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Abstract approved: Signature redacted for privacy.
Dr. David A. Bostwick

The Pennsylvanian rocks in south-central Idaho and adjacent areas consist of three main facies: a platform facies, a shelf facies, and a marginal basin facies. The platform facies is represented by the Amsden, Quadrant, and Tensleep Formations, in southwestern Montana and western Wyoming, and contain Middle and probably Lower Pennsylvanian strata. The shelf facies is represented by the Pennsylvanian part of the White Knob Limestone, which extends from the Lemhi Range to the White Knob Mountains west of the Lost River Range in south-central Idaho, and contains Lower, Middle, and Upper Pennsylvanian strata. The marginal basin facies is represented by clastics of the Middle and Upper Pennsylvanian part of the Wood River Formation, in the Wood River region in south-central Idaho, and the Lower, Middle, and Upper Pennsylvanian part of the Wells Formation in southeastern Idaho.

Broad epeirogenic upwarps or eustatic sea level caused the shelf and platform to be alternately positive and negative during Pennsylvanian time. Pennsylvanian seas reached maximum inundation during Desmoinesian time after which a temporary offlap developed during Missourian through Middle Virgilian time on the platform and shelf areas, and epicontinental seas were restricted to the Wells and Wood River basins. During Late Virgilian time the seas spread to the east over former areas of post-Desmoinesian erosion on the shelf area.

Generalized isopachous and lithofacies maps of Pennsylvanian time-stratigraphic units are presented, with interpretations of the positions and periods of activity of positive and negative elements.

Pennsylvanian Stratigraphy in South-Central Idaho and Adjacent Areas

by

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The writer is particularly grateful to his wife, Emy, who assisted him in the field and in preparation of the manuscript.

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INTRODUCTION

Locations and Accessibility

The Bellevue area includes approximately 20 square miles east of Bellevue in parts of T. 1, 2 N., R. 19 E., in central Blaine County, Idaho (Figure 1). This area lies in the Big Wood River Valley, in the western part of the Pioneer Mountains.

The Muldoon County Road provides general access to the area. Unimproved jeep trails are passable and contribute to the accessibility of the area.

The Cedar Canyon area includes 7.5 square miles in parts of T. 7 N., R. 30 E., in northeastern Butte County, Idaho (Figure 1). This area lies on the eastern flank of the Lemhi Range. Numerous unimproved U. S. Forest Service Roads and jeep trails west of State Highway 28 provide access to the area.

The Railroad Canyon area includes parts of T. 16 N., R. 27, 28 E., approximately 8 miles northeast of Leadore, Idaho, to which State Highway 29 provides access. No mapping was done in the area, but the Quadrant Formation was measured along the east and west sides of Railroad Canyon.

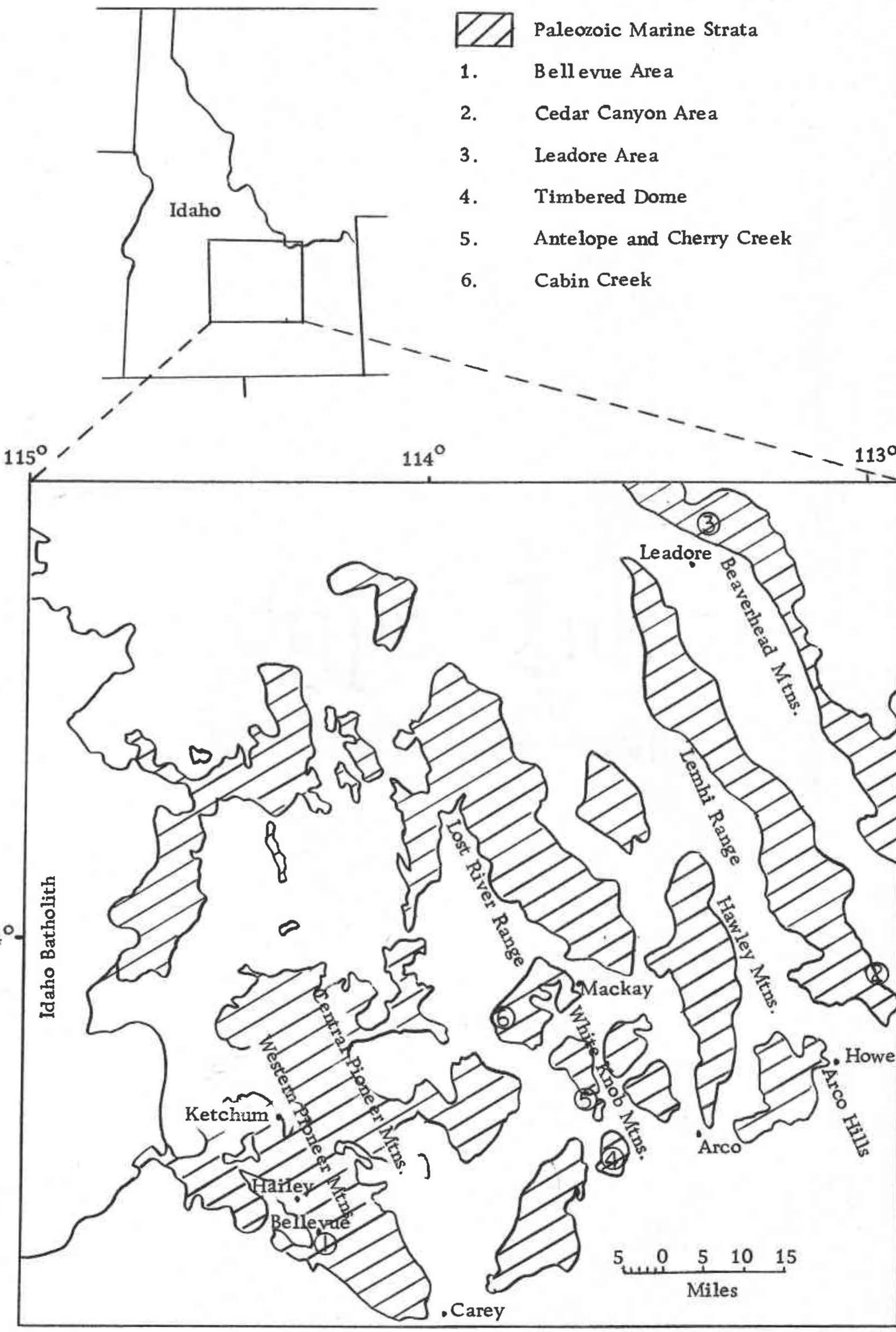


Fig. 1. Index map showing locations of referenced and thesis areas.

Previous Work

Upper Paleozoic rocks of the central Pioneer Mountains were studied by Anderson (1929), Anderson and Wagner (1946), Thomasson (1959), Ross (1960, 1962a), Nelson and Ross (1969), and Paull *et al.*, (1972). In the Big Wood River Valley of the western part of the Pioneer Mountains, Upper Paleozoic rocks were studied by Lindgren (1900), Umpleby *et al.*, (1930), Bostwick (1955), Thomasson (1959), and Roberts and Thomasson (1964).

In the White Knob Mountains, Lost River Range, Hawley Mountains, and the Lemhi Range, Upper Paleozoic rocks have received considerable study by Umpleby (1917), Ross (1947), Thomasson (1959), Ross (1961, 1962b), Shannon (1961), Skipp (1961 a, b). Mapel *et al.*, (1965), Sandberg *et al.*, (1967), Nelson and Ross (1969), Skipp and Mamet, (1970), and Mamet *et al.*, (1971).

Purpose, Scope, and Methods

The purpose of this study is to obtain and understanding of the stratigraphic relationship between time equivalent strata throughout a region in south-central Idaho and western Montana. The recognition of lateral shifts of facies boundaries through time is necessary for the reconstruction of geologic history.

Eight weeks were devoted to field work during the summer of 1971, during which time field work was concentrated on Pennsylvanian strata, which were mapped, measured, described, and sampled. Geologic data, obtained from ground traversed, were plotted on low-altitude, vertical aerial photographs at a scale of 1:20,000. Due to incomplete coverage by topographic sheets of the Bellevue area, a base map was prepared from aerial photographs. Three stratigraphic sections of Pennsylvanian strata were measured using Jacob's staff mounted with an Abney level.

All sandstones are classified according to Gilbert's (1954) classification. The term "siliceous sandstone" is used for sandstones cemented by silica. Very fine-grained clastic sediments are classified using Ingram's (1953) classification. The limestones are classified using Folk's (1959) classification of carbonate rocks. Throughout the report, references to roundness of sedimentary particles are based on visual comparison with the chart prepared by Powers (1953). McKee and Weir's (1953) classification and nomenclature of stratification and cross-stratification are used in describing bedding characteristics.

Stratigraphic Setting

Churkin (1962) pointed out that the Lower and Middle Paleozoic sediments in south-central Idaho were deposited in a generally stable miogeosyncline. Deformation associated with the Antler orogeny began in the Late Devonian, disrupting the miogeosynclinal pattern and replacing the craton as a principal source of detrital sediment in south-central Idaho, which apparently included thrusting of Lower and Middle Paleozoic eugeosynclinal rocks from the west over miogeosynclinal rocks to the east, and brought to a close eugeosynclinal deposition in south-central Idaho (Churkin, 1962). The Upper Paleozoic sediments were deposited, in part, in basins related to this regional tectonism.

The Milligen Formation, a time-transgressive clastic wedge of Late Devonian and Early Mississippian age, thins eastward from the Wood River region and is recognized throughout south-central Idaho. In the Pioneer Mountains the Milligen consists predominently of argillite, and calcareous and siliceous quartz arenites. The Late Devonian (?), Early and Late Mississippian Copper Basin Group (Paull et al., 1972), which includes the Milligen Formation at its base in the central Pioneer Mountains, is approximately 17,000 feet thick, and apparently represents a coarse clastic synorogenic sequence consisting of conglomerate, sandstone, shale, and limestone. Eastward, the Copper Basin Group intertongues with approximately 5000 feet of finer clastic rocks and limestones represented by the Mississippian part of the White Knob Limestone (Skipp and Mamet, 1970) in the White Knob Mountains. Sediments of the Copper Basin

Group were apparently derived from the emergent Antler orogenic belt in the area now occupied by the Idaho Batholith. The Mississippean sequence is essentially correlative with the Diamond Peak Formation, Chainman Shale, Pilot Shale, and Joanna Limestone in east-central Nevada.

The Pennsylvanian rocks in south-central Idaho consist of three main facies: a platform facies, a shelf facies, and a marginal basin facies.

The platform facies consists of the Quadrant sandstones, with subordinate limestone and dolomite, present in the eastern Idaho Beaverhead Mountains and throughout southwestern Montana. The shelf facies is represented by limestones of the Pennsylvanian part of the White Knob Limestone which extends in south-central Idaho from the Lemhi Range to the White Knob Mountains west of the Lost River Range near Mackay. The marginal basin facies is represented by clastics of the Wood River Formation in the Wood River Region of the western Pioneer Mountains, and the Wells Formation in southeastern Idaho.

Permian strata are present in the shelf facies (White Knob Limestone), and in the basin facies (Wells and Wood River Formations), conformably overlying the Pennsylvanian strata. The Permian Phosphoria Formation disconformably overlies the platform facies (Quadrant Formation) in southwestern Montana.

Figure 2 is a stratigraphic nomenclature chart showing the approximate time relations of principal stratigraphic units referred to in this study.

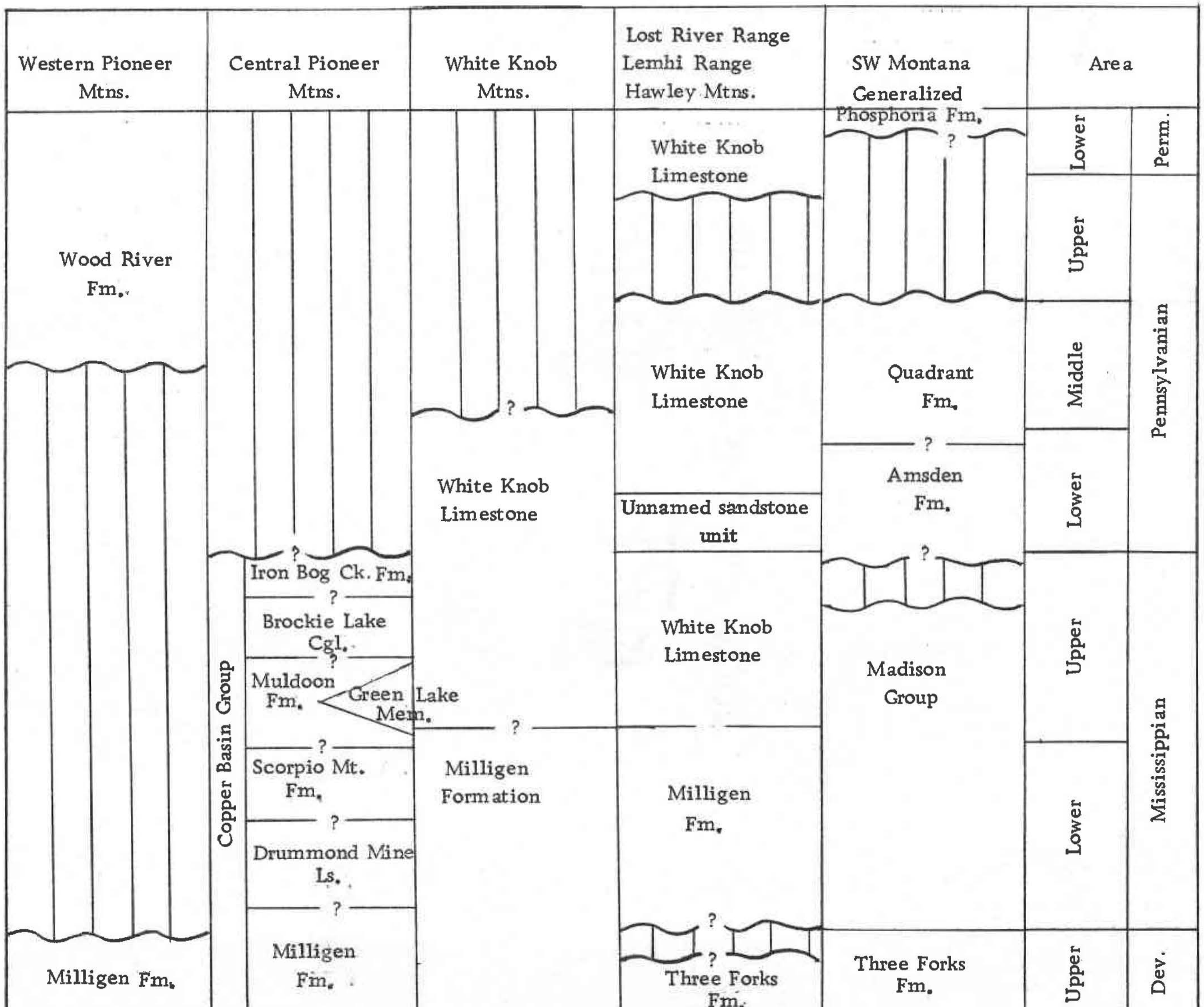
Regional Structure

The geologic structure in south-central Idaho is characterized by folds and thrusts upon which basin-and-range type block faulting is superimposed. The regional structural trend of the Paleozoic rocks is generally north-northwest and is expressed in both folding and thrusting, which suggests west-to-east movements.

Mesozoic thrusting in the Pioneer Mountains has displaced the Upper Paleozoic rocks. The Copper Basin Group has apparently been thrust eastward into juxtaposition with the Paleozoic rocks of the White Knob Mountains, and the Wood River and Milligen Formations have apparently been thrust into juxtaposition with the Copper Basin Group (Figure 3), (Dover, in Paull et al., 1972).

The folding in south-central Idaho can be dated no closer than post-Permian to pre-Late Cretaceous. The thrusting in the area seems to be of about the same age as the folding. Deformation of this general age is ascribed to the Laramide orogeny, which took place in the later part of Mesozoic time (Nelson and Ross, 1969).

Figure 2. Correlation chart of strata in the study area.



Western Pioneer Mtns.
Central Pioneer Mtns.
White Knob Mtns.
Lost River Range
Lemhi Range
Hawley Mtns.
SW Montana Generalized
Area
Wood River Fm.
Milligen Fm.
Iron Bog Ck. Fm.
Brockie Lake Cgl.
Muldoon Fm.
Green Lake Mem.
Scorpio Mt. Fm.
Drummond Mine Ls.
Milligen Fm.
Copper Basin Group
White Knob Limestone
Milligen Formation
White Knob Limestone
White Knob Limestone
Unnamed sandstone unit
White Knob Limestone
Milligen Fm.
Three Forks Fm.
Phosphoria Fm.
Quadrant Fm.
Amsden Fm.
Madison Group
Three Forks Fm.
Lower
Perm.
Upper
Middle
Lower
Pennsylvanian
Upper
Lower
Mississippian
Upper
Dev.
?

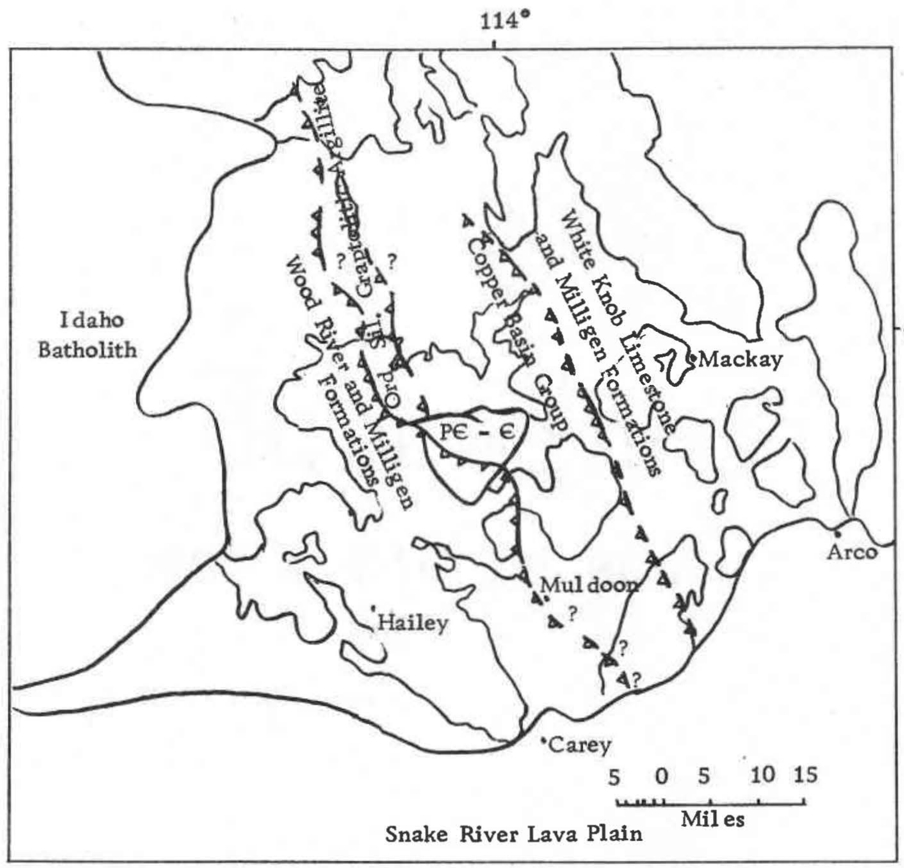


Fig. 3. Relationship of Upper Palezoic strata in the western and central Pioneer Mountains and White Knob Mountains (after Paull et al., 1972).

PLATFORM FACIES

Quadrant Formation, Railroad Canyon

Definition

The name "Quadrant Formation" was first used in the Three Forks, Montana area by Peale (1893) for strata between the underlying Madison Limestone and the overlying Jurassic Ellis Formation. Quadrant Quartzite was applied by Weed (1896) and by Iddings and Weed (1899) at it's type section on Quadrant Mountain in the northwestern part of Yellowstone National Park. The concept of Peale's Quadrant was widely used, rather indiscriminately for a time, in western and central Montana. Subsequently these strata have been divided in this region into the Big Snowy Group, Amsden Formation, Quadrant Formation (Scott, 1935), and the Phosphoria Formation. Current Pennsylvanian nomenclature in western and southwestern Montana include the Amsden and Quadrant Formations. In central Montana, Pennsylvanian nomenclature includes Amsden equivalents, the Tyler and Alaska Bench Limestones, as well as the Quadrant equivalent, the Devil's Pocket Formation.

Distribution and Thickness

The Quadrant Formation is a widespread stratigraphic unit in western and southwestern Montana. It ranges in thickness over the area, from zero, 35 miles northeast of Three Forks, Montana, to 2400 feet 140 miles to the southwest in the Lima area, near the Idaho-Montana divide (Sloss and Moritz, 1951). It is 230 feet thick at the type section on Quadrant Mountain. The Quadrant Formation is in conformable and transitional contact with the underlying Amsden Formation (Sloss and Moritz, 1951). The Amsden is not everywhere present with the Quadrant. Scott (1935) described the widespread occurrence of the Amsden in south-central and southwestern Montana, and showed how the Amsden ends in a wedge edge in the vicinity of Three Forks, Montana.

The great east-to-west increase in thickness of the Quadrant is probably due to eastward transgressive epicontinental seas during Early Pennsylvanian time, reaching maximum inundation during the Middle Pennsylvanian, thus creating a wedge of cratonically derived clastics thinning to the east. The thickness variations are also partly due to post-Desmoinesian erosion on tectonically positive areas.

Traced toward Idaho, the Quadrant is believed to interfinger with the Pennsylvanian part of the White Knob Limestone in the southern Lemhi Range, Lost River Range, and Hawley Mountains, where it is apparently represented as a basal unnamed sandstone unit.

Lithology and Petrography

Sloss and Moritz (1951) described the Quadrant as a monotonous succession of sandstones with only a few thin dolomite and limestone interbeds in the average section. Scott (1935) pointed out that the limestone component increased westward and emphasized the marine origin of the formation. Sloss (1950) described the cementation as highly irregular, varying vertically and horizontally with abrupt lateral variation from a high degree of cementation by silica to almost complete friability color ranges from white to cream and light yellow, and weathered surfaces are characteristically rusty brown.

The Quadrant Formation at Railroad Canyon has been subdivided into three units: a lower sandstone unit, a middle limestone unit, and an upper sandstone unit, each making up approximately one third of a 1300 foot section (Ruppel, 1968).

The writer measured the Quadrant section to be approximately 1500 feet thick in Railroad Canyon. The discrepancy between Ruppel's measurement of thickness and that which the writer obtained is perhaps partly due to the difference of locations in traverses to obtain the best exposures of the section. The lower most beds of the Quadrant are covered, but an abrupt lithologic change from limestone to siliceous quartz arenite may indicate a sharp contact with the underlying Madison Group. The upper contact (Figure 4) is sharp and

Figure 4. Contact between the upper sandstone unit of the Quadrant Formation and the overlying Grandeur Member of the Phosphoria Formation, east of Salt Creek, Railroad Canyon.

slightly undulatory and was arbitrarily placed by the writer above the highest calcareous quartz arenite bed and overlying dolomites that have been assigned by Ruppel to the Grandeur Member of the Phosphoria Formation.

Lower Sandstone Unit

The lower 545 feet of the formation is thick-bedded to massive, medium- to coarse-grained siliceous quartz arenite which includes minor interbedded limestone and dolomite in the lower 25 feet. In the upper 100 feet some beds are very thinly cross-bedded.

The quartz grains are well cemented by secondary quartz, which has completely removed all initial porosity in many places. The secondary quartz occurs as optically continuous overgrowths on detrital grains. Commonly, sutures between quartz grains are well developed. In composition, the quartz arenites vary from 70 to 80 percent quartz, well-sorted and well-rounded, with less than 1 percent accessory minerals of zircon, green hornblende, sphene, chert, plagioclase, and white opaque material. Silica (20 to 28 percent) and sparry calcite (2 percent) are the cementing agents.

The interbedded dolomites are a finely crystalline mosaic, consisting of 99 percent dolomite and 1 percent silt-sized detritus of quartz.

The interbedded limestones are thick-bedded (1 to 3 feet), sandy, sparse, mixed biomicrites, consisting of 50 percent micrite, 40 percent skeletal fragmental debris composed of algae, crinoid columnals, brachiopods, bryozoans, and tabulate corals.

The upper contact was placed above the highest massive siliceous quartz arenite bed, which is gradational with the overlying limestone unit through a thickness of about 50 feet.

Middle Limestone Unit

The characteristic lithology of the middle limestone unit is cherty limestone, cherty dolomite, limestone with intercalated shale, minor poorly fissile black (N1) mudstone, and interbedded, very thinly cross-bedded calcareous quartz arenites. The rocks of the member range from thin-bedded to thick-bedded, but beds are generally 1 to 2 feet thick.

Chert nodules and thin lenticular chert are common in the dolomite and limestone beds (Figure 5); some beds contain up to 30 percent chert in this form.

The limestones vary from rounded biosparites at or near the base, to cherty micrite with intercalated shale, and sandy, sparse, and packed biomicrites. Fossil debris consists of bryozoans, foraminifers, brachiopods, crinoid columnals and plates, tabulate corals, algae, and echinoid spines, and 3 to 15 percent quartz

Figure 5. Nodular chert in the middle limestone unit of the Quadrant Formation, Railroad Canyon.

detritus. Accessory minerals (1 to 2 percent) include plagioclase, green hornblende, muscovite, zircon, and sphene. Calcite usually replaces quartz, leaving irregular grain boundaries, but quartz frequently exhibits euhedral grain boundaries owing to secondary overgrowths. Micrite commonly recrystallizes to microspar. Many of the limestones are dolomitic, the dolomite being in the form of euhedral rhombohedra.

The dolomite beds are generally thin-bedded, with very thin-bedded intercalated shale at bedding interfaces. In thin section, the dolomites consist of a mosaic of medium- to finely-crystalline dolomite and includes 3 to 12 percent detritus consisting of quartz, and accessory minerals including zircon, plagioclase, hornblende, and muscovite. Fossil material is rare and occurs as fossil "ghosts." Vugs are rarely developed in the dolomite.

The quartz arenites are observed to be cemented by calcite and dolomite in amounts between 40 to 47 percent. Quartz makes up 50 to 58 percent of the rock. Detrital grains are well-sorted and rounded. Accessory minerals (2 to 3 percent) include zircon, chert, polycrystalline quartz, hornblende, plagioclase, microcline, sphene, and muscovite.

The contact with the overlying upper sandstone unit is gradational and was placed at the base of the lowest massive dolomitic quartz arenite bed of the upper sandstone unit.

Upper Sandstone Unit

Characteristic lithology consists of thick- to thin-bedded sandy colomites with intercalated shales, calcareous and dolomitic quartz arenites. Fossil material is rare and poorly preserved.

The sandy dolomites consist of 10 to 45 percent quartz detritus and 55 to 85 percent coarse mosiac of dolomite. Accessory minerals (1 to 3 percent) include zircon, hornblende, plagioclase, muscovite, sphene, and white opaque material. Fossils include gastropods, crinoid columnals, bryozoans, and echinoid spines. Vugs up to 1 to 2 percent of volume are developed.

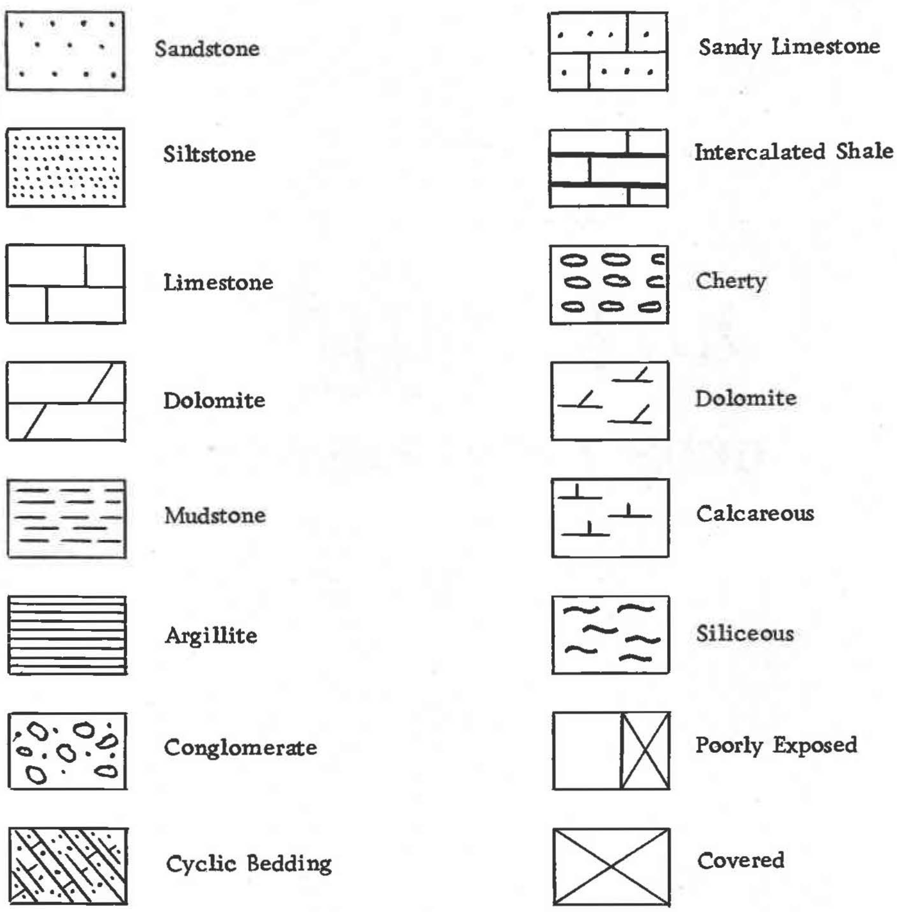
The calcareous and dolomitic quartz arenites are well-sorted and medium- to fine-grained. The cementing material ranges from 10 to 50 percent in the rocks.

The Quadrant Formation was measured along the east and west sides of Railroad Canyon in sections 7 and 8, T. 16 N., R. 27 E., and sections 29 and 32, T. 16 N., R. 28 E. (see Figure 6 a,b,c). The Appendix includes a detailed written description.

Age and Correlation

Fusulinids were collected from the middle limestone unit of the Quadrant Formation at Railroad Canyon and were identified by D. A. Bostwick (oral communication) as Pseudostaffella?, Profusulinella,

Lithologic Symbols Used in Columnar Sections



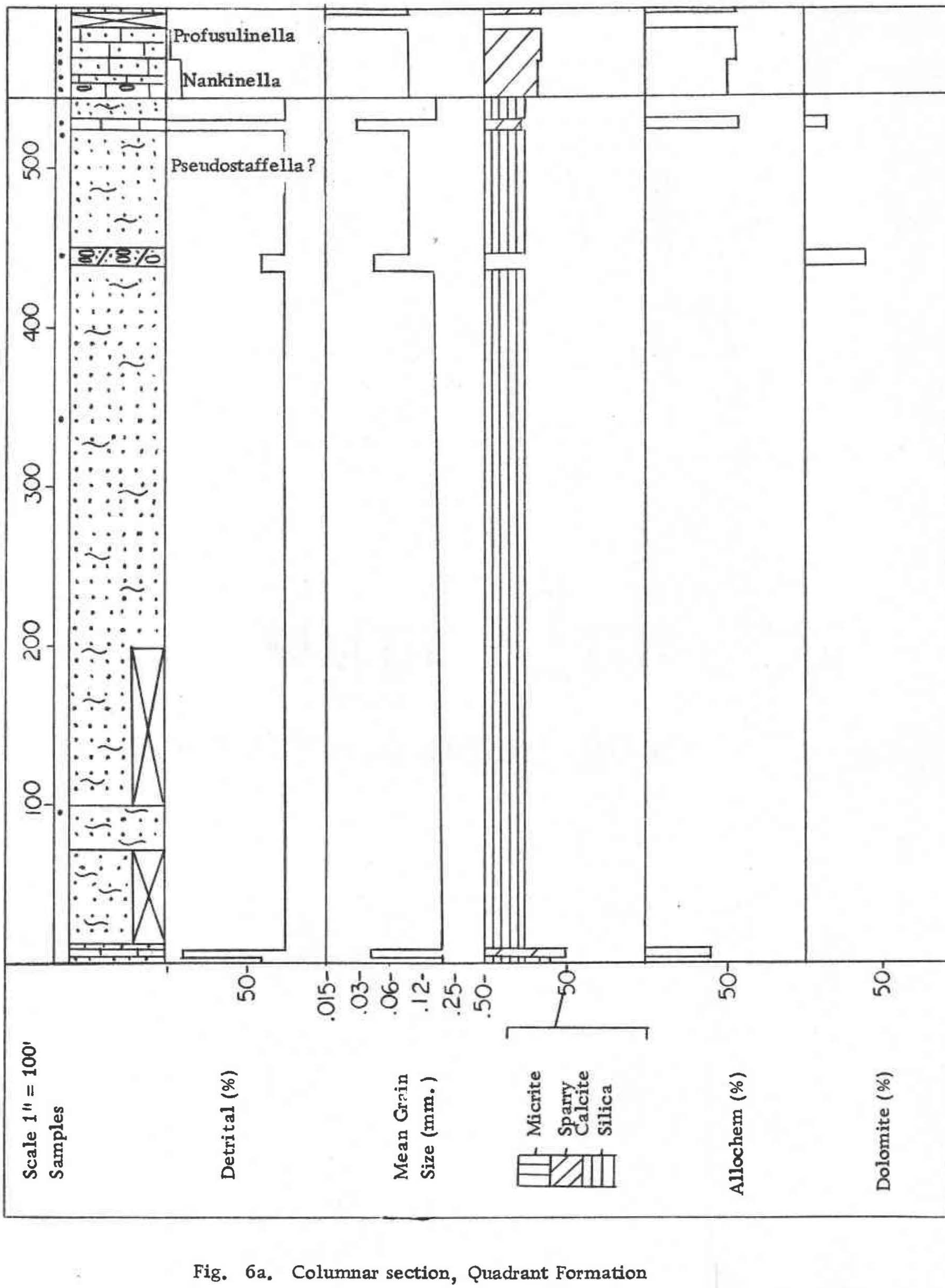


Fig. 6a. Columnar section, Quadrant Formation

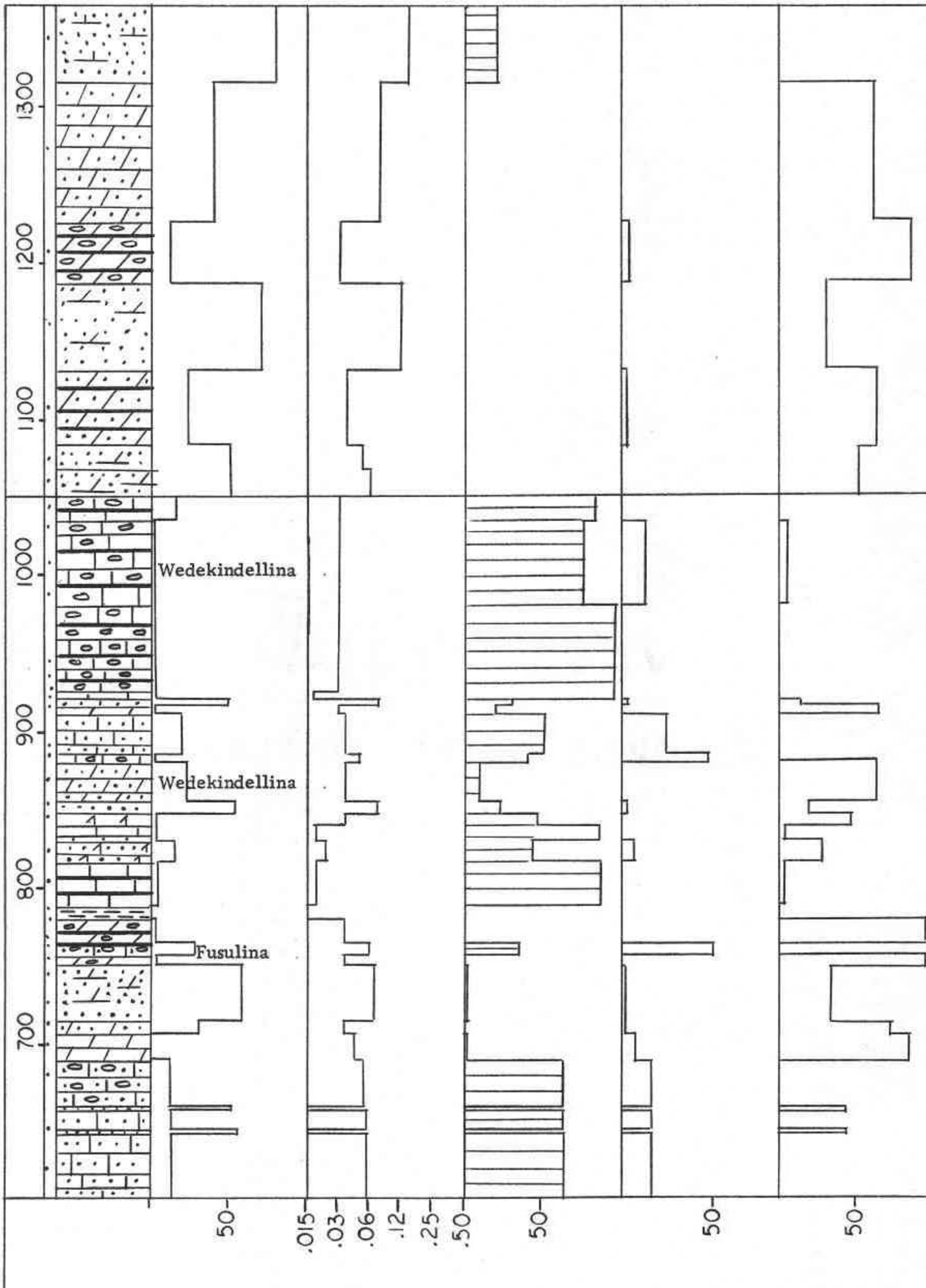


Fig. 6b. Quadrant Formation continued.

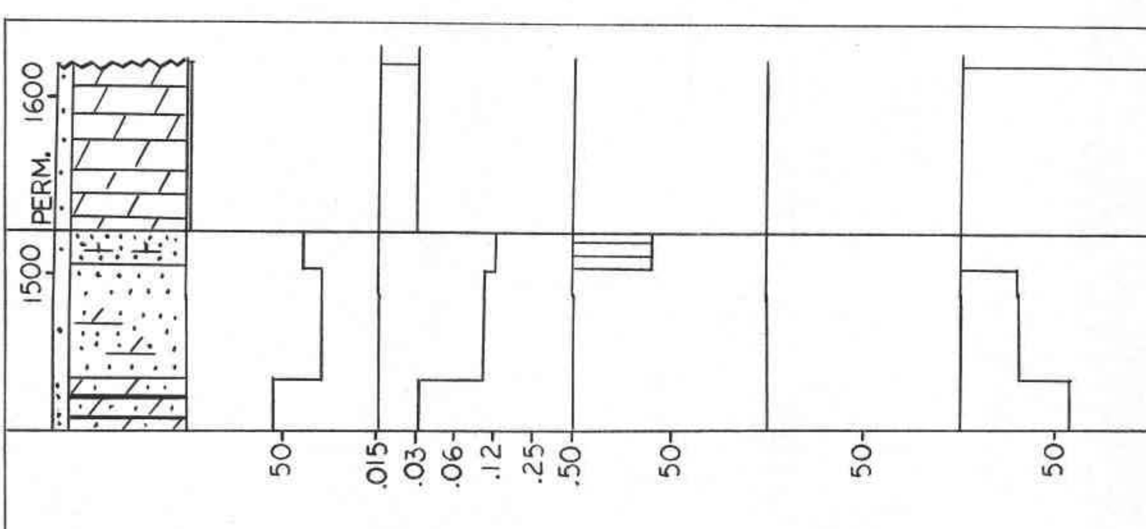


Fig. 6c. Quadrant Formation continued.

Nankinella, Fusulina, and Wedekindellina. The middle limestone unit ranges from early Atokan at the base to Desmoinesian at the top (see Figure 6). No fusulinids were found in the lower and upper sandstone units.

Waert (1950) collected Fusulina 200 feet below the top of the Quadrant section in Big Sheep Canyon and Wedekindellina 400 feet below the top of the section, approximately 10 miles west of Lima, Montana.

Thompson and Scott (1941) identified Fusulina and one or more species of Wedekindellina that were collected from near the top of the Quadrant Formation at its type locality, Quadrant Mountain, in the northwestern part of Yellowstone Park.

The Quadrant Formation is several thousand feet thick along the Idaho-Montana divide (Railroad Canyon, Big Sheep Creek, and Basin Creek) and is believed to represent Lower and Middle Pennsylvanian deposition. Lower Pennsylvanian deposition is supported by the occurrence of an unnamed sandstone unit which is present in the Pennsylvanian part of the White Knob Limestone in the Lemhi and Lost River Range, thinning to the west and dated by Mamet et al. (1971) as pre-Atohan in age. Moreover the occurrence of Pseudostaffella? and Profusulinella reported by the writer at the base of the middle limestone unit in the Railroad Canyon section suggests that the lower sandstone unit of the Quadrant at Railroad Canyon probably includes pre-Atokan rocks. The Quadrant Formation thins in a short distance to the east, northeast, and south from the Idaho-Montana divide. The Quadrant on the eastern Montana platform is characterized by a Desmoinesian fauna, and the writer believes the Quadrant is mainly Desmoinesian in age. Supporting evidence includes the Early Pennsylvanian age of the underlying Amsden Formation, and no Atokan fusulinids have been identified from the Quadrant on the eastern Montana platform. No post-Desmoinesian fusulinids have been identified from the Quadrant Formation in southwestern Montana.

The Amsden Formation, regionally subdivided into lower and upper units, is widespread in southwestern Montana and western Wyoming. The Amsden underlies the Quadrant and Tensleep Formations and has been assigned a Mississippian and Early Pennsylvanian age.

Scott (1945) concluded that the upper part of the Amsden in southwestern Montana is of Morrowan age. Thompson (In: Scott, 1945) identified Millerella marblensis and Millerella advena, which were assigned to the Morrowan. Henbest (1954) examined six collections of foraminifers from Golden Valley and Carbon County in southwestern Montana. The fusulinid genera Pseudostaffella, and Profusulinella were identified. An Atokan (Pennsylvanian) age seems to be well substantiated. Henbest pointed out that only parts of the Amsden may be Pennsylvanian and caution against assigning a Pennsylvanian age to the whole formation.

Wanless et al., (1955), studied the fauna of the upper Amsden Formation in Teton County, northwestern Wyoming, and provisionally referred the upper Amsden to Morrowan or slightly younger Atokan age. Zeller (In: Wanless et al., 1955) identified Staffella symmetrica and S. globula from South Indian Creek, Snake River Range, and Thompson (In: Wanless et al., 1955) identified Millerella advena and Millerella from the Hoback Range, Hoback Canyon. However, in western and west-central Wyoming, many workers, including Wanless and Shaw (1955), confirm a Late Mississippian age for the lower Amsden in these areas.

The lower sandstone unit and the lower part of the middle limestone unit of the Quadrant Formation at Railroad Canyon is time equivalent to the upper Amsden in Montana and Wyoming.

As has been recognized by many workers, the Wyoming Tensleep Formation is essentially the equivalent of the Quadrant Formation of Montana. The formations are remarkably alike in lithology and relationship to the underlying Amsden Formation.

Henbest (1956) found the most characteristic fusulinid genera of the Tensleep Formation in western Wyoming to be Fusulina and Wedekindellina, but Fusulinella was found to occur in one section of the Tensleep Formation. He concluded that the Tensleep ranges from Late Atokan into Late Desmoinesian, but the Desmoinesian fauna is the most widespread and characteristic. Workers in the Big Horn Mountains and the Casper Arch in eastern Wyoming, including Verville (1957) and Agatston (1957), have reported Missourian, Virgilian, and Wolfcampian fusulinids from the upper Tensleep Sandstone in Natrona County, Wyoming, which there begins to assume the stratigraphic spread of the Casper Formation. Agatston (1957) pointed out that uplift in western Wyoming in Late Pennsylvanian time was followed by erosion of the Tensleep in that area, and its deposition farther east, continuing into Wolfcampian time. In far western Wyoming, where the Pennsylvanian rocks begin thickening into the Wells Basin, Wanless _et al._, (1955) reported the finding of a Middle Missourian form of _Triticites_ 300 feet below the top of the Tensleep in the Jackson area near the west edge of the state. At this section (South Indian Creek, Snake River Range) the Virgilian Series may also be represented in the upper 300 feet of the formation, but illustrations have not been published and the determinations have not been verified in print (Henbest, 1956).

The age of the lower member of the Wells Formation (700-1200 feet), as defined by Mansfield (1927) in Caribou County, Idaho, is Middle Pennsylvanian in age. _Fusulina_ and _Wedekindellina_ were reported from this lower member. Youngquist and Haegele (1955), in the Sublett Range, reported the Wells Formation to contain an Early Desmoinesian fauna that included Fusulina and Fusulinella. The Quadrant Formation is also correlative with the lower part of the Wood River Formation where Fusulina, Fusulinella? and Wedekindellina have been identified 50 to 100 feet above the 240 foot basal conglomerate (Bostwick, 1955). In south-central Idaho the Quadrant Formation is also partly correlative with the Pennsylvanian part of the White Knob Limestone, which contains fusulinids of Early and Middle Pennsylvanian age.

McGugan and Rapson (1962), in their description of the Permo-Carboniferous rocks in the Crownest area, Alberta and British Columbia, noted that the Tunnel Mountain and Kananaskis Formations are correlative with the Quadrant Formation, and are similar in lithologic character. The Kananaskis Formation contains the fusulinid genera Profusulinella and Pseudostaffella. The underlying Tunnel Mountain Formation was assigned a probable Morrowan age by these workers.

Depositional Environments

Lower Sandstone Unit

This unit is dominantly siliceous quartz arenites and minor interbedded limestone and dolomite. Bedding ranges from thick to massive. The sandstones contain scattered aggregates of sparry calcite, which have been interpreted as dissolved and reprecipitated shelly matter. The sandstones are notably impoverished in both variety and quantity of heavy minerals. Species present are limited to the most stable, notably zircon, though some slightly less stable species occur, such as hornblende and sphene. The high quartz content and the excellent sorting and rounding exhibited is indicative of a high degree of textural and mineralogical maturity.

The lower sandstone unit is interpreted as having formed marginal to a low-lying tectonically stable land surface, at or near the base level, with repeated washing and winnowing of sediment that gave rise to a supermature quartz sand. The provenance of the Quadrant sands was probably, in part, from the north and northeast regional uplift in northern Montana, Alberta, and Saskatchewan, and Late Mississippian regression of the epicontinental seas exposed pre-Pennsylvanian rocks, which were subject to erosion.

Middle Limestone Unit

The middle unit rock types suggest both deep and shallow marine depositional environments (Figure 6 a, b, c).

The basal 55 feet of the unit is characterized by rounded biosparites containing intraclasts, coated grains, and mixed, well-sorted fossil material. The sediments were probably deposited in a winnowed shelf carbonate sand environment, whose modern analog is that of the winnowed carbonate sands within a half mile of the shelf edge in the Florida outer reef tract (Tyrrell, 1969).

The overlying sparse and packed biomicrites are well-bedded and contain mixed, normal, marine skeletal debris probably derived from the shelf edge environment and transported and redeposited in a basin slope or basin margin carbonate environment. The occurrence of micrite with intercalated shales has a deep-water character. Such occurrence has been described by Wilson (1969), Garrison and Fischer (1969), Thompson and Thomasson (1969), and Tyrrell (1969), all of whom contend that this type of bedding is probably a product of submarine slumping and turbidity currents. Wilson (1969) contends that they are not necessarily deposited in exceedingly deep water and could have been deposited on slopes below the shelf margins or inter-platform basins. These rocks are argillaceous, thin-bedded, and commonly barren of skeletal debris.

Middle Pennsylvanian eastward transgression of epicontinental seas produced littoral platform sands which extended into central Montana and apparently spread carbonate deposition eastward from the Idaho carbonate shelf facies.

Upper Sandstone Unit

The upper sandstone unit is characterized by sandy dolomites with intercalated shales, dolomitic quartz arenites, and calcareous quartz arenites. The upper sandstone unit overlies approximately 100 feet of thin-bedded micrite with intercalated shales. The depositional environment apparently changed from moderately deep-water to a shallow inner-neritic or intertidal environment. This change in depositional environment may indicate regression of the epicontinental seas to the west during the Late-Middle Pennsylvanian and would account for the increase in the clastic ratio in the upper sandstone unit.

SHELF FACIES

White Knob Limestone, Cedar Canyon

Definition

Ross (1934) proposed the term "Brazer Limestone" for a thick carbonate sequence in south-central Idaho that included rocks of Mississippian, Pennsylvanian, and Permian age. The type Brazer Formation in northeastern Utah has been assigned a Meramecian and possibly Chesterian age (Sando et al., 1959). Moreover, rocks of the type Brazer of Utah are dolomite rather than limestone. Therefore, workers in south-central Idaho have abandoned the term "Brazer" for these limestones. Thomasson (1959) introduced the term "Lemhi Formation" to include strata previously called "Brazer Limestone." Ross (1962) introduced the term "White Knob Limestone" for the assemblage of rocks called "Brazer" in the vicinity of the Mackay quadrangle, exposed in the White Knob Mountains. The age of the White Knob Limestone was designated Early Mississippian through Permian, and a ridge above Cabin Creek five miles west of Mackay, Idaho, was designated the type section. Recent study has shown that this section is no younger than Late Mississippian (Skipp and Mamet, 1970).

Huh (1968) subdivided the Mississippian strata in the Lost River and Lemhi Range and proposed four new stratigraphic units. From oldest to youngest they are: the Middle Canyon Formation, Scott Peak Formation, South Creek Formation, and Surrett Canyon Formation. These formations have been accepted as reliable map units, but no formal nomenclature has been applied to the Pennsylvanian and Permian strata.

In this study the term "White Knob Limestone," as proposed by Ross (1962), will be used for the Pennsylvanian and Permian carbonate assembledge in south-central Idaho because no better subdivision is available, with full realization by the writer that the original White Knob Limestone type section does not include Pennsylvanian and Permian strata. In areas where the Mississippian sequence has not been subdivided, the term "White Knob Limestone" will also be used.

Distribution and Thickness

The Pennsylvanian White Knob Limestone ranges in thickness from a minimum of 1200 feet on the eastern flank of the Lemhi Range to approximately 3500 feet thick in the White Knob Mountains 45 miles to the west. The Pennsylvanian White Knob Limestone in the Cedar Canyon area (Figure 7) ranges in thickness from a minimum of 1200 feet to approximately 3000 feet (Plate 1). This local variation is attributed to thrusting in the Cedar Canyon area.

Shannon (1961) measured and described a Late Paleozoic composite section on the west flank of the southern Lemhi Range,

Figure 7. View looking west at the southern end of the Lemhi Range. Entrance to Cedar Canyon in center of photo.

approximately 6 miles south of the Cedar Canyon area. There the Pennsylvanian part of the White Knob Limestone is approximately 3000 feet thick. He also described a composite Late Paleozoic section in the Arco Hills 10 miles west of the southern Lemhi Range, and there the Pennsylvanian part of the White Knob Limestone is approximately 3000 feet thick.

Mamet et al. (1971) measured and described 3500 feet of Pennsylvanian strata in the Hawley Mountain quadrangle 30 miles northwest of the Arco Hills and approximately 300 feet of Pennsylvanian strata in the Doublespring quadrangle about 60 miles northwest of the Arco Hills.

Skipp (1961) assigned a Pennsylvanian age to approximately 3200 feet of strata in the measured section at Timbered Dome, 30 miles south of Mackay, Idaho, in the White Knob Mountains. Pennsylvanian rocks have been reported six miles to the north of Timbered Dome at the junction of Cherry and Antelope Creek (Douglas and Yochelson; In: Nelson and Ross, 1969). However, the thickness of the beds is unknown.

Lithology and Petrography

As shown in Plate 1, the Pennsylvanian rocks of the Cedar Canyon area in secs. 8, 9, 16, 17, 20, 21, T. 7 N., R. 30 E., are approximately 1200 feet thick. The rocks in secs. 7, 18, 19, T. 7 N.,

R. 30 E. are approximately 3000 feet thick. Fossil data indicate that they are time equivalent sequences, but they differ in lithology and thickness. Therefore, for the purpose of discussion in this study, the rocks in secs. 8, 9, 16, 17, 20, 21 are termed "Eastern Sequence," and the rocks in secs. 7, 18, 19 are termed "Western Sequence."

Two partial sections of the Pennsylvanian part of the White Knob Limestone of the Eastern Sequence were measured by the writer in the Cedar Canyon area (sec. 17, T. 7 N., R. 30 E.). A composite section is graphically illustrated in Figure 8 a, b. The Appendix includes a detailed written description.

The lower 350 feet of section is characterized by friable, calcareous and dolomitic, fine-grained, sandstones. Grains are well-sorted and well-rounded. Thin interbeds of limestone occur throughout the unit. This unit yields readily to erosion, forming gentle slopes and inconspicuous outcrops. However, the base of the sandstone unit is not exposed in the area.

The limestone overlying the basal sandstone, is in general thin- to thick-bedded and fossiliferous. The color on weathered surface varies from medium-light-gray (N6) to medium-dark-gray (N4). The limestones contain chert nodules, commonly with concentric structure, which never exceed 15 percent of a single bed. Fossil material characteristic of the limestones ranges from 10 to 70 percent, and includes echinoid spines, corals, bryozoans, fusulinids, foraminifers,

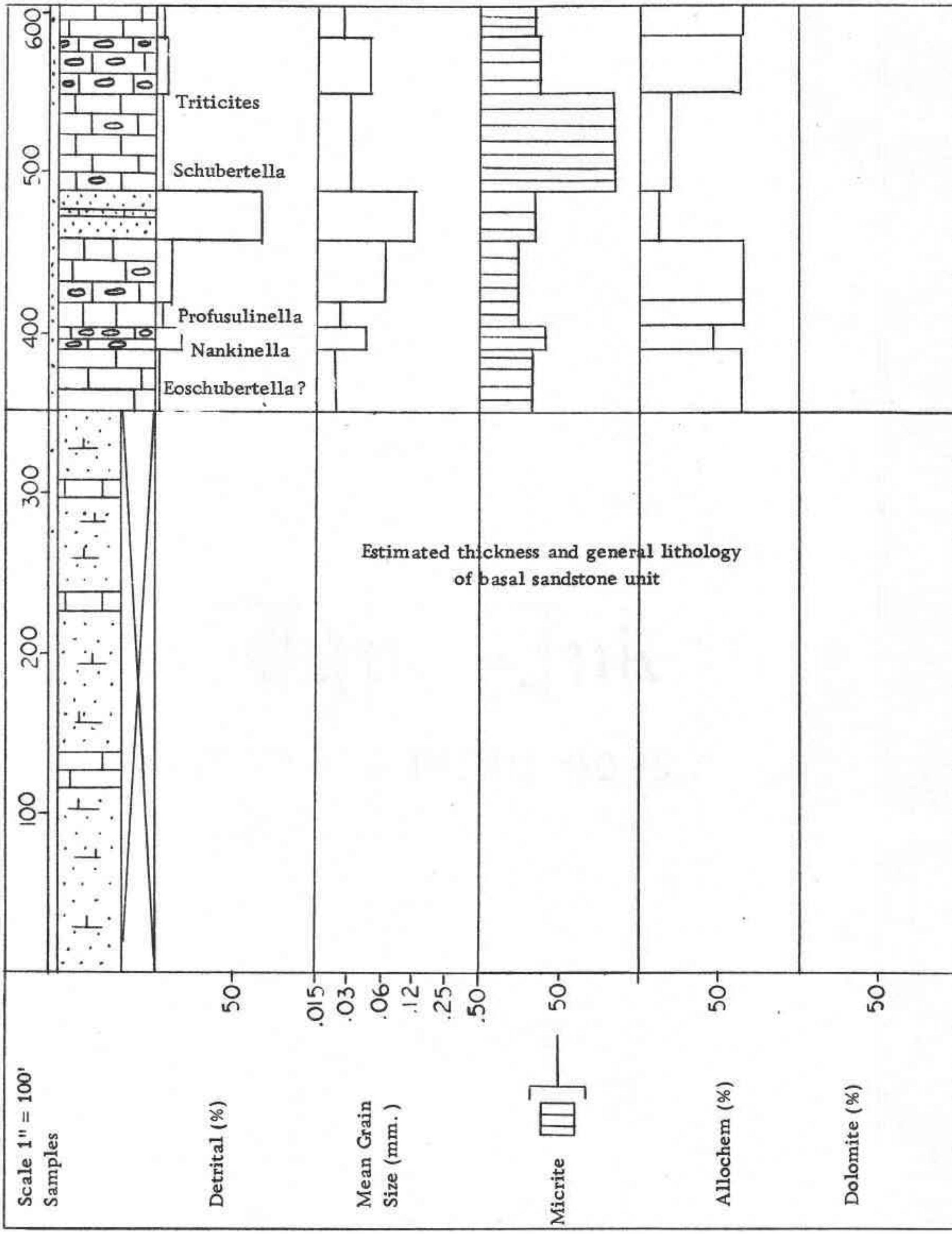


Fig. 8a. Columnar section of the composite White Knob Limestone section, Cedar Canyon.

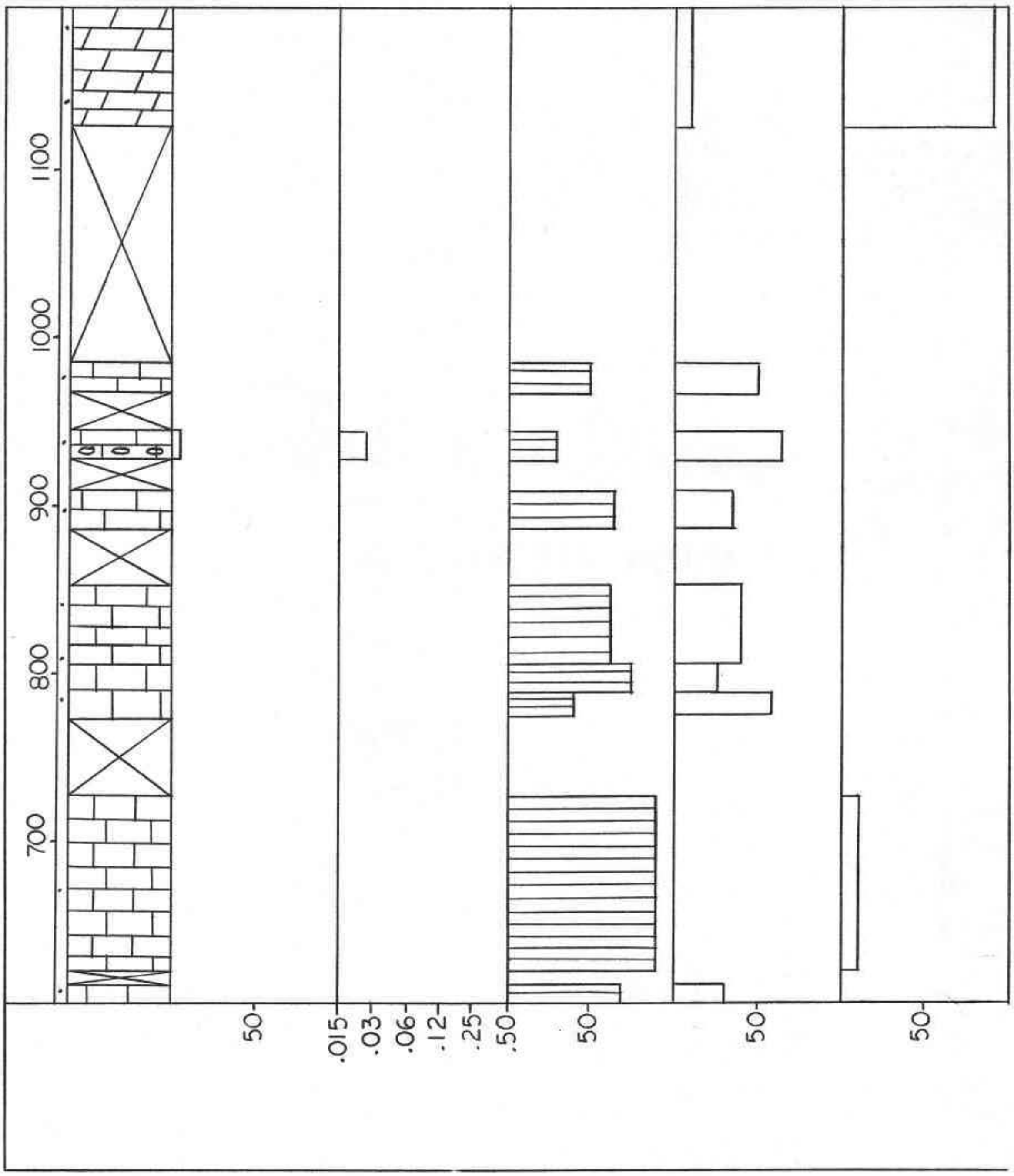


Fig. 8b. White Knob Limestone section continued.

gastropods, ostracods, brachiopods, crinoidal debris, and unidentifiable hash. Micrite is the principal matrix, and sand content ranges from 1 to 10 percent. Detritus consists of quartz, and less than 1 percent accessory minerals, which, in order of abundance, include: zircon, muscovite, plagioclase, chert, hornblende, sphene, and biotite.

Age and Correlation

Bostwick (oral communication) identified fusulinids of the Eastern and Western Sequences. He reported *Profusulinella*, *Staffella*, *Nankinella*, and *Eoschubertella* of probable Atokan age, as well as a Late Virgilian form of *Triticites*, in rocks of the Eastern Sequence. He also reported *Profusulinella*, *Fusulina*, and *Triticites*, of Atokan, Desmoinesian, and Late Virgilian age respectively, from the Western Sequence.

No Missourian, Early Virgilian or Permian fusulinids were found during this study in the Cedar Canyon area. Fossil localities from the Cedar Canyon area have been plotted on Plate 1, and a list of localities follows:

604-cc (Map location 1)
Fusulina

617-cc (Map location 2)
Nankinella
Staffella

639-cc (Map location 3)
Staffella

650-cc (Map location 4)
Triticites (Late Virgilian form)

651-cc (Map location 5)
Triticites?

661-cc (Map location 6)
Eoschubertella?

669-cc (Map location 7)
Helicoprion

671-cc (Map location 8)
Triticites?

674-cc (Map location 9)
Eoschubertella?
Nankinella?

681-cc (Map location 10)
Nankinella

682-cc (Map location 11)
Profusulinella
Nankinella?

685-cc (Map location 12)
Schubertella

694-cc (Map location 13)
Triticites (Late Virgilian form)
Nankinella
Staffella

709-cc (Map location 14)
Profusulinella

710-cc (Map location 15)
Profusulinella

716-cc (Map location 16)
Profusulinella

717-cc (Map location 17)
Triticites (Late Virgilian Form)

718-cc (Map location 18)
Profusulinella?

731-cc (Map location 19)
Profusulinella?

741-cc (Map location 20)
Profusulinella

The 3000 feet of the Pennsylvanian part of the White Knob Limestone measured by Shannon (1961), which includes beds of Atokan and Desmoinesian age, approximately 6 miles south of Cedar Canyon, includes fusulinids identified by Thompson as Pseudostaffella and Fusulinella 1400 feet above the base of the section, and Fusulina megista at the top of the Pennsylvanian part of the section. Schwagerina, an index of Permian age, was identified from rocks 165 feet above the occurrence of Fusulina megista.

The Hawley Mountain section contains approximately 3500 feet of Pennsylvanian strata. The base of this section is characterized by an unnamed basal sandstone unit 300 feet thick. The overlying carbonate rocks contain a characteristic Pennsylvanian (Morrowan and Atokan) microfauna that include Lipinella and the fusulinids Millerella, Eoschubertella, Pseudostaffella, and Profusulinella (Mamet et al., 1971). However, only 2000 feet of limestone strata above the basal sandstone unit were checked for microfauna by these workers, and no detailed sampling for microfauna in higher beds has been made.

Approximately 3200 feet of strata at Timbered Dome in the White Knob Mountains was assigned a Pennsylvanian age on the basis of megafossil content. Six miles to the north of Timbered Dome, south of Antelope and Cherry Creeks, beds containing Fusulinella or Profusulinella are regarded by Douglas and Yochelson (In: Nelson and Ross, 1969) as Middle Pennsylvanian in age. Megafauna in beds northeast of Antelope and Cherry Creeks are regarded by Dutro, Yochelson, Duncan, and Sando (In: Nelson and Ross, 1969) as Middle Pennsylvanian and post-Wolfcampian in age. However, no measured sections in the Antelope and Cherry Creek area have been reported that includes the Pennsylvanian and Permian faunas. More detailed work is suggested for this area.

The shelf facies represented by the Pennsylvanian part of the White Knob Limestone in south-central Idaho contains Lower, Middle, and Upper Pennsylvanian strata.

To the west the shelf facies is, in part, time equivalent to the Middle Pennsylvanian strata of the Wood River Formation. In southeastern Idaho, the shelf facies is, in part, time equivalent to the Pennsylvanian part of the Wells Formation. The Lower and Middle Pennsylvanian strata of the shelf facies appears to be correlative with the Quadrant and Amsden Formations in southwestern Montana and their correlatives in adjacent areas.

The basal sandstone unit in Cedar Canyon was estimated to be approximately 350 feet thick. Ross (1961) estimated a thickness of 450 feet 3 miles south of the Cedar Canyon area for this unit; however, the base of the unit is not exposed in either area. The basal sandstone unit appears to have correlative strata to the west. Shannon (1961) described a seemingly similar basal sandstone unit in his Lemhi and Howe Peak sections. There the basal sandstone is approximately 200 feet thick. In the Hawley Mountain section and Doublespring quadrangles the basal sandstone unit is approximately 300 feet thick and is pre-Atokan in age (Mamet et al., 1971). The basal sandstone unit consists of mineralogically mature, well-rounded, and well-sorted, cratonically derived sands, apparently thinning to the west and southwest from Cedar Canyon area, and is likely a western extension of the Quadrant Formation.

Depositional Environment

The basal sandstone unit in Cedar Canyon and seemingly similar units to the west indicate that the basal sandstone unit is areally extensive and may indicate a zone of shallow water bordering a coastline. The clean, mature sands appear to be cratonically derived. Interbedded limestones in the basal sandstone unit, and the fine detrital grain size of the sandstones compared to the generally medium- to coarse-grained Quadrant sands suggest a sub-littoral marine near-shore environment.

The 650 feet of limestones overlying the basal sandstone unit were probably laid down in neritic freely circulating, marine waters. The normal marine biota and the presence of autocthonous coral biolithite, packed biomicrites, and coarse skeletal grains suggest a reef, shelf-edge, and basin-margin carbonate environment. Higher in the section the limestones are succeeded by dolomite, suggesting a back-reef intertidal environment.

The Pennsylvanian part of the White Knob Limestone in south-central Idaho apparently has been deposited as an aerally extensive carbonate bank at moderate to shallow depths. Moreover, no deep-water basinal carbonate environments have been suggested by any workers for the Pennsylvanian part of the White Knob Limestone in south-central Idaho.

Structural Geology

Pennsylvanian rocks in the area of Cedar and Deer Canyons have been folded and faulted (Plate 1). An unnamed anticline in the eastern half of the area has dips ranging from 13 to 27 degrees, and the axial trace trends northwest, tight asymmetrical folding occurs at the entrance to Deer Canyon. The axial traces coincide with the unnamed anticline, but the fold relationships were not worked out for this study.

Known major faulting in the area is restricted to three thrust faults. The western flank of the unnamed anticline is cut by two major thrust faults. Beds west of these thrust faults dip to the west and are overturned. These faults have telescoped the thicker Pennsylvanian Western Sequence into juxtaposition with the thinner Eastern Sequence.

A third thrust fault, mapped at the head of Cedar Canyon, SE 1/4, sec. 17, T. 7 N., R. 30 E., causes repetition of the Eastern Sequence of rocks. The fault plane has been folded along with the anticline.

Deformational History

The oldest structural feature in the area to have been developed was a post-Desmoinesian to pre-Late Virgilian disconformity here ascribed to Pennsylvanian epeirogenic uplift accompanied by eustatic changes and withdrawal of epicontinental seas. This disconformity affected the shelf and platform facies in south-central Idaho, southwestern Montana, and western Wyoming. The disconformity does not appear to be represented in the Wells Formation in southeastern Idaho and may not be represented in the Wood River Formation in the western Pioneer Mountains.

Evidence for this disconformity is as follows:

(1) Absence of any known post-Desmoinesian to pre-Late Virgilian fusulinids in the Pennsylvanian part of the White Knob

Limestone in south-central Idaho.

(2) The occurrence of *Fusulina megista* only 165 feet below the appearance of *Schwagerina* in the Pennsylvanian part of the White Knob Limestone section on the west flank of the Lemhi Range.

(3) The occurrence of *Fusulina* approximately 200 feet below the earliest appearance of a Late Virgilian form of Triticites in the Western Sequence of the Cedar Canyon area.

(4) The occurrence of *Profusulinella* approximately 150 feet below the earliest appearance of the Late Virgilian form of *Triticites* in the Eastern Sequence of the Cedar Canyon area.

(5) A break in sedimentation reported by Thomasson (1959) in the Pennsylvanian White Knob Limestone in the southern Lemhi Range: a lenticular sandstone and a limestone pebble conglomerate appearing to overlie a surface of erosion; fusulinids identified as *Profusulinella* or *Fusulinella* occurring approximately 110 feet below this break.

(6) Absence of any known post-Desmoinesian to pre-Wolfcampian rocks in southwestern Montana and western Wyoming.

(7) Absence of any known Missourian to pre-Middle Virgilian fusulinids in the Wood River Formation (Weart, 1950; Bostwick, 1955). However, 1000 feet of unfossiliferous strata in the Wood River Formation may represent these ages.

Absence of Mesozoic and Early Tertiary strata in the southern Lemhi Range makes it impossible to date directly the folds and thrusts that involve Late Paleozoic strata. The beds of the southern part of the Lemhi Range have been compressed into folds and broken by thrust faults that trend northwest. The favored explanation, proposed by Ross (1961), and based partly on the regional setting, is that several pulses of major folding, rendered obscure by late-stage wrinkling of limestones, have affected the rocks in the Lemhi Range. He ascribed this deformation to the Laramide orogeny, which took place in the later part of Mesozoic time.

In reference to known folding and faulting in the Cedar Canyon area, the first structural feature to have been developed was the thrust fault at the head of Cedar Canyon. This was followed by folding of the Eastern Sequence of rocks. The youngest structural features appear to be the two thrust faults that cut the western flank of the unnamed anticline.

BASIN FACIES

Wood River Formation

Definition

The Wood River Formation was named by Lindgren (1900) and was restricted by Umpleby et al. (1930) to the calcareous quartz arenites, sandy limestones, limestones, and a basal conglomerate, which overly the fine-grained argillaceous rocks of the Milligen Formation in the western Pioneer Mountains. However, no type section was assigned.

Strata previously assigned to the Wood River Formation in the northeastern part of the Hailey quadrangle, central Pioneer Mountains, and southeastern corner of the Bayhorse quadrangle (Umpleby et al., 1930; Ross, 1934; Anderson, 1947), have been variously redefined as the Muldoon Formation by Thomasson (1959), the Copper Basin Formation by Ross (1962), and the Copper Basin Group by Paull et al. (1972). The Copper Basin Group has been dated as Mississippian but Late Devonian beds may be included (Paull, written communication).

Pre-Wood River Unconformity

The Milligen Formation was named by Umpleby et al. (1930) for dark, fine-grained, argillaceous rocks with subordinate limestone and calcareous and dolomitic quartz arenites that underlie the Wood River Formation in the western Pioneer Mountains. These beds were previously included in Lindgren's (1900) Wood River Formation. These workers arbitrarily attributed a tentative thickness of 3000 feet to the Milligen, which they considered probably Mississippian, but possibly Devonian, in age. However, the Milligen has never been adequately dated.

Fossil data collected during this study indicate that the Milligen Formation needs to be redefined in the western Pioneer Mountains. Conodonts collected by the writer from fossil localities 1, 2 (see Plate 2) were identified by Charles A. Sandberg (U. S. G. S., Denver), who assigned an Early Frasnian (Late Devonian) age to the Milligen that underlies the Wood River Formation in the Bellevue area. A major hiatus exists between the Upper Devonian Milligen Formation and the overlying basal Middle Pennsylvanian beds of the Wood River Formation.

The contact between the basal conglomerate of the Wood River Formation with the underlying Milligen Formation is poorly exposed in the Bellevue area. Only one location in SE 1/4, Sec. 29, T. 7 N., R. 19 E., provided limited exposure for study. Here the Milligen appears to have a disconformable relationship with the Wood River Formation. The basal conglomerate is 230 feet thick in the Bellevue area. Thomasson (1959) pointed out that in the Hailey quadrangle the basal conglomerate ranges from 118 to 696 feet thick. He attributed this variation in thickness to deposition over a surface of relief and concluded that the Wood River-Milligen contact has a disconformable relationship.

The Milligen Formation is a widespread unit throughout the south-central Idaho. In the central Pioneer Mountains, Paull et al., (1972) reported a minimum thickness of 3700 feet. The Milligen Formation in the Lost River Range at Lower Cedar Creek 4 miles northeast of Mackay, Idaho, is approximately 500 feet thick. Conodonts collected 13 feet above the base of the Milligen at Lower Cedar Creek were dated Early Mississippian (Kinderhookian) in age (Sandberg et al., 1967). Fossil data in the Hawley Mountains, 15 miles to the east of the Lost River Range, suggest that the middle part of the Milligen is Early or Middle Osagean (Mamet et al., 1971).

In the Lemhi Range the Milligen is considerably thinner. Sandberg et al., (1967) reported a thickness of 200 feet or less for the Milligen at Black Canyon.

The eastern limit of the Milligen is in the Idaho-Montana Beaverhead Mountains (Scholten et al., 1957; Sloss and Moritz, 1951) and according to Sandberg et al. (1967). the original depositional thickness of the Milligen in the Beaverhead Mountains was probably 100 feet or less.

Rocks similar to those of the Milligen of the Pioneer Mountains have been described as far south as the Sublett Range in southeastern Idaho (Youngquist and Haegele, 1955).

In the central Pioneer Mountains, White Knob Mountains, Lost River Range, and Lemhi Range, the Milligen is conformably overlain by Mississippian strata. The major disconformity apparently is restricted to the Milligen and Wood River Formations.

The Milligen in the Lost River Range and to the east includes no rocks as old as Devonian. The Devonian age of the Milligen in the Bellevue area indicates that the Milligen Formation is a time transgressive unit, thinning to the east, oldest to the west and youngest to the east.

Distribution and Thickness

The Wood River Formation is exposed in the western Pioneer Mountains, Hailey, Sawtooth, and Custer quadrangles.

Umpleby (1917) measured and described the Wood River Formation along the ridge north of the Bellevue-Muldoon Road a few miles east of Bellevue, Idaho, and he obtained a thickness of 7115 feet.. Bostwick (1955) measured the Wood River Formation in the same general area as that measured by Umpleby (1917), and obtained a maximal thickness of 12,000 feet. He concluded that the true thickness probably was between 8000 and 12,000 feet. Thomasson (1959) measured and described a composite section in the Trail Creek area, 35 miles north of the Bellevue area, and reported a minimum thickness of 8647 feet. The writer measured and described the Wood River Formation two miles east of Bellevue, north of the Muldoon Road (Figure 9), beginning at the base of the "Hailey Conglomerate," SE 1/4, Sec. 29, T. 2 N., R. 19 E., (Plate 2), and obtained a thickness of 8150 feet. However, the traverse did not include the upper part of the formation because of poor exposures, structural complications, and difficulty of obtaining reliable dips and strikes. Faulting has disturbed the section, and although displacements along the faults could not be determined, the section does not appear to be repeated. Bostwick (1955) pointed out that these faults probably are not large enough to greatly disturb the stratigraphic succession of fusulinids.

Bostwick (1955) established Pennsylvanian and Permian ages for rocks included in the Wood River Formation. He placed the Pennsylvanian-Permian boundary 4850 feet above the base of his measured section, a decision based on the earliest appearance of a Lower Permian fusulinid identified as _Triticites_ cf. _T. ventricosus_ and the earliest appearance of _Triticites cellamagnus_ 6470 feet above the base of the formation. The writer's measured section contains _T. cellamagnus_ 6340 feet above the base of the section. The earliest appearance of _T. cellamagnus_ is only 130 feet lower in the section than that measured by Bostwick (1955) in the same area. The writer's

Figure 9. View looking east showing the ridge crest between Martin Gulch and the Muldoon Road along which the Wood River Formation was measured. Thickness of the formation at the peak in the upper left of the photo is 5200 feet.

collection of fusulinids did not contain Permian forms lower in the section but this is probably due to incomplete sampling.

Thomasson (1959) reported a minimum thickness of 8647 feet for the Wood River Formation in the Trail Creek area. The earliest appearance of a Lower Wolfcampian fusulinid in Thomasson's collections occurs approximately 5000 feet above the base of that section.

The thickness of the Pennsylvanian part of the Wood River Formation in the western Pioneer Mountains appears to be approximately 5000 feet.

Lithology and Petrography

The predominent rock types of the Wood River Formation in the Bellevue area include calcareous quartz arenites with interbedded sandy limestone. Additional rock types include: siliceous quartz arenites, limestone, mudstone, argillaceous and calcareous siltstones, and a prominent basal chert-quartzite, and pebble conglomerate. These additional rock types are restricted to the lower 2500 feet of the 8150 feet measured and described.

The following descriptions will give an idea of the Wood River sequence in a general way. See Figure 10 a, b, c, d, e, f for graphic illustrations. The Appendix includes a detailed written description.

The basal part of the Wood River Formation consists of a massive pebble conglomerate, in which bedding cannot be recognized

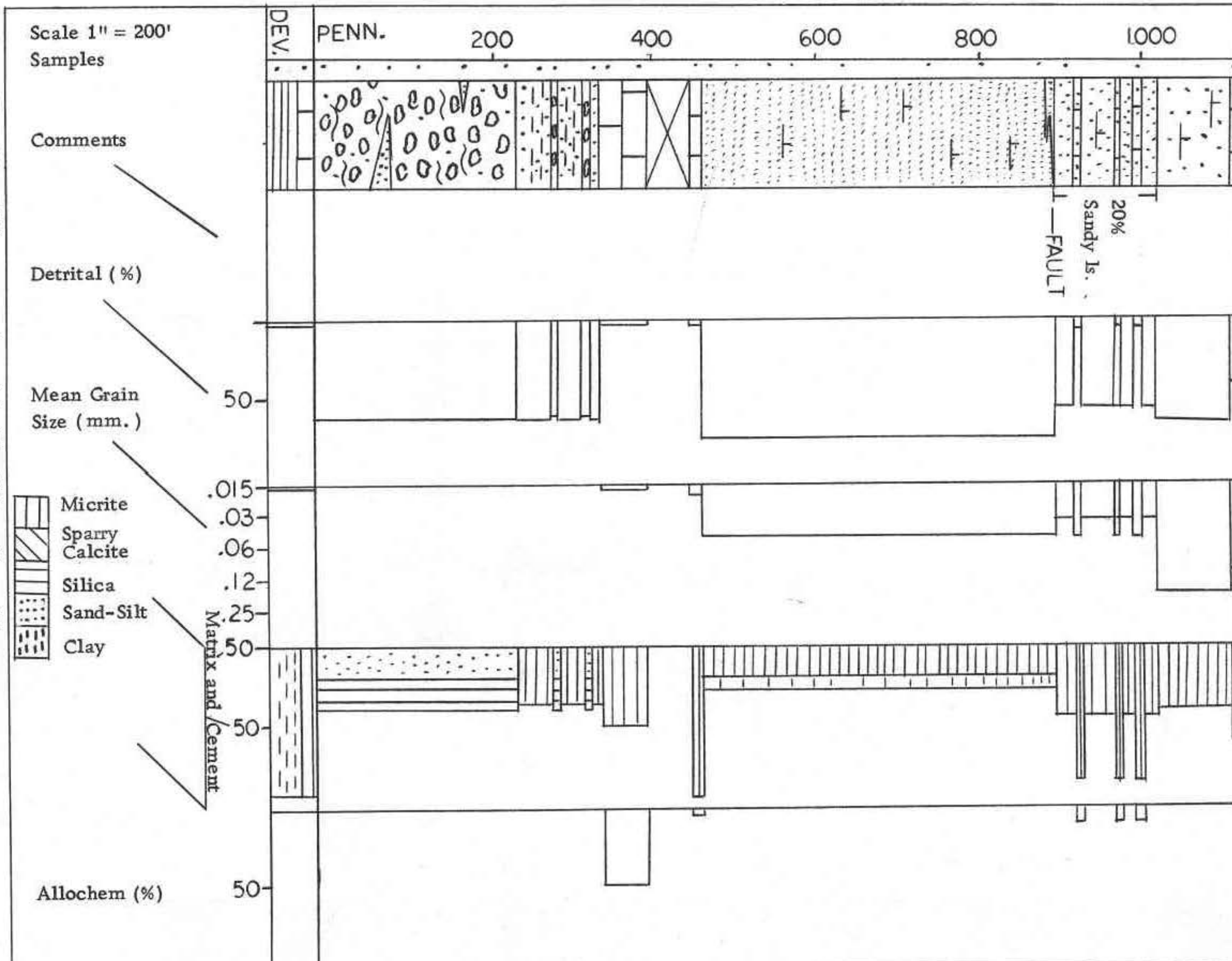


Fig. 10a. Columnar section of the Wood River Formation.

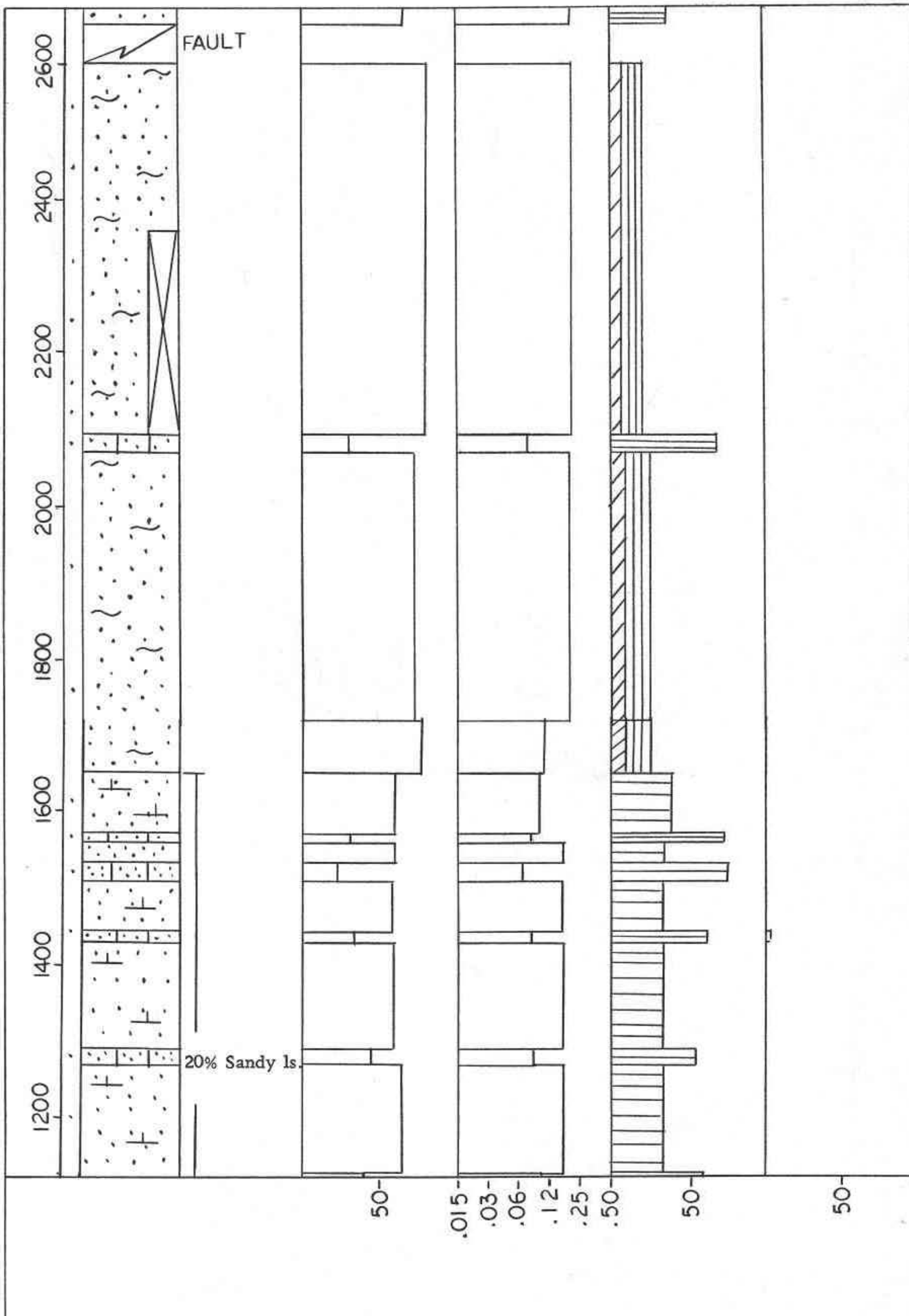


Fig. 10b. Wood River Formation continued.

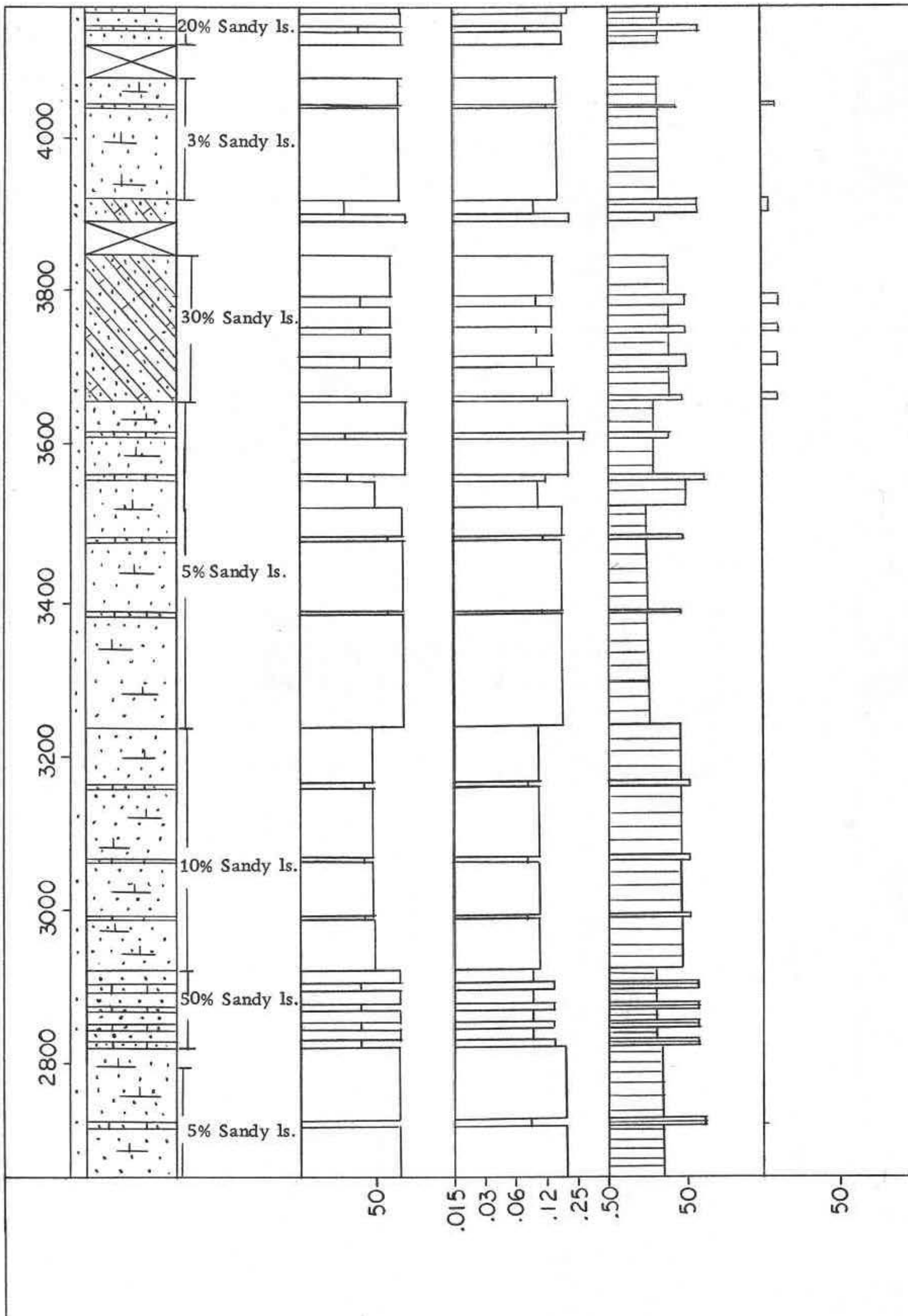


Fig. 10c. Wood River Formation continued.

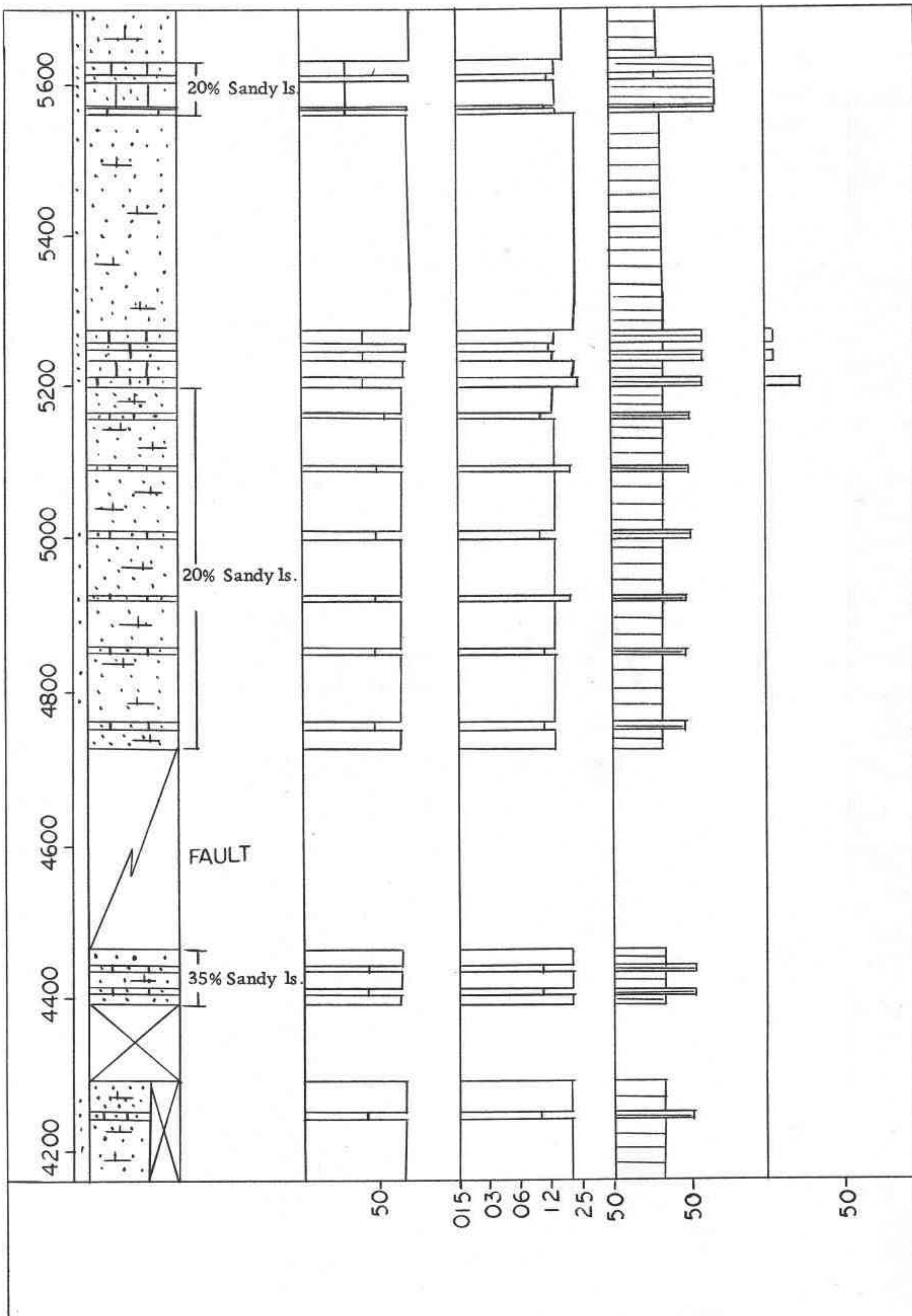


Fig. 10d. Wood River Formation continued.

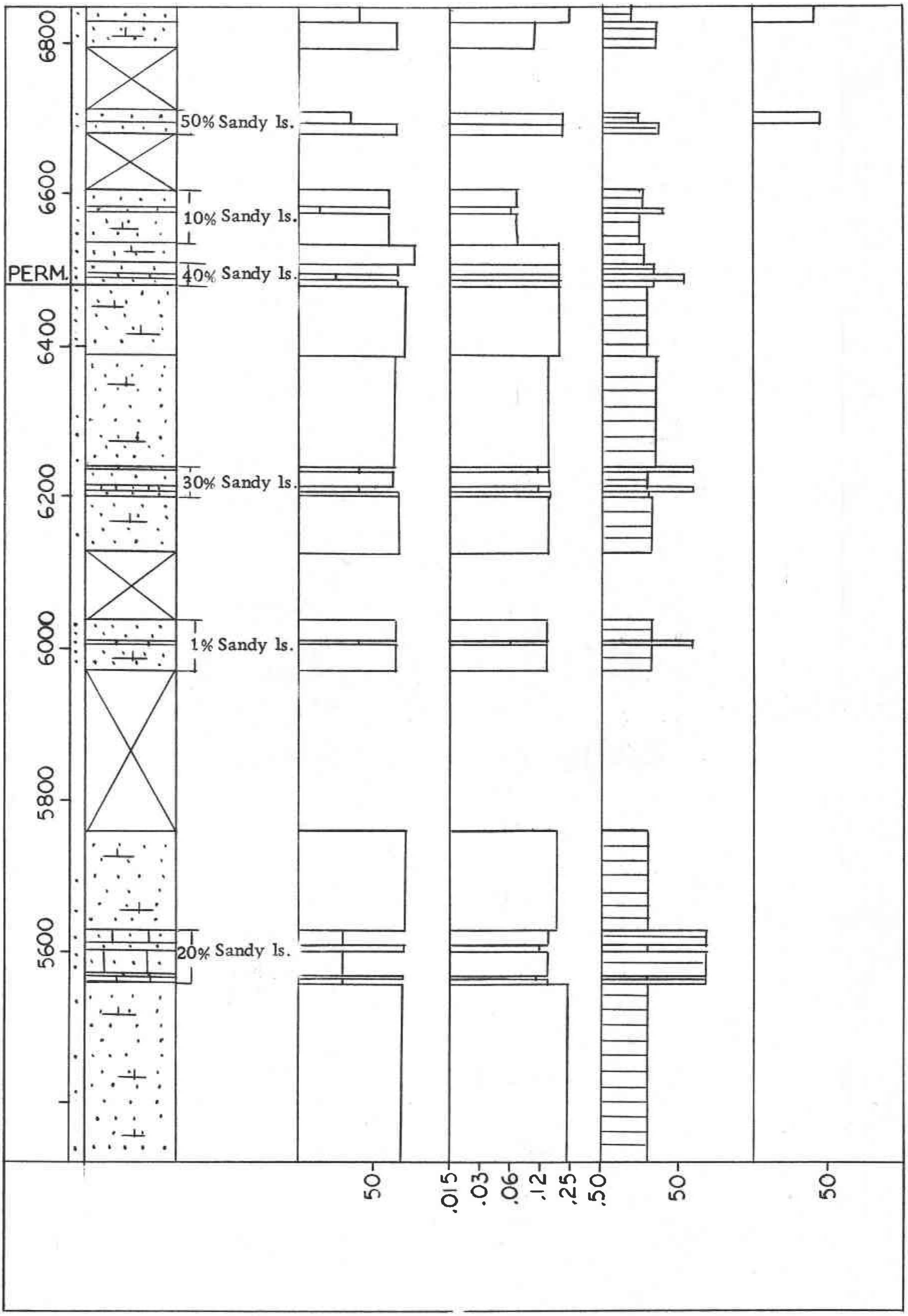


Fig. 10e. Wood River Formation continued.

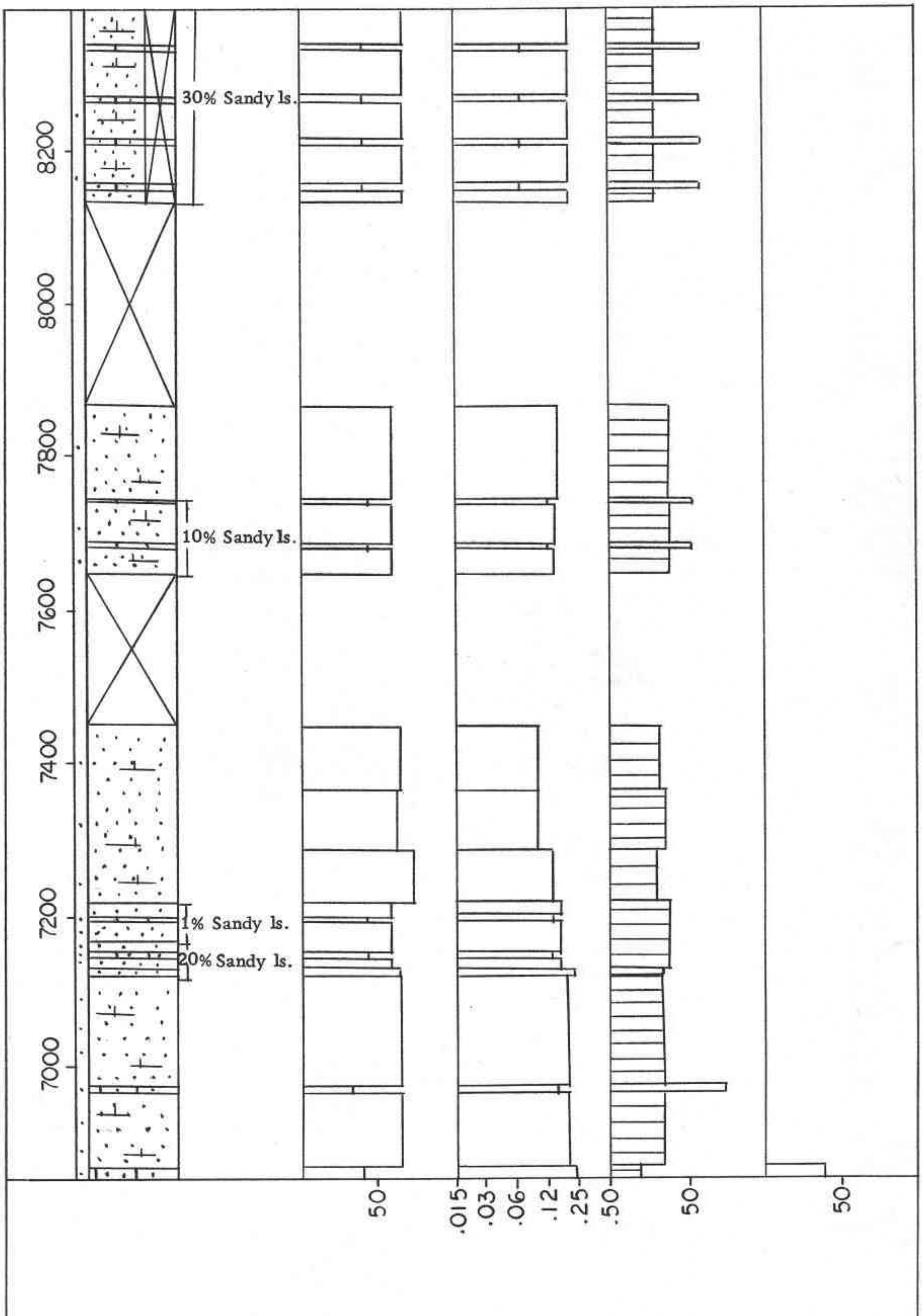


Fig. 10f. Wood River Formation continued.

except where sandstone interlayers are present. Because of its resistance to weathering, the conglomerate forms conspicuous ledges and cliffs.

The basal conglomerate is composed of rounded to subangular granules and pebbles of chert, quartzite, calcareous quartz arenite, and minor phyllite. Rare rounded limestone pebbles and cobbles occur in the upper part of the conglomerate unit.

The basal conglomerate clasts consist of 55 percent chert, 5 percent quartzite, 2 percent calcareous quartz arenites, 1 percent siliceous quartz arenites, less than 1 percent phyllite, and 15 to 20 percent interstitial, fine to medium-grained, sand-sized quartz and chert. Silica is the cementing medium and averages 20 percent. The clasts average about 1 inch in diameter.

Overlying the basal conglomerate is a transitional interval 115 feet thick consisting of laminated mudstones, thin-bedded calcareous siltstones, fine-grained, thin-bedded, calcareous quartz arenites, and lenticular, thin-bedded, pebble conglomerates. This interval marks the highest occurrence of conglomerate in the Wood River section, and the highest occurrence where chert is a major mineralogical constituent.

Overlying this transitional interval is a medium-light-gray (N6), thin- to thick-bedded limestone unit containing abundant crinoid debris, brachiopods, corals, and bryozoans, and fine-grained sandy stringers.

The limestones consist of sparse and packed biomicrites. Coral biolithites were observed in the outcrop.

Above this limestone unit is a generally unfossiliferous medium-dark-gray (N4), thin-bedded limestone containing algal structures, fine-grained sandy stringers, and crinoidal debris. The limestone produces a strong fetid odor when broken. A small amount of fossil hash (1 to 5 percent) is included in the limestone.

The limestone units lie near the base of the Wood River Formation throughout the Hailey quadrangle (Ross, 1934), and can be used in deciphering structure where the conglomerate is absent. Overlying the limestones are very thin-bedded, argillaceous siltstones 440 feet thick, which weather pale-purple (5RP6/2) to pale-brown (10YR6/2).

The greater part of the Wood River Formation consists of fine- to medium-grained, thin- to thick-bedded, calcareous quartz arenites and interbedded limestones. Few recognizable beds can be distinguished. At a few intervals the calcareous quartz arenites and sandy limestone beds are distinctly cyclically bedded (Figures 11 and 12). Throughout the Wood River section, sandy limestones are subordinate to the calcareous quartz arenites.

The calcareous quartz arenites are thin- to thick-bedded, fine- to medium-grained (Figure 13). They weather moderate yellowish-brown (10YR5/4), and are commonly cross-laminated, a feature that

Figure 11. Thin cyclic-bedding consisting of moderate yellowish-brown (10YR5/4) calcareous quartz arenites, and medium-gray (N5) sandy limestones in the Wood River Formation.

Figure 12. Polished section showing internal relationships of cyclic beds. Medium-gray (N5) normal graded sandy limestone; interval has a sharp upper contact with parallel and thinly cross-laminated calcareous quartz arenite that subsequently grades into the sandy limestone interval.

Figure 13. Thick-bedded calcareous quartz arenites along Martin Gulch exhibiting sharp bedding contacts.

is difficult to impossible to see on weathered surfaces. They are seen to consist of 60 to 65 percent subrounded to subangular quartz, 1 to 5 percent accessory minerals and 35 to 40 percent micrite and microspar cement.

The sandy limestones are finely crystalline rocks that weather medium-gray (N5). They generally consist of 55 to 70 percent micrite and microspar, 30 to 45 percent subangular to subrounded quartz and 1 to 5 percent accessory minerals. They differ from the calcareous sandstones in the percentage of carbonate matrix, and commonly contain calcarenite material. Graded bedding was observed locally but is not characteristic of the sandy limestone beds as a whole. Fossil material ranges from 1 to 3 percent and consists of generally unidentifiable hash, which includes brachiopods, bryozoans, crinoidal debris, and disoriented, commonly broken fusulinids visible as dark grains, cylindrical or fusiform in shape.

Accessory minerals common in 200 thin sections of the calcareous quartz arenites and sandy limestones include more species than previously reported in the literature. The accessory minerals range from 1 to 5 percent, and listed in decreasing order of abundance include plagioclase, chert, zircon, muscovite, tourmaline, hornblende, garnet, epidote, white opaques, sphene, rutile, biotite, microcline, goethite, and limonite.

Age and Correlation

Bostwick (1955) concluded that rocks of Desmoinesian, Virgilian, and Wolfcampian age are represented in the Wood River Formation, and possibly rocks of Atokan and Missourian age. He identified *Fusulinella?*, *Staffella* cf. *S. powwowensis*, and *Nankinella* from a sandy limestone overlying the basal conglomerate on Lookout Mountain (Plate 2). He found the fusulinid genera *Fusulina*, and *Wedekindellina* to occur less than 100 feet above the basal conglomerate on the ridge north of Martin Gulch, and on the ridge between Martin Gulch and the Muldoon Road. He considered the lower beds of the Wood River Formation to be of Early and Middle Desmoinesian age and possibly Late Atokan age.

The lower beds of the Wood River Formation seem to be time equivalent to those beds that contain *Fusulina* and *Wedekindellina* in the Quadrant Formation in southwestern Montana, the Tensleep Formation in western Wyoming, and the Pennsylvanian White Knob Limestone in south-central Idaho. Youngquist and Haegele (1955) identified *Fusulinella* and a primitive form of *Fusulina* from the basal beds of the Wells Formation in the Sublett Range, southeastern Idaho. Bissell (*In*: Roberts, 1965) reported Desmoinesian beds in the Wells Formation in the Black Pine Mountains, 20 miles southwest of the Sublett Range, and in the Blue Spring Hills, 30 miles southeast of the

Sublett Range, southeastern Idaho. Heppert and Reder (In: Williams, 1962) identified the fusulinid genera Fusulina and Wedkindellina from the Wells Formation in Wells Canyon, Caribou County, Idaho, which seemingly is the same age as the lower beds of the Wood River Formation.

Bostwick also identified a form of Triticites that indicates a Middle Virgilian age 1300 feet above the base of the Wood River Formation. Approximately 1000 feet of non-fossiliferous strata underlies this horizon. He points out that these strata may possibly represent Late Desmoinesian, Missourian, and Early Virgilian time.

Bostwick identified additional fusulinids of Virgilian age through a sequence of beds 3500 feet thick. These beds are partly time equivalent to the upper part of the Pennsylvanian part of the White Knob Limestone that contains a Late Virgilian fauna in the Cedar Canyon section. These beds are also time equivalent to the Virgilian part of the Wells Formation in the Sublett Range, Wells Canyon, Black Pine Mountains, and Blue Spring Hills, southeastern Idaho.

The upper part of the Wood River Formation in the Bellevue area is Permian (Wolfcampian) in age (Bostwick, 1955), and partly equivalent to the Permian part of the White Knob Limestone in south-central Idaho, and at least in part to Permian beds of the Wells Formation in Wells Canyon, Sublett Range, Black Pine Mountains and Blue Spring Hills, southeastern Idaho.

Depositional Environments

The basal Wood River conglomerate, an areally extensive unit, apparently lies on a scoured surface and has a disconformable relationship with the underlying Milligen Formation. As seen in Figure 3 the Mississippian Copper Basin Group, a 17,000 foot clastic sequence, is allocthonous. Sandberg (U. S. G. S. Denver, oral communication) suggests that the Copper Basin Group is in superposition with the thinner Mississippian part of the White Knob Limestone sequence in the White Knob Mountains. If he is correct, the Copper Basin Group was thrust from the west and was originally deposited west of the Wood River basin. The basal conglomerate of the Wood River Formation possibly formed due to transgression upon a western positive area by the reworking of older Mississippian conglomeratic beds. Laramide thrusting resulted in juxtaposition and probably in the superposition of thrust slices carrying thick basin sections onto the thinner shelf sections in the Pioneer and White Knob Mountains. Sandstone lenses occur in the conglomerate member, and a few lenses contain gastropod and brachiopod hash (Bostwick, 1955). The conglomerate member appears to have been deposited in a littoral environment as beach deposits gravel.

The basal conglomerate member is overlain by a normal marine shallow-water limestone unit, which contains a diverse, normal, marine biota. This fossiliferous limestone unit is believed to represent a period of stability and reef edge carbonate environments. Supporting evidence includes the occurrence of coral biolithite, coarseness of skeletal grains, and normal marine biota. This limestone unit is overlain by a generally unfossiliferous limestone unit and approximately 440 feet of argillaceous and calcareous siltstones. This interval is believed to indicate a restricted, marine, quiet-water condition, and may also indicate subsidence and the initial development of the Wood River basin.

The great quantity of sand above the limestone horizon presents a greater problem. These sands appear to be closely related to the conditions of deposition of the sands of the Wells Formation. Youngquist and Haegele (1955) pointed out that cyclic sedimentation is clearly evident in the deposition of the Wells, in which arenaceous zones alternate with calcareous zones throughout the section. The strata of the Wells contains few macrofossils, but fusulinids are relatively abundant. The Wood River also exhibits cyclic sedimentation. Macrofossils are rare in the Wood River Formation except in the lower limestone units, but fusulinids are found through the greater part of the section.

Thomasson (1959) reported a great abundance of primary sedimentary structures in the Wood River Formation in the northern part of the Hailey quadrangle. These include cross-lamination, convoluted bedding, flame structures, graded bedding, and slump structures, which indicate post-depositional disturbance by slumping, or gravity movements of the Wood River clastics in that area. The Wood River Formation in the Bellevue area generally lacks primary sedimentary structures, a feature also noted by Wayne E. Hall, (U. S. G. S. Menlo Park, oral communication). However, post-depositional transport of sediments is indicated by the fact that fusulinids in the sequence are disoriented and occur at random angles to the bedding planes. Moreover, the sediments exhibit characteristics attributed to cyclic sedimentation.

The Wood River basin during Virgilian time is visualized by the writers as a broad, shallow basin with flanking littoral and shallow-water shelf areas. This view is supported by the occurrence of abundant fusulinids in the Virgilian sequence.

The Virgilian sequence of rocks consist of calcareous sandstone and sandy limestones. The sandy limestones commonly contain broken fossil fragments in a finer grained matrix consisting of micrite, microspar, and fine-grained quartz detritus. Graded bedding was seen in places but is not characteristic of sandy limestone units as a whole. The sandstones are mostly clean, fine- to medium-grained, thin- to thick-bedded, calcareous quartz arenite. The sandstones are distinctly bedded, commonly showing planar and cross-laminations.

Bedding contacts are sharp. The bedding contacts with the interbedded sandy limestones are generally sharp, characterized by small-scale channeling, but gradational contacts are common through a distance of an inch to a few inches.

The writer is inclined to believe that the sediments were spread by turbidity currents over the floor of a rapidly subsiding basin under high-energy sedimentary conditions as a result of slumping or over-steepening of bordering shelf areas. An increase in gradient, either by rapid uplift of the bordering shelf areas or downwarping of the basin, resulted in surges of sand-sized debris from unstable shelves or bars into an environment in which carbonate mud and fine-grained sand normally accumulated. This mechanism simply involves periodic transportation of sandy detritus into a subsiding basin.

The source areas for the Wood River clastics probably were located to the east and west. To the west lies the Sonoma orogenic belt. The disconformity between the Wood River and Milligen Formation indicates that a positive area extended into the area of the western Pioneer Mountains during Early Pennsylvanian time. This positive area may be a northern extension of the Northeast Nevada High, or an eastern extension of the Sonoma orogenic belt. Middle Pennsylvanian marine transgression onto this western positive area undoubtedly supplied detritus to the Wood River basin. The absence of coarse clastics, excluding the basal conglomerate, may imply that the western positive area was an area of low relief or a distal source area during post Middle Pennsylvanian time.

The probability of a shelf and platform clastic source east of the Wood River exposures cannot be excluded. The major post-Desmoinesian disconformity indicates that the Pennsylvanian part of the White Knob Limestone was a positive area, at least in part of Missourian to pre-Late Virgilian time. The platform area in southwestern Montana was a positive area, at least in part of post-Desmoinesian to Early Permian time. The probability of a shelf and platform source is further supported because of the high quartz content and seemingly cratonic character of the Wood River sediments. However, the accessory minerals (plagioclase, chert, epidote, and the basal Wood River conglomerate) included in the Wood River sediments are well represented in the Mississippian Copper Basin Group sediments and support a western source. The overall view of the Wood River sediments suggest a composite terrigenous mineralogical province.

Structural Geology

Late Devonian, Pennsylvanian, and Permian rocks in the Bellevue area have been deformed into a broad anticline whose axial trace trends approximately N. 17° W.

The fold in the area is broad and open with dips ranging from 72 to 30 degrees. The range in dips are caused by the many faults within the area. Wayne Hall (U.S.G.S. Menlo Park, personal communication) mapped the Hailey quadrangle, and has mapped this anticline in and to the north of the Bellevue area.

Faulting in the area is very complex. The conglomerate member and overlying limestone units are the only horizons sufficiently distinctive and persistent in the stratigraphic column to be used as horizon markers throughout the area. The lack of recognizable horizons and the generally poor outcrops make it difficult or impossible to trace faults where the conglomerate is absent. Faults within the formation are recognized by the occurrence of tectonic breccia consisting of angular fragments of pebbles and cobbles that have been recemented by hydrothermal calcite, as well as major dip and strike changes within the sequence. In areas covered by rocks of a single formation in which distinctive beds are lacking, such as the Wood River Formation, faults can be recognized in few places, and traced in still fewer, although they are probably abundant in such areas.

Most of the faults mapped appear to be normal faults, and may, for convenience of description, be divided into two groups; (1) those with northwest trend; (2) those with an average northeast trend.

The faults of the first group trend N. 30°-50^{0} W., approximately parallel to folding. The second group comprises faults trending

N. 30^{o}-50^{o} E., and causes offsets in the basal conglomerate member (Plate 2).

No fault planes were exposed in the thesis area. Umpleby et al., (1930), in their early map of the Hailey quadrangle, considered the fault planes to be high angle, but proof is difficult to obtain because of poor exposure.

Deformational History

From the data presented it is evident that an important unconformity exists between the Milligen Formation and the Wood River Formation. The event responsible for this unconformity can be dated no closer than Late Devonian to Middle Pennsylvanian. This hiatus is ascribed to a pulse of the Antler orogeny.

The folding in the Wood River area can be dated no closer than post-Early Permian to pre-Late Cretaceous but probably is the result of the Mesozoic Laramide orogenic disturbance.

In the Wood River area, the northwest and northeast faults probably resulted from this period of disturbance, although the faults of northeast strike appear to cut sets of faults of northwest strike. Umpleby et al., (1930) pointed out that while folding and thrusting was going on in the western Pioneer Mountains, normal faulting was in progress, and certainly normal faulting occurred after folding had ceased.

PRE-PENNSYLVANIAN PALEOGEOGRAPHY

The Lower Mississippian rocks that underlie the rocks of the Pennsylvanian system in south-central Idaho include the Upper Devonian-Lower Mississippian Milligen Formation. The Milligen Formation apparently bordered the Antler Highlands in Idaho, and represents a clastic wedge derived from the west. In southwestern Montana, western Wyoming, and southeastern Idaho, Lower Mississippian strata are represented by the Lodgepole Formation and lower beds of the Madison Limestone. Figure 14 is an attempt to depict generalized lithofacies and distribution of the Milligen Formation and Lower Mississippian rocks in adjacent areas.

Figure 15 is an attempt to depict the lithofacies and distribution of marine rocks of Late Mississippian age. The Copper Basin Group, a clastic sequence in the central Pioneer Mountains, consists of a continuous Mississippian sequence approximately 17,000 feet thick that interfingers with thinner shelf facies of the Mississippian White Knob Limestone in the Mackay quadrangle (Ross, 1962; Nelson and Ross, 1969; and Skipp and Mamet, 1970). The Mississippian White Knob Limestone extends eastward into the Lemhi Range. In southwestern Montana, Upper Mississippian rocks are represented by the Mission Canyon Limestone and Big Snowy Group. In southeastern Idaho and western Wyoming this time is represented by the Little

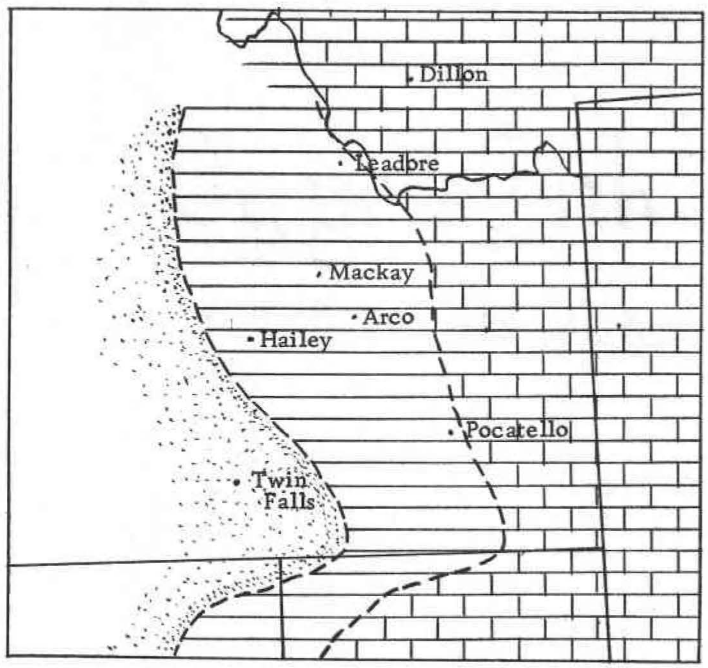


Fig. 14. Late Devonian-Early Mississippian paleogeography and generalized lithofacies. Lithotopes indicated by patterns - brickwork = limestone, horizontal ruling = sandstone and shale, stippled = marine rocks absent. (after Johnson, 1971).

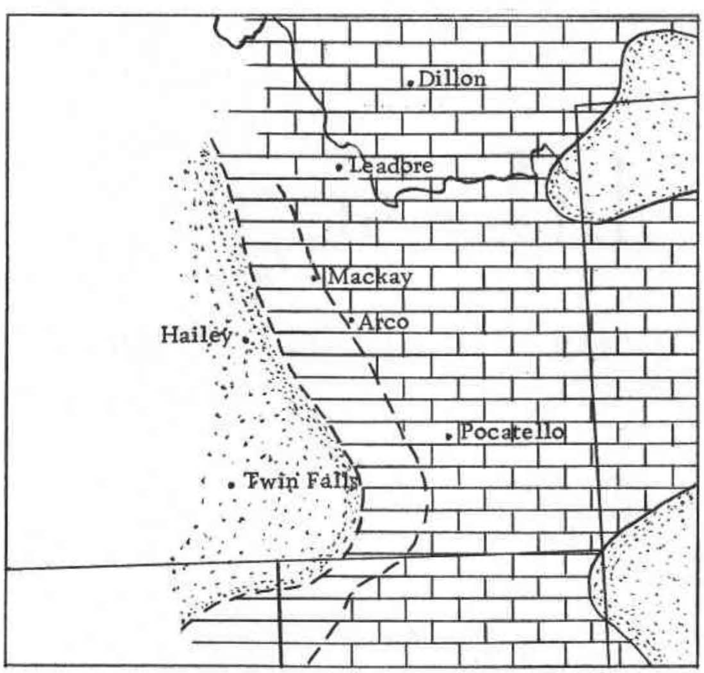


Fig. 15. Late Mississippian paleogeography and generalized lithofacies. Lithotopes indicated by patterns - brickwork = limestone, horizontal ruling = sandstone, conglomerate and shale, stippled = marine rocks absent (in part adapted from Sloss, 1950).

Flat Formation, Monroe Canyon Formation, and undivided Madison and Brazer Limestone (Dutro and Sando, 1963; Armstrong and Oriel, 1965).

The thinning of the clastic belt in south-central Idaho is not fully understood. Paull _et al._, (1972) suggests thrust faulting to explain the present relationships of the clastic sequence (Figure 3). Sandberg (U.S.G.S. Denver, oral communication) holds similar views, and suggests that the thick Copper Basin Group has been thrust from the west into juxtaposition or into superposition with the thinner Mississippian strata in the White Knob Mountains. If these workers are correct, marine Mississippian rocks probably extend west of present exposures. Additional analysis of the sedimentary facies of the Upper Paleozoic rocks in the Pioneer Mountains will be required for the delineation of major thrusts.

Figure 16 illustrates the approximate zero isopachous line for Early Mississippian and Late Mississippian time. During Mississippian time the epicontinental seas regressed from the craton. This regression is of major proportions in western North America and western Canada (Proctor and Macauley, 1968).

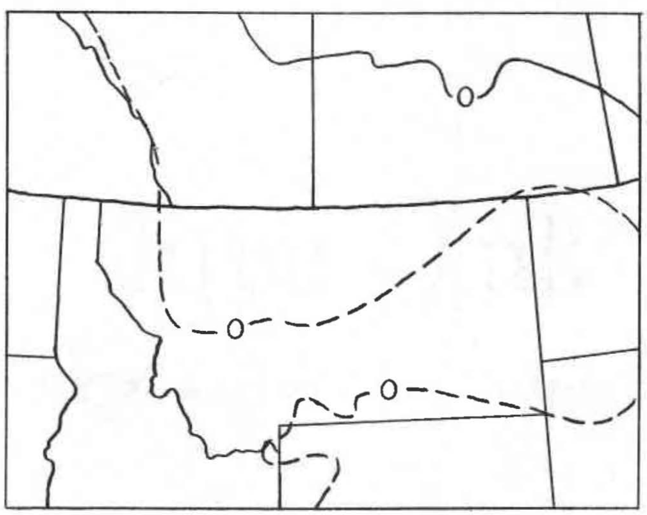


Fig. 16. Illustrates zero isopachous lines for Lower and Upper Mississippian strata. Lower Mississippian = solid line, Upper Mississippian = dashed line (adapted from Sloss, 1950, and Procter and Macauley, 1968).

PENNSYLVANIAN PALEOGEOGRAPHY

The isopachous and lithofacies maps discussed in this part of the text are based on the sequences as they appear now. The maps are based on time-stratigraphic units, but, at present, in many sections, time boundaries are not precisely known. However, the maps are generally representative of the rocks and thicknesses occurring in the region. The writer believes it is possible to reconstruct the generalized paleogeography and to hypothesize on time and direction of major sea advances or retreats. Isopachous lines in southwestern Montana and western Wyoming were adapted from maps published by Sloss (1950) and Williams (1962).

Springeran, Morrowan, and Atokan Paleogeography

By Middle Pennsylvanian time the fundamental pattern of basins, shelf, and platforms, and related positive areas was developed, and was generally persistent throughout Pennsylvanian time (Figure 17). The major elements controlling sedimentation consisted of (1) the platform area in southwestern Montana and western Wyoming, (2) the Wood River and Wells basins in south-central and southeastern Idaho, and (3) the shelf area in south-central Idaho. Positive areas were located in northern Montana, Alberta and Saskatchewan, western Idaho, and, to the south and southeast, the Front Range Highlands.

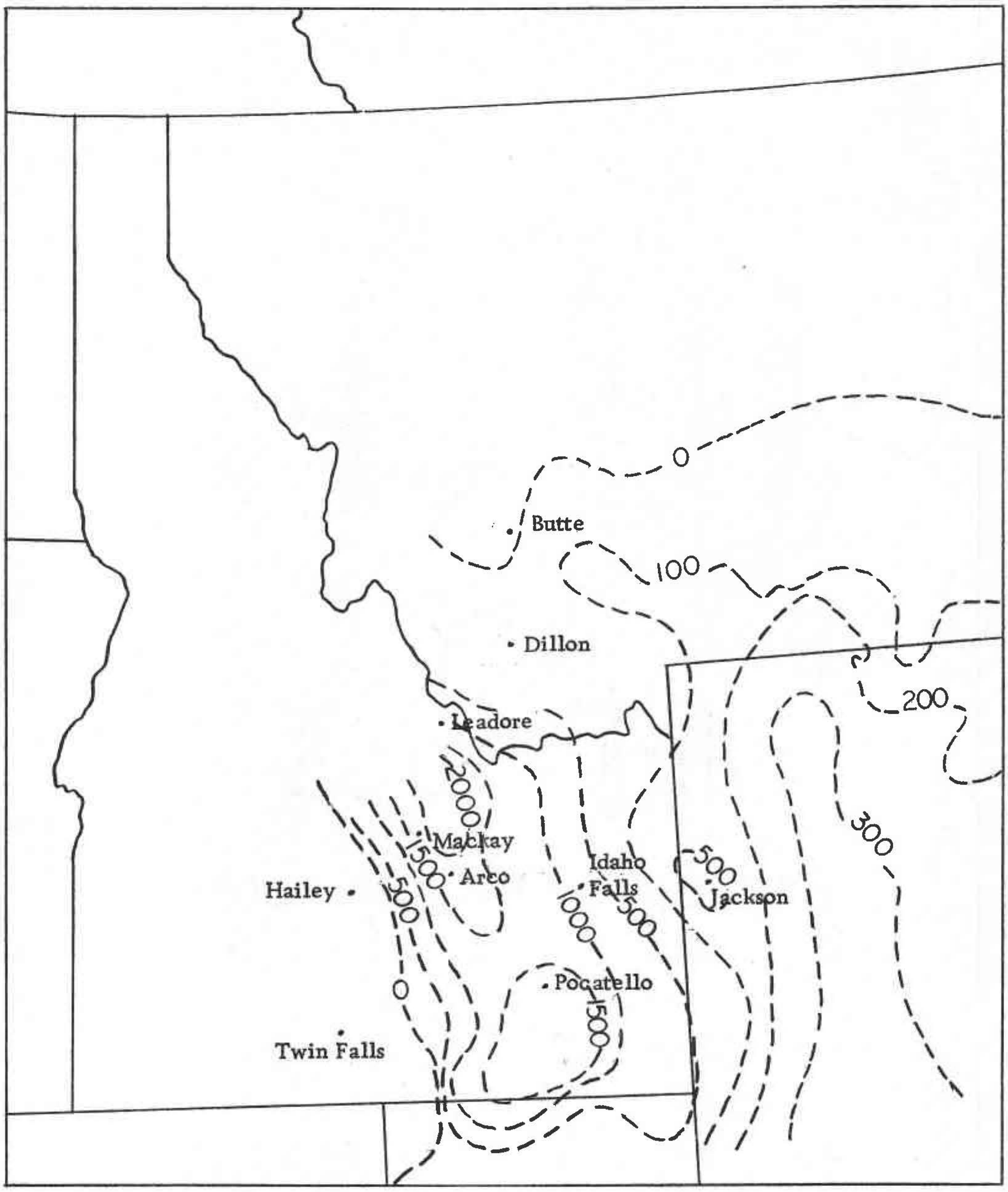


Fig. 17. Isopachous map of the Springeran, Morrowan and Atokan strata. C. I. = 100 and 500 feet.

Figure 18 is an attempt to illustrate lithofacies of Early and early-Middle Pennsylvanian time. The Amsden Formation, restricted to the upper carbonate portion, was deposited in western Wyoming and southwestern Montana. The seas primarily deposited carbonates, but fine clastic material produces siltstones and shales.

In south-central Idaho a stable carbonate shelf existed. Limestones of the Pennsylvanian part of the White Knob Limestone indicate normal marine shallow-water environment. Eastward, along the Montana-Idaho divide, the basal Quadrant sands began to accumulate from a source probably to the north and northeast, and gave way eastward to the Amsden Formation.

In southeastern Idaho sediments of the Wells Formation began to accumulate in a basin persistent throughout the Pennsylvanian. In the western Pioneer Mountains Early and early-Middle Pennsylvanian sediments apparently were absent.

Desmoinesian Paleogeography

During Desmoinesian time Pennsylvanian seas spread to the west. This onlap apparently represents the maximum inundation of Pennsylvanian seas (Figure 19).

Deposition over Wyoming and western Montana platform areas was restricted to sands and subordinate calcareous and dolomitic interbeds of the Quadrant and Tensleep Formations (Figure 20). The

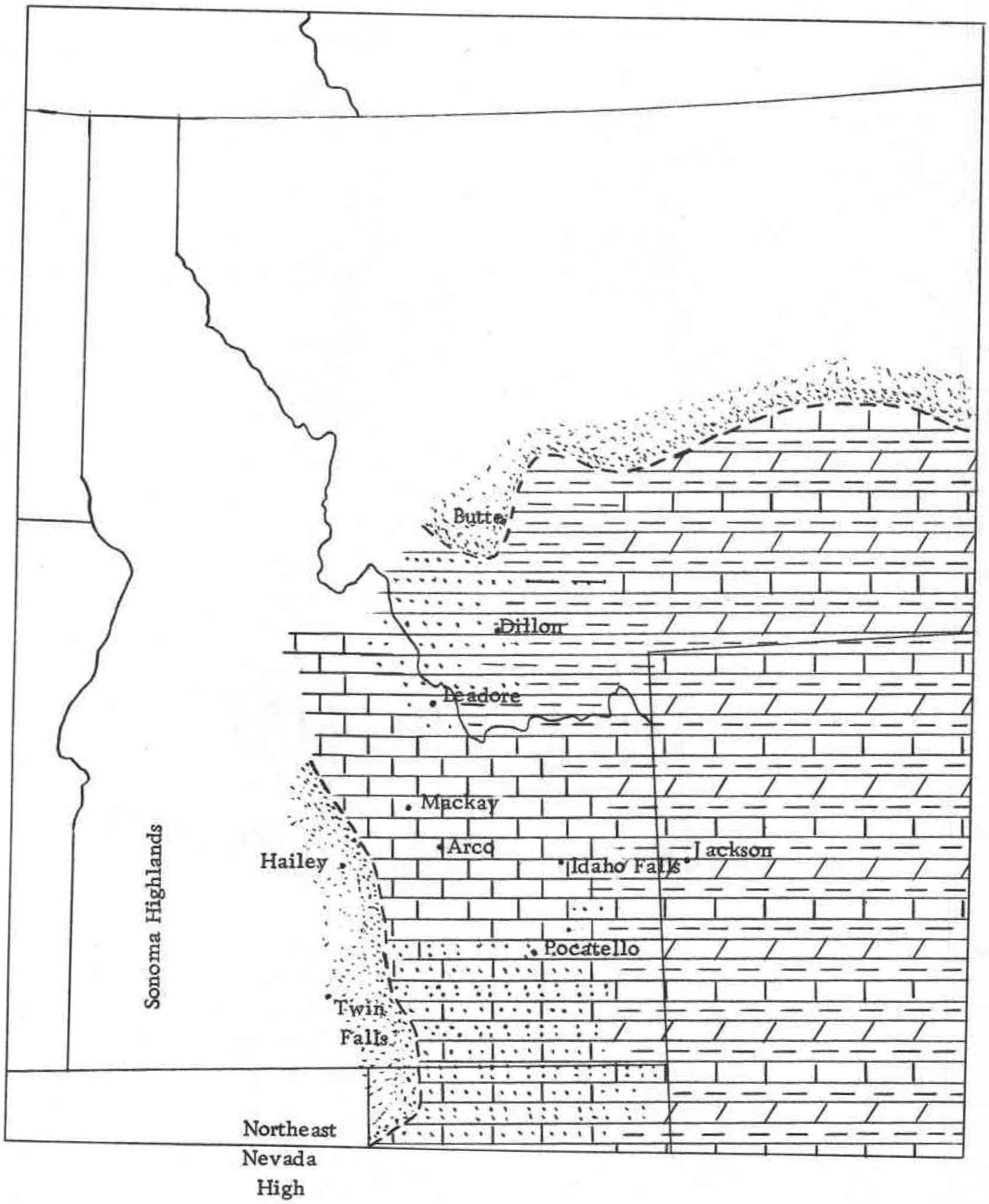


Fig. 18. Springeran, Morrowan and Atokan paleogeography and generalized lithofacies. Lithotopes indicated by patterns - brickwork = limestone, brickwork with inclined hatching = dolomite, dots = sandstone, horizontal dashes = shale, stippled = marine rocks absent.

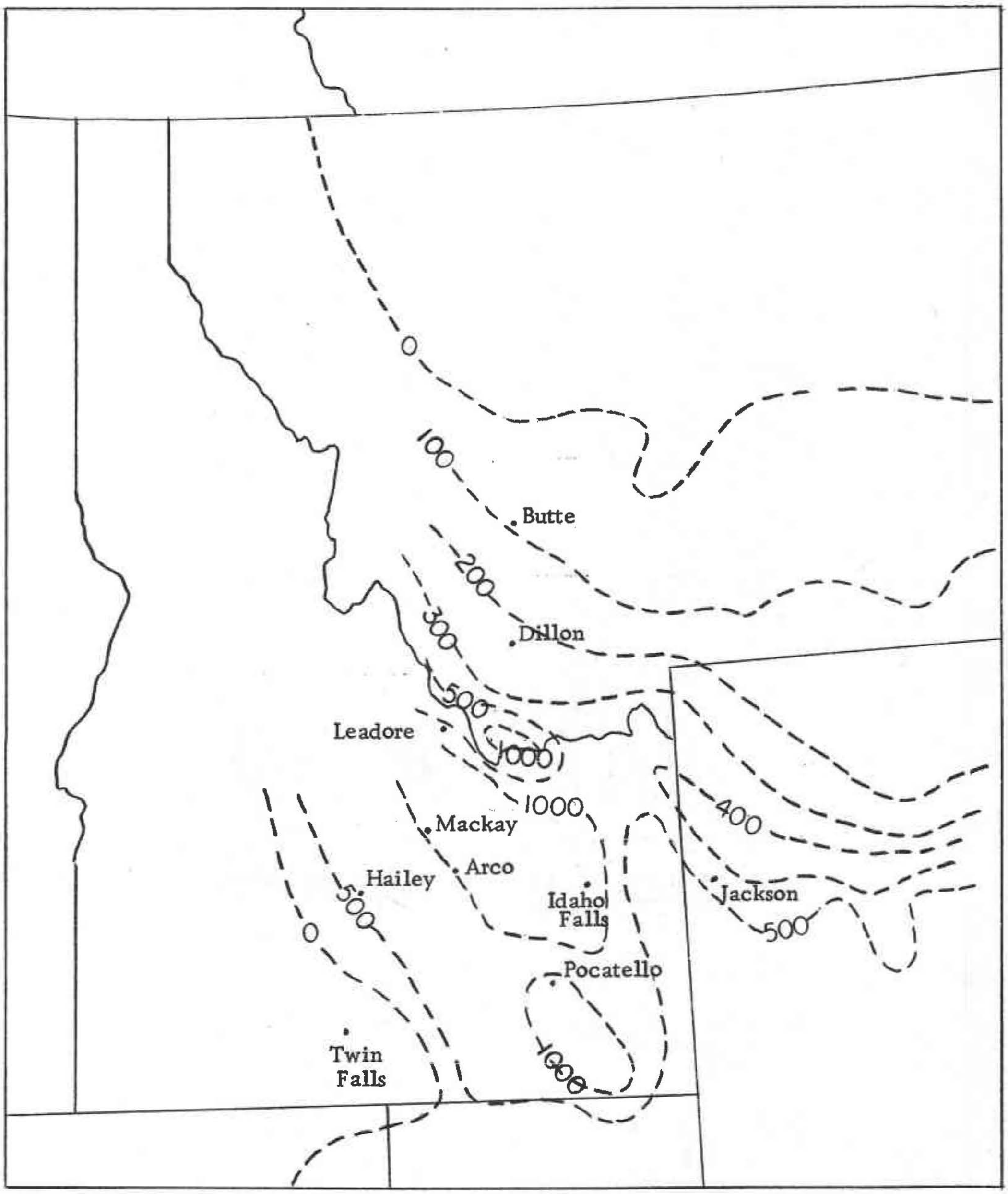


Fig. 19. Isopachous map of the Desmoinesian strata. C. I. =100 and 500 feet.

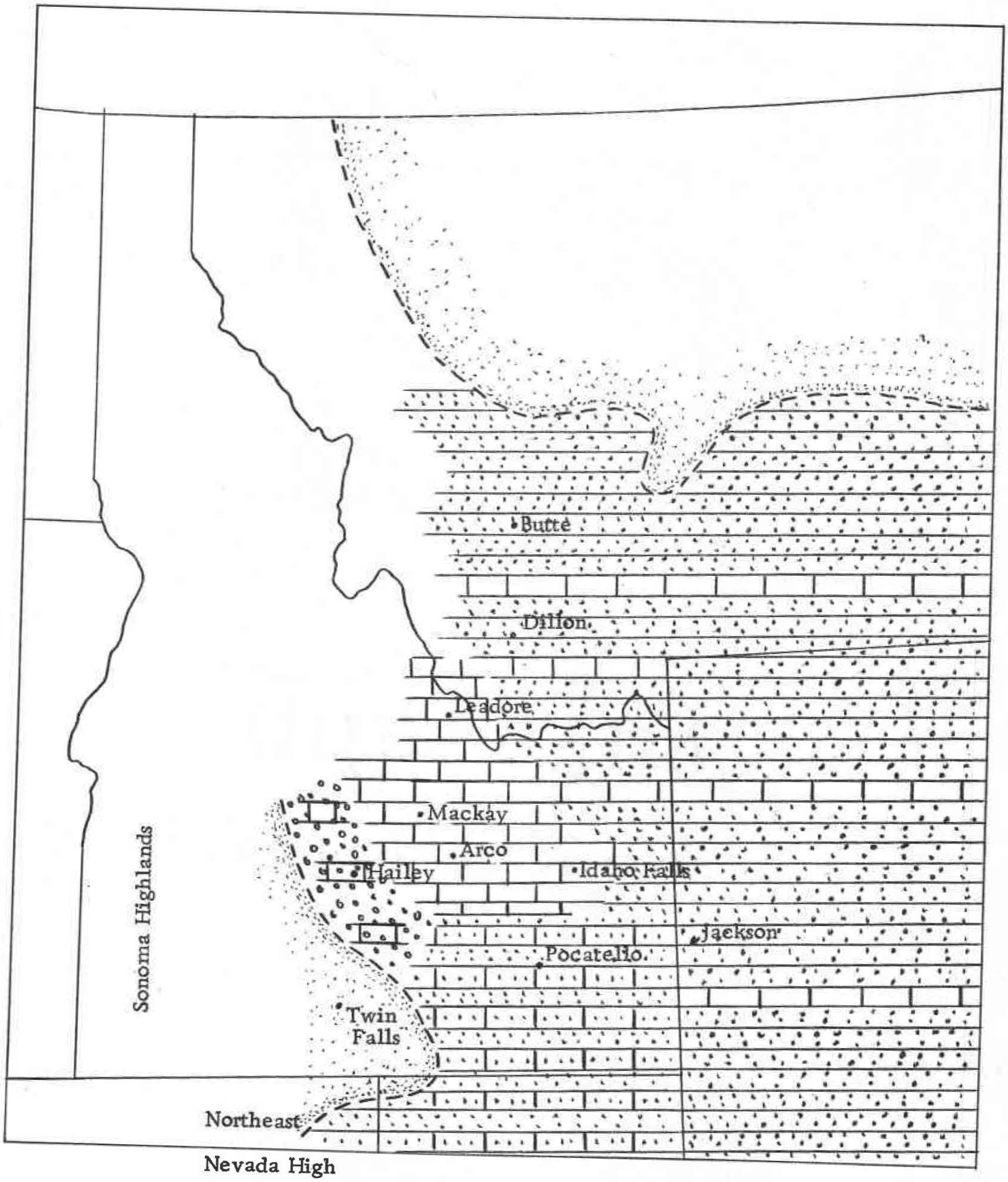


Fig. 20. Desmoinesian paleogeography and generalized lithofacies. Lithotopes indicated by patterns - brickwork = limestone, dots = sandstone, small circles = conglomerate, stippled = marine rocks absent.

source area for these sands appears to be from the north, the northeast, and the southeast from the Front Range Highlands.

Westward in south-central Idaho, the sands gave way to shelf carbonates of shallow, normal, marine environments. In the western Pioneer Mountains Desmoinesian rocks are characterized by a basal conglomerate and overlying limestone. The coarse clastics of the basal conglomerate were probably deposited as a result of marine transgression upon a western positive area of a deepening sea whose ability to transport coarse material ceased in Middle Desmoinesian time, after which carbonate deposition was initiated. In southeastern Idaho the Wells basin continued to accumulate calcareous sandstones and sandy limestones. The principal source areas to the west were apparently the Sonoma Highlands and Northeast Nevada High.

Missourian Paleogeography

Missourian time was marked by a temporary offlap of Pennsylvanian seas that withdrew to the east in Wyoming, and to the west in south-central Idaho and southwestern Montana (Figure 21). Desmoinesian strata were subject to erosion in southwestern Montana, western Wyoming, and most of south-central Idaho.

The Wells basin continued to accumulate clastics (Figure 22). In the Bellevue area, western Pioneer Mountains, 1000 feet of nonfossiliferous strata occur between Middle Desmoinesian and Middle

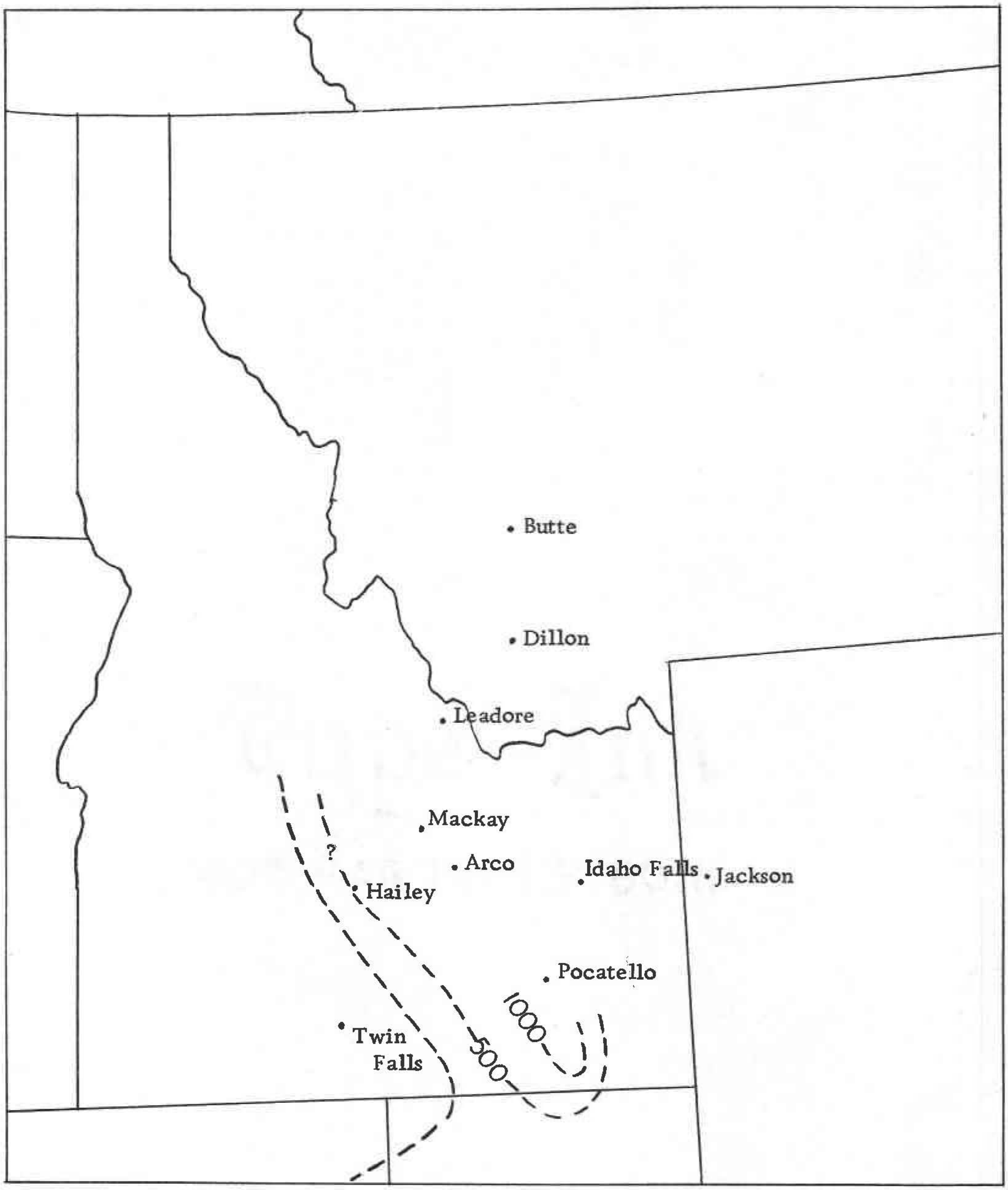


Fig. 21. Isopachous map of Missourian strata. C. I. = 500 feet.

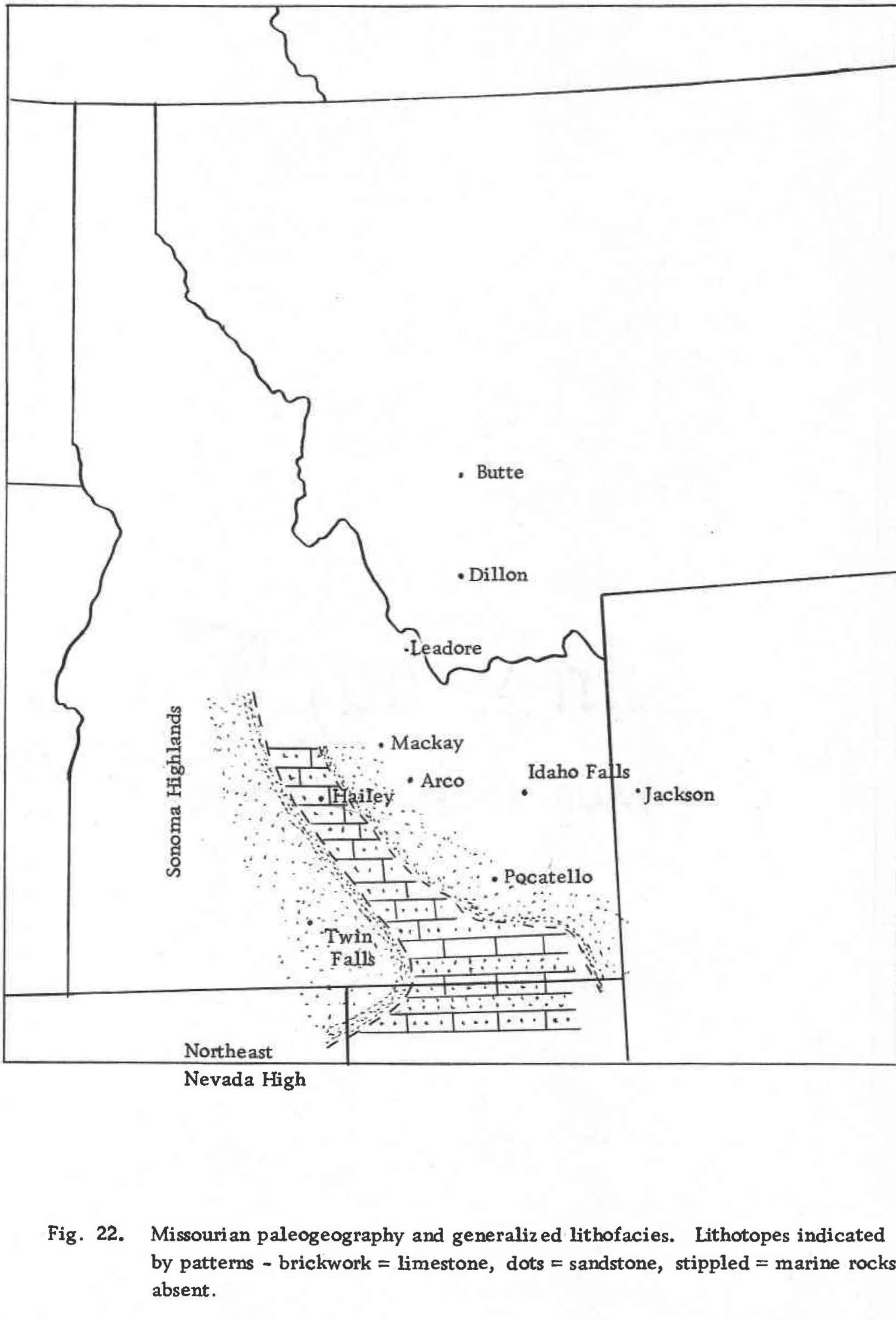


Fig. 22. Missourian paleogeography and generalized lithofacies. Lithotopes indicated by patterns - brickwork = limestone, dots = sandstone, stippled = marine rocks absent.

Virgilian strata, part of which may be Missourian and Early Virgilian in age.

This offlap produced a major regional Pennsylvanian unconformity in Montana, Wyoming, and Idaho, and has been recognized in Alberta (McGugan and Rapson, 1962), and in east-central Nevada (Steele, 1960). This stratigraphic break makes it impossible to evaluate the role erosion has played in altering isopach patterns; however, it probably played a minor role in altering basins, seaways, and positive areas as they are here interpreted.

Virgilian Paleogeography

During Virgilian time the prominent Wood River basin developed in south-central Idaho (Figure 23). This basin accumulated a thick clastic sequence represented by clastics of the Virgilian part of the Wood River Formation (Figure 24). In southeastern Idaho the Wells basin was still actively receiving sediments.

During Middle Virgilian time the seas were restricted to these two basins, but in Late Virgilian time the Pennsylvanian seas spread to the east over former areas of post-Desmoinesian erosion.

The clastic sediments of the Wells and the Wood River Formations were probably derived from the Sonoma Highlands and Northeast Nevada High to the west, and from post-Desmoinesian erosion of the platform and shelf areas to the east and northeast.

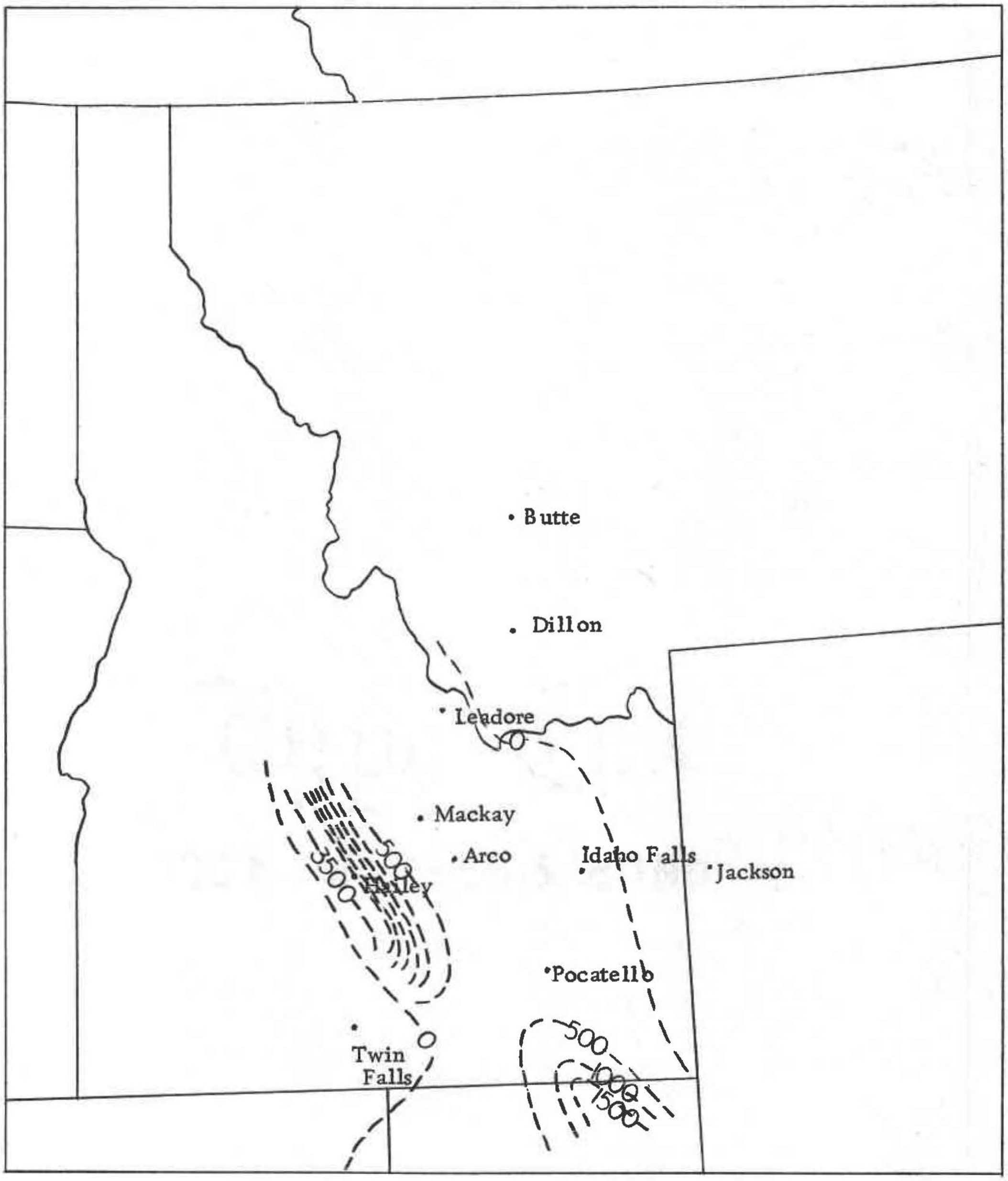


Fig. 23. Isopachous map of Virgilian strata. C. I. = 500 feet.

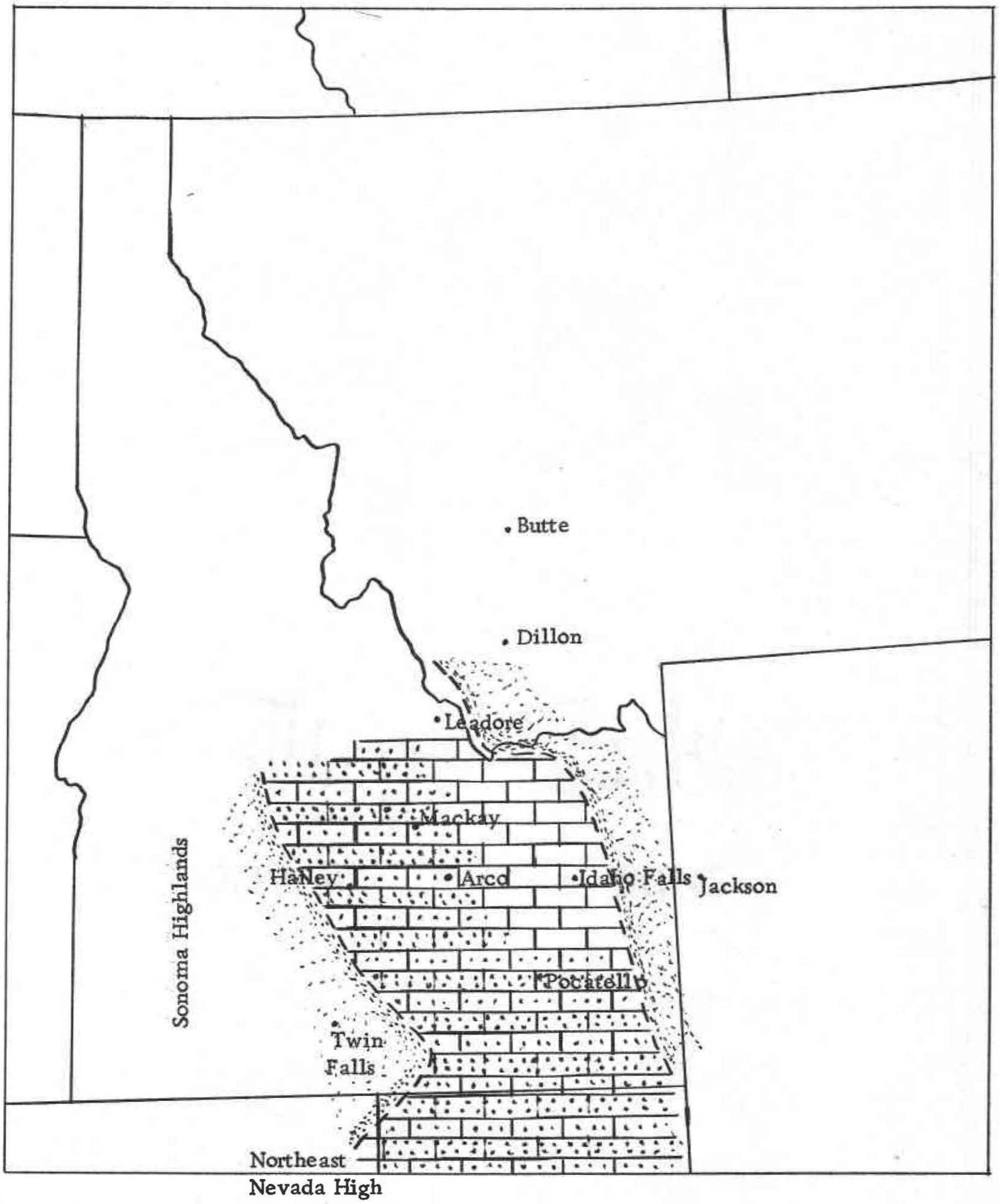


Fig. 24. Virgilian paleogeography and generalized lithofacies. Lithotopes indicated by patterns - brickwork = limestone, dots = sandstone, stippled = marine rocks absent.

Recapitulation

The Pennsylvanian strata in south-central Idaho and adjacent areas were deposited in three major facies. These facies include an eastern platform facies, a central shelf facies, and a marginal basin facies to the west and south. Broad epeirogenic upwarps or eustatic sea level changes resulted in the shelf and platform being alternately positive and negative during Pennsylvanian time. One major disconformity, and possibly minor diastems and hiatuses, are included in the Pennsylvanian sequences, but no major angular unconformities are recognized. Figure 25 represents an isopachous map of the total Pennsylvanian strata in the study area.

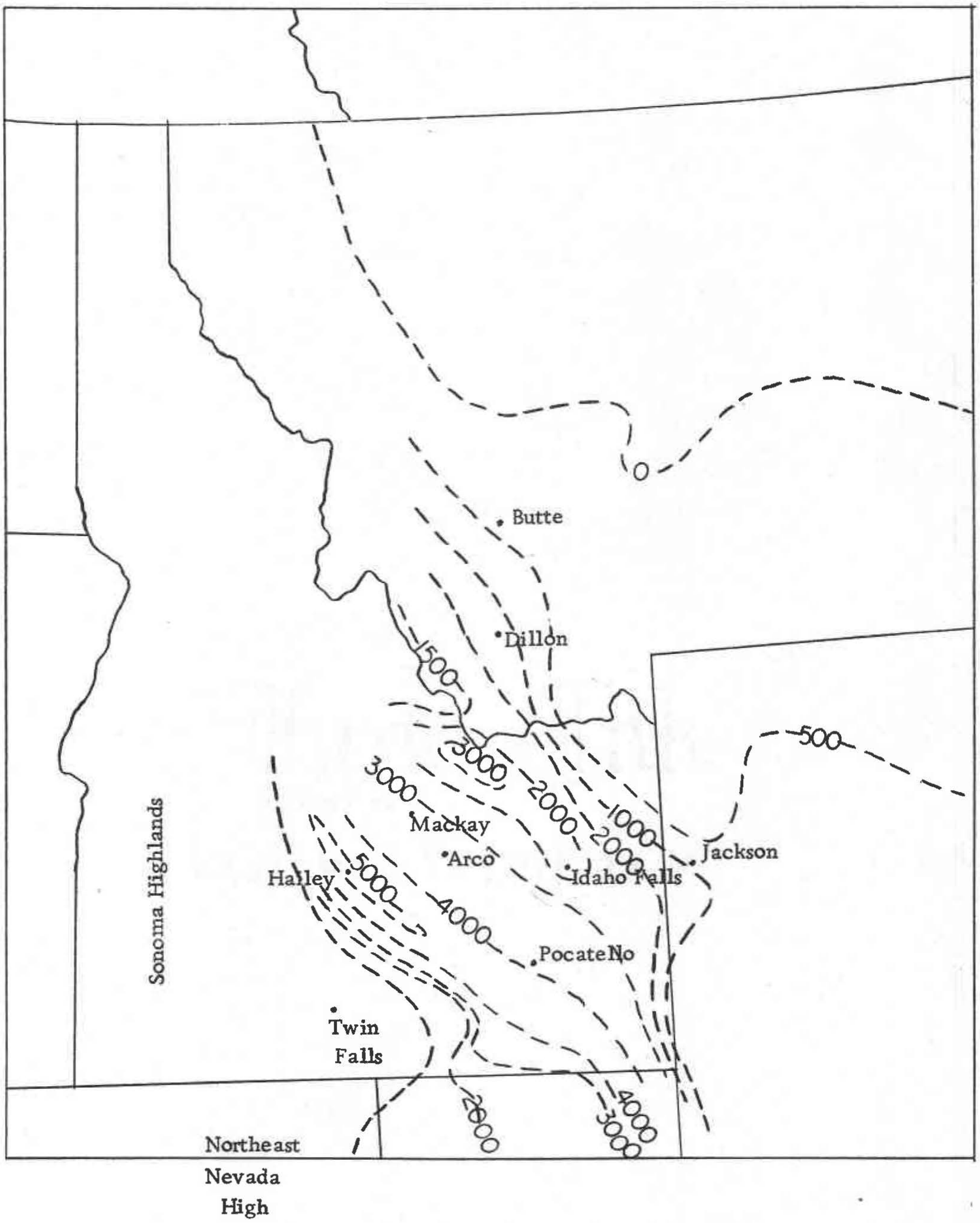


Fig. 25. Isopachous map of total Pennsylvania strata. C.I. = 500 and 1000 feet.

CONCLUSIONS

The following are the conclusions determined by the writer from this study:

1. Upper beds of the Milligen Formation in the western Pioneer Mountains are Late Devonian in age and appear to be transgressive, thinning to the east.

2. The pre-Wood River unconformity in the western Pioneer Mountains represents a hiatus from Late Devonian to Middle Pennsylvanian time.

3. A major disconformity exists in the Pennsylvanian part of the White Knob Limestone (shelf carbonate sequence) and a hiatus ranging from post-Desmoinesian to Late Virgilian time is represented.

4. The major elements controlling Pennsylvanian sedimentation are a platform area in southwestern and western Wyoming, a shelf area in south-central Idaho, and marginal basin areas in south-central and southeastern Idaho.

5. The Wood River and Wells basins are lithologically similar and partly time equivalent, but the Wood River basin was not well developed before Virgilian time.

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APPENDIX

Sources of Isopachous and Lithofacies maps

The isopachous and lithofacies maps (Figures 12, 13, 14, 16, 17, 18, 19, 20, 21, 22, 23, 24) were adapted and modified from published sources, especially areas in western Montana and Wyoming. The main sources of information used in the writer's map construction, with the figures to which they contributed listed after the year of publication, are as follows: Sloss (1950; 8, 9, 10), Steele (1960; Plate 8, 1, 2, 3, 4). Bissell (1962; 2-A, 4-A, 4-B), Williams (1962; 1, 2, 3, 4, 5, 6, 7, 8, 9), Armstrong and Oriel (1965; 6, 7), Roberts *et al.* (1965; Table II, Table III, 18, 19), Procter and Macauley (1968; 4, 5, 6), Johnson (1971; 9, 10).

Stratigraphic Section of the Quadrant Formation, Railroad Canyon

Terminal Point: Approximately 100 feet above ridge-forming upper sandstone unit north of Salt Creek in the SE 1/4, NW 1/4, NE 1/4, Sec. 8, T. 16 N., R. 27 E.

Phosphoria Formation:

	Feet
Gradeur Member: complete section not measured.	
Dolomite, weathers medium-light-gray (N6) to yellowish-gray (5Y8/1), thin-bedded, fossils rare and poorly preserved, vuggy, slope-former, poorly exposed; basal 25 feet is characterized by dolomite with birdseye structure. -------------------------------	100
Contact: sharp and slightly undulating; prominent break in slope.	

Quadrant Formation:

Upper Sandstone Unit: ridge-former.	
Sandstone, weathers light-gray (N7) to light-olive-gray (5Y6/1), massive, medium-grained, calcareous. ---------------------	20
Sandstone, weathers light-olive-gray (5Y6/1) to yellowish-gray (5Y8/1), medium-grained, thick-	

	Feet
bedded, dolomitic; intercalated with very thin-bedded shale, weathers medium-dark-gray (N4), contacts with sandstones undulatory to sharp. ----------------------------------	55
Domomite, weathers light-olive-gray (5Y6/1) to very pale-orange (10YR8/2), thin- to very thin-bedded, nodular chert, finely crystalline, argillaceous; intercalated shale. ------------	26
Sandstone, weathers light-olive-gray (5Y6/1) to medium-gray (N5), thick-bedded, medium- to coarse-grained, dolomitic. ---------------	55
Sandstone, weathers yellowish-gray (5Y8/1) thick-bedded, medium-grained, siliceous. ---------	50
Dolomite, weathers medium-gray (N5) to light-olive-gray (5Y6/1), thick-bedded, sandy, fossils rare and poorly preserved. ----------	70
Dolomite, light-olive-gray (5Y6/1) to dark-yellowish-orange (5YR6/6), sandy, fossiliferous, thin- to very thin-bedded, nodular chert, Vuggy; intercalated shale. -------------------------	40
Sandstone, weathers yellowish-gray (5Y7/2), dolomitic, thick-bedded, medium- to coarse-grained. ----------------------------------	55

	Feet
Dolomite, weathers pale-yellowish-brown (10YR6/2), sandy, thick-bedded, fossiliferous, vuggy; intercalated shale, bedding planes undulatory. ------------------------	50
Sandstone, weathers grayish-orange (10YR7/4), thick-bedded, fine-grained, dolomitic. ------	15
Sandstone, weathers very pale-orange (10YR8/2), nodular chert, thin-bedded, fine-grained, dolomitic. -------------------------------	24
Total upper sandstone unit -------------	460

Contact: gradational

Middle Limestone Unit:

Limestone, weathers grayish-orange (10YR7/4), finely crystalline, nodular chert, thin-bedded; intercalated very thin-bedded shale, bedding interfaces undulatory. --------------	15
Limestone, weathers very pale-orange (10YR8/2), to dark-gray (N5), thick- to thin-bedded, cherty, medium crystalline, fossiliferous: intercalated very thin-bedded argillaceous limestone. Wedekindellina. --------------	55

	Feet
Limestone, weathers light-olive-gray (5Y6/1), cherty, thin-bedded, finely crystalline. ------	60
Limestone, weathers medium-dark-gray (N4), very thin-bedded to laminated, finely crystalline. ------------------------------	5
Sandstone, weathers very pale-orange (10YR8/2), thick-bedded, fine-grained, calcareous. -----	7
Dolomite, weathers light-olive-gray (5Y6/1), thin-bedded, finely crystalline, nodular and lenticular chert. -------------------------	5
Limestone, weathers medium-gray (N5), coarsely crystalline, thin- to thick-bedded, fossiliferous, sandy. ---------------------	17
Limestone, weathers medium-dark-gray (N4), medium crystalline, fossiliferous, chert nodules, *Wedekindellina*. ------------------	6
Dolomite, weathers light-brownish-gray (5YR6/1) to light-olive-gray (5Y6/1), chert nodules, silty, thin-bedded; interbedded very thin-bedded to laminated siltstone. -------------	25

	Feet
Sandstone, weathers pale-yellowish-brown (10YR6/2), thick- to thin-bedded, calcareous, cross-bedded, medium-grained; interbedded finely crystalline dolomitic limestone, cherty, weathers medium-light-gray (N6) in lower five feet. --------------------------------	15
Limestone, weathers medium-light-gray (N6), finely crystalline, nodular chert, thin-bedded.	10
Limestone, weathers medium-light-gray (N6), thick-bedded, sandy, dolomitic, finely crystalline, fossiliferous. ----------------	14
Limestone, weathers medium-gray (N5), finely crystalline, thin-bedded, nodular chert; intercalated shale, bedding planes undulatory.	25
Mudstone, weathers black (N1), imperfectly fissile, slope-former. --------------------	7
Dolomite, weathers grayish-orange (10YR7/4), finely crystalline, thick-bedded, nodular chert; interbedded very thin-bedded argillaceous limestone and calcareous siltstone. _Fusulina_ -------------------------	28

	Feet
Sandstone, weathers grayish-orange (10YR7/4) thin-bedded, dolomitic, fine-grained. -------	35
Dolomite, weathers medium-gray (N5), sandy, finely crystalline, thick-bedded. ------------	8
Dolomite, weathers grayish-yellow (5Y8/1), thin-bedded, medium crystalline. -----------	16
Limestone, weathers medium-gray (N5) to very pale-orange (10YR8/2), finely crystalline, chert nodules, thick-bedded; interbedded sandstone, calcareous, weathers pale-yellowish-brown (10YR6/2), thin-bedded, fine-grained. ----------------------------	90
Covered ---------------------------------------	8
Limestone, weathers medium-light-gray (N6) to light-olive-gray (5Y6/1), sandy, coarsely crystalline, fossiliferous, thin- to thick-bedded; interbedded cross-bedded sandstone, medium-grained, calcareous, weathers grayish-orange (10YR7/4). <u>Profusulinella</u>, <u>Nankinella</u> -------	19
Covered ---------------------------------------	5

	Feet
Limestone, weathers light-gray (N7) to pale-yellowish-orange (10YR8/6), medium- to coarsely crystalline, thin-bedded, fossiliferous; base contains nodular and lenticular chert. -------------------------	33
Total middle limestone unit -----------	508
Contact: gradiational	
Lower Sandstone Unit:	
Sandstone, weathers pale-yellowish-brown (10YR6/2), medium- to coarse-grained, thick-bedded, siliceous. ------------------	15
Limestone, weathers medium-gray (N5), fossiliferous, thin-bedded, medium crystalline. <u>Pseudostaffella?</u> -------------	5
Sandstone, weathers light-olive-gray (5Y6/1) to pale-yellowish-brown (10YR6/2), siliceous, thin-bedded, medium-grained. ---	3
Dolomite, weathers medium-dark-gray (N4), finely crystalline, thin-bedded. ------------	3
Sandstone, weathers pale-yellowish-brown (10YR6/2), medium-grained, siliceous, thin-bedded. --------------------------	70

	Feet
Dolomite, weathers light-olive-gray (5Y6/1), thin- to very thin-bedded, chert nodules, finely crystalline, irregular bedding planes. --	10
Sandstone, weathers pale-yellowish-brown (10YR6/2), thick- to very thick-bedded, medium- to coarse-grained, siliceous; same beds thinly-crossbedded in upper 100 feet. ----------------------------------	240
Covered: ------------------------------------	100
Sandstone, weathers pale-yellowish-brown (10YR6/2), thin-bedded, siliceous, some horizons are cross-bedded. ---------------	27
Covered: ------------------------------------	60
Sandstone, weathers pale-yellowish-brown (10YR6/2), medium-grained, cross-bedded; interbedded limestone, medium-gray (N5), fossiliferous, chert nodules, sandy. --------	12
Total lower sandstone unit -------------	545
Contact: Covered	
Total Quadrant Formation -------------	1513

Initial Point: NE 1/4, SE 1/4, SW 1/4, Sec. 30, T. 17 N., R. 27 E., approximately one mile northwest of the junction between unimproved road along Cruikshank Creek and State Highway 29.

Stratigraphic Sections of the White Knob
Limestone, Cedar Canyon

	Feet
Terminal Point: On top of ridge south of Cedar Canyon road SE 1/4, SE 1/4, SE1/4, Sec. 17, T. 7 N., R. 30 E.	
White Knob Limestone: south section	
Dolomite, weathers light-gray (N7), thin-bedded, bedding planes sharp, vuggy, weathers with a rough pitted surface, fossiliferous; "Fossil ghosts," crinoidal and brachiopod debris. ----	65
Covered ------------------------------------	140
Limestone, weathers medium-light-gray (N6), thin-bedded, finely crystalline. ----------------	15
Covered ------------------------------------	25
Limestone, weathers medium-dark-gray (N4), thin-bedded, black (N1) to pale-yellowish-brown (10YR6/2) concretionary chert near base, fossiliferous, finely crystalline. -----------	15
Covered ------------------------------------	20
Limestone, weathers medium-gray (N5), thin- to thick-bedded, chert stringers in upper two feet, fossiliferous, finely crystalline. -----------	22
Covered ------------------------------------	35

	Feet
Limestone, weathers light-gray (N7), thick-bedded, finely crystalline, fossiliferous. ----	50
Covered --	5
Limestone, weathers dark-gray (N3), ridge-former, thin-bedded, medium crystalline, concentric chert structures at the base, fossiliferous; crinoid, brachiopods, and bryozoan debris. --	15
Limestone, weathers light-gray (N6), thick-bedded, dolomitic, fossiliferous, finely crystalline. --	10
Covered --	45
Limestone, weathers medium-light-gray (N6), thick- to very thick-bedded, dolomitic, finely crystalline, vuggy; poorly exposed. ---------	105
Limestone, weathers grayish-orange (10YR7/4), dolomitic, vuggy, thick-bedded, finely crystalline. ------------------------------	10
Covered --	15
Limestone, weathers light-gray (N7), thick-bedded, cherty, fossiliferous. --------------------	5
Covered --	5
Limestone, weathers dark-gray (N3), medium to coarsely crystalline, thin-bedded, approximately	

Feet

20% lenticular, nodular, and concentric chert structures. Concentric chert structures up to 6 feet long and 8-10 inches wide. Fossiliferous, fusulinids, tabulate corals, crinoid hash, bryozoans, and brachiopods; biostromal. Triticites (Virgilian form). ----- 35

Limestone, weathers medium-dark-gray (N4), thick- to very thick-bedded, concentric chert nodules, contains sandy interlayers and sandy zones, fossiliferous; crinoid and bryozoan hash. ------------------------------------ 65

Sandstone, weathers yellowish-gray (5Y8/2), to a grayish-orange (5Y8/4), calcareous, slope-former, soft and friable; interbedded limestone, weathers light-gray (N7), finely crystalline, thin- to very-thin-bedded. ----------------- 25

Limestone, weathers medium-gray (N5), thick-bedded, finely crystalline, fossiliferous. Schubertella ---------------------------- 16

Limestone, weathers light-gray (N7), thin-bedded, nodular chert, medium crystalline, fossiliferous. 15

Feet

Limestone, weathers dark-gray (N4), thick-bedded, finely crystalline, fossiliferous; brachiopods and crinoid hash. Nankinella, Eoschubertella?, Profusulinella ---------------------------- 1.5

Covered -- 5

Limestone, weathers light-gray (N7), thick-bedded lenticular chert and chert nodules, fossiliferous. ---------------------------- 15

Limestone, weathers medium-dark-gray (N4), finely crystalline, biostromal, fossiliferous; corals, brachiopods, crinoid, echnoid and bryozoan hash. Eoschubertella? --------- 34

Total White Knob Limestone south section - 827

Contact: Structural; thrust fault

Initial Point: Above thrust fault on ridge south of Cedar Canyon NE 1/4, SW 1/4, SE 1/4, Sec. 17, T. 7 N., R. 30 E.

Terminal Point: Below thrust fault on ridge south of Cedar Canyon NE 1/4, SW 1/4, SE 1/4, Sec. 17, T. 7 N., R. 30 E.

White Knob Limestone: north section.

Feet

Limestone, weathers pale-yellowish-orange (10YR8/6), very thick-bedded, finely crystalline, fossiliferous. ----------------- 15

Traverse change: north side of Cedar Canyon SE 1/4, NE 1/4, NW 1/4, Sec. 17, T. 7 N., R. 30 E.

	Feet
Limestone, weathers pale-yellowish-orange (10YR8/6) to dark-yellowish-orange (10YR6/6), very thick-bedded, finely crystalline, fossiliferous. *Eoschubertella?* --	65
Limestone, weathers medium-light-gray (N6), thick-bedded, finely crystalline. -----------	34
Covered --------------------------------------	9
Limestone, weathers light-gray (N6), thick-bedded, finely crystalline, biostromal, fossiliferous; tabulate corals, bryozoans, brachiopods. ---------------------------	8
Limestone, weathers pale-yellowish-orange (10YR8/6) to medium-gray (N5), thin-bedded, finely crystalline, fossiliferous. *Eoschubertella?* -------------------------	12
Limestone, weathers medium-gray (N5), thin-bedded, finely crystalline, fossiliferous. ----	10
Limestone, weathers light-gray (N6), thin-bedded, chert nodules, finely crystalline, biostromal, fossiliferous; corals, brachiopods, cronoidal hash, echnoid spines. --------------------	10

	Feet
Limestone, weathers medium-gray (N5), thin-bedded, lenticular chert, finely crystalline, fossiliferous. Helicoprion ----------------	6
Limestone, weathers pale-yellowish-orange (10YR8/6), dolomitic, easily eroded and forms caverns. --------------------------	15
Limestone, weathers pale-yellowish-brown (10YR6/2), concentric chert, finely crystalline, fossiliferous. Eoschubertella? ------------	9
Covered --	10
Limestone, weathers medium-light-gray (N6) to medium-dark-gray (N4), thin-bedded, chert nodules and stringers, finely crystalline, fossiliferous: Triticites (Virgilian form), Triticites? ------------------------------	44
Dolomite, weathers yellowish-gray (5Y8/1), thin-bedded, finely crystalline. Staffella ----	4
Limestone, weathers medium-light-gray (N6), chert nodules, thin-bedded, finely crystalline. ----------------------------	4
Limestone, weathers dark-gray (N3), thick-bedded, biostromal, fossiliferous; 50% bryozoans,	

	Feet
crinoidal hash, brachiopods, corals, echnoid spines. ----------------------------	5
Limestone, weathers medium-dark-gray (N4), thick-bedded, finely crystalline, chert nodules, concentric chert, fossiliferous. Staffella, Nankinella --------------------------------	39
Limestone, weathers yellowish-gray (5Y8/1), massive, chert nodules and stringers, dolomitic, fossiliferous; crinoid debris. Staffella, Nankinella ----------------------	13
Covered ---------------------------------------	6
Dolomite, weathers medium-light-gray (N6), thick-bedded, finely crystalline. ------------	6
Total White Knob Limestone north section ---------------------	324

Initial Point: North side of Cedar Canyon in the SE 1/4, SE 1/4, NW 1/4, Sec. 17, T. 7 N., R. 30 E.

Underlying north section is a poorly exposed slope-forming basal unit consisting of sandstones, limestones and siltstones. It is estimated to be 350 feet thick in the area.

White Knob Limestone: basal unit

Sandstone, siltstone, interbedded limestone.

	Feet
Sandstone, soft, friable, weathers light-gray (N7) to yellowish-gray (5Y8/1), calcareous and dolomitic. Limestones, thin-bedded, weathered sugary, forms inconspicuous outcrops. --------------------	350 approximate
Total White Knob Limestone including basal unit ----------------	1177

The north section is repeated due to thrusting and a composite section that includes the basal unit and the south section is approximately 1177 feet thick.

Stratigraphic Section of the Wood River Formation, Bellevue Area

Terminal Point: Top of ridge between Martin Gulch and the Muldoon Road where reliable dips and strikes cannot be obtained because of excessive cover in the NE 1/4, SW 1/4, NE 1/4, Sec. 23, T. 2 N., R. 19 E.

Wood River Formation: Permian part.

	Feet
Sandstone, weathers light-olive-gray (5Y6/1) to grayish-orange-pink (5YR7/2), thick- to very thick-bedded, medium-grained, calcareous and siliceous; interbedded limestone, sandy, weathers medium-light gray (N6), thin-bedded, approximately 30% of interval. ------------------------	175
Covered ------------------------------------	310
Sandstone, weathers pale-yellowish-brown (10YR6/2), medium-grained, very thick-bedded, calcareous. --------------------	25
Sandstone, weathers pale-yellowish-brown (10YR6/2), thick-bedded, calcareous, fine-grained. ------------------------------	75
Sandstone, weathers light-olive-gray (5Y6/1) to pale-yellowish-brown (10YR6/2), fine-grained	

	Feet
calcareous, thick-bedded; interbedded limestone, sandy, approximately 10% of interval, weathers medium-dark-gray (N4), thick-bedded. Fossiliferous interval containing fusulinids. ------------------------------	135
Covered ------------------------------------	205
Sandstone, weathers dark-yellowish-brown (10YR4/2), fine-grained, thin- to thick-bedded, calcareous. ----------------------	240
Sandstone, weathers pale-yellowish-brown (10YR6/2), calcareous, fine-grained, thin- to thick-bedded; interbedded limestone, sandy, thin-bedded approximately 1% of interval, fossiliferous; fusulinids. -----------	55
Sandstone, weathers moderate-yellowish (10YR5/4), fine-grained, calcareous; interbedded limestone, sandy, approximately 20% of interval, weathers medium-light-gray (N6), thin-bedded.	50
Sandstone, weathers moderate-yellowish-brown (10YR5/4), calcareous, fine-grained, thin-bedded. ---------------------------------	175

	Feet
Limestone, weathers medium-light-gray (N6), thin-bedded, coarse calcarenite, sandy, fossiliferous; abundant fusulinids. -----------	10
Sandstone, weathers moderate-yellowish-brown (10YR5/4), fine-grained, calcareous, thin- to thick-bedded, fossiliferous; some horizons containing fusulinids. ---------------------	100
Limestone, weathers light-olive-gray (5Y6/1) to medium-light-gray (N6), thin-bedded, sandy, coarse calcarenite, fossiliferous; fusulinids, bryozoans and crinoidal hash. Lenticular sandstone, calcareous, weathers moderate-yellowish-brown (10YR5/4); minor laminated argillaceous siltstones. -----------	40
Sandstone, weathers pale-yellowish-brown (10YR6/2, thin-bedded, fine-grained, calcareous. ------------------------------	35
Covered ---------------------------------------	85
Sandstone, weathers moderate-yellowish-brown (10YR6/2), fine-grained, thin-bedded, calcareous. Interbedded limestone sandy, medium to coarse calcarenite, thin-bedded,	

	Feet
approximately 40% of interval, weathers medium-gray (N5), fossiliferous; fusulinids.	30
Covered	70
Sandstone, weathers moderate-yellowish-brown (10YR5/4), thin-bedded, fine-grained, calcareous; interbedded limestone, sandy, weathers light-olive-gray (5Y6/1) to medium-dark-gray (N4), approximately 15% of interval, fossiliferous; fusulinids, crinoidal and bryozoan hash.	70
Sandstone, weathers pale-yellowish-brown (10YR6/2), fine-grained, calcareous, thin-bedded.	30
Sandstone, weathers moderate-yellowish-brown (10YR5/4), fine-grained, calcareous; interbedded limestone, sandy, thin-bedded, weathers medium-light-gray (N6), approximately 40% of interval, fossiliferous; fusulinids, bryozoan and crinoidal hash.	35
Total Permian part of Wood River Formation, partial section.	1940

Systemic Break; marks earliest appearance of *Triticites cellamagnus*.

Wood River Formation: Pennsylvanian part.

	Feet
Sandstone, weathers moderate-yellowish-brown (10YR5/4), calcareous, fine-grained, thin-bedded; minor interbedded limestone, sandy, weathers light-gray (N7), fossiliferous; fusulinids.	90
Sandstone, weathers moderate-yellowish-brown (10YR5/4), fine-grained, calcareous, thick-bedded.	145
Sandstone, weathers moderate-yellowish-brown (10YR5/4), fine-grained, calcareous, thin-bedded; interbedded limestone, sandy, cross-laminated, thin-bedded, weathers medium-light-gray (N6).	125
Covered	95
Sandstone, weathers moderate-yellowish-brown (10YR5/4), thick-bedded, calcareous, fine-grained.	90
Covered	155
Sandstone, weathers pale-yellowish-brown (10YR6/2), thick-bedded, calcareous, fine-grained.	135

	Feet
Limestone, weathers medium-light-gray (N6), sandy, thin-bedded, cross-laminated; interbedded sandstone, calcareous, weathers moderate-yellowish-brown (10YR5/4), fine-grained; approximately 20% of interval. --	75
Sandstone, weathers moderate-yellowish-brown (10YR5/4), fine-grained, thick-bedded, calcareous. ------------------------------	290
Limestone, weathers light-olive-gray (5Y6/1), sandy, fossiliferous, thin-bedded; interbedded sandstone, calcareous, approximately 40% of interval, thin-bedded, fine-grained, weathers moderate-yellowish-brown (10YR5/4).	45
Limestone, weathers light-olive-gray (5Y6/1), to medium-light-gray (N6), coarse to medium calcarenite, fossiliferous; fusulinids. --------	30
Sandstone, weathers moderate-yellowish-brown (10YR5/4), calcareous, fine-grained; interbedded limestone, sandy, weathers medium-light-gray (N6), thin- to thick-bedded, approximately 20% of interval. -------------	475

Fault: 270 foot Breccia zone.

	Feet
Sandstone, weathers moderate-yellowish-brown (10YR5/4), thin-bedded, calcareous, fine-grained; interbedded limestone, sandy, weathers medium-light-gray (N6), approximately 35% of interval. -------------------	60
Covered --------------------------------------	95
Sandstone, weathers moderate-yellowish-brown (10YR5/4), fine-grained, calcareous, thin-bedded; interbedded limestone, sandy, approximately 5% of interval, weathers medium-light-gray (N6), fossiliferous; fusulinids. ----------------------------	175
Covered --------------------------------------	40
Sandstone, weathers grayish-orange (10YR7/4), thick- to very thick-bedded, fine- to medium-grained, calcareous; interbedded limestone, sandy, approximately 3% of interval, laminated and cross-laminated, fossiliferous; fusulinids.	165
Sandstone and limestone, cyclically-bedded. Sandstones weather moderate-yellowish-brown (10YR5/4), calcareous, thin-bedded, fine-grained, cross-bedded and cross-laminated.	

	Feet
Limestones, sandy, weather medium-light-gray (N6), fossiliferous, graded, coarse to medium calcarenite. ----------------------	35
Covered --	50
Sandstone and limestone, cyclically-bedded. Sandstones, weather moderate-yellowish-brown (10YR5/4), calcareous, thin-bedded, fine-grained, cross-bedded and cross-laminated. Limestone, sandy, weathers medium-light-gray (N6), fossiliferous, graded, coarse to medium calcarenite. ------	195
Sandstone, weathers moderate-yellowish-brown (10YR5/4), fine-grained, calcareous, thick-bedded; interbedded limestone, sandy, approximately 5% of interval, weathers medium-gray (N5), fossiliferous; fusulinids.	417
Sandstone, weathers moderate-yellowish-brown (10YR5/4), fine-grained, calcareous, thin-bedded; interbedded limestone, sandy, approximately 10% of interval, thin-bedded, fossiliferous; fusulinids. -----------------	305

	Feet
Sandstone and limestone, interbedded. Sandstones, weather moderate-yellowish-brown (10YR5/4), fine-grained, thin-bedded, calcareous. Limestone, weathers medium-gray (N5), fossiliferous; fusulinids, approximately 50% sandstone in the interval. ----------------------------------	107
Sandstone, weathers moderate-yellowish-brown (10YR5/4), calcareous, fine-grained, thick-bedded; interbedded limestone, sandy, approximately 5% of interval, weathers medium-gray (N5), fossiliferous; fusulinids. -------------	160
Fault: 75-foot breccia zone	
Sandstone, weathers light-olive-gray (5Y6/1), siliceous, medium-grained, very thick-bedded. -----------------------------------	475
Limestone, weathers medium-gray (N5), chert laminae, sandy, thin-bedded. --------------	20
Sandstone, weathers dark-yellowish-brown (10YR4/2), medium-grained, very thick-bedded, siliceous. -----------------------	420

Feet

Sandstone, weathers moderate-yellowish-brown (10YR5/4), thin- to thick-bedded, calcareous, fine-grained; interbedded limestone, sandy, approximately 20% of interval, thin-bedded, weathers medium-light-gray (N6). ----------- 760

Fault: significant 20 degree change in dip.

Siltstones, weathers pale-red-purple (5RP6/2), to pale-brown (10YR6/2), very thin-bedded, laminated, argillaceous, calcareous. -------- 440

Limestone, weathers medium-dark-gray (N4), thin-bedded, sandstone interlayers, finely crystalline, sandy, fossiliferous; algal structures, crinoidal debris. --------------- 15

Covered --------------------------------------- 55

Limestone, weathers medium-light-gray (N6), sandy, thin-bedded, finely crystalline, fossiliferous; crinoidal hash, bryozoans, brachiopods, corals, fusulinids. ------------ 60

Conglomerate, mudstone, siltstone, and sandstone, interbedded. Pebbly conglomerate, lenticular, thin-bedded, weathers grayish-orange (10YR7/4),

Feet

graded. Mudstones, laminated, weathers dark-yellowish-orange (10YR6/6). Siltstones, weather moderate-yellowish-brown (10YR6/6), very thin-bedded, calcareous. Sandstones weather moderate-yellowish-brown (10YR5/4), fine-grained, calcareous, thin-bedded. ------ 115

Conglomerate, weathers moderate-yellowish-brown (10YR5/4), pebbly, thick- to very thick-bedded; average clast-size one inch; minor limestone clasts near top of member; interbedded sandstone lenses. ---------------------------------- 230

Total Pennsylvanian part of the Wood River Formation ------------- 6489

Total Wood River Formation measured -- 8429

Contact: sharp

Milligen Formation:

Conglomerate, weathers grayish-orange (10YR7/4), angular micrite clasts up to 3 inches, siltstone matrix. This may represent an erosional surface. ---------------------------------- 15

Limestone, weathers very pale-orange (10YR8/2), very finely crystalline, massive. ------------ 10

	Feet
Argillite, weathers dark-gray (N3), laminated, thin-bedded. -------------------------------	21
Total Milligen measured ---------------	46

Initial Point: Below conglomerate member one half mile up Martin Gulch from the Muldoon Road SE 1/4, NE 1/4, SE 1/4, T. 2 N., R. 19 E.