The thickness of the Little Tongue Member ranges from 50 ft (15.3 m) in the Casper Mountain TV Tower section to 93.5 ft (28.6 m) at Fremont Canyon (pl. 1). The member thickens both eastward and westward from Casper Mountain.

The lower 13 to 30 ft (4–9.1 m) of the Little Tongue Member constitutes the lower solution zone, an informal stratigraphic unit that consists of carbonate solution breccia produced by leaching of evaporite beds (Sando, 1974). The breccia consists of poorly bedded, angular fragments of limestone, fine-grained dolomite, and chert as much as 1 ft (0.3 m), but mostly 0.3 ft (0.09 m) or less, in diameter in a matrix of fine-grained dolomite or calcareous rock flour, calcareous quartz siltstone, or fine-grained quartz sandstone. Bedded, platy, calcareous siltstone also occurs in the unit. The rocks weather mostly yellow, pink, and red. This unit is poorly exposed and forms a reentrant beneath a massive cliff at most localities.

The main body of the Little Tongue Member consists of gray-weathering, cliff-forming, cherty, medium-bedded limestone that overlies the lower solution zone. The limestone beds are fine to coarse grained and include micrite, pelmicrite, biomicrite, and intrabiosparite as well as grapestone biosparite, oosparite, and oobiosparite. Biogenic grains include fragments of crinoids, brachiopods, foraminifers, bryozoans, gastropods, corals, and ostracodes. Brown chert lenses, nodules, and stringers that parallel bedding make up 10–20 percent of the rock. The limestone beds are dolomitized at some localities.

Brecciation of the limestone owing to collapse of these beds into the underlying solution zone is evident at all localities. Rotated blocks of limestone as much as several feet in diameter are a common feature of the lower half the limestone unit, and undulant bedding is common in the upper part. Where the limestone is thin, the entire unit is brecciated.

FOSSILS, AGE, AND CORRELATION

Although no fossils were found in the lower solution zone of the Little Tongue Member, the limestone that makes up most of the member contains a moderately rich shelly benthonic fauna. Crinoidal debris is the most common organic material, but fragments of brachiopods, foraminifers, bryozoans, gastropods, corals, and ostracodes are also evident in thin sections of the limestone. Brachiopods of the *Unispirifer madisonensis* type are the most common fossils. The coral *Vesiculophyllum* was collected at the Casper Mountain TV Tower section. Mamet Zone 8 or 9 (late Osagean) foraminifers were found in the upper 32 ft (9.8 m) of the member at Fremont Canyon, and foraminifers probably representing Mamet Zone 9 (late Osagean) were found 2 ft (0.6 m) below the top of the member at Steeple Pasture.

A late Osagean age is indicated for the Little Tongue Member by late Osagean foraminifers found in the upper part and by the occurrence of middle Osagean foraminifers at the top of the underlying Big Goose Member (fig. 5). The base of the Little Tongue Member appears to be older in the study area than it is throughout most of north-central Wyoming (see Sando, 1979, fig. 3).

ORIGIN

The lower part of the Little Tongue Member (lower solution zone) is interpreted as a leached evaporite, terrigenous, and carbonate sequence (Sando, 1974). Deposition was probably in shallow, highly saline lagoons.

The lithic facies of the upper limestone sequence in the member are suggestive of shallow-subtidal offshore marine environments. Both micrite and sparite are present, indicating periods of relatively quiet-water deposition interspersed with times of turbulent-water deposition. The presence of shelly benthonic fossils throughout the limestone attests to predominantly normal marine conditions.

The Little Tongue Member is the most widespread of all the members of the Madison Limestone in Wyoming. It has been identified in all the places where Madison rocks are exposed throughout south-central, southeast, and north-central Wyoming and in extensions of the Wyoming Shelf into southern Montana. It may have completely covered the Laramie Range prong of the Transcontinental Arch prior to late uplift and erosion.

BULL RIDGE MEMBER

DESCRIPTION

The Bull Ridge Member is the youngest member of the Madison in the area studied. It conformably overlies the Little Tongue Member and is overlain unconformably by the Darwin Sandstone Member of the Casper Formation (pl. 1). The Bull Ridge Member is present only in the western part of the study area, where it was observed at Fremont Canyon and Casper Mountain. It was removed by post-Madison, pre-Casper erosion at Steeple Pasture and Box Elder Canyon. Where present, the Bull Ridge ranges from 5 ft (1.5 m) to 51.5 ft (15.8 m) thick.

The lower 3 to 39 ft (0.9–11.9 m) of the Bull Ridge Member in the study area consists predominantly of yellow- and red-weathering, platy, calcareous quartz siltstone or very fine-grained to fine-grained quartz sandstone that contains thin interbeds of brecciated fine-grained limestone and dolomite at some localities. Cherty, fine-grained dolomitic limestone breccia occurs at the base of the member in the Casper Mountain Road section. This unit is the upper solution zone of north-central Wyoming (Sando, 1974). Like the lower solution zone, this unit is thought to represent a leached evaporite-terrigenous-carbonate sequence.

The remaining upper part of the Bull Ridge Member consists mainly of gray-weathering fine-grained limestone in beds 0.1 to 1 ft (0.03 to 0.3 m) thick. At Casper Mountain, a thin unit of platy quartz siltstone and fine-grained sandstone occurs near the top of the member, and the member is capped by a thin bed of irregularly laminated, probably stromatolitic limestone. The main part of the limestone is composed of micrite, pelmicrite, and biomicrite. At Fremont Canyon, post-Madison, pre-Casper erosion removed all of the limestone unit and left only 5 ft (1.5 m) of the upper solution zone at the top of the Madison beneath the Darwin Sandstone Member.

FOSSILS, AGE, AND CORRELATION

No fossils were found in the upper solution zone. The limestone above the upper solution zone contains pelmatozoan debris, ostracodes, brachiopods, and corals. *Syringopora* sp., *Vesiculophyllum* sp., and *Lophophyllum*? sp. were identified in the unit at Casper Mountain.

In north-central Wyoming, the Bull Ridge Member contains a distinctive early Meramecian fauna that includes phaceloid lithostrotionoid corals, foraminifers of Mamet Zones 10–12, and conodonts of the *texanus* Zone. Although these critical fossils were not found in the study area, the corals that were found are similar to those associated with diagnostic fossils elsewhere. In the absence of contrary evidence, we assume that the Bull Ridge Member is the same age as it is in north-central Wyoming.

ORIGIN

The rocks of the Bull Ridge Member record a depositional history similar to that of the underlying Little Tongue Member. Deposition of the Bull Ridge began with a period of restricted terrigenous-carbonate-evaporite sedimentation in shallow lagoons followed by deposition of carbonates in freely circulating marine waters in offshore environments. The occurrence of probable stromatolites at the top of the member marked the return of intertidal-flat conditions similar to those represented in the Big Goose Member.

The former areal extent of the Bull Ridge Member is difficult to determine. Its present distribution is erratic throughout north-central and southern Wyoming, owing to the influence of post-Madison, pre-Amsden uplift and erosion. The discovery of remnants of the member in the northern Laramie Range was not expected because of its absence from the southern Wind River Mountains, Granite Mountains, western Owl Creek Mountains, and southern Bighorn Mountains (see Sando, Gordon, and Dutro, 1975, p. A17, pl. 2). Occurrences of the Bull Ridge in the study area suggests that the member formerly extended across the Laramie Range prong of the Transcontinental Arch. These occurrences also suggest that parts of the northern Laramie Range were sheltered from erosion prior to deposition of the Casper Formation.

POST-MADISON, PRE-CASPER SOLUTION FEATURES

Widespread solution features related to emergence and karst development prior to deposition of the Darwin Sandstone Member have been cataloged and described in the Madison Limestone throughout north-central Wyoming (Sando, 1974; Sando, Gordon, and Dutro, 1975). These features include solution zones, sinkholes, joints, and caves in the Bull Ridge and Little Tongue Members. Henbest (1958) described and illustrated the unconformity and sinkholes at the top of the Madison on the west side of the North Platte River just northwest of our Hartville Canyon section. The occurrence in the solution cavities of sandstone continuous with the main body of the overlying Darwin Sandstone Member is important evidence for the postulated solution history and distinguishes these features from later superimposed solution features.

Definite sinkholes were not observed in the Madison of the Laramie Range, although a feature interpreted as a channel in the top of the Madison at Fremont Canyon may actually be a sinkhole (see description of Darwin Sandstone Member of Casper Formation). Sandstone-filled joints and other cavities are common features. Vertical and horizontal joints filled with sandstone were observed in the upper 12.5 to 15 ft (3.8–4.6 m) of the Bull Ridge Member at Casper Mountain and in the upper 16 ft (4.9 m) of the Little Tongue Member at Box Elder Canyon. Sandstone occurs as matrix in collapse breccia in the Little Tongue Member 60 to 90.5 ft (18.3–27.6 m) below the top of the Madison at Fremont Canyon, 0 to 35 ft (0–10.7 m) below the top of the Madison at Steeple Pasture, and 16 to 57 ft (4.9–17.4 m) below the top of the Madison at Box Elder Canyon. At Box Elder Canyon, sandstone fills irregular cavities within the lower solution zone 57 to 85 ft (17.4–25.9 m) below the top of the Madison. These features indicate the same solution history for the Madison of the study area as previously described for the Madison of north-central Wyoming (Sando, 1974).

The youngest beds of the Madison in southeast Wyoming are probably of Late Mississippian (early Meramecian) age. The basal Darwin Sandstone Member of the Casper and Hartville Formations is of Pennsylvanian age. Therefore, uplift, erosion, and karst development began in the Meramecian and extended into Pennsylvanian time. Thus, the Madison Limestone in the study area was subjected to a longer period of emergency than it was in the Bighorn Mountains to the north, where transgression of the Darwin sea began in middle Chesterian time (Sando, Gordon, and Dutro, 1975, p. A18).

CASPER AND HARTVILLE FORMATIONS

Interbedded quartz sandstone, limestone, and dolomitic limestone that unconformably overlie the

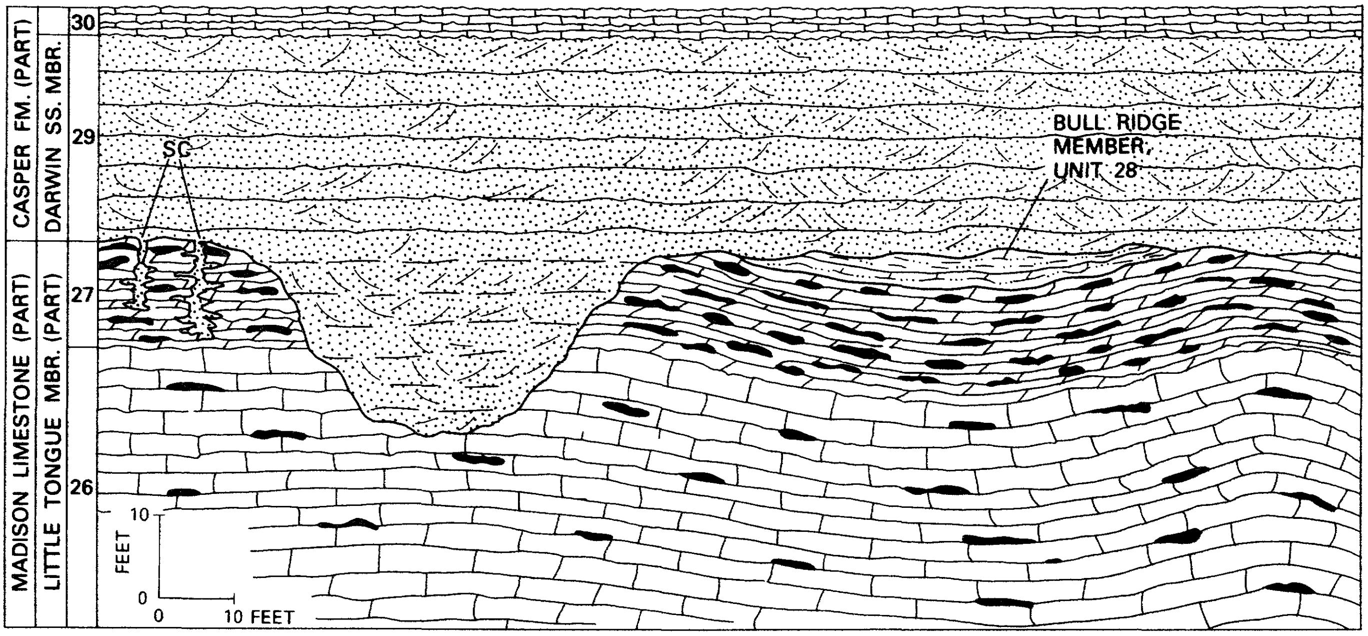


FIGURE 6.—Interpretive field sketch of geologic relationships at contact between Madison Limestone and Casper Formation at Fremont Canyon section. Numbers refer to unit numbers in measured section description. SC, sandstone filling solution cavities.

Madison Limestone in the Laramie Range are referred to the Casper Formation (Darton, 1908), and correlative beds in the Hartville uplift are included in the Hartville Formation (Smith, 1903). Because the principal focus of this study was the pre-Pennsylvanian part of the Paleozoic sequence, only the lower parts of these formations were studied.

A persistent basal sandstone member of the Casper and Hartville in the study area is referred to the Darwin Sandstone Member (Blackwelder, 1918), which is extended into the study area from central Wyoming, where the Darwin is a member of the Amsden Formation (see Sando, Gordon, and Dutro, 1975). This usage of the Darwin differs significantly from that of Mallory (1967, 1975), who regarded the basal sandstone of the Casper Formation as a discrete unit separated geographically from the Darwin.

DARWIN SANDSTONE MEMBER

DESCRIPTION

The Darwin Sandstone Member is the oldest unit of the Casper and Hartville Formations in the study area. It overlies the Madison Limestone unconformably and is conformably overlain by undifferentiated interbedded sandstone and carbonate beds in the lower part of the Casper or Hartville (pl. 1). The thickness of the Darwin ranges from 6 ft (1.8 m) in the Casper Mountain TV Tower section to 60 ft (18.3 m) at Box Elder Canyon. The member thickens both eastward and westward from Casper Mountain.

The contact between the Madison and the overlying Darwin Sandstone Member of the Casper and Hartville Formations in the study area is an irregular surface having a local relief of as much as 15 ft (4.6 m). An excellent exposure of the unconformity can be seen at Fremont Canyon, where the Darwin rests on a remnant of the upper solution zone of the Bull Ridge Member and on the upper part of the underlying Little Tongue Member (fig. 6). Maximum relief in the study area is estimated to be at least 52.5 ft (15.9 m), on the basis of preserved thickness of the Bull Ridge Member at Casper Mountain compared to the absence of this member at Steeple Pasture and Box Elder Canyon.

The Darwin Sandstone Member consists predominantly of fine-grained, calcareous, generally crossbedded quartz sandstone that weathers white, gray, yellow, orange, and red. The beds range from 0.3 to 4 ft (0.09–1.2 m) in thickness. Current ripples were observed at the top of the member at Box Elder Canyon.

Petrographic samples from the Darwin are exclusively quartzarenite as used by Pettijohn, Potter, and Siever (1972). Roundness of the quartz grains ranges from very angular to rounded. Sorting is fair at all localities except Box Elder Canyon, where the sandstone is well sorted. The most common accessory mineral is feldspar, which constitutes 1 percent or less of the rock at all localities. Tourmaline and zircon are present at Casper Mountain but account for less than 1 percent of the rock. About 5 percent chert grains are present at Fremont Canyon. Heavy mineral residues are very low and consist of secondary hematite and limonite and rare magnetite. All samples are characterized by carbonate cement, predominantly calcite.

FOSSILS, AGE, AND CORRELATION

The lower 3.5 ft (1.1 m) of the Darwin in the Casper Mountain Road section contains molds and casts of large crinoid columnals and gastropods of indeterminate age. A well-rounded grain, barely recognizable as a fragment of the conodont *Idiognathoides* sp., was recovered from the upper 1 ft (0.3 m) of the Darwin, 7.9 ft (2.4 m) above the base of the member, at the same locality (USGS 25904–PC) (pl. 1). *Idiognathoides* is indicative of a Pennsylvanian age.

Fossils have not been found in the Darwin in other areas where the unit has been studied. Sando, Gordon, and Dutro (1975, p. A23) regarded the Darwin as a time-trangressive facies that ranges in age from Meramecian to Chesterian in western and central Wyoming and into the Pennsylvanian in eastern Wyoming, based on the ages of fossils collected above and below the sandstone. The discovery of Pennsylvanian conodonts in the Darwin at Casper Mountain confirms the age predictable for the Darwin in this area using the transgressive facies model. The occurrence of Desmoinesian or younger fossils in the beds above the Darwin indicates a possible age range of Morrowan to Desmoinesian for the Darwin in this area.

ORIGIN

Sando, Gordon, and Dutro (1975, p. A23) postulated deposition of the Darwin Sandstone Member of the Amsden Formation in beaches and offshore bars adjacent to an eastward-transgressing shoreline following drowning of a fluvial system associated with post-Madison karst development. The Darwin in the study area is regarded as an eastward extension of this transgressive nearshore facies.

POST-DARWIN BEDS

DESCRIPTION

Beds belonging to the Casper and Hartville Formations were examined only up to a stratigraphic level about 100 ft (30.5 m) above the base of the formation in the study area (pl. 1). These beds conformably overlie the Darwin Sandstone Member.

The post-Darwin beds consist of interbedded quartz sandstone, limestone, dolomite, and dolomitic limestone. Carbonate beds make up about 60 to 70 percent of the sequence. Limestone beds in the sequence are predominantly fine grained; dolomitic beds are medium crystalline. The limestone facies include micrite, biomicrite, pelmicrite, and rare pelsparite. Stromatolites are common. Beds are 2 ft (0.6 m) or less thick, and bedding is mostly irregular to nodular. The dolomitic beds are commonly sandy. Limestones weather mostly medium light gray, whereas dolomitic beds weather mostly yellowish gray.

The quartz sandstone is predominantly fine grained and in beds 0.1 to 2 ft (0.03–0.6 m) thick that weather white, gray, yellow, and red and are commonly crossbedded. Heavy minerals account for less than 1 percent of the rock and include secondary limonite and detrital tourmaline and magnetite.

FOSSILS, AGE, AND CORRELATION

Undetermined brachiopods, gastropods, ostracodes, and crinoidal debris are common constituents of the limestones. Foraminifers of Mamet Zone 25 or younger (Desmoinesian or younger) were found between about 25 and 35 ft (7.6 and 10.7 m) above the base of the Casper Formation at Casper Mountain Road Section B and Steeple Pasture (pl. 1). Well-rounded grains barely recognizable as conodonts belonging to the genus *Idiognathodus* (Pennsylvanian) were found 25.9 (7.9 m) above the base of the Casper at Casper Mountain (pl. 1). A large, well-preserved conodont fauna (sample BAH–4, USGS 26026–PC), including *Idiognathodus sinuosis* and *Hindeodus minutus*, was found 16 ft (4.9 m) above the top of the Darwin Sandstone Member at Steeple Pasture. Thus, evidence from the present study suggests that the post-Darwin beds studied belong to the middle member of the Casper of Maughan (1979, p. U22, U23, fig. 10), who summarized fusulinid evidence for a Desmoinesian to Virgilian age for the member.

ORIGIN

The lithology and fauna of the carbonates is suggestive of offshore shallow-water marine bank deposition. Stromatolites in some beds may represent periods of intertidal or supratidal conditions. The quartz sandstones probably represent pulses of terrigenous sediment derived from upland areas on the Transcontinental Arch deposited in beaches and offshore bars.

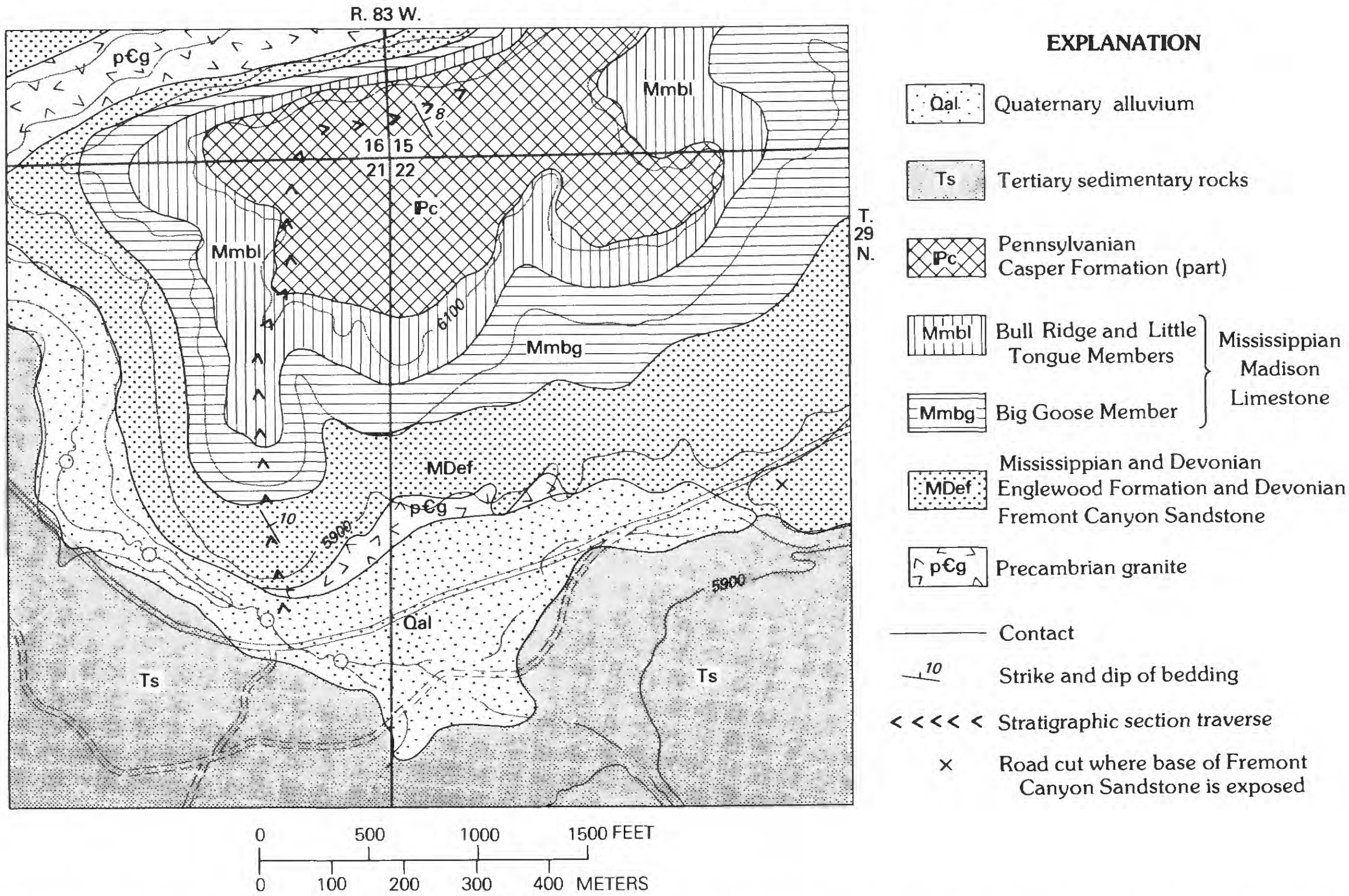


FIGURE 7.—Geologic sketch map of Fremont Canyon section. Base from Pathfinder Dam 7.5′ minute quadrangle. Contour interval is 100 feet.

STRATIGRAPHIC SECTION DESCRIPTIONS

FREMONT CANYON SECTION

(Type section of Fremont Canyon Sandstone)

Section begins at foot of south-facing nose in NE1/4 sec. 21, T. 29 N., R. 83 W., Natrona County, at a point on the Fremont Canyon power plant road 2 mi (odometer) west of intersection with Kortes Road (fig. 7). This intersection is 6.2 mi south of Alcova on Wyoming Highway 220. The section is about 0.5 mi (odometer) east of the bridge over Fremont Canyon. The base of the Fremont Canyon Sandstone is exposed at several places along the foot of the hills here (fig. 8). The best exposure of this datum is in the road cut east of the section traverse (fig. 7). The section was measured with a Jacobs staff and steel tape.

	Thickness Feet	Meters
Casper Formation:		
46. Dolobiomicrite; similar to unit 38; beds 0.3–2 ft thick; undetermined brachiopods and gastropods from upper 1.5 ft (USGS 26002–PC) ----------	7.0	2.1
45. Quartz sandstone; fine- to medium-grained; weathers white; beds regular, 0.2–1 ft thick --------------------	14.0	4.3
44. Quartz sandstone; fine-grained; dolomitic; weathers grayish orange to moderate reddish orange; beds irregular, 0.1–0.2 ft thick ---------------	2.8	0.9
43. Dolomite; medium crystalline; irregularly laminated (stromatolitic?); weathers moderate reddish orange; single bed -----------------------	1.0	0.3
42. Quartz sandstone; fine-grained; friable; calcareous; weathers white; crossbedded (large scale), beds 0.5–2 ft thick;		

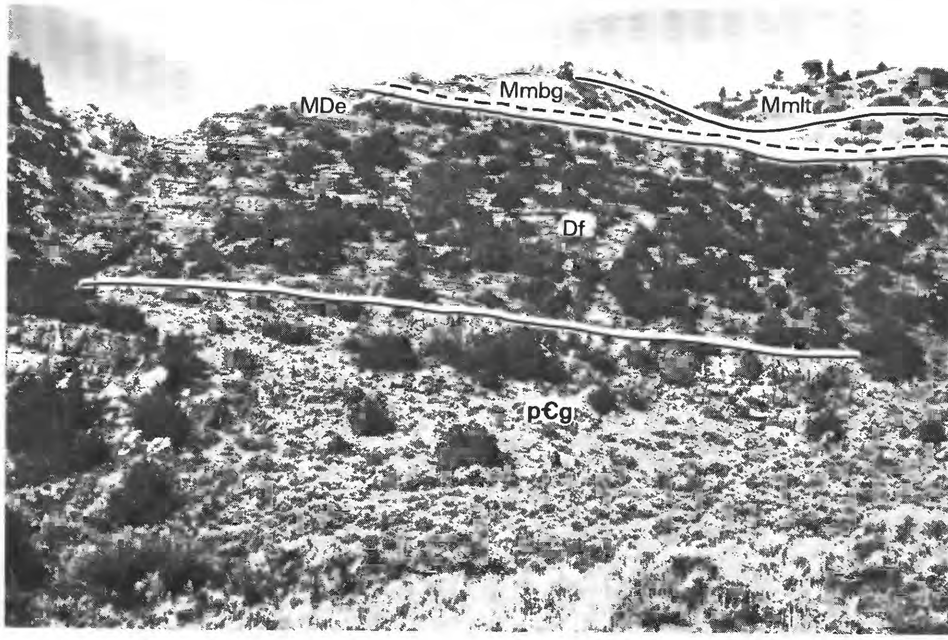


FIGURE 8.—Precambrian granite (p€g), Fremont Canyon Sandstone (Df), Englewood Formation (MDe), and Big Goose (Mmbg) and Little Tongue (Mmlt) Members of Madison Limestone in Fremont Canyon section.

	Thickness Feet	Meters
unit forms base of prominent white cliff. Barren conodont sample from lower foot (USGS 26001–PC) -------	10.0	3.1
41. Dolomite; medium crystalline; texture obscure; some beds slightly sandy; weathers grayish orange; beds 1–2 ft thick ----------------------------	10.0	3.1
40. Covered and dolomitic limestone float like unit 38; some beds in place in lower 4 ft ------------------------	10.0	3.1
39. Quartz sandstone; fine-grained; weathers grayish yellow; beds 0.1–0.3 ft thick; poorly exposed -------------	2.0	0.6
38. Dolopelmicrite; crinoidal; weathers grayish yellow to moderate orange pink; beds irregular, 0.5–2 ft thick; exposed in cliff. Barren conodont sample USGS 26000–PC 15 ft above base --	28.0	8.5
37. Dolomitic limestone; like unit 35; poorly exposed --------------------------	3.0	0.9
36. Micrite; recrystallized; like unit 34; poorly exposed -------------------	2.0	0.6
35. Dolomitic limestone; fine-grained; weathers yellowish gray; contains scattered crinoidal debris as molds and casts; beds 0.5–1 ft thick; poorly exposed --------------------------	3.0	0.9
34. Micrite; recrystallized; with dolomitic partings; like unit 30; poorly exposed. Barren foram sample USGS 25999–PC 3 ft above base ---------------	6.5	2.0
33. Dolomite; sandy; like unit 31 ---------	3.0	0.9
32. Quartz sandstone; fine-grained; weathers white to grayish yellow; crossbedded, beds 0.5 ft thick. Barren conodont sample USGS 25998–PC 2 ft above base. Traverse follows edge of cliff --	3.0	0.9
31. Dolomite; fine to medium crystalline; sandy; some beds platy; beds 0.1–0.5 ft thick ----------------------------	2.5	0.8
30. Biomicrite, crinoidal, and pelsparite, stromatolitic; olive gray weathering medium light gray; irregular beds 0.1–0.3 ft thick separated by orange-weathering dolomitic partings; grades into unit above. Indeterminate foraminifers from lower 0.5 ft (USGS 25996–PC); barren foram sample USGS 25997–PC 1.5 ft above base --	3.5	1.1
Measured thickness of Casper Formation above Darwin Sandstone Member ------	111.3	34.1
Darwin Sandstone Member:		
29. Quartz sandstone; fine-grained; weathers white, yellowish gray, grayish yellow, moderate orange pink, and moderate red; crossbedded, beds 4 ft thick; fills sinkholes in underlying units. Barren conodont samples 2 ft above base (USGS 25994–PC) and from upper foot (USGS 25995–PC) ------	26.0	7.9
Total thickness of Darwin Sandstone Member ---------------------------------	26.0	7.9

	Thickness Feet	Thickness Meters
Measured thickness of Casper Formation (incomplete)	137.3	42.0
Madison Limestone:		
Bull Ridge Member:		
28. Quartz siltstone; platy; calcareous; weathers predominantly moderate red and grayish orange; a fine-grained dolomite bed about 0.2 ft thick in lower half and a fine-grained limestone bed 0.3 ft thick near middle; exposed on dipslope. Barren foram sample from limestone bed near middle (USGS 25993–PC). Unit represents lower solution zone	5.0	1.5
Total thickness of Bull Ridge Member	5.0	1.5
Little Tongue Member:		
27. Dolomite; predominantly fine-grained; fossiliferous; weathers yellowish gray to grayish yellow; beds undulant, 0.5–1 ft thick; about 50 percent dark brown chert in thick lenses and beds; chert contains abundant brachiopods, gastropods, and crinoid columnals; unit exposed on dipslope. Undetermined brachiopods 3 ft below top (USGS 25992–PC)	14.0	4.3
26. Pelmicrite, intramicrite, oosparite, and oobiosparite; olive gray weathering medium light gray to light gray; beds regular but undulant, 0.5–2 ft thick; about 10 percent brown chert nodules and lenses; unit is main cliff-former. Foraminifers of Mamet Zone 8 or 9, 4 ft above base (USGS 25989–PC) and from upper foot (USGS 25991–PC); barren foram sample 15 ft above base (USGS 25990–PC)	36.0	11.0
25. Biosparite, crinoidal; olive gray weathering medium light gray to light gray; bedding undulant, 0.5–1 ft thick, brecciated in lower half, with sandstone matrix; about 10 percent brown chert nodules; unit is main cliff-former. Abundant spiriferoid brachiopods throughout (sample USGS 25988–PC from 7 ft above base)	10.5	3.2
24. Limestone collapse breccia; mostly crinoidal biomicrite in large angular blocks up to several feet in diameter in yellowish-weathering fine-grained quartz sandstone matrix; limestone weathers medium light gray to light gray; about 10 percent brown chert nodules; unit forms lower part of main cliff. Spiriferoid brachiopods rare	20.0	6.1
23. Covered; float of silty fine-grained dolomite and chert breccia with matrix of silty dolomite weathering grayish yellow and siltstone weathering light red. Unit represents lower solution zone	13.0	4.0
Total thickness of Little Tongue Member	93.5	28.6
Big Goose Member:		
22. Micrite and dolomicrite; stromatolitic; abundant hemispherical stromatolites as much as 0.5 ft in diameter and 1 ft high, some silicified; beds 2 ft thick. USGS 25987–PC	4.5	1.4
21. Dolomicrite; weathers yellowish gray; beds laminated, 0.2–0.5 ft thick; about 20 percent brown chert lenses and stringers; partly brecciated, including large blocks at angles to bedding; contains at least two lenses of fine-grained quartz sandstone as much as 2 ft thick and 4 ft wide in solution cavities. Barren conodont sample USGS 25986–PC 5 ft above base	19.0	5.8
20. Micrite and pelmicrite; olive gray weathering medium light gray; interbedded with fine-grained dolomitic limestone weathering yellowish gray; beds 0.5–1 ft thick; contacts fuzzy; all beds contorted, shattered, some brecciated; unit forms prominent cliff. Barren foram sample USGS 25985–PC 7 ft above base	35.0	10.7
19. Covered and few outcrops of shattered fine-grained dolomitic limestone in lower half; float is dolomitic limestone and limestone from above	22.0	6.7
18. Dolomitic limestone; fine-grained; weathers yellowish gray; shattered and brecciated	9.0	2.8
17. Covered and a few outcrops of fine-grained dolomitic limestone at base; dolomitic limestone float	6.0	1.8
16. Dolomitic limestone and dolomite; medium crystalline; weathers yellowish gray; crossbedded, beds 0.3–0.5 ft thick; forms cliff in ridge. Barren conodont sample USGS 25984–PC from upper foot	4.0	1.2
15. Dolomitic pelmicrite; weathers yellowish gray; beds regular to irregular, 0.3–0.5 ft thick; some beds faintly laminated; some beds shattered; structure obscure in most beds; about 5 percent brown chert nodules and stringers; unit forms ridge. Barren conodont sample USGS 25983–PC 8 ft above base	11.5	3.5

	Thickness Feet	Meters
14. Dolomicrite and crinoidal dolomite; weathers yellowish gray; crossbedded, beds 0.3–1 ft thick; forms prominent cliff. Abundant brachiopods as molds and casts in lower half. Brachiopods 3–6 ft above base (USGS 25981–PC); barren conodont sample USGS 25982–PC from upper foot	14.5	4.4
13. Covered and dolomitic limestone float	7.5	2.3
12. Dolomicrite; laminated (stromatolitic); weathers yellowish gray; beds irregular, 0.5–1 ft thick. Barren conodont sample USGS 25980–PC from lower foot	4.5	1.4
11. Dolomicrite; crinoidal, silty; weathers yellowish gray; bed regular, 0.1–0.5 ft thick; some beds faintly laminated; chert nodules in upper 2 ft; poorly exposed. Barren conodont sample USGS 25979–PC from lower foot	11.0	3.4
10. Dolomicrite; olive gray weathering yellowish gray to grayish orange; beds irregular to nodular, 0.1–0.5 ft thick; about 40 percent milky white and gray irregular nodular chert. Barren conodont samples USGS 25978–PC 7 ft above base and USGS 25977–PC a foot above base	12.5	3.8
Total thickness of Big Goose Member	161	49.2
Total thickness of Madison Limestone	259.5	79.3

	Feet	Meters
Englewood Formation:		
9. Dolomicrite; silty and sandy; fine quartz sand in lower foot grades up into silty beds; weathers yellowish gray; beds regular, 0.2–0.3 ft thick. *Polygnathus inornatus rostratus* and *P. longiposticus* from lower foot (USGS 25976–PC). Disconformity at base of unit marks base of Mississippian	4.0	1.2
8. Quartz sandstone; like unit 6 but not conglomeratic	1.0	0.3
7. Covered; probably siltstone, like unit 5	2.0	0.6
6. Quartz sandstone; predominantly fine- to medium-grained with conglomeratic layers; friable to quartzitic; weathers white, brown, and pink; beds regular, 0.3–1 ft thick. *Polygnathus semicostatus*, *Clydagnathus ormistoni*, and *Scaphignathus* sp. from lower foot (USGS 25975–PC)	4.0	1.2
5. Covered and outcrop of platy calcareous quartz siltstone weathering moderate red at base; unit is probably all siltstone	6.0	1.8
Total thickness of Englewood Formation	17.0	5.1

	Thickness Feet	Meters
Fremont Canyon Sandstone:		
4. Quartz sandstone; predominantly medium- to coarse-grained; with scattered layers of very coarse sand and rare pebbles; friable to quartzitic; weathers light gray, brown, red, and orange; crossbedded, beds 0.1–0.3 thick; unit forms cliffy slope. Barren conodont samples from lower foot, and 5, 12, 16, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95, 99, 110, 115, 121, 125, 130, 140, 147, 150, 155, 160, and 165 ft above base (USGS 25943—25974–PC)	166.5	50.8
3. Quartz sandstone; conglomeratic; medium- to very coarse sand with layers of quartz and feldspar pebbles as much as 10 mm in diameter; weathers white, brown, and red; crossbedded, beds 0.3–1.5 ft thick. Barren conodont samples from lower foot and 5, 10, and 15 ft above base (USGS 25939—25942–PC)	17.5	5.3
2. Conglomerate; quartz pebbles up to 0.2 ft in diameter, rounded to angular, in matrix of medium to coarse quartz and feldspar sand. Altitude 5,800 ft at base. Barren conodont sample USGS 25938–PC from lower foot	2.0	0.6
Total thickness of Fremont Canyon Sandstone	186.0	56.7
Precambrian granite:		
1. Granite; equigranular; pink; exposed in draw east of main traverse line; 0.1 ft of relief at top.		

CASPER MOUNTAIN ROAD SECTION A

Section begins in road cut on east side of Casper Mountain Road at a point about 40 yd north of intersection with dirt road leading to cabins on west side of road in NE1/4SE1/4 sec. 8, T. 32 N., R. 79 W., Natrona County (fig. 9). The road cut is covered by slump above the top of unit 5 so that the top of the Fremont Canyon Sandstone cannot be determined with confidence in this section. A conodont sample from the lower foot of unit 4 (USGS 25801–PC) and 28 conodont samples collected at 2-ft intervals from unit 5 (USGS 25802—25829–PC) were barren. These samples were also used for petrographic analysis. Section was measured with a steel tape.

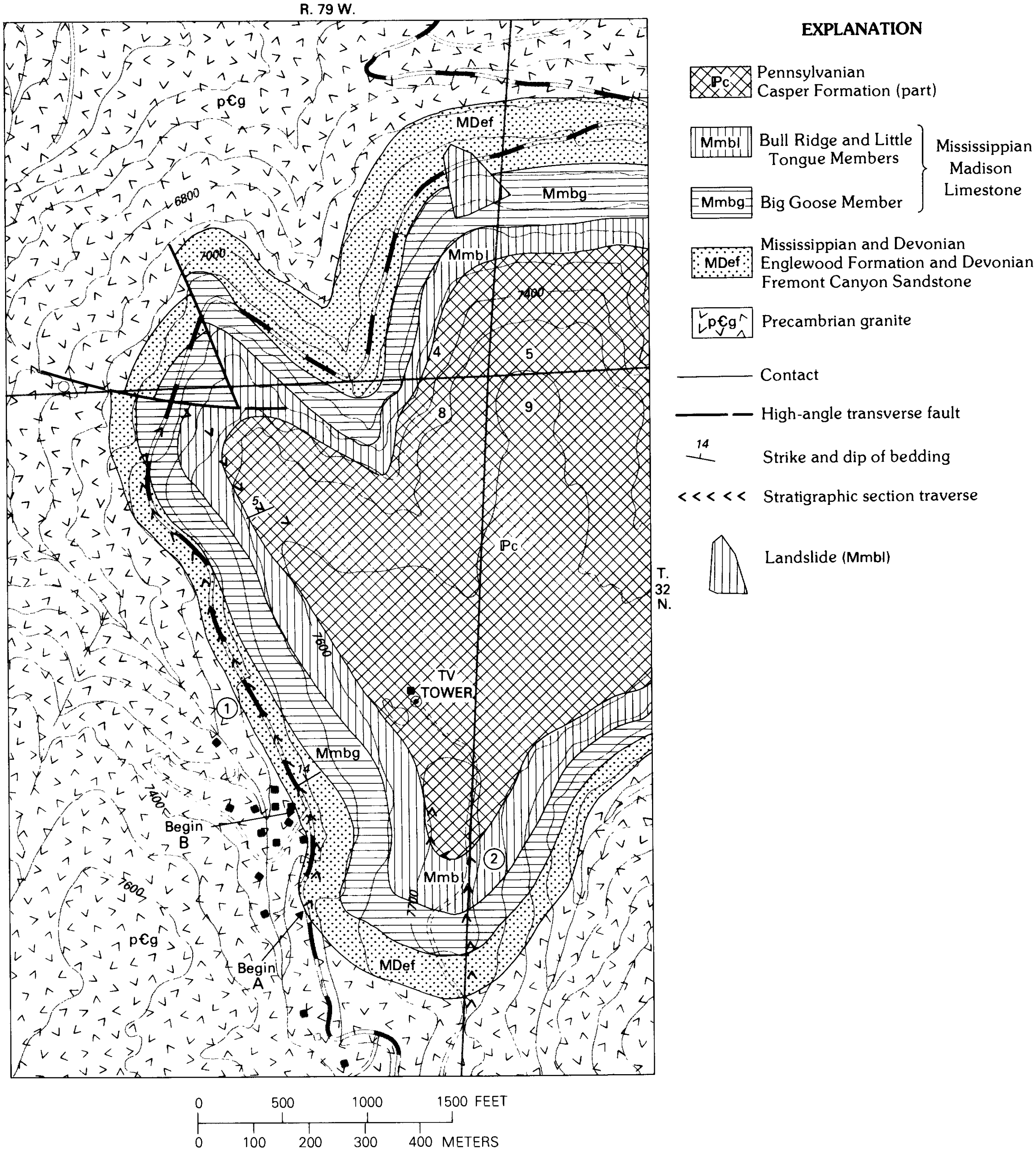


FIGURE 9.—Geologic sketch map of Casper Mountain Road (1) and TV Tower (2) sections. Base from Casper 7.5′ quadrangle. Contour interval is 100 feet.

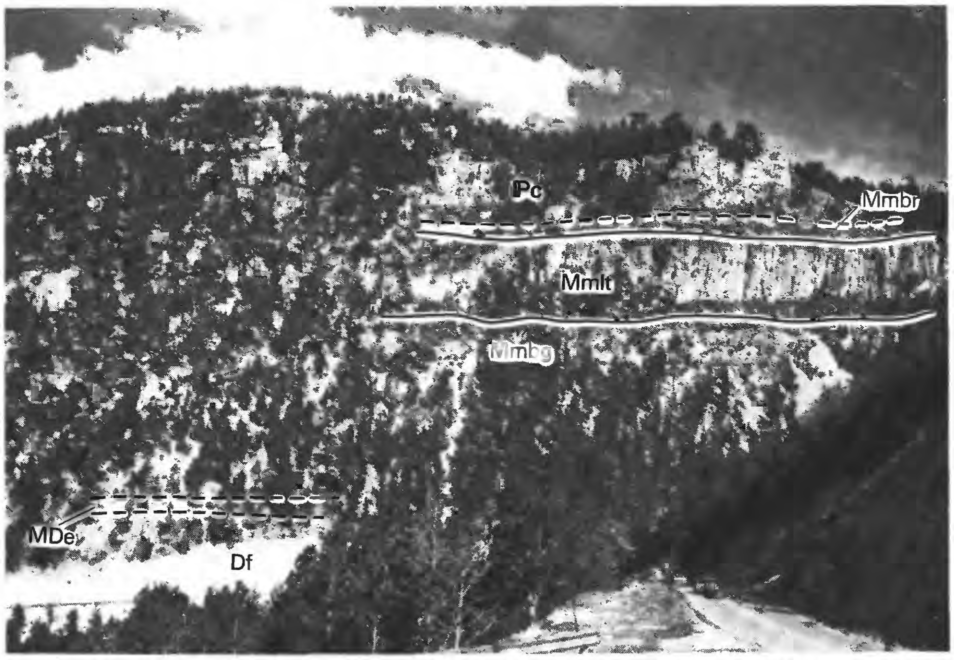


FIGURE 10.—Fremont Canyon Sandstone (Df); Englewood Formation (MDe); Big Goose (Mmbg), Little Tongue (Mmlt), and Bull Ridge (Mmbr) Members of Madison Limestone; and Casper Formation (IPc) exposed in cliffs at front of Casper Mountain northeast of Casper Mountain Road section.

	Thickness Feet	*Thickness Meters*
Fremont Canyon Sandstone:		
5. Quartz sandstone; friable to quartzitic, predominantly medium- to coarse-grained, with abundant thin layers of very coarse sand; grains mostly rounded; weathers predominantly yellowish gray to grayish orange with minor pink and red stain; beds 0.1–0.4 ft thick parting into units as much as 3 ft thick; intricately crossbedded; current ripples, sets 0.1–0.4 ft thick, dipping north at about 30° to bedding; a few thin, greenish, discontinuous shaly zones in upper half; linear ichnofossils parallel to bedding seen on a few float blocks	56.0	17.1
4. Quartz sandstone; like unit above but poorly exposed and deeply weathered; outcrop brownish; exposed by trenching	9.0	2.8
3. Covered and loose blocks of quartz sandstone like unit above; blocks of sandstone in correct bedding orientation at base; yellowish and tan soil zone	5.0	1.5
Total thickness of Fremont Canyon Sandstone (incomplete)	70.0	21.4
Precambrian granite:		
2. Covered and loose blocks of granite and minor sandstone; red soil zone	21.4	6.5
1. Granite; composed of pink feldspar, biotite, and quartz in equal grains 2–5 mm in diameter; weathers pink; poorly foliated; massive	Not measured	

CASPER MOUNTAIN ROAD SECTION B

Section begins in road cut 180 yd northwest of section A at a point directly opposite macadam road leading to cabins on west side of road (fig. 9); granite is exposed just below road on west side where an old foundation rests on granite. Section proceeds northwestward in road cuts to base of unit 28, where traverse continues up cliff face south of main bend in road. The Paleozoic section forms bold cliffs at the front of Casper Mountain (fig. 10).

	Thickness Feet	*Thickness Meters*
Casper Formation:		
60. Sandy dolomitic limestone and dolomitic sandstone; like unit 58	3.5	1.1
59. Quartz sandstone; friable; calcareous; predominantly fine-grained; weathers white to yellowish gray; beds 0.1–0.3 ft thick; a few beds have small-scale crossbedding. Barren conodont samples from lower foot (USGS 25911–PC) and upper foot (USGS 25912–PC)	16.0	4.9

	Thickness Feet	Thickness Meters
58. Dolomitic limestone, sandy, and dolomitic quartz sandstone; predominantly fine-grained; weathers yellowish gray; bedding irregular, beds 0.5–2 ft thick; calcite vugs; forms bench	7.5	2.3
57. Fossiliferous micrite and biomicrite, partly recrystallized; olive gray weathering medium light gray, stained moderate red in lower part; beds nodular to stylolitic, 0.1–0.3 ft thick, becoming thicker in upper half, many with red silty partings; forms cliff. Indeterminate foraminifers, gastropods, pectinoid clams, and brachiopods in sample 1 ft above base (USGS 25909–PC); barren foram sample (USGS 25910–PC) 10 ft above base	15.5	4.7
56. Quartz sandstone; predominantly fine-grained; weathers pale yellowish orange; beds 0.3 ft thick; poorly exposed on bench. Well-rounded grains of *Idiognathodus* sp. (USGS 25908–PC)	0.6	0.2
55. Biomicrite and fossiliferous pelmicrite; contains abundant dolomite rhombs in upper half; olive gray weathering medium light gray. Indeterminate brachiopods and ostracodes in lower 2 ft (USGS 25906–PC); gastropods and foraminifers of Mamet Zone 25 or younger in upper foot (USGS 25907–PC)	13.0	4.0
54. Micrite and fossiliferous pelmicrite; olive gray weathering medium light gray to light gray; beds regular, stylolitic, 0.1–0.4 ft thick; vertical joints filled with yellow-weathering calcareous siltstone. Indeterminate brachiopods and ostracodes in lower foot (USGS 25905–PC)	4.0	1.2
Measured thickness of Casper Formation above Darwin Sandstone Member	60.1	18.4
Darwin Sandstone Member:		
53. Quartz sandstone; predominantly fine-grained; friable; calcareous; weathers yellowish gray to pale yellowish orange; faintly crossbedded, beds 0.5–2 ft thick. *Idiognathoides* sp. (one specimen well-rounded) in upper foot (USGS 25904–PC)	5.4	1.7
52. Quartz sandstone; dolomitic; predominantly fine-grained; weathers yellowish gray to grayish yellow; poorly bedded; contains molds and casts of large crinoid columnals and gastropods. Barren conodont sample from lower foot (USGS 25903–PC)	3.5	1.1
Total thickness of Darwin Sandstone Member	8.9	2.8
Measured thickness of Casper Formation (incomplete)	69.0	21.2
Madison Limestone:		
Bull Ridge Member:		
51. Pelmicrite; silty; stromatolitic; partly recrystallized; having irregular fine lamination; olive gray weathering medium light gray. Barren foram sample 0.5 ft above base (USGS 25902–PC)	1.5	0.5
50. Quartz siltstone and fine-grained sandstone; weathers dark reddish brown to grayish yellow; contains many calcite vugs	1.0	0.3
49. Fossiliferous micrite and pelmicrite; olive gray weathering medium light gray; beds 0.1–0.2 ft thick, separated by 2–3-mm-thick silty yellowish-weathering partings; quartz sandstone in vertical joints. Indeterminate crinoid debris in lower foot (USGS 25900–PC); indeterminate ostracodes in upper foot (USGS 25901–PC)	4.5	1.4
48. Biomicrite; olive gray weathering medium light gray to light gray; beds 0.5–1 ft thick; contains a lens of fine-grained quartz sandstone in a solution cavity parallel to bedding and sandstone in horizontal and vertical joints that lead to top of unit 51. Crinoidal debris, spiriferoid brachiopods, gastropods, bryozoans, and *Syringopora*; *Vesiculophyllum*? sp. from 3–4.5 ft above base (USGS 25899–PC)	5.5	1.7
47. Covered and rubble from beds above, mostly limestone and sandstone. Indeterminate brachiopods in loose limestone block probably from Casper Formation 3 ft above base (USGS 25898–PC)	14.0	4.3
46. Covered and float of platy calcareous siltstone weathering grayish yellow; break in slope at top. Top marks probable top of upper solution zone	5.0	1.5
45. Dolomitic limestone breccia; cherty; clasts fine grained, olive gray weathering yellowish gray, some laminated, angular to rounded, mostly 0.1 ft or less in diameter; matrix fine-grained dolomitic limestone; about 20 percent fragmented gray, brown, and white chert; beds irregular, 0.3–0.5 ft thick; unit poorly exposed on slope above cliff	20.0	6.1
Total thickness of Bull Ridge Member	51.5	15.8

	Thickness Feet	Meters
Little Tongue Member:		
44. Micrite and crinoidal pelmicrite, partly recrystallized and partly dolomitized; olive gray weathering medium light gray; beds regular, 0.5–1 ft thick, bedding generally obscure; about 20 percent brown chert lenses and stringers parallel to bedding; unit forms massive cliff. Spiriferoid brachiopods from 19 ft above base (USGS 25895–PC); barren foram samples from lower foot (USGS 25893–PC), 10 ft above base (USGS 25894–PC), 34 ft above base (USGS 25896–PC), and 47 ft above base (USGS 25897–PC). Traverse offset about 100 yd updip along top of cliff at top of unit	47.0	14.3
43. Limestone collapse breccia; clasts are olive-gray micrite weathering medium light gray; angular fragments up to 0.5 ft in diameter in calcareous rock flour matrix; exposed in a few outcrops in slope	18.0	5.5
42. Covered and unreliable blocks of limestone collapse breccia like that in unit above	15.0	4.6
41. Covered and unreliable blocks of dolomite and chert breccia; angular fragments of fine-grained dolomite and chert like that in units below as much as 0.3 ft in diameter in fine-grained dolomite matrix. Unit represents lower solution zone	13.0	4.0
Total thickness of Little Tongue Member	93.0	28.4
Big Goose Member:		
40. Dolomitic limestone; fine-grained; weathers yellowish gray; shattered; beds regular, 0.3–0.5 ft thick; exposed at top of cliff in road cut	10.0	3.1
39. Micrite and pelmicrite; partly recrystallized; olive gray weathering light gray; beds regular, 0.5–3 ft thick, massive in appearance; 5 percent or less black chert nodules. Barren foram samples 5 ft and 10 ft above base (USGS 25891, 25892–PC)	16.0	4.9
38. Dolomite and dolomitic limestone, like unit 36; contacts irregular	8.0	2.4
37. Pelmicrite; algal (cysts); partly recrystallized; olive gray weathering medium light gray to light gray; beds regular, 0.3–1 ft thick, massive in appearance. Barren foram and conodont samples a foot above base (USGS 25889–PC) and from upper foot (USGS 25890–PC). Traverse ascends notch in cliff here	6.5	2.0
36. Dolomicrite, fractured, recrystallized, like unit 35, and limestone, fine-grained, olive gray weathering light gray; lenses with fuzzy boundaries, beds 0.5–2 ft thick; entire unit shattered and composed of breccia and pseudobreccia. Barren foram sample a foot above base (USGS 25888–PC)	14.5	4.4
35. Dolomicrite; fractured; medium light gray weathering yellowish gray to grayish orange; beds irregular, 0.3–2 ft thick; shaly partings weather pale red to dark yellowish orange; entire unit shattered and composed of breccia and pseudobreccia. Barren conodont sample 2 ft below top (USGS 25887–PC)	5.0	1.5
34. Dolomicrite; like unit 33; badly shattered; bedding obscure	14.0	4.3
33. Dolomicrite and scattered vuggy layers of dolomitized crinoidal biomicrite; medium gray weathering yellowish gray; beds regular, 0.3–2 ft thick; about 20 percent gray, brown, and white chert in thin stringers and minor small nodules; entire unit is well bedded but shattered; no breccia seen; many small faults	36.5	11.1
Conodont samples:		
USGS 25886–PC, 35 ft above base—barren		
25885–PC, 30 ft above base—barren		
25884–PC, 25 ft above base—*Polygnathus* sp.		
25883–PC, 20 ft above base—*Patrognathus andersoni*		
25882–PC, 15 ft above base—*Patrognathus andersoni*, *Bispathodus aculeatus*		
25881–PC, 10 ft above base—barren		
25880–PC, 5 ft above base—*Pandorinellina* n. sp. (Pa element)		
Total thickness of Big Goose Member	110.5	33.7
Total thickness of Madison Limestone	255.0	77.9
Englewood Formation:		
32. Dolobiomicrite; crinoidal, weathers yellowish gray to dark yellowish orange; beds 0.5 ft thick; very vuggy. *Polygnathus inornatus* and *Patrognathus andersoni* in lower foot (USGS 25879–PC)	3.0	0.9
31. Quartz siltstone; weathers dark yellowish orange to moderate brown; beds 0.1–0.5 ft thick; a few shaly partings. *Polygnathus inornatus* a foot above		

	Thickness Feet	Thickness Meters
base (USGS 25878–PC). Disconformity at base of unit marks base of Mississippian	1.5	0.5
30. Quartz sandstone; predominantly very fine- to medium-grained, with some layers up to very coarse-grained; weathers white to grayish red; crossbedded, beds 0.3–1 ft thick; a few interbeds of greenish-weathering silty clay shale as much as 0.3 ft thick. Barren conodont samples 4 ft above base (USGS 25876–PC) and from upper foot (USGS 25877–PC)	10.5	3.2
29. Quartz siltstone and silty dolomicrite with some thin layers of fine quartz sand; weathers dark yellowish orange to very dusky red; beds 0.1–0.5 ft thick, separated by beds of silty clay shale weathering grayish green 0.1–0.3 ft thick; some beds appear to have dessication cracks; salt casts in float; unit stands in marked contrast to gray sandstone below. Barren conodont samples from lower 0.3 ft (USGS 25872–PC), 3 ft above base (USGS 25873–PC), 6 ft above base (USGS 25874–PC), and 6.3 ft above base (USGS 25875–PC)	7.0	2.1
Total thickness of Englewood Formation	22.0	6.7

Fremont Canyon Sandstone:

	Thickness Feet	Thickness Meters
28. Quartz sandstone; friable; predominantly medium- to coarse-grained; crossbedded (current ripples), beds 0.1–0.5 ft thick; weathers like unit 27; pink- and orange-weathering layers of silt and fine sand 0.1 ft thick or less; beds tend to break out thicker than in unit below. Barren conodont samples 5 ft above base (USGS 25869–PC), 5 ft below top (USGS 25970–PC), and from upper 0.5 ft (USGS 25871–PC). Measured up cliff face just south of bend in road	35.0	10.7
27. Quartz sandstone; medium- to very coarse-grained; crossbedded (current ripples), beds 0.1–0.5 ft thick; weathers white, gray, tan, orange with some pink stain; mostly friable, some quartzitic; abundant interbeds of silty, sandy clay shale weathering mostly dusky yellow green; some orange and red beds; shaly beds 0.1–0.3 ft thick, containing abundant linear ichnofossils mostly parallel to bedding; unit exposed at turn in road. Barren conodont samples from lower 0.1 ft (USGS 25861–PC), 5.2 ft above base (USGS 25862–PC), 16.4 ft above base (USGS 25863–PC), 18.7 ft above base (USGS 25865–PC), and from upper 0.3 ft (USGS 25868–PC); trails from 16.4 ft above base (USGS 25864–PC) and 20.5 ft above base (USGS 25867–PC)	22.3	6.8
26. Quartz sandstone; predominantly medium- to coarse-grained with abundant layers of very coarse sand; predominantly friable, with few quartzitic beds; weathers white, tan, and orange, with minor pink stain; intricately crossbedded (current ripples), beds 0.1–0.5 ft thick; measured along road cut. Barren conodont samples 5, 10, 15, 20, 25, 30, 35, 40, and 45 ft above base (USGS 25852—25860–PC); paleomagnetism samples 15.3, 22.4, and 22.8 ft above base (ML1–3)	47.5	14.5
25. Quartz sandstone; friable, white, crossbedded; thin green clay parting at top	0.4	0.1
24. Clay shale and clay, micaceous, like unit 20. Barren conodont sample (USGS 25851–PC)	0.3	0.1
23. Quartz sandstone, like unit 19	0.2	0.1
22. Clay, like unit 16. Barren conodont sample (USGS 25850–PC)	0.2	0.1
21. Quartz sandstone, like unit 19	0.9	0.3
20. Clay shale and clay; silty and sandy; micaceous; weathers dusky yellow green. Barren conodont sample USGS 25849–PC	0.2	0.1
19. Quartz sandstone; predominantly coarse- to very coarse-grained, with some pebble layers; crossbedded, beds 0.2–1 ft thick; weathers yellowish gray and pale orange; resistant beds at top of road cut; unit measured by projection across covered interval. Barren conodont samples from lower 0.5 ft (USGS 25847–PC) and 5 ft above base (USGS 25848–PC)	8.5	2.6
18. Clay, silty, like unit 16. Barren conodont sample USGS 25845–PC	0.4	0.1
17. Quartz sandstone; like unit 13; green clay bed 0.1 ft thick 1 ft above base and 0.3 ft below top; very deeply weathered. Barren conodont sample from lower foot (USGS 25844–PC)	3.0	0.9
16. Clay, silty, like unit 14; weathers dusky yellow green. Barren conodont sample USGS 25843–PC	0.3	0.1
15. Quartz sandstone, like unit 13, very deeply weathered. Barren conodont sample USGS 25842–PC	1.0	0.3
14. Clay; silty; weathers very dusky red and dusky yellow green. Barren conodont sample USGS 25841–PC	0.3	0.1

	Thickness Feet	Meters
13. Quartz sandstone; predominantly medium- to coarse-grained, with some very coarse sand and pebbles; weathers yellowish gray and orange; no crossbedding seen; very deeply weathered. Barren conodont sample from lower half (USGS 25840–PC)	1.2	0.4
12. Quartz siltstone, clayey, micaceous; weathers very dusky red; shaly. Barren conodont sample USGS 25839–PC	0.2	0.1
11. Quartz sandstone; predominantly coarse- to very coarse-grained; like unit 5; weathers tan and orange like beds below; crossbedded, beds 0.2–0.3 ft thick; some resistant beds; a few thin conglomerate layers. Barren conodont sample from lower foot (USGS 25838–PC)	3.0	0.9
10. Quartz conglomerate, sandy, like unit 6 but contains more sand (about 5 percent); contains abundant black pebbles; resistant bed that can be traced about 50 yd laterally. Barren conodont sample from lower foot (USGS 25837–PC)	0.7	0.2
9. Quartz sandstone; like unit 5; deeply weathered in road cut; resistant near middle. Barren conodont sample from lower foot (USGS 25836–PC)	1.6	0.5
8. Quartz conglomerate; sandy; like unit 6; deeply weathered in road cut. Barren conodont sample from lower foot (USGS 25835–PC)	2.0	0.6
7. Quartz sandstone; like unit 5 but a little more conglomeratic; deeply weathered in road cut. Barren conodont sample from lower foot (USGS 25834–PC)	1.7	0.5
6. Quartz conglomerate; sandy; like unit 4; pebbles as much as 30 mm in diameter; deeply weathered in road cut. Barren conodont sample from lower foot (USGS 25833–PC)	2.0	0.6
5. Quartz sandstone; predominantly coarse- to very coarse-grained with some pebbles up to 5 mm in diameter; clasts subangular to rounded; crossbedded, beds 0.1–0.3 ft thick; weathers tan; deeply weathered in road cut. Barren conodont sample from lower foot (USGS 25832–PC)	1.4	0.4
4. Quartz conglomerate; sandy; pebbles as much as 20 mm in diameter, subangular to rounded; poorly bedded; contains a few granite pebbles; deeply weathered to red micaceous clay; exposed by trenching. Barren conodont samples from lower foot (USGS 25830–PC) and upper foot (USGS 25831–PC)	2.2–3	0.6–0.9
Total thickness of Fremont Canyon Sandstone	137.3	42.0

	Thickness Feet	Meters
Precambrian granite:		
3. Clay; micaceous; red; represents weathered granite in place; 0.8 ft of relief at top; exposed in trench on east side of road	1.0	0.3
2. Covered slope to edge of road	5.0	1.5
1. Granite; pink; like unit 1 of section A; massive rounded outcrops	10+	3.1

CASPER MOUNTAIN TV TOWER SECTION

Section begins at top of granite exposure in saddle about 20 ft east of dirt road to TV tower at a point directly under power line (fig. 9). Initial leg of traverse follows power line up sandstone cliff. Section was measured mostly with a Jacobs staff. The Paleozoic section is well displayed in cliffs just east of the section traverse (fig. 11).

	Thickness Feet	Meters
Casper Formation:		
20. Pelmicrite and pelsparite; fossiliferous; partly fractured; beds regular, 0.1–0.3 ft thick. Orthotetoid brachiopods from throughout unit (USGS 25937–PC); barren foram samples from lower foot (USGS 25935–PC) and upper foot (USGS 25936–PC). Section terminates at top of cliff	7.0	2.1
Darwin Sandstone Member:		
19. Quartz sandstone; fine-grained; calcareous; weathers yellowish gray and grayish orange; some beds crossbedded, beds 0.3–0.5 ft thick. Barren conodont sample 3 ft above base (USGS 25934–PC)	6.0	1.8
Total thickness of Darwin Sandstone Member	6.0	1.8
Measured thickness of Casper Formation (incomplete)	13.0	3.9
Madison Limestone:		
Bull Ridge Member:		
18. Micrite; irregularly laminated, probably stromatolitic; olive gray weathering medium light gray	0.7	0.2
17. Quartz siltstone and fine-grained sandstone; weathers grayish orange; platy; very calcareous; contacts irregular but seemingly gradational. Barren conodont sample (USGS 25933–PC)	1.4	0.4

	Thickness Feet	Thickness Meters
16. Micrite; fossiliferous (ostracodes); olive gray weathering medium light gray; nodular bedded, beds 0.1–0.3 ft thick; yellowish-weathering silty partings. Barren foram sample from upper foot (USGS 25932–PC) -----------------	6.0	1.8
15. Micrite and pelmicrite; crinoidal; olive gray weathering light gray to medium light gray; beds 0.5–1 ft thick, indistinct; vertical and horizontal joints filled with yellow- and brown-weathering quartz sandstone; about 10 percent incipient brown chert lenses. *Syringopora*, horn corals, large orthotetoid brachiopods, and bryozoans throughout; *Lophophyllum*? sp. and *Vesiculophyllum* sp. from 5 to 10 ft above base (USGS 25931–PC) ----	10.0	3.1

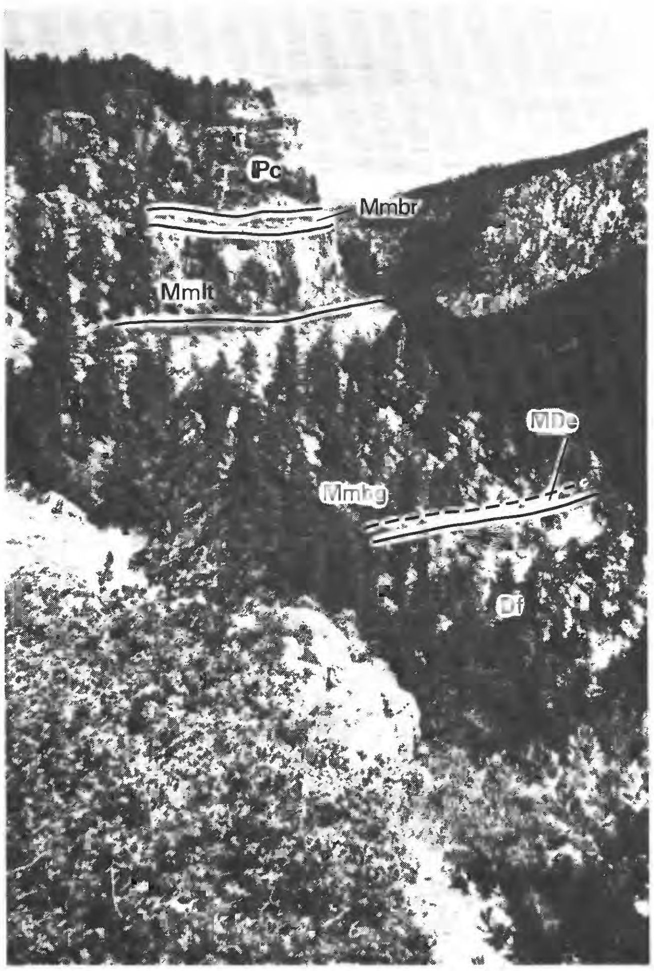


FIGURE 11.—Fremont Canyon Sandstone (Df); Englewood Formation (MDe); Big Goose (Mmbg), Little Tongue (Mmlt), and Bull Ridge (Mmbr) Members of Madison Limestone; and Casper Formation (IPc) exposed in west wall of canyon east of Casper Mountain TV Tower section.

	Thickness Feet	Thickness Meters
14. Quartz sandstone; fine- to very fine-grained; very calcareous; friable to hard; weathers yellowish gray to grayish orange; beds irregular, 0.1–0.3 ft thick; upper half of unit poorly exposed. Unit represents upper solution zone -----------------------------	3.0	0.9
Total thickness of Bull Ridge Member ----	21.1	6.4
Little Tongue Member:		
13. Micrite and dismicrite; fossiliferous; olive gray weathering medium light gray; some beds nodular; beds 0.1–0.3 ft thick; about 20 percent incipient brown chert. Indeterminate brachiopods from upper foot (USGS 25930–PC) ------------------------	3.0	0.9
12. Biomicrite, pelmicrite, oomicrite, and biosparite; crinoidal; olive gray weathering medium light gray to light gray; beds undulant, 0.5–1 ft thick; about 10 percent brown chert lenses and nodules; collapse breccia in lower 15 ft. Spiriferoid brachiopods throughout; *Vesiculophyllum* sp. 30 ft above base (USGS 25929–PC); brachiopods from 2 ft above base (USGS 25928–PC) ------------------------------	32.0	9.8
11. Covered and float of breccia like that below; yellowish-weathering platy calcareous siltstone. Top of lower solution zone at top of unit ------------	5.0	1.5
10. Breccia; clasts predominantly micrite (olive gray weathering medium light gray), brown chert (5 percent), and fine-grained dolomitic limestone weathering yellowish gray to grayish yellow (10 percent); matrix calcareous, fine-grained, weathering very light gray; clasts angular, mostly 0.1 ft or less in diameter, but blocks as much as 1 ft in diameter are also present; bedding obscure (fig. 12). Base of lower solution zone at base of unit. Lithic sample (USGS 25927–PC) near middle -----------------------	10.0	3.1
Total thickness of Little Tongue Member -	50.0	15.3
Big Goose Member:		
9. Micrite, fractured and laminated, and rare intra-biosparite; olive gray weathering medium light gray to light gray; beds regular, 0.5–2 ft thick; about 10 percent chert lenses in upper half; unit forms cliff and was measured along rim of canyon. Barren foram samples a foot above base (USGS 25924–PC) and 10 ft above base (USGS 25925–PC); foraminifers of Mamet Zone 8 (upper) from a foot below top (USGS 25926–PC) -------	21.0	6.4

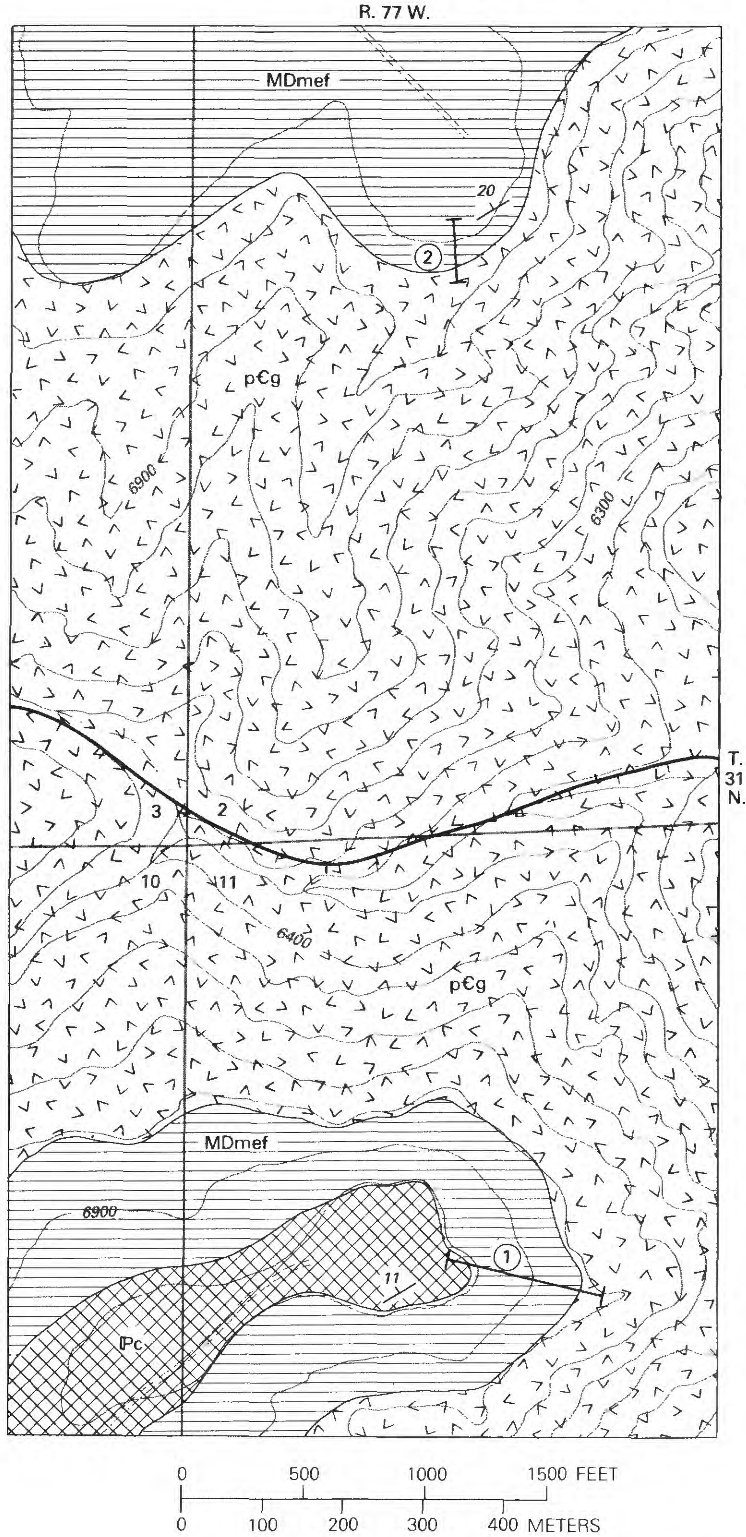
	Thickness Feet	Thickness Meters
8. Covered and large blocks of limestone from unit above; no dolomite seen; forms slope leading up to cliff ------	13.0	4.0
7. Dolomite, like unit 6, and oomicrite, olive gray, interbedded; beds 0.3–1 ft thick; fuzzy boundaries; poorly exposed on slope. Indeterminate foraminifers from lower foot (USGS 25922–PC); barren foram sample 5 ft above base (USGS 25923–PC) ------	15.0	4.6
6. Dolomite; fine-grained; weathers yellowish gray; faintly laminated; beds 0.3–0.5 ft thick; about 20 percent brown, gray, and white chert in irregular patches and stringers; unit about 90 percent covered on slope; best exposures are at canyon rim east of traverse. Barren conodont sample 7 ft above base (USGS 25921–PC) ------	38.0	11.6
Total thickness of Big Goose Member -----	87.0	26.6
Total thickness of Madison Limestone --------	158.1	48.3
Englewood Formation:		
5. Covered; dark-brown soil contains pieces of dark-reddish-brown quartz siltstone and sandstone --------------------	17.0	5.2
Total thickness of Englewood Formation ------	17.0	5.2
Fremont Canyon Sandstone:		
4. Quartz sandstone; predominantly medium- to coarse-grained with scattered layers of very coarse sand; friable to hard; weathers white, yellowish gray, grayish yellow, and grayish orange; crossbedded, beds 0.1–0.3 ft thick; forms cliffy slope. Barren conodont samples 1, 12, 24, 36, 47, 67, and 100 ft above base and from upper foot (USGS 25913—25920–PC) -----	106.0	32.3
3. Covered; tan sandy soil and rubble of sandstone blocks from unit above; forms slope below cliffy outcrops ----	30.0	9.2
2. Covered; tan sandy soil containing abundant quartz pebbles; forms saddle ------------------------------	15.0	4.6
Total thickness of Fremont Canyon Sandstone -	151.0	46.1
Precambrian granite:		
1. Granite, pink, like that in Casper Mountain Road Section B.		

FIGURE 12.—Solution breccia in lower solution zone of Little Tongue Member of Madison Limestone, unit 10 of Casper Mountain TV Tower section.

BANNER MOUNTAIN SECTION

Section is located at rim of Lower Deer Creek Canyon on south flank of Banner Mountain in NW1/4SW1/4 sec. 2, T. 31 N., R. 77 W., Converse County (fig. 13). Access to section is along jeep trail that follows power line that intersects Negro Hill Road in NW1/4NW1/4 sec. 10. Section begins at top of Precambrian granite exposed on bench at altitude 7,050 ft and terminates on hillside strewn with dolomite in lower part of Big Goose Member of Madison Limestone. Section was measured with Jacobs staff and steel tape. Paleozoic section is well displayed in east wall of Lower Deer Creek Canyon (fig. 14).

	Thickness Feet	Thickness Meters
Madison Limestone:		
Big Goose Member:		
10. Covered and intermittent outcrops of silty dolomicrite weathering pale red and grayish yellow, beds regular to nodular, 0.1–0.3 ft thick; most beds faintly laminated; about 5 percent small varicolored chert nodules. *Polygnathus inornatus*, *Patrognathus andersoni*, and *Bispathodus aculeatus* 9 ft above base (USGS 26009–PC). Outcrops become unreliable above this unit -------------------------	40.0	12.2
Measured thickness of Big Goose Member (incomplete) -------------------------	40.0	12.2
Measured thickness of Madison Limestone (incomplete) --------------------------------	40.0	12.2
Englewood Formation:		
9. Dolomicrite; sandy; crinoidal; weathers yellowish gray; crinoidal debris as molds and casts and layers of quartz sand to very coarse size; beds 0.1–0.5 ft thick. Rare spiriferoid brachiopods; *Polygnathus inornatus*		



EXPLANATION

Pc — Pennsylvanian Casper Formation (part)

MDmef — Mississippian to Devonian: Madison Limestone, Englewood Formation and Fremont Canyon Sandstone

p€g — Precambrian granite

Contact

Normal fault, hachured on downthrown side

11 — Strike and dip of bedding

1 — Stratigraphic section traverse

FIGURE 13.—Geologic sketch map of Steeple Pasture (1) and Banner Mountain (2) sections. Base from Banner Mountain 7.5′ quadrangle. Contour interval is 100 feet.

FIGURE 14.—Precambrian granite (p€g); Fremont Canyon Sandstone and Englewood Formation (MDef); Big Goose (Mmbg) and Little Tongue (Mmlt) Members of Madison Limestone; and Casper Formation (IPc) exposed in east wall of Lower Deer Creek Canyon near Banner Mountain and Steeple Pasture sections.

	Thickness Feet	Thickness Meters
(abundant), *P. longiposticus*, *Pandorinellina* n. sp., *Patrognathus andersoni*, and *Siphonodella* sp. 1 to 2 ft above base (USGS 26008–PC, BAH–2, and BAH–3). This unit is same bed as unit 5 at Steeple Pasture --------	3.0	0.9
8. Quartz sandstone; coarse- to very coarse-grained; dolomitic; weathers white to grayish orange; crossbedded, beds 0.3–0.5 ft thick. Indeterminate conodonts (USGS 26007–PC). Disconformity at base of unit marks base of Mississippian --------------------	1.3	0.4
7. Dolomicrite; sandy; weathers yellowish gray; beds irregular, 0.1–0.3 ft thick. *Polygnathus communis carina*, *P. semicostatus*, and *Icriodus costatus*? (USGS 26006–PC and BAH–1) -----	1.5	0.5
6. Quartz sandstone; like unit 4 --------	2.5	0.8
5. Covered; float from above ------------	26.0	7.9
4. Quartz sandstone; coarse- to very coarse-grained; weathers white; crossbedded ------------------------------	1.5	0.5
3. Quartz sandstone and siltstone, interbedded; medium- to very coarse-grained quartz sand with siltstone pebbles up to 0.3 ft in diameter; weathers pale red; crossbedded, beds 0.1–0.3 ft thick; lower part poorly exposed. Barren conodont sample 2 ft below top (USGS 26005–PC) ---------	9.0	2.8
Total thickness of Englewood Formation ------	44.8	13.8

	Thickness Feet	Thickness Meters
Fremont Canyon Sandstone:		
2. Quartz sandstone; medium- to very coarse-grained containing lenses of very coarse angular quartz pebbles up to 0.3 ft in diameter in lower 3 ft, perhaps deposited in depressions in underlying surface; weathers pale red to grayish red; crossbedded, beds 0.5–3 ft thick. Barren conodont samples from lower 0.5 ft (USGS 26003–PC) and 10 ft above base (26004–PC) ---	11.0	3.4
Total thickness of Fremont Canyon Sandstone -	11.0	3.4
Precambrian granite:		
1. Granite; pink; equigranular; kaolinized feldspar in upper 5 ft; at least 2 ft of relief on top.		

STEEPLE PASTURE SECTION

Section is located at rim of Lower Deer Creek Canyon just below Steeple Pasture in S1/2NW1/4 sec. 11, T. 31 N., R. 77 W., Converse County (fig. 13). Access to section is along jeep trail to Steeple Pasture that intersects Negro Hill Road in NW1/4 sec. 10. Section begins at top of Precambrian granite exposed on bench at altitude 6,800 ft and terminates on knob forming part of dipslope dipping into fault to north. Section was measured with Jacobs staff and steel tape.

	Thickness Feet	Thickness Meters
Casper Formation:		
21. Dolomitic limestone; predominantly medium crystalline; like unit 17; some beds crinoidal; weathers yellowish gray, grayish yellow, grayish orange, and grayish red; beds 0.2–1 ft thick -----------------------------	10.0	3.0
20. Micrite and biomicrite; like unit 18. Barren foram sample USGS 26028–PC a foot above base --------------------	2.0	0.6
19. Dolomitic limestone; like unit 17; contacts gradational ------------------	1.5	0.5
18. Biomicrite; partly dolomitized; some beds in upper half crinoidal; olive gray weathering medium light gray to pale red; beds irregular, 0.1–0.3 ft thick; thin red-weathering partings in upper half. Indeterminate ostracodes in lower foot (USGS 26025–PC); foraminifers of Mamet Zone 25 or younger and the conodonts *Idiognathodus sinuosis*, *Adetognathus lautus*, and *Hindeodus minutus* 5 ft above base (USGS 26026–PC, BAH–4); foraminifers of Mamet Zone 25 or younger a foot below top (USGS 26027–PC) ---------	12.0	3.7

	Thickness Feet	Thickness Meters
17. Dolomitic limestone; medium crystalline; weathers yellowish gray to grayish orange; beds 0.5–2 ft thick; forms cliffy slope	11.0	3.4
Measured thickness of Casper Formation above Darwin Sandstone Member	36.5	11.2
Darwin Sandstone Member:		
16. Quartz sandstone; fine-grained; calcareous; weathers white to grayish orange; poorly bedded, beds 0.2–4 ft thick; grades into unit above; prominent cliff-former. Barren conodont sample USGS 26024–PC from lower foot	13.0	4.0
Total thickness of Darwin Sandstone Member	13.0	4.0
Measured thickness of Casper Formation (incomplete)	49.5	15.2
Madison Limestone:		
Little Tongue Member:		
15. Biomicrite, pelsparite, oomicrite, and oosparite; crinoidal; olive gray weathering medium light gray; beds 0.5–2 ft thick; entire unit is collapse breccia consisting of blocks as much as several feet in diameter in red fine-grained quartz sandstone matrix. Spiriferoid brachiopods in lower 20 ft (USGS 26022–PC 15 ft above base) and foraminifers of Mamet Zone 9? 2 ft below top (USGS 26023–PC)	35.0	10.7
14. Covered; rubble of limestone from above; lower solution zone probably represented in lower part of unit, but no solution breccia seen in float	30.0	9.2
Total thickness of Little Tongue Member	65.0	19.9
Big Goose Member:		
13. Dolomicrite; weathers yellowish gray; some beds laminated; beds irregular, 0.3–1 ft thick; about 20 percent brown chert lenses; poorly exposed	18.0	5.5
12. Dolomicrite and micrite, interbedded; about 50 percent of each; like unit 10; about 10 percent brown chert lenses; poorly exposed	10.0	3.1
11. Micrite; partly dolomitized; olive gray weathering medium light gray; crinoidal; beds regular, 0.5–1 ft thick; about 5 percent brown chert lenses; forms ledge in slope. Indeterminate brachiopods 3 ft above base (USGS 26020–PC); barren foram sample from upper foot (USGS 26021–PC)	14.0	4.3
10. Limestone and dolomite, interbedded; like unit 9 but not brecciated although some beds are shattered; about 5 percent chert; about 90 percent covered on slope	15.0	4.6
9. Micrite and pelsparite; olive gray weathering medium light gray; about 5 percent interbedded dolomite and dolomitic limestone, as in unit 7; beds 0.5–2 ft thick; brecciated mostly in lower half (matrix is fine-grained carbonate); about 5 percent irregular brown chert. Barren foram samples 2 ft about base (USGS 26018–PC) and 3 ft below top (USGS 26019–PC)	15.0	4.6
8. Covered and predominantly fine-grained limestone float, some dolomite	15.0	4.6
7. Dolomitic limestone and dolomite; predominantly medium crystalline; weathers yellowish gray to grayish orange; some fine-grained beds weather yellowish gray to pale red like those in unit 5; beds 0.3–1 ft thick; about 5–10 percent irregular brown chert; some beds appear to be crossbedded; beds shattered and brecciated in upper half. A few beds contain poorly preserved brachiopods; silicified *Vesiculophyllum* sp. 15 ft above base; barren conodont sample USGS 26017–PC 15 ft above base	65.0	19.8
6. Dolomicrite; silty; laminated; weathers pale red with grayish yellow streaks; beds nodular to regular, 0.3–1 ft thick; about 5 percent varicolored chert in thin stringers and small nodules; about 90 percent covered on slope. *Patrognathus andersoni*, *Siphonodella* advanced sp., *Pandorinellina* n. sp. (Pa element), *P. plumula*, *Hindeodus* cf. *H. cristulus*, *Bispathodus stabilis*, and *Polygnathus inornatus* from lower foot (USGS 26013–PC); barren conodont samples 25 and 47 ft above base and from upper foot (USGS 26014—26016–PC)	54.0	16.5
Total thickness of Big Goose Member	206.0	63.0
Total thickness of Madison Limestone	271.0	82.9
Englewood Formation:		
5. Dolomite; predominantly fine-grained; sandy; weathers yellowish gray with pale red streaks; beds 0.3–0.5 ft thick; poorly exposed; same bed as unit 9 at Banner Mountain. Disconformity at base of unit marks base of Mississippian	1.7	0.5
4. Quartz sandstone; coarse- to very coarse-grained; weathers white to moderate red; beds regular, 0.3–0.5 ft thick; poorly exposed. Barren conodont sample USGS 26012–PC 3 ft below top	5.0	1.5

	Thickness Feet	Thickness Meters
3. Quartz siltstone and very fine-grained sandstone with scattered medium sand; platy; weathers pale red; exposed in trench. Barren conodont sample USGS 26011–PC 2 ft above base	5.0	1.5
2. Clay shale; silty; weathers grayish red; exposed in trench. Barren conodont sample USGS 26010–PC	1.0	0.3
Total thickness of Englewood Formation	12.7	3.8
Precambrian granite:		
1. Granite; pink; equigranular; containing pegmatite veins; feldspars kaolinitized in upper 2–3 ft; relief on top not measurable; top exposed in trench.		

BOX ELDER CANYON SECTION

Section begins near bottom of gorge at top of Precambrian granite (figs. 15, 16) exposed at altitude 5,950 ft in N1/2NE1/4 sec. 13, T. 32 N., R. 75 W., Converse County (fig. 17). Access to section is along jeep trail leading north from ranch house located just east of west boundary and on north boundary of SE1/4 sec. 24. The ranch house is reached by dirt road that intersects Box Elder Road in NW1/4 sec. 25. Section was measured with Jacobs staff and steel tape. The Paleozoic sequence is well displayed in the walls of the canyon. (fig. 18).

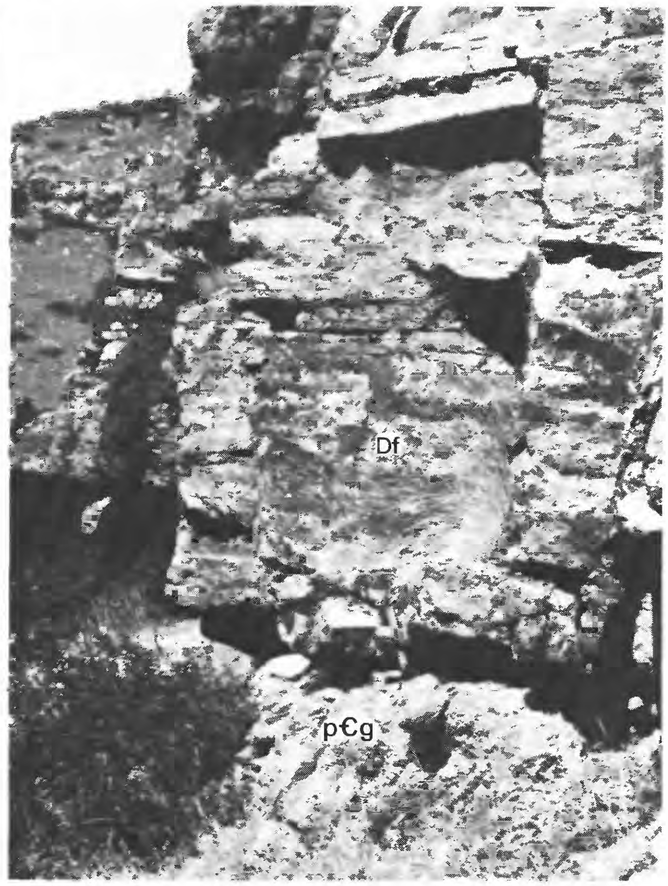


FIGURE 15.—Fremont Canyon Sandstone (Df) resting on Precambrian granite (p€g) at Box Elder Canyon section. Hammerhead rests on top of granite.

	Thickness Feet	Thickness Meters
Casper Formation:		
25. Quartz sandstone; like unit 23. Barren conodont sample USGS 26044–PC from lower foot. Section terminates in cliff; more section is exposed for about 100 ft in notch in cliff to top of cliff	19.0	5.8
24. Dolomitic limestone; like unit 20	2.0	0.6
23. Quartz sandstone; like unit 21; beds 0.3–2 ft thick. Barren conodont sample USGS 26043–PC from lower foot	4.0	1.2
22. Dolomitic limestone; like unit 20; some pink stain	14.0	4.3
21. Quartz sandstone; fine-grained; weathers pale red; crossbedded. Barren conodont sample USGS 26042–PC	3.0	0.9
20. Dolomitic limestone; medium crystalline; contains some bioclastic debris; pockmarked; weathers yellowish gray; beds irregular, 0.3–0.5 ft thick	7.5	2.3
Measured thickness of Casper Formation above Darwin Sandstone Member (incomplete)	49.5	15.1
Darwin Sandstone Member:		
19. Quartz sandstone; fine-grained; calcareous; laminated; ripplemarked; weathers moderate pink	4.0	1.2
18. Quartz sandstone; fine-grained; weathers white to moderate red (white and brown in lower third, middle third covered, red in upper third); crossbedded, beds 0.3–2 ft thick. Barren conodont sample USGS 26041–PC 50 ft above base	56.0	17.1
Total thickness of Darwin Sandstone Member	60.0	18.3
Measured thickness of Casper Formation (incomplete)	109.5	33.4
Madison Limestone:		
Little Tongue Member:		
17. Dolomite; fine-grained to medium crystalline; weathers yellowish gray; some beds laminated, some crossbedded; beds 0.5–1 ft thick; bioclastic (brachiopods); entire unit is riddled with solution cavities following vertical and horizontal joints and filled with fine-grained calcareous quartz sand-		

FIGURE 16.—Precambrian granite (p€g), Fremont Canyon Sandstone (Df), Englewood Formation (MDe), and Big Goose Member of Madison Limestone (Mmbg) at Box Elder Canyon section.

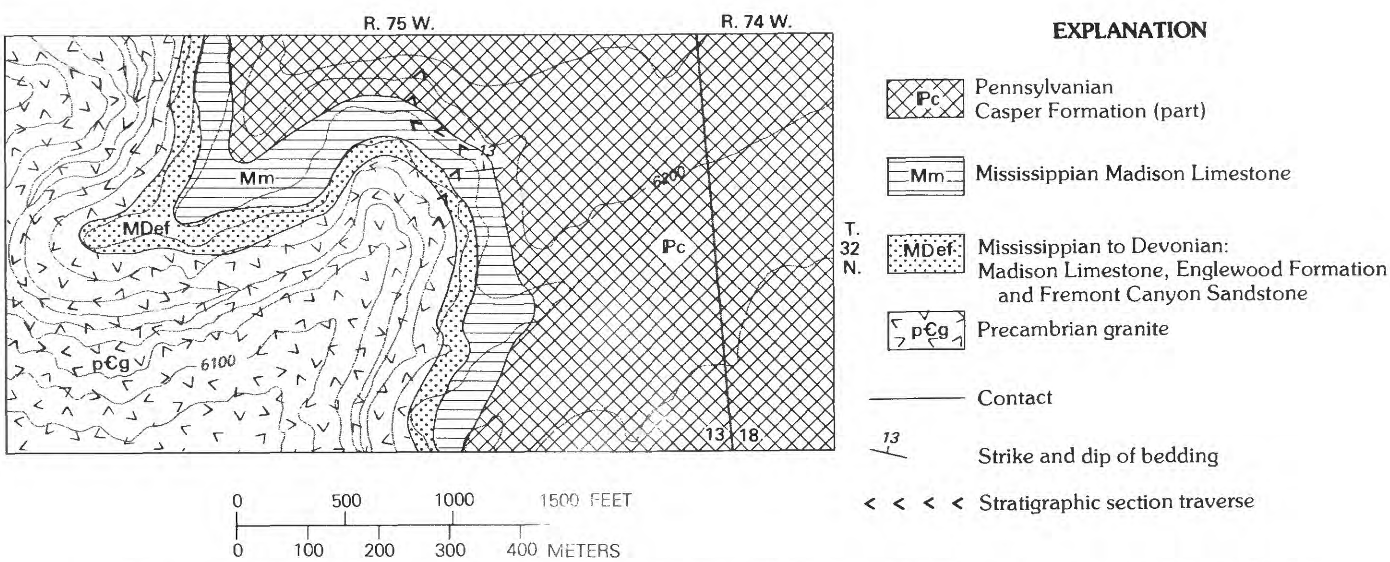


FIGURE 17.—Geologic sketch map of Box Elder Canyon section. Base from Root Creek 7.5′ quadrangle. Contour interval is 100 feet.

	Thickness Feet	Thickness Meters
stone weathering moderate red. Traverse offset about 70 yds west at top of unit to better outcrops of overlying units ----------------------------	16.0	4.9

	Thickness Feet	Thickness Meters
16. Limestone collapse breccia; micrite, biomicrite, intrasparite, and oosparite; olive gray weathering medium light gray; beds regular, 0.5–1 ft		

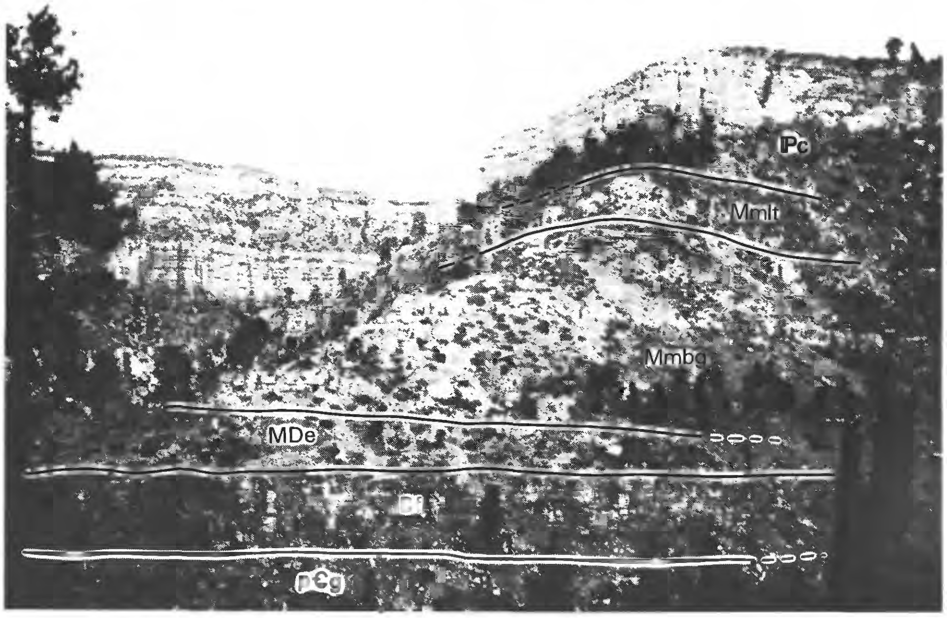


FIGURE 18.—Precambrian granite (pЄg); Fremont Canyon Sandstone (Df); Englewood Formation (MDe); Big Goose (Mmbg) and Little Tongue (Mmlt) Members of Madison Limestone; and Casper Formation (IPc) exposed in east wall of Box Elder Canyon near section traverse.

	Thickness *Feet*	*Meters*
thick; entire unit is brecciated into large blocks; matrix is fine-grained calcareous quartz sandstone weathering light red; where bedded, bedding is undulant; about 10 percent brown chert nodules and stringers. Large spiriferoid brachiopods throughout (USGS 26040–PC from 10 ft above base) ----------------------------	30.0	9.2
15. Limestone solution breccia; angular clasts of micrite (olive gray weathering medium light gray) in matrix of fine-grained calcareous quartz sandstone weathering light red; clasts mostly 0.2 ft or less in diameter, some up to 2 ft. Upper part of lower solution zone -----------------------------	11.0	3.4
14. Dolomite solution breccia; angular clasts of fine-grained dolomite weathering yellowish gray in matrix of calcareous siltstone weathering grayish orange; clasts mostly 0.1 ft or less in diameter, some up to 1 ft; about 5–10 percent brown chert clasts; at top is an irregular lens of fine-grained quartz sandstone weathering white to dark yellowish orange filling a solution cavity 4 ft high and 30 ft wide; another smaller lens at base. Lower part of lower solution zone ---------------	28.0	8.5
Total thickness of Little Tongue Member -	85.0	26.0

	Thickness *Feet*	*Meters*
Big Goose Member:		
13. Dolomite; like unit 11; mostly shattered; about 20–30 percent brown chert mostly in stringers; poorly exposed in lower half, cliffy in upper half ------	60.0	18.3
12. Covered; fine-grained to medium crystalline dolomite in float -----------	10.0	3.1
11. Dolomite; fine-grained to medium crystalline; shattered; weathers yellowish gray; beds 0.3–0.5 ft thick; about 30 percent irregular networks and sheets of brown chert; a lens of fine-grained quartz sandstone weathering dark yellowish orange in solution cavity 1.5 ft high and 5 ft wide 5 ft below top -	25.0	7.6
10. Dolomitic limestone and dolomite; interbedded fine- and medium-grained; bioclastic (molds and casts of brachiopods); weathers yellowish gray; beds mostly regular, 0.1–1 ft thick; some coarse-grained beds having small-scale crossbedding; unit forms cliffs ----------------------------	19.0	5.8
9. Pelbiosparite; algal (cysts); olive gray weathering medium light gray; beds regular, 0.5–2 ft thick. Barren foram sample USGS 26039–PC 3 ft above base; lower part of cliff -----------	7.0	2.1
8. Dolomite; fine-grained; weathers yellowish gray; crossbedded, beds 0.3–1 ft thick. Barren conodont sample from upper foot (USGS 26038–PC) ------	5.0	1.5

	Thickness Feet	Thickness Meters
7. Dolomicrite; silty; with rare layers of bioclastic debris; weathers yellowish gray; many beds laminated; beds regular to irregular, 0.3–1 ft thick; about 10 percent small, irregular, moderate-red nodules and stringers of chert in lower half. Undetermined brachiopods from lower foot (USGS 26037–PC) --	34.0	10.4
6. Dolomitic limestone; medium- to coarse-grained; bioclastic (molds and casts); weathers yellowish gray; crossbedded, beds 0.5–1 ft thick ----------------	3.0	0.9
5. Covered and rubble from above; fine-grained dolomite in place at top ----	10.5	3.2
Total thickness of Big Goose Member -----	173.5	52.9
Total thickness of Madison Limestone --------	258.5	78.9
Englewood Formation:		
4. Quartz sandstone; predominantly coarse- to very coarse-grained, with some pebbles up to 5 mm in diameter; calcareous; friable to hard; weathers white to pale red; crossbedded, beds 0.3–0.5 ft thick; thin beds of quartz siltstone like unit 3, 2 ft above base. *Polygnathus experplexus* and *P*. sp. 2 ft above base (USGS 26036–PC) ------	9.0	2.8
3. Covered and a few outcrops of platy calcareous quartz siltstone and fine-grained sandstone weathering pale red to moderate red; entire interval seems to be of this lithology; outcrops mostly in lower half. Barren conodont sample USGS 26035–PC from lower foot ----------------------------	24.0	7.3
Total thickness of Englewood Formation ------	33.0	10.1
Fremont Canyon Sandstone:		
2. Quartz sandstone; predominantly coarse- to very coarse-grained with thin lenses containing pebbles up to 15 mm in diameter at base; friable to hard; weathers white to moderate brown; crossbedded, beds 0.2–2 ft thick; some beds have greenish-weathering shaly partings; forms massive cliff. Barren conodont samples from lower foot (USGS 26029–PC), from 10, 21.5, 30, 40 ft above base (USGS 26030—26033–PC), and from upper foot (USGS 26034–PC) ------	48.0	14.6
Total thickness of Fremont Canyon Sandstone ------------------------------------	48.0	14.6
Precambrian granite:		
1. Granite; pink; equigranular; kaolinized feldspars in upper 3 ft; about 2 ft of relief on top.		

HARTVILLE CANYON SECTION

Section is located on south-facing nose immediately east of North Platte River below Guernsey Reservoir in $S^{1}/_{2}NE^{1}/_{4}$ sec. 27, T. 27 N., R. 66 W., Platte County. Section begins at or near base of Fremont Canyon Sandstone at base of nose (Precambrian granite is exposed in draw just east of nose) and proceeds westward up nose to top of Madison Limestone exposed on dipslope. Access to section is by dirt road leading westward from main road up Hartville Canyon. Section measured with steel tape. No samples were collected here.

This section location appears to be at or very near the location described by Smith (1903, p. 2) as representative of the Guernsey Formation, which included all the beds from the top of the Precambrian granite to the base of the Hartville Formation. We regard the section as the type section of the Guernsey Formation.

	Thickness Feet	Thickness Meters
Hartville Formation:		
Darwin Sandstone Member:		
12. Quartz sandstone; fine- to medium-grained; weathers red; crossbedded; rests unconformably on unit below; at least 25 ft exposed (not measured).		
Madison Limestone:		
Little Tongue Member:		
11. Limestone, fine- to medium-grained, and dolomite, medium crystalline; cherty; dolomite is in lower 10 ft only; medium-bedded; red-weathering siltstone and sandstone fills solution cavities following vertical and horizontal joints; forms cliffy outcrop ---------	29.0	8.9
Total thickness of Little Tongue Member -	29.0	8.9
Big Goose Member:		
10. Dolomite; fine-grained; silty, shattered; weathers yellowish; thin-bedded; top irregular -------------------------	3.0	0.9
9. Dolomitic limestone; fine-grained; weathers yellowish; shattered and contorted; contains red siltstone and sandstone solution cavity fillings ---	5.5	1.7
8. Limestone; fine-grained; weathers pink and gray; passes laterally into coarse-grained dolomitic limestone; single bed ------------------------------	4.0	1.2
7. Dolomitic limestone; fossiliferous; medium-bedded; laminated; weathers yellowish ------------------------	11.0	3.4
Total thickness of Big Goose Member -----	23.5	7.2
Total thickness of Madison Limestone --------	52.5	16.1
Englewood Formation:		
6. Quartz siltstone; calcareous; platy; weathers purplish -----------------	5.0	1.5

	Thickness Feet	Meters
5. Quartz siltstone; predominantly calcareous, some beds dolomitic; some beds oolitic; weathers yellowish; beds regular, thin	11.0	3.4
4. Quartz siltstone; calcareous; thin-bedded; weathers yellowish	5.0	1.5
3. Quartz siltstone and fine-grained sandstone; thin- to medium-bedded; weathers red. Silicified brachiopods and rare *Vesiculophyllum* sp.	5.0	1.5
2. Quartz siltstone; calcareous; thin-bedded; weathers yellowish	6.5	2.0
Total thickness of Englewood Formation	32.5	9.9
Fremont Canyon Sandstone:		
1. Quartz sandstone; coarse- to very coarse-grained; weathers brown; crossbedded	6.0	1.8
Total thickness of Fremont Canyon Sandstone	6.0	1.8

Precambrian granite:
Granite; pink; equigranular; exposed in draw east of traverse.

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