Stratigraphy and Geologic History of the Amsden Formation (Mississippian and Pennsylvanian) of Wyoming

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J. THOMAS DUTRO, JR.

THE AMSDEN FORMATION (MISSISSIPPIAN AND PENNSYLVANIAN) OF WYOMING

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An analysis of the history of a late Paleozoic sea based on a comprehensive biostratigraphic study

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By William J. Sando, Mackenzie Gordon, Jr., and J. Thomas Dutro, Jr.

ABSTRACT

The age and correlation of the Amsden Formation of Wyoming, which has been the subject of long-standing confusion, is examined by means of a comprehensive biostratigraphic approach to the problem. Study of fossils previously reported from the formation, together with many new collections, is integrated with lithostratigraphic and petrographic data compiled by the writers and other geologists. This study is extended into areas adjacent to Wyoming to produce a regional synthesis of the geologic history of the northern Cordilleran region during Late Mississippian-Middle Pennsylvanian time.

Four members are recognized in the Amsden Formation of Wyoming. These are, in ascending order, the Darwin Sandstone Member (Blackwelder, 1918), Horseshoe Shale Member (Mallory, 1967), Moffat Trail Limestone Member (new name), and Ranchester Limestone Member (Mallory, 1967). All the members are diachronous as a result of a general west-to-east transgression of the Amsden sea from the miogeosyncline of Idaho onto the cratonic Wyoming shelf.

The Darwin Sandstone Member (late Meramecian-late Chesterian) formed as nearshore sand in beaches and offshore bars adjacent to the transgressing shoreline. Principal sources of this sand were probably lower Paleozoic sedimentary rocks and Precambrian crystalline rocks on the Transcontinental arch to the east and southeast of the Wyoming shelf.

The Horseshoe Shale Member (early Chesterian-Morrowan) represents offshore deposits of fine terrigenous detritus accumulated principally in a lagoonal environment. Sources of Horseshoe detritus may have been lateritic soil developed on the karst surface of the Madison Limestone or they may have been the same as the sources of the Darwin Sandstone.

The Moffat Trail Limestone Member (middle and late Chesterian) is a lobate western Wyoming tongue of a great body of open-marine carbonates that was deposited in the miogeosyncline of Idaho. The Moffat Trail consists of calcareous detritus produced in situ by shelly marine organisms.

The Ranchester Limestone Member (late Chesterian-Atokan) is a mixed dolomitic carbonate-shale-sandstone facies that accumulated in a restricted marine offshore environment. Sources of the Ranchester, though pulsating and changing in geographic location throughout its deposition, were probably located mainly on the Transcontinental arch to the east and southeast of the Wyoming shelf.

Though sparsely fossiliferous, the Amsden Formation contains a highly diverse, principally endemic fauna that consists of 210 taxa of megafossils and more than 140 taxa of microfossils. The fauna includes marine representatives of the animal phyla Protozoa, Coelenterata, Bryozoa, Brachiopoda, Mollusca, Echinodermata, Arthropoda, and Vertebrata—and less abundant marine and terrestrial plants. Several faunal assemblages, principally of brachiopods and corals, occupy zones that are limited stratigraphically and geographically, and these zones have been integrated with interregional foraminiferal zones.

The *Caninia* Zone is restricted to the Moffat Trail Limestone Member in western Wyoming and is of late Chesterian age (foraminiferal zones 17 and 18). The *Anthracospirifer welleri-shawi* Zone is represented in the Horseshoe Shale Member of central Wyoming and in the Horseshoe and the lower part of the Ranchester Limestone Member in western Wyoming; it is of late Chesterian age (foraminiferal zones 18 and 19). In central Wyoming, the *Anthracospirifer welleri-shawi* Zone is divided into a lower *Carlinia amsdeniana* Subzone and an upper *Composita poposiensis* Subzone. The *Antiquatonia blackwelderi* Zone is represented in the lower part of the Ranchester Limestone Member in western Wyoming and is of early Morrowan age (foraminiferal zone 20). The *Neokoninckophyllum hamatilis* Zone is found in the Horseshoe Shale Member and the lower part of the Ranchester Limestone Member in the Rawlins uplift of central Wyoming and is of late Morrowan age (foraminiferal zone 30). The *Mesolobus* Zone is restricted to the Ranchester Limestone Member in the Rawlins uplift of central Wyoming and is of Atokan age (foraminiferal zone 21). The horizontal and vertical relations of these zones and occurrences of fossils not assigned to zones, with respect to the lithostratigraphic subdivisions of the Amsden Formation, form the main basis for analyzing the geometry of the Amsden transgression.

Regional synthesis of lithostratigraphic, biostratigraphic, and biogeographic evidence indicates that the miogeosynclinal sea in Idaho began to encroach on the margin of the cratonic Cordilleran platform at two separate locations in latest

Meramecian time. Sand was carried across the complexly dissected karst limestone plain of the Cordilleran platform from sources on the Canadian shield and Transcontinental arch by two river systems to estuarine depositional sites at the cratonic margin in southwest Montana and western Wyoming. A northern arm of the sea transgressed eastward during the Chesterian into the Big Snowy basin, which ultimately extended across the state of Montana into the Dakotas. A southern arm of the sea expanded eastward during the Chesterian into the restricted Wyoming basin, which was separated from the Big Snowy basin by a progressively narrowing peninsula, the Southern Montana arch. In latest Chesterian time, an uplift in the area of the Big Snowy basin drained the sea from that area while the Wyoming basin expanded only slightly. A great Morrowan expansion of the Wyoming sea transgressed the Southern Montana arch, covering most of the area previously occupied by the Big Snowy basin, and also opened up connections across the Transcontinental arch with the Midcontinent platform sea to the southeast. The Wyoming sea continued to expand in Atokan time to cover most of the Cordilleran platform. During the same time, two island uplifts developed, the Montana uplift in the northern part of the Wyoming basin and the Pathfinder uplift in southeast Wyoming.

INTRODUCTION

The Amsden Formation is one of many classical geologic units described by N. H. Darton in the early days of the study of Wyoming geology. The Amsden was originally proposed by Darton in 1904 during his mapping of the Bighorn Mountains, and the formation was subsequenty recognized throughout a large area in central and western Wyoming in both outcrop and subsurface (fig. 1). During the past 30 years the name has also been used widely in the mountain ranges of Montana and in the subsurface of Montana and North Dakota.

Despite widespread usage of the term Amsden Formation, its age and correlation have been steeped in controversy since the name first appeared in the geological literature. Although originally dated by Girty (*in* Darton, 1906a) as Mississippian and Pennsylvanian, the formation has been regarded by most subsequent writers as entirely of Pennsylvanian age. Differences of opinion as to its age stem largely from the scarcity of fossils, particularly in the lower part, and from disagreement on position of upper and lower contacts. Age determination has been complicated by lithic and faunal miscorrelations, diverse interpretations of the pronounced basal disconformity, and different opinions concerning the temporal significance of the Amsden faunas. Probably the most significant factor in the confusion has been the failure of most contributors to the Amsden problem to recognize that the formation is time transgressive.

Since 1954, we have dealt with the Amsden problem in both field and laboratory research on the biostratigraphy of the Carboniferous rocks of the Rocky Mountain region, and also while examining fossils referred to us for age determinations by geologists of the U.S. Geological Survey. This work led us to examine and reinterpret Amsden faunas in the collections of the U.S. Geological Survey, many of which served as the basis for early evaluations of the age of the formation. Beginning in 1966 these studies were extended to include most of the fossils previously reported from the Amsden Formation of Wyoming, and new collections as well. This comprehensive analysis of Amsden fossils from Wyoming localities forms the basis for the present reappraisal of the age, correlation, and geologic history of the formation. Although the emphasis of this study is on the Amsden Formation in Wyoming, interpretations of the stratigraphy and geologic history have been extended to adjacent areas in which there is a sedimentary record during Amsden time.

Several specialists on the various groups of fossils found in the Amsden have contributed to this study. In this summary of the stratigraphy and geologic history of the Amsden Formation, we have integrated the paleontologic data with lithostratigraphic and petrographic data. The following reports, which are part of this study, deal with the systematic paleontology of the Amsden: Foraminifera and algae (Mamet, 1975), Coelenterata (Sando, 1975), Brachiopoda (Gordon, 1975), Pelecypoda and Rostroconchia (Gordon and Pojeta, 1975), Gastropoda, Cephalopoda, and Trilobita (Gordon and Yochelson, 1975), and Ostracoda (Sohn, 1975). Other paleontologists who contributed identifications of Amsden fossils are: Betty Skipp, Foraminifera; Helen Duncan, Bryozoa; J. W. Huddle, conodonts; and D. H. Dunkle, fish remains.

Other contributors to the study are J. D. Love and J. F. Murphy, who provided stratigraphic data on some of the fossil localities, and J. T. Hack, E. D. McKee, and J. W. Pierce, who read parts of the manuscript and made helpful suggestions concerning some of the concepts. K. M. Towe was consulted concerning the significance of clay-mineral distribution. K. R. Moore provided field and laboratory assistance during most of the investigations, and Elinor Stromberg drafted most of the illustrations.

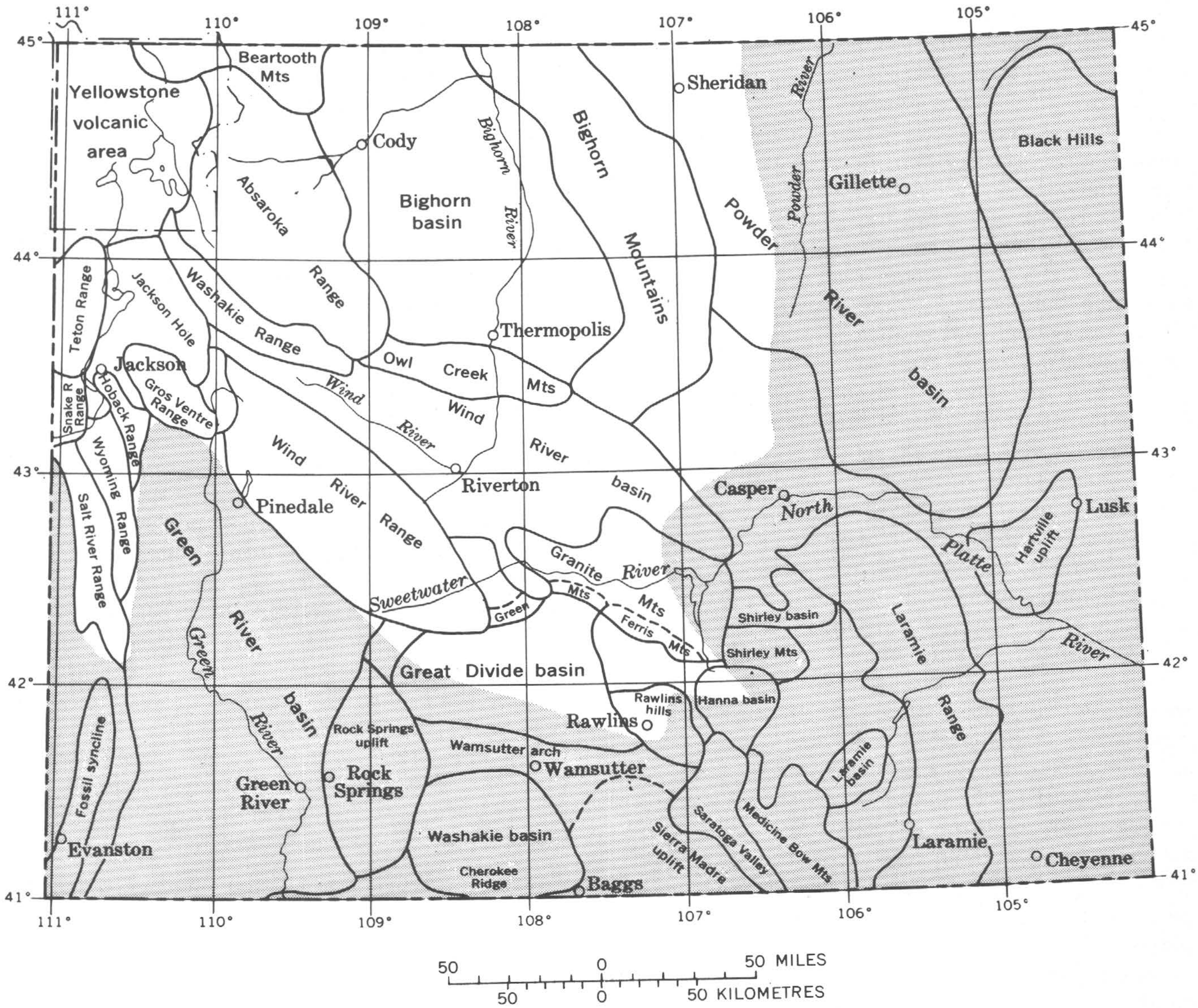

FIGURE 1.—Present structural features of Wyoming (from Welder and McGreevy, 1966) and area (unpatterned) in which Amsden Formation is currently recognized. Unnamed areas cannot be classified either as major uplifts or as basins.

H. I. Saunders and Mario Suarez-Riglos also assisted in some of the field investigations. The manuscript for this report was reviewed by W. R. Keefer, J. D. Love, W. W. Mallory, E. K. Maughan, J. F. Murphy, S. S. Oriel, and C. A. Sandberg, whose comments and suggestions are gratefully acknowledged.

REVIEW AND ANALYSIS OF THE AMSDEN PROBLEM

The tangled web of the Amsden problem is composed of many intricately interwoven threads. The following discussion attempts to sort out the principal elements of the problem and review previous interpretations in the light of recent observations by the writers and other geologists.

DEFINITION

COMPOSITION AND NOMENCLATURE

Although the original concept of the Amsden was relatively simple, the long usage of the name includes numerous changes in the definition and composition of the formation and its subdivisions. A historical summary of Amsden usage is shown in figure 2, which illustrates diagrammatically Darton's original concept and significant deviations from it.

Darton (1904, p. 396) defined the Amsden Formation to include the "variable succession of red shales, limestones, cherty and sandy members" between the Littlehorn Limestone (redesignated Madison Limestone by Darton, 1906a) and the overlying Tensleep Sandstone on the east flank of the Bighorn Mountains. He recognized two informal subdivisions: a basal member of red sandy shale or sandstone, and an upper series of variable limestone, sandstone, and shale. In subsequent reports on central Wyoming, Darton (1906a, d, 1908) used a threefold division: a red shale, generally at the base, but separated from the top of the Madison by a sandstone unit at some localities, and an upper variable carbonate-sandstone-shale unit.

Blackwelder (1918, p. 422–423) recognized a widespread sandstone unit at the base of the Amsden Formation in many parts of western and central Wyoming. He named this unit "Dorwin sandstone member" from "Dorwin Peak in the Gros Ventre Range," but Richmond (1945) later corrected the spelling of the name to "Darwin." Blackwelder's Amsden was composed of the resistant basal sandstone member and an informal "upper division of shales, sandstones, and dolomites of weak character." Condit (1924, p. 9–10) recognized essentially the same units in the Wind River Mountains but did not use a formal name for the basal sandstone.

To subdivide the Amsden Formation, most later geologists working in central Wyoming have employed either a two-member scheme similar to that of Blackwelder (1918) or a three-member scheme similar to that of Darton (1906a). The three-member scheme, including the basal Darwin sandstone Member, an informal middle red shale or siltstone unit, and an upper informal predominantly carbonate unit, was popularized by Baker (1946), Tourtelot and Thompson (1948), Tourtelot (1953), Agatston (1954, 1957), Woodward (1957), and Tenney (1966). Recently, Mallory (1967) proposed formal names for the two units above the Darwin Sandstone Member: Horseshoe Shale Member for the medial shale and Ranchester Limestone Member for the upper carbonate. A significant deviation from the generally recognized three-member scheme was that of Gorman (1963), who divided the Amsden in the Bighorn Mountains into a lower clastic zone including the Darwin and the red shale interval above it, a middle carbonate zone, and an upper clastic zone.

After E. B. Branson and Greger (1918) found Mississippian fossils in the lower red beds of the Amsden in the southern Wind River Range, C. C. Branson (1936, 1937, 1938a) reassigned these strata to a separate formation, which he named the Sacajawea Formation. Shortly thereafter, he (Branson, 1939, p. 1202) suggested that the Tensleep be extended downward to include the Pennsylvanian beds of the upper part of Darton's Amsden in central Wyoming. This proposal amounted to abandonment of the Amsden in the Wind River Range (Branson and Branson, 1941, p. 132).

The age and stratigraphic relations of the Sacajawea Formation have prompted much discussion and controversy. In recent years most students of the Sacajawea problem in the Wind River Range have concluded that the interval assigned by Branson to the Sacajawea in its type locality at Bull Lake Creek lies below the Darwin Sandstone and is actually a part of the Madison Limestone, whereas the red beds originally regarded as Sacajawea in the southern part of the Wind River Range are above the Madison and form the lower part of the Amsden Formation as defined by Darton. The true stratigraphic position of the type Sacajawea was pointed out by Biggs (1951), Burk (1954), Love (1954), Strickland (1957, 1960), Keefer and Van Lieu (1966), and Sando (1967a) and is implicit in the work of Murphy, Privrasky, and Moerlein (1956) and Murphy and Richmond (1965).

In recent years, most writers have avoided using the term, Sacajawea, because of the past confusion over its stratigraphic position and age. There have been two principal divergences from this viewpoint. Strickland (1957, 1960) and Sando (1967a) suggested that the name Sacajawea be retained for the uppermost member of the Madison in central Wyoming. On the other hand, Scott and Wilson (1953), Todd (1959, 1964), Peterson (1960), and Wilson (1962) advocated recognition of the Sacajawea as a formation which includes essentially the lower part of the Amsden of Darton throughout most of central and western Wyoming. Todd (1959) also proposed the name Montchauve Group to include the Sacajawea Formation, Amsden Formation (restricted), and Tensleep Sandstone. More recently, Sando (1968) concluded that revival of the Sacajawea as a formal geologic name would not be accepted by most geologists, in spite of recent clarification of the concept; he therefore proposed the name Bull Ridge Member of the Madison Limestone, to replace the Sacajawea of Strickland (1957) and Sando (1967a).

A somewhat different nomenclature for the Amsden and subjacent and superjacent units has been presented in published studies of the geology of western Wyoming. At Quadrant Mountain in the northwest corner of Yellowstone National Park, beds equivalent to the Amsden Formation of central Wyoming were included in the Quadrant Sandstone until Scott (1935) restricted the Quadrant and recognized the Amsden as a formation between the Quadrant and the Madison Limestone. Thompson and Scott (1941), influenced by the interpretations of C. C. Branson in central Wyoming, extended the base of the Quadrant down to include beds of Pennsylvanian age previously included in the Amsden, abandoned the Amsden, and tentatively recognized the Sacajawea Formation between the Madison and the Quadrant. Shaw (1954, 1955b) returned to the original interpretation of Scott (1935) in his classification of the Paleozoic formations in the Yellowstone area.

In the mountain ranges south of Yellowstone Park, beds equivalent to the Amsden of central Wyoming were at one time included in the Wells Formation or the underlying "Brazer Limestone," as that term was then used. A trend toward restricting previous usage of the Wells was initiated by Nelson (1942) and Nelson and Church (1943), who differentiated the "Dorwin sandstone," "Amsden linestone," and "Tensleep sandstone" as members of the Wells Formation in the Gros Ventre and Hoback Ranges. Foster (1947) recognized the Amsden as a formation between the "Brazer Limestone" and the Tensleep Formation in the Gros Ventre Range. She included in the Amsden a basal limestone and shale unit called "lower Amsden," the "Darwin sandstone," and above the Darwin an informal unit of limestone, shale, and siltstone called "upper Amsden." Foster's threefold subdivision was adopted, with slight emendation, by Wanless, Belknap, and Foster (1955) in their study of the Gros Ventre, Teton, Hoback, and Snake River Ranges. Reeves (1964) and Dixon and Reeves (1965) subscribed to a similar classification for equivalent rocks on the west flank of the Teton Range. On the other hand, Sando and Dutro (1960) and Sando (1967a) regarded the interval of shale, gypsum, and carbonate rocks immediately below the Darwin Sandstone at Hoback Canyon as a facies of the Mission Canyon Limestone of the Madison Group. In the Salt River Range, Rubey (1958) mapped the Amsden as a formation between a combined Brazer-Madison unit and the Wells Formation.

In our opinion, Darton's original concept is still the most practical definition of the Amsden. Efforts of some geologists to restrict the name to that part of the interval thought to be of Pennsylvanian age or to the upper carbonate unit, regardless of its age, have not met with general approval. As Williams (1949) pointed out, such a practice results in recognition of the formation on the basis of key beds or fossil zones or in rock units that are not readily mappable on scales commonly used. Our conclusions regarding the definition of the formation are independent of the question of its age.

We follow Mallory (1967) in recognizing three formal members within the formation in central Wyoming. In western Wyoming, where a somewhat different lithic succession is developed, we include the newly named Moffat Trail Limestone Member, in addition to the three central Wyoming units. This member includes marine limestone that contains fossils of Chesterian age that are older than any of the fossils found in the Amsden of central Wyoming.

LOWER BOUNDARY

Darton (1904, 1906a, b, c, d, 1908) placed the base of the Amsden in central Wyoming where resistant massive limestone in the upper part of the Madison Limestone changes to a soft red terrigenous sequence in the lower part of the Amsden. The basal unit of the Amsden was said to be red shale at most localities except where a brown or gray sandstone intervened locally between the upper limestone of the Madison and the lower shale of the Amsden. Darton recognized no unconformity at the contact, perhaps because the available faunal evidence indicated that the boundary between the Mississippian and Pennsylvanian Systems was within the Amsden Formation.

Blackwelder (1913, 1918) first pointed out an important unconformity at the base of the Amsden and emphasized the significance of the widespread basal Darwin Sandstone. Nearly all subsequent writers have recognized a regional unconformity at the interface between the Amsden and Madison throughout western and central Wyoming. The concept of the lower boundary placed at a regional unconformity overlain by a basal sandstone was maintained by Love (1954).

A recent study of the Madison-Amsden contact at four localities in western Wyoming led Houlik (1973) to conclude that the contact is conformable and that deposition was continuous across the boundary between the two formations. Houlik interpreted the sequence in western Wyoming as a

CARBONIFEROUS UNITS			
Littlehorn Limestone		Amsden Formation: Red shale or sandstone member; Limestone, sandstone, shale series	Tensleep Sandstone
Madison Limestone		Amsden Formation: Sandstone; Red shale; Limestone, sandstone, shale	Tensleep Sandstone
Madison Limestone		Amsden Formation: Dorwin sandstone Member; Upper division of shale, sandstone, and dolomite	Tensleep Sandstone
Madison Limestone		Amsden Formation: Lower sandstone member; Upper shale and dolomite member	Tensleep Sandstone
Madison Limestone		Amsden Formation	Quadrant Sandstone
Madison Limestone		Sacajawea Formation; Upper Amsden Formation	Tensleep Sandstone
Madison Limestone		Sacajawea Formation; Lower Amsden Formation; Upper Amsden Formation	Tensleep Sandstone
Madison Limestone		Sacajawea Formation; Beds of Chester age; Tensleep Sandstone	
Madison Limestone		Sacajawea (?) Formation; Quadrant Formation	
Madison Limestone		Wells Formation: Dorwin Sandstone Member; Amsden Limestone Member	Tensleep Sandstone Member
Madison Limestone		Amsden Formation: Darwin Sandstone Member; Upper sequence of clay, shale, dolomite, limestone, sandstone	Tensleep Sandstone
Madison Limestone		Sandstone; Red and yellow clay member; Limestone and sandstone member	Tensleep Sandstone
Brazer Limestone	Lower Amsden	Amsden Formation: Darwin Sandstone Member; Upper Amsden	Tensleep Formation
Madison Formation		Amsden Formation: Darwin Sandstone Member; Siltstone member; Dolomite	Tensleep Sandstone
Madison Limestone	Sacajawea Formation	Lower Amsden Formation; Upper Amsden Formation	Tensleep Sandstone
Madison Limestone		Sacajawea Formation: Darwin Ss. Member; Amsden Formation	Tensleep Sandstone
Madison Limestone		Amsden Formation: Darwin Sandstone; Red shale zone; Upper carbonate zone	Tensleep Formation
	Sacajawea Formation	Amsden Formation: Darwin Sandstone Member	Tensleep Sandstone
Madison Limestone		Amsden Formation: Darwin Sandstone Member / Sacajawea; Red bed facies; Non-red facies	Tensleep Sandstone
Brazer Formation	Lower Amsden red shale sequence	Amsden Formation (restricted): Darwin Sandstone Member	Tensleep Formation
Madison Group	Sacajawea Formation	Amsden Formation: Darwin Sandstone Member	Tensleep
Upper Madison	Sacajawea Member	Amsden Formation: Darwin Sandstone Member	Not discussed
Not discussed		Montchauve Group: Darwin Member; Sacajawea Formation; Amsden Formation	Tensleep Sandstone
Madison Formation		Amsden Formation: Lower clastic zone / Darwin Sandstone; Middle carbonate zone; Upper clastic zone	Tensleep Sandstone
Madison Limestone		Amsden Formation: Darwin Sandstone Member; Upper member	Tensleep Sandstone
Mission Canyon Limestone		Amsden Formation: Basal Ss. Mbr.; Lower red shale member; Medial limestone member; Upper red shale member	Tensleep Sandstone
Madison Limestone		Amsden Formation: Darwin Sandstone Member; Horseshoe Shale Member; Ranchester Limestone Member	Tensleep Sandstone
Madison Limestone	Bull Ridge Member	Amsden Formation: Darwin Sandstone Member; Horseshoe Shale Member; Ranchester Limestone Member	Tensleep Sandstone
Mission Canyon Limestone		Amsden Formation: Darwin Sandstone Member; Horseshoe Sh. Mbr.; Moffat Trail L. s. Mbr.; Ranchester Limestone Member	Tensleep Sandstone

FIGURE 2.—Condensed diagrammatic history of usage of the Amsden Formation and related Carboniferous units in Wyoming, 1904–70, compared with usage advocated in this report.

REFERENCES	AREA
Darton 1904 1906b, c	Bighorn Mountains
Darton 1906a, d, 1908	Central Wyoming
Blackwelder, 1918; Love, 1939	Western and central Wyoming
Condit, 1924	Wind River Range
Scott, 1935	Quadrant Mountain
Branson, 1936	Wind River Range
Branson, 1937, 1938a	Do.
Branson, 1938b, 1939; Branson and Branson, 1941	Do.
Thompson and Scott, 1941	Quadrant Mountain
Nelson, 1942; Nelson and Church, 1943	Gros Ventre and Hoback Ranges
Richmond, 1945	Wind River Range
Baker, 1946	Do.
Foster, 1947	Gros Ventre Range
Tourtelot and Thompson, 1948; Tourtelot, 1953; Woodward, 1957	Owl Creek and southern Bighorn Mountains
Williams *in* Weller and others, 1948	Northwestern and central Wyoming
Scott and Wilson, 1953; Peterson, 1960; Wilson, 1962; Todd, 1964	Wyoming
Agatston, 1954, 1957; Tenney. 1966	North-central Wyoming
Love, 1954	Bull Lake
Shaw and Bell, 1955; Shaw 1955a, b	Wind River Range
Wanless and others, 1955; Reeves, 1964; Dixon and Reeves, 1965	Gros Ventre, Teton, Hoback, and Snake River Ranges
Strickland, 1956	Western Wyoming
Strickland, 1957, 1960; Sando, 1967a	Wind River Range and basin
Todd, 1959	Bighorn basin
Gorman, 1963	Bighorn Mountain
Murphy and Richmond, 1965	Wind River Ranges
Maughan and Roberts, 1967	Amsden Creek
Mallory, 1967	Central and western Wyoming
Sando, Gordon, and Dutro, this report	Central Wyoming
Do.	Western Wyoming

FIGURE 2.—Continued

sabkha complex in which the upper part of the Madison represents a carbonate coastal sabkha and the Darwin Sandstone represents a continental sabkha. Houlik's model would require contemporaneity of the upper part of the Madison with the Darwin. This interpretation is not consistent with the paleontologic evidence or the regional stratigraphic relationships compiled in our study.

The Darwin Sandstone Member has been identified at the base of the Amsden at most localities in Wyoming. However, limited development of sandstone at the base of red beds assigned to the Amsden in the southern Wind River Range (Branson and Greger, 1918; Branson, 1939), Rawlins hills (Thomas, 1951), and the area north of the Rawlins hills (Ritzma, 1951) has caused some doubt as to whether the Darwin should be recognized in these areas. Shaw and Bell (1955, p. 336) and Shaw (1955a, p. 60) concluded that the basal sandstone in the southern Wind River Range is actually older than the Darwin. Strickland (1956, p. 55–56; 1960, p. 223) thought that a conglomerate zone higher in the formation correlates with the Darwin in the southern Wind River Range, but Agatston (1957, p. 29) believed that the basal sandstone in this area is most probably a Darwin correlative. At some localities in the Bighorn Mountains, no sandstone is present in the lower part of the Amsden, and the basal beds are red shale or siltstone (Darton, 1906a, p. 32, 33; Agatston, 1954, p. 569, 571; Richards, 1955, p. 26; Woodward, 1957, p. 225).

Red beds between the top of the Mississippian limestone and the base of the Darwin Sandstone have been described at several localities in western Wyoming (Wanless and others, 1945, p. 1211; Foster, 1947, p. 1557; Wanless and others, 1955, p. 30–31; Reeves, 1964, p. 223–224; and Dixon and Reeves, 1965, p. 704). Sando and Dutro (1960, p. 124) regarded this "Lower Amsden red shale sequence" at Hoback Canyon as the uppermost part of the Mission Canyon Limestone and placed the base of the Amsden at the base of the Darwin Sandstone. A 35-foot largely covered interval at Darby Canyon in the Teton Range considered by Sando and Dutro (1960, p. 125) as the basal beds of the Amsden probably correlates with the same interval (Reeves, 1964, p. 223).

The absence of the Darwin Sandstone at some localities and the presence of red beds below the Darwin at other localities has resulted in some disagreement as to the position of the Madison-Amsden contact. Williams (1948, p. 336) suggested that although use of the base of the Darwin is practical for mapping the contact in many areas, it is a different criterion from those used elsewhere and would not provide a boundary that is closely controlled by faunal data. Todd (1959, p. 2231; 1964, p. 1088) argued against the use of the Darwin as a horizon marker on the grounds that it is a river deposit inherently subject to discontinuous occurrence at more than one stratigraphic level. Other geologists have experienced some difficulty in mapping the base of the Amsden in areas where the underlying Bull Ridge Member is poorly developed and included in a poorly resistant slope overlying the prominent cliff-forming beds of the unnamed member of the Madison.

We continue to follow the accepted practice of Blackwelder (1918) of recognizing the Darwin as the basal sandstone of the Amsden cycle of deposition. Inclusion of the Bull Ridge Member in the Amsden is not acceptable because:

1. The Bull Ridge is predominantly of Madison lithology.
2. The Bull Ridge can be traced into beds included in the type Madison.
3. Such a procedure would obscure the widely recognized regional unconformity between the Madison and the Amsden and place rocks of two different sedimentary cycles in the same formation.

In the relatively few areas where the Darwin is absent, placement of the contact depends on separation of distinctive rock types of the Amsden from those of the underlying Madison. Identifying the boundary in these areas requires using varying lithic criteria owing to deposition of the Amsden on the irregular topography developed during post-Madison erosion, which caused different parts of the Amsden to rest on different parts of the Madison.

Observed relationships at the lower boundary of the Amsden Formation are illustrated on plate 1, which presents graphic sections at various localities in western and central Wyoming where these relationships can be clearly seen. Most of the examples shown are at localities where the interpretations of the writers differ significantly from previously published interpretations (as indicated on pl. 1). Relationships at the contact can be resolved into six possible cases:

1. Darwin Sandstone Member of the Amsden Formation rests on Bull Ridge Member of the Madison Limestone (pl. 1, secs. B, C, D, F, H, M, N). This occurs over a large area that includes most of the Wind River Range, the western part of the Wind River Basin, the

western Owl Creek Mountains, the Washakie Range, most of the Bighorn Basin and Bighorn Mountains, the Gros Ventre Range, and probably in Jackson Hole in western Wyoming. The Bull Ridge Member was removed by post-Madison, pre-Amsden erosion elsewhere in central Wyoming. Local relief at the Bull Ridge-Darwin interface ordinarily ranges from less than a foot to about ten feet, but the sandstone commonly fills joint cracks in the underlying carbonate rocks, and sinkholes extending as much as 100 ft into the Madison have been noted at localities such as Wolf Creek (pl. 1, sec. C) and North Crazy Woman Creek (pl. 1, sec. N).

2. Darwin Sandstone Member of the Amsden Formation rests on unnamed limestone member of Madison Limestone (pl. 1, sec. I) where post-Madison, pre-Amsden erosion removed the Bull Ridge Member in central Wyoming.
3. Darwin Sandstone Member of the Amsden Formation rests on red beds and related rocks of the Mission Canyon Limestone of Madison Group (pl. 1, secs. A and E) in much of western Wyoming. At Hoback Canyon, this interval includes many beds of gypsum and gypsiferous shale. In the Salt River Range, the same interval is largely brecciated carbonate rock. This red sequence beneath the Darwin is regarded as the upper part of the Mission Canyon Limestone (Sando and Dutro, 1960) and appears to represent an interval that is the same age or slightly younger than the Bull Ridge Member of the Madison in central Wyoming (Sando, 1967a, p. 546, fig. 7).
4. Horseshoe Shale Member of the Amsden Formation rests on Bull Ridge Member of Madison Limestone (pl. 1, secs. G and K) in parts of the Rawlins hills, northern Bighorn Mountains, eastern Absaroka Range, and in the Pryor Mountains and Bighorn Canyon area of southern Montana without any intervening Darwin Sandstone, although sandstone may be present in sinkholes and caves below the contact at some localities. The contact is easily established where the poorly resistant red siltstone and shale of the Horseshoe rests on the upper carbonate unit of the Bull Ridge (pl. 1, sec. G). Placement of the contact is difficult where the erosion surface has cut down into the lower silty unit of the Bull Ridge (pl. 1, sec. K), and care must be taken to differentiate the varicolored thin-bedded siltstone and silty dolomite beds of the Bull Ridge from poorly bedded bright red clay shale and shaly siltstone of the Horseshoe. Local erosion relief of as much as 50 feet has been observed at the contact at some localities, and the upper carbonate unit of the Bull Ridge is commonly strongly affected by solution.
5. Horseshoe Shale Member of the Amsden Formation rests on unnamed limestone member of Madison Limestone (pl. 1, sec. L). In parts of the Rawlins hills northern Bighorn Mountains, and in the Bighorn Canyon area and Pryor Mountains of southern Montana, post-Madison, pre-Amsden erosion exhumed the carbonate sequence underlying the Bull Ridge Member prior to deposition of the Horseshoe. At such places, poorly resistant, slope-forming red siltstone and shale directly overlies cliff-forming limestone and dolomite containing the *Spirifer madisonensis* fauna.
6. Ranchester Limestone Member of Amsden Formation rests on unnamed limestone member of Madison Limestone (pl. 1, sec. J) at Little Bighorn Canyon in the northern Bighorn Mountains. Relief of at least 50 feet was observed at the contact in this area. At some places in the canyon, red siltstone of the Horseshoe Member occurs in sinkholes and caves below the Ranchester-Madison interface.

UPPER BOUNDARY

Darton (1904, 1906a, b, c, d, 1908) placed the upper limit of the formation where a predominantly carbonate and shale sequence changes to the predominantly sandstone sequence of the overlying Tensleep Sandstone. However, Darton noted that because the upper part of the Amsden included sandy beds at some localities, the contact with the Tensleep is locally difficult to place.

Although depositional irregularities have been noted at the Amsden-Tensleep interface at several localities in central Wyoming (Love, 1939, p. 28, 30; Baker, 1946, p. 576; Agatston, 1952, p. 44, 1954, p. 515; Mapel, 1959, p. 23), most writers have regarded these as local diastems without regional significance (Agatston, 1957, p. 29; Wilson, 1962, p. 123; Todd, 1964, p. 1068; Keefer and Van Lieu, 1966, p. 37), and the consensus is overwhelmingly in favor of regarding the contact as transitional. Intertonguing of upper Amsden carbonate and shale with the lower part of the Tensleep sandstone facies has also been described in northwestern and central Wyoming (Walton, 1947, p. 1443; Love, 1954, and in Wanless and others, 1955, p. 31; Richards, 1955, p. 27).

Other criteria have also been used to define the Tensleep-Amsden contact. The contact has been placed "at the first occurrence of red and lavender dolomite or shale" beneath the main sandstone body of the Tensleep in the subsurface of the Bighorn Basin (Walton, 1947, p. 1442–1443). It has also been defined as the top of the main body of cherty carbonate rocks below the sandstone beds of the Tensleep in north-central Wyoming (Agatston, 1952, p. 44; 1954, p. 515; 1957, p. 29) and in the eastern Bighorn Mountains (Hose, 1955, p. 50). Fisher (1963, p. 54) defined the contact by giving several criteria for recognizing the uppermost beds of the Amsden in the eastern Bighorn Mountains. He stated that purple coloration of shale, sandstone, or carbonate beds is characteristic of the Amsden, that carbonates are more abundant and more commonly cherty in the Amsden, and that sandstone beds are less common and thinner in the Amsden.

Wilson (1962, p. 123–124) and Todd (1964, p. 1068) advocated recognition of the Amsden-Tensleep interface on the basis of general lithologic characteristics. According to Wilson, specific lithologic criteria, such as suggested by Walton and Agatston, may not be present or may not occur in the same stratigraphic position at all localities. Wilson suggested placing the boundary "at a point where a dominant Tensleep aspect gives way to a dominant Amsden one" which in most cases separates a "predominance of sandstone above from that of carbonates or shale below." Separation on color is used in sections where the lower sequence (Amsden) is largely sandstone.

We agree with Wilson in defining the Amsden-Tensleep boundary on general lithologic characteristics, recognizing that this coincides with and demonstrates the practicality of Darton's original concept of this boundary. Nevertheless, use of any of the published criteria results in the placement of the boundary, at most localities, within a relatively narrow stratigraphic interval.

The problem of identifying a consistent Amsden-Tensleep boundary has had no appreciable effect on the mapping of the two formations. A survey of 89 geologic maps of the outcrop areas of the two units published from 1906 through 1970 shows that the Amsden and Tensleep have been mapped separately on 56 of 63 maps published at a scale of 1:125,000 or larger. The Amsden and Tensleep were mapped as a combined unit on 23 of 26 maps published at scales smaller than 1:125,000.

TYPE SECTION

Darton (1904, p. 396), in his original description of the Amsden Formation stated that the formation was "named from a branch of Tongue river west of Dayton." However, this and subsequent reports by Darton contain no designation of a type section or type locality. In two of his reports Darton (1906a, p. 32; 1906b, p. 5) described a section in the canyon of the Little Tongue River and noted that this is a "very clear exposure of the formation."

Williams (1948, p. 334) interpreted Darton's remarks to mean that the type locality is "the Amsden Branch of Tongue River, about 5 miles southwest of Dayton, in the Dayton quadrangle, Wyoming." Subsequent writers have accepted this interpretation.

The precise location of a type section for the Amsden Formation has been subject to several interpretations (fig. 3). Although Agatston (1954) did not designate a type section, he identified Amsden Creek as the type locality (Agatston, 1954, p. 515) and presented a graphic section for Amsden Creek in sec. 32, T. 57 N., R. 87 W. (Agatston, 1954, p. 569).

Gorman (1962, p. 1), in an unpublished Ph.D. thesis, stated that the type section is on Amsden Creek, and he presented a detailed description of a section measured in sec. 34, T. 57 N., R 87 W. as his Amsden Creek section (Gorman, 1962, p. 158–161). The same section was briefly described and illustrated by Gorman in a subsequent guidebook article (Gorman, 1963, p. 67–69, fig. 1).

Maughan and Roberts (1967, p. 1) presented a graphic illustration of a section attributed to P. A. Mundt and W. W. Mallory measured on Amsden Creek in sec. 32, T. 57 N., R. 87 W. On page 11 of their report, Maughan and Roberts identified this section as the type of the Amsden Formation.

Mallory (1967, p. 8) stated that the Amsden Formation was named by Darton for exposures on Amsden Creek and designated a section in SE¼ sec. 33, T. 57 N., R. 87 W. as the type section for his Ranchester and Horseshoe Members. He also referred to this as the type section of the Amsden Formation (Mallory, 1967, fig. 6), and proposed a reference section for the formation in Tensleep Canyon.

A reconnaissance of the Amsden Creek area by W. J. Sando and K. R. Moore indicated that the best section is on the north slope of the canyon cut by one of the two main branches of Amsden Creek in SW¼ sec. 34, T. 57 N., R. 87 W., Sheridan County (fig. 4). Here the formation is well exposed, all three members are present, and the locality is readily accessible. A section measured at this place

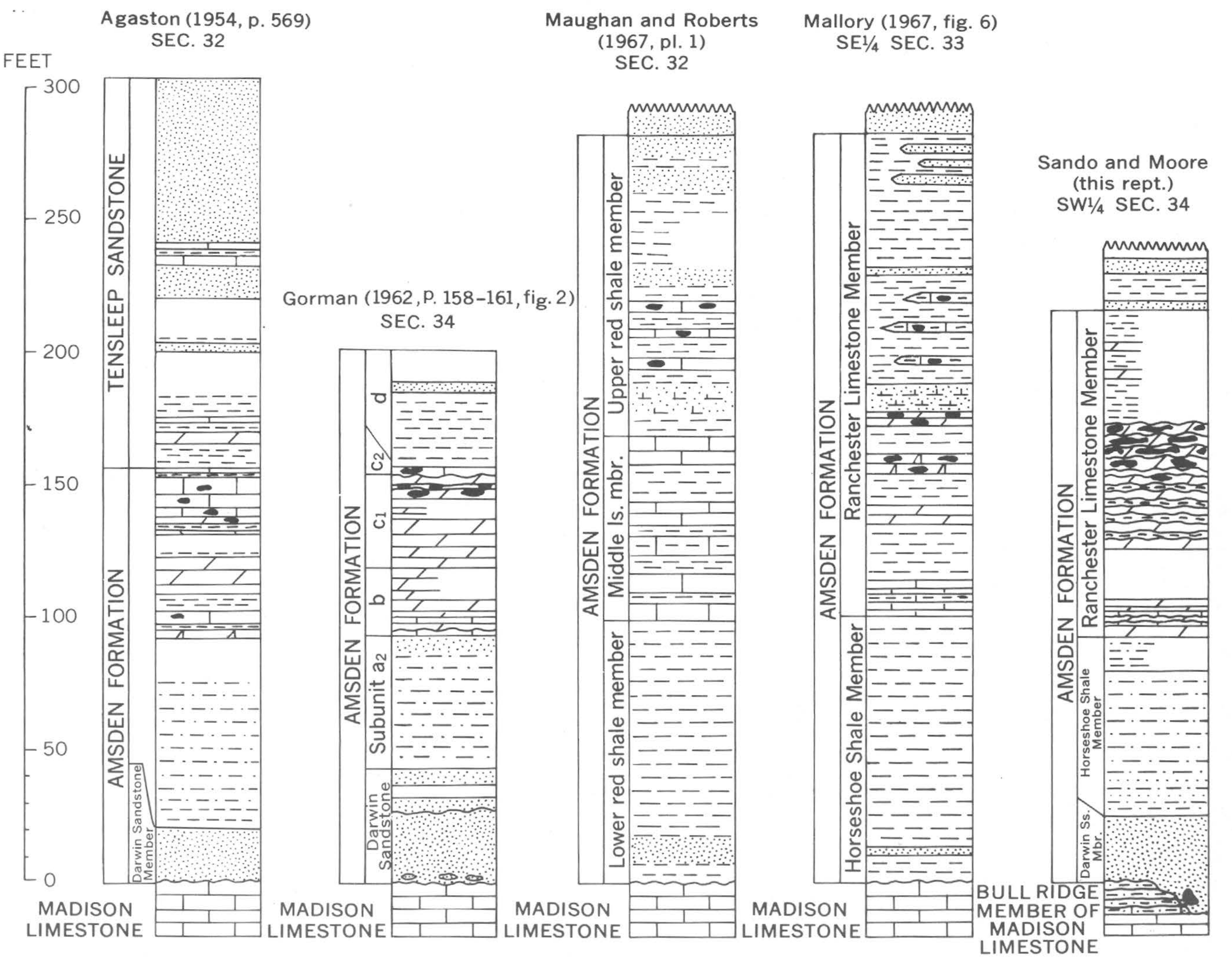

FIGURE 3.—Stratigraphic sections of the Amsden Formation measured by various authors on Amsden Creek in T. 57 N., R. 87 W., Sheridan County, Wyo. See plate 1 for explanation of lithic symbols.

by Sando and Moore in August 1965, is considered to be the type section of the Amsden. The locality is reached by following the road from Dayton into a game preserve, where the road crosses Amsden Creek. Just east of the creek crossing, a jeep trail leads southward between two red buttes to a point about 150 yards northeast of the canyon mouth. The section location is attained by a walk of about one-half mile from the end of the jeep trail.

Amsden Creek section

	Thickness (feet)
Tensleep Sandstone:	
20. Quartz sandstone; calcareous; fine- to medium-grained, weathers white; crossbedded; overlain by 10-ft covered interval followed by more crossbedded quartz sandstone leading up to massive quartzite cliff	3.0
Amsden Formation:	
Ranchester Limestone Member:	
19. Covered; float consists of cherty, fine-grained to medium-crystalline white-weathering dolomite; purple shale in lower 6 ft; purple shale and fine-grained dolomite in place near middle; interval probably consists mostly of shale	42.5
18. Dolomite; predominantly medium crystalline; weathers yellowish gray to pale red; weathers to sandy surface of dolomite rhombs; beds irregular, 0.5–3 ft thick; about 40 percent large irregular bodies of white to jasperoid chert; some beds have purple shale partings; red paint markings of a previous worker at base	13.0

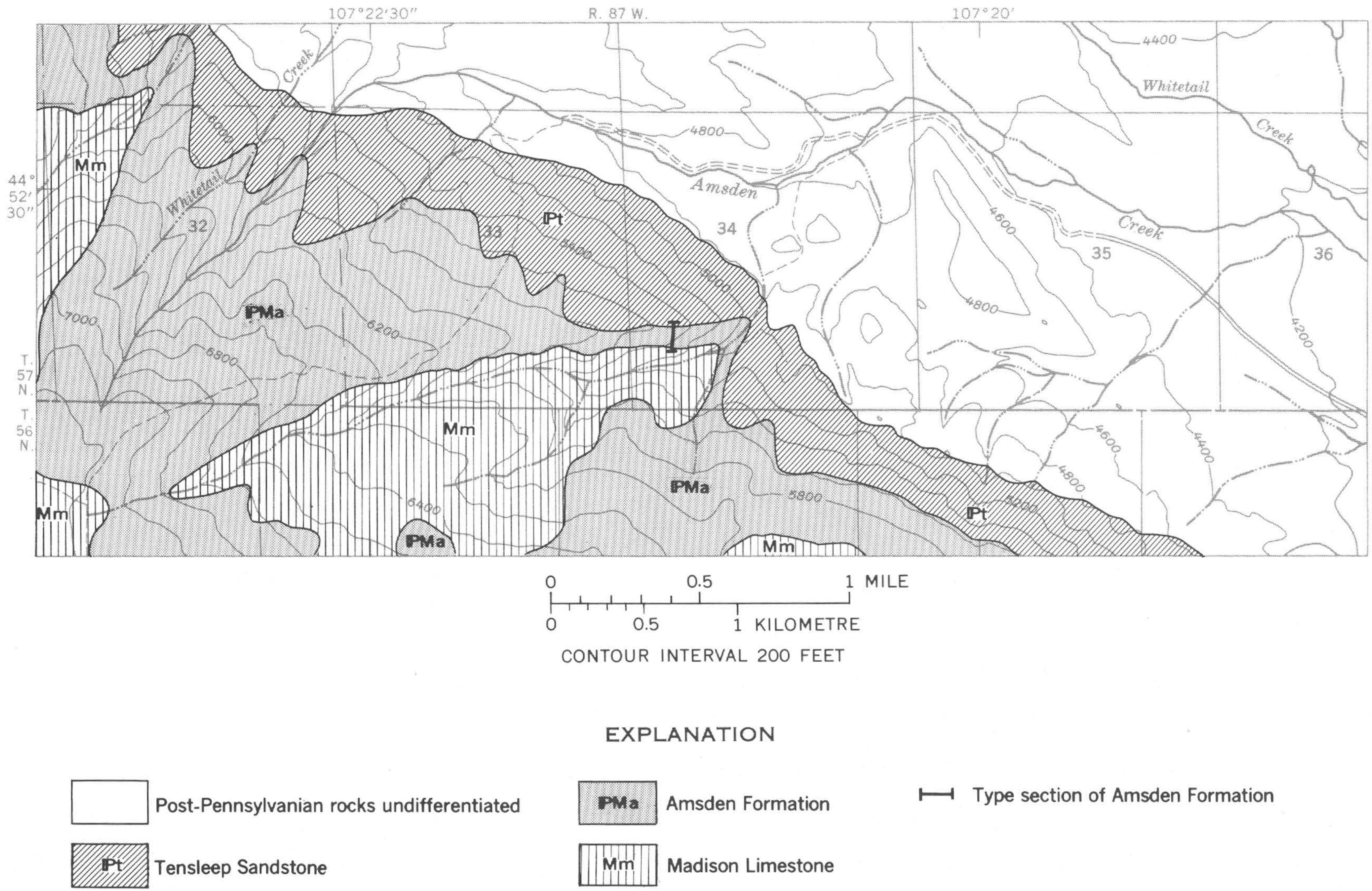

FIGURE 4.—Geologic map of the Amsden Creek area in T. 56 N. and T. 57 N., R. 87 W., Sheridan County, showing location of the type section of the Amsden Formation. Geology sketched by W. J. Sando from aerial photographs. Base map from U.S. Geological Survey Dayton South, Dayton North, Skull Ridge, and Columbus Peak quadrangle maps (7½-min series).

	Thickness (feet)
Amsden Formation—Continued:	
Ranchester Limestone Member—Continued:	
17. Dolomite; interbedded fine-grained, like unit 16 and medium-crystalline, with sandy surface of dolomite rhombs, weathering yellowish gray to pale red; beds irregular, 0.5–1 ft thick; pale-red shale partings; about 5–10 percent white to jasperoid chert in irregular lenses; poorly exposed	12.5
16. Dolomite; fine-grained; light-olive-gray weathering yellowish gray to very light gray; beds irregular, 1–4 ft thick; with grayish-red (purple) shale partings 0.1–.2 ft thick; shattered; poorly exposed	22.0
15. Covered; float consists of purple siltstone and talus from above	19.5
14. Dolomite; medium-crystalline; weathers yellowish gray; weathers to sandy surface of dolomite rhombs; cross-bedded; upper contact irregular	1.0
13. Dolomite; silty; fine-grained; light-olive-gray weathering yellowish gray to light gray with some purple mottling; beds 0.1–.5 ft thick; some beds laminated	4.0
12. Limestone; medium-grained; bioclastic; like unit 10; fills irregularities in surface of underlying bed. USGS loc. 22208–PC	2.0
11. Dolomite; fine-grained, with conglomeratic texture in places; weathers yellowish gray; beds very irregular, 0.3–.5 ft thick; red shale partings at base; about 1 ft relief on top	1.5
10. Limestone; medium-grained; bioclastic; light-olive-gray weathering medium-light gray to light gray; foraminifers, echinoid debris, brachiopods. USGS loc. 22207–PC	1.0
9. Dolomite; fine-grained; weathers yellowish gray; beds 0.5–1 ft thick	4.0
Total Ranchester Limestone Member	123.0
Horseshoe Shale Member:	
8. Covered; red soil and rubble of dolomite and limestone from above; seemingly a few feet of red shale at base. USGS loc. 22206–PC, float from unit 10 or 12	14.0
7. Quartz siltstone; sandy; red; like unit 5; some beds have yellow and red polka dots	40.0
6. Quartz sandstone; fine-grained; weathers pale reddish brown	1.0
5. Quartz siltstone; grayish-red; contains scattered fine-grained quartz sand and a few thin beds of white fine-grained sandstone (in upper half);	

	Thickness (feet)
Amsden Formation—Continued:	
Ranchester Limestone Member—Continued:	
polka-dot beds (red and yellow) in upper 3 ft	13.5
Total Horseshoe Shale Member	68.5
Darwin Sandstone Member:	
4. Quartz sandstone; fine-grained; weathers pale reddish brown; crossbedded in places, beds 1–2 ft thick; seems to cut down into unit 1 near traverse line	24.0
Total Amsden Formation	215.5
Madison Limestone:	
Bull Ridge Member:	
3. Quartz siltstone; calcareous; weathers yellowish gray and moderate red with red streaks; beds 0.1–.5 ft thick; quartz sandstone of unit 4 appears to cut down through this unit. USGS loc. 22205–PC in quartz sandstone 2 ft below top	9.0
2. Limestone; silty; fine-grained; light-olive-gray weathering medium light gray; beds 0.05–.2 ft thick; poorly exposed	4.0
Total Bull Ridge Member	13.0
Unnamed limestone member (base not exposed):	
1. Limestone; fine- to medium-grained; light-olive-gray weathering medium light gray to light gray; beds 1–2 ft thick; minor brown chert.	

Sando and Moore's traverse appears to be virtually identical with the traverse used by Gorman (1962, 1963), who first designated and was the only previous writer to describe a type section for the Amsden. The formation is not so well exposed on the other main branch of Amsden Creek in sec. 32, T. 57 N., R. 87 W., the locality designated by Maughan and Roberts (1967). Mallory's (1967) location in sec. 33, T. 57 N., R. 87 W., only about a quarter of a mile up the canyon, apparently does not include the Darwin Sandstone Member. The Sando-Moore section also serves as a convenient reference section for the Ranchester Limestone and Horseshoe Shale Members of the Amsden because of its proximity to Mallory's type section, and it has the advantage of showing these members at a place where the Amsden is complete.

AGE AND CORRELATION

Controversy over the age and correlation of the Amsden Formation has focused principally on whether the formation is entirely Mississippian or Pennsylvanian or whether both periods are represented. Figure 5 shows graphically the variation in

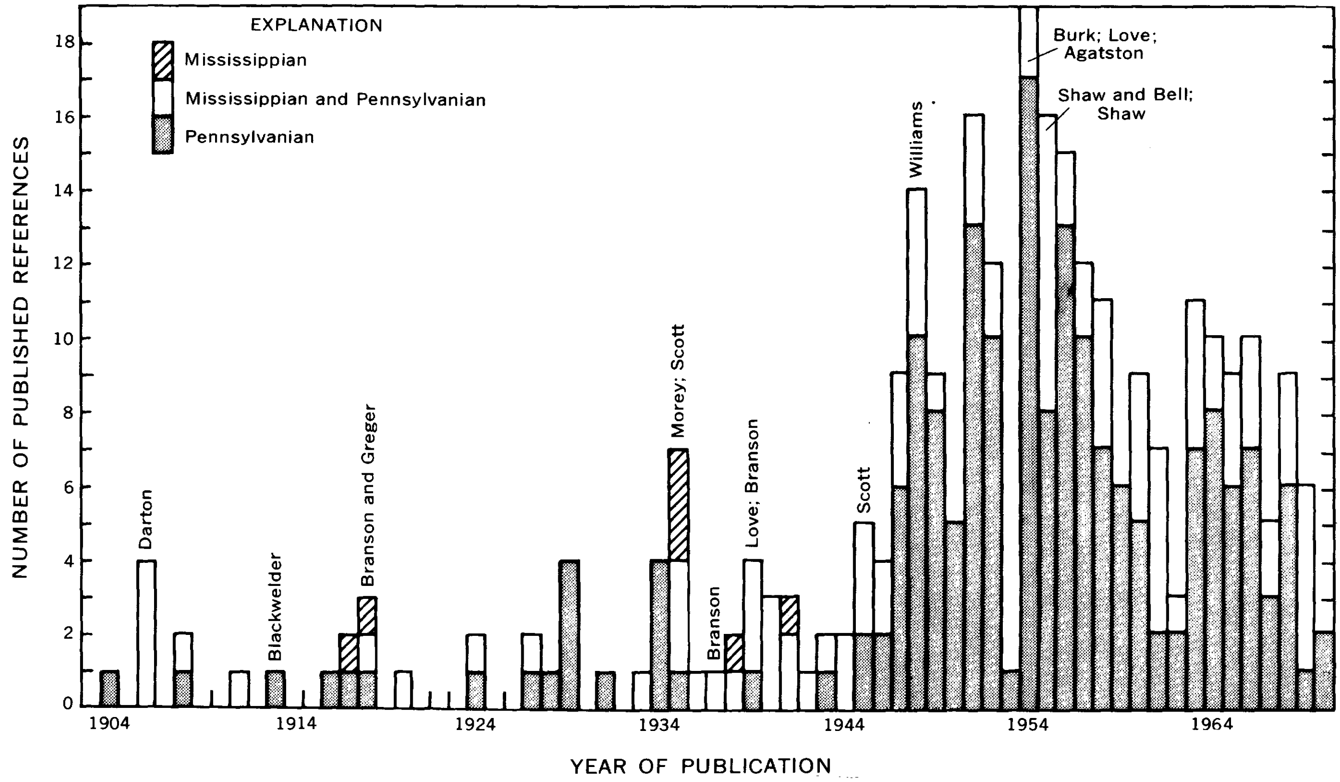

FIGURE 5.—Published age designations for the Amsden Formation in Wyoming based on analysis of 292 references from 1904 to the end of 1970. Positions of reports considered most influential in shaping opinion are indicated by names of authors over their year-of-publication bar.

opinion from 1904 through 1970 regarding the age of the Amsden in Wyoming, based on 292 published records. Publications in which the formation was listed simply as Carboniferous or in which no age was designated are omitted. The survey includes published maps, guidebooks, and abstracts but does not include unpublished theses.

Darton (1904) originally regarded the Amsden Formation as Pennsylvanian, based partly on a few fossils of uncertain significance from the upper part of the formation in the Bighorn Mountains and on a comparison with the Minnelusa Formation of the Black Hills (Darton, 1904, p. 397, 437, pl. 35). Subsequently, Darton (1906a, b, c) listed fossils identified by Girty from two localities in the Bighorn Mountains as the basis for regarding the upper part of the formation as Pennsylvanian and the lower part as probably Mississippian in age.

In 1913, Blackwelder listed fossils identified by Girty from a little below the middle of the Amsden at several localities in the Gros Ventre Range. Girty (in Blackwelder, 1913, p. 176) distinguished an upper faunule that he regarded as definitely Pennsylvanian and a lower faunule that he could not date positively but stated that it "may prove to be of Upper Mississippian age." Blackwelder (1913, p. 176) concluded that because both faunules "occur in a single formation of distinctive and unified character, separated from the known lower Mississippian limestone by a distinctive unconformity * * * it seems probable that both faunules belong to the same [Pennsylvanian] period." Blackwelder's emphasis on the importance of the post-Madison unconformity in determining the position of the systemic boundary later became a leading factor in shaping opinion regarding the age of the Amsden.

Between 1917 and 1947, evidence for the Mississippian age of at least part of the Amsden overshadowed the view that the formation is entirely of Pennsylvanian age. Large faunules from the lower part of the formation in the Wind River Range described by Branson and Greger (1917, 1918), Branson (1937), and Morey (1935) were interpreted as representing Meramecian equivalents. Later studies by Croneis and Funkhouser (1938), Coryell and Johnson (1939), and Cooper (1941) indicated that many of the ostracode species described by Morey are present in the type Chester of the Midcontinent region. Scott (1935) also interpreted fossils that he collected from the Amsden of central Montana as Chesterian in age, and Sloss (1946) noted similarities between the Wind River Range fauna and those of the Big Snowy Group in Montana, which indicated a Chesterian age. New finds of Pennsylvanian fossils in the Rawlins hills (Lee, 1927, p. 42) and Washakie Range (Love, 1939, p. 28) reinforced the Pennsylvanian age of the upper part of the formation. Scott (1945a, b) later renounced his previous interpretation and regarded the Amsden as Pennsylvanian (Morrowan).

The prevailing opinion since 1947 has been overwhelmingly in favor of a Pennsylvanian age for the entire formation. Pennsylvanian fossils were reported from the upper part of the formation in the Bighorn Mountains, Wind River Mountains, Granite Mountains, and the mountains of western Wyoming by Williams (1948), Tourtelot (1953), Love (1954), Wanless and others (1955), Murphy and others (1956), Henbest (1956), Koucky and others (1961), Gorman (1963), and Keefer and Van Lieu (1966). On the other hand, new finds of Mississippian fossils were reported from the lower part of the formation in the Washakie Range and the mountains of western Wyoming by Williams (1948), Sando and Dutro (1960), Dutro and Sando (1963a, b), Sando (1967a), and Sando and others (1969).

Renewed interest in Amsden fossils from the Wind River Range in recent years has given rise to several different interpretations of the age of the formation. Biggs (1951), in a University of Wyoming thesis, documented a number of new Amsden fossil localities. Most of them are in what is now called the Horseshoe Shale Member in the southern part of the range. The localities include Cherry Creek, where some of Branson and Greger's earlier collections were made. According to Biggs (1951, pl. 1, p. 33), Branson and Greger's collections from Bull Lake Creek came from the Madison Limestone and are Mississippian in age. He regarded the Amsden fossils as Pennsylvanian in age, as did Burk (1954), who described the fossils collected by Biggs. Burk concluded that although the faunules include species whose ranges extend from Mississippian into Pennsylvanian, the absence of exclusively Mississippian species and the preponderance of exclusively Pennsylvanian species indicate a Pennsylvanian age for the Amsden.

Burk's conclusions were partly contradicted by Shaw and Bell (1955), who recognized two distinct faunal assemblages, a lower one of Mississippian age, and an upper one which they regarded as Pennsylvanian at Cherry Creek, the principal locality of Branson and Greger (1918) in the southern Wind River Range. In another paper, Shaw (1955a) revised many of Burk's identifications and recognized two faunal zones of Pennsylvanian age and a single zone of Mississippian (Chesterian) age in the Amsden of the Washakie Range, Wind River Range, and Rawlins hills. Sadlick (1955, p. 56), in a comparison of the Amsden faunas with those of the Manning Canyon Shale of Utah, agreed with Burk's conclusion that the Amsden fossils are Pennsylvanian, but later (Sadlick, 1960) recognized both Mississippian and Pennsylvanian faunas in the Wind River Range. Sando (1967a, p. 548–549) showed that the fossils collected by Branson and Greger at Bull Lake Creek are from the Madison and are of Meramecian age, whereas the Cherry Creek fossils are distinct and represent younger beds (late Chesterian).

Many exclusively Pennsylvanian age assignments for the Amsden Formation of Wyoming may be based on the assumption that the Mississippian-Pennsylvanian boundary coincides with the unconformity that separates the Amsden from the subjacent Madison Limestone. This assumption, first made by Blackwelder (1913, p. 176), was continued by Love (1954) and Agatston (1954, p. 520), although each of these authors acknowledged the possibility that the unconformity might represent an intra-Mississippian event. Burk (1954, p. 4) pointed out that both the Mississippian and Pennsylvanian subcommittees of the National Research Council (Moore and others, 1944, p. 663; Weller and others, 1948, p. 106) emphasized the importance of a widespread unconformity in determining the position of the systemic boundary. However, in the reports of both subcommittees (Moore and others, 1944, p. 701, pl. 1, col. 46; Weller and others, 1948, p. 140, pl. 2, col. 44) the systemic boundary was placed within the Amsden Formation of Wyoming.

Williams (1948, 1949), Wilson (1962), and Sando (1967b) presented arguments in opposition to the view that the post-Madison, pre-Amsden unconformity represents the Mississippian-Pennsylvanian boundary. Williams (1948, p. 334–338) discussed contemporary evidence on the age of the Amsden in the Bighorn Mountains, Gros Ventre, Wind River, and Salt River Ranges and concluded (p. 347) that the unconformity at the top of the Madison "is mainly a pre-Chester or pre-Ste. Genevieve unconformity." Wilson (1962, p. 137–138) in arguing for a Mississippian-Pennsylvanian age for the Amsden, ascribed the controversy over its age to "(1) failure to place the Madison unconformity in its proper time position, (2) failure to recognize vertical and lateral age variations within a formation, (3) assignment of regional age designations on the basis of local faunal collections, and (4) dependence on faunal assemblages largely lacking in diagnostic forms." Regional faunal zonation studies by Sando (1967b) led him to conclude that the post-Madison unconformity represented a withdrawal of the Madison sea during early or middle Meramecian time followed by a later Meramecian and Chesterian transgression. A regional zonation study by Sando, Mamet, and Dutro (1969), based on Foraminifera as well as larger invertebrate fossils, corroborated a Late Mississippian dating of the unconformity and immediately superjacent strata.

Paleontologic evidence given in this study indicates that the Amsden Formation ranges in age from Late Mississippian to Middle Pennsylvanian. Before a discussion of this evidence, some misconceptions that have arisen concerning previously published paleontologic evidence should be clarified.

1. Fossils reported by Darton (1906a, p. 33; 1906b, p. 5; 1906c, p. 5) from the lower part of the Amsden at Soldier Creek in the Bighorn Mountains and determined as Mississippian by Girty are indeed Mississippian but were collected from the Madison Limestone, probably from the unnamed limestone member that underlies the Bull Ridge Member. In his unpublished report to Darton, Girty indicated that this material represented a Madison fauna. This collection, USGS 2479–PC, contains *Homalophyllites* sp., *Schizophoria* sp., and a spirieroid brachiopod. *Homalophyllites* is restricted to the Madison Limestone, and the assemblage is characteristically Madison. Consequently, the Soldier Creek collection has no bearing on the age of the Amsden.
2. The only fossils (colln. 63–68 of this report) found in the Amsden at its type locality are of Early Pennsylvanian age; these fossils occur near the base of the Ranchester Limestone Member, approximately 95 to 100 feet above the base of the formation. Assignment of a Pennsylvanian age to the entire type Amsden solely on the basis of fossils found well above its base (Gorman, 1963, p. 70) is unwarranted.
3. The argument advanced by Burk (1954, p. 3) and Gorman (1962, p. 14–15) that the fossils indicating a Mississippian age for the lower part of the Amsden in the Wind River Range came from a formation other than the Amsden is based on erroneous assumptions. Although it is true that the fossils collected by the Bransons at Bull Lake Creek are actually from the Madison Limestone, the bulk of their collections was made from the Horseshoe Shale Member at Cherry Creek and other localities in the southern Wind River Range. Madison and Horseshoe faunas in collections made by the Bransons and their associates are readily differentiated (Sando, 1967a, p. 548–549). Moreover, the careful studies of Shaw and Bell (1955) and Shaw (1955a) clearly demonstrated a Mississippian age for the lower part of the formation in the Wind River Range.
4. The assertion that stratigraphic leaks related to karst development at and below the Madison-Amsden interface are responsible for an erroneous Mississippian age assignment for the lower part of the Amsden (Foster, 1964, 1966) is not supported by evidence in the literature or by our field observations. The fossils upon which the Mississippian age determinations are based are from the Horseshoe Shale Member, a considerable distance stratigraphically above the complex solution features developed in the upper part of the Madison. Moreover, the Horseshoe faunas are distinct from and definitely younger than those found in the Madison.
5. Interpretation of the Darwin Sandstone Member as a basal Pennsylvanian sand in its type section, perhaps due in part to Girty's (*in* Blackwelder, 1913, p. 176) hesitance to assign a positive date to the lower fauna above the Darwin, is not supported by a restudy of the original collections from the type section. We regard the collections (colln. 137 and 138 of this report) from the lower zone as unquestionably of Mississippian age.
6. Assignment of a Pennsylvanian age to the limestone unit herein called Moffat Trail Limestone Member at Hoback Canyon and South Indian Creek in western Wyoming (Wanless and others, 1955, p. 33) was based on erroneous interpretation of the identity and temporal significance of the foraminifers found in this unit. Large foramineral assemblages identified by B. L. Mamet in the present study from the same beds at the same localities represent Zones 17 and 18 of Sando, Mamet, and Dutro (1969), which are of Chesterian age. Moreover, the larger invertebrate fossils studied by us from these localities are in complete agreement with the foraminiferal age determinations.
7. Burk's (1954, p. 4, 5) conclusion that the lower part of the Amsden in the Wind River and

Washakie Ranges is of Pennsylvanian age was based on fossils referred to the *Spirifer welleri* and *Spirifer "opimus"* assemblages by Shaw (1955a). Shaw (1955a) regarded the *Spirifer welleri* assemblage as Chesterian and the *Spirifer "opimus"* assemblage as Pennsylvanian but warned that the age of the upper assemblage was uncertain. Sadlick (1955, p. 56) suggested a Springeran age for the *Spirifer "opimus"* assemblage, but later (Sadlick, 1960, p. 1211) pointed out that "these beds can be considered either very late Mississippian or early Pennsylvanian." In the present study, the fossils of both assemblages are all referred to the Chesterian *Anthracospirifer welleri-shawi* Zone.

LITHOSTRATIGRAPHY AND LITHOGENESIS

PALEOGEOLOGY OF PRE-AMSDEN SURFACE

STRATIGRAPHY OF SUBJACENT UNITS

The Amsden Formation of Wyoming unconformably overlies the Madison Limestone or Group of Kinderhookian to early Meramecian age. Throughout most of Wyoming, the Madison Limestone consists of predominantly shelf carbonate deposits that belong to the Wyoming province of Sando (1967b). In the overthrust belt of western Wyoming, the Madison Group consists of the Lodgepole and Mission Canyon Limestones, which make up a somewhat thicker carbonate sequence of approximately the same age as the beds in the Wyoming province. These beds are similar to the Madison of southwest Montana and represent a southern extension of the Montana province of Sando (1967b). Palinspastic relations of Carboniferous rocks of the overthrust belt have yet to be determined, but the rocks have clearly been moved eastward onto the Wyoming shelf. This brief discussion deals only with those parts of the Madison that directly underlie the Amsden Formation.

Preliminary study of the Madison in the Wyoming province indicates that the upper part of the formation is divisible into two widespread members. The uppermost, the Bull Ridge Member, was named and described by Sando (1968). At most localities, this member consists of a lower unit of dolomitic siltstone, silty dolomite and shale overlain by limestone and dolomite that contain fossils of early Meramecian age (*Diphyphyllum* Zone of Sando, 1967a). The Bull Ridge Member ranges from a few feet to as much as 120 feet in thickness; at many localities its thickness is dependent on the depth of post-Madison erosion. Underlying the Bull Ridge Member is an unnamed member that consists largely of cliff-forming cherty limestone and dolomite of Osagean age (*Spirifer madisonensis* Zone of Sando, 1967a). The lower part of this unnamed member consists of a solution zone made up of limestone and dolomite breccia in siltstone and shale matrix (lower solution zone of Sando, 1967a). The unnamed member ranges in thickness from about 80 feet to 240 feet.

In the overthrust belt of western Wyoming, the Amsden Formation rests uncomfortably on a carbonate sequence referred to the Mission Canyon Limestone (Sando and Dutro, 1960; Sando, 1967b). The Mission Canyon consists principally of shallow-water marine limestone and dolomite but contains some evaporite beds or leached evaporites. At Hoback Canyon, the upper part of the Mission Canyon consists of a gypsiferous red bed sequence; elsewhere the same interval is largely brecciated carbonate and red beds. The upper part of the Mission Canyon Limestone contains a fauna of early Meramecian age and is correlated with the Bull Ridge Member of the Madison Limestone in the Wyoming province (Sando, 1967a, p. 546, fig. 7; Sando and others, 1969, p. E22, fig. 7).

STRUCTURE OF SUBJACENT UNITS

The pronounced unconformity that separates the Madison Limestone from overlying rocks records a period of epeirogenic emergence over most of the northern Cordilleran region. The paleogeology of the pre-Amsden surface together with thickness distribution of the Darwin Sandstone, basal unit of the Amsden at most localities, is shown on plate 2. This map shows a general pattern of southeastward truncation of the Madison in the Wyoming province, suggesting that the focal point of the uplift was southeast of the area of Darwin deposition. Absence of the Bull Ridge Member over a broad area reflects erosion of this unit rather than nondeposition. The Medicine Bow Mountains and Laramie Range region formed a northern prong of an uplift that was active during Mississippian time (Maughan, 1963). Northwest of the subcrop area of the unnamed limestone member of the Madison, the surface upon which the Amsden was deposited consists mainly of the Bull Ridge Member of the Madison, except for local patches where it was eroded in the northern part of the Bighorn Mountains and in the Bighorn Canyon area.

Structure of the Wyoming shelf before Amsden deposition is depicted on four cross sections (pl. 2) across critical parts of the area. The base of the

Horseshoe Shale Member is used as an approximate time plane with which to analyze the structure of the underlying units. If the Darwin had been deposited in simple erosional valleys cut into flat-lying beds of the Madison, its thickness should vary inversely with the thickness of the upper members of the Madison. The cross sections suggest that thickness variation of the Darwin is not related in any simple way to the thicknesses of the Madison members. In some areas, the Darwin is thicker where it rests on the Bull Ridge Member than where it rests on the underlying unnamed limestone member. A logical inference is that the thickness of the Darwin was controlled by erosional modification of local structural depressions related to post-Madison uplift.

SOLUTION EFFECTS RELATED TO POST-MADISON UPLIFT

Uplift of the area prior to deposition of the Amsden exposed the carbonate rocks of the Madison Limestone to the chemical and physical forces of subaerial erosion and produced an extremely irregular interface between the Madison and the Amsden. Caves and sinkholes characteristic of an ancient karst topography are evident at many localities; these solution cavities are filled with terrigenous material derived largely from the Darwin or Horseshoe Member of the Amsden or with breccia of Madison carbonate rock in a terrigenous matrix. At some localities, the upper part of the Bull Ridge Member is represented by a solution-riddled framework of limestone infiltrated by Amsden deposits along joint planes. Solution features related to post-Madison uplift have been discussed in detail by Sando (1974).

SUMMARY OF POST-MADISON TO EARLIEST AMSDEN HISTORY OF CENTRAL WYOMING

The geomorphic development of the central Wyoming area before and during early Amsden deposition can be divided into several overlapping stages.

1. After Madison deposition, much of the northern Cordilleran foreland area was epeirogenically uplifted to form land of low relief, and the sea withdrew to a geosynclinal trough that lay to the west. The uplift took place between early Meramecian (middle Salem) and middle Chesterian time, as indicated by the youngest fossils found in the Madison Limestone and the oldest fossils found in the Amsden Formation. Local variations in the intensity of the epeirogenic process produced broad folds in the Madison strata.
2. When the Wyoming area became land, a groundwater system, characterized by a shallow water table, developed in the carbonate terrane. Phreatic caverns were carved in the upper 400 ft of bedrock by ground-water guided in part by readily soluble evaporite intervals in the carbonate sequence. Solution breccias were formed by collapse of thin carbonate beds within the evaporite intervals and of roofs of large cavities, particularly in the lower solution zone.
3. As uplift proceeded, a karst topography was developed on the surface of the limestone terrane. Part of the Bull Ridge Member of the Madison was eroded, particularly toward the southeast. Although the main lines of surface drainage are not apparent, the valleys appear to have been dominantly synclinal, and maximum relief probably did not exceed 200 feet. The drainage pattern was probably complex and characterized by stream capture by numerous sinkholes developed to a depth of about 100 ft below the bedrock surface. Red residual products from a thin soil cover, formed on the bedrock surface, infiltrated many of the solution cavities.
4. Beginning in late Meramecian or early Chesterian time, the area subsided and the sea swept eastward from the geosyncline across the karst surface. No appreciable dripstone and flowstone formed in the caves, suggesting that vadose circulation was never extensively developed. Initial reworking by the sea of stream deposits and residual soil was followed by deposition of a layer of sand derived largely from outside the Amsden basin. The sand covered all but a few isolated topographic highs that remained as islands in the Darwin sea and infiltrated sinkholes and caves in the bedrock and filled most of the open spaces produced by prior solution.

DARWIN SANDSTONE MEMBER

Distribution.—The distribution of the Darwin Sandstone Member in Wyoming is shown on plate 2. The conservative limits of the Darwin shown on plate 2 are largely nomenclatural and reflect areas of poor or no stratigraphic control and problems of correlation with adjacent sandstone units. In fact, the basin of Darwin deposition opened westward into the Cordilleran geosyncline in Idaho, and extended northward into Montana and probably eastward into the Dakotas and Nebraska.

Type section.—The Darwin Sandstone Member was named by Blackwelder (1918, p. 433) for exposures on Darwin Peak in the Gros Ventre Range of western Wyoming. Blackwelder did not designate a type section for the member. A stratigraphic section at Darwin Peak taken from Blackwelder's field notes is shown by Love (1954) on a diagram of the Tensleep, Amsden, Casper, and Hartville Formations in Wyoming and identified as the type section. This section is reproduced below through the courtesy of J. D. Love, who transcribed it from pages 109–112 of Blackwelder's field notebook. The section was measured by Blackwelder in 1911 on the north slope of Darwin Peak in S½ sec. 28, T. 40 N., R. 112 W., Teton County. Although the descriptions and thicknesses of individual section units are taken verbatim from Blackwelder's notes, the terminology of members and positions of member boundaries are those of the writers. Moreover, Blackwelder placed the top of the Amsden at the top of unit 45, whereas we place this boundary at the top of unit 41.

Darwin Peak section

	Unit	Thickness (feet)
Tensleep Sandstone:		
46.	Great white to buff cliff-making layers of quartzite and sandstone, not measured	----
45.	Shale and dolomite; gray calcareous shale with minor platy dolomite	0.6
44.	Quartzite; light gray	3.7
43.	Dolomite and shale; platy dolomite and calcareous shale, pearl gray	14.7
42.	Quartzite; light gray, some calcareous laminae?	13.0
	Total measured part of Tensleep Sandstone	32.0+
Amsden Formation:		
Ranchester Limestone Member:		
41.	Dolomite; dense, brittle, white, partly talus-covered	16.5
40.	Largely concealed. Much chocolate-drab and gray calcareous shale, red, gray and white dolomite, and calcareous sandstone in alternate beds	75.0
39.	Dolomite; sandy(?), gray, massive, with thin layers of chocolate shale(?)	8.4
38.	Sandstone; white, very calcareous, surface pitted and seamed	4.5
37.	Shale and dolomite; chocolate and lavendar shale, calcareous, and thin beds of earthy gray dolomite 6–8 in. thick	20.0
36.	Dolomite; white, dense, brittle	1.0
35.	Sandstone; purple to pure white, calcareous	2.4
34.	Dolomite; sandy(?), gray to purple	3.0
33.	Concealed; debris of buff argillaceous dolomite	.8
32.	Sandstone; cream-white, friable, calcareous, crossbedded; ridges on weathered surface	6.6
31.	Limestone or dolomite; flesh-colored, hard to friable, sugary	4.8
30.	Shale, limestone, and sandstone, largely concealed; purple calcareous shale spotted with buff, thin calcareous sandstones, and dense brittle gray argillaceous limestone	14.6
29.	Limestone; white to cream, mostly hard and massive; some thin-bedded layers; a few elliptical brown chert nodules; traces of brachiopods	21.5
28.	Limestone; earthy to hard and ringing, blue gray; some purplish layers; fossils in section on surface	2.5
27.	Shale; sandy, calcareous, dark purple-gray	.3
26.	Limestone; chocolate-gray, sandy; rests on clear, uneven dissolved surface like one 16 ft below	3–.8
25.	Limestone; blue-gray to purplish	3.0
24.	Limestone; cream-white, hard, with brown chert seams; traces of fossils	3.5
23.	Shale; green, white, calcareous	1.0
22.	Limestone; light gray, dense, brittle, massive	7.0
21.	Shale; calcareous, sandy, buff to pale green	.4
20.	Limestone; sandy(?), dense, hard, gray	.4
19.	Sandstone; green gray, calcareous; small pieces of limestone at base; base irregular, a clear "disconformity."; at one place a 6-in. layer of brown chert is present at the base	.8
18.	Limestone; blue-gray, hard, dense, massive	5.9
17.	Limestone; dull gray, massive, crystalline; full of chips of fossils, including bits of bryozoans. USGS locs. 6191a–PC, 6191c–PC	2.5
	Total Ranchester Limestone Member	207.2
Horseshoe Shale Member:		
16.	Shale and limestone; chocolate and gray calcareous blocky shale with layers of nodular gray limestone or limestone nodules	3.0
15.	Concealed by talus; shale and limelimestone(?)	29.5
14.	Limestone and shale(?); lavendar-gray shaly limestone and calcareous shale; poorly exposed	7.5
13.	Shale and limestone(?); chocolate, red, and olive; dense limestone nodules; no exposures	15.0
12.	Limestone and clay; nodules of limestone like underlying bed crowded in pink clay	4.5
11.	Limestone; olive gray to purple, very dense and hard; big crinoid stems, *Composita*, *Spirifer*, and other fossils; fossils poorly preserved. USGS locs. 6191–PC, 6191b–PC	2.8
10.	Concealed; mostly maroon shale(?)	5.5
9.	Limestone and shale; yellow and maroon shale crowded with big nodules and nodular layers of lavendar dense	

	Thickness (feet)
Madison Limestone)measured nearby)—Continued:	
Bull Ridge Member—Continued	
limestone and olive-yellow botryoidal limestone	6.6
8. Limestone; hard, dense, violet-gray with blood-red dots and streaks; light gray above	4.2
7. No clear exposure; debris of ocher, buff, and chocolate shale with nodules of chert, dense olive and red resinous limestone, and hematite; a few traces of fossils	19.5
6. Limestone(?); dense, lavendar-gray	1.2
5. Shale and limestone; buff sandy clay with one bed of gray sandy limestone and many nodules of dense purple limestone	2.8
Total Horseshoe Shale Member	102.1
Darwin Sandstone Member:	
4. Sandstone; white, weathering buff to tawny; shaly below, massive above; forms cliff	19.0
3. Shale, limestone, and other rocks; poorly exposed; buff to russet sandy calcareous shale; gray sandy dolomite; some limonite nodules	7.0
2. Sandstone; white, weathering cream-buff; massive to thin-bedded; crossbedded; dips northwest	52.3
1. Sandstone; laminated, rather crumbly; buff, white; pieces of gray limestone in lower part	.5
Total Darwin Sandstone Member	78.8
Total Amsden Formation	388.1
Madison Limestone (measured nearby):	
Bull Ridge Member?	
Limestone; a single bed; light gray, very hard, dense; thickness varies 6 in. from point to point	6.3
Dolomite; laminated, drab, with geodes and limonite cavities	.7
Shale; sandy, buff, with argillaceous green laminae; mud cracks	2.3
Shale; purple, sandy, calcareous	6.2
Limestone(?); brick red, earthy; green blotches	.8
Calcareous shale or limestone; buff to orange	2.5
Total Bull Ridge Member?	18.8
Limestone; thin-bedded, drab	2.3
Limestone; massive, hard, black-gray	6.0

Thickness.—The thickness of the Darwin ranges from a thin edge to about 200 feet; it is less than 100 feet in most of Wyoming. Thicknesses (pl. 2) are irregular and change abruptly throughout most of the area, increasing southwestward from central Wyoming to the western Wyoming overthrust belt, and manifesting a northeast-southwest grain. Thickness of the Darwin bears no simple relationship to thickness of the upper members of the Madison Limestone (pl. 2).

Lithology.—The Darwin Sandstone Member is a friable to well-cemented, gray, white, buff, or red, fine- to medium-grained quartz standstone. Bedding ranges from thin to massive, and crossbedding is very common throughout the member.

Relation to adjacent units.—Darwin rests disconformably on Madison Limestone. Lowest beds of the Darwin are obscured by slump at most localities. No residual soil has been reported, and basal limestone conglomerate is rare. The upper boundary of the member is ordinarily sharp and conformable.

Petrography.—Although the Darwin has been studied in more detail than any other member of the Amsden, no comprehensive petrographic studies have been published. Bishop (1957) studied 19 samples from 7 localities at the north end of the Wind River Range and one locality in Jackson Hole. Agatston (1954, p. 516–517) reported on mechanical analyses of 30 samples from 23 localities in the Bighorn Mountains. Gorman (1962) determined size distribution in an unstated number of samples from 11 localities ranging from western Wyoming to the Bighorn Mountains. Todd (1959, 1964) presented extensive petrographic data based on 13 samples from 6 localities in the Bighorn basin and western Bighorn Mountains.

The Darwin of the Bighorns includes orthoquartzite, subgraywacke, and subarkose of the Folk (1954) classification (Todd, 1959, 1964). The average sample is subarkose and is characterized by the following composition (Todd, 1964):

	Percent
Quartz:	
Plutonic	70
Vein	8
Recrystallized metaquartz	5
Pressure metaquartz	2
Metamorphic rock fragments	Trace
Feldspar	9
Chert	3
Quartz cement	3
Clay (kaolinite)	Trace

Samples from the Wind River Range and Jackson Hole have a similar composition but are generally characterized by calcite composition but are generally characterized by calcite cement (4.6–52.3 percent); several, classified as arkose, are richer in feldspar and clay and also contain chlorite and biotite (Bishop, 1957).

Heavy minerals constitute only 0.2 percent or less of the Bighorn area samples (Todd, 1964). Heavy mineral suites are dominated by the opaque minerals leucoxene, magnetite, and ilmenite; leucoxene is the most abundant opaque mineral, (Bishop, 1957; Todd, 1964). Nonopaque minerals make up about 25 percent (Todd, 1964) to 50 percent (Bishop, 1957) of the average Darwin sample. Tourmaline, zircon, and rutile are the most abundant nonopaque minerals, and tourmaline is the dominant mineral. Arkose samples differ from "normal Darwin" in having a greater proportion of nonopaque minerals and in the presence of garnet, barite, and staurolite (Bishop, 1957).

Grain size ranges from very fine sand to very coarse sand (Wentworth scale), and the mode is fine sand (Agatston, 1954; Bishop, 1957; Todd, 1964). Average sorting values are generally in the moderately sorted to well-sorted range. Samples from the Bighorn area are characteristically trimodal and have fine-grained "tails"; moreover, most samples from the lower part of the Darwin are poorly sorted (Todd, 1964). Arkose samples are poorly sorted and bimodal (Bishop, 1957).

Grains range from very angular to well rounded; average roundness is in the subrounded class (Agatston, 1954; Bishop, 1957; Todd, 1964). Heavy mineral grains are uniformly well-rounded (Bishop, 1957). Eighty percent of all the Darwin grains are rounded, and 20 percent are angular (Todd, 1964). Moreover, there is no correlation between mean roundness and grain size, and the size frequency distribution curves of rounded and angular grains are almost identical. Five to 25 percent of the rounded grains have fractured or abraded overgrowths. These observations suggest that the rounded grains were inherited from previous abrasion cycles, and the angular grains represented the true transportational history of the Darwin (Todd, 1964).

Age.—Inasmuch as no fossils have been found in the Darwin Sandstone Member, paleontologic dating of this unit depends on ages determined from fossils found in the subjacent and superjacent beds. The Darwin rests disconformably on three different units in Wyoming: the upper part of the Mission Canyon Limestone, the Bull Ridge Member of the Madison Limestone, and an unnamed limestone member of the Madison Limestone. The upper part of the Mission Canyon Limestone and the Bull Ridge Member of the Madison are of early Meramec (early and middle Salem) age. The unnamed limestone member of the Madison is of late Osagean (Keokuk) age; this unit normally underlies the Bull Ridge Member and is overlain by the Darwin only where the Bull Ridge Member was removed by post-Madison, pre-Darwin erosion. Thus, the Darwin can be no older than early Meramecian (middle Salem).

The Darwin is overlain conformably by the Horseshoe Shale Member. The geographic and stratigraphic distribution of collections of fossils from the Horseshoe is shown on plates 3–9. The ages and distribution of the lowest collections of fossils from the Horseshoe Shale Member where it overlies the Darwin are given in table 1.

Available faunal data support the following conclusions regarding the age of the lowest beds in the Horseshoe Shale Member, which provide an upper limit to the age of the Darwin Sandstone Member: (1) fossils occur in the Horseshoe Member overlying the Darwin Member at 12 localities in the Teton Range, Hoback Range, Gros Ventre Range, Washakie Range, Wind River Range, and Bighorn Mountains; (2) all but one of the lowest datable collections at these localities are of Chesterian age; (3) the only locality where the Horseshoe contains Pennsylvanian (Morrowan) fossils that overlie the Darwin is at the northeast margin of its outcrop area; (4) fossils collected from the Moffat Trail Limestone Member, which overlies the Horseshoe in the Wyoming overthrust belt, suggest that the lower part of the Moffat Trail is older than the oldest fossiliferous beds in the Horseshoe in central Wyoming. This supports the interpretation that Darwin deposition began earlier in western Wyoming than it did in central Wyoming. A synthesis of the biostratigraphic and lithostratigraphic evidence presented later in this report indicates that deposition of the Darwin began in middle Meramecian time and extended into the Chesterian but probably did not breach the Mississippian-Pennsylvanian boundary.

Depositional environment.—Previous interpretations of the origin of the Darwin Sandstone Member have stressed both continental and marine aspects of deposition (Agatston, 1954, p. 561–562; Bishop, 1957, p. 46–51; Gorman, 1962, p. 87–88, 1963, p. 70; Wilson 1962, p. 141; Todd, 1964, p. 1087; Mallory, 1967, p. G11–G12). Critical evidence bearing on the depositional history of the Darwin is summarized below.

1. The Darwin covered at least 4,000 square miles (pl. 2) and probably an even greater area. The gross geometry of the member is that of a sheet sand. Local areas where the Darwin is absent probably were islands.
2. The Darwin thickens regionally toward the west (pl. 2), and local thickness variations seem to be mainly a reflection of the topography of the surface upon which the sand was deposited.

TABLE 1.—*Distribution and ages of lowest collections of fossils from Horseshoe Shale Member overlying Darwin Sandstone Member*

See Register of Fossil Collections (p. A67) and Register of Selected Stratigraphic Sections (p. A66)

Collection No.	Section		Location	Feet above top of Darwin	Age and zone
	No.	Name			
19	5	Beaver Creek	Wind River Range	25	Late Chesterian, *Anthracospirifer welleri-shawi* Zone.
21	6	South Pass	do	43	Do.
28	7	Cherry Creek	do	28	Do.
41	13	Soda Creek	Washakie Range	0	Chesterian.
42–44	14	Horse Creek	do	30	Late Chesterian, *Anthracospirifer welleri-shawi* Zone.
45	15	Livingston Ranch	do	70	Do.
46	16	Wiggins Fork	do	28	Do.
53, 54	24	South Rock Creek	Bighorn Mountains	2	Morrowan.
69	30	Devils Canyon	do	15	Late Chesterian, *Anthracospirifer welleri-shawi* Zone.
111, 112	44	Hoback Canyon	Hoback Range	15	Chesterian.
137, 138	45	Darwin Peak	Gros Ventre Range	40	Late Chesterian, *Anthracospirifer welleri-shawi* Zone.
149	49	Berry Creek	Teton Range	13	Do.

3. The beds overlying the Darwin contain progressively younger fossils from west to east across the Wyoming shelf, suggesting that the Darwin was the earliest deposit of a transgressing sea.
4. Local occurrences of arkose (Bishop, 1957) and limestone conglomerate at the base of the Darwin suggest a fluvial origin for the oldest beds in the sequence.
5. Poor sorting of sandstone in the lower part of the Darwin (Todd, 1964) suggests a fluvial history, but better sorting in other parts of member (Agatston, 1954; Bishop, 1957) indicate deposition in an environment where winnowing was more effective.
6. The presence of angular grains and the lack of correlation between coarser grain size and higher roundness in the sand-size range (Todd, 1964) support a fluvial interpretation for the lower beds of the member.
7. The compositional maturity of most of the sandstone, although probably inherited from older sandstone (Todd, 1964), indicates a stable shelf deposit.
8. The absence of fossils in the Darwin is consistent with a fluvial to rapidly transgressing nearshore origin.

Provenance.—Previous interpretations of provenance (Agatston, 1954, p. 561; Bishop, 1957, p. 39–45; Todd, 1964, p. 1082–1084; Mallory, 1967, p. G25–G27) suggested seven possible sources for the detritus in the Darwin Sandstone:

1. The Black Hills uplift in northeastern Wyoming and southwestern South Dakota, which Agatston (1954) pointed out could not be traced southwestward.
2. An emergent area in southeastern Wyoming, considered an unlikely source by Agatston (1954) because it was a limestone terrane of low relief.
3. The Transcontinental arch, which occupied a broad area across North Dakota, South Dakota, Nebraska, and parts of Colorado and Wyoming, Agatston, 1954).
4. A pre-existing orthoquartzite or subgraywacke sandstone on the Canadian shield, which could account for the rounded grains that make up 80 percent of the Darwin sediment, explains the 5–25 percent quartz grains with fractured or abraded overgrowths, and rounded grains of tourmaline, zircon, and rutile (Todd, 1964). Sandstone of Chazy age was suggested by Mallory (1967) as the most likely contributor.
5. Silicic crystalline intrusive rocks on the Canadian shield, which would account for most of the remaining 20 percent of the Darwin grains (Todd, 1964).
6. A regolith on the Madison Limestone, which would account for rare chert and carbonate fragments and kaolinite found in the Darwin (Todd, 1964).
7. Metamorphic and volcanic rocks exposed in an island arc or welt that lay west of the depositional site. Originally proposed by Agatston (1954), this source was favored by Bishop (1957) to explain a southeastward decrease in zircon and increase in tourmaline in his arkose samples from western Wyoming and by Todd (1964) to account for minor amounts of angular garnet, metaquartz, and euhedral apatite and zircon.

Summary of origin.—The gross geometry of the Darwin and particularly its great areal extent preclude an entirely fluviatile origin such as postulated by Todd (1959, 1964). Early fluvial deposition followed by drowning of the area by marine transgression, as suggested by Agatston (1954) and Mallory (1967), is a more reasonable explanation of available evidence. Thickness seems to have been controlled by the structure of the underlying Madison as well as by pre-Darwin erosion. We conclude that the Darwin sand was deposited principally in beaches and offshore bars adjacent to an eastward-transgressing shoreline following drowning of a complicated fluvial system associated with a karst topography.

Regional considerations presented later in this report indicate that the principal sources of terrigenous materials in the Darwin were Precambrian and lower Paleozoic rocks exposed on the Canadian shield and Transcontinental arch during Late Mississippian and Early Pennsylvanian time. Growth of the Big Snowy basin effectively limited contributions from the north and northeast during much of Darwin time. Eastern and southeastern sources on the Transcontinental arch were probably the most important contributors of terrigenous materials

HORSESHOE SHALE MEMBER

Distribution.—The known distribution of the Horseshoe Shale Member in Wyoming approximates that of the Darwin Sandstone Member (pl. 2). Our interpretation of the distribution of this member differs from that of Mallory (1967, pl. 2B) mainly in western Wyoming, where we have identified it in the Salt River, Snake River, Hoback, and Teton Ranges (pl. 9). In addition, we have traced this facies northward into Montana, where the Horseshoe merges with the Tyler Formation. Beds continuous with the main body of the Horseshoe have been identified to the west in the Snake River Range of Idaho, where they have been mapped with the Wells Formation (Staatz and Albee, 1966, p. 31). Mallory (1967, pl. 2B) also showed inferred marginal equivalents of the Horseshoe in the Morgan, Casper, Hartville, and Minnelusa Formations of southern, southeastern and eastern Wyoming.

Type section.—The type section of the Horseshoe Shale Member is on Amsden Creek in SE¼ sec. 33, T. 57 N., R. 87 W., Sheridan County, Wyoming (Mallory, 1967, p. 8). The Amsden type section measured by Sando and Moore about one quarter mile east of Mallory's section serves as a reference section for the Horseshoe (p. A10).

Thickness.—The thickness of the Horseshoe may be as much as 150 feet; the average thickness is about 75 feet (Mallory, 1967, pl. 2B). Variation in thickness seems to be without significant pattern. Local areas where the member is absent seem to represent islands in the Horseshoe sea. The member is somewhat thinner than average in the Wyoming overthrust belt and southern Tetons where it is overlain by the Moffat Trail Limestone Member, which is partly equivalent to the Horseshoe of central Wyoming.

Lithology.—The Horseshoe Member is made up predominantly of fissile, platy or blocky siltstone, shale, and mudstone that characteristically weathers bright red to grayish red or purple. The member is poorly exposed at most localities and forms talus-covered red soil slopes. Thin beds and lenses of platy, white to red, fine-grained, commonly calcareous quartz sandstone occur sporadically throughout the member. Thin beds of silty, sandy, or argillaceous limestone, though rare in central Wyoming, make up a significant proportion of the member in western Wyoming. Dolomite is a rare constituent. Black or gray shale occurs in the Horseshoe Member at Hoback Canyon in western Wyoming.

Anhydrite and gypsum are present in the Horseshoe at several localities in central Wyoming (Biggs, 1951, p. 22; Agatston, 1954, p. 518; Wilson, 1962, p. 126) mostly as accessory constituents in shale or sandstone. Pisolitic hematite has been reported 20 to 35 feet above the base of the member at six localities in the Wind River and Washakie Ranges (Biggs, 1951, p. 19), about 20 feet below the top of the member at two localities in the Bighorn Basin (Agatston, 1954, p. 518), and near the middle of the member at two localities in the Bighorn Mountains (Gorman, 1963, p. 67). Phosphatic pisolites have been found at varying intervals above the base of the member at three localities in the Bighorn Basin (Todd, 1964, p. 1088). Pisolitic hematite in thin beds has also been observed at several levels of the Horseshoe in both central and western Wyoming; at some localities (Hoback Canyon, Livingston Ranch, Sheep Mountain) more than one bed was found in the same section. The pisolite beds apparently are unreliable as stratigraphic markers.

Limestone beds in the Horseshoe Member are either fine grained and unfossiliferous or fine to medium grained and contain a shelly marine fauna. A few marine invertebrates are also in thin sandstone beds. At Hoback Canyon in western Wyoming, some sandstone, siltstone, and shale beds contain plant remains, and plant remains have been reported from the Horseshoe in the Bighorn Mountains (Wilson, 1962, p. 126).

Relation to adjacent units.—The Horseshoe Shale Member overlies the Darwin Sandstone Member conformably, but at some places in the Rawlins hills and in north-central Wyoming, the member rests disconformably on the underlying Madison

Limestone. The Horseshoe is overlain conformably by the Ranchester Limestone Member except at some localities in western Wyoming, where it is succeeded conformably by the Moffat Train Limestone Member.

Petrography.—The petrography of the Horseshoe Shale Member is very poorly known. Todd's (1959, 1964) study of this unit (called Sacajawea Formation by Todd) included examination of 19 thin sections from 6 localities and X-ray analyses of 11 samples from 3 localities in the Bighorn Basin area. Gorman (1962) presented data on size distribution and clay mineralogy of an unstated number of samples from the Horseshoe Shale Member (subunit a_2 of Gorman) at 7 localities in western Wyoming, the Wind River Mountains, and the Bighorn Mountains.

The Horseshoe Member contains about 70 percent clay-size material and 30 percent poorly sorted sand and silt (Todd, 1964). The sand grains are similar to those in the Darwin Sandstone Member, that is, the sand would probably fall in the subgraywacke or subarkose class. Primary hydrous iron oxide cement is characteristic. Most of the feldspar grains are kaolinitized.

Clay minerals in the Horseshoe are illite and kaolinite (Todd, 1959, 1964; Gorman, 1962). The clays change progressively from dominantly kaolinite at the base of the member to dominantly illite at the top of the member at localities where the Darwin Sandstone is absent (Todd, 1959, 1964). In sections that have the Darwin at the base of the sequence, the clays are kaolinitic to the top of the Horseshoe, where an abrupt change to illite takes place at the base of the overlying Ranchester Member. Clays in the Horseshoe in western Wyoming are entirely illite and are dominantly kaolinite in the Bighorn Mountains (Gorman, 1962).

Study of 18 thin sections of fossiliferous limestone in the Horseshoe by Sando (table 2) revealed a predominance of poorly sorted and poorly washed sediments; the samples are composed mostly of organic debris in micrite matrix.

Age.—Fossils collected from the Horseshoe Shale Member in Wyoming range in age from late Chesterian to Morrowan. The late Chesterian faunules include elements of the *Anthracospirifer welleri-shawi* Zone, which is divided into the *Carlinia amsdeniana* and *Composita poposiensis* Subzones, and foraminiferal Zones 18 and 19. Morrowan faunules are represented by fossils assigned to the *Neokoninckophyllum hamatilis* Zone and foraminiferal Zone 20.

TABLE 2.—*Petrographic classification of limestone samples from Horseshoe Shale Member*

[Petrographic categories are from Folk (1959, 1962). Localities are described in Register of Fossil Collections, p. A67]

Collection No.	Geographic area	Folk rock term
1	Rawlins hills	Recrystallized packed biomicrite.
2	do	Do.
3	do	Recrystallized packed biopelmicrite.
4	do	Recrystallized packed biomicrite.
5	do	Packed biomicrite.
32	Wind River Range.	Fossiliferous micrite.
41	Washakie Range.	Sparse biomicrite.
45	do	Packed biomicrite.
53	Bighorn Mountains.	Fossiliferous micrite.
54	do	Do.
69	do	Fossiliferous coarse intrasparite.
149	Teton Range	Fossiliferous sandy oomicrite.
153	do	Sparse sandy oobiomicrite.
154	do	Packed sandy oobiomicrite.
159	do	Unsorted biosparite.

The geographic distribution of fossils collected from the Horseshoe Shale Member is shown in figure 6. The available paleontologic evidence indicates that the Horseshoe is of Chesterian age (probably beginning in early Chesterian) throughout western and most of central Wyoming, but ranges into the Morrowan in the eastern part of the Bighorn Mountains and the Rawlins hills.

Depositional environment.—Evidence bearing on the depositional environment of the Horseshoe Shale Member is summarized below.

1. The absence of dessication cracks, raindrop impressions, leaf prints, and general lack of terrestrial vegetation is suggestive of subaqueous conditions.
2. The fine grain size, thin regular bedding, and poor sorting of most of the Horseshoe rocks indicate a prevalence of low-energy conditions in the environment of deposition.
3. The predominance of kaolinite in the eastern part of the basin and of illite in the western part suggests greater proximity to a deeply weathered source area for the kaolinite toward the east.
4. The presence of gypsum and anhydrite in the sequence suggests some periods of abnormal salinity.
5. Sporadic thin limestone beds that contain a normal marine fauna indicate periods of deposition in shallow water of normal marine salinity.
6. Phosphatic pisolites may represent intermittent periods of stillstand or emergence.
7. Local, gray or black, plant-bearing sediments indicate a terrigenous source, but plant re-

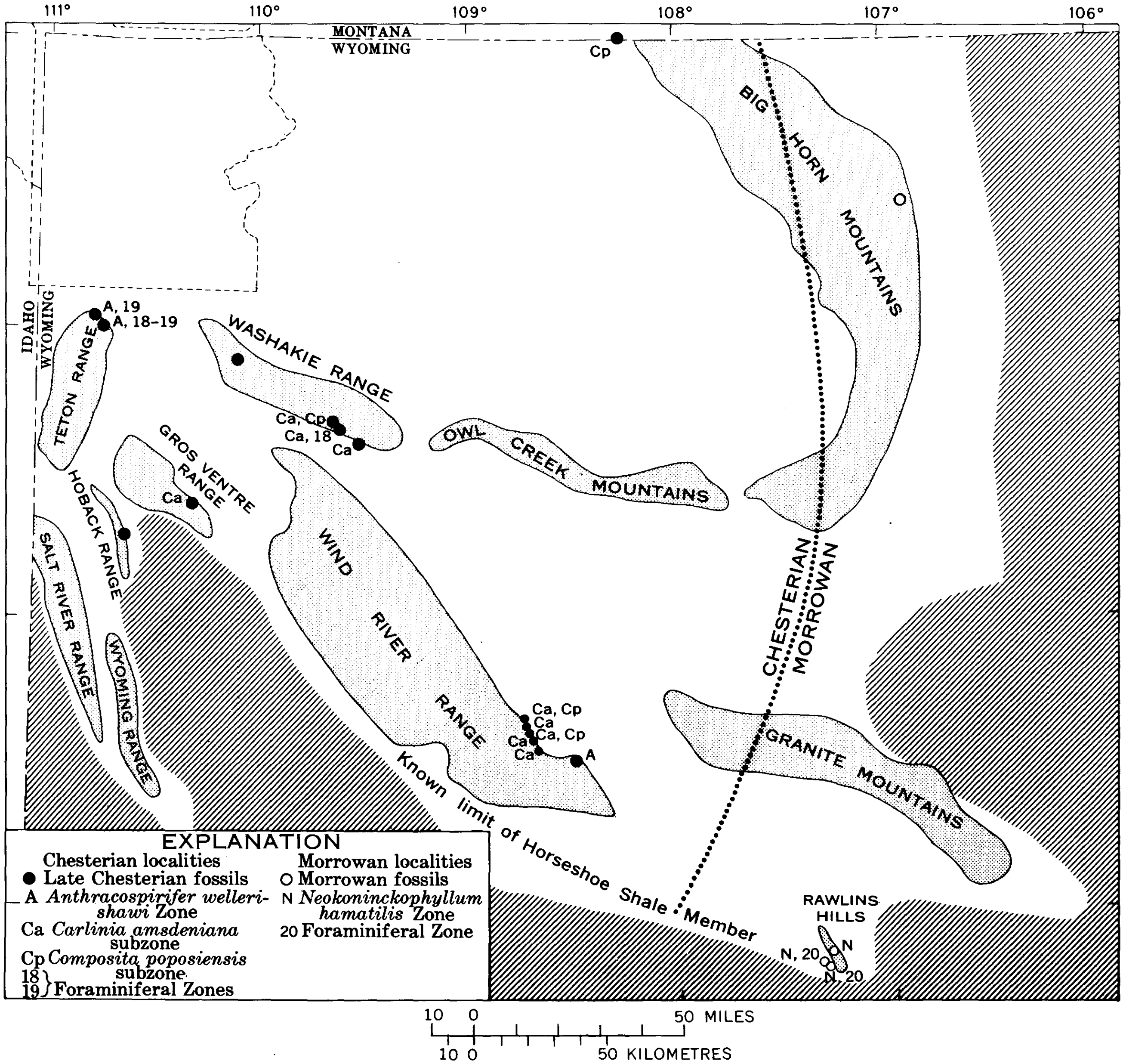

FIGURE 6.—Geographic distribution and ages of fossil localities in the Horseshoe Shale Member.

mains are strongly abraded and consist only of parts most resistant to wear, which suggests that the source was not nearby.

8. The Horseshoe is an essentially tabular body bounded on the north, east, and south by nearshore sands and on the west by carbonate bank deposits that separated it from the open sea.

Gorman (1962, p. 75–95) and Wilson (1962, p. 141) regarded the Horseshoe Shale Member as a reworked regolith derived from the weathering of the Madison Limestone and deposited in a sea that transgressed from west to east across the Wyoming shelf. According to Gorman, the Horseshoe is in part a seaward equivalent of the upper part of the Darwin Sandstone Member. Todd (1964, p. 1088) concluded that the lower part of the Horseshoe represents a flood-plain deposit associated with the fluvial deposits of the Darwin Sandstone Member. According to Todd, a phosphatic pisolite zone in the Bighorn basin marks an unconformity that was succeeded by transgressive marine deposition in strandline environments that included tidal flat, lagoonal, estuarine, and neritic sites.

We believe that the Horseshoe sediments were deposited in a relatively stable basin restricted from the open sea during most of Horseshoe time. We conclude that the character of the sediments and the geometry of their distribution are compatible with a lagoonal environment.

Provenance.—Previous studies (Gorman, 1962, p. 87–90; Wilson, 1962, p. 141, 144; Todd, 1964, p. 1082–1084; and Mallory, 1967, p. G13) suggested that the Horseshoe sediments were derived mainly from deeply weathered lateritic soil developed on the Madison Limestone during post-Madison, pre-Amsden emergence. Detritus may have been brought into the basin of deposition by streams flowing off land areas located to the south and east (Gorman, 1962). A source area of low relief in southeastern Wyoming was indicated by coarsening of the sediments toward the southeast (Wilson, 1962), although there is disagreement on this point (Mallory, 1967). Possible stream capture or other unrecorded events in the drainage area of a major river system may have accounted for the change from sandstone to shale deposition and for the abundance of iron in the Horseshoe sediments (Mallory, 1967). The principal source of fine detritus was probably local but sand-size material came from the same, more distant areas that contributed most of the Darwin Sandstone (Todd, 1964). The type and intensity of feldspar alteration suggest a warm, humid climate in the source area (Todd, 1964).

Origin of red color.—Determination of the origin of the red color that characterizes most of the Horseshoe rocks has an important bearing on the depositional history of the Horseshoe and on the climate in the basin of deposition and source areas. Previous explanations of the origin of the Horseshoe (Gorman, 1962; Wilson, 1962; Todd, 1964; Mallory, 1967) were based on formation of a deeply weathered, lateritic soil in a warm, humid climate on the emergent Madison Limestone as the principal source for the Horseshoe sediments. This reasoning is compatible with the theory of red bed formation expounded by Krynine (1949), who maintained that the red pigment was formed in warm, humid source areas and transported to desert basins where the oxidation state of the iron minerals was preserved. Krynine's theory has been strongly challenged recently by Walker (1967a, 1967b, 1968) and Walker and Honea (1969), who have presented evidence that hematite in red beds is formed by intrastratal alteration of iron-bearing detrital grains after deposition in hot arid or semiarid climates.

J. F. Murphy (oral. commun., 1972) noted that shale beds in the Horseshoe exposed in the glacially gouged canyons of Bull Lake Creek and Dinwoody Creek in the Wind River Range are green and pyritic, in marked contrast to their red hematitic character at other local surface exposures. Murphy's observations agree with those of Sando in the same area. Murphy also noted a change from green to red coloration and ultimately to pisolitic redbeds updip along the walls of Bull Lake Canyon. He stated that the peculiar green shales are found at the surface only where exposed by relatively recent erosion—in these canyons by Pleistocene glaciation. The original iron-bearing mineral in the Horseshoe was pyrite according to Murphy, and this mineral was protected from oxidation until after uplift of the Wind River Range during Paleocene and early Eocene time, when the eroded edges of the Amsden strata were oxidized. During Pleistocene time, glacial ice cut deep valleys in previously protected beds and exposed the unoxidized green sediments, which have not had time to be oxidized by the present regime. Murphy also believes that the ferruginous pisolites of the Horseshoe are not of depositional origin but were formed by later oxidation.

The recording of red coloration in well logs of the Horseshoe would seem to contradict Murphy's conclusions. However, he believes that red coloration has been overemphasized in well logs because the well samples that he has seen from nearby wells in the Wind River basin are predominantly green, contain significant pyrite, and red coloration occurred only as traces in these samples. M. R. Wockovich of the American Stratigraphic Company supports Murphy's observations; he has studied many well cuttings from all over Wyoming. According to Wockovich (written commun., 1972), green color is as common or more common than red in most well cuttings from the Horseshoe in Wyoming. However, J. D. Love (written commun., 1972) cautions that red coloration is commonly altered to green by the reducing action of high sulfur oil in oilfield areas.

These findings pose difficulties to interpreting the environmental history of the Horseshoe. On the one hand, the extensive solution effects noted previously in the Madison Limestone seem to indicate a humid climate in the land areas surrounding the basin of Horseshoe deposition. Moreover, Todd (1964, p. 1076, 1081–1082) pointed to the alteration of feldspars and the predominance of kaolinite in the Horseshoe to support a warm, humid climate in the source areas. On the other hand, Murphy's observations seem to preclude pre-depositional oxidation of the iron minerals in the sediment.

One might conclude that the principal source of the clay minerals in the Horseshoe was not a great mass of lateritic soil formed on the eroded surface of the Madison Limestone but another more distant source, perhaps the same Precambian and lower Paleozoic rocks on the Transcontinental arch that supplied quartz grains to the Darwin Sandstone Member. Although we favor this interpretation, more data than are now available are needed to resolve this question.

Summary of origin.—The Horseshoe Shale Member represents an offshore marine facies of the transgressing Amsden sea. (J. W. Pierce, oral commun., 1970). Horseshoe faunas become younger from western Wyoming eastward across the Wyoming shelf, supporting eastward transgression. Eastward encroachment of the Darwin sea reduced the transporting capacity of the streams draining eastern land areas so that clay and silt was deposited where sand had been deposited earlier. Periodic floods in the source areas increased the transportive power of the streams and brought minor amounts of sand into the area of deposition. Turbidity of the water may have effectively excluded a marine fauna except in rare places of unusual quiescence where fossiliferous carbonate sediment was deposited. The Horseshoe sea also included some areas of abnormal salinity where evaporite minerals were deposited and possibly some areas of stillstand where phosphatic pisolites formed.

Data are inadequate to prove the existence of a marginal belt of sand east of the area of the Horseshoe between this area and the shoreline. However, the marginal sand facies may be represented by Division VI of the Hartville Formation in southeastern Wyoming and by the "Bell Sand" at the base of the Minnelusa Formation in the Powder River Basin (see Agatston, 1954, and Tenney, 1966). Bates (1955) recognized this sand (as Fairbank Formation of Condra and others, 1940) between the Laramie Range of southeastern Wyoming and Black Hills of South Dakota. Moreover, such strandline deposits are commonly destroyed by subsequent erosion and redistribution. A part of the postulated sand belt may have been redistributed later and redeposited as a part of the Tensleep Sandstone.

Regional synthesis indicates that the fine terrigenous sediments of the Horseshoe were separated from open-sea carbonate deposits to the west by a barrier, perhaps a sporadically emergent ridge, during the early part of Horseshoe time. The regional pattern of the Horseshoe at this time is that of a large lagoon. During later Horseshoe time, the Horseshoe facies merged to the west into the Ranchester facies, also thought to have been deposited in a restricted arm of the Cordilleran sea.

MOFFAT TRAIL LIMESTONE MEMBER

Distribution.—The Moffat Trail Limestone Member is restricted to the mountain ranges of western Wyoming (fig. 7). The northern limit of the member is relatively well established. The isopach pattern suggests that the eastern feather edge of the member is near the western margin of the Green River basin. The member is not present in the Tip Top well near Labarge, which penetrated autochthonous Paleozoic rocks of the Green River basin beneath the Darby Thrust (Marzolf, 1965). The southern extent of the member is not known; the member is not present at Mount Darby in the Wyoming Range west of Big Piney. Information in southeasternmost Idaho and southwesternmost Wyoming is limited by the lack of Paleozoic outcrops or wells penetrating Paleozoic rocks.

Type section.—The type section of the Moffat Trail Limestone Member is on the ridge north of Moffat Trail in NE¼ sec. 3, T. 33 N., R. 117 W., Lincoln County. The area is shown on Rubey's (1958) geologic map of the Bedford quadrangle. The section can be reached by jeep road up Bear Creek to a point about a mile west of the Greys River road, where a logging road proceeds northwestward and up the northern fork of Cabin Creek to a point in NW¼ sec. 12, T. 33 N., R. 117 W. at an altitude of about 8,200 feet. From this point the section was attained by walking about 2 miles northwestward. The following section was measured and described by J. T. Dutro, Jr., and Mario Suarez in July 1966.

Moffat Trail Section

	Thickness (feet)
Tensleep Sandstone:	50+
Amsden Formation:	
Ranchester Limestone Member:	
16i. Sandstone; medium-grained; about 40–50 percent of thickness composed of light-gray to white chert in irregular knots and nodules, ½–2 in. across	3.0
16h. Sandstone; medium- to coarse-grained; crossbedded; dolomitic in upper ½ ft; one thin light-gray chert layer in upper foot	3.0
16g. Dolomite; finely crystalline; medium-gray, weathers light-gray; with scattered lenses of light-	

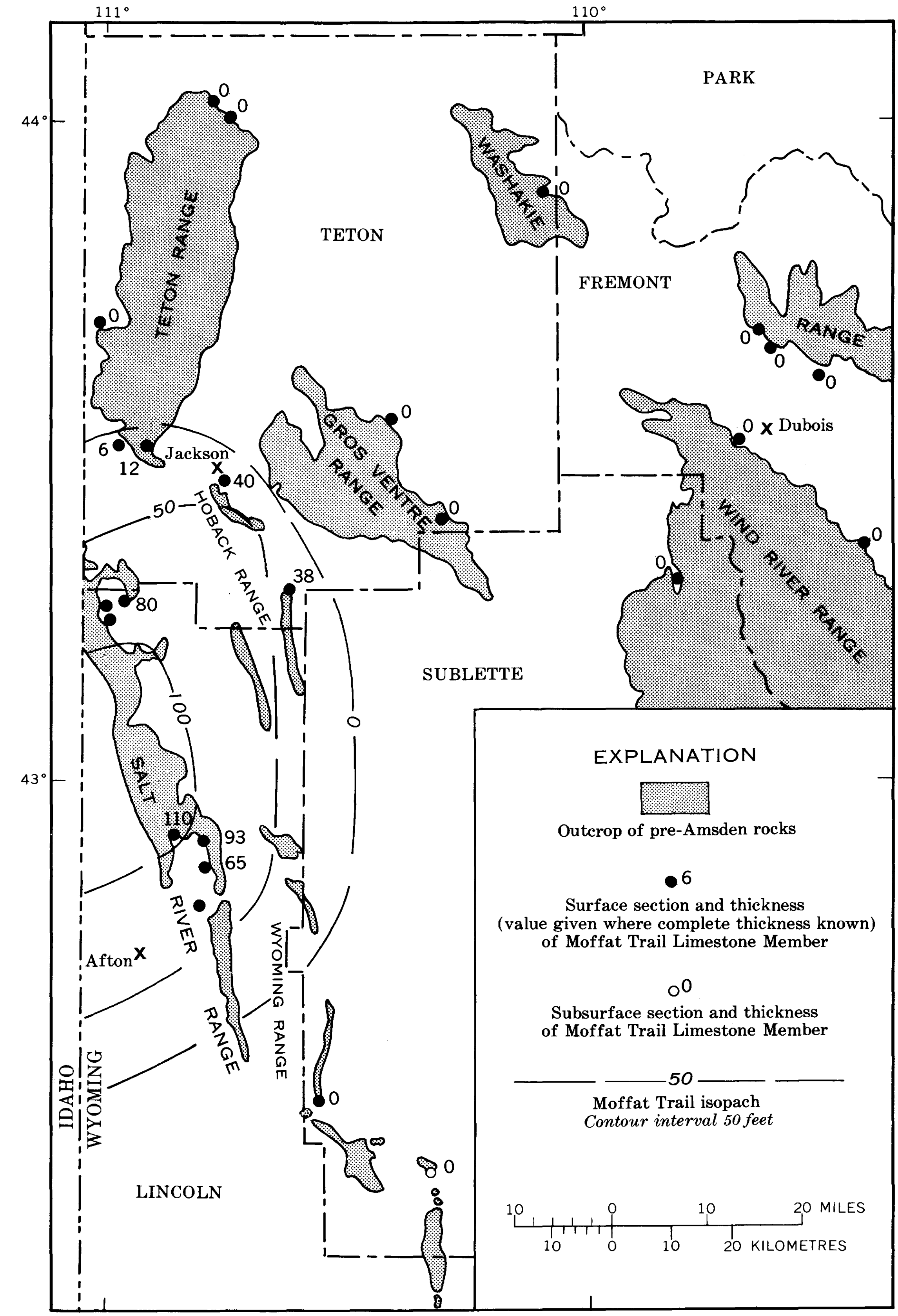

FIGURE 7.—Thickness and areal extent of the Moffat Trail Limestone Member of the Amsden Formation in Wyoming.

Thickness (feet)

Amsden Formation—Continued:

Ranchester Limestone Member—Continued:

gray chert and silicified shelly fossils near base; sandstone fillings of possible organic burrows on upper surface of unit 7.0

16f. Quartzite; fine-grained; light-gray to white, weathers light brown; laminated; beds 0.3–0.5 ft thick 10.0

16e. Covered interval 4.0

16d. Sandstone, dolomitic, and dolomite, sandy, like unit 16h 3.0

16c. Sandstone; fine- to medium-grained; crossbedded 8.0

16b. Sandstone, medium-grained, dolomitic, and dolomite, sandy; thin, light-gray chert layer about 5 ft above base 6.0

16a. Sandstone, dolomitic, and dolomite, sandy, like unit 16h; thin layer of silicified shell material and echinoderm debris, 8 ft above base (USGS 22991–PC) 18.0
(Units 16a-i measured in NE¼ sec. 34, T. 34 N., R. 117 W.)

15. Sandstone; medium-grained; pale yellowish-brown; weathers pale yellowish-brown to light brown; crossbedded in ⅛–¼-in. beds; beds 0.2–1 ft thick; forms small cliff; chert layer 0.5–1 ft thick at top of unit in a silicified pelletal limestone with scattered brachiopod valves (USGS 22990–PC; 6960C–PC) 16.0

14. Sandstone; medium-grained; grayish-orange-pink, weathers pale yellowish-brown; crossbedded and laminated layers about 1/16 in. thick; beds 0.3–1 ft thick; contains nodules and lenses of brownish-gray chert that weathers light gray to light brownish-gray; chert about 25 percent; fossiliferous (USGS 22989–PC about 5 ft above base) 21.0

13. Sandstone; medium- to coarse-grained; dolomitic, and dolomite, sandy; brownish-gray, weathers to light brown; laminated; thin-bedded (0.1–0.5 ft thick); no chert; forms saddle on ridge 12.0

12. Sandstone; as in unit 14; chert about 10–15 percent; lower 4 ft covered; fossils in upper 2-ft-chert bed (USGS 22988–PC) 22.0

11. Limestone, coarse bioclastic calcarenite; light olive-gray, weathers medium light-gray; nodular beds 0.1–0.3 ft thick; becomes sandy in upper few inches; fossiliferous (USGS 22984–PC) 3.0

10. Sandstone; fine-grained; pale-olive, weathers light olive-gray to light-brown; planar beds 0.1–0.3 ft thick; blocky fracturing; worm trails and markings on bedding surfaces (*Taonurus*-type); fish teeth in upper 0.5 ft with concentration on top surface (USGS 22983–PC) 6.0

9. Dolomite; medium to coarsely crystalline; pale yellowish-brown, weathers light brown to dark yellowish-orange; less than 5 percent light brownish-gray chert nodules that weather light gray; beds 0.5–1 ft thick 9.0

8. Sandstone, fine-grained; light brownish-gray, weathers pale yellowish-brown to light brown; worm trails and markings on bedding planes; planar beds 0.2–0.3 ft thick 3.5

Thickness Ranchester Limestone Member 154.5

Moffat Trail Limestone Member (new):

7. Limestone; medium to coarse bioclastic calcarenite; brownish-gray, weathers medium-gray; thin beds of pale-brown, silty dolomite that weather pale yellowish-brown; dolomite less than 10 percent of total thickness; limestone beds 1–3 ft thick; dark-gray chert nodules, 0.2–1.5 ft long, weather light brown, form less than 5 percent of total thickness; chert nodule zones about 5 ft above base and from 5 to 10 ft below top; fossiliferous, coral zone 32 to 36 ft above base (USGS 22985–PC), USGS 22986–PC at 40 ft above base, USGS 22987–PC at 47 ft above base, coral zone 60 ft above base (USGS 22981, 22982, 6960A and 6960B–PC), fossils at base of unit (USGS 6960–PC) 65.0

Thickness Moffat Trail Limestone Member 65.0

Horseshoe Shale Member:

6. Limestone, nodular, and red siltstone; siltstone weathers pink and makes up about 30 percent of thickness; limestone is fine grained, light brownish gray, weathers light gray; limestone intergrades laterally and verti-

	Thickness (feet)
Horseshoe Shale Member—Continued	
cally with the siltstone; basal bed is 3 ft thick, upper part nodular beds 0.1–0.3 ft thick with red siltstone and shale beds interbedded; grades upward into unit 7	18.0
Thickness Horseshoe Shale Member	18.0
Darwin Sandstone Member:	
5. Sandstone; quartzitic; fine-grained; moderate red-brown, weathers pale reddish-brown to grayish-red; beds 0.2–0.5 ft thick; dark-gray laminae	15.0
4. Sandstone and quartzite; medium-grained; pale yellowish-brown, weathers light brown to pale red; laminated in some beds; blocky fracturing; beds 0.2–1 ft thick	138.0
Thickness of Darwin Sandstone Member	153.0
Total thickness Amsden Formation	390.5
Mission Canyon Limestone:	
3. Sandstone and silty shale; sandstone is fine grained; pale reddish-brown, weathers moderate red-brown to brownish-gray; interval mostly covered by snowbank	30.0
2. Limestone and dolomite breccia; medium-dark-gray, fine-grained limestone and brownish-gray, finely crystalline dolomite fragments in medium-gray, tan-weathering, fine to medium crystalline dolomitic matrix; fragments 0.1–0.2 ft across make up about 50 percent of rock; dolomite is about 75 percent of fragments; beds 1–2 ft thick; forms low cliff	50.0
1. Dolomite breccia; fragments of finely crystalline, light olive-gray, tan-weathering dolomite in moderate reddish-brown, fine sandstone to siltstone matrix; angular to subangular fragments 1–30 mm in longest dimension; fragments form about 75 percent of unit; forms red-weathering slope	35.0
Partial thickness	115+

Thickness.—The Moffat Trail Limestone is as much as 110 feet thick (fig. 7). The known thickness distribution indicates that the member has the form of a lobate wedge that thickens toward the west.

Lithology.—The Moffat Trail Member is predominantly light gray, medium- to coarse-grained, fossiliferous limestone composed largely of comminuted organic debris, mostly crinoidal, in beds 0.3 to 5 feet thick. Brown, gray, or jasperoid chert nodules and lenses are common in the limestone. Thin intercalated beds of silty dolomite or dolomitic limestone that weather yellowish brown or buff occur sparsely in some sections. At some localities, the limestone contains considerable quantities of fine quartz sand, and some beds of fine-grained quartz sandstone and quartzite are present. At Hoback Canyon, the upper half of the member includes partings and beds of dark-grey, fissile clay shale. Ferruginous pisolites occur in the thin crinoidal limestone that represents the member at Glory Mountain.

The Moffat Trail Member contains a rich, normal benthonic marine, shelly invertebrate fauna. Most of the larger fossils are abraded, fragmented, and haphazardly oriented with respect to bedding planes.

Relation to adjacent units.—The Moffat Trail conformably overlies the Horseshoe Shale Member and is succeeded conformably by the Ranchester Limestone Member. Biostratigraphic evidence indicates that the Moffat Trail is equivalent to a part of the Horseshoe Shale Member of central Wyoming.

Lithic and faunal similarities to the cherty limestone member of the Monroe Canyon Limestone indicate that the Moffat Trail is a tongue of the miogeosynclinal Upper Mississippian carbonate sequence of southeast Idaho. The thickness pattern of the Moffat Trail also supports this interpretation. The transition zone between these two units is evidently buried under cover of Mesozoic rocks. The Monroe Canyon Limestone has been identified as far east as Wells Canyon in Caribou County, Ida.

Petrography.—Petrographic data (table 3) compiled by Sando were derived from 24 thin sections of fossiliferous limestone. These samples, which were collected for megafossils, were taken throughout the member and seem to be representative of the entire limestone sequence. No studies have been made of the sandstones and shales in the member.

The limestone samples from the Moffat Trail Member are composed predominantly of sand-size to gravel-size biogenic grains in micrite matrix. Disarticulated parts of echinoderm skeletons, predominantly crinoids, are the most abundant allochemical constituents. The echinoderm grains are generally poorly rounded and sorted. Foraminifer tests are probably second in abundance. Angular fragments of bryozoans, brachiopods, corals, and gastropods are common but generally not abundant. Ostracodes occur as whole shells or fragments. Stromatolitic algal structures were observed in two samples; in one sample the algal oncolites encrust gastropod shells. Original sparry calcite cement is rare, but many of the samples show partial sparry recrystallization of micrite matrix. Allochemical grains are well-rounded in the rare sparites.

TABLE 3.—*Petrographic classification of limestone samples from the Moffat Trail Limestone Member*

[Petrographic categories from Folk (1959, 1962). Localities are described in Register of Fossil Collections. (USGS 23003–PC is from the Glory Mountain section)]

Collection No.	Geographic area	Folk rock term	Biogenic grains (in decreasing order of abundance)
74	Salt River Range	Recrystallized packed biomicrite	Foraminifers, echinoderms, ostracodes, bryozoans.
75	do	Packed biomicrite	Echinoderms, foraminifers, gastropods, brachiopods, bryozoans.
77	do	Recrystallized sparse biomicrite	Foraminifers, bryozoans, echinoderms, gastropods.
78	do	Packed biomicrite	Echinoderms, foraminifers.
79	do	Recrystallized and dolomitized packed biomicrite.	Foraminifers and echinoderms.
88	do	Silty micrite.	
90	do	Recrystallized packed intrabiosparite.	Foraminifers, echinoderms, bryozoans.
91	do	Packed biomicrite	Echinoderms and bryozoans.
92	do	do	Echinoderms, bryozoans, brachiopods.
93	do	Recrystallized packed biomicrite	Foraminifers, echinoderms, bryozoans.
102	do	Fossiliferous micrite	Echinoderms, bryozoans, brachiopods.
103	do	Recrystallized packed biomicrite	Echinoderms, foraminifers, brachiopods.
104	do	do	Echinoderms, foraminifers, bryozoans.
109	Snake River Range	Packed biomicrite	Echinoderms, foraminifers, brachiopods.
120	Hoback range	Fossiliferous micrite	Echinoderms, bryozoans, brachiopods.
122	do	Packed biomicrite	Echinoderms, foraminifers, ostracodes, bryozoans, corals.
124	do	Sparse biomicrite	Echinoderms, ostracodes, bryozoans.
125	do	Algal fossiliferous pelmicrite	Ostracodes and gastropods.
126	do	Algal packed biomicrite	Ostracodes, foraminifers, bryozoans, echinoderms.
145	Teton Range	Sparse biomicrite	Echinoderms, foraminifers, ostracodes.
USGS 23003–PC	do	Pisolitic coarse intrabiosparite	Echinoderms and bryozoans.

Age.—Fossils collected from the Moffat Trail Limestone Member are of middle and late Chesterian age. The Moffat Trail faunules have been assigned to the *Caninia* Zone and to foraminiferal Zones 17 and 18.

Foraminifers show a diachroneity that indicates slight west-to-east transgression of the Moffat Trail sea (fig. 8). Near the thickest part of the limestone lobe, Foraminifera of Zone 17 occur nearly to the top of the member, whereas toward the margins of the lobe, the Foraminifera belong to Zone 18. These data are in harmony with the general picture of transgression of the Amsden sea.

Provenance and depositional environment.—Most of the rock mass (limestone) that makes up the Moffat Trail Member originated within the basin of deposition. The minor amounts of clay and quartz sand brought in from outside the area of deposition require detailed study before their provenance can be determined. The shale at Hoback Canyon may represent contributions of fine terrigenous detritus from a western source. The quartz sand found in some parts of the Salt River Range may represent periodic increases in the transportive capacity of streams draining into the area of deposition.

Poorly sorted and poorly rounded skeletal remains, derived in situ from benthonic organisms, are the most common components of the Moffat Trail rocks. Taxonomic associations suggest an environment of warm, relatively shallow, generally clear marine waters. The presence of algae in some of the samples indicates deposition within the euphotic zone. Intergranular lime mud suggests that currents and waves were not effective in winnowing out fine sediment. The lime mud may have been derived largely from disintegration of the fragile skeletons of algae, as in south Florida (Stockman and others, 1967). Destruction by organisms such as worms, as is common today in south Florida, may account for most of the fragmentation of invertebrate skeletons and may also have contributed to the production of lime mud.

Inferred environmental characteristics of the Moffat Trail are similar to those of the Horseshoe, differing principally in the autochthonous versus allochthonous source of detritus. The Moffat Trail Member was deposited in relatively clear water protected from fine terrigenous debris that spread westward from an eastern land area during Horseshoe time. A submarine barrier peripheral to the area of Moffat Trail deposition may have limited the dispersal of fine terrigenous sediment. The 6-foot interval of intrabiosparite containing ferruginous pisolites at Glory Mountain in the Teton Range may represent a facies that was deposited very near or on the postulated barrier. The high area may have been an important source of the lime mud and coarser organic debris swept into the deeper and quieter site of Moffat Trail deposition.

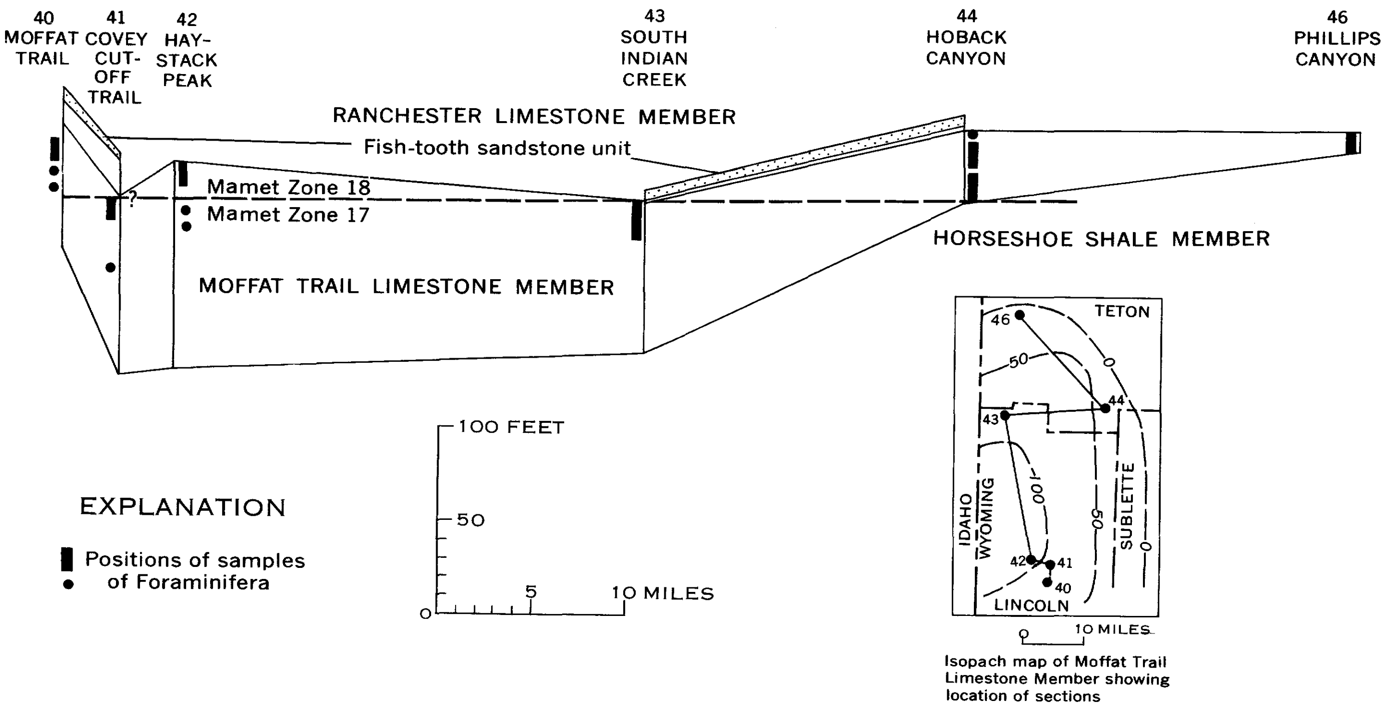

FIGURE 8.—Correlation of stratigraphic sections of Moffat Trail Limestone Member using Foraminifera. Inset shows locations of sections with respect to Moffat Trail isopach lines

RANCHESTER LIMESTONE MEMBER

Distribution.—The Ranchester Limestone, the most widespread member of the Amsden Formation, is present wherever the Amsden has been identified (Mallory, 1967, pl. 2C). The limits of the Ranchester Limestone Member are largely nomenclatural and do not reflect the limits of the basin in which the member was deposited. This is due to lateral continuity with parts of the rock sequences assigned to the Minnelusa, Hartville, Casper, Morgan, and Fountain Formations. Two areas in southeastern Wyoming, the northern part of the Front Range uplift and the Pathfinder uplift, were emergent during Ranchester time. North and northeast of Wyoming, equivalent strata extend an unknown distance into Montana and South Dakota. Equivalents of the Ranchester Limestone Member presumably extended westward into Idaho, but correlations with that area are not well-established and the problem is complicated by a disconformity between the Chesterfield Range Group and the overlying Wells Formation.

Type section.—The type section of the Ranchester Limestone Member is on Amsden Creek in SE¼ sec. 33, T. 57 N., R. 87 W., Sheridan County, Wyo. (Mallory, 1967, p. 8). The Amsden type section measured by Sando and Moore about one quarter mile east of Mallory's section serves as a reference section for the Ranchester (see page A10).

Thickness.—Disagreement on the exact position of the transitional contact with the overlying Tensleep Sandstone makes it difficult to prepare an isopach map for the Ranchester that is generally accepted. Thickness shown on Mallory's (1967, pl. 2C) map of the Ranchester differ in detail from those expressed on plates 5–10 of this report, but his map, based on more control points, better depicts thickness variations.

The Ranchester is as much as 250 feet thick and averages about 100 feet (Mallory, 1967, p. G14). The member thins to extinction around the Pathfinder uplift and northern margin of the Front Range uplift in southeastern Wyoming. An axis of thinning extends northwestward from Casper to the Montana line, and northwest trends of thickening are evident in the western part of the Bighorn Basin and the Wind River Basin. Our measurements of the member in western Wyoming, an area of poor control on Mallory's map, show thicknesses generally ranging from 100 to 200 feet .

Lithology.—The Ranchester Limestone Member is a heterogeneous sequence of interbedded cherty dolomite and limestone, sandstone, and shale. Carbonate rocks predominate; thin- to thick-bedded, fine-grained to coarsely crystalline, yellowish-gray-weathering dolomite and dolomitic limestone are generally much more abundant than thin-bedded, fine- to medium-grained, light-gray to purple-weathering limestone. The carbonate beds, particularly the dolomites, contain abundant gray, brown, or jasperoid chert in small nodules, irregular lenses, and irregular networks. Red and green shale in thin beds and partings are commonly interbedded with the carbonate rocks, particularly in the upper half, and may compose significant thicknesses of the member at some localities. Thin beds of fine- to medium-grained, white to pink quartz sandstone occur throughout the member but are most abundant in the upper half. Quartz sand is also a minor constituent of some of the carbonate beds. Anhydrite was reported by Biggs (1951, p. 26) as a minor constituent of dolomite beds at two localities in the Wind River Range. Agatston (1954, p. 520) noted minor amounts of gypsum and anhydrite in the subsurface of the Bighorn Basin, and Wilson (1962, p. 125) noted that anhydrite is commonly encountered in well sections in the Powder River Basin.

Shale and sandy carbonate rocks, largely in the upper part of the member, are concentrated in the northern part of the Bighorn Basin, at the north end of the Bighorn Mountains and at the north end of the Wind River Range (Mallory, 1967, pl. 2C). Concentrations of these terrigenous beds are also present along the margins of the Pathfinder uplift and Front Range uplift. Sandstone, sandy carbonate rock, and shale also make up significant proportions of the member in the Wyoming overthrust belt.

The Ranchester contains a sparse normal marine fauna that is dominated by brachiopods and mollusks. These fossils occur mostly in beds of limestone and dolomite, in which they are locally abundant. A marker sandstone bed near the base of the member in western Wyoming (pl. 9) contains abundant fish teeth.

Relation to adjacent units.—The Ranchester Limestone Member conformably overlies the Horseshoe Shale Member over most of central Wyoming and parts of western Wyoming. However, the member rests unconformably on the Madison Limestone at Little Bighorn Canyon at the north end of the Bighorn Mountains. In the Wyoming overthrust belt, the Ranchester lies conformably on the Moffat Trail Limestone Member. The Ranchester is succeeded conformably and transitionally by the Tensleep Sandstone throughout Wyoming.

Petrography.—Studies by Todd (1959, 1964) and Gorman (1962) are the only available sources of detailed petrographic data on the Ranchester Limestone Member.

The most common rock type in the Ranchester (Amsden Formation of Todd) of the Bighorn Basin area is disdolmicrite or microcrystalline dolomite that displays structures attributed to bioturbation (Todd, 1964, p. 1078). The dolomite may be a primary chemical precipitate from hypersaline water or a product of calcite replacement that took place on the sea floor (Todd, 1964, p. 1076). Coarsely crystalline dolspar, regarded as a replacement or pore-filling product, is also common in the Ranchester.

Sandstone from the Ranchester has a mineral composition similar to that of the Darwin Sandstone Member, differing chiefly in the presence of considerable dolomite and anhydrite cement and larger amounts of shale fragments and hematite or hematitic clay (Todd, 1964, p. 1078). The sandstone is very fine grained and moderately sorted. A typical shale sample from the Ranchester is 87 percent illitic clay, 10 percent sand and silt (largely plutonic quartz), and 3 percent pyrite. Clay from the Ranchester is entirely illite.

A quartz-deficient zone in the lower part of the Ranchester is succeeded by cyclic intervals of quartz-rich and quartz-poor rocks in 12 stratigraphic sections of the Amsden in western and central Wyoming (Gorman, 1962). Illite predominates to the near exclusion of kaolinite in the Ranchester, and chlorite, although less abundant than illite, is restricted to western Wyoming (Gorman, 1962).

Twelve thin sections of fossiliferous rocks from the Ranchester Limestone Member (table 4) examined by Sando in the present study are exclu-

TABLE 4.—*Petrographic classification of rock samples from the Ranchester Limestone Member*

[Petrographic categories from Folk (1959, 1962). Localities are described in Register of Fossil Collections]

Collection No.	Geographic area	Folk rock term	Biogenic grains (in decreasing order of abundance)
6	Rawlins hills	Silty packed biomicrite	Echinoderms and brachiopods.
15	---do	Packed biomicrite	Do.
50	Bighorn Mountains	Sparse dolbiomicrite	Echinoderms, foraminifers, mollusks.
64	---do	Silty packed biomicrite	Echinoderms, foraminifers, brachiopods.
65	---do	Recrystallized silty packed biomicrite.	Foraminifers, echinoderms, brachiopods.
82	Salt River Range	Sparse biomicrite	Echinoderms.
100	---do	Packed biomicrite	Echinoderms, foraminifers, ostracodes.
129	Hoback range	Recrystallized micrite.	
139	Gros Ventre Range	Silty sparse biomicrite	Echinoderms and brachiopods.
144	---do	Silicified packed biomicrite	Foraminifers, brachiopods, gastropods.
146	Teton Range	Sparse biomicrite	Echinoderms.

sively biomicrite. Because these thin sections were cut primarily for study of foraminifers, the samples are predominantly limestone, although one sample each of chert and dolomite is included. The limestone samples are petrographically similar to those studied from the Moffat Trail Member, but many of the Ranchester samples contain significant quantities of silt-size clastic quartz. Evidence of bioturbation is common.

Age.—The Ranchester Limestone Member contains late Chesterian to Atokan fossils. The late Chesterian fanules include some fossils assigned to the *Anthracospirifer welleri-shawi* Zone, some assigned to foraminiferal Zone 19, and some not assigned to any zone. Morrowan faunules include fossils assigned to the *Antiquatonia blackwelderi* Zone and to foraminiferal Zone 20. Atokan faunules are represented by fossils assigned to the *Mesolobus* Zone, foraminiferal Zone 21, and some not assigned to any zone.

The geographic distribution of fossils collected from the Ranchester Limestone Member is shown in figure 9. The Ranchester ranges in age from late Chesterian to Morrowan in the mountains of western Wyoming, but includes only strata of Morrowan to Atokan age elsewhere in Wyoming.

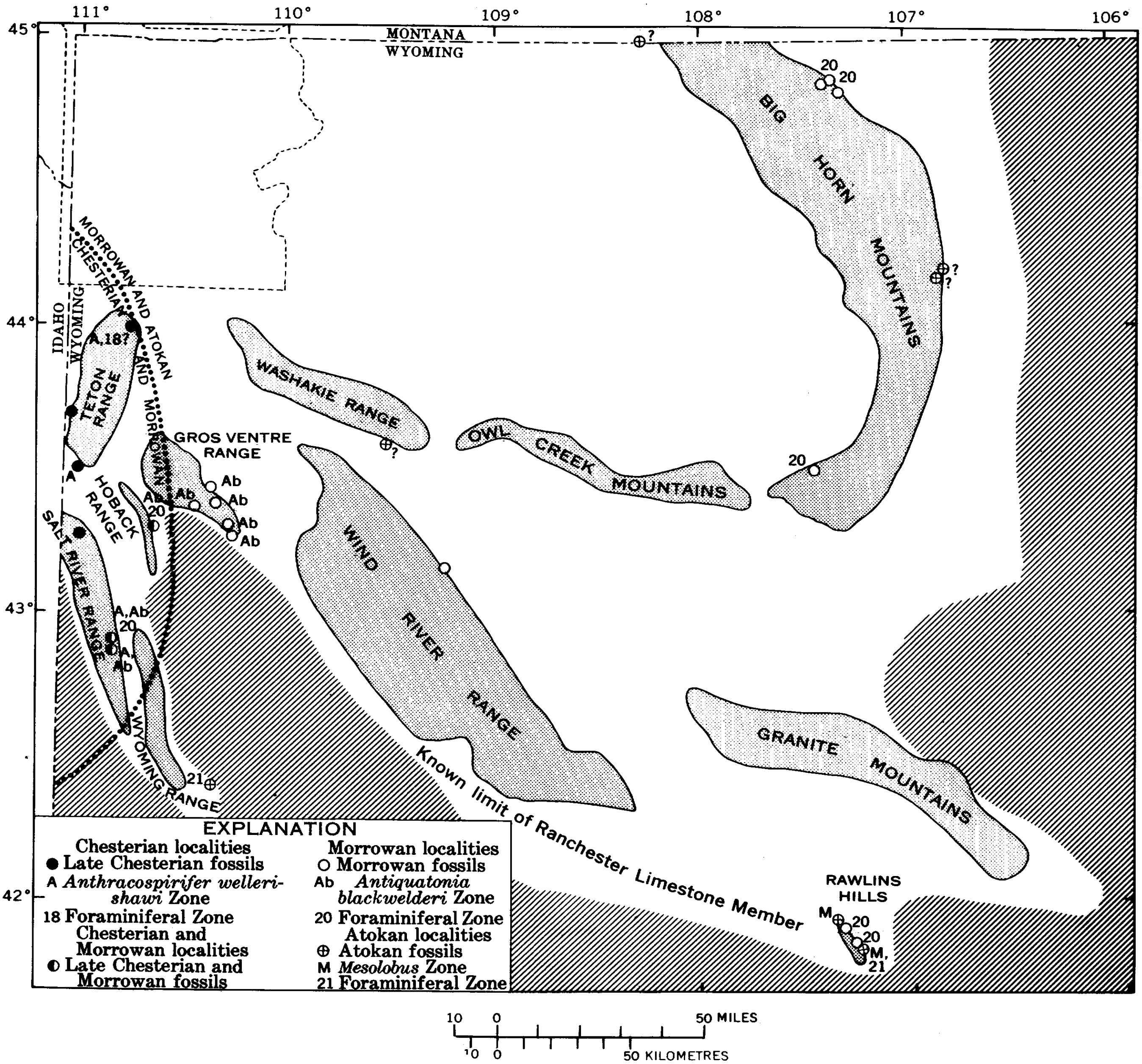

FIGURE 9.—Geographic distribution and ages of fossil localities in the Ranchester Limestone Member.

shoe Shale Member in the Rawlins hills in Carbon County (colln. 3).

A poorly preserved specimen of *Pentremites* from the Moffat Trail Limestone Member at Hoback Canyon (colln. 123) was mentioned by Wanless and others (1955, p. 33) and seems to be the only blastoid recorded from the Amsden.

Depositional environment.—The Ranchester Limestone is generally agreed to be a marine deposit that marks the culmination of Amsden transgression, which was followed by regressive deposits of the Tensleep Sandstone. A deepening of the sea during Ranchester time produced a neritic environment on a stable or mildly unstable shelf that received only fine terrigenous sediment from a distant source (Agatston, 1954, p. 562; Todd, 1964, p. 1089). Quartz-rich and quartz-deficient cycles may represent alternation of basinward and shoreword environments and migration of the strandline back and forth due to oscillation of sea level over an area of low regional slope (Gorman, 1962, p. 87–95). The shallow offshore facies may have been increasingly restricted by southward encroachment of the Tensleep sands, and a reef barrier may have separated northern and northeastern areas of evaporite deposition from a central area of relatively pure carbonate in central Wyoming (Wilson, 1962; p. 141).

Provenance.—Previously postulated sources for the sand and clay in the Ranchester Limestone Member are:

1. A land area in northeastern Wyoming and adjacent South Dakota (Black Hills high) (Agatston, 1954, fig. 17C; Wilson, 1962, fig. 9).
2. A land area in southeastern Wyoming (ancestral Front Range) (Agatston, 1954, fig. 17C; Wilson, 1962, fig. 9; Mallory, 1967, p. G15–G17).
3. The Bannock Highland in southeastern Idaho (Williams, 1962, fig. 2).
4. A sedimentary terrane northeast of Wyoming that was the main source for the Darwin Sandstone Member (Todd, 1964, p. 1082–1083).
5. The Pathfinder uplift in southeastern Wyoming (Mallory, 1967, p. G15).
6. An island source in the Wind River Range (Mallory, 1967, p. G17).
7. A source in southern Canada (Mallory, 1967, p. G17).

The carbonate rock that makes up most of the Ranchester was undoubtedly derived from within the basin of deposition. Shale and sandstone that are found in varying quantities throughout the member were probably derived largely from the same sources that supplied the Darwin Sandstone Member and Horseshoe Shale Member. Illitic clay may be the product of climatic changes in the predominantly eastern sources of the Horseshoe. Chlorite found in the Ranchester in western Wyoming suggests possible influence of a western source. Possible recycling of earlier deposited terrigenous rocks, particularly in the Big Snowy basin to the north, adds to the problem of determining the locations of major source areas. Further consideration of terrigenous sources is reserved for regional synthesis made later in this report.

Summary of origin.—The predominance of carbonate and occurrence of normal marine invertebrate fossils throughout the Ranchester support a shallow, warm-water, offshore marine origin, although some restricted areas are suggested by evaporite deposits. Cyclic terrigenous beds suggest a pulsating supply of detritus from sources outside the basin of deposition.

The greater age of the Ranchester in western Wyoming than in central Wyoming supports eastward transgression of the Amsden sea. Clay compositions (Gorman, 1962; Todd, 1964) suggest that an illitic facies that originated in the Horseshoe Shale Member of western Wyoming followed the pattern of eastward transgression of an offshore marine facies in the Ranchester Member.

BIOSTRATIGRAPHY

The Amsden Formation by most standards would not be considered very fossiliferous. A geologist can follow its outcrop for miles in some areas without seeing a fossil. In other areas, however, fossils are fairly common in some beds. Prior to the present work, approximately 50 species of invertebrates, most of which were figured, had been described from the Amsden of Wyoming. Nearly all came from the Horseshoe Shale Member in the Wind River Range. A similar number of additional species have appeared in faunal lists based on collections from scattered localities. Thus, only a few more than 100 species had previously been reported from this formation.

Our studies more than triple the number of fossils known from the Wyoming Amsden. More than 210 taxa of megafossils and more than 140 taxa of microfossils have been found in the formation. These include foraminifers, corals, hydrozoans, bryozoans, conulariids, brachiopods, pelecypods, gastropods, cephalopods, echinoids, trilobites, ostracodes, conodonts, fish and plant remains, and several minor groups. The distribution of these fossils, although uneven, has provided the key to interpreting the depositional history of the Amsden.

COMPOSITION OF THE FAUNA

The distribution of fossil specimens among invertebrate megafaunal groups is shown in table 5.

TABLE 5.—*Number of specimens of Amsden megafauna studied*

	Mississippian	Pennsylvanian	Total
Coelenterates	291	312	603
Conulariids	2	----	2
Bryozoans	133	23	156
Brachiopods	4,168	767	4,935
Mollusks	223	292	515
Echinoderms	28	5	33
Arthropods (trilobites)	19	15	34
Total	4,864	1,414	6,278

The three columns record the numbers of individuals occurring in the Mississippian part of the formation, in the Pennsylvanian part, and in the entire formation. The predominance of the brachiopods is marked.

Table 6 shows the number of taxa (named, unnamed, and unidentifiable species and subspecies) represented by these specimens. The mollusks are shown to be the most diverse in number of taxa, despite their relative paucity in individuals as compared to the brachiopods.

TABLE 6.—*Number of taxa in each major group present in the Amsden megafauna*

	Mississippian	Pennsylvanian	Total
Coelenterates	11	3	14
Conulariids	1	--	1
Bryozoans	15	5	20
Brachiopods	46	25	66
Mollusks	46	48	91
Echinoderms	2+	2+	4+
Arthropods (trilobites)	1	1	2
Total	122+	84+	198+

Table 7 presents a similar breakdown for the microfauna. As the number of individuals is not available for the microfauna, we have not included a table giving relative abundance.

TABLE 7.—*Number of taxa of each major group of animals in the Amsden microfauna*

	Mississippian	Pennsylvanian	Total
Foraminifers	56	62	[1] 77
Sponges (boring)	1	--	1
Annelids	2	--	2
Ostracodes	21	--	21
Conodonts	10	6	16
Totals	90	68	117

[1] As shown on faunal lists. According to Mamet (1975), the number actually exceeds 100.

In addition to invertebrates, a few fragmental fish and plant fossils have been recorded, representing perhaps about a dozen species in each group. Information regarding these and all the major groups of fossils are given on the following pages. The total fauna of the Amsden Formation as identified by the various specialists is shown in table 8. These include only the collections actually seen and studied.

All collections of fossils from the Amsden Formation in Wyoming known to the writers have been referred to a master-numbering system used throughout this report. Data on the geographic location and stratigraphic occurrence of these collections are recorded in the Register of Fossil Collections, p. A67. The geographic locations of these collections are also shown on plate 3; the stratigraphic positions of most collections are shown on columnar section diagrams (pls. 4–9).

Foraminifers.—Small foraminifers are widely but sporadically distributed through the Amsden Formation. Mamet (1975) recognizes more than 100 different taxa of Foraminifera in thin sections from 40 collections; about 70 taxa are particularly helpful in determining the foraminiferal zone represented by each assemblage. The various assemblages that Mamet has identified include those typical of his foraminiferal Zones 17 through 21, which extend approximately from middle Chesterian through early Atokan time. These, collated with the brachiopods and corals, permit an interregional correlation of the Amsden fauna.

In addition to the primitive fusulinids noted by Mamet in Zones 20 and 21, the literature also contains reference to the sporadic occurrence of *Fusulinella* in the upper beds of the formation. Love (1939, p. 28) reported the occurrence of two silicified specimens of *Fusulinella* in the section at Wiggins Fork, 10 feet below the top of the formation. One of these specimens, borrowed from the Peabody Museum of Yale University, consists of an axial thin section without matrix and thus seems to have been collected as a loose specimen. Sando's detailed measurement of the section at Wiggins Fork did not disclose a marine fusulinid-bearing bed in the upper part of the Amsden; so he suggests that this might be a float specimen from a bed in the lower part of the overlying Tensleep Sandstone, where *Fusulinella* is locally fairly common. Nevertheless, the presence of Zone 21 Foraminifera elsewhere in the upper part of the Amsden suggests that this formation may include the lower part of the range zone of *Fusulinella*.

Richards (1955, p. 27) has cited *Profusulinella* or *Fusulinella* as identified by Henbest from the Ranchester Limestone Member, 80 feet above the base of the Amsden at Devils Canyon, Carbon County, Mont. (colln. 70) just across the state line from Wyoming.

Coelenterates.—The coelenterates are the second most abundant group of megafossils in the Amsden, owing to the coralliferous Moffat Trail Limestone Member and the proliferation of rugose corals at several localities in the Horseshoe Shale Member. There are, however, relatively few taxa. Sando (1975) describes, figures, and discusses 11 taxa of corals and 3 taxa of hydrozoans.

Conulariids.—Two fragmentary specimens from a limestone bed in the Horseshoe Shale Member at Hoback Canyon, Teton County (collns. 117, 118), are identified as *Paraconularia* sp. indet. Each face is ornamented by adaperturally bowed growth ridges, which are interrupted and displaced along a longitudinal line at mid-face on some of the faces and also in all the visible interfacial corner furrows. This species is the only representative of this group so far known in the Amsden.

Bryozoans.—Among the less abundant elements of the Amsden faunas, the bryozoans are represented by approximately 20 species. They are present in 20 collections, all but two of them from the western region of Amsden outcrop. Bryozoans are, for the most part, not very well preserved and have not been studied in detail. Preliminary identifications are given in the chart that lists the Amsden faunas in their entirety (table 8).

Approximately 10 species were found in the Moffat Trail Member, including two new chaetetiform genera previously recognized by Helen Duncan in *Caninia* Zone collections from other western mountain ranges. One of these is figured by Sando (1975) to point out differences that distinguish the bryozoans from true *Chaetetes*, which occurs also in this assemblage.

The Horseshoe Shale Member in the Wind River Range also contains bryozoans. Five forms were noted in a University of Missouri collection from the Little Popo Agie River. Tiny rhomboporoids are by far the most common, but thin stenoporoid colonies are fairly common incrusting some of the brachiopods, particularly *Composita.*

A specimen of the screw-shaped bryozoan *Archimedes* was found in the Mississippian part of the Ranchester Limestone Member in the Salt River Range (colln. 97).

In the Pennsylvanian part of the Ranchester, a few bryozoans occur in the *Antiquatonia blackwelderi* assemblage, but these are limited to stenoporoids and other trepostomatous bryozoans, most of them ramose forms.

An unidentifiable fenestrate bryozoan was discovered in a brachiopod- and mollusk-bearing sandstone on the east slope of the Bighorn Mountains. This is the only bryozoan specimen in our collections from the eastern region of Amsden outcrop.

Brachiopods.—Brachiopods are the most abundant and widespread megafaunal element in the Amsden Formation. Our collections contain almost four times as many individuals as the rest of the megafauna combined. Gordon (1975) describes, figures, and discusses 66 taxa of brachiopods, including 7 subspecies. The scheme of local zonation adopted for this region is based primarily on the distribution of these fossils and some of the corals.

Mollusks.—Although the mollusks constitute less than one-tenth of the total Amsden fauna in number of individuals, they represent the most varied phylum in number of species. Ninety-one taxa have been recognized but owing to the rather poor preservation of much of the material, very few could be assigned to previously described species. Accordingly, an open nomenclature has been employed for many of them.

The pelecypods and rostroconchians have been studied by Gordon and Pojeto (1975) who have described, illustrated, and discussed them. Similarly, Gordon and Yochelson (1975) have treated the gastropods and cephalopods. Faunal diversity of the pelecypods and gastropods is marked. Although most of the genera have long ranges through much of the Carboniferous and Permian, with only three exceptions different species occur in the Mississippian and Pennsylvanian parts of the formation.

Echinoderms.—Three classes of echinoderms are represented in the Amsden Formation: Echinoidea, Blastoidea, and Crinoidea. Two genera are identifiable, but the indifferent preservation precludes recognition of any species.

Branson (1937, pl. 89, fig. 5) figured an interambulacral echinoid plate as *Archeocidaris* sp. Twenty more plates that show the same nodose pattern around the marginal areas are in the University of Missouri collection (UM no. A433). They are associated with seven broken, longitudinally striate spines that presumably are from the same animal. Branson (1937, pl. 89, fig. 4) also illustrated a clavate spine with pointed nodes that may be the tip of one of the spines of this echinoid. The UM material is from the Horseshoe Shale Member in the Little Popo Agie River valley (colln. 36d).

Another species of *Archeocidaris*, represented by interambulacral plates without nodose marginal areas associated with long striate spines that bear a few scattered barbs, occurs in the Morrowan part of the Ranchester at a locality in Sublette County (colln. 133). The basal end of a spine is present also in a collection of Morrowan age from the Horse-

No crinoid calices have been found in the Amsden. Pelmatozoan debris is locally abundant in the Moffat Trail Limestone Member, and most of this material is believed to have been derived from crinoids. In the Mississippian part of the Horseshoe Shale Member the only crinoidal remains known are from limestone layers at Berry Creek in the Teton Range. These limestone layers belong in foraminiferal Zone 19. Scattered crinoidal debris is present in this member in limestone beds of Pennsylvanian (Morrowan) age in the Rawlins hills. More recognizable crinoid remains are found in some carbonate beds of Morrowan age in the Ranchester Limestone Member in western Wyoming. These include crinoid columnals as much as 1 cm in diameter (colln. 131) and spines (colln. 133).

Arthropods.—Two species of the trilobite genus *Paladin* are recognized in our collections from the Amsden Formation, one in the Mississippian part and the other in the Pennsylvanian part. These are described by Gordon and Yochelson (1975). Wanless and others (1955, p. 33) also reported some trilobite pygidia from Hoback Canyon (colln. 123) that were identified by Marvin Weller as belonging to *Kaskia chesterensis* Weller and Weller. We have not seen these specimens.

Morey (1935) described 17 species of ostracodes from the Amsden Formation and referred them to 12 genera. These came from the Horseshoe Shale Member at two localities in the Wind River Range, Fremont County, all of them probably from beds now referred to the *Anthracospirifer welleri-shawi* Zone, *Carlinia amsdeniana* Subzone.

Sohn (1975) has restudied Morey's material and his report gives his results, including some new generic assignments. Sohn's report also describes six additional ostracode species from the Horseshoe Shale Member at a locality in the Hoback range. These beds lie beneath the Moffat Trail Limestone Member at that locality and are considered to be slightly older than the ostracode-bearing beds in the Wind River Range.

Conodonts.—The collecting of conodonts from the Amsden Formation of Wyoming has been merely incidental to the collecting of other fossils. Conodonts have been found in only two of the four members. Our list of approximately 15 species from this formation is, therefore, not exhaustive. The conodont evidence confirms the age determinations derived from our studies of the foraminifers and brachiopods.

Matrix from seven collections of *Caninia* Zone corals and brachiopods from the Moffat Trail Limestone Member in Lincoln and Teton Counties (collns. 74, 79, 88, 90, 91, 109, 126) provided the following conodonts, identified by J. W. Huddle of the U.S. Geological Survey:

Hindeodella sp.
Neoprioniodus sp.
Hibbardella sp.
Magnilaterella? sp.
Spathognathodus cf. *S. cristula* Youngquist and Miller
Bar fragments, indet.
Cavusgnathus unicornis Miller and Youngquist sp.

These indicate Chesterian age, according to Huddle (written commun., 1968). They are associated at six of the localities with Foraminifera of Zones 17 or 18.

A single collection of invertebrates of the *Anthracospirifer welleri-shawi* Zone from the Mississippian part of the Ranchester Limestone Member in the Moffat Trail section (colln. 82), Lincoln County, yielded the following, according to Huddle (written commun., 1968).

Ozarkodina sp.
Gnathodus modocensis Rexroad?

Typical Morrowan conodonts have been found in beds of Pennsylvanian age in the Ranchester Limestone Member at two localities (J. W. Huddle, 1967, written commun.). A mollusk-bearing marlstone on the west side of the Bighorn Mountains (colln. 50) has provided two conodont species, associated with Foraminifera of Zone 20, or higher.

Adetognathodus cf. *A. gigantea* Rexroad and Burton
Streptognathodus sp.

Also, in the type area of the Amsden Formation at Amsden Creek on the east flank of the Bighorns in Sheridan County (collns. 63, 68), the following conodonts were found in association with Zone 20 Foraminifera:

Cavusgnathus sp.
Idiognathoides corrugata Harris and Hollingsworth
sinuata Harris and Hollingsworth
Streptognathodus parvus Dunn

Miscellaneous invertebrates.—A single annulate conical shell, about 5 mm long, cemented to the lectotype of *Reticulariina browni* (Branson and Greger), was identified as *Cornulitella* cf. *C. blachleyi* (Cumings and Beede) [originally described as *Ortonia*] by Branson and Greger (1918, p. 321, pl. 18, fig. 15). This specimen can be seen in the enlarged figure of the brachiopod in Gordon (1975, pl. 13, fig. 42). It may have housed a small annelid worm.

Tiny coiled tests, presumably of an annelid worm, were named *Spirorbis moreyi* C. Branson (1937, p. 654, pl. 89, figs. 1, 2). Most of Branson's specimens were found loose, but two were cemented to fragments of shell.

Some tiny burrows in brachiopod shells, mostly in those now referred to *Carlinia amsdeniana* Gordon, were named *Clionolithes pricei* C. Branson (1937, p. 654, pl. 89, fig. 3). Branson regarded them as made by boring sponges, which entered the shell through broken spine bases. These three tiny fossils are from the *Anthracospirifer welleri-shawi* Zone, *Carlinia amsdeniana* Subzone in the middle part of the Horseshoe Shale Member in the drainage basin of the Little Popo Agie River, Wind River Range, Fremont County.

Fish.—Fossil fish remains in the Amsden of Wyoming are confined to Lincoln and Teton Counties, where they occur in the Moffat Trail and Ranchester Limestone Members in beds of Late Mississippian age. D. H. Dunkle (written commun., 1968) has identified fish in ten of our collections. From the Moffat Trail (collns. 102, 109, 122, 126) he referred specimens to "*Cladodus*," *Pristicladodus, Lambdodus, Thrinacodus, Stemmatodus, Deltodus, Psephodus*, and mentioned indeterminate cochliodont tooth fragments and paleoniscoid fish scales of two types. From the Ranchester (collns. 81, 82, 110, 127, 128, 146), most of them from a fish-tooth-bearing sandstone a few feet below the top of the Mississippian, he recognized "*Cladodus*," *Deltodus, Deltodus*?, *Psephodus*, cochliodont tooth fragments, *Psammodus*, and indeterminate paleoniscoid fish teeth. The genera cited are, according to Dunkle, for the most part "form genera" whose variations and relationships are poorly understood. As a consequence, one cannot say how many different species of fish are represented by these fossils. Nevertheless, they seem to have been an important element of the biota in the most typically marine part of the Amsden depositional basin.

Plants.—Marine algae occur sparingly throughout the Amsden and have been recognized in the microfaunal slides studied by Mamet. They are listed along with the foraminifers by Mamet (1975). In western Wyoming *Stacheia* sp. and *Stacheioides* sp. are present in the Moffat Trail Member in Lincoln County (collns. 90, 104). The same two genera were recognized by Betty Skipp in the Tip Top well in Sublette County (colln. 71) near the top of the Amsden.

The rest of the algae are from the eastern region of Amsden outcrop. *Asphaltina* sp., *Girvanella* sp., and a form identified as a Rodophycophyta were identified from the Pennsylvanian part of the Horseshoe Shale Member in Carbon County (collns. 1–5), and a member of the subfamily Stacheiinae from the Ranchester Member in Sheridan County (collns. 63, 68).

Land plants in our Amsden collections are from western Wyoming. They were collected from a 41-foot siltstone unit with intercalated sandstone layers in the Horseshoe Shale Member at Hoback Canyon, beneath the Moffat Trail Limestone Member (collns. 111–113, 115). The following species were identified by Sergius H. Mamay of the U.S. Geological Survey:

- *Mesocalamites* sp.
- *Rhodea* cf. *R. moravica* (Ettinghausen) Stur? sp.
- *Adiantites*? sp.
- *Sphenopteris* cf. *S. mississippiana* White
- *Lepidodendron* sp.
- Stigmarian rootlets

These species are similar to those in the Wedington Sandstone Member of the Fayetteville Shale of Arkansas, the Stanley Shale of Arkansas, and the Poti Formation of Brazil, all of Late Mississippian age (S. H. Mamay, written commun., 1955). The North American floras referred to are included in their floral zone 3 by Read and Mamay (1964, p. K6), who further state that the Wedington flora might constitute a late subzone of that zone. Mamay (oral commun., 1972) confirms the assignment but warns that the fragmental condition of the Wyoming plants renders the zonal assignment a probability rather than a certainty.

Unidentified plant remains have been reported in the Horseshoe Shale Member at Powder River Canyon near the south end of the Bighorn Mountains (Wilson, 1962, p. 126). As no fossils of Mississippian age have been found in the Amsden Formation in the Bighorn Mountains, these plants are probably somewhat younger than those from Hoback Canyon.

FAUNAL ZONES

Several faunal assemblages, principally of corals and brachiopods, occupy zones that are limited both stratigraphically and geographically. In addition to these, foraminiferal assemblages in the limestone beds of the Amsden Formation are distributed in a zonal sequence shown by Mamet and his associates (Mamet, 1968; Sando and others, 1969; Armstrong, and others, 1970; Mamet and Skipp, 1970b; Mamet and others, 1971) to be of considerable use in interregional correlation. By combining the evidence derived from both zonation schemes we have been able to deduce a great deal about the depositional history of the Amsden basin. In the discussion that follows we will consider first the coral-brachiopod zones and their distribution, and then the foraminiferal zones and their relationship to the coral-brachiopod zones (fig. 10).

CANINIA ZONE

This zone was proposed by Parks (1951, p. 183, text-fig. 2) as the highest of five Mississippian coral zones in the section at Dry Lake, Cache County, Utah, where it is 635 feet thick. Subsequent investigations by Dutro and Sando (1963a, b), Mamet and others (1971), and Sando (1975) in the Rocky Mountain region and by Gordon and Duncan (1970) in the Great Basin region have shown that the coralliferous facies extends from the Big Snowy Mountains of central Montana to the Wasatch, Oquirrh, and Confusion Ranges of Utah. The approximate geographic limits of this facies are shown in figure 11. This zone has also been referred to as Zone K by Dutro and Sando (1963b, p. 1974), Sando (1967b), and Sando and others (1969).

The coralline facies tongues into the western part of the Amsden Formation in Wyoming, but lies within the Montana Province of Sando (1967b, p. D33); it coincides with the Moffat Trail Limestone Member. Characteristic of this zone are several species of corals of the genera *Caninia, Zaphrentites?, Londaleia (Actinocyathus), Pleurosiphonella, Multithecopora?, Duncanopora,* and the hydrozoan Chaetetes. Also present are two undescribed chaetetiform bryozoan genera, some specimens of which are fastened to and envelop shells of a bellerophontid snail (colln. 105) in a manner similar to the specimens described from the Green Ravine Formation of Utah by Gordon and Duncan (1970, p. A41).

Among the brachiopods, one ubiquitous though

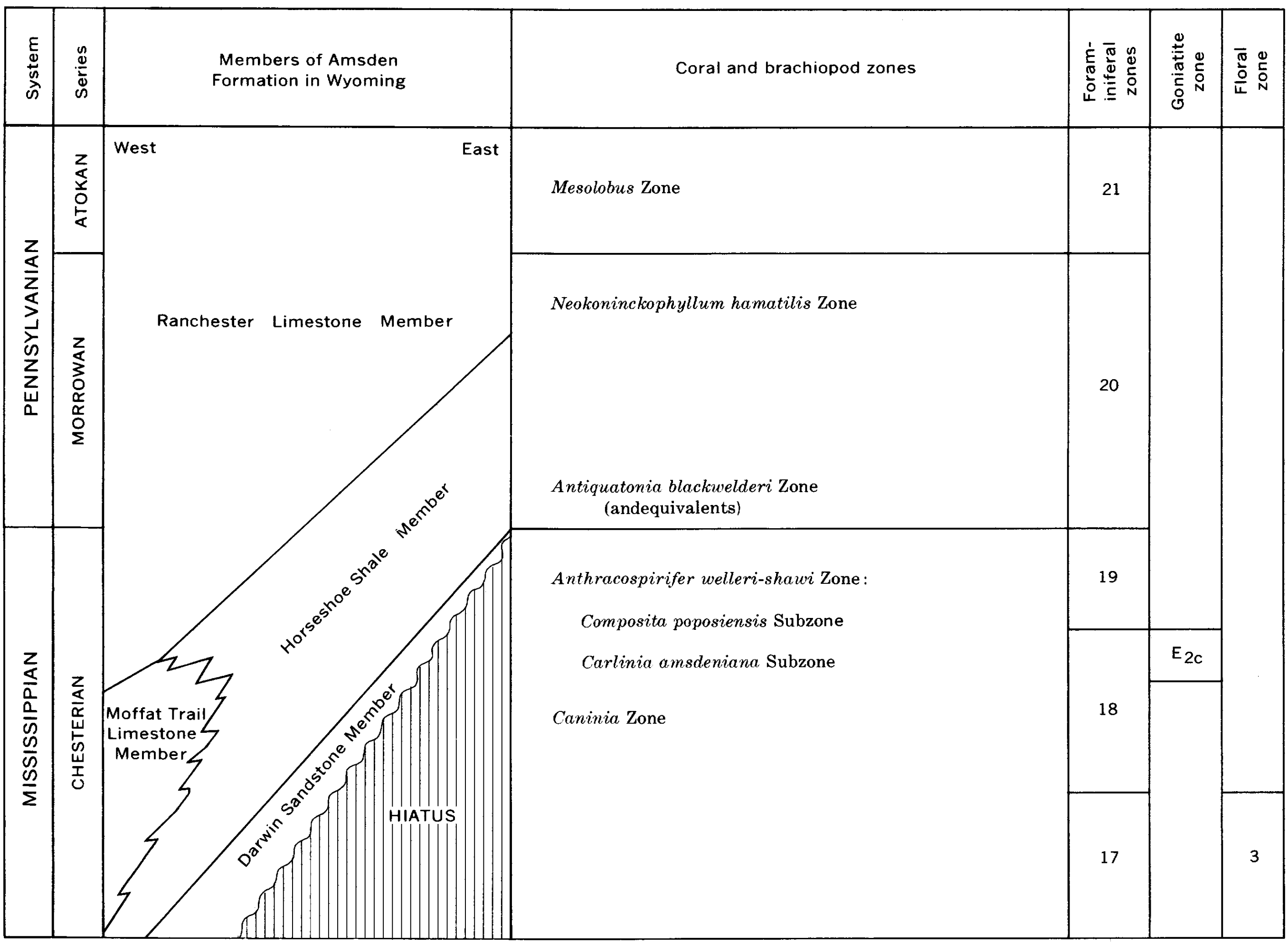

FIGURE 10.—Distribution of faunal and floral zones in the Amsden Formation of Wyoming.

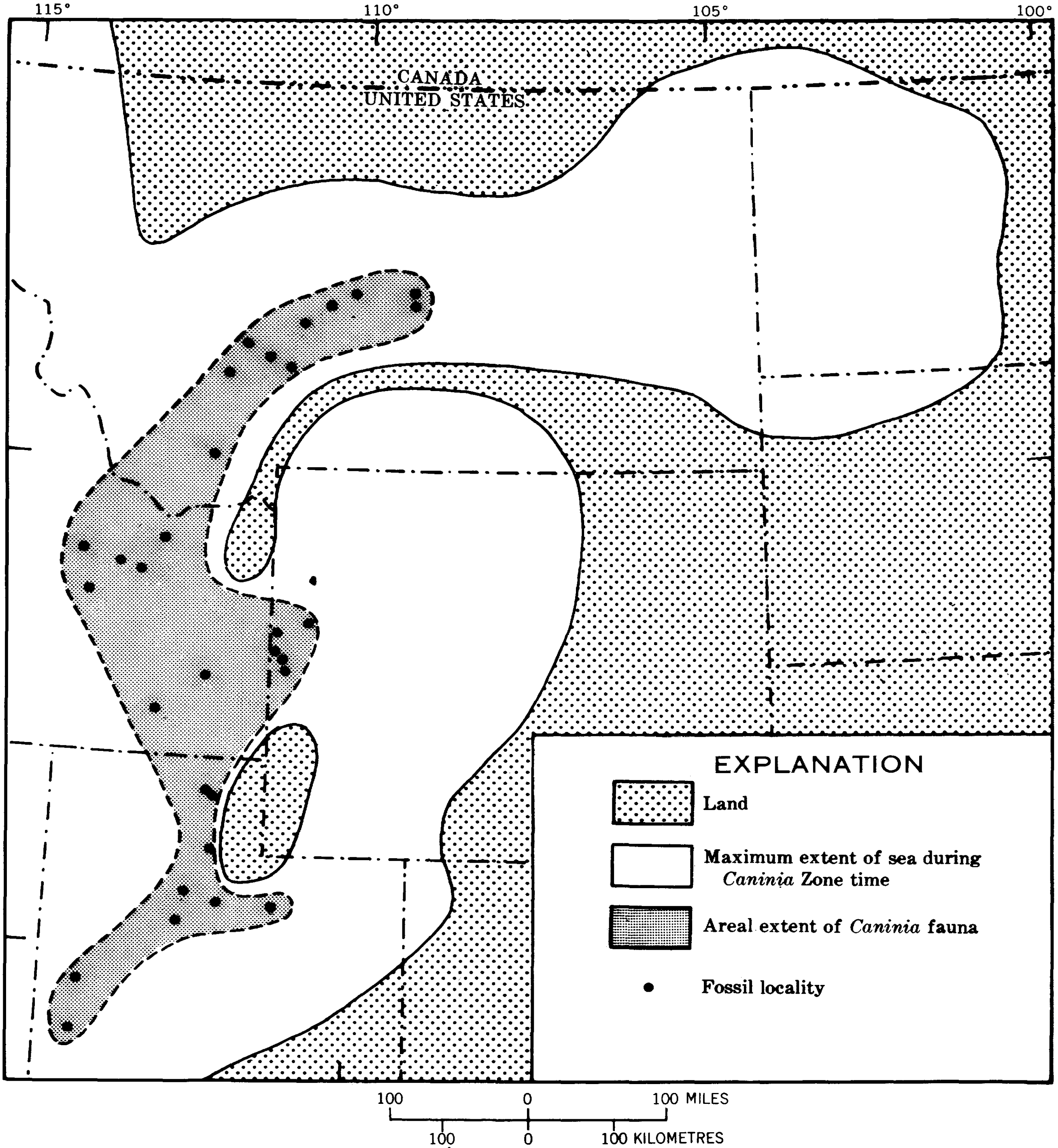

FIGURE 11.—Distribution of *Caninia* Zone fauna.

not necessarily common form in this assemblage is *Anthracospirifer curvilateralis brutus* Gordon, n. subsp. Locally, within this facies *Diaphragmus cestriensis* (Worthen), *Ovatia muralis* Gordon, n. sp., *Coledium fragum* Gordon, n. sp., *Composita subquadrata* (Hall), *Anthracospirifer curvilateralis curvilateralis* (Easton), are found. Also present are numerous Foraminifera (of Zones 17 and 18), crinoidal remains, and some fish teeth.

The thickest section of the *Caninia* Zone in Wyoming is at Haystack Peak in Lincoln County, where it is 110 feet thick. The coralliferous beds wedge out northward and eastward.

The *Caninia* Zone was developed in shallow shoalwater of an open sea. The fossils in the assemblage and the containing matrix indicate that the water was of normal salinity and relatively free from terrigenous sediment. Evidence from the Hoback Canyon section, where this facies overlies a 41-foot siltstone containing macerated plant fragments, indicates that the coralline facies may have formed a barrier that trapped fine clastic material of terrigenous origin on the landward side.

ANTHRACOSPIRIFER WELLERI-SHAWI ZONE

Between the *Caninia* Zone and the top of the Mississippian, the Amsden fauna is dominated by spirifers of the *Anthracospirifer welleri-shawi* group. The type locality for this zone is the section at Cherry Creek in the Wind River Range. Shaw (1955a, p. 60) recognized a *Spirifer welleri* fauna and a higher *Spirifer "opimus"* fauna in this area. The taxon identified by Burk (1954, p. 11) as *Spirifer opimus* Hall is here regarded as distinct; it is redescribed as *Anthracospirifer shawi exoletus* Gordon, n. subsp. (Gordon, 1975). This subspecies is an advanced form of *A. shawi* Gordon n. sp. Typical *A. shawi shawi* occurs with *A. welleri welleri* (Branson and Greger) in the lowest fossiliferous beds of the Horseshoe Shale Member in the Wind River Range; the typical forms of both species are restricted to these beds.

In western Wyoming a more complex and therefore presumably more advanced form of *A. welleri*, named *A. welleri lincolnensis* Gordon, n. subsp. (Gordon, 1975), is present in the uppermost Mississippian beds. In Lincoln County this species is found in the lower beds of the Ranchester Limestone Member that overlie the Moffat Trail Limestone Member.

The youngest part of the *Anthracospirifer welleri-shawi* Zone is present at Berry Creek in Teton County. Here, abundant *A. welleri lincolnensis* and scarce *A. shawi exoletus* occur in thin limestone layers interbedded with reddish-gray shale containing numerous *A.* aff. *A. occiduus* (Sadlick) form A, together with *Orthotetes kaskaskiensis bransonorum* Gordon, n. subsp., and *Eolissochonetes pseudoliratus* (Easton). What seems to be a mixture of very late Mississippian and very early Pennsylvanian brachiopods is associated with foraminifers of very late Mississippian age (Zone 19).

Only one coral, *Barytichisma amsdenense* (Branson and Greger), is common in this zone, and it is restricted to Fremont County. Besides the spirifers, the brachiopods *Schuchertella poposiensis* (C. Branson), *Orthotetes kaskaskiensis bransonorum* Gordon, n. subsp., *Inflatia lovei* Gordon, n. sp., *Ovatia croneisi* (C. Branson), *Composita sigma* Gordon, n. sp., and *Reticulariina browni* (Branson and Greger) are typical of this zone and may range through much of it. A relatively large molluscan fauna is present in the lower part of this zone in the Wind River Range and includes the pelecypod genera *Nuculopsis, Paleyoldia, Septimyalina, Aviculopecten, Schizodus, Cypricardella, Sphenotus,* and *Wilkingia* and the gastropods *Bellerophon, Euphemites, Knightites,* n. gen. aff. *Colpites, Gosseletina, Dictyotomaria, Strophostylus, Paleostylus (Pseudozygopleura), Ianthinopsis, Girtyspira,* and *Donaldina.*

Among the microfossils, ostracodes are fairly common, and conodonts are scarce. No foraminifers have been reported in the Wind River Range, but several foraminiferal collections (Zones 18 and 19) have come from limestone beds in Lincoln and Teton Counties and the northwestern part of Fremont County.

The fauna of this zone is restricted to relatively scattered sandstone beds and limestone layers in the red siltstone and shale of the Horseshoe Shale Member; fossils are not known in the siltstone and shale beds. In Fremont County, therefore, this fauna seems to have developed in a generally turbid-water environment during relatively brief lulls in the deposition of fine terrigenous sediments. The considerable variety of the fauna, however, indicates that, except for the excessive amount of fine terrigenous sediment, the waters were typically marine. In Lincoln County, where this zone is present in the Ranchester the conditions were somewhat different. The water was much less turbid, as is indicated by the greater abundance of carbonate rocks; but as the fauna is much more limited in number of species and many of the carbonte beds are dolomite, a less favorable chemical environment of the seawater is indicated.

The total thickness of this zone is not precisely known, as it probably is not fully developed in any one section. The aggregate thickness at the type locality, based on published sections, is 45 feet. At Covey Cutoff, *Anthracospirifer welleri lincolnensis* occurs in the Ranchester Limestone Member 50 feet above the top of the Moffat Trail Limestone Member. At Berry Creek the fossiliferous beds referred to this zone are 24 feet thick, but the presence in the Ranchester in the nearby section at Elk Ridge of *Composita sigma* and *Anthracospirifer shawi exoletus* indicates that this zone may exceed 40 feet in this area, with its lower part not represented The early forms present in this zone in the central region of Amsden outcrop have not been found in western Wyoming. In Fremont County the *A. welleri-shawi* Zone is divided into two subzones.

CARLINIA AMSDENIANA SUBZONE

The fossils included by Shaw (1955a) in the *Spirifer welleri* fauna are referred to this subzone. It has been recognized in Fremont County at localities in the Wind River and Washakie Ranges and in Teton County in the Gros Ventre Range at Darwin Peak, Particularly characteristic of this zone and restricted to it in Fremont County are the brachiopods *Orthotetina amsdenensis* (Branson and Greger), *Schuchertella poposiensis* (C. Branson), *Carlinia amsdeniana* Gordon, *Inflatia lovei* Gordon, n. sp., *Cleiothyridina hirsuta darwinensis* Gordon, n. subsp. *Composita sigma* Gordon, n. sp., *Anthracospirifer welleri welleri* (Branson and Greger), *A. shawi shawi* Gordon, n. subsp. and *Reticulariina browni* (Branson and Greger), the pelecypod *Paleyoldia amsdenensis* (Branson and Greger) and various other small mollusks. Outside of Fremont County, however, *Schuchertella poposiensis, Inflatia lovei, Composita sigma,* and *Reticulariina browni* range higher locally.

Beds containing fossils of this subzone were found in trenches dug across the Horseshoe Shale Member at Cherry Creek by W. G. Bell (Shaw and Bell, 1955). Collections in the University of Wyoming made from the sandstone beds 45–48 feet above the base of the member by Bell (collns. 28–31) were first identified by Shaw (in Shaw and Bell, 1955 and Shaw, 1955a) and have been restudied. Most of the fossils from this subzone in the University of Missouri collection were found loose on the surface. They are calcareous and covered by a limonitic coating, which seems to be secondary, probably due to weathering. Those collected in place in the sandstone are not coated.

The thickness of this subzone at Cherry Creek is 3 feet; at Livingstone Ranch in the Washakie Range it is 3½ feet thick. No greater thicknesses of the *Carlinia amsdeniana* Subzone are known.

COMPOSITA POPOSIENSIS SUBZONE

This subzone includes the higher of the two faunas in the Wind River Range, which is the *Spirifer "opimus"* fauna of Shaw (1955a). Except for an occurrence at Devils Canyon, Carbon County, Mont., tentatively referred here, this subzone is restricted to Fremont County, Wyo. (fig. 6). At all known localities in this county the brachiopods of the *Composita poposiensis* Subzone are rather coarsely silicified, although some of them have very thin calcareous surficial layers, most of which have been dissolved away. This silification is in contrast to the calcareous preservation of specimens in the underlying *Carlinia amsdeniana* Subzone.

Species particularly characteristic and common in this subzone include the coral *Barytichisma amsdenense* (Branson and Greger) and the brachiopods *Pugnoides quinqueplecis* Easton, *Composita poposiensis* Gordon, n. sp., *C. sulcata* Weller, and *Anthracospirifer shawi exoletus* Gordon, n. subsp. *C. poposiensis* and *A. shawi exoletus* are the dominant fossils in the assemblage but they are not restricted to this subzone. One specimen of *C. poposiensis* has been collected in place in the *Carlinia amsdeniana* Subzone (colln. 31) and two calcareous specimens of *A. shawi exoletus* seem to have come from the same subzone (colln. F). This underscores the fact that these are assemblage zones and subzones and not range zones.

Pugnoides quinqueplecis is restricted, in the Amsden of Wyoming, to this subzone. In central Montana, however, this species ranges somewhat higher stratigraphically. The collection from Devils Canyon, Montana (colln. 69) is included here because of the presence in it of *P. quinqueplecis.* It occurs in this collection with *Eumetria sulcata* Burk, which is present in both subzones, and *Schuchertella* cf. *S. poposiensis* (C. Branson) and *Reticulariina browni* (Branson and Greger), species restricted to the *Carlinia amsedeniana* Subzone in Fremont County. This collection is far from typical, as it does not contain any *Composita* or *Anthracospirifer.*

The thickness of this subzone is not known for certain, but it seems to be somewhat greater than that of the *Carlinia amsdeniana* Subzone. Fossils of the *Composita poposiensis* Subzone collected from beds in place at Cherry Creek by Bell (collns. 32–34) were recorded as occurring 63–67 feet above the base of the Amsden. These fossils were given preliminary identification by Shaw (in Shaw and Bell, 1955 and Shaw, 1955a) and have been restudied. The fossils in C. A. Biggs' collection from the same subzone (Burk, 1954, p. 7) were reported to have come from 60 to 90 feet above the base, in a measured section. Although mollusks are rather rare in this subzone, a small ammonoid here identified as *Cravenoceratoides* sp. is present in this collection.

As much of the collecting in Fremont County has been from float, fossils from both subzones are commonly present in these collections. Nevertheless, the faunal differences noted in the material collected in place, as well as the difference in preservation noted above, have made it possible to distinguish between the two subzones in most sections.

ANTIQUATONIA BLACKWELDERI ZONE

The earliest of the Pennsylvanian zones is named for a large dictyoclostid brachiopod that occurs at a number of localities in western Wyoming. This zone is present in Teton, Lincoln, and Sublette Counties; it lies almost entirely within the Montana province of Sando (1967b, p. D33) but is present also at Darwin Peak, a few miles within the Wyoming province.

Characteristic of this zone are several rather large productoids and other brachiopods, including *Orthotetes* sp. A., *Eolissochonetes pseudoliratus* (Easton), *Rugoclostus williamsi* Gordon, n. sp., *Antiquatonia blackwelderi* Gordon, n. sp., *Composita ovata* Mather, *C. subtilita* (Hall), and *Anthracospirifer occiduus* (Sadlick). Associated with these brachiopods at some localities are trepostomatous bryozoans of several sizes, mostly branching forms, and small foraminifers of Zone 20.

This assemblage is found in carbonate rocks, both limestone and dolomite, a few feet thick and 25 to 30 feet above the beds of the *Anthracospirifer welleri-shawi* Zone in most sections. At Darwin Peak the bed containing fossils of this zone lies at the base of the Ranchester Limestone Member, 60 feet stratigraphically above the one with fossils of the *Carlinia amsdeniana* Subzone. The conditions of deposition are similar to those for the Mississippian part of the Ranchester Limestone Member.

In central Wyoming in the Wind River Range only one early Pennsylvanian collection has been found—a molluscan mold fauna in a dolomite bed at the base of the Ranchester in Bull Lake Canyon.

In eastern Wyoming on both flanks of the Bighorn Mountains early Pennsylvanian faunas with either brachiopods or mollusks predominant have been found both in the Horseshoe Shale Member and in the Ranchester Limestone Member. The brachiopods are similar to those in western Wyoming, except that *Antiquatonia blackwelderi* is absent, its place taken by *A.* cf. *A. coloradoensis* (Girty) which is associated with *Linoproductus eastoni* Gordon, n. sp., both of which were described originally from central Montana specimens. Zone 20 foraminifers are present in the limestone beds.

The restricted distribution of the early Pennsylvanian brachiopod faunas and their composition suggests that although normal marine conditions prevailed locally, much of the environment within the Amsden depositional basin was not favorable for supporting marine communities. This is particularly true of the central region of Amsden outcrop. The *Antiquatonia blackwelderi* assemblage seems to have been an adjunct of the Idaho province and occurs there within the Wells Formation. The collections from the eastern area of outcrop, on the other hand, show closer relationship to those of the Amsden of Montana. As both brachiopod and mollusk assemblages are present and combinations of the two, as the brachiopods are longer ranging, and as the stratigraphic control is less certain, we have not attempted to refer the Pennsylvanian assemblages in the region of the Bighorn Mountains to a specific faunal zone.

NEOKONINCKOPHYLLUM HAMATILIS ZONE

In the Rawlins hills in Carbon County, Pennsylvanian brachiopods are associated with corals of the genus *Neokoninckophyllum* in argillaceous limestone beds in the Horseshoe Shale Member and in the lower part of the Ranchester Limestone Member. The fauna includes (collns. 1–5, 7) *Neokoninckophyllum hamatilis* Sando, n. sp., *N. inconstans* Sando, n. sp., *Derbyia* cf. *D. robusta* (Hall), *Echinoconchus* sp. A, *Antiquatonia* cf. *A. coloradoensis* (Girty), *Linoproductus eastoni* Gordon, n. sp., *L. planiventralis* Hoare, *Composita ovata* Mather, *C. elongata* Dunbar & Condra, *C. subtilita* (Hall), *Anthracospirifer occiduus* (Sadlick), *A., rawlinsensis* Gordon, n. sp., several pelecypods, most commonly *Wilkingia terminalis* (Hall), and Zone 20 foraminifers.

In the measured section at Meadow Ranch the fossiliferous limestones occupy a section aggregating 50 feet in thickness (collns. 7–13), the corals occurring in the basal bed.

MESOLOBUS ZONE

The highest zone in the Amsden occurs in the Rawlins hills, but the beds were encountered only at localities outside of measured sections. The brachiopods include (collns. 6, 15) *Derbyia* cf. *D. robusta* (Hall)?, *Mesolobus* sp., *Echinoconchus* sp. A., *Antiquatonia* cf. *A. coloradoensis* (Girty), *Linoproductus planiventralis* Hoare, *Composita subtilita* (Hall), and *Anthracospirifer occiduus* (Sadlick). They are associated with Zone 21 foraminifers in one collection.

RELATIONSHIP OF THE CORAL-BRACHIOPOD, FORAMINIFERAL, AND OTHER ZONES

Zonal determinations and time-rock assignments were made independently by each specialist based upon the distribution in the Amsden of several animal phyla and one collection of fossil plants. The evidence provided by each group of fossils has been taken into account and so far as possible given equal weight in the overall biostratigraphic study. The result is a remarkably uniform picture of the depositional history within the Amsden basin.

In figure 10 the coral-brachiopod zones are equated with the foraminiferal, goniatite, and floral zones of interregional significance which were found in the Amsden Formation in the stratigraphic positions shown in the diagram. This arrangement has no direct relationship to the lithology; it depicts only the biostratigraphic zones and shows their relationship to the major chronostratigraphic divisions. The diagram shows the framework by means of which the lithologic units of the Amsden Formation are to be interpreted. It also demonstrates the general agreement in age and continuity of the biostratigraphic evidence from several independent sources

The coral-brachiopod zones were assigned originally to system and series by comparison with sections in the Great Basin region that had been studied by Gordon and Duncan and in the northern Rocky Mountain region by Sando and Dutro. The *Caninia* Zone is widespread in these areas and occupies the middle part of the Chesterian Series and locally some of the lower and upper parts. Brachiopods in this facies in Wyoming, such as *Diaphragmus cestriensis* (Worthen) indicate a link also to the Chesterian of the American Midcontinent.

The brachiopod genus *Carlinia*, a close relative of *Diaphragmus*, is restricted to the western United States, and it is represented in the Great Basin by species other than the Wyoming one. In western Utah this genus reaches its greatest development in the Chainman Shale roughly midway between the top of the *Caninia* Zone and the top of the Mississippian. The restricted stratigraphic distribution of *Carlinia* has prompted the assignment of the *Carlinia amsdeniana* Subzone of Wyoming to a level not far below the top of the Mississippian. The *Composita poposiensis* Subzone contains species and subspecies of *Composita, Anthracospirifer*, and *Eumetria* similar to and derived from those in the lower subzone. Forms similar to the low-ribbed *Eumetria sulcata* Burk are fairly common in beds of very late Mississippian age in the American Midcontinent; but we have not seen them in Lower Pennsylvanian rocks. For this reason the upper subzone of the *Anthracospirifer welleri-shawi* Zone in Fremont County was assigned to the very late Mississippian. The beds on Berry Creek, Teton County, that contain *Eolissochonetes pseudoliratus* (Easton) and an early form of *Anthracospirifer occiduus* (Sadlick), both suggesting Pennsylvanian age, in association with *Orthotetes kaskaskiensis bransonorum*, n. subsp., *Composita sigma* Gordon, n. sp., *Anthracospirifer welleri lincolnensis* n. subsp., and *A. shawi exoletus* n. subsp., all suggesting Mississippian age, were an enigma until the foraminifers were studied.

The *Antiquatonia blackwelderi* Zone in western Wyoming was recognized as the earliest Pennsylvanian megafaunal zone and therefore a Morrowan equivalent because it contains moderately large productoids of the genera *Rugoclostus, Antiquatonia*, and *Linoproductus*, together with *Composita ovata* Mather, and *Anthracospirifer occiduus* (Sadlick). This fauna is similar to that of the *Rugoclostus* Zone of the Great Basin (Gordon and Duncan, 1970, p. A45; Gordon, 1971, p. 51). Also assigned to the Morrowan are beds in the eastern part of the Amsden basin that contain *Antiquatonia* cf. *A. coloradoensis* (Girty), although these may be in part younger; they were also regarded as Morrowan by Shaw (1955a, p. 62).

Mamet (1975) refers 15 collections to Zone 20, which he regards as coinciding in stratigraphic extent to the Morrowan Series. All of these collections were also considered to be Morrowan in age on the basis of their megafauna. Of the two collections containing *Mesolobus*, one contained foraminifers determined to belong in Zone 21, which Mamet regards as early Atokan in age.

Only one goniatite of stratigraphic significance was found. This is from a collection made by C. A. Biggs (colln. 34) from the *Composita poposiensis* Subzone at Cherry Creek. It is identified by Gordon and Yochelson (1975) as *Cravenoceratoides* sp. This genus is rare in the United States but has been recorded previously from the upper part of the Upper *Eumorphoceras* Zone in the Inyo Mountains of California (Gordon, 1964, p. A5). It also is found in the upper half of the Upper *Eumorphoceras* (E_2) Zone in northwest Europe, where it is restricted to the E_2c Subzone. The Upper *Eumorphoceras* (E_2) Zone has been determined by Mamet (1968) to be equivalent to foraminiferal Zone 18. This is the basis for considering the lower part of the *Composita poposiensis* Subzone at Cherry Creek to belong in Zone 18.

Conodont zones have not been included in the diagram (fig. 12) because specific faunal zones could not be recognized from the material available (J. W. Huddle, oral commun., 1972). Nevertheless, the conodonts from the *Caninia* Zone and the overlying Mississippian part of the Ranchester Limestone

Member in Lincoln County are Chesterian forms, while those from the Ranchester on both flanks of the Bighorn Mountains are Morrowan forms. This agrees with the age determinations from other fossils.

Finally, the macerated plant fragments from collections at Hoback Canyon were compared to those of the Wedington Sandstone Member of the Fayetteville Shale in Arkansas (S. H. Mamay, written commun., 1955). The stratigraphic position of the plant-bearing beds at Hoback Canyon below a coralline limestone containing Zone 18 foraminifers is in harmony with assignment to floral zone 3 of Read and Mamay (1964). In general, however, the Chesterian flora is regarded as essentially uniform; Read and Mamay (1964, p. K5) so far recognize only one floral zone in Chesterian rocks.

CORRELATION

MISSISSIPPIAN-PENNSYLVANIAN BOUNDARY

The delimiting of this boundary in Wyoming is consistent with the present practice of American biostratigraphers of placing it at the base of the Morrow Group (Morrowan Series) in Washington County, Ark. Biostratigraphically, this recognizes it at the base of the Lower *Reticuloceras* (R_1) ammonoid zone (Gordon, 1968) and at the base of foraminiferal Zone 20 (Mamet and others, 1971, p. 29–31). In the western part of the United States, this boundary lies just beneath a zone of rather large productoid brachiopods which includes the genus *Rugoclostus* Easton (Gordon and Duncan, 1970, p. A42; Gordon, 1971, p. 51).

The Mississippian-Pennsylvanian boundary within the Amsden Formation was recognized by Gordon, based principally upon the brachiopod fauna, and independently by Mamet, based primarily on the foraminifers. At nearly every section where magofossils and microfossils are both present, no conflict arose in the placement of the boundary. In the Berry Creek section, Teton County, where a transitional fauna of Mississippian brachiopods associated with several early Pennsylvanian forms is present, the microfaunal evidence indicated the presence of Zone 19 foraminifers, and for this reason the beds were assigned to the Late Mississippian. No foraminifers were found in the Amsden in the Wind River Range. In that area the Mississippian beds were determined by their brachiopod fauna and the Pennsylvanian by a molluscan fauna at the base of the Ranchester Limestone Member.

Definition of the Mississippian-Pennsylvanian boundary in the United States by any criterion is troublesome. In the Appalachian region, the type Pennsylvanian is composed mainly of continental sediments, and its correlation with the marine sections in other parts of the United States is very difficult. In West Virginia, where marine strata are more fully developed than in Pennsylvania, the lowest unit assigned to the Pennsylvanian (Pocahontas Formation) includes beds that interfinger laterally with the Bluestone Formation of the Pennington Group (Englund, 1969), assigned to the latest Mississippian (Chesterian).

In the type region of the Chesterian Series in southwestern Illinois, the highest beds present are those of foraminiferal Zone 18 (Mamet and Skipp, 1970b). The North American craton was emergent during the time that the sediments of foraminiferal Zone 19 were being deposited, most of them elsewhere. Although Zone 19 is represented in neither the Mississippian nor Pennsylvanian of the American Midcontinent sections, the megafauna and microfauna of these beds more nearly resemble those of the Mississippian than the Pennsylvanian and are assigned to that system here.

Approximate positions of the systemic boundary are shown in the Wyoming sections on plates 4 through 9, where the highest Chesterian fauna is marked by the letter C in each measured section and the lowest Morrowan fauna by the letter M. Between these two horizons of faunal control is an interval of uncertainty wherein lies the systemic boundary. Because of the continuous and transgressive deposition of the Amsden, this boundary is not marked by a recognizable lithologic break. It can merely be approximated, bracketed by datable faunas. Nevertheless, the interval of uncertainty is normally small enough for the Mississippian-Pennsylvanian boundary to be shown as a line on correlation charts which appear later in this report.

CORRELATION WITH STANDARD SECTIONS IN THE UNITED STATES

In figure 12 the correlation of the members and faunal zones of the Amsden Formation with two standard sections in the southern Midcontinent region of the United States is shown. These correlations are based upon the foraminiferal zones as determined by Mamet and Skipp (1970a), Sando and others (1969), and Mamet and others (1971). Correlation of unfossiliferous beds in the lower part of the Amsden in western Wyoming is not shown in figure 12. These beds have been determined to be of late Meramecian and early Chesterian age by projecting lithic trends westward into paleontologically dated sequences in southeast and south-central Idaho.

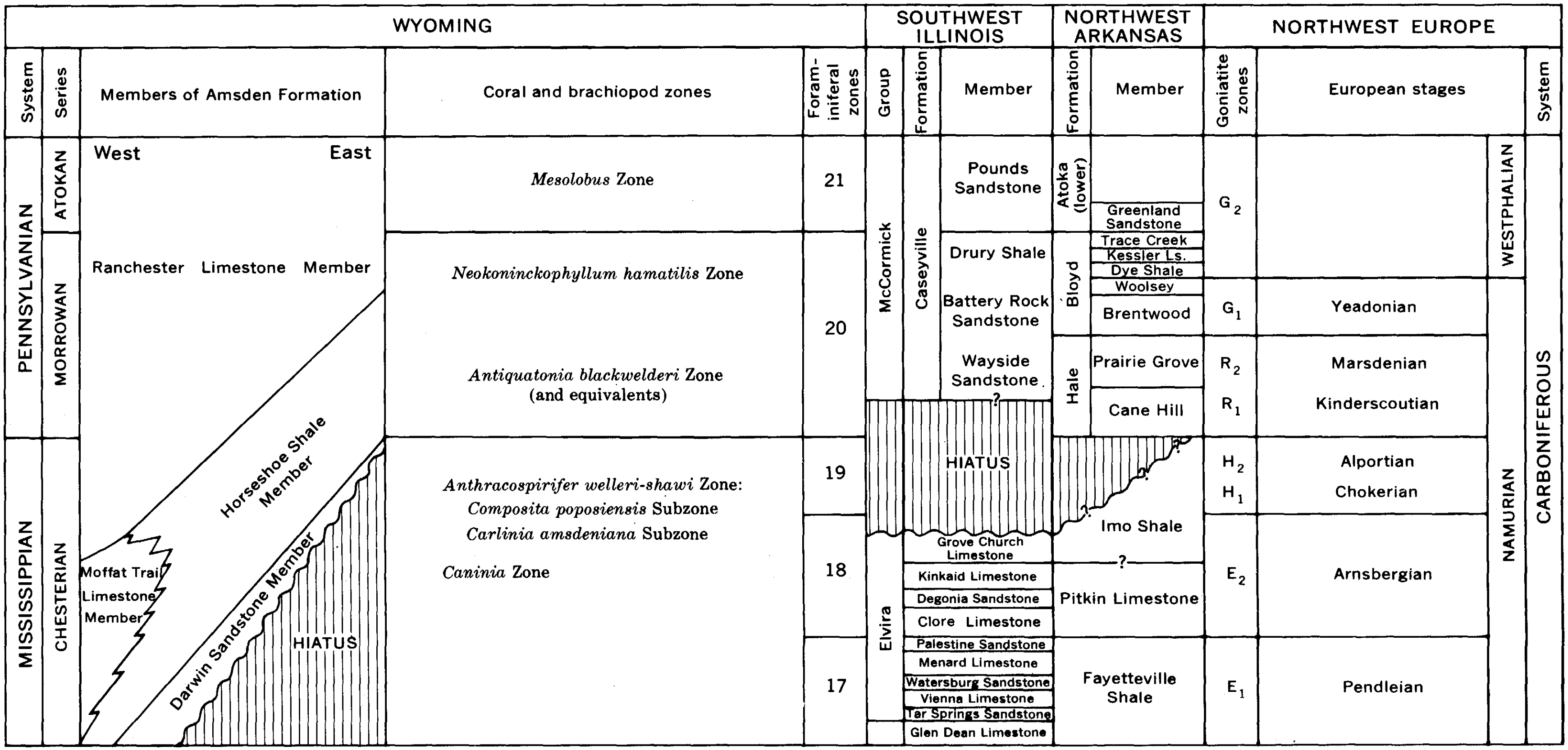

Figure 12.—Correlation of Amsden Formation with American Midcontinent and northwest European standard Carboniferous successions.

In the Chesterian section of southwest Illinois the subdivisions are those of Swann (1963). As no foraminifers have been found in the sandstone units of this section, their precise correlation in terms of the foraminiferal zones is not known. The correlations of the limestone units are based on Mamet's sampling of those rocks (Mamet and Skipp, 1970b). The early Pennsylvanian part of the southwest Illinois section is based upon the classification of Kosanke and others (1960). The correlation of these beds is tentative.

The other North American section shown in the diagram is that in northern Arkansas, which includes the type area of the Morrowan Series (Henbest, 1953, 1962a, b) and is a composite section of northwestern and north-central Arkansas rocks. The correlation of this section is based mainly on the ammonoid succession (Gordon, 1964, 1970) and the relationship of the ammonoid zones to the foraminiferal zones, derived from other sections in the United States and in northwest Europe (Sando and others, 1969; Mamet and Skipp, 1970a). It also takes into account the equivalence of foraminiferal Zone 20 with the Morrowan Series and of Zone 21 with the early part of the Atokan Series (Mamet and Skipp, 1970a; Mamet and others, 1971).

CORRELATION WITH NORTHWEST EUROPEAN STANDARD SECTION

Figure 12 also shows the correlation of the Amsden Formation, its members, and its faunal zones with the stages and series of the standard section for northwest Europe. For the Late Mississippian rocks this correlation is based primarily on previous correlations of foraminiferal zones and northwest Europe goniatite zones with which the stages coincide (Mamet, 1968; Sando and others, 1969; Mamet and Skipp, 1970a, b; Mamet and others, 1971). These are fairly well established for the Upper Mississippian rocks (Zones 9 through 19) but are less certain for the Lower and Middle Pennsylvanian rocks.

Correlation of the Pennsylvanian part of the Amsden is less direct, being based on the ranges, so far as is known, of the foraminiferal zones in the American standard section and the correlation of these rocks with the European standard section by means of ammonoids.

Foraminiferal Zone 20 is found in rocks of Morrowan age and correlates with the *Reticuloceras* ammonoid zones (R_1 and R_2) of northwest Europe (Mamet and others, 1971, p. 31). The lower of these two ammonoid zones was recognized in the Hale Formation of northwest Arkansas (Gordon, 1968, 1970). The upper *Reticuloceras* (R_2) Zone is represented by the *Arkanites-Baschkirites-Gastrioceras* assemblage in the upper part of the Hale Formation of Arkansas, according to Ramsbottom (Quinn and Saunders, 1968, p. 402). The lower *Gastrioceras* (G_1) Zone is represented, at least in part, by the *Branneroceras branneri-Gastrioceras fittsi* assemblage (*Branneroceras branneri* Zone of Gordon, 1970, p. 820) in the Brentwood Limestone Member of the Bloyd Shale, also according to W. H. C. Ramsbottom (oral commun. to Gordon, 1967).

The Namurian-Westphalian boundary is not recognized in Carboniferous sections in the United States, but can at least be approximated. In northwest Europe this boundary coincides with the boundary between the lower and upper *Gastrioceras* (G_1 and G_2) Zones and is placed at the base of the *Gastrioceras subcrenatum* Subzone, a relatively thin marine bed in a generally continental sequence. This horizon cannot be recognized in the United States, and its correlation must be arrived at indirectly.

The suggestion of McCaleb and Furnish (1964, p. 253) that *"Paralegoceras" percostatum* Schmidt from the Upper Carboniferous of Spain and Algeria (Schmidt, 1955) is related to *Axinolobus modulus* Gordon carries with it the implication that this Mediterranean species may represent the *Axinolobus modulus* Zone of Gordon (1970, p. 820). Although the ventral lobe is not completely preserved in Schmidt's holotype, the shape of the remainder of the suture and the shape of the shell are closer to *Axinolobus* than to any other genus. In northwestern Spain *Axinolobus? percostatus* is associated with spores and a megaflora of early Westphalian (Westphalian A) age, according to Wagner (1962, p. 755). If *A.? percostatus* is the same age as the *Axinolobus modulus* Zone of Arkansas, the base of the Westphalian would correspond roughly with the base of the Dye Shale Member, marked by a marine conglomerate that overlies the Woolsey Member of continental origin (Henbest, 1962b, p. D42, D43). This constitutes a stratigraphically lower correlation of the base of the Westphalian than that of Gordon (1970, p. 823. fig. 2). Further study will be needed to validate such a correlation, which nevertheless seems reasonable. If foraminiferal Zone 20 coincides with all of Morrowan time, it straddles the Namurian-Westphalian boundary, as suggested by Mamet and Skipp (1970a, p. 336).

The long range of *Gastrioceras* upward through the Atokan Series into beds of Desmoinesian age suggests that it is reasonable to assign the lower part of the Atokan to the upper *Gastrioceras* (G_2) Zone. The lower Atokan also corresponds to foraminiferal Zone 21 (Mamet and others, 1971, fig. 3).

In summary, the fossiliferous parts of the Amsden Formation of Wyoming are equivalent to nearly the entire Namurian Series of northwest Europe, beginning with its earliest stage (Pendleian) and continuing upward into the lower part of the Westphalian Series. The underlying unfossiliferous parts of the Amsden in western Wyoming, as indicated by projecting their lithologic trends westward, include rocks of late Viséan age.

CORRELATION WITH THE CARBONIFEROUS SEQUENCES OF MONTANA AND IDAHO

Lithostratigraphic and biostratigraphic evidence compiled during this study provides an excellent basis for detailed analysis of the depositional relations of the Amsden Formation of Wyoming with Carboniferous sequences in two key areas adjacent to Wyoming. To the west, in southeast and south-central Idaho, a thick sequence of carbonate sediments and quartz sand was deposited in the Cordilleran miogeosyncline during Amsden time. To the north, in southwest and central Montana, a thinner sequence of carbonate and terrigenous sediments was deposited in an unstable intracratonic basin during Amsden time. A summary of the temporal relations of these sequences is presented in figure 13, and detailed correlations of the various lithostratigraphic units is shown on plates 10 and 11.

CARBONIFEROUS SEQUENCE OF MONTANA

This analysis of the relations between Late Mississippian and Pennsylvanian rocks of Wyoming and Montana has been made by comparing our data with the lithostratigraphic synthesis of Maughan and Roberts (1967) and by reinterpreting the fossils listed and described by Gardner and others (1946) and Easton (1962) from the Montana sequence. Our data include not only fossils and stratigraphic sections from Wyoming but also similar data, much of it not previously published, collected in Montana.

We have adopted the stratigraphic subdivisions recognized by Maughan and Roberts (1967) for the Montana area with minor modifications (fig. 13). Accordingly, we recognize in central and eastern Montana the Big Snowy Group (Chesterian), composed of Kibbey, Otter, and Heath Formations overlying the Madison Group unconformably, and the Amsden Group, composed of the Tyler Formation (Morrowan), the Alaska Bench Limestone (Morrowan and Atokan), and the Devils Pocket Formation (Atokan and Des Moinesian) overlying the Big Snowy Group unconformably. In southwestern Montana, we recognize the Big Snowy Formation, in which Kibbey, Otter, and Heath equivalents can be distinguished at some localities, and the Amsden Formation, in which Tyler, Alaska Bench, and Devils Pocket equivalents can be distinguished at some localities. Comprehensive discussion of the historical development of this nomenclature and the rationale upon which it is based may be found in Maughan and Roberts (1967).

Three lines of stratigraphic sections (pl. 10) depict our interpretation of stratigraphic relations between northern Wyoming and southwest and central Montana. In these diagrams, series boundaries have been determined by the positions of fossil collections shown and by lithostratigraphic considerations at localities where paleontologic data are poor or lacking. Principal modifications of Maughan and Roberts' (1967, pl. 1, *A–A′*) interpretation of our section *A–A′* is the recognition of the widespread intra-Mississippian unconformity between the Madison Group and the Kibbey Formation in central Montana and the elimination of their projection of the unconformity between the Devils Pocket Formation and Alaska Bench Limestone into the Ranchester Limestone Member of the Amsden Formation in southern Montana and northern Wyoming.

This new interpretation leads to the conclusion that the Wyoming shelf was separated from the Big Snowy basin during Chesterian time by an emergent barrier, here named the Southern Montana arch. Thus, the lower part of the Amsden Formation (Darwin Sandstone Member and Horseshoe Shale Member) of Wyoming and southern Montana was being deposited at the same time as the Big Snowy Group of central and southwest Montana, but in a separate basin of deposition. The unconformity at the top of the Big Snowy Group indicates a period of emergence that was followed by transgression of the Wyoming sea northward across the Southern Montana arch during Morrowan time. Breaching of the arch is reflected in the northward lateral continuity of the Horseshoe Shale Member of the Amsden Formation with the lower part of the Tyler Formation of the Amsden Group.

A similar two-basin hypothesis for Late Mississippian sedimentation in Wyoming and Montana was suggested in reports by Perry and Sloss (1943, p. 1301–1303, fig. 7C) and Sloss (1950, p. 444, fig. 9). However, these earlier authors used a different nomenclature for the beds in question and did not recognize as large an areal extent for the Upper Mississippian strata in Wyoming.

CARBONIFEROUS SEQUENCE OF IDAHO

Correlations of the Wyoming and Montana sequences with the miogeosynclinal sequence of southeast and south-central Idaho are based on integra-

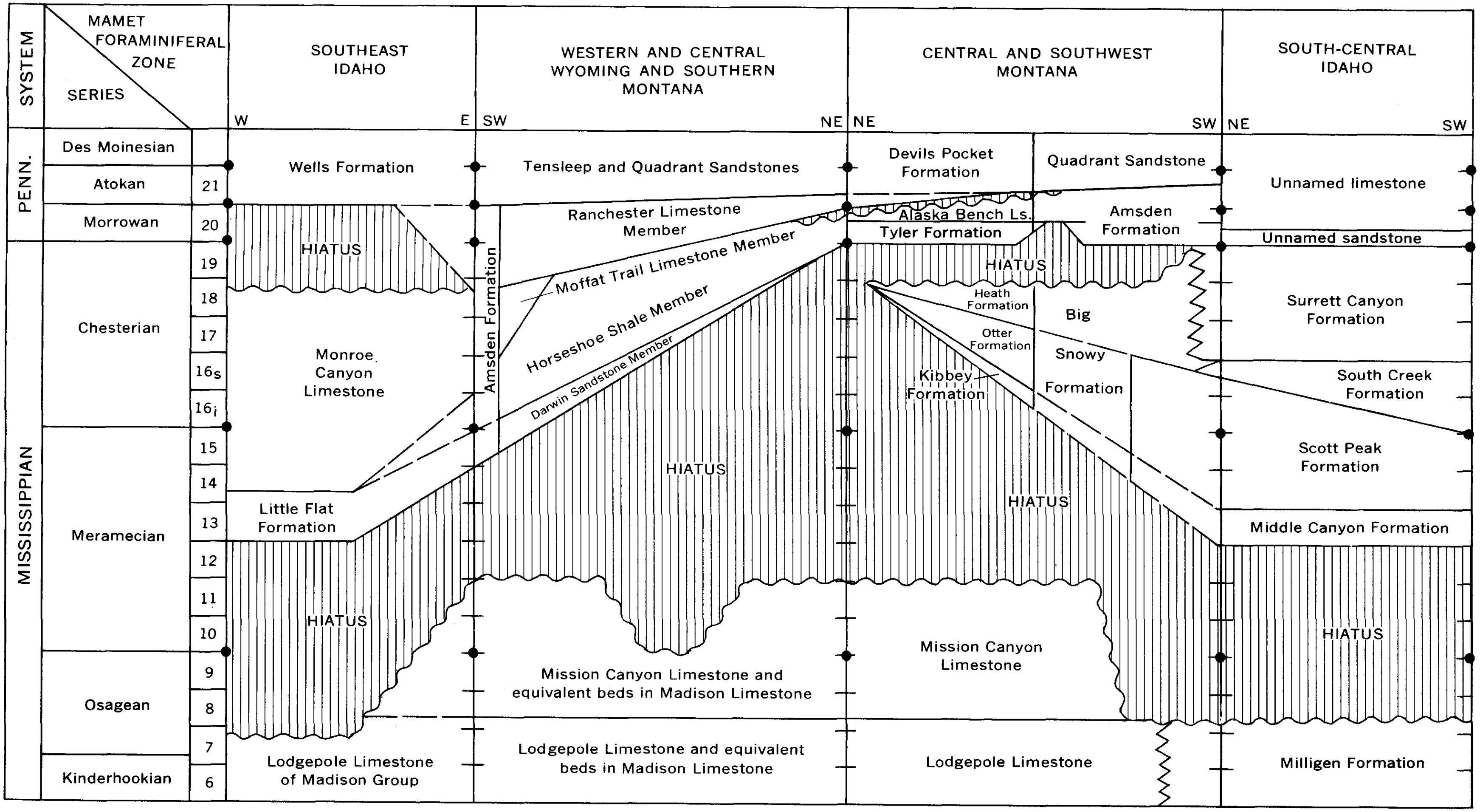

FIGURE 13.—Temporal relations of rock units in Idaho, Montana, and Wyoming during Mississippian and Pennsylvanian time.

tion of our data from Wyoming, southwest Montana, and Idaho with the lithostratigraphic synthesis of Maughan and Roberts (1967) in Montana and restudy of the fossils listed and described in Gardner and others (1946) and Easton (1962). Much of the biostratigraphic evidence for the present interpretations can be found in reports by Dutro and Sando (1963a, b), Huh (1967), Sando (1967b), Sando and others (1969), and Mamet and others (1971).

In south-central Idaho, we recognize the Middle Canyon Formation (middle Meramecian), which rests unconformably on the Milligen Formation (Kinderhookian and Osagean), followed in ascending order by the Scott Peak Formation (late Meramecian-early Chesterian), South Creek Formation (early Chesterian), Surrett Canyon Formation (middle and late Chesterian), an unnamed sandstone unit (Morrowan), and a thick sequence of Morrowan and post-Morrowan limestone (fig. 13). In southeast Idaho, we recognize the Little Flat Formation (middle Meramecian), which rests unconformably on the Lodgepole Limestone (Kinderhookian and Osagean), and is overlain by the Monroe Canyon Limestone (late Meramecian-late Chesterian). The Monroe Canyon Limestone is overlain unconformably by the Wells Formation of Atokan and post-Atokan age.

Section *A–A′* on plate 11 illustrates inferred stratigraphic relations between south-central Idaho and central Montana. Marine transgression from the miogeosyncline in Idaho into the Big Snowy basin during late Meramecian and Chesterian time, was followed by emergence of the Big Snowy basin and later inundation beginning in Morrowan time. The diagram is based in part on a modification of section *B–B′* of Maughan and Roberts (1967, pl. 1). Our interpretation differs from that of Maughan and Roberts on the following points:

1. We do not recognize an unconformity at the top of the Amsden in southwest Montana because the Amsden appears to grade into the overlying Quadrant Formation, and there is no faunal evidence of a break.
2. We do not recognize an unconformity at the base of the Amsden Formation in southwesternmost Montana and Idaho because Zone 20 (Morrowan) fossils directly overlie Zone 19 (latest Chesterian) fossils, suggesting continuous deposition from Mississippian into Pennsylvanian. The unconformity apparently does not extend into the area southwest of the Baldy Mountain section.
3. Restudy of fossils reported by Gardner and others (1946) and Easton (1962) from the Moss Agate, Delpine, and Hopley Creek sections (sections 11, 12, and 13 along *A–A′* on pl. 11) resulted in a new interpretation of the stratigraphy in these sections and the adjacent Judith Gap section in the Castle and Little Belt Mountains. Fossils in these sections, placed by Maughan and Roberts in the Alaska Bench Limestone and the Tyler Formation, are regarded by us as Mississippian and of the same age as the fauna of the Heath Formation in the Big Snowy Mountains. This revision results in the elimination of the Tyler Formation from these sections; the Alaska Bench Limestone rests unconformably on the Heath and Otter Formations. Thus, the Hopley Creek-Delpine-Moss Agate-Judith Gap area seems to have been emergent during the time of the Tyler deposition.

Sections *B–B′* and *C–C′* on plate 11 illustrate stratigraphic relations between southeast Idaho and Wyoming and show transgression of the Amsden sea from the miogeosyncline onto the Wyoming shelf, beginning in late Meramecian time and extending into the Atokan. They also indicate an uplift, called Bannock Highland by J. Stewart Williams (1962) near the cratonic margin during the late Chesterian and Morrowan.

BIOGEOGRAPHIC CONSIDERATIONS

Distributions of Late Mississippian and Early Pennsylvanian faunas in Idaho, Montana, and Wyoming have an important bearing on interpretation of the geometry and chronology of the Amsden transgression. High degrees of endemism are evident in the Late Mississippian faunas of Wyoming and Montana, but the Pennsylvanian faunas of these two areas are more cosmopolitan.

BRACHIOPODS

The brachiopods provide possibly the strongest evidence of geographic separation of the Montana and Wyoming areas during Mississippian time followed by marine continuity during the Pennsylvanian. Gordon (1975) describes 66 brachiopod species and subspecies from the Amsden Formation of Wyoming, of which 41 are restricted to the Mississippian, 20 are restricted to the Pennsylvanian, and 5 occur in both Mississippian and Pennsylvanian strata. Only 18 of the Wyoming taxa have been identified by Gordon in the collections reported by Gardner and others (1946) and Easton (1962) from the Mississippian and Pennsylvanian of Montana. Table 9 shows the occurrences of brachiopod taxa common to Wyoming and Montana. The following conclusions are evident from these data:

TABLE 9.—*Occurrence of Amsden brachiopod taxa that occur in both Wyoming and Montana*

Brachiopod taxa	Geographic area and stratigraphic unit			
	Central Wyoming	Western Wyoming	Southwest Montana	Central Montana
Exclusively Mississippian in Wyoming				
Orbiculoidea wyomingensis Branson and Greger.	Horseshoe Shale Member.	Horseshoe Shale Member.		Alaska Bench Limestone.
Orthotetes kaskaskiensis bransonorum Gordon.	Horseshoe Shale Member.	Horseshoe Shale Member. Moffat Trail Limestone Member.		Otter and Heath Formations.
Diaphragmus nivosus Gordon		Horseshoe Shale Member.	Otter Formation equivalent	Heath Formation.
Pugnoides quinqueplecis Easton	Horseshoe Shale Member.	Ranchester Limestone Member.		Tyler Formation. Alaska Bench Limestone.
Cleiothyridina cf. *C. sublamellosa* (Hall).		Moffat Trail Limestone Member.		Otter and Heath Formations.
Composita subquadrata (Hall)		Horseshoe Shale Member. Moffat Trail Limestone Member.	Otter Formation equivalent	Heath Formation.
C. sulcata Weller	Horseshoe Shale Member.		Otter Formation equivalent	Heath Formation.
Anthracospirifer curvilateralis curvilateralis (Easton).		Moffat Trail Limestone Member.	Otter Formation equivalent	Heath Formation Heath Formation. Tyler Formation. Alaska Bench Limestone.
A. cf. *A. occiduus* (Sadlick) form A.	Horseshoe Shale Member.	Horseshoe Shale Member.		Tyler Formation.
Neospirifer praenuntius Easton		Moffat Trail Limestone Member.		Heath Formation.
Exclusively Pennsylvanian in Wyoming				
Orthotetes sp. A. Gordon	Horseshoe Shale Member.	Horseshoe Shale Member. Ranchester Limestone Member.		Tyler Formation. Alaska Bench Limestone.
Echinoconchus sp. A Gordon	Horseshoe Shale Member.			Tyler Formation. Alaska Bench Limestone.
Antiquatonia cf. *A. coloradoensis* (Girty).	Horseshoe Shale Member. Ranchester Lime- Member.		Tyler Formation equivalent	Tyler Formation. Alaska Bench Limestone.
Linoproductus eastoni Gordon	Horseshoe Shale Member. Ranchester Limestone Member.	Ranchester Limestone Member.	Alaska Bench Limestone?	Tyler Formation. Alaska Bench Limestone.
Composita ovata Mather	Horseshoe Shale Member. Ranchester Limestone Member.	Ranchester Limestone Member.		Tyler Formation. Alaska Bench Limestone.
Anthracospirifer occiduus (Sadlick).	Horseshoe Shale Member. Ranchester Limestone Member.	Ranchester Limestone Member.		Tyler Formation?. Alaska Bench Limestone.
Mississippian and Pennsylvanian in Wyoming				
Schizoporia depressa Easton	Horseshoe Shale stone Member. Ranchester Limestone Member.	Horseshoe Shale Member. Ranchester Limestone Member.	Alaska Bench Limestone, Devils Pocket Formation equivalent?	Otter, Heath, Tyler Formations. Alaska Bench Limestone
Eolissochonetes pseudoliratus (Easton).	Ranchester Limestone Member.	Horseshoe Shale Member. Ranchester Limestone Member.	Tyler and Devils Pocket Formation equivalents. Alaska Bench Limestone.	Tyler Formation. Alaska Bench Limestone.

1. Of the 41 exclusively Mississippian taxa in the Amsden of Wyoming, only 10 are known from Montana, where 6 are restricted to the Mississippian, 3 are restricted to the Pennsylvanian, and one may range from Mississippian into Pennsylvanian.
2. Of the 20 exclusively Pennsylvanian taxa in the Amsden of Wyoming, 6 are also known from Montana, where all are restricted to the Pennsylvanian.
3. Three of the taxa that are restricted to the Mississippian in Wyoming are found in the Pennsylvanian of Montana.
4. None of the taxa that are restricted to the Mississippian in Montana are found in the Pennsylvanian of Wyoming.

Detailed relations of the Wyoming and Montana brachiopod faunas with those of Idaho cannot be established at this time, owing to the lack of complete systematic study of the prolific collections from Idaho. However, preliminary studies of these collections by Dutro and Gordon indicate a general phylogenetic continuity with the Idaho faunas. An example of this continuity is the occurrence of *Spirifer brazerianus* Girty, a common Chesterian brachiopod in the Monroe Canyon Limestone and Surrett Canyon Formation of Idaho, in the Otter Formation equivalent at Baldy Mountain and Indian Creek in southwest Montana (Dutro and Sando, 1963a).

Gordon (1975) concludes that a brachiopod fauna of mixed origins, associated with a coralline facies, migrated to the Wyoming shelf from the miogeosyncline beginning in middle Chesterian time. The fauna spread eastward, diversified, and became highly endemic during the remainder of the Chesterian. Restudy of the Montana brachiopods suggests that a similar migration and differentiation was taking place in a separate basin in the Montana area during the same time. Beginning in Morrowan time, some new elements entered the Wyoming area from the southeast and the Amsden fauna spread northward into Montana during the Morrowan and Atokan.

OSTRACODES

All Amsden ostracodes from Wyoming are of Mississippian age and are assigned (Sohn, 1975) to 22 species representing an endemic fauna. Only two of the Wyoming species are known in Montana; these species occur in the Horseshoe Shale Member of the Amsden in western Wyoming and in the Otter Formation equivalent in southwest Montana. No ostracodes have been described from the Pennsylvanian part of the Amsden Formation in Wyoming or from equivalent beds in Montana.

COELENTERATES

Most of the coelenterates in the Amsden Formation occur in clean carbonate rocks of the Moffat Trail Limestone Member, where they are restricted to the middle and late Chesterian (*Caninia* Zone) (Sando, 1975). Only two taxa are known from the Mississippian and three from the Pennsylvanian in central Wyoming, where high turbidity and high salinity seem to have been unfavorable for the coelenterate growth. None of the central Wyoming taxa are known elsewhere in Wyoming, with the possible exception of *Zaphrentites*? cf. *Z. spinulosa* (Milne-Edwards and Haime), a somewhat broadly defined taxon common in the Chesterian of the Cordilleran region.

The Pennsylvanian species *Neokoninckophyllum hamatilis* Sando, *N. inconstans* Sando, and *Chaetetes* cf. *C. eximius* Moore and Jeffords are most closely related to Morrowan species in Texas and Oklahoma, suggesting that these forms were derived from coelenterates that migrated into south-central Wyoming from the southeast when the Transcontinental arch was breached during the Morrowan but did not spread farther northward because of unfavorable environmental conditions.

The middle and late Chesterian *Caninia* Zone fauna of the Moffat Trail Limestone Member is common in the Cordilleran miogeosyncline in south-central Idaho and southeast Idaho and extends as far north as central Montana (fig. 11, table 10). The principal index genus in this fauna is represented by four different taxa, which are closely related phylogenetically and may be only geographic subspecies. The *Caninia* fauna probably originated in the miogeosyncline and migrated eastward into western Wyoming and northwestward into Montana in the transgressing carbonate banks of Chesterian time.

FORAMINIFERA

Carboniferous foraminiferal samples are very uniform throughout the western United States (Mamet and Skipp, 1970a, p. 329–332). The entire Idaho-Montana-Wyoming region is included in the North American realm, which is part of a single foraminiferal province that includes all of western North America.

Large foraminiferal faunas are known from the Late Mississippian of south-central Idaho (Zones 13–19), southeast Idaho (Zones 13–18), western Wyoming (Zones 17–19), and southwest Montana

TABLE 10.—*Occurrence of coelenterate taxa of* Caninia *Zone in Wyoming, Montana, and Idaho*

Coelenterate taxa	Geographic area and stratigraphic unit					
	Central Wyoming	Western Wyoming	Southeast Idaho	South-central Idaho	Southwest Montana	Central Montana
Chaetetes wyomingensis Sando.	----------	Moffatt Trail Limestone Member.	----------	Surrett Canyon Formation?	----------	----------
Zaphrentites? cf. *Z*? *spinulosa* (Milne-Edwards and Haime).	Horseshoe Shale Member?.	---do	Monroe Canyon Limestone.	---do	Otter Formation equivalent.	Heath Formation.
Caninia cf. *C. nevadensis* (Meek).	----------	---do	----------	Surrett Canyon Formation.	---do	----------
excentrica (Meek)	----------	----------	Monroe Canyon Limestone.	---do	---do	----------
enormis Easton	----------	----------	----------	----------	---do	----------
montanensis Easton	----------	----------	----------	----------	---do	Heath Formation.
Turbinatocaninia? sp	----------	Moffatt Trail Limestone Member.	----------	----------	----------	Heath Formation?.
Lonsdaleia (*Actinocyathus*) *stelcki* (Nelson).	----------	---do	Monroe Canyon Limestone.	Surrett Canyon Formation.	----------	----------
Pleurosiphonella drummondi (Nelson).	----------	---do	----------	----------	----------	----------
Multithecopora? *amsdenensis* Sando.	----------	---do	----------	----------	Otter Formation equivalent.	----------
Duncanopora duncanae Sando	----------	---do	Monroe Canyon Limestone.	Surrett Canyon Formation.	----------	----------

(Zones 17 and 18) and from the Pennsylvanian of south-central Idaho (Zones 20 and 21) and western and central Wyoming (Zones 20 and 21). No endemism has been noted by Mamet (1975) in the Wyoming faunas. The Foraminifera of central Montana have not been thoroughly investigated. Thus, these ubiquitous microfossils do not seem very useful as indicators of provincialism in the area studied; their value is greater as chronologic indices for correlation of lithic sequences.

OTHER FAUNAL GROUPS

Although the Amsden molluscan fauna is highly diversified, the paucity and generally poor preservation of the specimens make meaningful comparisons between the faunas of Wyoming, Montana, and Idaho impossible. Moreover, the Idaho faunas have not been carefully studied. Of 38 species of gastropods recognized by Gordon and Yochelson (1975), only one species is known from central Montana. Of 40 species of pelecypods recognized by Gordon and Pojeta (1975), only one species is questionably present in central Montana. Among the cephalopods, three species are known from the Late Mississippian and one from the Pennsylvanian in Wyoming, and six are known from the Late Mississippian of Montana; none of these species is common to both Wyoming and Montana.

The trilobites are very poorly represented. Two species are known from Wyoming, one from the Mississippian and one from the Pennsylvanian, and one each from the Mississippian and Pennsylvanian of Montana. The Mississippian forms may possibly belong to the same species.

CONCLUSIONS

Amsden faunas apparently originated during the middle Chesterian in the open miogeosynclinal sea in Idaho and migrated northeastward into an intracratonic basin in Montana and into an area of transgression in Wyoming, where another faunal offshoot followed the course of the sea. The two geographically separated groups of organisms diversified as they spread eastward and developed into endemic faunas until Morrowan time. During the Morrowan, the Wyoming sea connected with the interior of the continent across the Transcontinental arch, permitting limited access to Wyoming of a few exotic elements, which mingled with the endemic organisms. This mixed fauna then migrated northward as the Wyoming sea spread into Montana during the Morrowan and Atokan.

REGIONAL SYNTHESIS OF MID-CARBONIFEROUS DEPOSITION

To comprehend the history of Amsden deposition in Wyoming, one must look beyond the state boun-

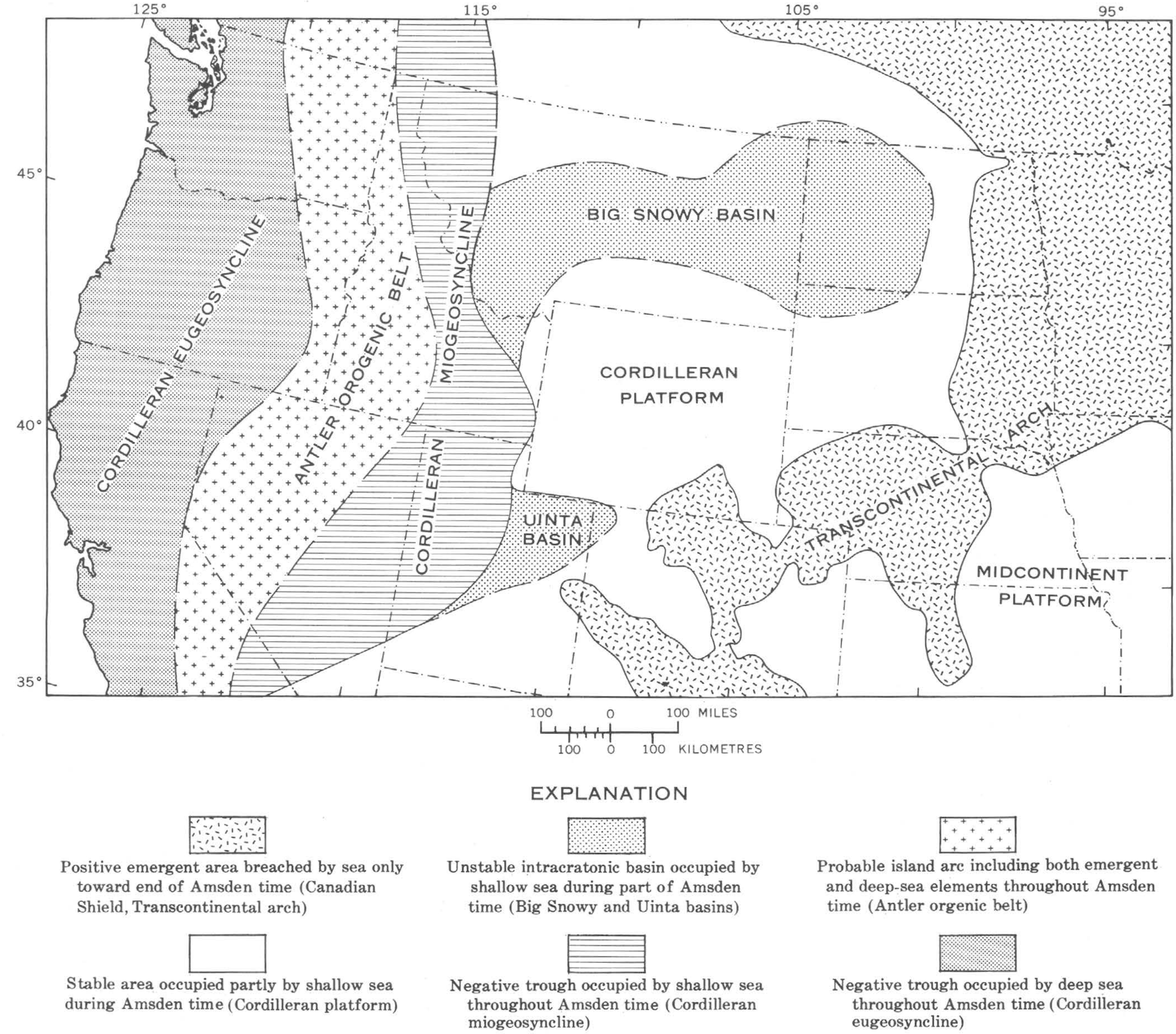

FIGURE 14.—Major structural and depositional features of the western United States during Amsden time. Limits of Transcontinental arch are mainly the boundaries between Mississippian carbonate rocks and pre-Mississippian rocks in pre-Amsden subcrop modified from Mallory (1972) and Sloss and others (1960). Limits of Antler orogenic belt are generalized from Roberts (1972). Limits of Big Snowy basin are modified from Mallory (1972).

daries into adjacent areas that influenced events in Wyoming. Conversely, comprehension of the geologic history of Wyoming during Amsden time is vital to a better understanding of the history of the entire northern Cordilleran region during the Late Mississippian-Middle Pennsylvanian interval. The regional synthesis presented here is based on our personal knowledge of many localities outside of Wyoming and on information published by other geologists. The works of Mallory (1967, 1972) and Maughan and Roberts (1967) have been particularly helpful as sources of basic data.

Major structural elements of the western United States during Amsden time are generalized in figure 14. Just before Amsden deposition, most of the northern Cordilleran region was occupied by a broad cratonic platform (Cordilleran platform) bordered on the west by the Cordilleran geosyncline. Within the geosynclinal belt, one can recognize a western eugeosyncline (Cordilleran eugeosyncline), a central organic belt (Antler orogenic belt), and an eastern miogeosyncline (Cordilleran miogeosyncline). East of the Cordilleran platform, a linear positive area (Transcontinental arch) extended southwestward from the Canadian shield and separated the Cordilleran province of deposition from the Midcontinent platform. Separation of the Cordilleran platform from the Midcontinent platform by the emergent Transcontinental arch continued into Morrowan time, when the Cordilleran and Midcontinent seas breached the arch and became continuous.

The Amsden Formation of Wyoming and equivalent stratigraphic units in adjacent areas represent eastward transgressions of the miogeosynclinal sea onto the Cordilleran platform. These transgressions took place on the relatively stable shelf in Wyoming and adjacent areas (Wyoming basin), and in two unstable intracratonic basins, the Big Snowy basin to the north in Montana and the Dakotas, and the Uinta basin to the south in Utah and Colorado.

Cordilleran events during Amsden deposition are depicted on paleogeographic maps (figs. 15–22) showing geographic elements, kinds of sediments deposited, and principal routes of terrigenous transport from Late Mississippian into Middle Pennsylvanian time. Each map represents maximum marine incursion during the time represented by one foraminiferal zone (Mississippian) or a part of one zone (Pennsylvanian). Many of the data on which

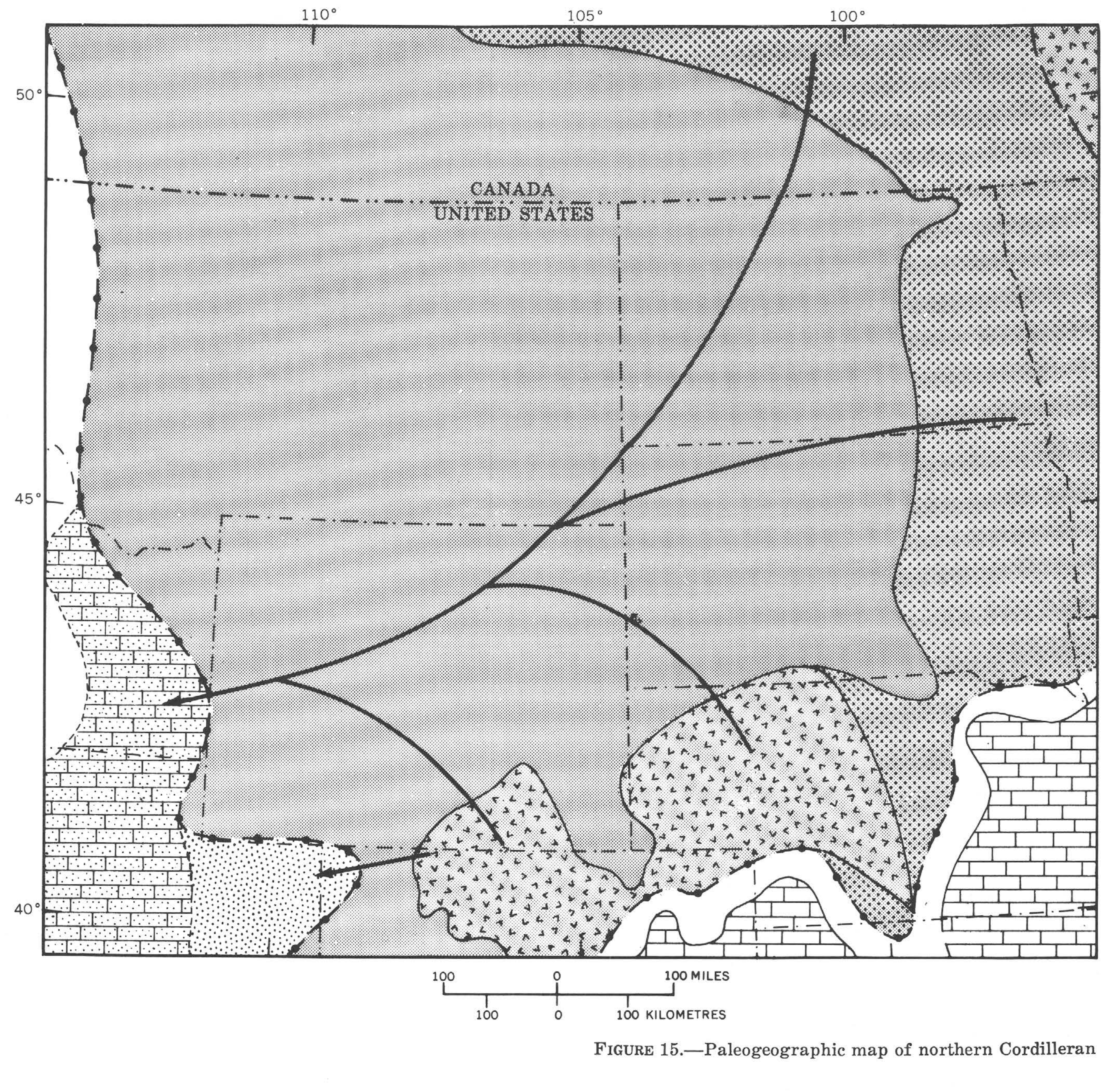

FIGURE 15.—Paleogeographic map of northern Cordilleran

the maps are based are summarized in figure 13 and plates 10 and 11.

Exact positions of contacts—between various rock units in the land areas at each stage of the Amsden transgression are unknown. Positions shown on the maps generally reflect maximum

Area of no control

EXPLANATION FOR FIGURES 15–22

LAND AREAS

Upland composed mostly of Precambrian crystalline rocks

Upland composed mostly of lower Paleozoic terrigenous and carbonate rocks

Lowland composed mostly of Mississippian carbonate rocks

Upland composed mostly of Big Snowy Group terrigenous and carbonate rocks

Upland composed mostly of Amsden Group terrigenous and carbonate rocks

LOCAL UPLIFTS

B Bannock uplift

BS Big Snowy uplift

F Front Range uplift

M Montana uplift

P Pathfinder uplift

S Southern Montana arch

DEPOSITIONAL AREAS

Principally arkosic sand and conglomerate deposited in nearshore environment

Principally quartz sand deposited in nearshore banks and bars in sea of shallow depth

Principally quartz sand and sandy carbonate sediments deposited in nearshore to offshore open marine environment in sea of shallow to moderate depth

Principally carbonate sediments deposited in offshore open marine banks in sea of shallow depth

Principally clay and argillaceous carbonate sediments deposited in sea of shallow to moderate depth

Principally carbonaceous clay deposited in sea of moderate depth

Dolomitic carbonates, limy carbonates, clay, and minor sand and evaporitic sediments deposited in restricted marine offshore banks in sea of shallow depth

Principally red clay, silt, and sand and locally carbonaceous clay deposited in lagoons and nearshore swamps

Present erosional edge of depositional basin, *Dashed where uncertain*

Postulated shoreline

Postulated submarine barrier

Postulated major paths of terrigenous sediment transport from land sources to sites of deposition

region during middle Meramecian (foraminiferal Zone 13) time.

erosion of the Transcontinental arch because they are based mostly on the subcrop underlying the youngest rocks of the Pennsylvanian sequence. Consequently, Precambrian and lower Paleozoic sources of terrigenous sediment during the earlier phases of the Amsden transgression were probably farther north, east, and south from depositional sites than shown on the maps. The southern limit of Precambrian rocks exposed on the Canadian Shield, as shown, is based on postulated former greater extent of lower Paleozoic rocks across the northern part of the Transcontinental arch.

Positions of depositional areas are not restored palinspastically for post-Amsden folding and faulting except in the inferred shorelines of the Big Snowy basin. However, such restoration is probably unnecessary for most of the Cordilleran platform though probably required for true spatial relations along the western margin of the Cordilleran platform and in the Cordilleran miogeosyncline, where folding and thrust faulting are moderate. Despite moderate telescoping, no major translocations of original sedimentary facies have been noted in the areas shown.

MISSISSIPPIAN HISTORY

MIDDLE MERAMECIAN

During middle Meramecian (Zone 13) time, just before Amsden deposition, the Cordilleran platform was a karst lowland composed of relatively terrigenous-free carbonate rocks of the Madison Limetone (fig. 15). Maximum relief probably did not exceed 200 feet. Erosion was probably slow and influenced by moderate chemical weathering.

Bordering the broad Cordilleran plain on the north, east, and south was a chain of hills made up of more resistant Precambrian crystalline and lower Paleozoic sedimentary rocks. Ordovician sandstones may have been exposed on the Transcontinental arch in Nebraska and the Dakotas and along the southern margin of the Canadian Shield at this time. According to Mallory (1967, p. G26) these rocks once covered many of the Cordilleran and central states and much of Canada.

Siliceous detritus was transported by rivers across the Cordilleran plain to marine depositional sites in the miogeosyncline along the margin of the craton, where it is represented in the Deep Creek, Little Flat, and Middle Canyon Formations of southern Idaho and the Humbug and Woodman Formations of northern Utah. Stream patterns on the karst terrain were complex, and much siliceous detritus was trapped in solution cavities and deposited in complicated stream valleys before it reached the sea.

LATEST MERAMECIAN

The Cordilleran sea remained in the miogeosyncline until latest Meramecian (Zone 15) time, when subsidence of parts of the cratonic margin permitted encroachment onto the Cordilleran platform (fig. 16). The sea transgressed in two arms, one in southwest Montana and the other in western Wyoming. A belt of relatively pure carbonate sediments, represented in the Monroe Canyon Limestone and Scott Peak Formation of Idaho and the Great Blue Limestone of Idaho and Utah, developed on marine banks in the miogeosyncline.

Two major drainage systems were developed on the Cordilleran platform: a northern system deriving detritus from the hilly Canadian Shield and a more extensive southern system supplied by sources mainly on the Transcontinental arch to the east and southeast. Buildup of carbonate banks restricted areas of terrigenous deposition to estuarine reentrants in the platform margin, where the earliest sediments of the Kibbey Sandstone and Darwin Sandstone Member of the Amsden Formation were deposited. Between the miogeosynclinal carbonate belt and the area of the Darwin Sandstone Member, a lagoonal belt began to develop, represented by the fine terrigenous sediments of the Horseshoe Shale Member of the Amsden Formation.

EARLIEST CHESTERIAN

Earliest Chesterian (Zone 16i) time was marked by enlargement and eastward encroachment of both arms of the sea (fig. 17). Tributaries of the northern river system began to encroach on the drainage area of the southern river system by stream capture. The miogeosynclinal carbonate banks of southern Idaho (Monroe Canyon Limestone and Scott Peak Formation) continued to develop without appreciable terrigenous contamination. In the embryonic Big Snowy basin in southwest Montana, the carbonate area (Otter Formation equivalent) received significant amounts of clay and silt from the same northeastern sources that supplied the nearshore sands (Kibbey Sandstone). A small area of shale also began to develop in a depression near the mouth of that basin.

The pure carbonates of southern Idaho were protected from terrigenous influx by a submarine or sporadically emergent barrier that extended across the neck of the embryonic Wyoming basin. East of this barrier was a lagoonal belt of fine terrigenous sediments (Horseshoe Shale Member of Amsden Formation) bordered on the east by sand banks.

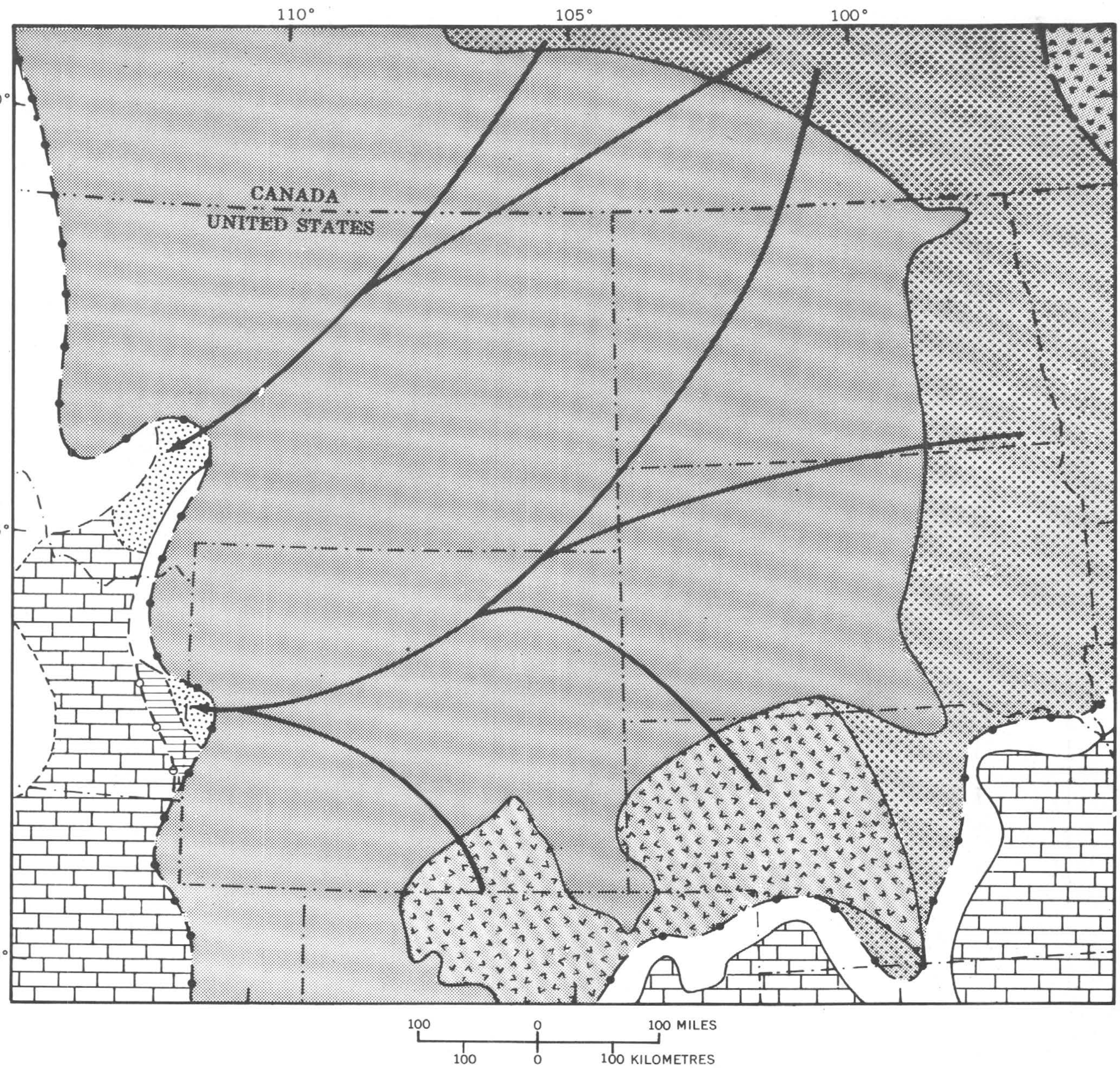

FIGURE 16.—Paleogeographic map of northern Cordilleran region during latest Meramecian (foraminiferal Zone 15) time. See figure 15 for explanation.

bars, and beaches (Darwin Sandstone Member of Amsden Formation). In southwesternmost Wyoming and northeastern Utah, the Bannock uplift (B), an emergent area of carbonate rocks that contributed little or no terrigenous debris, began to take form. During this period, the carbonate banks of northern Utah and part of southern Idaho received influxes of clay derived from the Antler orogenic belt to the west (Paymaster Member of Great Blue Formation, Long Trail Shale Member of Great Blue Limestone, Doughnut Formation).

MIDDLE CHESTERIAN

Middle Chesterian (Zone 17) time was marked by enlargement of the Big Snowy basin across Montana into the Dakotas and continued encroachment of streams supplying the Big Snowy basin on the original drainage area of the southern river system (fig. 18). Deposition in the Big Snowy basin continued to consist mostly of limestone and shale (Otter Formation) flanked by an eastern sand belt (Kibbey Sandstone). The expansion of the Big Snowy basin was limited to the south by the growth

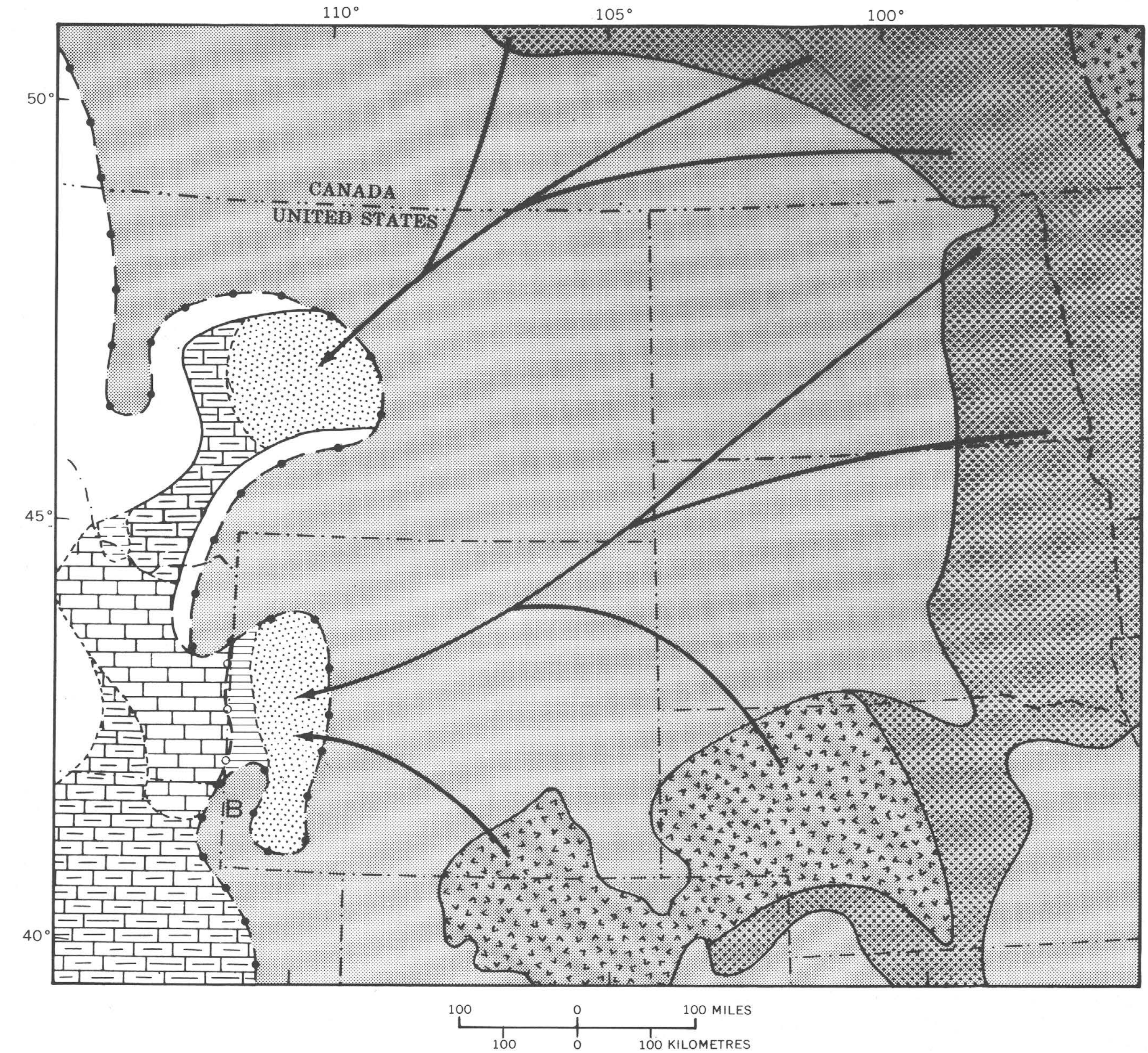

FIGURE 17.—Paleogeographic map of northern Cordilleran region during earliest Chesterian (foraminiferal Zone 16i) time. See figure 15 for explanation.

of the Southern Montana arch (S), which formed an emergent barrier separating the Big Snowy basin from the expanding Wyoming basin.

The Bannock uplift (B) restricted the opening of the Wyoming basin. Deposition in Wyoming consisted of an eastern nearshore sand (Darwin Sandstone Member) adjacent to a narrow lagoon (Horseshoe Shale Member) to the west, which was in turn separated by a barrier from the carbonate banks of southern Idaho (Monroe Canyon Limestone, Surrett Canyon Formation, and Great Blue Limestone) and westernmost Wyoming (Moffat Trail Limestone Member of Amsden Formation). The Antler orogenic belt supplied little clay, so that a pure carbonate belt extended from Idaho southward across northwestern Utah (Great Blue Limestone).

A third marine incursion took place in the Uinta basin of Utah and Colorado, where the Wyoming sea extended southward to a largely submarine barrier that separated this sea from the waters of the mio-

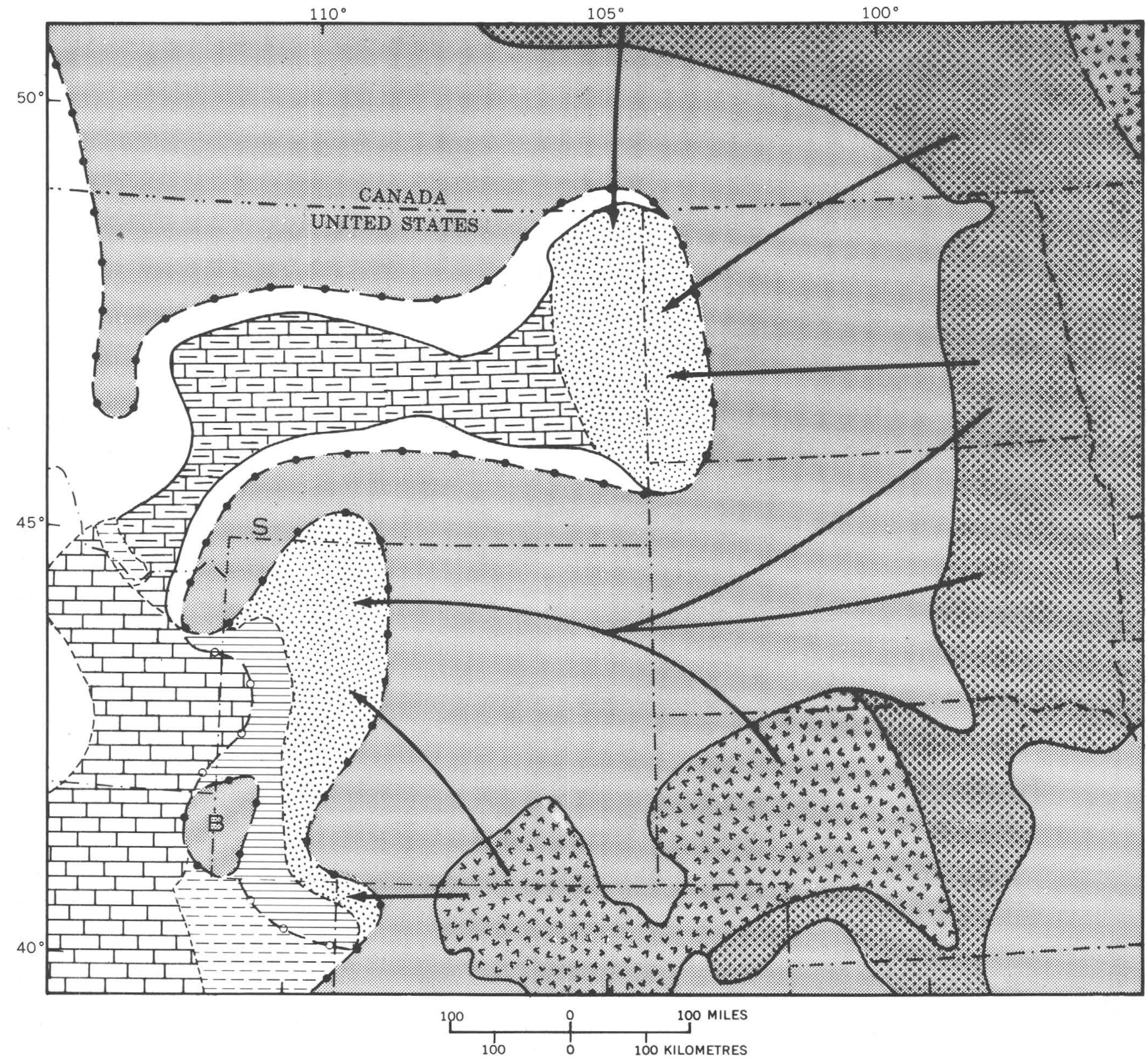

FIGURE 18.—Paleogeographic map of northern Cordilleran region during middle Chesterian (foraminiferal Zone 17) time. See figure 15 for explanation.

geosynclinal trough. The Uinta basin was receiving fine terrigenous sediment (Doughnut Formation), whose source is unknown and was probably outside the area of this study.

LATE CHESTERIAN

The Big Snowy basin expanded to its maximum areal extent in late Chesterian (Zone 18) time (fig. 19). In addition to nearshore sand (Kibbey Sandstone) and offshore shaly carbonates (Otter Formation), dark shale (Heath Formation) formed in the deeper waters of the axial region of the Big Snowy basin.

The Wyoming basin expanded with enlargement of its restricted lagoonal facies (Horseshoe Shale Member) through most of the basin during this time. Expansion of the Wyoming basin restricted the Southern Montana arch (S) to a narrow peninsula.

The Bannock uplift (B) continued to grow and exert its influence on the restricted mouth of the Wyoming basin. The pure carbonate banks of southern Idaho (Monroe Canyon Limestone, Surrett Canyon Formation, and Great Blue Limestone) and westernmost Wyoming (Moffat Trail Limestone

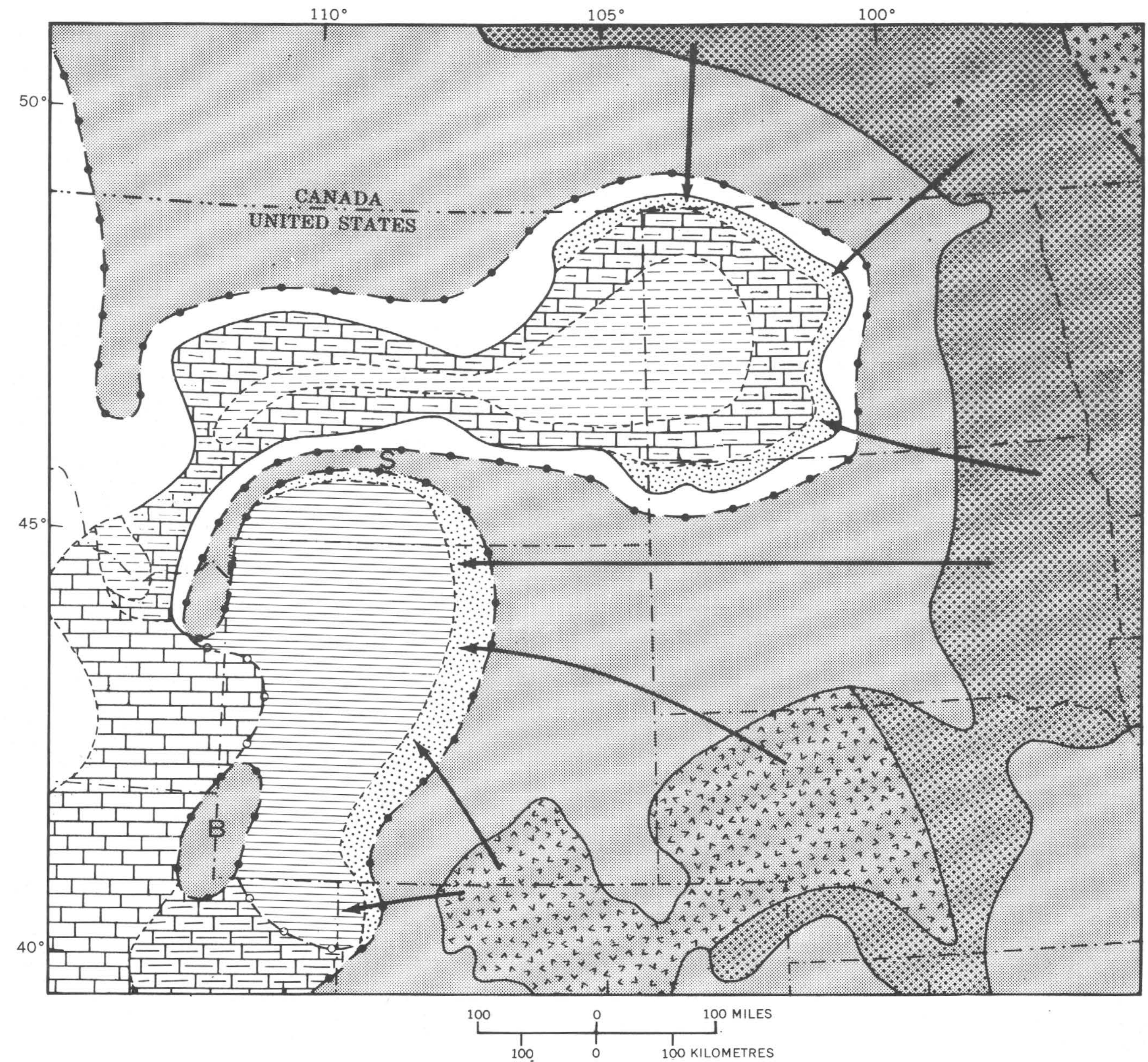

FIGURE 19.—Paleogeographic map of the northern Cordilleran region during late Chesterian (foraminiferal Zone 18) time. See figure 15 for explanation.

Member) attained their maximum areal extent. The Uinta basin was characterized by shaly carbonate deposits (Doughnut Formation).

LATEST CHESTERIAN

Latest Chesterian (Zone 19) was a time of major earth movement in Montana, where the sea was drained by the emergence of the Big Snowy uplift (BS) (fig. 20). Evidence for complete withdrawal of the sea from this area is largely lithostratigraphic; more detailed paleontologic information, particularly studies of Foraminifera, is needed to determine whether some remnants of the Big Snowy sea remained in the area shown on the map as land.

Although enlargement of the Wyoming basin was minimal, its northern shore pushed slightly northward across the Southern Montana arch, whose influence as a depositional barrier terminated during this time. Principal transport of terrigenous detritus continued to be from sources on the Transcontinental arch to the east and southeast of the basin. Meanwhile, the Bannock uplift (B) attained its maximum development, narrowing the restricted

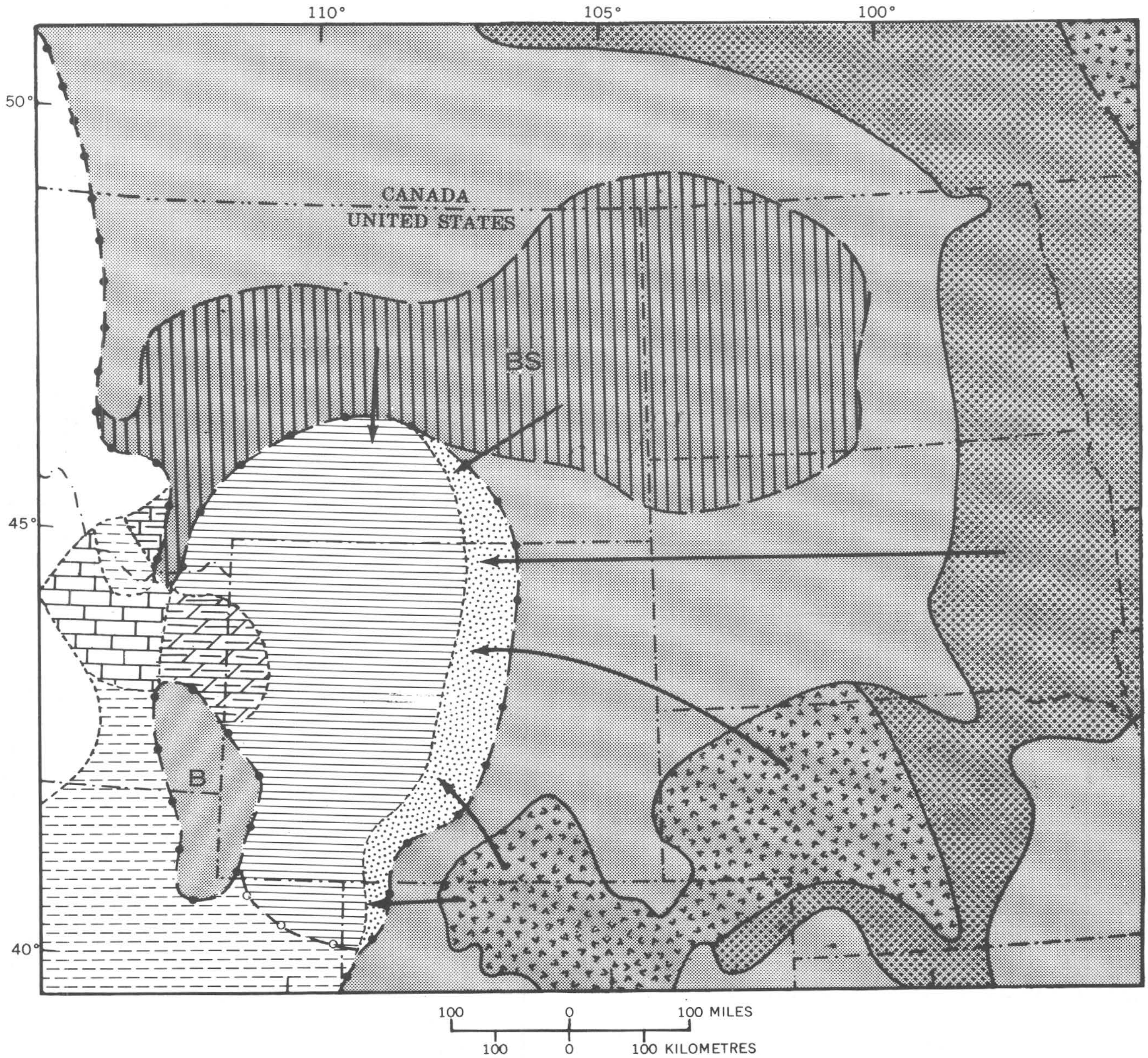

FIGURE 20.—Paleogeographic map of northern Cordilleran region during latest Chesterian (foraminiferal Zone 19) time. See figure 15 for explanation.

mouth of the Wyoming basin in Idaho. Evidently the barrier formerly present across this mouth became less restrictive because a carbonate-shale facies (Ranchester Limestone Member of Amsden Formation) began to develop immediately east of the mouth in Wyoming, implying freer communication with the waters of the miogeosyncline. This facies, which was predominantly dolomitic, graded eastward into the large area of lagoonal terrigenous sediments (Horseshoe Shale Member) that occupied most of the Wyoming basin.

The pure carbonate banks in the miogeosyncline were largely covered by fine terrigenous sediment (Manning Canyon Shale) in northern Utah and southeastern Idaho, probably from western sources.

PENNSYLVANIAN HISTORY

EARLY MORROWAN

During early Morrowan (lower Zone 20) time, a great expansion of the intracratonic Wyoming sea took place. It spread northward to cover most of Montana, eastward into the Dakotas and Nebraska, and breached the Transcontinental arch across the southeast corner of Wyoming and northeastern Colorado to mingle with the waters of the Mid-

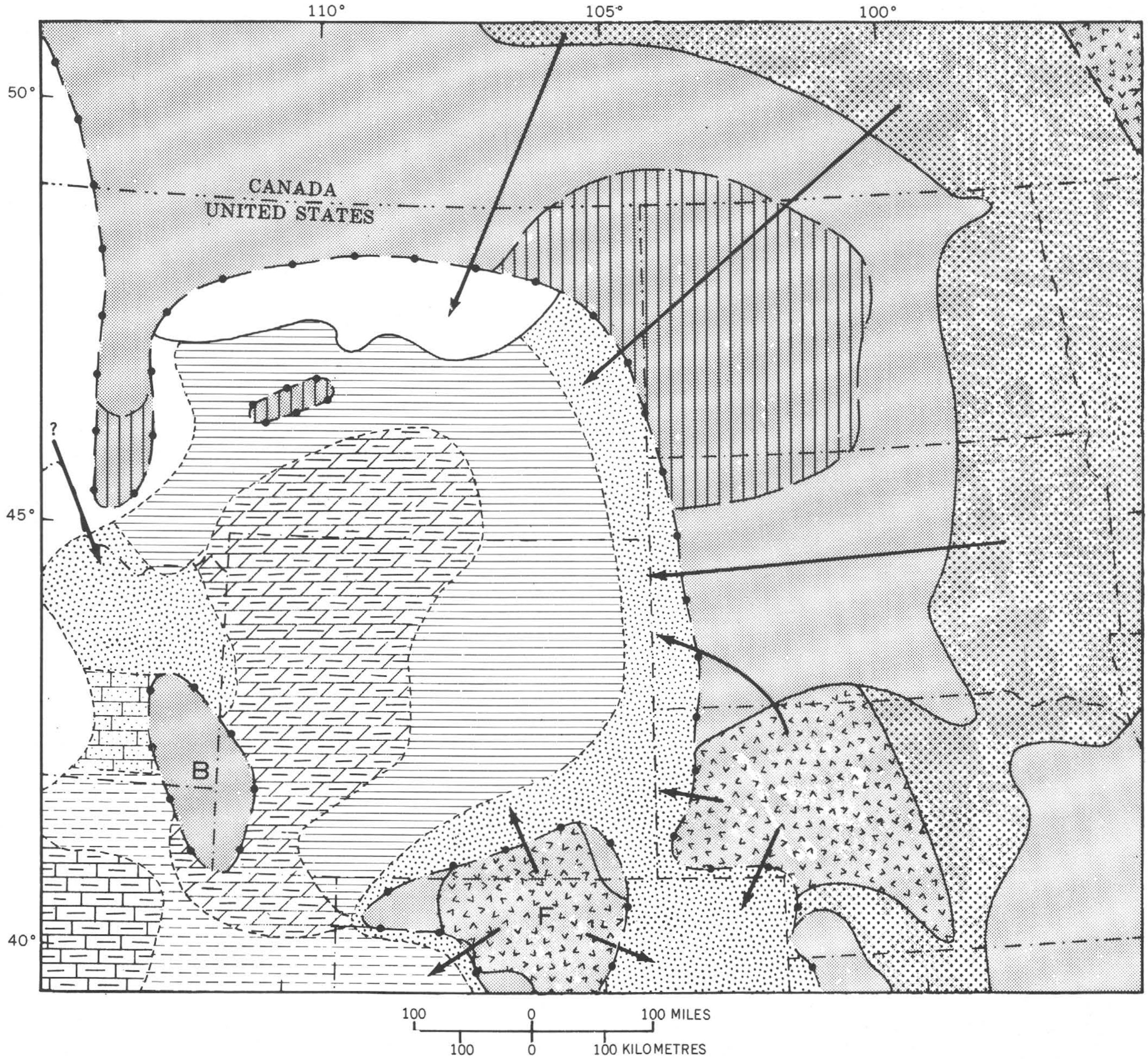

FIGURE 21.—Paleogeographic map of northern Cordilleran region in early Morrowan (lower part of foraminiferal Zone 20) time. See figure 15 for explanation.

continent sea (fig. 21). Sources of terrigenous debris were now available northeast, east, and southeast of the Wyoming basin. The mouth of the basin was less restricted than before but was still partly blocked by the Bannock uplift (B), which was diminishing in areal extent. At the southeast end of the basin, a highland area composed mostly of Precambrian crystalline rocks at the north end of the Front Range uplift (F) began to influence sedimentation (Casper and Fountain Formations) in that area.

Roughly concentric sedimentation consisted of a nearshore sand belt ("Bell Sand" in Minnelusa Formation, Division VI of Hartville Formation), an intermediate offshore lagoonal facies (Horseshoe Shale Member of Amsden Formation, Tyler Formation) and an approximately central dolomitic carbonate-shale facies (Ranchester Limestone Member of Amsden Formation). In Montana, a small island in the area now occupied by the Castle and Little Belt Mountains was all that remained of the Big Snowy uplift.

At the mouth of the Wyoming basin in south-central Idaho and westernmost Wyoming was a flood of sand (Tyler Formation equivalent), probably from an unknown western source, which may have acted as a restrictive factor. This sand graded southward into carbonate and sand deposits ("Manning Canyon Shale") in the miogeosyncline west of the Bannock uplift in southeastern Idaho. Marine shale and mixed shale and carbonate were deposited in the miogeosyncline of northern Utah (Manning Canyon Shale) and northwestern Colorado (Belden Shale).

EARLY ATOKAN

The Wyoming basin continued to expand during early Atokan (lower Zone 21) time (fig. 22). The island area of the Bannock uplift was completely inundated, so that the waters of the miogeosyncline had freer access to the Wyoming sea. Connections with the Midcontinent basin across the Transcontinental arch were also widened, owing to the diminution of the Front Range uplift (F) in northern Colorado. At the same time, tectonism that began in the late Morrowan produced a large island area, the Montana uplift (M), that covered most of south-central and southeast Montana and extended into northwest South Dakota. Another island area, the Pathfinder uplift (P), emerged in southeastern Wy-

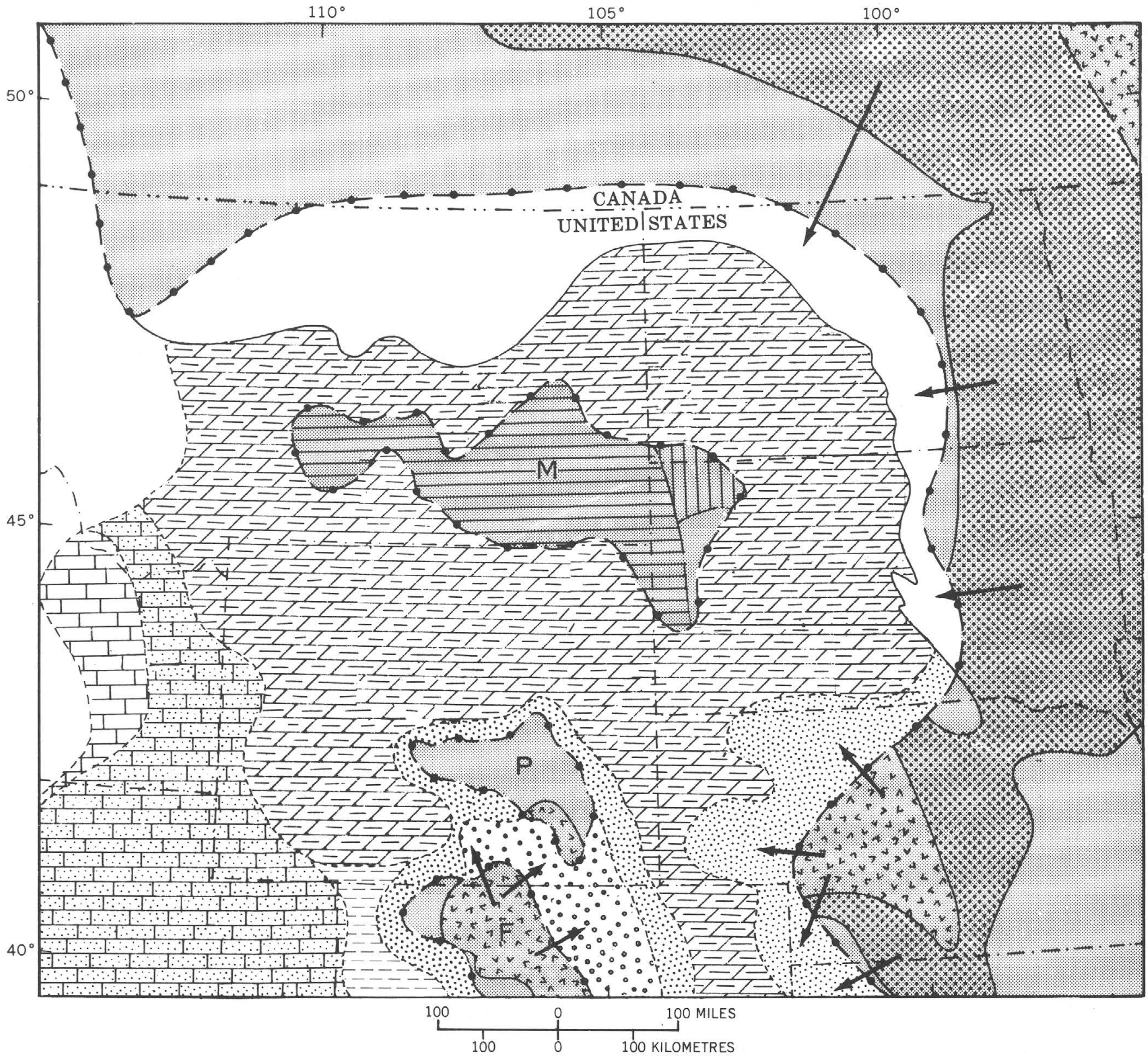

FIGURE 22.—Paleogeographic map of northern Cordilleran region during early Atokan (lower part of foraminiferal Zone 21) time. See figure 15 for explanation.

oming. The Montana uplift evidently had little effect on the adjacent sedimentation, suggesting that it was a lowland terrane. The Pathfinder uplift was bordered by a narrow sand belt (Casper Formation) and also contributed to the arkose (Fountain Formation) deposited in the narrow strait between the Pathfinder and Front Range uplifts.

A marginal nearshore sand facies presumably ringed most of the basin, but subsequent erosion has removed all traces of this belt except in western Nebraska, where two sand lobes seem to be related to an adjacent highland area on the remnant of the Transcontinental arch. Freer communication with the miogeosynclinal sea and diminution of the supply of fine terrigenous detritus eliminated the lagoonal terrigenous facies of previous times. Thus, the entire offshore part of the basin was occupied by a dolomitic carbonate-shale-sandstone facies (Ranchester Limestone Member of Amsden Formation, Minnelusa Formation, Hartville Formation, Devils Pocket Formation). Meanwhile, sedimentation in the miogeosyncline was characterized by sand and sandy carbonate (Quadrant, Wells, and Oquirrh Formations) except for a small area of shale deposition in northwestern Colorado (Belden Shale). The sands marked the beginning of a great flood of sand that spread over most of the Wyoming basin during later Pennsylvanian time.

REGISTER OF SELECTED STRATIGRAPHIC SECTIONS (PLATES 4–9)

[No. 30 is in Montana; all other sections are in Wyoming]

Section		Geographic location		
No.	Name	Township and range	County	Source of data
1	Meadow Ranch	NE¼ sec. 25, T. 22 N., R. 88 W	Carbon	Measured by W. J. Sando and K. R. Moore, 1964.
2	Buck Spring	NW¼ sec. 33, T. 23 N., R. 88 W	do	Do.
3	Sweetwater Canyon	SE¼ sec. 27, T. 29, N., R. 97 W	Fremont	Do.
4	Long Creek Canyon	Sec. 23, T. 32 N., R. 94 W	do	Modified from Keefer and Van Lieu (1966, pl. 4).
5	Beaver Creek	NW¼ sec. 6, T. 29 N., R. 97 W	do	Biggs (1951, p. 118–121, pl. 1).
6	South Pass	Center sec. 9, T. 30 N., R. 99 W	do	Shaw (1955a, fig. 1).
7	Cherry Creek	SE¼NW¼ sec. 19, T. 31 N., R. 99 W	do	Shaw and Bell (1955, fig. 1).
8	Sinks Canyon	SE¼ sec. 18, T. 32 N., R. 100 W	do	Amsden modified from Biggs (1951, p. 109–113, pl. 1); Madison measured by W. J. Sando and K. R. Moore, 1964.
9	Washakie Reservoir	SW¼ sec. 18, T. 1 S., R. 2 W	do	Measured by W. J. Sando and K. R. Moore, 1964.
10	Bull Lake Creek	SW¼ sec. 2, T. 2 N., R. 4 W	do	Do.
11	Dinwoody Canyon	Sec. 1, T. 4 N., R. 6 W	do	Amsden modified from Biggs (1951, p. 76–83, pl. 1); Madison measured by W. J. Sando and K. R. Moore, 1964.
12	Little Warm Spring Canyon.	Secs. 14 and 15, T. 41 N., R. 107 W (Amsden); sec. 31, T. 42 N., R. 107 W. (Madison).	do	Amsden modified from Keefer (1957, p. 170); Madison measured by W. J. Sando and K. R. Moore, 1964.
13	Soda Creek	Sec. 5, T. 45 N., R. 110 W	Teton	Measured by J. D. Love, 1945.
14	Horse Creek	SW¼ sec. 19, T. 43 N., R. 106 W	Fremont	Amsden from Biggs (1951, p. 54–60, pl. 1); Madison measured by W. J. Sando and K. R. Moore, 1964.
15	Livingston Ranch	SW¼SW¼ sec. 29, T. 43 N., R. 106 W.	do	Measured by W. J. Sando and K. R. Moore, 1964.
16	Wiggins Fork	SW¼ sec. 7, T. 42 N., R. 105 W	do	Do.
17	Sheep Ridge	Secs. 10 and 35, T. 7 N., R. 1 E	Fremont and Hot Springs.	Keefer and Van Lieu (1966, pl. 3).
18	Wind River Canyon	Sec. 30, T. 7 N., R. 6 E	Hot Springs	Modified from Keefer and Van Lieu (1966, pl. 3).
19	Brown Spring Draw	NE¼ sec. 35, T. 41 N., R. 92 W	do	Measured by W. J. Sando and K. R. Moore, 1965.
20	Snyder Creek	Sec. 20, T. 40 N., R. 89 W	Fremont	Keefer and Van Lieu (1966, pl. 3).
21	Middle Buffalo Creek	SE¼ sec. 21, T. 40 N., R. 86 W	Natrona	Measured by W. J. Sando and K. R. Moore, 1965; thickness of Ranchester from Woodward (1957, p. 259).
22	Middle Powder River	Secs. 29 and 30, T. 42 N., R. 84 W (Amsden); SE¼ sec. 3, T. 42 N., R. 85 W. (Madison).	Johnson	Amsden from Agatston (1954, p. 568); Madison measured by W. J. Sando and K. R. Moore, 1965.
23	North Crazy Woman Creek.	SW¼NW¼ sec. 27, T. 49 N., R. 83 W	do	Modified from Hose (1955, p. 109–110) with emendations from measurements of W. J. Sando and K. R. Moore, 1965.
24	South Rock Creek	SW¼ sec. 25, T. 52 N., R. 84 W	do	Modified from Mapel (1959, p. 21) with emendations from measurements by W. J. Sando and K. R. Moore, 1965

REGISTER OF SELECTED STRATIGRAPHIC SECTIONS (PLATES 4–9)—Continued

Section No.	Section Name	Geographic location: Township and range	Geographic location: County	Source of data
25	Big Goose Creek	SW¼ sec. 35, T. 55 N., R. 86 W	Sheridan	Agatston (1954, p. 569).
26	Wolf Creek	SE¼ sec. 5, T. 55 N., R. 86 W	do	Measured by W. J. Sando and K. R. Moore, 1966.
27	Little Tongue River —U.S. 14.	Secs. 14 and 15, T. 56 N., R. 87 W. (Amsden); NE¼ sec. 22, T. 56 N., R. 87 W. (Madison and lower Darwin).	do	Gorman (1962, p. 148–158) modified by measurements of W. J. Sando and K. R. Moore, 1965.
28	Amsden Creek	SW¼ sec. 34, T. 57 N., R. 87 W	do	Measured by W. J. Sando and K. R. Moore, 1965.
29	Little Bighorn Canyon.	Sec. 20, T. 58 N., R. 89 W	do	Modified from Agatston, 1954, p. 569).
30	Devils Canyon	S½ sec. 34 and W½ sec. 35, T. 9 S., R. 28 E.	Carbon, Mont	Modified from Richards (1955, p. 28).
31	Cottonwood Canyon	SE¼ sec. 33, T. 57 N., R. 93 W	Big Horn	Measured by W. J. Sando and K. R. Moore, 1966.
32	Five Springs Creek	NW¼SW¼ sec. 30, T. 56 N., R. 92 W	do	Do.
33	Sheep Mountain	NW¼ sec. 2, T. 53 N., R. 84 W	do	Do.
34	Shell Canyon	NE¼ sec. 17, T. 53 N., R. 90 W	do	Do.
35	Paintrock Creek	NE¼ sec. 26, T. 50 N., R. 89 W	do	Do.
36	Tensleep Canyon	Secs. 5, 6, and 8, T. 47 N., R. 87 W	Washakie	Modified from Wilson (1962, p. 128–129).
37	Clarks Fork Canyon	NE¼SE¼ sec. 6, T. 56 N., R. 103 W	Park	Measured by W. J. Sando and K. R. Moore, 1966.
38	Shoshone Canyon	NE¼ sec. 5, T. 52 N., R. 102 W	do	Measured by W. J. Sando and K. R. Moore, 1966; thickness of Horseshoe Shale Member from Stipp (1947, p. 277).
39	Tip Top	Mobil Oil Co. Paleozoic test well 22–19–G, Tip Top unit, NW¼NW¼ sec. 19, T. 28 N., R. 113 W.	Sublette	Modified from Marzolf (1965, sheet 2).
40	Moffat Trail	NW¼NE¼ sec. 3, T. 33 N., R. 117 W.	Lincoln	Measured by J. T. Dutro, Jr., and Mario Suarez, 1966.
41	Covey Cutoff Trail	NW¼NE¼ sec. 27, T. 34 N., R. 117 W.	do	Measured by J. S. Williams, 1927, modified by W. J. Sando and J. T. Dutro, Jr., 1958.
42	Haystack Peak	Center sec. 19, T. 34 N., R. 117 W	do	Measured by W. J. Sando and J. T. Dutro, Jr., 1957 and 1958.
43	South Indian Creek	NE¼ sec. 14, T. 38 N., R. 118 W	do	Measured by J. T. Dutro, Jr., and Mario Suarez, 1966.
44	Hoback Canyon	Sec. 2, T. 38 N., R. 115 W	Teton	Measured by J. T. Dutro, Jr., and W. J. Sando, 1959.
45	Darwin Peak	S½ sec. 28, T. 40 N., R. 112 W	do	Measured by Eliot Blackweller, 1911.
46	Phillips Canyon	SW¼ sec. 16, T. 41 N., R. 117 W	do	Measured by J. T. Dutro, Jr., and Mario Suarez, 1966.
47	Glory Mountain	SE¼ sec. 13, T. 41 N., R. 118 W	do	Do.
48	Darby Canyon	SE¼ sec. 15, T. 43 N., R. 118 W	do	Measured by W. J. Sando and J. T. Dutro, Jr., 1959.
49	Berry Creek	NW¼ sec. 22, T. 47 N., R. 116 W	do	Measured by J. D. Love, 1955.
50	Elk Ridge	SW¼ sec. 26, T. 47 N., R. 116 W	do	Measured by J. D. Love, 1968.

REGISTER OF FOSSIL COLLECTIONS

This register includes locality data on all collections of Amsden fossils described and discussed in the various parts of this report, as well as pertinent data on all collections reported by other authors from Wyoming localities. Except for a few miscellaneous collections found by Gordon in the U.S. National Museum, the collections are arranged geographically by mountain ranges and are assigned master collection numbers that are keyed to the locality map (pl. 3), master faunal list (table 8), columnar sections. (pls. 4–9), and descriptions of fossils in Mamet (1975), Sando (1975), Gordon (1975), Gordon and Pojeta (1975), Gordon and Yochelson (1975), and Sohn (1975). We take no responsibility for the accuracy of fossil identifications in collections that we have not studied; these are indicated by asterisks (*) in the register.

Collections designated USGS with PC ending are in the upper Paleozoic collections of the U.S. Geological Survey, Washington, D.C. A few collections are in the paleobotanical collections of the U.S. Geological Survey, Washington, D.C. and are so indicated. Collections designated USGS with f prefix are in the foraminiferal collections of the U.S. Geological Survey, Washington, D.C. Collections designated USNM are in the U.S. National Museum, Washington, D.C. Collections designated YPM are in the Yale Peabody Museum, New Haven, Conn. Collections designated UW are at the University of Wyoming, Laramie, Wyo. Collections designated UM are at the University of Missouri, Columbia, Mo.

RAWLINS HILLS

1. Cherokee Spring. USGS 5441–PC. Geographic location uncertain, probably in SW¼ sec. 11, T. 21 N., R. 88 W., Carbon County. Horseshoe Member, *Neokoninckophyllum hamatilis* Zone Pennsylvanian (Morrowan). Collected by A. J. Collier, 1924(?).
2. Cherokee Spring. USGS 8071–PC. About three-quarters of a mile west of Cherokee Spring, probably in SW¼ sec. 11, T. 21 N., R. 88 W., Carbon County. Horseshoe Member, *Neokoninckophyllum hamatilis* Zone, Pennsylvanian (Morrowan). Collected by E. W. Kindle, 1901.
3. Cherokee Spring. USGS 3139–PC. NW¼SW¼ sec. 11, T. 21 N., R. 88 W., Carbon County. Limestone bed in Horseshoe Member about 60 ft above base of Amsden Formation, *Neokoninckophyllum hamatilis* Zone, Pennsylvanian (Morrowan). Collected by V. H. Barnett, 1907. Fossils listed by Branson (1939, p. 1213).
4. Cherokee Peak. USGS 3140–PC. NE¼ sec. 10, T. 21 N., R. 88 W., Carbon County. Horseshoe Member, *Neokoninckophyllum hamatilis* Zone, Pennsylvanian (Morrowan). Collected by V. H. Barnett, 1907.
5. Cherokee Peak. USGS 3085–PC. SE¼NE¼ sec. 10, T. 21 N., R. 88 W., Carbon County. Horseshoe Member, *Neokoninckophyllum hamatilis* Zone, Pennsylvanian (Morrowan). Collected by M. A. Pishel, 1906.
6. Rawlins US 287. USGS 3843–PC. Geographic location uncertain, probably in NW¼NW¼ sec. 32, T. 22 N., R. 87 W., Carbon County, about 3 miles north of Rawlins. Upper limestone of Amsden Formation, Ranchester Member, *Mesolobus* Zone, Pennsylvanian (Atokan). Collected by W. T. Lee, 1921. Fossils originally identified by G. H. Girty and listed in Lee (1927, p. 72); subsequently listed by Branson (1939, p. 1213) and Burk (1954, p. 3).
7. Meadow Ranch. USGS 21727–PC. SW¼NE¼ sec. 25, T. 22 N., R. 88 W., Carbon County. Limestone bed 45–46 ft above base of Amsden Formation, Horseshoe Member, *Neokoninckophyllum hamatilis* Zone, Pennsylvanian (Morrowan). Collected by W. J. Sando and K. R. Moore, 1964. Apparently same assemblage as listed by Shaw (1955, p. 63, fig. 1, faunas 1 and 2).
8. Meadow Ranch. USGS 21728–PC. SW¼NE¼ sec. 25, T. 22 N., R. 88 W., Carbon County. Limestone bed 46–46.5 ft above base of Amsden Formation, Horseshoe Member, Pennsylvanian (Morrowan?). Collected by W. J. Sando and K. R. Moore, 1964.

*9. Meadow Ranch. NE¼ sec. 25, T. 22 N., R. 88 W., Carbon County. Shale about 54 ft above base of Amsden Formation, Horseshoe Member, Pennsylvanian. Collected by A. B. Shaw. Fossils listed by Shaw (1955a, p. 63, fig. 1, fauna 3).

*10. Meadow Ranch. NE¼ sec. 25, T. 22 N., R. 88 W., Carbon County. Limestone about 57 ft above base of Amsden Formation, Horseshoe Member, Pennsylvanian. Collected by A. B. Shaw. Fossils listed by Shaw (1955a, p. 63, fig. 1, fauna 4).

*11. Meadow Ranch. NE¼ sec. 25, T. 22 N., R. 88 W., Carbon County. Limestone about 70 ft above base of Amsden Formation, Horseshoe Member, Pennsylvanian. Collected by A. B. Shaw. Fossils listed by Shaw (1955a, p. 63, fig. 1, fauna 5).

*12. Meadow Ranch. Secs. 10 and 25, T. 22 N., R. 88 W., Carbon County. Limestone about 85 ft above base base of Amsden Formation, Ranchester Member, Pennsylvanian. Fossils collected and listed by Branson (1939, p. 1213) and Shaw (1955a, p. 63, fig. 1, fauna 6).

13. Meadow Ranch. USGS 21729–PC. SW¼NE¼ sec. 25, T. 22 N., R. 88 W., Carbon County. Limestone bed 92.5–95.5 ft above base of Amsden Formation, Ranchester Member, Pennsylvanian (Morrowan). Collected by W. J. Sando and K. R. Moore, 1964.
14. Buck Spring. USGS 21725–PC. NW¼ sec. 33, T 23 N., R. 88 W., Carbon County. Float from limestone 140.5–142.5 ft above base of Amsden Formation, Ranchester Member, Pennsylvanian (Morrowan). Collected by W. J. Sando and K. R. Moore, 1964.
15. Belle Springs. USGS 5864–PC. Near Belle Springs, probably in SE¼NE¼ sec. 29, T. 23 N., R. 88 W., Carbon County. Limestone just below top of Amsden Formation, Ranchester Member, *Mesolobus* Zone, Pennsylvanian (Atokan). Collected by C. E. Dobbin, 1925.

GRANITE MOUNTAINS

*16. East Canyon Creek. Sec. 23, T. 33 N., R. 89 W., Natrona County. Carbonate about 145 ft above base of Amsden Formation, Ranchester Member, Pennsylvanian? Collected by J. L. Weitz, 1953. Fossils listed by Love (1954. col. 25, colln. 1) and Keefer and Van Lieu (1966, table 6).

17. Long Creek Canyon. USGS 19236–PC. SW¼ sec. 23, T. 32 N., R. 94 W., Fremont County. Carbonate about 135 ft above base of Amsden Formation, Ranchester Member, Pennsylvanian? Collected by J. D. Love and V. L. White, 1950. Fossil listed by Love (1954, col. 23, colln. 1) and Keefer and Van Lieu (1966, table 6).

WIND RIVER RANGE

*18. Sweetwater Canyon. Sec. 27, T. 29 N., R. 97 W., Fremont County. Limestone about 240 ft above base of Amsden Formation, Ranchester Member, Pennsylvanian? Fossils from unpublished thesis by W. G. Bell listed by Keefer and Van Lieu (1966, table 6).

19. Beaver Creek. UW 2997/6A. NW¼ sec. 6, T. 29 N., R 97 W., Fremont County. Float 45 ft above base of Amsden Formation, Horseshoe Member, *Anthracospirifer welleri-shawi* Zone, Late Mississippian (Chesterian). Collection evidently made from float because it includes a mixture of forms from two subzones and a coral from the Madison Limestone. Collected by C. A. Biggs, 1950. Fossils listed by Burk (1954, p. 6).
20. Tweed Creek. USGS 19285–PC. South side of Cherry Creek, 20 miles south of Lander, probably in SE¼ sec. 22, T. 30 N., R. 99 W., Fremont County. Float from Amsden Formation, Horseshoe Member, *Anthracospirifer welleri-shawi* Zone, *Carlinia amsdeniana* Subzone?, Late Mississippian (Chesterian). Collected by C. C. Branson, 1939.

21. South Pass. UW 3099/9B. Center sec. 9, T. 30 N., R. 99 W., Fremont County. Sandstone 50 ft above base of Amsden Formation, Horseshoe Member, *Anthracospirifer welleri-shawi* Zone, Late Mississippian (Chesterian). Collected by C. A. Biggs, 1950. Fossils listed by Burk (1954, p. 7), Shaw (1955a, p. 63, fig. 1), and Keefer and Van Lieu (1966, table 6).

22. South Pass. UW 3099/9A. Center sec. 9, T. 30 N., R. 99 W., Fremont County. Shale 55 ft above base of Amsden Formation, Horseshoe Member, *Anthracospirifer welleri-shawi* Zone, *Carlinia amsdeniana* Subzone, Late Mississippian (Chesterian). Collected by C. A. Biggs, 1950. Fossils listed by Burk (1954, p. 6) and Shaw (1955a, p. 63, fig. 1).

*23. South Pass. Center sec. 9, T. 30 N., R. 99 W., Fremont County. Float about 75 ft above base of Horseshoe Member, Late Mississippian? Fossil listed by Shaw (1955a, p. 63, fig. 1) and Keefer and Van Lieu (1966, table 6).

24. Amsden Hill. UM collections. About 4 miles southeast of Little Popo Agie River, probably in SW¼ sec. 32, T. 31 N., R. 99 W., Fremont County. Purple limestone float below red shale in lower part of Amsden Formation, Horseshoe Member, *Anthracospirifer welleri-shawi* Zone, Late Mississippian (Chesterian). Fossils listed by Morey (1935, p. 474–482).

25. Amsden Hill. UM collections. About 4 miles southeast of Little Popo Agie River, probably in SW¼ sec. 32, T. 31 N., R. 99 W., Fremont County. Float from middle red shale unit in lower part of Amsden Formation, Horseshoe Member, *Anthracospirifer welleri-shawi* Zone, Late Mississippian (Chesterian). Fossils listed by Morey (1935, p. 474–482).

26. Amsden Hill. USGS 19284–PC and USNM 487. Amsden Hill locality of Morey (1935), probably in SW¼ sec. 32, T. 31 N., R. 99 W., Fremont County. Float from Amsden Formation, Horseshoe Member, *Anthracospirifer welleri-shawi* Zone, Late Mississippian (Chesterian). This is a composite of two collections:

26a. USGS 19284–PC. *Composita poposiensis* Subzone. Collected by C. C. Branson, 1939.

26b. USNM 487. *Composita poposiensis* Subzone and *Car. linia amsdeniana* Subzone. Collected by Branson and Hackett, date unknown.

27. Cherry Creek. USGS 19283–PC. South side of Cherry Creek, 15 miles south of Lander, probably in sec. 30, T. 31 N., R. 99 W., Fremont County. Float from Horseshoe Member, *Anthracospirifer welleri-shawi* Zone, *Carlinia amsdeniana* Subzone, Late Mississippian (Chesterian). Collected by C. C. Branson, 1939.

28. Cherry Creek. UW 3199/19B2. North side of Cherry Creek, SE¼NW¼ sec. 19, T. 31 N., R. 99 W., Fremont County. Sandstone 45 ft above base of Amsden Formation, Horseshoe Member, *Anthracospirifer welleri-shawi* Zone, *Carlinia amsdeniana* Subzone, Late Mississippian (Chesterian). Collected by W. G. Bell, 1954.

29. Cherry Creek. UW 3199/19B3. North side of Cherry Creek, SE¼NW¼ sec. 19, T. 31 N., R. 99 W., Fremont County. Sandstone 46 ft above base of Amsden Formation, Horseshoe Member, *Anthracospirifer welleri-shawi* Zone, Late Mississippian (Chesterian). Collected by W. G. Bell, 1954. Fossils listed by Shaw and Bell (1955, fig. 1) and Shaw (1955a, p. 62, fig. 1).

30. Cherry Creek. UW 3199/19B4. North side of Cherry Creek, SE¼NW¼ sec 19, T. 31 N. R. 99 W., Fremont County. Sandstone 47 ft above base of Amsden Formation, Horseshoe Member, *Anthracospirifer welleri-shawi* Zone, *Carlinia amsdeniana* Subzone, Late Mississippian (Chesterian). Collected by W. G. Bell, 1954. Fossils listed by Shaw and Bell (1955, fig. 1) and Shaw (1955a, p. 62, fig. 1).

31. Cherry Creek. UW 3199/19B5. North side of Cherry Creek, SE¼NW¼ sec. 19, T. 31 N., R. 99 W., Fremont County. Limestone 48 ft above base of Amsden Formation, Horseshoe Member, *Anthracospirifer welleri-shawi* Zone, *Carlinia amsdeniana* Subzone, Late Mississippian (Chesterian). Collected by W. G. Bell, 1954. Fossils listed by Shaw and Bell (1955, fig. 1) and Shaw (1955a, p. 62, fig. 1).

32. Cherry Creek. UW 3199/19B6. North side of Cherry Creek, SE¼NW¼ sec. 19, T. 31 N., R. 99 W., Fremont County. Sandstone 64 ft above base of Amsden Formation, Horseshoe Member, *Anthracospirifer welleri-shawi* Zone, *Composita poposiensis* Subzone, Late Mississippian (Chesterian). Collected by W. G. Bell, 1954. Fossils listed by Shaw and Bell (1955, fig. 1) and Shaw (1955a, p. 62, fig. 1).

*33. Cherry Creek. UW 3199/19B7. North side of Cherry Creek, SE¼NW¼ sec. 19, T. 31 N., R. 99 W., Fremont County. Sandstone 65 ft above base of Amsden Formation, Horseshoe Member, *Anthracospirifer welleri-shawi* Zone, *Composita poposiensis* Subzone, Late Mississippian (Chesterian). Collected by W. G. Bell, 1954. Fossils listed by Shaw and Bell (1955, fig. 1 and Shaw (1955a, p. 62, fig. 1).

34. Cherry Creek. UW 3199/19B8. North side of Cherry Creek, SE¼NW¼ sec. 19, T. 31 N., R. 99 W., Fremont County. Sandstone 67 ft above base of Amsden Formation, Horseshoe Member, *Anthracospirifer welleri-shawi* Zone, *Composita poposiensis* Subzone, Late Mississippian (Chesterian). Collected by W. G. Bell, 1954. Fossils listed by Shaw and Bell (1955, fig. 1) and Shaw (1955a, p. 62, fig. 1).

35. Cherry Creek. UW 3199/19A. NW¼ sec. 19, T. 31, N., R. 99 W., Fremont County. Float 60–90 ft above base of Amsden Formation, Horseshoe Member, *Anthracospirifer welleri-shawi* Zone, *Composita poposiensis* Subzone, Late Mississippian (Chesterian). Collected by C. A. Biggs, 1950. Fossils listed by Burk (1954, p. 7), Love (1954, col. 20, colln. 1), and Sadlick (1960, p. 1211, cephalopod only).

36. Cherry Creek. UM 2641–6832 (not inclusive), A–1577, A–1595, and USNM 487A. A composite of collections of uncertain location in or near sec. 19, T. 31 N., R. 99 W., Fremont County. Float about 50–80 ft above base of Amsden Formation, Horseshoe Member, *Anthracospirifer welleri-shawi* Zone, Late Mississippian (Chesterian). Collected by E. B. Branson and C. C. Branson and their associates prior to 1937. Includes most of the specimens listed by Branson and Greger (1918, p. 312) and Branson (1937, p. 652–653) from the southern Wind River Range. Love (1954, col. 20, colln. 2) also listed these fossils. Specimens from the Bull Ridge Member of the Madison Limestone at Bull Creek are excluded. Also included here are specimens collected by Branson and deposited

in the U.S. National Museum under USNM 487A. The collections are segregated below into locality categories suggested by labels that accompany the specimens:

36a. UM specimens labelled "Cherry Creek." Includes fossils from *Composita poposiensis* Subzone and *Carlinia amsdeniana* Subzone.

36b. UM specimens labelled "sec. 31, T. 19 N., R. 99 W." (actually sec. 19, T. 31 N., R. 99 W.). This may be the Amsden Hill locality of Morey (1935).

36c. UM specimens labelled "near Lander." *Composita poposiensis* Subzone.

36d. UM specimens labelled "Little Popo Agie River."

36e. USNM 487A, specimens labelled "Cherry Creek." *Composita poposiensis* Subzone.

37. Cherry Creek. UM collections. About 2 miles south of Little Popo Agie River in sec. 19, T. 31 N., R. 99 W., Fremont County. Float from lower part of Amsden Formation, Horseshoe Member, *Anthracospirifer welleri-shawi* Zone, Late Mississippian (Chesterian). Fossils listed by Morey (1935, p. 474–482).

38. Little Popo Agie Canyon. USGS 16397–PC. NW¼NW¼ sec. 19, T. 31 N., R. 99 W., Fremont County. Float from middle of Amsden Formation, Horseshoe Member, *Anthracospirifer welleri-shawi* Zone, *Composita poposiensis* Subzone?, Late Mississippian (Chesterian). Collected by L. G. Henbest and others, 1948.

39. Little Popo Agie Canyon. USGS 14025–PC. SE¼SE¼ sec. 13, T. 31 N., R. 100 W., Fremont County. Float from lower part of Amsden Formation, Horseshoe Member, *Anthracospirifer welleri-shawi* Zone, Late Mississippian (Chesterian). Collected by L. G. Henbest, 1948.

40. Bull Lake Creek. USGS 21676–PC. SW¼ sec. 2, T. 2 N., R. 4 W., Fremont County. Dolomite 40 ft above top of Darwin Member, Ranchester Member, Pennsylvanian (Morrowan). Collected by W. J. Sando and K. R. Moore, 1964.

WASHAKIE RANGE

41. Soda Creek. USGS 19156–PC. Fifty yards east of Forest Service trail where it goes over pass from Soda Creek to South Fork of Buffalo River, sec. 5, T. 45 N., R. 110 W., Teton County. Limestone and shale about 20–30 ft above base of Amsden Formation, Horseshoe Member, Late Mississippian (Chesterian). Collected by J. D. Love and H. R. Bergquist, 1945.

42. Horse Creek. UW 43106/19A. SW¼ sec. 19, T. 43 N., R. 106 W., Fremont County. Shale 88 ft above base of Amsden Formation, Horseshoe Member, *Anthracospirifer welleri-shawi* Zone, *Composita poposiensis* Subzone, Late Mississippian (Chesterian). Collected by C. A. Biggs, 1950. Fossils listed by Burk (1954, p. 7) and Shaw (1955a, p. 62, fig. 1). The material consists of loose silicified specimens that appear to have come from a level above Collection 43, which is 89 ft above the base of the Amsden.

43. Horse Creek. UW 43106/19B. SW¼ sec. 19, T. 43 N., R. 106 W., Fremont County. Limestone and shale 89.1 ft above base of Amsden Formation, Horseshoe Member, *Anthracospirifer welleri-shawi* Zone, Late Mississippian (Chesterian). Collected by C. A. Biggs, 1950. Fossils listed by Burk (1954, p. 8), Shaw (1955a, p. 62, fig. 1), and Keefer and Van Lieu (1966, table 6). Collection appears to represent a mixture of fossils from *Carlinia amsdeniana* Subzone (whitish speckled limestone and yellowish limestone matrix) and *Composita poposiensis* Subzone (loose silicified specimens). It also includes a brachiopod from the Madison Limestone.

44. Horse Creek, YPM 5154a–u, 20103, 20106. Sec. 19, T. 43 N., R. 106 W., Fremont County. Float probably about 90 ft above the base of Amsden Formation, Horseshoe Member, *Anthracospirifer welleri-shawi* Zone, Late Mississippian (Chesterian). Collected by J. D. Love, 1937.

45. Livingston Ranch. USGS 21719–PC. SW¼SW¼ sec. 29, T. 43 N., R. 106 W., Fremont County. Limestone 70.5–74 ft above top of Darwin Member, Horseshoe Member, *Anthracospirifer welleri-shawi* Zone, *Carlinia amsdeniana* Subzone, Late Mississippian (Chesterian). Collected by W. J. Sando and K. R. Moore, 1964. Fossils listed by Sando (1967a, p. 549–550).

46. Wiggins Fork. USGS 16197–PC. SW¼ sec. 7, T. 42 N., R. 105 W., Fremont County. Shale 28–36 ft above top of Darwin Member, Horseshoe Member, *Anthracospirifer welleri-shawi* Zone, *Carlinia amsdeniana* Subzone, Late Mississippian (Chesterian). Collected by J. D. Love, 1955.

47. Wiggins Fork. USGS 16198–PC. SW¼ sec. 7, T. 42 N., R. 105 W., Fremont County. Dolomite 39–43 ft above top of Darwin Member, Horseshoe Member, *Anthracospirifer welleri-shawi* Zone, *Carlinia amsdeniana* Subzone, Late Mississippian (Chesterian). Collected by J. D. Love, 1955.

48. Wiggins Fork. YPM 20101–20110. SW¼ sec. 7, T. 42 N., R. 105 W., Fremont County. Dolomite 39–43 ft above top of Darwin Member, Horseshoe Member, *Anthracospirifer welleri-shawi* Zone, *Carlinia amsdeniana* Subzone, Late Mississippian (Chesterian). Collected by J. D. Love, 1937? Fossils listed by Love (1939, p. 28), Burk (1954, p. 4), Shaw (1955a, p. 62, fig. 1), and Keefer and Van Lieu (1966, table 6).

*49. Wiggins Fork. YPM 5154. SW¼ sec. 7, T. 42 N., R. 105 W., Fremont County. Shale about 13 ft below top of Amsden Formation, Ranchester Member, Pennsylvanian (Atokan). Collected by J. D. Love, 1937? Fossils listed by Love (1939, p. 28), Burk (1954, p. 4), Shaw (1955a, p. 62, fig. 1), and Keefer and Van Lieu (1966, table 6). This material may be float from overlying Tensleep Sandstone.

BIGHORN MOUNTAINS

50. Trout Creek. USGS 11112–PC and 19187–PC. Sec. 19, T. 41 N., R. 88 W., Washakie County. Dolomite within about 50 ft of base of Tensleep Sandstone, Ranchester Member, Pennsylvanian (Morrowan?). Collected by H. A. Tourtelot, 1947. Fossils listed by Tourtelot (1953, table 2).

51. North Crazy Woman Creek. USGS 19230–PC. NW¼ NE¼ sec. 33, T. 49 W., R. 83 W., Johnson County. Sandstone in upper 50 ft of Amsden Formation, Ranchester Member, Pennsylvanian (Atokan?). Collected by Theodore Scott, 1950 (indeterminate chaetetid hydrozoans).

52. North Crazy Woman Creek. USGS 2461–PC, 2461A–PC. On slopes south of North Fork of Crazy Woman Creek near Crazy Woman road, probably in SE¼ sec. 28 or NE¼ sec. 33, T. 49 N., R. 83 W., Johnson County. Chert bed near top of Amsden Formation, Ranchester Member, Pennsylvanian (Atokan?). Col-

lected by N. H. Darton, 1903. Fossils listed by Darton (1906a, p. 33–34; 1906b, p. 5, 1906c, p. 5), Branson (1939, p. 1201), and Burk (1954, p. 2, 3).

53. South Rock Creek. USGS 19241–PC. SW¼ sec. 25, T. 52 N., R. 84 W., Johnson County. Limestone 3–5 ft above base of Amsden Formation, Horseshoe Member, Pennsylvanian (Morrowan). Collected by Helen Duncan and others, 1951.

54. South Rock Creek. USGS 19240–PC. SW¼ sec. 25, T. 52 N., R. 84 W., Johnson County. Limestone 3–5 ft above base of Amsden Formation, Horseshoe Member, Pennsylvanian (Morrowan). Collected by W. J. Mapel and others, 1950. Fossils listed by Mapel (1959, p. 22).

55–58. Collections of Madison Limestone fossils not discussed in this report.

*59. Little Tongue River-U.S. Highway 14. Roadcuts along U.S. Highway 14 west of Dayton, probably in SW¼ sec. 14, T. 56 N., R. 87 W., Sheridan County. Lowest limestone above lower red shales, Ranchester Member, Pennsylvanian. Fossils listed by Koucky and others (1961, p. 879).

*60 Little Tongue River-U.S. Highway 14. Roadcuts on south side of U.S. Highway 14 in SW¼ sec. 14, T. 56 N., R. 87 W., Sheridan County. Limestone at base of 100 ft carbonate interval, about 100 ft above base of Amsden Formation, Ranchester Member, Pennsylvanian (Morrowan). Collected by D. R. Gorman, 1961?. Fossil listed by Gorman (1963, p. 69).

*61. Little Tongue River-U.S. Highway 14. Roadcuts on south side of U.S. Highway 14 in SW¼ sec. 14, T. 56 N., R. 87 W., Sheridan County. Limestone near base of 100-ft carbonate interval, about 105 ft above base of Amsden Formation, Ranchester Member, Pennsylvanian (Morrowan). Collected by D. R. Gorman, 1961? Fossil listed by Gorman (1963, p. 69).

*62. Little Tongue River-U.S. Highway 14. Roadcuts on south side of U.S. Highway 14 in SW¼ sec. 14, T. 56 N., R. 87 W., Sheridan County. Shale in upper part of 100 ft carbonate interval, about 195 ft above base of Amsden Formation, Ranchester Member, Pennsylvanian. Collected by D. R. Gorman, 1961? Fossils listed by Gorman (1963, p. 69).

63. Amsden Creek. USGS 22206–PC. SW¼ sec. 34, T. 57 N., R. 87 W., Sheridan County. Float from limestone 96.5–97.5 ft above base of Amsden Formation, Ranchester Member, Pennsylvanian (Morrowan). Collected by W. J. Sando and K. R. Moore ,1965.

64. Amsden Creek. USGS 22207–PC. SW¼ sec. 34, T. 57 N., R. 87 W., Sheridan County. Limestone 96.5–97.5 ft above base of Amsden Formation, Ranchester Member, Pennsylvanian (Morrowan). Collected by W. J. Sando and K. R. Moore, 1965.

65. Amsden Creek. USGS 22208–PC. SW¼ sec. 34, T. 57 N., R. 87 W., Sheridan County. Limestone 99–101 ft above base of Amsden Formation, Ranchester Member, Pennsylvanian (Morrowan). Collected by W. J. Sando and K. R. Moore, 1965.

*66. Amsden Creek. Sec. 34, T. 57 N., R. 87 W., Sheridan County. Limestone 98.9–100.9 ft above base of Amsden Formation, Ranchester Member, Pennsylvanian Morrowan). Collected by D. R. Gorman, 1961? Fossils listed by Gorman (1963, p. 69).

67. Amsden Creek. USGS 16215–PC. SW¼ sec. 34, T. 57 N., R. 87 W., Sheridan County. Limestone about 100 ft above base of Amsden Formation, Ranchester Member, Pennsylvanian (Morrowan). Collected by M. Gordon, Jr. and others, 1955.

68. Amsden Creek. USGS 22204–PC. SE¼ sec. 32, T. 57 N., R. 87 W., Sheridan County. Float from limestone about 100 ft above base of Amsden Formation, Ranchester Member, Pennsylvanian (Morrowan). Collected by W. J. Sando and K. R. Moore, 1965.

69. Devils Canyon. USGS 16216–PC. W½ sec. 35, T. 9 S., R. 28 E., Carbon County, Mont. Limestone about 15 ft above base of Amsden Formation, Horseshoe Member, *Anthracospirifer welleri-shawi* Zone, *Composita poposiensis* Subzone, Late Mississippian (Chesterian). Collected by M. Gordon, Jr., and others, 1955.

*70. Devils Canyon. USGS f8009. W½ sec. 35, T. 9 S., R. 28 E., Carbon County, Mont. Limestone about 80 ft ft above base of Amsden Formation, Ranchester Member, Pennsylvanian (Atokan?). Collected by L. G. Henbest. Fossils listed by Richards (1955, p. 27).

GREEN RIVER BASIN

71. Tip Top. Mobil Oil Company Palozoic test well 22–19–g, Tip Top Unit. NW¼NW¼ sec. 19, T. 28 N., R. 113 W., Sublette County. Limestone 30–55 ft below top of Amsden Formation, Ranchester Member, Pennsylvanian (Atokan). Fossils listed by Marzolf (1965, p. 4).

SALT RIVER RANGE

72. Bear Creek. USGS 6957–PC. NE¼SW¼SW¼ sec. 27, T. 33 N., R. 117 W., Lincoln County. Limestone in upper part of Amsden Formation, Moffat Trail Member, *Caninia* Zone, Late Mississippian (Chesterian). Collected by J. S. Williams, 1931.

73. Moffat Trail. USGS 6960–PC. NW¼NE¼ sec. 3, T. 33 N., R. 117 W., Lincoln County. Limestone about 175 ft above base of Amsden Formation, Moffat Trail Member, *Caninia* Zone, Late Mississippian (Chesterian). Collected by J. S. Williams, 1931.

74. Moffat Trail. USGS 22985–PC. NW¼NE¼ sec. 3, T. 33 N., R. 117 W., Lincoln County. Limestone 202–206 ft above base of Amsden Formation, Moffat Trail Member, *Caninia* Zone, Late Mississippian (Chesterian). Collected by J. T. Dutro, Jr. and Mario Suarez, 1966.

75. Moffat Trail. USGS 22986–PC. NW¼NE¼ sec. 3, T. 33 N., R. 117 W., Lincoln County. Limestone 210 ft above base of Amsden Formation, Moffat Trail Member, *Caninia* Zone, Late Mississippian (Chesterian). Collected by J. T. Dutro, Jr. and Mario Suarez, 1966.

76. Moffat Trail. USGS 22987–PC. NW¼NE¼ sec. 3, T. 33 N., R. 117 W., Lincoln County. Limestone 217 ft above base of Amsden Formation, Moffat Trail Member, *Caninia* Zone, Late Mississippian (Chesterian). Collected by J. T. Dutro, Jr. and Mario Suarez, 1966.

77. Moffat Trail. USGS 6960A–PC. NW¼NE¼ sec. 3, T. 33 N., R. 117 W., Lincoln County. Limestone 215–225 ft above base of Amsden Formation, Moffat Trail Member, *Caninia* Zone, Late Mississippian (Chesterian). Collected by J. S. Williams, 1931.

78. Moffat Trail. USGS 6960B–PC. NW¼NE¼ sec. 3, T. 33 N., R. 117 W., Lincoln County. Limestone 215–225 ft above base of Amsden Formation, Moffat Trail Member, *Caninia* Zone, Late Mississippian (Chesterian). Collected by J. S. Williams, 1931.

79. Moffat Trail. USGS 22981–PC. NW¼NE¼ sec. 3, T. 33 N. ,R. 117 W., Lincoln County. Limestone 227 ft above base of Amsden Formation, Moffat Trail Member, *Caninia* Zone, Late Mississippian (Chesterian). Collected by J. T. Dutro, Jr. and Mario Suarez, 1966.
80. Moffat Trail. USGS 22982–PC. NW¼NE¼ sec. 3, T. 33 N., R. 117 W., Lincoln County. Limestone 227 ft above base of Amsden Formation, Moffat Trail Member, *Caninia* Zone, Late Mississippian (Chesterian). Collected by J. T. Dutro and Mario Suarez, 1966.
81. Moffat Trail. USGS 22983–PC. NW¼NE¼ sec. 3, T. 33 N., R. 117 W., Lincoln County. Sandstone 255 ft above base of Amsden Formation, Ranchester Member, Late Mississippian (Chesterian). Collected by J. T. Dutro, Jr. and Mario Suarez, 1966.
82. Moffat Trail. USGS 22984–PC. NW¼NE¼ sec. 3, T. 33 N., R. 117 W., Lincoln County. Limestone 257 ft above base of Amsden Formation, Ranchester Member, *Anthracospirifer welleri-shawi* Zone, Late Mississippian (Chesterian). Collected by J. T. Dutro, Jr. and Mario Suarez, 1966.
83. Moffat Trail. USGS 22988–PC. NW¼NE¼ sec. 3, T. 33 N., R. 117 W., Lincoln County. Chert 280 ft above base of Amsden Formation, Ranchester Member, *Antiquatonia blackwelderi* Zone, Pennsylvanian (Morrowan). Collected by J. T. Dutro, Jr. and Mario Suarez, 1966.
84. Moffat Trail. USGS 22989–PC. NW¼NE¼ sec. 3, T. 33 N., R. 117 W., Lincoln County. Chert and sandstone 297 ft above base of Amsden Formation, Ranchester Member, *Antiquatonia blackwelderi* Zone, Pennsylvanian (Morrowan). Collected by J. T. Dutro, Jr., and Mario Suarez, 1966.
85. Moffat Trail. USGS 22990–PC. NW¼NE¼ sec. 3, T. 33 N., R. 117 W., Lincoln County. Chert and dolomite 328 ft above base of Amsden Formation, Ranchester Member, Pennsylvanian (Morrowan). Collected by J. T. Dutro, Jr., and Mario Suarez, 1966.
86. Moffat Trail. USGS 6960C–PC. NW¼NE¼ sec. 3, T. 33 N., R. 117 W., Lincoln County. Dolomite about 328 ft above base of Amsden Formation, Ranchester Member, Pennsylvanian (Morrowan?). Collected by J. S. Williams, 1931.
87. Moffat Trail. USGS 22991–PC. NW¼NE¼ sec. 3, T. 33 N., R. 117 W., Lincoln County. Dolomite 338 ft above base of Amsden Formation, Ranchester Member, Pennsylvanian (Morrowan?). Collected by J. T. Dutro, Jr., and Mario Suarez, 1966.
88. Peak 9837. USGS 22992–PC. NE¼ sec. 34, T. 34 N., R. 117 W., Lincoln County. About 227 ft above base of Amsden Formation, Moffat Trail Member, *Caninia* Zone, Late Mississippian (Chesterian). Collected by J. T. Dutro, Jr., and Mario Suarez, 1966.
stone 277 ft above base of Amsden Formation, Ran-
89. Peak 9837. USGS 22993–PC. NE¼ sec. 34, T. 34 N., R. 117 W., Lincoln County. Dolomite about 380 ft above base of Amsden Formation, Ranchester Member, Pennsylvanian. Collected by J. T. Dutro, Jr., and Mario Suarez, 1966.
90. Covey Cutoff Trail. USGS 22995–PC. NW¼NE¼ sec. 27, T. 34 N., R. 117 W., Lincoln County. Limestone about 218 ft above base of Amsden Formation, Moffat Trail Member, *Caninia* Zone, Late Mississippian (Chesterian). Collected by J. T. Dutro, Jr., and Mario Suarez, 1966.
91. Covey Cutoff Trail. USGS 22996–PC. NW¼NE¼ sec. 27, T. 34 N., R. 117 W., Lincoln County. Limestone 247–257 ft above base of Amsden Formation, Moffat Trail Member, *Caninia* Zone, Late Mississippian (Chesterian). Collected by J. T. Dutro, Jr., and Mario Suarez, 1966.
92. Covey Cutoff Trail. USGS 6965–PC. NW¼NE¼ sec. 27, T. 34 N., R. 117 W., Lincoln County. Limestone 247–257 ft above base of Amsden Formation, Moffat Trail Member, *Caninia* Zone, Late Mississippian (Chesterian). Collected by J. S. Williams, 1931. Fossil listed by Williams (1948, p. 338).
93. Covey Cutoff Trail. USGS 6951–PC. NW¼NE¼ sec. 27, T. 34 N., R. 117 W., Lincoln County. Limestone 247–257 ft above base of Amsden Formation, Moffat Trail Member, *Caninia* Zone, Late Mississippian (Chesterian). Collected by J. S. Williams, 1931. Fossils listed by Williams (1948, p. 338).
94. Covey Cutoff Trail. USGS 6965A–PC. NW¼NE¼ sec. 27, T. 34 N., R. 117 W., Lincoln County. Limestone 277 ft above base of Amsden Formation, Ranchester Member, Late Mississippian (Chesterian). Collected by J. S. Williams, 1931. Collection includes a Pennsylvanian brachiopod from higher beds. Bryozoan listed by Williams (1948, p. 338) as *Chaetetes*.
95. Covey Cutoff Trail. USGS 6951A–PC. NW¼NE¼ sec. 27, T. 34 N., R. 117 W., Lincoln County. Limestone 277 ft above base of Amsden Formation, Ranchester Member, Late Mississippian (Chesterian). Collected by J. S. Williams, 1931. Fossil listed by Williams (1948, p. 338).
96. Covey Cutoff Trail. USGS 17908–PC. NW¼NE¼ sec. 27, T. 34 N., R. 117 W., Lincoln County. Limestone 295.5–302.5 ft above base of Amsden Formation, Ranchester Member, *Anthracospirifer welleri-shawi* Zone, Late Mississippian (Chesterian). Collected by W. J. Sando and J. T. Dutro, Jr., 1958.
97. Covey Cutoff Trail. USGS 6965B–PC. NW¼NE¼ sec. 27, T. 34 N., R. 117 W., Lincoln County. Limestone 301 ft above base of Amsden Formation, Ranchester Member, *Anthracospirifer welleri-shawi* Zone, Late Mississippian (Chesterian). Collected by J. S. Williams, 1931.
98. Covey Cutoff Trail. USGS 6951B–PC. NW¼NE¼ sec. 27, T. 34 N., R. 117 W., Lincoln County. Limestone 301 ft above base of Amsden Formation, Ranchester Member, *Anthracospirifer welleri-shawi* Zone, Late Mississippian (Chesterian). Collected by J. S. Williams, 1931.
99. Covey Cutoff Trail. USGS 6965C–PC. NW¼NE¼ sec. 27, T. 34 N., R. 117 W., Lincoln County. Limestone 317 ft above base of Amsden Formation, Ranchester Member, *Antiquatonia blackwelderi* Zone, Pennsylvanian (Morrowan). Collected by J. S. Williams, 1931.
100. Covey Cutoff Trail. USGS 6965D–PC. NW¼NE¼ sec. 27, T. 34 N., R. 117 W., Lincoln County. Limestone 352 ft above base of Amsden Formation, Ranchester Member, *Antiquatonia blackwelderi* Zone, Pennsylvanian (Morrowan). Collected by J. S. Williams, 1931.
101. Covey Cutoff Trail. USGS 6965E–PC. NW¼NE¼ sec. 27, T. 34 N., R. 117 W., Lincoln County. Limestone 428–431 ft above base of Amsden Formation, Ranchester Member, *Antiquatonia blackwelderi*

Zone, Pennsylvanian (Morrowan). Collected by J. S. Williams, 1931.

102. Haystack Peak. USGS 17904–PC. Center sec. 19, T. 34, N., R. 117 W., Lincoln County. Limestone 102–105 ft above base of Amsden Formation, Moffat Trail Member, *Caninia* Zone, Late Mississippian (Chesterian). Collected by W. J. Sando and J. T. Dutro, Jr., 1958.

103. Haystack Peak. USGS 17905–PC. Center, sec. 19, T. 34 N., R. 117 W., Lincoln County. Limestone 177–178 ft above base of Amsden Formation, Moffat Trail Member, *Caninia* Zone, Late Mississippian (Chesterian). Collected by W. J. Sando and J. T. Dutro, Jr., 1958.

104. Haystack Peak. USGS 17906–PC. Center sec. 19, T. 34 N., R. 117 W., Lincoln County. Limestone 184–187 ft above base of Amsden Formation, Moffat Trail Member, *Caninia* Zone, Late Mississippian (Chesterian). Collected by W. J. Sando and J. T. Dutro, Jr., 1958.

105. Haystack Peak. USGS 17907–PC. Center sec. 19, T. 34 N., R. 117 W., Lincoln County. Limestone 199–209 ft above base of Amsden Formation, Moffat Trail Member, *Caninia* Zone, Late Mississippian (Chesterian). Collected by W. J. Sando and J. T. Dutro, Jr., 1958.

SNAKE RIVER RANGE

*106. Wolf Creek. Probably in NE¼ sec. 4, T. 37 N., R. R. 117 W., Lincoln County. Limestone in Ranchester Member, Pennsylvanian? Fossil listed by Wanless and others (1955, p. 34).

*107. South Indian Creek. Sec. 22, T. 38 N., R. 118 W., Lincoln County. Carbonate about 260 ft above base of Amsden Formation, Moffat Trail Member, *Caninia* Zone, Late Mississippian (Chesterian). Fossils listed by Love (1954, col. 1, colln. 2).

*108. South Indian Creek. Probably near center, sec. 15, T. 38 N., R. 118 W., Lincoln County. Limestone 65 ft above Darwin Member, Moffat Trail Member, *Caninia* Zone, Late Mississippian (Chesterian). Fossils listed by Wanless and others (1955, p. 33).

109. South Indian Creek. USGS 23002–PC. NE¼ sec. 14, T. 38 N., R. 118 W., Lincoln County. Limestone about 260–280 ft above base of Amsden Formation, Moffat Trail Member, *Caninia* Zone, Late Mississippian (Chesterian). Collected by J. T. Dutro, Jr., and Mario Suarez, 1966.

110. South Indian Creek. USGS 23001–PC. NE¼ sec. 14, T. 38 N., R. 118 W., Lincoln County. Sandstone about 280–285 ft above base of Amsden Formation, Ranchester Member, Late Mississippian (Chesterian). Collected by J. T. Dutro, Jr., and Mario Suarez, 1966.

HOBACK RANGE

111. Hoback Canyon, USGS Paleobotany 10065. Sec. 2, T. 38 N., R 115 W., Teton County. Shale and sandstone about 15–55 ft above top of Darwin Member, Horseshoe Member, Late Mississippian (Chesterian). Collected by M. Gordon, Jr., and others, 1955.

112. Hoback Canyon. USGS Paleobotany 10066. Sec. 2, T. 38 N., R. 115 W., Teton County. Shale about 15–55 ft above top of Darwin Member, Horseshoe Member, Late Mississippian (Chesterian). Collected by M. Gordon, Jr., and others, 1955.

113. Hoback Canyon. USGS 22997–PC. Sec. 2, T. 38 N., R. 115 W., Teton County. Sandstone 25–55 ft above top of Darwin Member, Horseshoe Member, Late Mississippian (Chesterian). Collected by J. T. Dutro, Jr., and Mario Suarez, 1966.

114. Hoback Canyon, USGS 18783–PC. Sec. 2, T. 38 N., R. 115 W., Teton County. Sandstone 37.3–38.3 ft above top of Darwin Member, Horseshoe Member, Late Mississippian (Chesterian). Collected by J. T. Dutro, Jr. and W. J. Sando, 1959.

115. Hoback Canyon, USGS 18787–PC. Sec. 2, T. 38 N., R. 115 W., Teton County. Siltstone 38.3–42.8 ft above top of Darwin Member, Horseshoe Member, Late Mississippian (Chesterian). Collected by J. T. Dutro, Jr., and W. J. Sando, 1959.

116. Hoback Canyon. USGS 18798–PC. Sec. 3, T. 38 N., R. 115 W., Teton County. Float from siltstone about 43.3 ft above top of Darwin Member, Horseshoe Member, Late Mississippian (Chesterian). Collected by J. T. Dutro, Jr., and W. J. Sando, 1959.

117. Hoback Canyon. USGS 18788–PC. Sec. 2, T. 38 N., R. 115 W., Teton County. Siltstone 42.8–43.3 ft above top of Darwin Member, Horseshoe Shale Member, Late Mississippian (Chesterian). Collected by J. T. Dutro, Jr., and W. J. Sando, 1959.

118. Hoback Canyon. USGS 16207–PC. Sec. 2, T. 38 N., R. 115 W., Teton County. Siltstone 42.8–43.3 ft above top of Darwin Member, Horseshoe Member, Late Mississippian (Chesterian). Collected by M. Gordon, Jr., and others, 1955.

119. Hoback Canyon, USGS 18790–PC. Sec. 2, T. 38 N., R. 115 W., Teton County. Sandstone 51.3–51.8 ft above top of Darwin Member, Horseshoe Member, Late Mississippian (Chesterian). Collected by J. T. Dutro, Jr., and W. J. Sando, 1959.

120. Hoback Canyon. USGS 18791–PC. Sec. 2, T. 38 N., R. 115 W., Teton County. Limestone 56.3–71.3 ft above top of Darwin Member, Moffat Trail Member, *Caninia* Zone, Late Mississippian (Chesterian). Collected by J. T. Dutro, Jr., and W. J. Sando, 1959.

121. Hoback Canyon. USGS 16208–PC. Sec. 2, T. 38 N., R. 115 W., Teton County. Limestone 62.3–64.3 ft above top of Darwin Sandstone Member, Moffat Trail Limestone Member, *Caninia* Zone, Late Mississippian (Chesterian). Collected by M. Gordon, Jr., and others, 1955.

122. Hoback Canyon. USGS 16209–PC. Sec. 2, T. 38 N., R. 115 W., Teton County. Float from limestone 76–91 ft above top of Darwin Member, Moffat Trail Member, *Caninia* Zone, Late Mississippian (Chesterian). Collected by M. Gordon, Jr., and others, 1955.

*123. Hoback Canyon. Sec. 2, T. 38 N., R. 115 W., Teton County. Limestone 77.4–78.9 ft above top of Darwin Member, Moffat Trail Member, *Caninia* Zone, Late Mississippian (Chesterian). Fossils listed by Wanless and others (1955, p. 27, 33).

124. Hoback Canyon. USGS 18799–PC. Sec. 3, T. 38 N., R. 115 W., Teton County. Float from limestone 91.6–94.1 ft above top of Darwin Member, Moffat Trail Member, *Caninia* Zone, Late Mississippian (Chesterian). Collected by J. T. Dutro, Jr., and W. J. Sando, 1959.

125. Hoback Canyon. USGS 18785–PC. Sec. 2, T. 38 N., R. 115 W., Teton County. Limestone 91.6–94.1 ft above top of Darwin Member, Moffat Trail Member,

Caninia Zone, Late Mississippian (Chesterian). Collected by J. T. Dutro, Jr., and W. J. Sando, 1959.

126. Hoback Canyon. USGS 22998–PC. Sec. 2, T. 38 N., R. 115 W., Teton County. Limestone about 95 ft above top of Darwin Member, Moffat Trail Member, *Caninia* Zone, Late Mississippian (Chesterian). Collected by J. T. Dutro, Jr., and Mario Suarez, 1966.

127. Hoback Canyon, USGS 22999–PC. Sec. 2, T. 38 N., R. 115 W., Teton County. Sandstone about 100 ft above top of Darwin Member, Ranchester Member, Late Mississippian (Chesterian). Collected by J. T. Dutro, Jr., and Mario Suarez, 1966.

128. Hoback Canyon, USGS 18785–PC. Sec. 2, T. 38 N., R. 115 W., Teton County. Sandstone 102.3 ft above top of Darwin Member, Ranchester Member, Late Mississippian (Chesterian). Collected by J. T. Dutro, Jr., and W. J. Sando, 1959.

129. Hoback Canyon. USGS 23000–PC. Sec. 2, T. 38 N., R. 115 W., Teton County. Limestone about 103–105 ft above top of Darwin Member, Ranchester Member. Collected by J. T. Dutro,Jr ., and Mario Suarez, 1966.

130. Hoback Canyon. USGS 18786–PC. Sec. 2, T. 38 N., R. 115 W., Teton County. Dolomite 126.3–132.8 ft above top of Darwin Member, Ranchester Member, *Antiquatonia blackwelderi* Zone, Pennsylvanian (Morrowan). Collected by J. T. Dutro, Jr., and W. J. Sando, 1959.

131. Hoback Canyon. USGS 16210–PC. Sec. 2, T. 38 N., R. 115 W., Teton County. Dolomite 126.3–132.8 ft above top of Darwin Member, Ranchester Member, *Antiquatonia blackwelderi* Zone, Pennsylvanian (Morrowan). Collected by M. Gordon, Jr., and others, 155.

132. Hoback Canyon. USGS 16211–PC. Sec. 2, T. 38 N., R. 115 W., Teton County. Limestone 142.8 ft above top of Darwin Member, Ranchester Member, Pennsylvanian (Morrowan). Collected by M. Gordon, Jr., and others, 1955.

GROS VENTRE RANGE

133. Tosi Ridge. USGS 6189–PC. South front of Tosi Ridge in sec. 1, T. 38 N., R. 112 W., Sublette County. Limestone near middle of Amsden Formation, Ranchester Member, *Antiquatonia blackwelderi* Zone, Pennsylvanian (Morrowan). Collected by Eliot Blackwelder, 1911. Fossils included in composite list referred to by Girty (in Blackwelder, 1913, p. 175–176) as the upper faunule of the Amsden. Same faunule listed by Branson (1939, p. 1217), Burk (1954, p. 2), and Love (1954, col. 10, colln. 1). Age of collection discussed by Sando (1967a, p. 540).

134. Hodges Peak. USGS 6192–PC. Probably in NW¼ sec. 26, T. 39 N., R. 112 W., Sublette County. Limestone in Ranchester Member, *Antiquatonia blackwelderi* Zone, Pennsylvanian (Morrowan). Collected by Eliot Blackwelder, 1911. Fossils included in composite list referred to by Girty (in Blackwelder, 1913, p. 175–176) as the upper faunule of the Amsden. Same faunule listed by Branson (1939, p. 1217), Burk (1954, p. 2), and Love (1954, col. 10, colln 1). Age of collection discussed by Sando (1967a, p. 540).

*135. Granite Creek. Mountain just east of Granite Creek Hot Springs, probably in sec. 4, T. 39 N., R. 113 W., Teton County. Limestone in Ranchester Member, *Antiquatonia blackwelderi* Zone, Pennsylvanian (Morrowan). Fossils listed by Wanless and others (1955, p. 33–34).

136. Granite Creek. USGS 6190–PC. Mountain just east of Granite Falls, probably in sec. 4, T. 39 N., R. 113 W., Teton County. Limestone in middle of Amsden Formation, Ranchester Member, *Antiquatonia blackwelderi* Zone, Pennsylvanian (Morrowan). Collected by Eliot Blackwelder, 1911. Fossils included in composite list referred to by Girty (in Blackwelder, 1913, p. 175–176) as the upper faunule of the Amsden. Same faunule listed by Branson (1939, p. 1217), Burk (1954, p. 2), and Love (1954, column 10, collection 1). Age of collection discussed by Sando (1967a, p. 540).

137. Darwin Peak. USGS 6191–PC. S½ sec. 28, T. 40 N., R. 112 W., Teton County. Limestone 118.6–121.4 ft above base of Amsden Formation, Horseshoe Member, *Anthracospirifer welleri-shawi* Zone, *Carlinia amsdeniana* Subzone, Late Mississippian (Chesterian), Collected by Eliot Blackwelder, 1911. Fossils included in composite list referred to by Girty (in Blackwelder, 1913, p. 175–176) as the lower faunule of the Amsden. Same faunule listed by Branson (1939, p. 1217), Burk (1954, p. 2, 3), and Love (1954, col. 10, colln. 2). Age of collection discussed by Sando (1967a, p. 540).

138. Darwin Peak. USGS 6191B–PC. S½ sec. 28, T. 40 N., R. 112 W., Teton County. Limestone 118.6–121.4 ft above base of Amsden Formation, Horseshoe Member, *Anthracospirifer welleri-shawi* Zone, Late Mississippian (Chesterian). Collected by Eliot Blackwelder, 1911. Fossil included in composite list referred to by Girty (in Blackwelder, 1913, p. 175–176) as the lower faunule of the Amsden. Same faunule listed by Branson (1939, p. 1217), Burk (1954, p. 2, 3), and Love (1954, col. 10, colln. 2). Age of collection discussed by Sando (1967a, p. 540).

139. Darwin Peak. USGS 6191A–PC. S½ sec. 28, T. 40 N., R. 112 W., Teton County. Limestone 180.9–182.4 ft above base of Amsden Formation, Ranchester Member, *Antiquatonia blackwelderi* Zone, Pennsylvanian (Morrowan). Collected by Eliot Blackwelder, 1911. Fossils included in composite list referred to by Girty (in Blackwelder, 1913, p. 175–176) as the upper faunule of the Amsden. Same faunule listed by Branson (1939, p. 1217), Burk (1954, p. 2), and Love (1954, col. 10, colln. 1). Age of collection discussed by Sando (1967a, p. 540).

140. Darwin Peak. USGS 6191C–PC. S½ sec. 28, T. 40 N., R 112 W., Teton County. Limestone 180.9–182.4 feet above base of Amsden Formation, Ranchester Member, *Antiquatonia blackwelderi* Zone, Pennsylvanian (Morrowan). Collected by Eliot Blackwelder, 1911. Fossil included in composite list referred to by Girty (in Blackwelder, 1913, p. 175–176) as the upper faunule of the Amsden. Same faunule listed by Branson (1939, p. 1217), Burk (1954, p. 2), and Love (1954, col. 10, colln. 1).

141. Black Peak. USGS 6193–PC. Two miles northeast of Black Peak, probably in sec. 7, T. 40 N., R. 112 W., Teton County. Limestone in Ranchester Member, *Antiquatonia blackwelderi* Zone, Pennsylvanian (Morrowan). Collected by C. W. Tomlinson, 1911. Fossils included in composite list referred to by Girty (in Blackwelder, 1913, p. 175–176) as the upper faunule of the Amsden. Same faunule listed

by Branson (1939, p. 1217), Burk (1954, p. 2), and Love (1954, col. 10, colln. 1). Age of collection discussed by Sando (1967a, p. 540).

142. Black Peak. USGS 6193A–PC. Head of Gros Ventre River near Black Peak, probably in sec. 7 or 18, T. 40 N., R. 112 W., Teton County. Dolomite in Ranchester Member, *Antiquatonia blackwelderi* Zone, Pennsylvanian (Morrowan). Collected by Eliot Blackwelder, 1911. Fossils included in composite list referred to by Girty (in Blackwelder, 1913, p. 175–176) as the upper fauna of the Amsden. Same faunule listed by Branson (1939, p. 1217), Burk (1954, p. 2), and Love (1954, col. 10, colln. 1).

143. Pyramid Peak. USGS 6194–PC. East spur of Pyramid Peak, three quarters of a mile from summit, probably in SE¼ sec. 6, T. 40 N., R. 113 W., Teton County. Limestone in Ranchester Member, *Antiquatonia blackwelderi* Zone, Pennsylvanian (Morrowan). Collected by C. W. Tomlinson, 1911. Fossils included in composite list referred to by Girty (in Blackwelder, 1913, p. 175–176) as the upper faunule of the Amsden. Same faunule listed by Burk (1954, p. 2) and Love (1954, col. 10, colln. 1). Age of collection discussed by Sando (1967a, p. 540).

144. Flat Creek. USGS 20231–PC. NW¼ sec. 36, T. 42 N., R. 115 W., Teton County. Chert and dolomite about 100 ft above Darwin Member, Ranchester Member? Collected by J. D. Love, 1955 (indeterminate foraminifers and gastropod).

TETON RANGE

145. Phillips Canyon. USGS 23006–PC. SW¼ sec. 16, T. 41 N., R. 117 W., Teton County. Limestone about 45–57 ft above top of Darwin Member, Moffat Trail Member, Late Mississippian (Chesterian). Collected by J. T. Dutro, Jr., and Mario Suarez, 1966.

146. Glory Mountain. USGS 23004–PC. SE¼ sec. 13, T. 41 N., R. 118 W., Teton County. Chert 176–179 ft above base of Amsden Formation, Ranchester Member, *Anthracospirifer welleri-shawi* Zone, Late Mississippian (Chesterian). Collected by J. T. Dutro, Jr., and Mario Suarez, 1966.

*147. Glory Mountain. South flank of Glory Mountain, probably in sec. 13, T. 41 N., R. 118 W., Teton County. Ranchester Member, Pennsylvanian? Fossils listed by Wanless and others (1955, p. 33).

148. Darby Canyon. USGS 18776–PC. NE¼SE¼ sec. 15, T. 43 N., R. 118 W., Teton County. Limestone 118 ft above base of Amsden Formation, Ranchester Member, Late Mississippian (Chesterian). Collected by W. J. Sando and J. T. Dutro, Jr., 1959.

149. Berry Creek. USGS 20229–PC. NW¼ sec. 22, T. 47 N., R 116 W., Teton County. Limestone 34.8–40.8 ft above base of Amsden Formation, Horseshoe Member, *Anthracospirifer welleri-shawi* Zone, Late Mississippian (Chesterian). Collected by J. D. Love, 1955.

150. Berry Creek. USGS 24055–PC NW¼ sec. 22, T. 47 N., R. 116 W., Teton County. Shale parting in limestone 40.8 ft above base of Amsden Formation, Horseshoe Member, *Anthracospirifer welleri-shawi* Zone, Late Mississippian (Chesterian). Collected by J. D. Love, 1968.

151. Berry Creek. USGS 24051–PC. NW¼ sec. 22, T. 47 N., R. 116 W., Teton County. Shale 40.8–41.8 ft above base of Amsden Formation, Horseshoe Member, *Anthracospirifer welleri-shawi* Zone, Late Mississippian (Chesterian). Collected by J. D. Love, 1968.

152. Berry Creek. USGS 24058–PC. NW¼ sec. 22, T. 47 N., R. 116 W., Teton County. Shale 40.8–41.8 ft above base of Amsden Formation, Horseshoe Member, *Anthracospirifer welleri-shawi* Zone, Late Mississippian (Chesterian). Collected by J. D. Love, 1968.

153. Berry Creek. USGS 24059–PC. NW¼ sec. 22, T. 47 N., R. 116 W., Teton County. Shale 40.8–41.8 ft above base of Amsden Formation, Horseshoe Member, *Anthracospirifer welleri-shawi* Zone, Late Mississippian (Chesterian). Collected by J. D. Love, 1968.

154. Berry Creek. USGS 24060–PC. NW¼ sec. 22, T. 47 N., R. 116 W., Teton County. Limestone 40.8–41.8 ft above base of Amsden Formation, Horseshoe Member, *Anthracospirifer welleri-shawi* Zone, Late Mississippian (Chesterian). Collected by J. D. Love, 1968.

155. Berry Creek. USGS 24052–PC. NW¼ sec. 22, T. 47 N., R. 116 W., Teton County. Shale 40.8–41.1 ft above base of Amsden Formation, Horseshoe Member, *Anthracospirifer welleri-shawi* Zone, Late Mississippian (Chesterian). Collected by J. D. Love, 1968.

156. Berry Creek. USGS 24056–PC. NW¼ sec. 22, T. 47 N., R. 116 W., Teton County. Shale 41.1–41.8 ft above base of Amsden Formation, Horseshoe Member, *Anthracospirifer welleri-shawi* Zone, Late Mississippian (Chesterian). Collected by J. D. Love, 1968.

157. Berry Creek. USGS 20230–PC. NW¼ sec. 22, T. 47 N., R. 116 W., Teton County. Shale 44.3–48.3 ft above base of Amsden Formation, Horseshoe Member, *Anthracospirifer welleri-shawi* Zone, Late Mississippian (Chesterian). Collected by J. D. Love, 1955.

158. Berry Creek. USGS 24053–PC. NW¼ sec. 22, T. 47 N., R. 116 W., Teton County. Limestone 48.3–49.3 ft above base of Amsden Formation, Horseshoe Member, *Anthracospirifer welleri-shawi* Zone, Late Mississippian (Chesterian). Collected by J. D. Love, 1968.

159. Elk Ridge. USGS 24050–PC. SW¼ sec. 26, T. 47 N., R. 116 W., Teton County. Limestone 15–20 ft above base of Amsden Formation, Horseshoe Member, *Anthracospirifer welleri-shawi* Zone, Late Mississippian (Chesterian). Collected by J. D. Love, 1968.

160. Elk Ridge. USGS 24057–PC. SW¼ sec. 26, T. 47 N., R. 116 W., Teton County. Limestone 55–70 ft above base of Amsden Formation, Ranchester Limestone Member, *Anthracospirifer welleri-shawi* Zone, Late Mississippian (Chesterian). Collected by J. D. Love, 1968.

Miscellaneous collections in the U.S. National Museum made by I. A. Keyte and his associates from the Horseshoe Shale Member in the Wind River Range, Fremont County, are listed below. Many, if not all, of these are from the same localities as the University of Missouri collections listed as collections 24, 25, and 36a–e.

A. Enterprise ditch
B. Amsden Hill
C. Cherry Creek
D. Youngs Basin
E. Near Lander
F. Fremont County

The following collections, previously reported as Amsden, are regarded as Madison or Tensleep by the writers. These collections are not assigned master collection numbers.

Soldier Creek. USGS 2479–PC. Soldier Creek Road, probably in NE¼ sec. 21, T. 55 N., R. 86 W., Sheridan County. Madison Limestone, probably from unnamed limestone member beneath Bull Ridge Member (*Spirifer* cf. *madisonensis* Zone of Sando, 1967a). Collected by N. H. Darton, 1901? Identifications by G. H. Girty of fossils in this collection were cited by Darton (1906a, p. 33; 1906b, p. 5; and 1906c, p. 5) Branson (1937, p. 650; 1939, p. 1201), Burk (1954, p. 2), and Williams (1948, p. 335).

*Sheep Mountain. Nine miles north of Greybull in T. 54 N., R. 94 W., Big Horn County. Tensleep Sandstone, about 10 ft above base. Collected by A. E. Brainerd and I. A. Keyte, 1925 or 1926. Fossils listed by Brainerd and Keyte (1927, p. 173).

Bull Lake Creek. USGS f9791 and 23210–PC. NE¼NW¼-NW¼ sec. 14, T. 2 N., R. 4 W., Fremont County. About 50 ft above base of Tensleep Sandstone. Collected by J. F. Murphy and N. C. Privrasky, 1953. This collection was first listed by Love (1954, col. 15, colln 2), who included foraminifers collected by Murphy and Privrasky and identified by L. G. Henbest with brachiopods and molluscs (USGS 6195–PC) listed by Branson (1939, p. 1210) thought by Love to represent the same zone. Murphy and others (1956) listed foraminifers identified by Henbest and brachiopods identified by J. E. Smedley in the collection. Henbest (1956, p. 61) presented a revised list of foraminifers from the collection. Murphy and Richmond (1965) repeated the list of Murphy and others (1956). Keefer and Van Lieu (1966, table 6) presented a composite list taken from Murphy and others (1956), Henbest (1956), and Love (1954). Geographic locations given by Love (1954), Murphy and Richmond (1965), and Keefer and Van Lieu (1966) are incorrect (J. F. Murphy, written commun., 1968).

Dinwoody Canyon. USGS 788–PC. Sec. 6, T. 4 N., R. 5 W., Fremont County. Tensleep Sandstone, about 135 ft above base. Collected by Eliot Blackwelder, 1910. Love (1954, col. 14, colln 2) and Keefer and Van Lieu (1966, table 6) listed this collection as upper Amsden.

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UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

V. E. McKelvey, *Director*

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