The Mississippian and Pennsylvanian (Carboniferous) Systems in the United States—Idaho

By BETTY SKIPP, W. J. SANDO, *and* W. E. HALL

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Historical review and summary of
areal, stratigraphic, structural,
and economic geology of Mississippian
and Pennsylvanian rocks in Idaho

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THE MISSISSIPPIAN AND PENNSYLVANIAN (CARBONIFEROUS) SYSTEMS IN THE UNITED STATES—IDAHO

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ABSTRACT

Pennsylvanian and Mississippian rocks of inner and outer cratonic-platform origins are present in south-central and southeastern Idaho. They are in elongate, generally north- or northwest-trending linear fault-block mountains on both sides of the Snake River Plain, an east-northeast-trending upper Cenozoic volcano-tectonic depression that separates outcrops in south-central Idaho from those of the southeastern part of the State.

North of the plain, in south-central Idaho, formation of a Lower Mississippian linear north-trending flysch trough east of the Antler highland is recorded in the lower part of the Copper Basin Formation. The Copper Basin comprises at least 3,500 m of conglomerate, sandstone, limestone, and argillite, which spread eastward across the shelf (McGowan Creek Formation) to the inner craton margin, the site of accumulation of a coeval carbonate-bank complex (Madison Group). South of the plain, a Lower Mississippian carbonate complex (Madison Group) also formed on the inner craton margin, but time-equivalent strata west of the carbonate-bank margin include relatively deep water carbonate rocks (Lodgepole Limestone) overlain by a deep-water starved-basin-facies complex (lower part of Little Flat Formation and others). Orogenic detritus is largely absent.

In Late Mississippian time, north of the plain, the flysch trough gradually shoaled. Shallow marine limestone, interbedded with bouldery mudstone, conglomerate, and minor coaly beds (upper part of Copper Basin Formation), is limited mostly to the area of the trough. A few conglomerate and sandstone lenses are present in the westernmost exposures (White Knob Limestone) of the thick Upper Mississippian carbonate-bank complex (Middle Canyon, Scott Peak, Surrett Canyon Formations), which occupied the outer cratonic platform from the inner cratonic margin west to the flysch trough. The inner cratonic platform was the site of deposition of thin sequences of shallow marine to restricted marine shale, sandstone, and limestone (Big Snowy Formation). In latest Mississippian time, a sheet of cratonic mudstone and sandstone (Big Snowy, Arco Hills, and Bluebird Mountain Formations) spread westward across the carbonate-bank complex.

South of the plain, in Late Mississippian time, the inner cratonic platform was the site of accumulation of the shallow and restricted marine sediments of the Amsden Formation. West of the inner cratonic margin, bank limestone interbedded with dark marine shale (Deep Creek and Monroe Canyon Formations, Great Blue Limestone) prograded westward, possibly as far as the Black Pine Range. Metamorphosed Mississippian rocks west of this, in the Albion Range (View Formation of Armstrong), have an orogenic aspect. In latest Mississippian time, mudstone and sandstone, probably of inner cratonic origin, spread across the carbonate-bank complex around the low broad Bannock highland, in much the same way as did similar deposits north of the plain.

Early Pennsylvanian time, both north and south of the plain, records a continuation of the conditions established in Late Mississippian time. In Middle Pennsylvanian time, however, the setting changed. North of the plain, the Copper Basin highland emerged, separating the Wood River basin on the site of the former Antler highland on the west, from a shallow-water carbonate bank (Snaky Canyon Formation) to the east. The limestone and sandstone of the carbonate bank give way both north and east to thick sandstone of the Quadrant Formation. South of the plain, the Bannock highland, which had no sediment accumulation in either Late Mississippian or Early Pennsylvanian time, became submerged, and thin carbonate and sandy carbonate deposits (Wells Formation) spread across it. To the west, a northern arm of the Oquirrh basin, the Sublett basin, subsided and received more than 2,300 m of sandy carbonate and calcareous sandstone (lower part of Oquirrh Formation); these deposits are present as far west as the Albion Range.

Though the paleotectonic settings of Carboniferous sedimentation differ on the two sides of the Snake River Plain, there are enough similarities to indicate that they formed in response to the same continent-margin tectonics. Two previously proposed plate-tectonic models seem feasible. The first is that of a gradually closing inner-arc basin between the edge of the continent and an island arc above an east-dipping subduction zone. The Antler orogeny would have taken place in response to a period of increased plate motion along the subduction zone. Because the Antler orogeny never underwent a molasse phase but was succeeded, in Pennsylvanian time, by a return to shelf conditions, an alternate model has been proposed. In this second model, the Antler orogeny is the product of an arc-continent collision followed by a period of arc withdrawal and tensional tectonics on the continent that produced the highlands and basins characteristic of Pennsylvanian time.

The Carboniferous rocks of eastern Idaho have a potential for hydrocarbons, though none had been produced through 1977. Metalliferous deposits in Carboniferous rocks north of the plain have produced a moderate recovery of almost $20 million in lead-silver, molybdenum, copper, zinc, barite, gold, and tungsten. The thick high-calcium limestones

of the Upper Mississippian carbonate-bank complex remain an untapped potential resource, as do vast resources of less pure limestones.

INTRODUCTION

Carboniferous (Mississippian and Pennsylvanian) rocks are known to crop out only in the central, southern, and eastern parts of Idaho, east of the granitic rocks of the Upper Cretaceous Idaho batholith (fig. 1). Within this part of the State, the outcrops are separated into two distinct areas by the Snake River Plain, a late Cenozoic volcano-tectonic depression, 80 to 90 km wide, which is filled with basalt, related rhyolite and rhyolitic ash, and margin-derived sediments. Carboniferous rocks north and south of the Snake River Plain have different names, markedly different stratigraphic successions, and related plate-tectonic histories. Both north and south of the plain, outcrops are present along the crests and flanks of narrow northwest-trending, north-trending, or arcuate, fault-bounded mountains (fig. 2), which rise to a maximum height of 3,859 m. Structural relations and several deep wells indicate that Carboniferous rocks are present at depth in many, but not all, of the intervening valleys. There is no information at this time on the presence, absence, or extent of Paleozoic rocks under the thick lavas and sediments of the eastern Snake River Plain, though geophysical studies and deep drilling programs are in progress. The nature of the bedrock/basalt contact along the northern margin of the plain suggests that Carboniferous rocks, which dip gently under, or are foundered in, basalt, probably extend under the plain a kilometer or so (fig. 3).

No rocks of definite Carboniferous age have been reported from Idaho west of the Idaho batholith, though deepwater stratified sedimentary and volcanic rocks in northeastern Oregon contain Pennsylvanian fusulinids (D. L. Bostwick *in* Vallier, 1977, p. 7), and correlative strata may be present in Idaho near lat 45° on the western edge of the State (fig. 1; Vallier, 1974; Vallier and others, 1977).

Several areas of scenic outcrops of Carboniferous rocks are present within Idaho. In almost every area the strata are folded, faulted, or sheared, but exposures are continuous enough to work out successions. Steeply dipping conglomerate, sandstone, argillite, and limestone of the Mississippian Copper Basin Formation are spectacularly exposed along the crest of the Pioneer Mountains (figs. 4, 5). Massive to thin-bedded folded limestones of the Upper Mississippian Scott Peak, South Creek, Surrett Canyon, and Bluebird Mountain Formations are well exposed along Antelope Creek in the White Knob Mountains (fig. 6) and make up the crests of the Lost River Range (fig. 7), the Lemhi Range, and the Beaverhead Mountains in several areas. The same formations are particularly well exposed on the southwest corner of the Lemhi Range in the general area of several type localities (Huh, 1967). The Snaky Canyon Formation is well exposed on the east sides of the southern Lost River and Lemhi Ranges and the southern Beaverhead Mountains (fig. 4).

South of the plain, Mississippian rocks of the Madison Group and Pennsylvanian rocks of the Wells Formation make up the ridge crests of the northern Snake River Range. Farther west, Mississippian rocks are exposed low on the flanks of the Portneuf and Chesterfield Ranges, the Deep Creek Mountains, and the Sublett and Albion Ranges; Pennsylvanian and Permian rocks of the Oquirrh Formation make up the crests of the ranges where the strata are moderately well exposed (see fig. 15).

Mean average rainfall within the area of outcrop of Carboniferous rocks (fig. 2) ranges from less than 20 cm per year in the Snake River Plain to more than 100 cm per year in the mountains bordering the plain (Travis and others, 1964, fig. 56). Frost action has affected Carboniferous rocks in all the mountainous areas, resulting in extensive colluvial cover in many outcrop areas. Large landslides of probable Pleistocene age are concentrated locally in shale and shaly limestone interbedded with thick-bedded Upper Mississippian limestone in the ranges north of the Snake River Plain (Radbruch-Hall and others, 1976).

The stratigraphic nomenclature used in this paper has not been reviewed by the Geologic Names Committee of the U.S. Geological Survey. The nomenclature used here conforms with the current usage of the Idaho Bureau of Mines and Geology.

HISTORY

The first scientific explorers to pass through Idaho probably were Lewis and Clark in 1805 (De Voto, 1953). Geologic mapping, which included study of Carboniferous rocks, was undertaken in 1877 in southeastern Idaho by parties of the Hayden Survey. The work resulted in publications by A. C. Peale and Orestes St. John in 1879 (Mansfield, 1927). After these early investigations, several workers published significant reports in the early decades of the 1900's that included studies of Car-

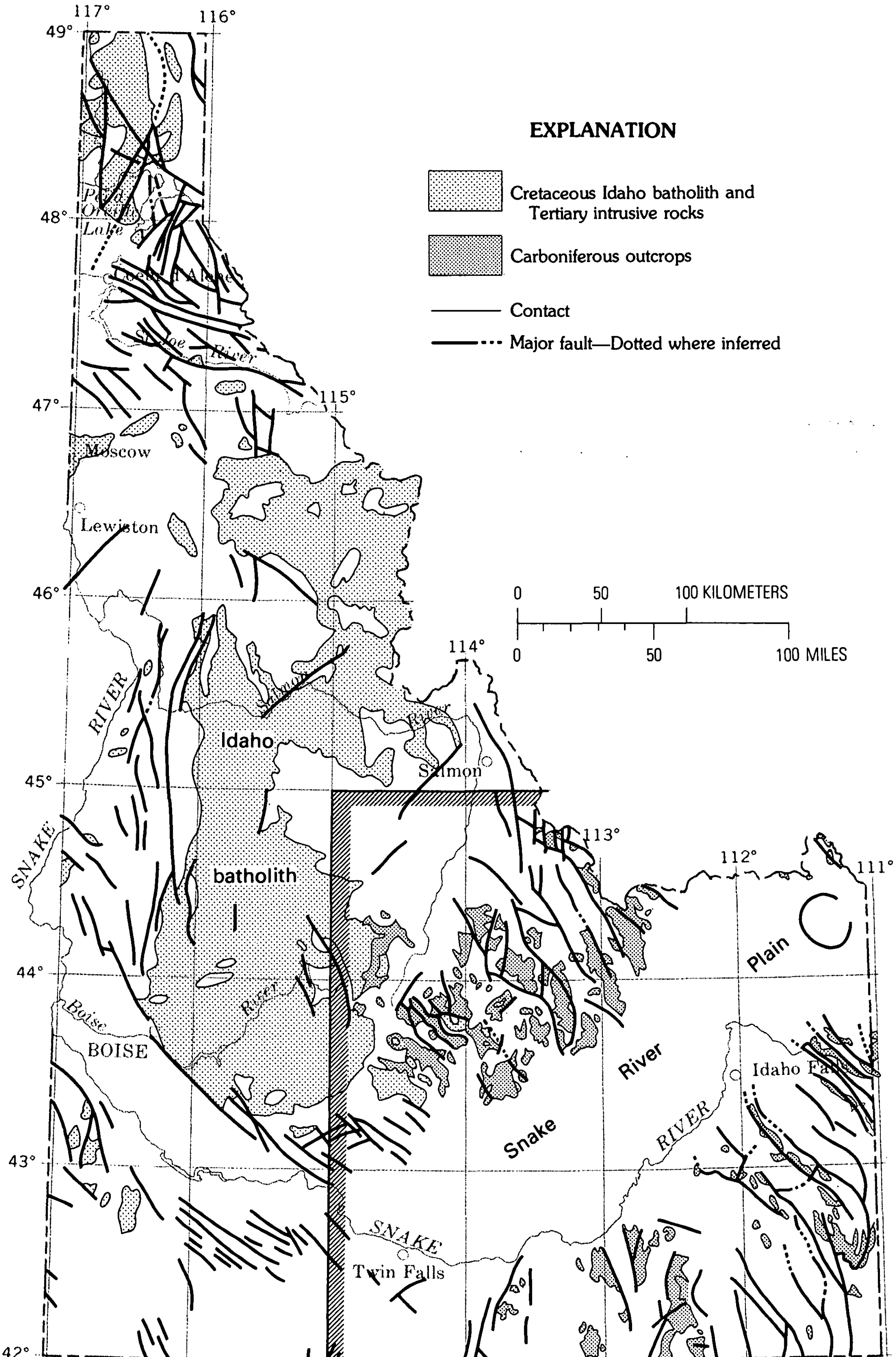


FIGURE 1.—Index map of Idaho showing outcrops of Carboniferous rocks and the location of major faults, the Snake River Plain, the Cretaceous Idaho batholith, and Tertiary intrusive rocks. Area of figures 2, 4, 9, 10, 12, and 13 shown by hachures. Modified from King and Beikman (1974).

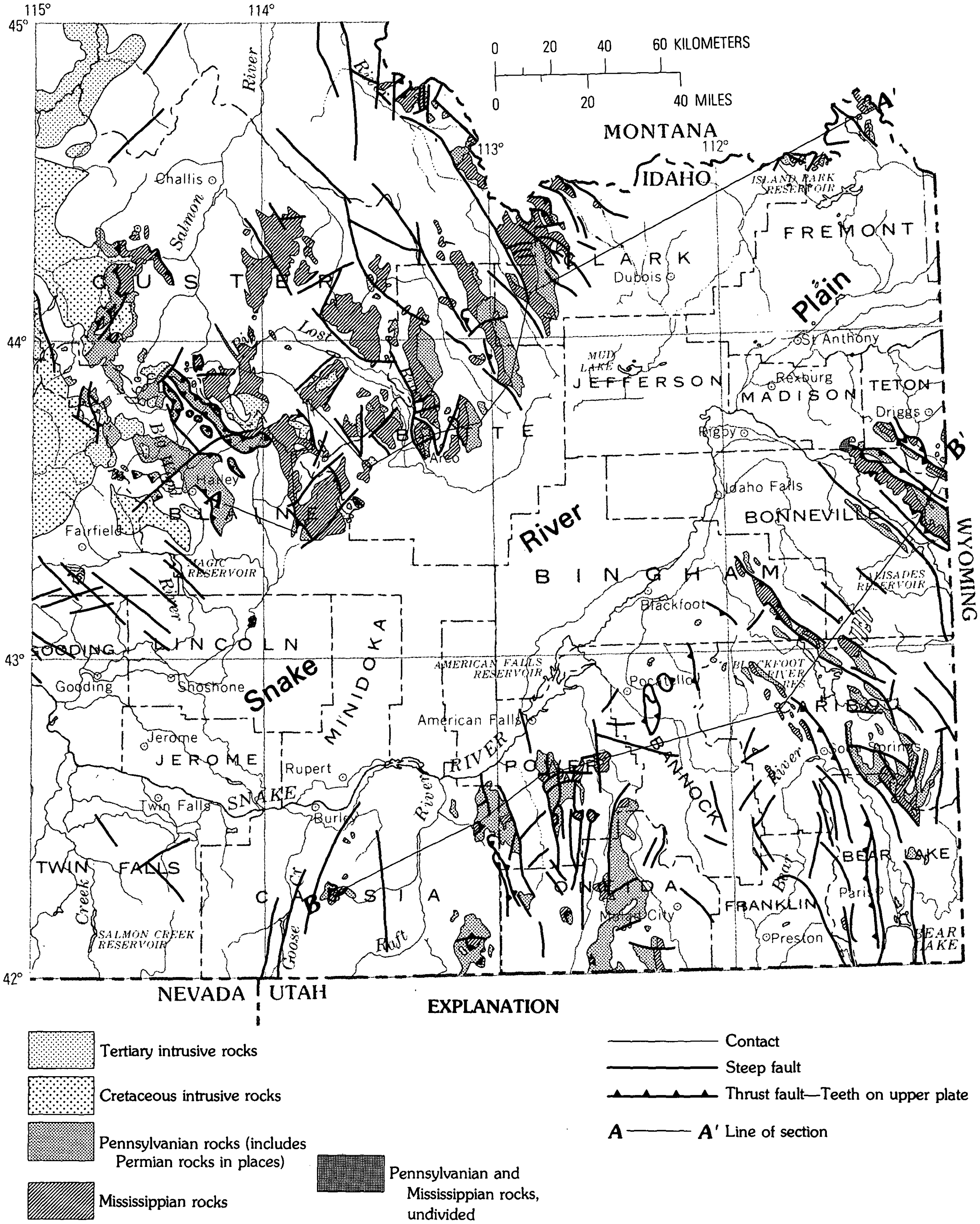


FIGURE 2.—(For caption see facing page.)

FIGURE 3.—Oblique aerial photograph of north edge of Snake River Plain showing outcrop of sandstone, conglomerate, and argillite in lower part of Copper Basin Formation (foreground) foundered in late Quaternary basalt of the Snake River Group. Outcrop of Mississippian rocks (about 100 m wide at bottom edge of photo) is just west of Craters-of-the-Moon National Monument in sec. 32, T. 1 N., R. 23 E., Blaine County. Photograph by W. B. Hall.

FIGURE 2.—Map showing outcrops of Carboniferous (Mississippian and Pennsylvanian) rocks in central and southeastern Idaho, location of Cretaceous and Tertiary intrusive rocks, major faults that affect distribution of the Carboniferous rocks, and locations of cross sections *A–A'* and *B–B'* of figures 11 and 14. The map was compiled from the following sources:

Armstrong, R. L., unpub. data
Bond, J. G. (1978)
Cress, L. D., unpub. data
Dover, Hall, Hobbs, Tschanz, Batchelder, and Simons (1976)
Hait, M. H., Jr., unpub. data
Hall, Rye, and Doe (1978)
Hall, W. E., and Batchelder, John, unpub. data
Hays, W. H., unpub. data
Hobbs, Hays, and McIntyre (1975)
King and Beikman (1974)
Lucchitta, B. K. (1966)
Mapel, Read, and Smith (1965)
Mapel and Shropshire (1973)
Mapel, W. J., unpub. data
Platt, L. B. (1977), and unpub. data
Prostka and Hackman (1974)
Pruit, J. D. (1971)
Ross, C. P. (1937)
Ruppel, E. T. (1968)
Skipp, Betty, unpub. data
Skipp and Hait (1977)
Smith, J. F., Jr., unpub. data
Thompson, M. E. (1977)
Trimble and Carr (1976)
Tschanz, Kiilsgaard, and Seeland, in Tschanz and others (1974)
Tschanz, C. M., unpub. data
Witkind, I. J. (1972, 1976)

LOCALITIES NORTH OF THE SNAKE RIVER PLAIN

1. Big Wood River area. T. 2 N., R. 19 E. Blaine Co. Hall, Batchelder and Douglass (1974); W. E. Hall, unpub. data.

1a. Wilson Creek Ridge. T. 5 N., R. 19 E. Blaine Co. W. E. Hall and J. N. Batchelder, unpub. data.

1b. Dollarhide Summit area. T. 3 N., R. 15 E. Blaine and Camas Cos. W. E. Hall and J. N. Batchelder, unpub. data.

2. Fish Creek Reservoir area. T. 1 N., R. 22 E. Blaine Co. Skipp and Hall (1975a).

3. Fish Creek Reservoir area. T. 1 N., R. 22 E. Blaine Co. Skipp and Hall (1975a).

4. Cottonwood Creek area. T. 2 N., R. 23 E. Blaine Co. Larson (1974).

5. Iron Mine Creek area. T. 2 N., R. 23 E. Blaine Co. Bollmann (1971); Betty Skipp, unpub. data.

6. Central Pioneer Mountains. T. 4 N., R. 21 E.; T. 4 N., R. 22 E. Custer Co. Paull, Wolbrink, Volkman, and Grover (1972); Paull and Gruber (1977); Nilsen (1977); J. H. Dover, unpub. data.

7. Salmon River-Clayton area. T. 11 N., R. 16 E. Custer Co. Hobbs, Hays, McIntyre (1975); S. W. Hobbs, unpub. data.

8. Iron Bog Creek area. T. 4 N., R. 23 E. Custer Co. R. A. Paull and Betty Skipp, unpub. data.

9. Cabin Creek area. T. 6 N., R. 22 E. Custer Co. Skipp (1961a); Skipp and Mamet (1970); R. A. Paull, unpub. data.

10. Hurst Canyon. T. 6 N., R. 28 E. Butte Co. Sandberg, Mapel, and Huddle (1967).

11. Timbered Dome area. T. 3 N., R. 25 E. Butte Co. Skipp (1961b); Betty Skipp, unpub. data.

12. Antelope Creek-Wood Canyon areas composite. T. 4 N., R. 24 E. and T. 5 N., R. 25 E. Custer Co. Betty Skipp, unpub. data.

13. Howe Peak-Arco Hills, T. 4 N., R. 28 E.; T. 5 N., R. 29 E. Butte Co. Shannon (1961); Breuninger (1976); Betty Skipp and R. D. Hoggan, unpub. data.

14. Arco Hills. T. 4 N., R. 26 E. Butte Co. Wornardt (1958); Roberts (1979); Betty Skipp, unpub. data.

15. Doublespring area. T. 12 N., R. 21 E. and T. 12 N., R. 22 E. Custer Co. Mapel, Read, and Smith (1965); Mamet, Skipp, Sando, and Mapel (1971).

16. McGowan Creek. T. 12 N., R. 21 E. Custer Co. Mapel, Read, and Smith (1965); Sandberg (1975).

17. Slate Creek. T. 10 N., R. 15 E. Custer Co. Thomasson (1959); Tschanz, Kiilsgaard, Seeland (*in* Tschanz and others, 1974).

18. Upper Pahsimeroi area. T. 9 N., R. 23 E. Custer Co. Huh (1967); Roberts (1979).

19. Donkey Hills. T. 10 N., R. 25 E. Custer Co. Mapel and Shropshire (1973; Roberts (1979).

20. Hawley Mountain. T. 9 N., R. 26 E. Butte Co. Mamet, Skipp, Sando, and Mapel (1971); Mapel and Shropshire (1973).

21. Hawley Mountain. T. 8 N., R. 26 E. Butte Co. Mamet, Skipp, Sando, and Mapel (1971); Mapel and Shropshire (1973).

22. Lower Cedar Creek. T. 7 N., R. 24 E. Custer Co. Sandberg, Mapel, and Huddle (1967); Sandberg (1975).

23. East and Box Canyons-southern Lemhi Range. T. 6 N., R. 30 E. Butte Co. Shannon (1961); Huh (1967); Sandberg (1975); Skipp, Hoggan, Schleicher, and Douglass (1979).

24. Copper Mountain area. T. 10 N., R. 30 E. and T. 10 N., R. 31 E. Clark Co. Huh (1967); Embree, Hoggan, Williams, and Skipp (1975); Skipp, Hoggan, Schleicher, and Douglass (1979), and unpub. data.

25. Snaky Canyon area. T. 9 N., R. 32 E. Clark Co. Skipp, Hoggan, Schleicher, and Douglass (1979).

26. Deadman Lake area. T. 16 S., R. 10 W. Beaverhead Co., Montana. Huh (1967).

27. Leadore area. T. 16 N., R. 26 E., and T. 16 N., R. 27 E. Lemhi Co. Ruppel (1968); E. T. Ruppel, unpub. data.

28. Hawley Creek area (generalized). T. 16 N., R. 27 E.; T. 15 N., R. 28 E.; T. 16 N., R. 28 E. Lemhi Co. Lucchitta (1966); B. K. Lucchitta, unpub. data.

29. Centennial Mountains. T. 14 N., R. 41 E. Fremont and Clark Cos. Witkind (1976).

30. Henrys Lake Mountains. T. 16 N., R. 44 E. Fremont Co. Witkind (1972); E. K. Maughan, unpub. data.

30a. Centennial Mountains. T. 14 N., R. 42 E. Fremont Co. Witkind (1972).

LOCALITIES SOUTH OF THE SNAKE RIVER PLAIN

31. Albion Range. T. 13 S., R. 23 E.; T. 13 S., R. 24 E. Cassia Co. Armstrong (1968).

31a. Albion Range. T. 11 S., R. 24 E. Cassia Co. Armstrong (1968).

32. Black Pine Range. T. 15 S., R. 28 E., T. 15 S., R. 29 E. Cassia Co. J. F. Smith, Jr., unpub data

33. Northern Sublett Range. T. 11 S., R. 29 E., approx. Cassia Co. R. L. Armstrong, unpub. data.

34. Northern Deep Creek Mountains, Hunter Canyon vicinity. T. 9 S., R. 31 E. and T. 9 S., R. 32 E. Power Co. Trimble and Carr (1976); Sando, Dutro, Sandberg, and Mamet (1976).

34a. Northern Deep Creek Mountains, Bannock Peak. T. 9 S., R. 32 E. Power Co. Trimble and Carr (1976).

34b. Hills east of Bannock Creek, T. 9 S., R. 33 E. Power Co. Trimble and Carr (1976).

35. Southern Deep Creek Mountains. T. 11 S., R. 32 E. Power Co. L. D. Cress, unpub. data.

36. Samaria Mountain. T. 16 S., R. 35 E. Oneida Co. Beus (1968), Platt (1977).

37. Chesterfield Range. T. 7 S., R. 40 E. Caribou Co. Dutro and Sando (1963), Sando, Dutro, Sandberg, and Mamet (1976).

37a. Soda Springs quadrangle, northeast corner. T. 8 S., R. 42 E. and T. 8 S., R. 43 E. Caribou Co. Armstrong (1953, 1969).

38. Portneuf Range. T. 9 S., R. 39 E. Caribou Co. Oriel (1968), S. S. Oriel, unpub. data.

39. Big Hole Mountains. T. 4 N., R. 43 E. Teton Co. Staatz and Albee (1966).

40. Black Mountain, Snake River Range. T. 3 N., R. 43 E. Bonneville Co. Sando (1977), Sando and Dutro *in* Roberts (1979).

41. Sheep Creek, Snake River Range. T. 1 N., R. 45 E. Bonneville Co. Jobin and Soister (1964), Sando (1977), Sando and Dutro *in* Roberts (1979).

42. Hell Creek Canyon. T. 1 S., R. 46 E., T. 1 N., R. 46 E. Bonneville Co. Gardner (1944); Roberts (1979).

43. Hot Springs mine. T. 13 S., R. 44 E., Bear Lake Co. Mallory (1975).

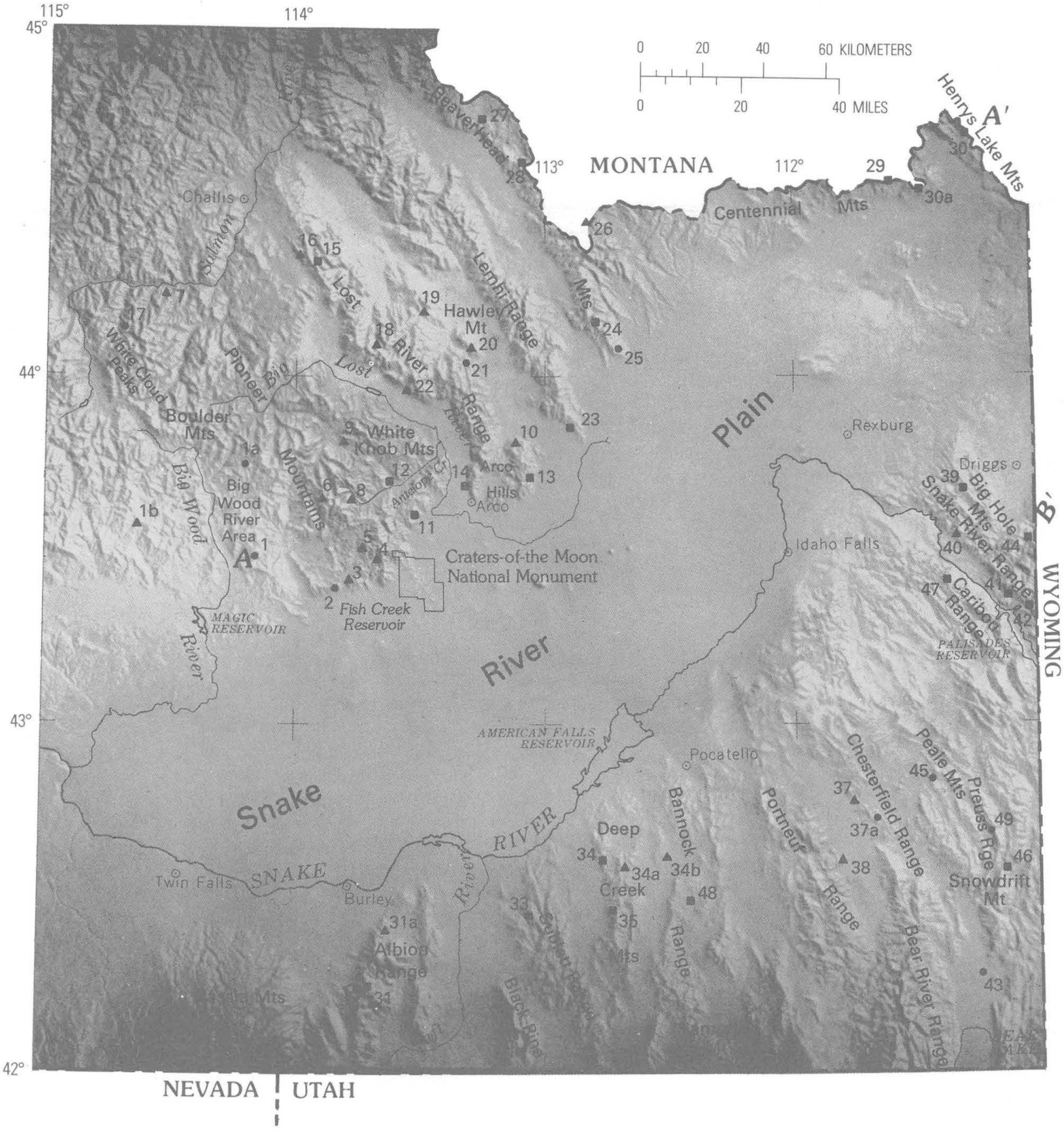


FIGURE 4.—Map showing section localities used in construction of the isopach and lithofacies maps of figures 9, 10, 12, and 13. Triangles indicate Mississippian rocks only; circles, Pennsylvanian rocks only; and squares, both Pennsylvanian and Mississippian rocks. Numbers indicate data sources. Major geographic features referred to in text are shown; also lines of sections *A–A'* and *B–B'* (figs. 11 and 14).

44. Snake River Range. T. 2 N., R. 46 E.; T. 3 N., R. 46 E. Bonneville and Teton Cos. Pampeyan, Schroeder, Schell and Cressman (1967).
45. Wooley Range, Peale Mountains. T. 6 S., R. 42 E., T. 6 S., R. 43 E., Caribou Co. McKelvey *in* Cressman (1964), Mallory (1975).
46. Snowdrift Mountain. T. 9 S., R. 45 E., T. 10 S., R. 45 E. Caribou Co. Gulbrandsen, McLaughlin, Honkala, and Clabaugh (1956); Cressman (1964); Mallory (1975).
47. Caribou Range. T. 1 N., R. 43 E. Bonneville Co. Jobin and Schroeder (1964).
48. Bannock Range. T. 10 S., R. 34 E., T. 11 S., R. 35 E. Bannock Co. Murk (1968).
49. Preuss Range, Peale Mountains. R. 8 S., R. 45 E. (generalized). Caribou Co. Cressman and Gulbrandsen (1955); Montgomery and Cheney (1967).

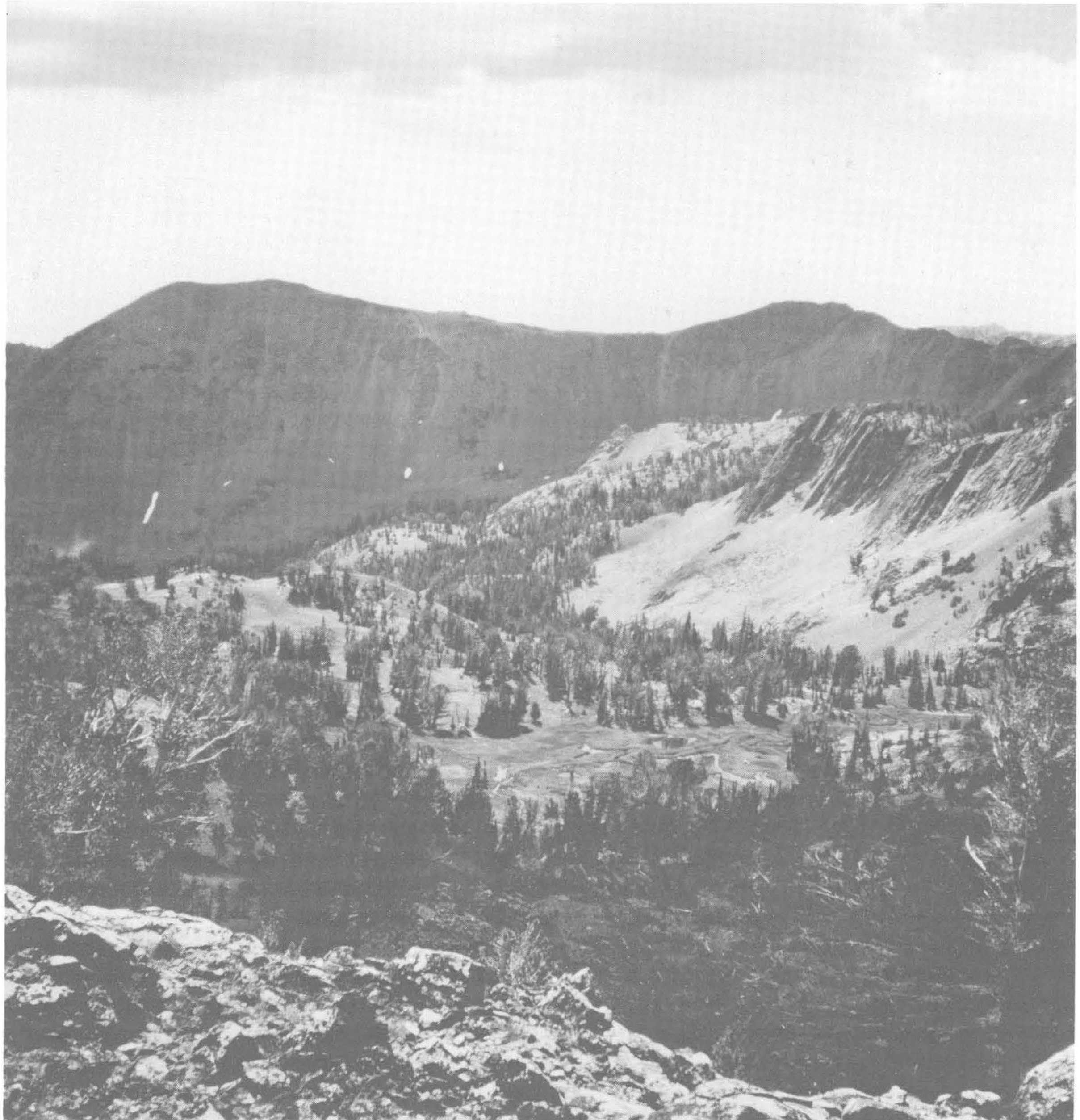


FIGURE 5.—Crest of Pioneer Mountain made up of steeply dipping quartzite, conglomerate, and argillite beds of lower part of Copper Basin Formation. View is taken from above Brockie Lake near locality 6 looking south.

boniferous rocks. Representative reports of this kind are: Schultz and Richards (1913), Umpleby (1913, 1917), Kirkham (1922, 1924, 1927), Mansfield (1927), Anderson (1929, 1931), Umpleby, Westgate, and Ross (1930), and Ross (1934, 1937). Several of the above reports were published by the Idaho Bureau of Mines and Geology. In 1947, the Idaho Bureau, in cooperation with the U.S. Geological Survey, published the "Geologic Map of the State of Idaho" at a scale of 1:500,000 (Ross and Forrester, 1947), which showed the generalized distribution of Carboniferous rocks. A new geologic map of Idaho recently has been published as the result of a similar cooperative effort (Bond, 1978).

In recent years, many workers have published reports dealing primarily with Carboniferous rocks and fossils in various parts of Idaho. These include: Bostwick (1955); Scholten (1957); Thomasson (1959); Ross (1960, 1962a, b, c); Skipp (1961a, b); Carr and Trimble (1961); Churkin (1962); Shannon (1961); Dutro and Sando (1963); Roberts, Crittenden, Tooker, Morris, Hose, and Cheney

FIGURE 6.—Oblique aerial photograph looking north from mouth of Antelope Creek in White Knob Mountains at folded Upper Mississippian and Pennsylvanian beds of the Scott Peak, South Creek, Surrett Canyon, Bluebird Mountain, and Snaky Canyon Formations. Photograph by W. B. Hall.

(1965); Sando (1967, 1976b); Sando, Mamet, and Dutro (1969); Skipp and Mamet (1970); Mamet, Skipp, Sando, and Mapel (1971); Paull, Wolbrink, Volkmann, and Grover (1972); Sandberg (1975); Sando, Gordon, and Dutro (1975); Breuninger (1976); Sando, Dutro, Sandberg, and Mamet (1976); Nilsen (1977); and Paull and Gruber (1977). Regional studies of Carboniferous rocks that have included Idaho have been published by Bissell (1962, 1974); Williams (1962); Schleh (1968); Poole (1974); Mallory (1975); Sando (1976a); Sando, Dutro, Sandberg, and Mamet (1976); Rose (1976); Peterson (1977); Poole and Sandberg (1977); Rich (1977); and Roberts (in press).

POSTDEPOSITIONAL STRUCTURAL SETTING

Some Carboniferous rocks in Idaho are thought to be parautochthonous, but most are allochthonous, having been transported east or northeast along complex thrust- and tear-fault systems; movements have dated from Pennsylvanian(?) to Early Tertiary, possibly extending into Late Tertiary, time (Richards and Mansfield, 1912; Mansfield, 1927; Rubey, 1955; Scholten and others, 1955; Rubey and Hubbert, 1959; Eardley, 1960; Armstrong and Cressman, 1963; Roberts and Thomasson, 1964; Armstrong and Oriel, 1965; Roberts and others, 1965; Armstrong, 1968; Monley, 1971; Beutner, 1972; Scholten, 1973; Hall and others, 1975; Royse and others, 1975; Skipp and Hall, 1975a, b; Ruppel, 1978; and Skipp and Hait, 1977). This list of references dealing with thrust faults in Idaho is representative but not complete.

The thrust faults on which Carboniferous rocks have moved northeast or east are deformed locally by granitic rocks of the Upper Cretaceous Idaho batholith, and are offset by upper Cenozoic basin-and-range extensional structures, steep normal faults that trend generally north or northwest (figs.

FIGURE 7.—Oblique aerial photograph of Arco Hills; crest of Lost River Range (King Mountain) in background. In foreground, Scott Peak Formation forms cliffs at base of hill; South Creek Formation forms slope above; dark cliffs of folded and faulted Surrett Canyon Formation are above the South Creek slope, and, above these, the slopes of the Arco Hills and Bluebird Mountain Formations. Letter "B" on top of ridge is in sandstone of Bluebird Mountain Formation. Photograph by W. B. Hall.

1 and 2). Vertical stratigraphic displacements on basin-and-range structures in Idaho locally are as much as 6,100 m (Skipp and Hait, 1977), though most are much less. The basin-and-range structures, in turn, are cut off or buried beneath the upper Cenozoic lava and sediments of the Snake River Plain (figs. 1 and 2).

The active late Paleozoic to Holocene tectonic history of Idaho has complicated the distribution of Carboniferous rocks. Horizontal displacements on individual thrusts north of the plain have been estimated to be as much as 160 km (Ruppel, 1976) and south of the plain, about 25 km (Armstrong and Oriel, 1965). Total extension on late Cenozoic basin-and-range structures north of the plain is estimated to be about 25 percent of that south of the plain, introducing an apparent right-lateral sense of displacement between outcrops on the two sides of the plain (Skipp, 1976). Both left- and right-slip movements since early Paleozoic time have been suggested along an inferred Snake River fault in the general position of the Snake River Plain (Sandberg and Mapel, 1967; Poole and others, 1977: Poole and Sandberg, 1977).

The isopach maps (figs. 9, 10, 12, and 13) are based on the present distribution of Carboniferous outcrops. Because of structural complexities, however, large isopach intervals have been used, and structure-controlled boundaries have been emphasized. Three major concepts have resulted from this synthesis of structural and stratigraphic data:

1. Carboniferous facies, thicknesses, and structural patterns on the north and south sides of the plain for the time-stratigraphic intervals

shown in figures 10, 12, and 13 are different and suggest separate crustal responses to plate-margin tectonics.

2. Total thrust displacements on both sides of the plain seem to be nearly equal, as the positions of the inner cratonic platform margin and the western edge of the Upper Mississippian carbonate-bank complex (Sando, 1976a; Rose, 1976) do not seem to be displaced significantly.
3. No large strike-slip displacements before late Cenozoic time seem necessary along the axis of the Snake River Plain to account for the present distribution of facies and thicknesses of Carboniferous rocks, according to our interpretation of sedimentary trends.

MISSISSIPPIAN SYSTEM

The Mississippian System of the United States correlates with the Lower Carboniferous and lowermost part of the Upper Carboniferous Series in Europe (fig. 8), and includes, from oldest to youngest, the Kinderhookian, Osagean, Meramecian, and Chesterian Provincial Series.

PALEOTECTONIC SETTING—ANTLER OROGENY

Mississippian rocks in Idaho, both north and south of the Snake River Plain, were deposited across a mobile former continental shelf and a cratonic platform that had been relatively stable from late Precambrian through Late Devonian time. In latest Devonian through earliest Mississippian time, the western edge of the North American continent was disrupted during the Antler orogeny, when Devonian and older rocks of continental-slope and ocean-basin origins were obducted onto the continental margin (Poole, 1974; Poole and Sandberg, 1977). The thrust system along which the translation took place in Nevada, the Roberts Mountains thrust, is nowhere identified with certainty in Idaho (Paull, 1976). Instead, indirect evidence of the tremendous magnitude of the disturbance exists in the more than 4,000 m (fig. 9) of Mississippian turbidites and interturbidites (Copper Basin Formation) that filled a deep and narrow flysch trough along the eastern margin of the Antler orogenic highland (Poole, 1974). At present, the flysch trough is represented largely by an incomplete allochthonous sequence, the Copper Basin Formation, which itself has been folded, faulted, and thrust eastward (Skipp and Hall, 1975b; Skipp and Hait, 1977; Nilsen, 1977). Undated parautochthonous strata, which lithologically resemble parts of the Copper Basin Formation, are present in two areas beneath the Wood River allochthon (structural elements 7 and 8 of fig. 9, and fig. 2).

East of the flysch trough, thick orogenic, thin starved-basin, and thick carbonate sediments were deposited without major interruption in an outer cratonic platform environment. (Sando prefers "foreland basin" usage of Poole and Sandberg (1977) for this feature.) Farther east, in easternmost Idaho, Mississippian rocks were laid down in two depositional cycles (cycles I and III of Sando, 1976a; and Sando, Dutro, Sandberg, and Mamet, 1976) separated by middle and late Meramecian emergence of the inner cratonic platform (Cycle II of Sando, 1976a, and Sando, Dutro, Sandberg, and Mamet, 1976) [1].

UNDERLYING ROCKS

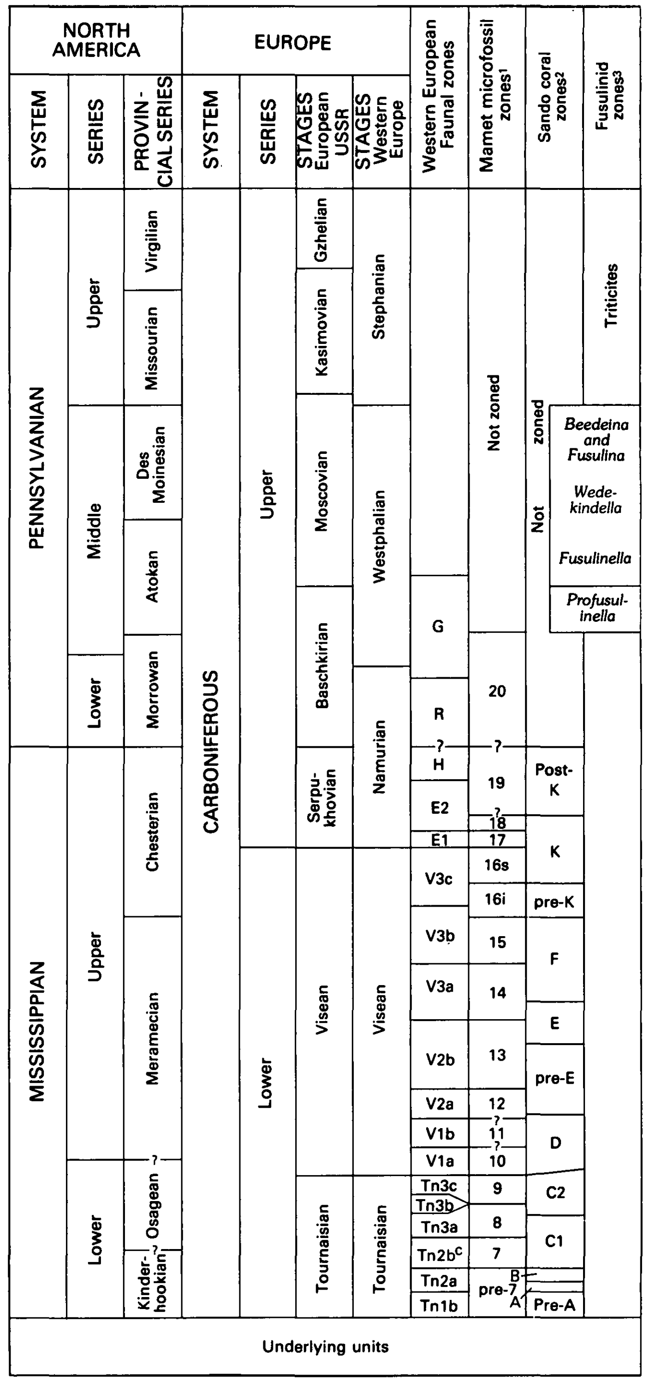
Lower Mississippian rocks rest unconformably on Upper Devonian rocks throughout most of Idaho (fig. 8; Poole and others, 1977, Sandberg and Poole, 1977), except in the White Knob and Pioneer Mountains, where the McGowan Creek and Copper Basin Formations locally unconformably overlie Middle Devonian rocks of the Carey Formation (Skipp and Sandberg, 1975; C. A. Sandberg, written commun., 1974). Elsewhere in the Pioneer Mountains region, the Copper Basin Formation has been thrust over rocks as old as Precambrian(?) (Dover, 1969; Dover and others, 1976). In the Albion Range, Mississippian rocks are thrust over strata as old as Cambrian (R. L. Armstrong, written commun., 1976).

THICKNESS

Mississippian rocks thin to the south and east across Idaho. The thickest recognized Mississippian sequences in Idaho are the flysch of the Copper Basin Formation north of the plain where thickness is greater than 3,896 m (fig. 9). This tremendous thickness drops to near zero at Fish Creek Reservoir (Skipp and Hall, 1975a), where the Copper Basin allochthon (Skipp and Hait, 1977) is overridden by the Wood River and Milligen allochthons (Hall and others, 1975; Skipp and Hait, 1977). In the area designated 7 on figure 9, however, parautochthonous undated metamorphosed turbidite siltite and limestone, which resemble the Drummond Mine Lime-

[1] The terms "outer cratonic platform" and "inner cratonic platform" as used in this paper replace, respectively, "miogeosyncline" and "craton" of former usage. The outer cratonic platform was a mobile marginal cratonic area, which, by the end of Paleozoic time, largely had become a part of the stable craton of the North American continent. The outer cratonic platform was the site of flysch-trough, starved-basin, carbonate-bank, and shelf-basin depositional environments in Carboniferous time.

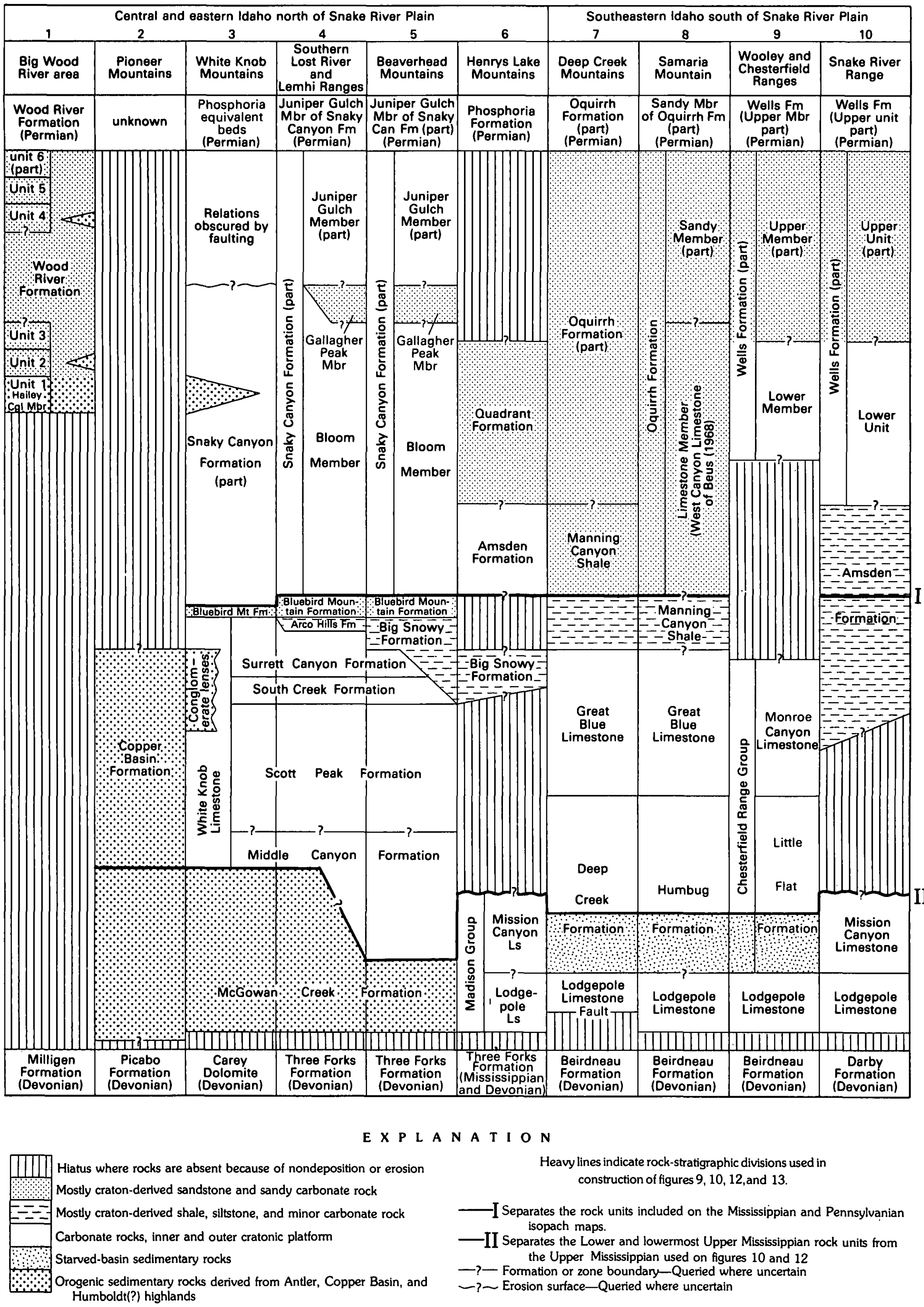
stone of the Copper Basin Group of Paull, Wolbrink, Volkmann, and Grover (1972), may represent the root zone of part of the Copper Basin allochthon (W. E. Hall, unpub. data). The siltite and limestone is about 1,000 m thick. Another parautochthonous sequence of Mississippian(?) argillite turbidites and deep-sea fan conglomerates, more than 500 m thick, is present in the White Cloud Peaks area (fig. 9, structural element 8) beneath the Wood River allochthon (C. M. Tschanz, written commun., 1977). Zero thickness occurs in the Big Wood River area where the Wood River Formation tectonically overlies the Devonian Milligen Formation. The combined thickness of the White Knob Limestone and McGowan Creek Formation is about 3,000 m in the White Knob Mountains (figs. 4 and 9, locality 9). Thicknesses decrease eastward toward the Idaho/Montana border where less than 500 m is reported



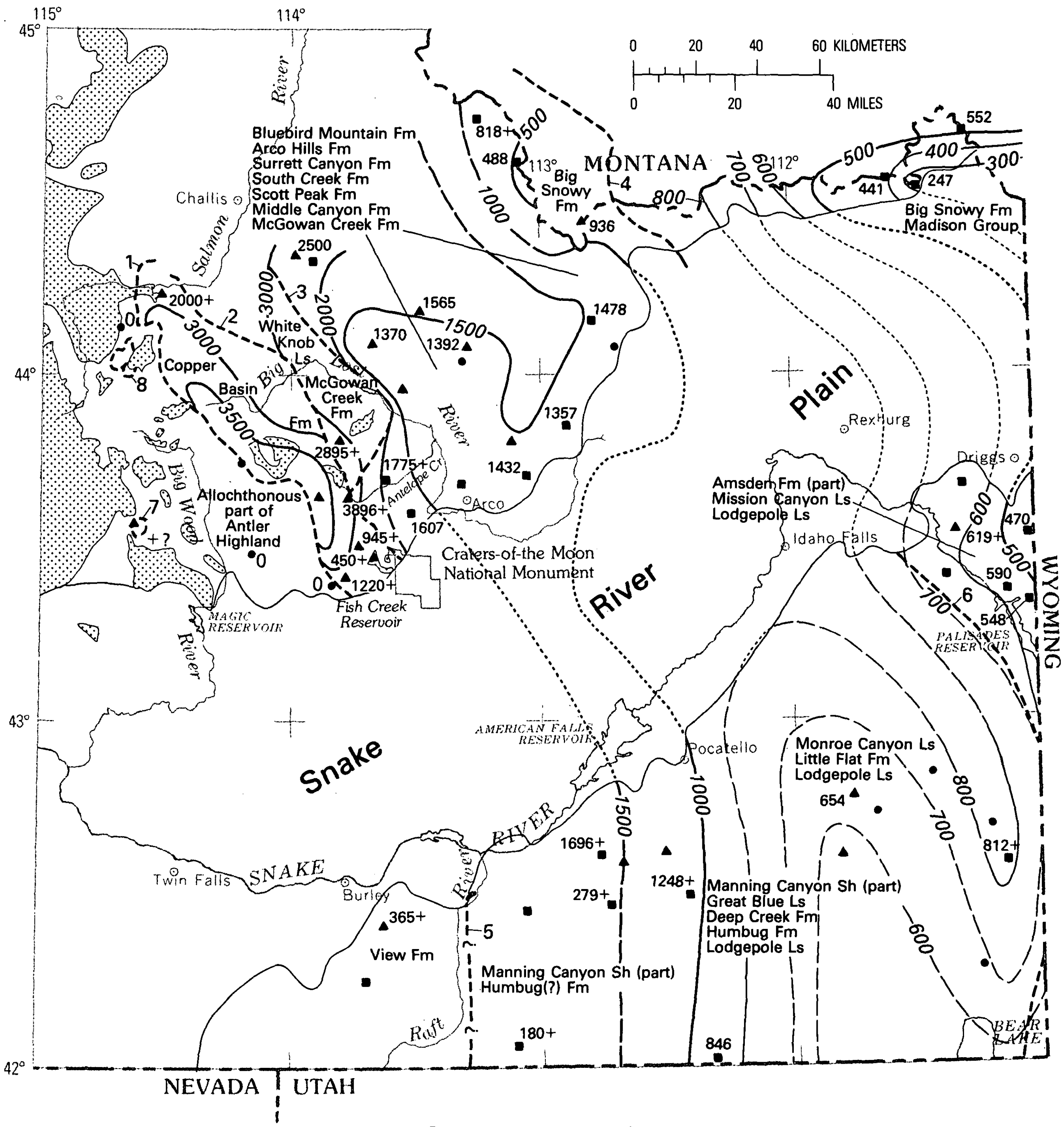
[1] Sando, Mamet, and Dutro (1969); Mamet and Skipp (1970) Brenckle, Lane, and Collinson (1974); Sando, Gordon, and Dutro (1975); Sando, Dutro, Sandberg, and Mamet (1976); Brenckle (1977)
[2] Sando, Mamet, and Dutro (1969); Sando, Dutro, Sandberg, and Mamet (1976); Sando, this volume
[3] Douglass (1977)

FIGURE 8.—Correlation chart. Numbered column refer to list of sources.

1. Umpleby, Westgate, and Ross (1930); Bostwick (1955); Thomasson (1959); Hall, Batchelder, and Douglass (1974); Skipp and Hall (1975a); Sandberg, Hall, Batchelder, and Axelsen (1975); Hall, W. E. (unpub. data).
2. Ross (1960, 1962a); Paull, Wolbrink, Volkman, and Grover 1972); Yokley (1974); Skipp and Hall (1975a); Skipp and Sandberg (1975); Nilsen (1977); Paull and Gruber (1977); Skipp, Betty (unpub. data).
3. Skipp (1961a); Ross (1962a); Skipp and Mamet (1970); Paull, Wolbrink, Volkman, and Grover (1972); Skipp and Sandberg (1975); Skipp and Hait (1977); Nilsen (1977); Skipp, Hoggan, (Schleicher, and Douglass (1979).
4. Thomasson (1959); Shannon (1961); Sandberg, Mapel, and Huddle (1967); Huh (1967); Mamet, Skipp, Sando, and Mapel (1971); Beutner (1972); Sandberg (1975); Skipp and Hait (1977); Sandberg and Poole (1977); Skipp, Hoggan, Schleicher, and Douglass, 1979; Skipp, Betty (unpub. data).
5. Huh (1967); Scholten and Ramspott (1968); Embree, Hoggan, Williams, and Skipp (1975); Sando, Gordon, and Dutro (1975); Sandberg (1975); Skipp and Hait (1977); Sandberg and Poole (1977); Skipp, Hoggan, Schleicher, and Douglass, 1979.
6. Thompson and Scott (1941); Witkind (1972); Sando, Gordon, and Dutro (1975); Maughan, E. K., (unpub. data).
7. Carr and Trimble (1961); Sando (1967, 1976a); Sando, Mamet, and Dutro (1969); Sando, Dutro, Sandberg, and Mamet (1976); Trimble and Carr (1976); Cress, L. D. (unpub. data, 1978).
8. Beus (1968); Platt (1977).
9. Dutro and Sando (1963); Cressman (1964); Sando (1967, 1977); Sando, Mamet and Dutro (1969); Armstrong (1969); Sando, Dutro, Sandberg, and Mamet (1976).
10. Staatz and Albee (1966); Sando (1967, 1977).



Central and eastern Idaho north of Snake River Plain
Southeastern Idaho south of Snake River Plain
1 Big Wood River area
2 Pioneer Mountains
3 White Knob Mountains
4 Southern Lost River and Lemhi Ranges
5 Beaverhead Mountains
6 Henrys Lake Mountains
7 Deep Creek Mountains
8 Samaria Mountain
9 Wooley and Chesterfield Ranges
10 Snake River Range
Wood River Formation (Permian)
unknown
Phosphoria equivalent beds (Permian)
Juniper Gulch Mbr of Snaky Canyon Fm (Permian)
Juniper Gulch Mbr of Snaky Can Fm (part) (Permian)
Phosphoria Formation (Permian)
Oquirrh Formation (part) (Permian)
Sandy Mbr of Oquirrh Fm (part) (Permian)
Wells Fm (Upper Mbr part) (Permian)
Wells Fm (Upper unit part) (Permian)
unit 6 (part)
Unit 5
Unit 4
Wood River Formation
Unit 3
Unit 2
Unit 1 Hailey Cgl Mbr
Relations obscured by faulting
Snaky Canyon Formation (part)
Juniper Gulch Member (part)
Gallagher Peak Mbr
Bloom Member
Quadrant Formation
Amsden Formation
Oquirrh Formation (part)
Manning Canyon Shale
Sandy Member (part)
Oquirrh Formation
Limestone Member (West Canyon Limestone of Beus (1968))
Wells Formation (part)
Upper Member (part)
Lower Member
Upper Unit (part)
Lower Unit
Amsden Formation
Bluebird Mt Fm
Bluebird Mountain Formation
Arco Hills Fm
Big Snowy Formation
Conglomerate lenses
Surrett Canyon Formation
South Creek Formation
Copper Basin Formation
White Knob Limestone
Scott Peak Formation
Middle Canyon Formation
Great Blue Limestone
Monroe Canyon Limestone
Chesterfield Range Group
Little Flat
Deep Creek Formation
Humbug Formation
Madison Group
Mission Canyon Ls
Lodgepole Ls
Mission Canyon Limestone
McGowan Creek Formation
Lodgepole Limestone
Fault
I
II
Milligen Formation (Devonian)
Picabo Formation (Devonian)
Carey Dolomite (Devonian)
Three Forks Formation (Devonian)
Three Forks Formation (Devonian)
Three Forks Formation (Mississippian and Devonian)
Beirdneau Formation (Devonian)
Beirdneau Formation (Devonian)
Beirdneau Formation (Devonian)
Darby Formation (Devonian)
EXPLANATION
Hiatus where rocks are absent because of nondeposition or erosion
Mostly craton-derived sandstone and sandy carbonate rock
Mostly craton-derived shale, siltstone, and minor carbonate rock
Carbonate rocks, inner and outer cratonic platform
Starved-basin sedimentary rocks
Orogenic sedimentary rocks derived from Antler, Copper Basin, and Humboldt(?) highlands
Heavy lines indicate rock-stratigraphic divisions used in construction of figures 9, 10, 12, and 13.
I Separates the rock units included on the Mississippian and Pennsylvanian isopach maps.
II Separates the Lower and lowermost Upper Mississippian rock units from the Upper Mississippian used on figures 10 and 12
—?— Formation or zone boundary—Queried where uncertain
—?— Erosion surface—Queried where uncertain



EXPLANATION

Tertiary and Cretaceous intrusive rocks

Contact

—500— Isopachs (partly restored) in 500-m and 1000-m intervals—Dashed where inferred; dotted across Snake River Plain

—300— Isopachs (partly restored) in 100-m intervals—Dashed where inferred; dotted across Snake River Plain

--1-- Structural element or boundary described in caption

▲ ● ■247 Sample localities—Same as on figure 4. Thicknesses in meters (locality 28). The thinnest Mississippian sequences of the cratonic platform in Idaho are in the eastern Centennial Mountains (localities 29 and 30a).

South of the plain, Mississippian rocks gradually thicken westward from 470 m in the Big Hole Mountains (locality 44) to more than 1,696 m in the northern Deep Creek Mountains (locality 34). West of this locality, incomplete and faulted outcrops of Mississippian shale and siltstone are present in parautochthonous sequences beneath thrust plates of Pennsylvanian and Permian rocks in the Sublett, Black Pine, and Albion Ranges (localities 33, 32, and 31).

Mississippian rocks in the western United States were divided into two depositional complexes by Rose (1976), a lower complex encompassing rocks ranging in age from early Kinderhookian to early Meramecian, and an upper complex containing strata of middle Meramecian through middle late Chesterian age. The Manning Canyon Shale and its equivalents were excluded from the concept of the upper depositional complex by Rose (1976). The divisions shown on figures 10 and 12 are based on Rose's depositional-complex concept, but rocks of latest Chesterian age have been included in thickness calculations of Upper Mississippian rocks. The Lower Mississippian complex, thus, generally corresponds to Cycle I, and the Upper Mississippian complex to Cycle III of Sando (1976a) and Sando, Dutro, Sandberg, and Mamet (1976), who divided the cycles into 13 phases and presented a paleogeographic map for each.

LOWER MISSISSIPPIAN COMPLEX

Rocks of Early Mississippian and earliest Late Mississippian age make up the Lower Mississippian complex (fig. 10). Included are those formations between line II and underlying units on the correlation chart (fig. 8). Flysch or foreland-basin, starved-basin and carbonate-platform depositional environments are represented.

North of the plain, most of the Copper Basin Formation, all of the McGowan Creek Formation, and the Madison Group constitute this interval. The Middle Canyon Formation is excluded on the isopach map even though a middle Osagean conodont fauna was recovered about 15 m above the base of the formation in the southern Beaverhead Mountains (Sandberg and Poole, 1977; Poole and Sandberg, 1977). The depositional environment of the Osagean part of the Middle Canyon is considered, however.

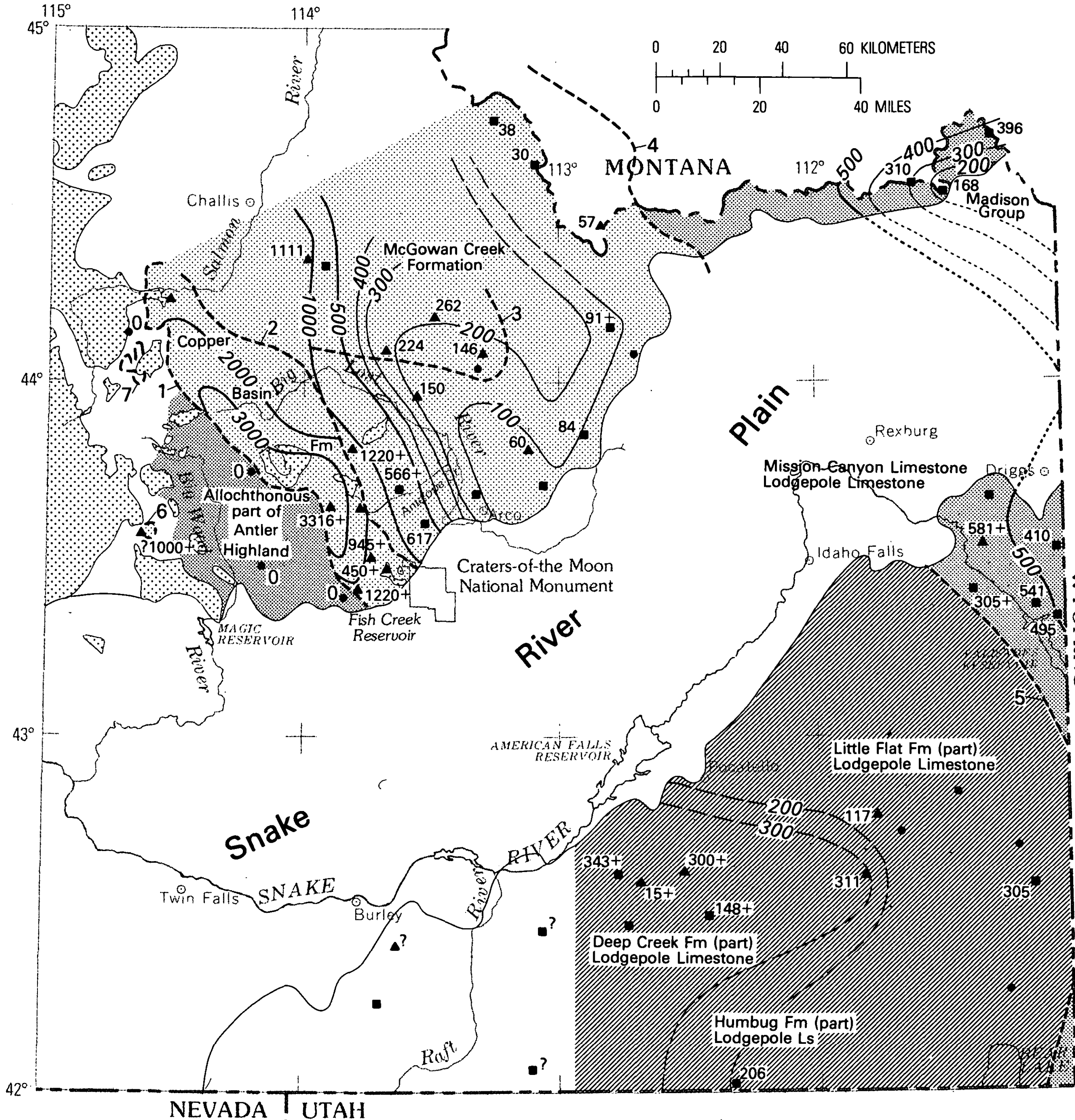
South of the plain, the phosphatic shale member of the Little Flat Formation, an arbitrary lower part of the Humbug Formation (86 m at locality 36), the lower siltstone member of the Deep Creek Formation, the Mission Canyon Limestone, and the Lodgepole Limestone are included.

COPPER BASIN FORMATION (PART)

More than 3,316 m of the Copper Basin Formation, the part of the formation designated the Scorpion plate by Nilsen (1977), is included on figure 10. The Scorpion plate of the Copper Basin allochthon includes, in ascending order, the Little Copper Formation (Paull and Gruber, 1977), the Drummond Mine Limestone, the Scorpion Mountain Formation, and the lower part of the Muldoon Canyon Formation of the Copper Basin Group of Paull, Wolbrink, Volkmann, and Grover (1972). The 18,000 feet (5,500 m) of section reported in 1972 contains a duplicating thrust (Nilsen, 1977; Nilsen, and Skipp, unpub. data); thus, the real thickness is somewhat less, though a complete section has not yet been pieced together. About 4,000 m is shown on figure 11. The Copper Basin Formation is made up of boulder- to granule-conglomerate, sandstone, siltstone, mudstone, and limestone (Paull and others, 1972), interpreted as foreland-basin flysch containing terrigenous turbidites derived from the Antler highland to the west and carbonate turbidites derived in part from cratonic carbonate banks to the

FIGURE 9.—Isopach map of the Mississippian System showing provincial formation names.

1. Structural eastern limit of the Pennsylvanian and Permian Wood River Formation.
2. Structural eastern limit of the Mississippian Copper Basin Formation.
3. Structural eastern limit of Mississippian White Knob Limestone.
4. Structural boundary between the carbonate platform to the west and the inner cratonic platform to the east, and eastern limit of Mississippian McGowan Creek, Middle Canyon, Scott Peak, South Creek, Surrett Canyon, Arco Hills, and Bluebird Mountain Formations. Also boundary between Idaho province and Montana province of Sando (1967).
5. Structural(?) western limit of Upper Mississippian carbonate depositional complex.
6. Boundary between Idaho province (western) and Montana province (eastern) of Sando (1967), in general position of western margin of inner cratonic platform.
7. Structural window of Copper Basin(?) Formation.
8. Structural windows(?) of Copper Basin(?) Formation (C. M. Tschanz, unpub. data).



EXPLANATION

- Tertiary and Cretaceous intrusive rocks
- Antler-derived flysch deposits—Conglomerate, sandstone, siltstone, and mudstone with minor limestone
- Mostly craton-derived deposits—Limestone, phosphatic shale, siltstone, and sandstone
- Cratonic-platform carbonate rocks
- Emergent area
- Contact
- —500— Isopachs (partly restored) in 500-m and 1000-m intervals; dotted across Snake River Plain
- —300— Isopachs (partly restored) in 100-m intervals—Dashed where inferred; dotted across Snake River Plain
- 5 Structural element or boundary described in caption
- ▲ ● ■ 206 Sample localities—Same as on figure 4. Thicknesses in meters

east (Poole, 1974; Poole and Sandberg, 1977; Nilsen, 1977). The age of the Drummond Mine Limestone unit of the Copper Basin Formation is Kinderhookian, as indicated by scattered conodont faunas identified by C. A. Sandberg (Skipp and Hall, 1975a; Paull and Gruber, 1977; Poole and Sandberg, 1977). Sparse ammonoids, trilobites, brachiopods, calcareous foraminifers, and numerous trace fossils also have been recovered from other parts of the flysch sequence considered to be correlative with the Lower Mississippian complex (Skipp and Hall, 1975a; Skipp, 1974; Poole, 1974; Skipp, unpub. data).

McGOWAN CREEK FORMATION

Most of the McGowan Creek Formation, which ranges in thickness from more than 1,220 m in the White Knob Mountains (locality 9) to 30 m in the Beaverhead Mountains (locality 28), is composed of orogenic detritus, recognized as such by Poole (1974) and designated the lower member of the McGowan Creek Formation by Sandberg (1975). This lower member consists of fine-grained, thinly bedded turbidites (Poole, 1974; Sandberg, 1975; Nilsen, 1977; Poole and Sandberg, 1977). The upper member of the McGowan Creek Formation, which ranges in thickness from 60 to 150 m, is present only north and west of Hawley Mountain (figs. 2, 4), where the McGowan Creek is thickest (Sandberg, 1975). This upper member, consisting of calcareous siltstone interbedded with silty micritic limestone, is considered a starved-basin facies (Poole and Sandberg, 1977). The McGowan Creek Formation has been dated by conodonts (Sandberg and others, 1967; Sandberg, 1975). Other fossils are sparse, though scattered brachiopods, mollusks (pelecypods, gastropods, cephalopods), trilobites, corals, and trace fossils have been found.

MADISON GROUP

The Madison Group, consisting of the transgressive Lodgepole Limestone overlain by the regressive Mission Canyon Limestone, is present on both the north and south sides of the plain, where it appears to thicken westward to the inner cratonic platform margin, aggregating more than 581 m in easternmost Idaho (fig. 10; locality 40). The Lodgepole Limestone is divided into the Paine Member and overlying Woodhurst Member. The Paine Member, a sparsely fossiliferous, thin-bedded, fine-grained, silty, and argillaceous limestone, is interpreted as a slope deposit laid down seaward from a shelf-carbonate bank (Sando, 1977). The Woodhurst Member consists of cyclically interbedded fine-grained and coarse-grained carbonate beds representing an alternation of high-energy and low-energy conditions intermediate between those of the Paine Member of the Lodgepole and the overlying Mission Canyon Limestone. The Mission Canyon contains thick beds of crinoidal limestone in the lower part and solution breccias, cherty fine-grained limestone, dolomite, and dolomitic limestone in the upper part. The Mission Canyon Limestone represents a westward-prograding shelf-carbonate envivironment characterized by several episodes of restricted circulation in highly saline lagoons in the upper part (Sando, 1977). Calcareous foraminifers, corals, brachiopods, and encrinitic debris are common in much of the Madison Group; all except the encrinitic debris have been valuable in age determinations.

The Lodgepole Limestone in the ranges west of the inner cratonic platform margin (fig. 8, columns 7, 8, and 9) is represented largely by lithologies like those of the Paine Member overlain by a thin Woodhurst Member. Total thickness in the Chesterfield Range (locality 37) is 79 m (figs. 10 and 11).

FIGURE 10.—Isopach map of the Lower Mississippian and lowermost Upper Mississippian rocks (lower depositional complex of Rose (1976) and cycle I of Sando (1976a), showing Osagean-early Meramecian lithofacies, provincial formation names, and position of allochthonous part of Antler highland.

1. Western structural limit of well-dated Lower Mississippian part of the Copper Basin Formation.
2. Eastern structural limit of the Copper Basin Formation.
3. Southern boundary of starved-basin facies of McGowan Creek Formation (Sandberg, 1975).
4. Eastern structural limit of the McGowan Creek Formation and western limit of lower shelf margin of Rose (1976), and craton margin of Sando (1976a).
5. Approximate western limit of lower carbonate shelf margin of Rose (1976), craton margin of Sando (1976a), and eastern limit of the starved-basin facies (Sandberg and Gutschick, 1977; Poole and Sandberg, 1977).
6. Structural window of Copper Basin(?) Formation.
7. Structural windows of Copper Basin(?) Formation.

Foraminifers, conodonts, and corals have been used to determine its age.

LITTLE FLAT, DEEP CREEK, AND HUMBUG FORMATIONS (PART)

In the Chesterfield Range, the Lodgepole is overlain by the siltstone member of the Little Flat Formation of the Chesterfield Range Group. The siltstone member consists of 38 m of phosphatic siltstone and dark cherty fine-grained limestone representing a starved-basin facies (Rose, 1976; Sando and others, 1976; Poole and Sandberg, 1977). The lower siltstone member of the Deep Creek Formation, 231 m thick at locality 34, has also been interpreted as a starved-basin deposit (fig. 11) (Sando and others, 1976). An arbitrary thickness of the Humbug Formation in the Samaria Mountain area (locality 36), consisting of dark-brown calcareous sandstone and siltstone, is assigned to the starved-basin facies. Conodonts, foraminifers, brachiopods, cephalopods, and fish fragments are present in the siltstone and limestone sequences.

DEPOSITIONAL HISTORY

The depositional histories north and south of the plain during the time frame of the lower depositional complex are somewhat different. The rapid transgression of the Cordilleran sea in late Kinderhookian and early Osagean time north of the plain spread orogenic detritus derived from the Antler highland eastward across the outer cratonic platform to the edge of the inner cratonic platform, and carbonate detritus from the platform spread westward to mingle with deep-water terrigenous turbidites in the flysch trough (Poole, 1974; Sandberg and others, 1975; Nilsen, 1977; Poole and Sandberg, 1977). South of the plain, in the apparent absence of orogenic detritus, carbonate sediments, largely slope and forebank deposits, were laid down in front of a prograding carbonate bank (Sando, 1976a; Rose, 1976; Sandberg and Poole, 1977).

In middle Osagean through early Meramecian time, the sea gradually regressed, forming the carbonate-bank deposits of the Mission Canyon Limestone along the inner cratonic platform margin. West of this area, and south of the plain, a starved basin formed. Relationships between starved-basin and carbonate-bank facies are shown in figure 11.

North of the plain, during the same interval, limestone of the lower part of the Middle Canyon Formation spread westward as forebank deposits in front of the westward-prograding bank limestone of the Mission Canyon Limestone (Sandberg and Poole, 1977; Poole and Sandberg, 1977). The eastward spread of flysch detritus had either ceased by this time or was restricted. Locally, siltstone and limestone of the upper member of the McGowan Creek Formation (fig. 10) grade upward into silty limestone of the overlying Middle Canyon and are interpreted as a starved-basin facies (Sandberg and Poole, 1977; Poole and Sandberg, 1977).

UPPER MISSISSIPPIAN COMPLEX

Rocks of Late Mississippian age make up the Upper Mississippian complex (fig. 12). Included are those formations between lines I and II on the correlation chart (fig. 8). Sediments of a shoaling flysch basin, carbonate bank, lagoon, and/or restricted marine basin are represented.

North of the plain, a poorly defined upper part of the Copper Basin Formation, the White Knob Limestone, the Middle Canyon, South Creek, Scott Peak, Surrett Canyon, Arco Hills, Bluebird Mountain, and Big Snowy Formations, are included. South of the plain, the upper chert-banded limestone member of the Deep Creek Formation, an arbitrary upper part of the Humbug Formation, the cherty limestone, sandstone, and sandy limestone members, in ascending order, of the Little Flat Formation, the Great Blue Limestone, the lower part or all of the Manning Canyon Shale, and the lower part of the Amsden Formation, make up the interval.

COPPER BASIN FORMATION (PART)

An incomplete part of the Copper Basin Formation having estimated minimum thicknesses of 580 and 2,000 m is shown on figure 12; about 1,000 m is estimated on figure 11. In the vicinity of locality 8, this part of the formation includes conglomerate, mudstone, pebbly mudstone, sandstone, scattered lenses of shallow-water fossiliferous marine limestone and sandy dolomite, and thin coal seams deposited in a marginal-marine to shallow-marine environment (Skipp and Hait, 1977; Nilsen, 1977). These shallow-water sedimentary rocks grade downward into turbidites that closely resemble those of the lower part of the formation. The upper part of the Copper Basin Formation is bounded by thrust faults (Skipp and Hait, 1977). The thickness at locality 8 is an estimate, as this part of the sequence was not included in the measured sections of Paull, Wolbrink, Volkmann, and Grover (1972). The thickness at locality 7 is an estimate of thickness by S. W. Hobbs (oral commun., 1976) of an isoclinally folded sequence of relatively fine grained

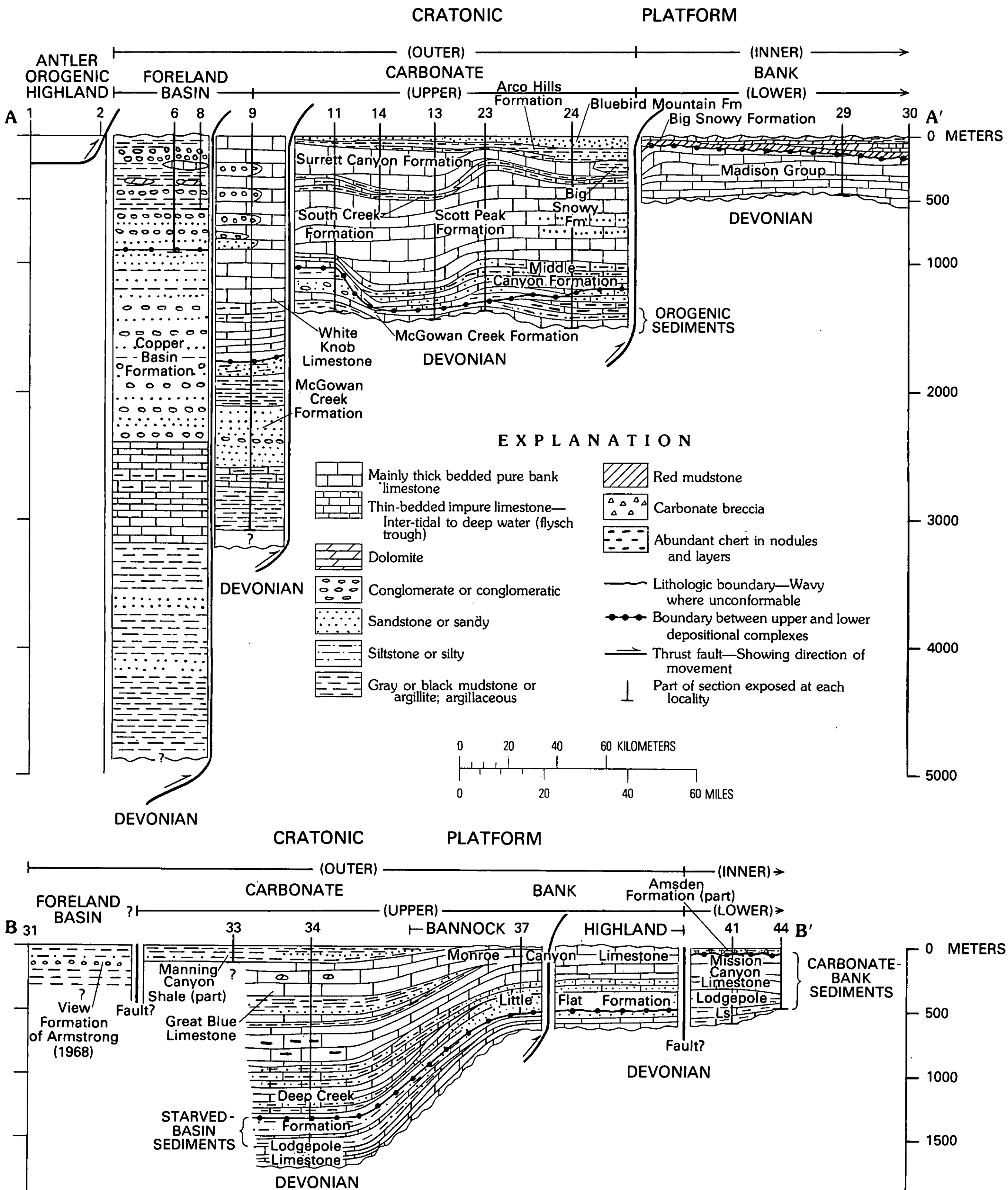
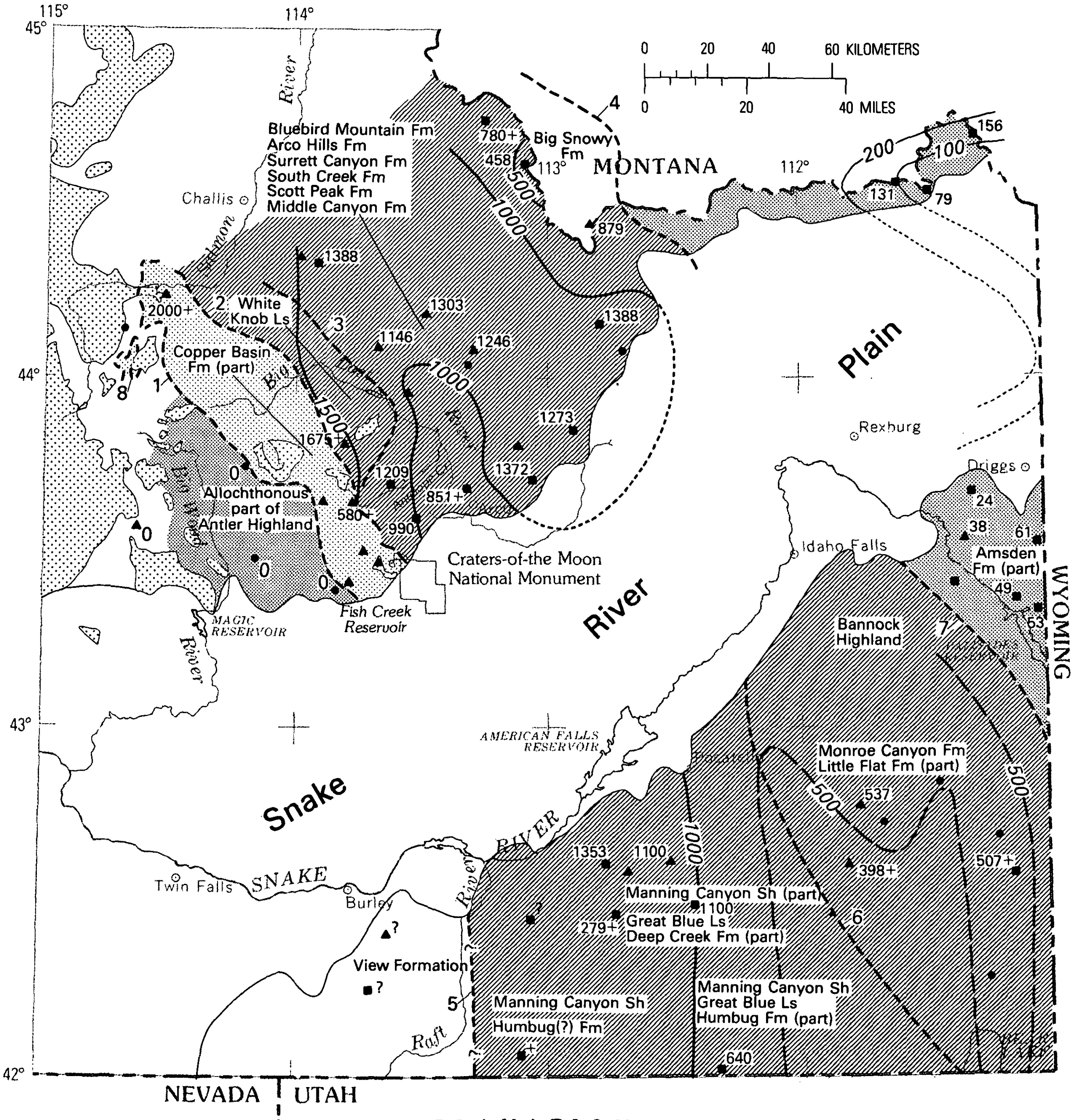


FIGURE 11.—Cross sections showing stratigraphic and structural relations of Mississippian rocks in Idaho north of the Snake River Plain (*A–A′*) and south of the plain (*B–B′*). Locations of cross sections are shown on figures 2 and 4. Locations of stratigraphic sections are shown on figure 4. Datum is the top of the Mississippian.



EXPLANATION

- Tertiary and Cretaceous intrusive rocks
- Conglomerate, sandstone, argillite, pebbly mudstone, limestone and sandy dolomite—Much of it of shallow-water origin. Minor coal present. Some deep-water flysch sediments may be present in lower part
- Shelf carbonate rocks locally interbedded with Antler-derived conglomerate and sandstone (White Knob Formation)
- Craton-derived red and black claystone, limestone, dolomite and sandstone
- Emergent area
- Contact
- —500— Isopachs (partly restored) in 500-m and 1000-m intervals—Dashed where inferred; dotted across Snake River Plain
- —200— Isopachs (partly restored) in 100-m intervals—Dotted across Snake River Plain
- 5 Structural element or boundary described in caption
- ▲ ● ■640 Sample localities—Same as on figure 4. Thicknesses in meters

quartzitic turbidites exposed along the Salmon River (Hobbs and others, 1975a; Nilsen, 1977). Strata exposed in the area outlined by structural element 8 (fig. 12) resemble the Salmon River turbidites (C. M. Tschanz, written commun., 1977). Locally abundant faunas, which include brachiopods, mollusks, bryozoans and calcareous foraminifers date parts of the sequences as late Meramecian to Chesterian.

The variety of lithologies in the upper part of the Copper Basin Formation suggests deposition in a shoaling foreland basin, which, before the end of Mississippian time, became a neutral area and, perhaps locally, an emergent-positive area.

WHITE KNOB LIMESTONE

The White Knob Limestone, at least 1,675 m thick at the type section in the White Knob Mountains, gradationally overlies the McGowan Creek Formation (Skipp, 1961a). It consists of fine-grained argillaceous and laminated silty spiculitic mudstone in the lower part. This mudstone grades upward into clean wackestone, grainstone, and packstone, which in the upper 840 m of the type section, are interbedded with lenses of conglomerate containing gravel fragments as much as 10 cm in diameter, medium- to coarse-grained sandstone, and minor siltstone beds (Skipp, 1961a). Fabrics of limestone, conglomerate, and sandstone in the upper part indicate deposition mostly in a subtidal to intertidal turbulent marine environment. The fine-grained lower beds are considered to be forebank deposits. The interbedded upper limestone-terrigenous clastic sequence of Chesterian age (Skipp and Mamet, 1970) is the westernmost representative of the prograding Upper Mississippian carbonate bank described by Rose (1976) north of the plain. Interbedded clastic rocks were derived from the Antler highland, though the mechanisms that produced this phenomenon remain obscure. Uplift of Copper Basin deposits to the west or north seems necessary for this interpretation. Mississippian-age thrusting has been postulated by Nilsen (1977). Shallow-water carbonate rocks of late Chesterian age are interbedded locally with terrigenous clastic rocks of the Copper Basin Formation.

Though much of the White Knob is recrystallized or altered by contact metamorphism, locally abundant faunas composed of bryozoans, mollusks, brachiopods, ostracodes, corals, trilobites, algae, foraminifers, crinoidal debris, and sparse fish plates are present in the upper part and were used to date the formation as middle Meramecian to late Chesterian (Skipp and Mamet, 1970; Yokley, 1974).

MIDDLE CANYON, SCOTT PEAK, SOUTH CREEK, AND SURRETT CANYON FORMATIONS

The carbonate-bank and forebank deposits of the Middle Canyon, Scott Peak, South Creek, and Surrett Canyon Formations are present from the White Knob Mountains east to the Idaho-Montana border and beyond. Thicknesses range from 1,288 m at localities 15 and 24, the northern Lost River Range and the southern Beaverhead Mountains, respectively, to 646 m in the Howe Peak area (locality 13) and about 390 m in the central Beaverhead Mountains (locality 28). These formations constitute a prograding carbonate-bank complex (Huh, 1967; Rose, 1976), which generally thickens westward (figs. 11, 12). The Middle Canyon, consisting of sandy, silty, and cherty, thin- to medium-bedded carbonate mudstone, is, in part, the forebank deposit formed in front of the prograding bank (Huh, 1967; Sandberg and Poole, 1977). The sandy

FIGURE 12.—Isopach map of Upper Mississippian rocks showing late Meramecian and Chesterian lithofacies and provincial formation names, and position of allochthonous part of Antler highland.

1. Structural western limit of well-dated Mississippian Copper Basin Formation, some of which is known to be of Late Mississippian age, and structural eastern limit of Wood River Formation.
2. Structural eastern limit of Copper Basin Formation and western limit of carbonate-bank complex.
3. Structural and/or depositional eastern limit of coarse detritus derived from Antler highland interbedded with shallow-water limestones (White Knob Limestone).
4. Eastern limit of Upper Mississippian carbonate-bank complex and structural boundary between the outer cratonic platform to the west and the inner cratonic platform to the east (craton margin of Sando (1976a), and upper carbonate-platform margin of Rose (1976)).
5. Structural western limit(?) of carbonate-bank complex.
6. Western limit of Bannock highland.
7. Structural boundary between outer cratonic platform and inner cratonic platform (craton margin of Sando (1976a) and upper carbonate-bank margin of Rose (1976)). Approximate eastern limit of Bannock highland.
8. Structural windows(?) of Copper Basin(?) Formation.

and silty parts of the Middle Canyon contain inner cratonic-platform-derived detritus deposited on the outer cratonic platform after Madison deposition; thus, they are correlative with the Kibbey Formation of the Big Snowy Group in Montana (Sando and others, 1975, fig. 13, pl. 11). Thick-bedded, variably cherty, fossiliferous bank limestones of the Scott Peak and Surrett Canyon Limestones, which form massive cliffs in several ranges, are separated by thin-bedded silty and argillaceous limestone of the South Creek Formation, which probably represents a period of relatively deep water marine circulation that temporarily interrupted carbonate-bank buildup. In the Beaverhead Mountains, the Scott Peak Formation contains sandy zones that are missing farther west. The Surrett Canyon Formation is thin or missing in the Beaverhead Mountains but is about 330 m thick in the northern Lost River Range (locality 15). Fossils are varied and abundant, particularly in the Scott Peak and Surrett Canyon bank limestones. They include corals, brachiopods, mollusks, bryozoans, algae, calcareous foraminifers, trilobites, ostracodes, and shark teeth, which indicate that the formations range in age from middle Meramecian to late Chesterian (Mamet and others, 1971). A valuable field guide to diagnostic rugose and colonial corals from these formations is available (Sando, 1976b).

BIG SNOWY, ARCO HILLS, AND BLUEBIRD MOUNTAIN FORMATIONS

In the Beaverhead Mountains, the South Creek and Surrett Canyon Formations are thin or absent and are replaced by black shale, siltstone, fine-grained calcareous sandstone, and phosphatic carbonate conglomerate of the Big Snowy Formation (fig. 8). These Big Snowy sediments mark the end of carbonate-bank buildup, the beginning of a restricted marine environment, and the westward spreading of inner cratonic-platform detritus onto the outer cratonic platform in late Meramecian to middle Chesterian time. Farther west, very fine grained silty limestone, shale, and siltstone of the Arco Hills Formation indicate the same restriction of circulation and shoaling of the seas near the site of the foundered flysch trough in late Chesterian time. The limestone, siltstone, and shale of the Big Snowy and Arco Hills Formations were succeeded by a very late Chesterian flood of very fine grained inner-craton-derived sand (the Bluebird Mountain Formation), which transgressed from east to west. The Bluebird Mountain Formation ranges in thickness from 99 m in the Beaverhead Mountains (locality 24) to about 5 m in the White Knob Mountains (locality 12). The Arco Hills Formation contains a fauna dominated by brachiopods (many phosphatic) and mollusks. Calcareous foraminifers, conodonts, and a few small rugose corals are present. The Big Snowy also contains numerous brachiopods, some mollusks, bryozoans (including *Archimedes* sp.), conodonts, algae, and calcareous foraminifers. The Bluebird Mountain Formation contains sparse foraminifers, conodonts, ostracodes, bryozoans, echinoderms, and brachiopods (Crawford, 1976; Skipp and others, 1979).

East of the inner cratonic platform margin, the Big Snowy in the Centennial Mountains (localities 29 and 30a) and Henrys Lake Mountains (locality 30) is less than 200 m thick and consists of sandstone, siltstone, red, green, and black claystone, thin-bedded limestone and thick-bedded, coarsely crystalline dolomite. The limestone contains corals, brachiopods, blastoids, bryozoans, foraminifers, and algae of late Chesterian age.

AMSDEN FORMATION (PART)

South of the plain, quartzite (Pampeyan and others, 1967; locality 44), sandstone, variegated shale, limestone (Staatz and Albee, 1966; locality 39), sandstone, siltstone, and shale (Jobin and Soister, 1964) have been assigned variously to the lower part of the Wells Formation, the Big Snowy Formation, or the lower part of the Amsden Formation. All these sequences, herein assigned to the Amsden Formation (fig. 8), are 61 m or less thick (fig. 12) and are of Late Mississippian (latest Meramecian and Chesterian) to Early Pennsylvanian age (Sando, 1976a). They compose the western extension of lagoonal and restricted marine facies of the cratonic platform of Wyoming (fig. 11) described by Sando in a companion paper (this volume). Faunas in the limestone beds consist of foraminifers, bryozoans, brachiopods, ostracodes, gastropods, and corals. The entire thickness of the Amsden Formation south of the plain is included on the isopach map for the Upper Mississippian (fig. 12), because it is not known how much of the interval might be Pennsylvanian. Most of the faunas reported are of Late Mississippian age, and it is concluded that only the uppermost part of the interval is of Pennsylvanian age.

DEEP CREEK, LITTLE FLAT, AND HUMBUG FORMATIONS (PART)

South of the plain and west of the inner craton margin, sandstone and sandy and cherty limestone of the upper member of the Deep Creek Formation, the upper three members of the Little Flat Formation, and an arbitrary upper part of the Humbug Formation were deposited on the outer cratonic platform. Included in this interval is a sequence of limestone, sandy limestone, and quartzite, more than 180 m thick, exposed in the Black Pine Range (locality 32; J. F. Smith, Jr., written commun., 1976). The sequence contains conodonts of probable middle Meramecian age (John Repetski, written commun., 1976) and is questionably assigned to the Humbug Formation. The interval is about 460 m thick in the Deep Creek Mountains (locality 34) and thins eastward to about 250 m in the Chesterfield Range (locality 37). Cratonic-platform-derived sandstone is dominant in the Chesterfield Range, whereas sandy limestone predominates in the Deep Creek Mountains. The sand and silt probably originated on the inner craton and were swept across the exposed and eroding Lower Mississippian carbonate complex (Sando and others, 1975; Rose, 1976); they are equivalent to the Darwin Sandstone Member of the Amsden Formation in Wyoming (Sando and others, 1975, fig. 13, pl. 11). A similar history is postulated for the sandy facies of the Middle Canyon Formation north of the plain. Fossils are sparse in these facies, but conodonts, foraminifers, brachiopods, and corals establish a middle Meramecian age for the sequences.

GREAT BLUE AND MONROE CANYON LIMESTONES

In the Deep Creek Mountains, above the Deep Creek Formation, about 760 m of Great Blue Limestone consists of thick- to thin-bedded carbonate-bank limestone, and a medial black to gray shale interval, 130 m thick. The Great Blue at this locality marks the westernmost outcrop of the upper carbonate shelf south of the plain (localities 34 and 35). The upper carbonate shelf margin was depicted by Rose (1976, fig. 9) and Poole and Sandberg (1977, fig. 7) as just east of the Deep Creek Mountains, whereas Sando (1976a, fig. 6) showed it west of this locality. Recent studies show that the Great Blue in the Deep Creek Mountains is probably part of the carbonate bank (L. D. Cress, unpub. data, 1978). Indirect evidence suggests to the senior author that the limestone of the Great Blue could extend as far west as the Black Pine Range (locality 32), where normally associated strata similar to the overlying Manning Canyon Shale and the upper part of the underlying Deep Creek or Humbug Formation are exposed in separate structural windows (J. F. Smith, Jr., written commun., 1976). To the east, thick- to thin-bedded limestone of the Monroe Canyon Limestone, more than 280 m thick, make up the eastward-thinning complex of shelf-carbonate deposits. Brachiopods, corals, bryozoans, echinoderms, gastropods, trilobites, foraminifers, and algae are abundant in the Monroe Canyon and Great Blue Limestones (Dutro and Sando, 1963; Sando, and others, 1969; Trimble and Carr, 1976).

MANNING CANYON SHALE (PART)

The Manning Canyon Shale is present west of boundary 6 and east of boundary 5 and is not present in the area of the Bannock highland (fig. 12). The formation consists of dark-gray or black to varicolored shale or argillite interbedded with calcareous siltstone and sandstone or quartzite, minor limestone, and oolitic phosphate rock. In the Deep Creek Mountains, 134 m of the lower part of the Manning Canyon is assigned to the Upper Mississippian complex. At Samaria Mountain, the entire interval is only 80 m thick and is assigned to the Mississippian. In the Black Pine Range, more than 600 m of black argillite containing a few lenses of quartzite and limestone has yielded a conodont that has an age range from latest Mississippian through Early Permian; the unit has been mapped as Manning Canyon Shale by J. F. Smith, Jr. (written commun., 1976). Part of the Black Pine sequence probably is Late Mississippian in age. The Manning Canyon Shale in southeasternmost Idaho has been interpreted as a wedge of fine terrigenous material probably derived from the margins of the inner cratonic platform (Rose, 1976; L. D. Cress, written commun., 1978), which spread westward across the upper depositional carbonate complex south of the plain, much as did the Arco Hills and Bluebird Mountain Formations north of the plain. Sando believes that the terrigenous material was derived from the Antler orogenic highland to the west. Black shale and phosphorite indicate a restricted marine environment in part. Fossils are rare, but brachiopods and conodonts of latest Chesterian age (Beus, 1968) have been identified in the lower part of the Manning Canyon Shale.

VIEW FORMATION OF ARMSTRONG (1968)

More than 100 m of dark, graphitic, muscovite-quartz-calcite schist and dolomitic quartz schist overlain by light-gray quartzite and scattered conglomerate lenses occurs in the Albion Range (locality 31) and is tentatively considered part of the Mississippian. Conglomerate in the sequence suggests correlation with the Chainman Shale or Diamond

Peak Formation, Antler highland-derived orogenic sequences present in northeastern Nevada. The sequence has been thrust eastward, and its original depositional site is unknown. The Raft River valley between the Albion and Sublett Ranges may contain the present boundary between the carbonate bank and the foreland basin (figs. 11, 12).

DEPOSITIONAL HISTORY

Regional uplift during latest early Meramecian time drained the inner cratonic platform and caused the sea to be confined to the outer cratonic platform and the foreland basin (Sando, 1976a). Lower Mississippian limestone banks of the Madison Group were exposed both north and south of the plain, and terrigenous detritus was carried westward into the foreland basin to form the sandy limestone of the Middle Canyon Formation north of the plain and the sandstone and sandy limestone of the upper parts of the Deep Creek, Little Flat, and Humbug Formations south of the plain. In middle Meramecian through late Chesterian time, thick-bedded fossiliferous bank limestones, representing several transgressive-regressive cycles, spread westward across the foreland basin (Huh, 1967; Rose, 1976). North of the plain, the bank limestone is interbedded with conglomeratic detritus derived from the shoaling distal flysch basin on the west (fig. 11). South of the plain, in Idaho, the location of the western edge of the carbonate bank is obscured by faulting, lack of outcrops, and metamorphism, but it may extend as far west as the Black Pine Range (fig. 11). In southeasternmost Idaho, the northern part of the Bannock highland was emergent in latest Chesterian time (Sando, 1976a, p. 332).

North of the plain, the inner cratonic platform remained emergent until latest Meramecian time. Black shale, sandstone, and limestone conglomerate (Big Snowy Formation) replaced carbonate-bank deposition in the western part of the inner cratonic platform during late Meramecian into Chesterian time. In latest Chesterian time, a blanket of mudstone and very fine grained sandstone spread westward from the inner platform at least as far west as the present eastern edge of the Copper Basin Formation. The flysch trough in middle Chesterian time was receiving fine- to coarse-grained western-derived detritus in a very shallow, locally restricted marine environment. As there is no evidence of western-derived detritus in the latest Chesterian part of the White Knob Limestone, we suggest that much of the area of the trough ceased to subside, became neutral, and then emergent, possibly before, or shortly after, the end of Mississippian time.

MISSISSIPPIAN-PENNSYLVANIAN CONTACT

The Mississippian-Pennsylvanian contact is gradational over much of the cratonic platform of Idaho, where Mississippian rocks are present. The systemic boundary lies within the Manning Canyon Shale south of the plain and is thought to be within the lowermost beds of the Snaky Canyon Formation near the contact with the underlying Bluebird Mountain Formation north of the plain. The base of the Bluebird Mountain Formation is a sharp boundary and relatively easy to find in the field, whereas the top is gradational and somewhat arbitrary. As the unit is sparsely fossiliferous and has a sharp basal contact, beds correlative with the formation have been considered lowermost Pennsylvanian (Mamet and others, 1971; Sando, 1976a). Calcareous Foraminifera of Mamet zone 19 (fig. 8), however, are present at several horizons within the formation (Skipp and others, 1979); the formation is assigned to the Mississippian in this paper.

Pennsylvanian rocks are absent in the outcrop area of the Copper Basin highland, which was a source area in Middle Pennsylvanian time (Skipp and Hall, 1975a; Skipp and Hait, 1977). The Mississippian-Pennsylvanian boundary is unconformable in the area of the Bannock highland in southeastern Idaho (figs. 13, 14; Williams, 1962; Sando, 1976a) and in the area of Big Snowy deposition on the inner cratonic platform at the Montana-Idaho border. The systemic boundary appears conformable south of the plain near the Wyoming border, where it is within the Amsden Formation (Sando, 1976a).

PENNSYLVANIAN SYSTEM

The Pennsylvanian System of the United States correlates with most of the Upper Carboniferous Series in Europe (fig. 8) and includes, from oldest to youngest, the Morrowan, Atokan, Des Moinesian, Missourian, and Virgilian Provincial Series.

PALEOTECTONIC SETTING—HUMBOLDT OROGENY

Pennsylvanian rocks in Idaho can best be grouped into two depositional frameworks. The early one, representing Early and early Middle Pennsylvanian (Morrowan and Atokan) time reflects the paleotectonic setting inherited from latest Mississippian time. Limestones, many sandy, silty or argillaceous, were deposited in shallow epeiric seas, which spread uniformly across the cratonic platform westward to the edge of the neutral or emergent Copper Basin area, the site of the former Mississippian flysch trough. The seas also flooded the inner cratonic platform along the eastern edge of the State, and both carbonate and terrigenous sediments accumulated in restricted marine and lagoonal environments.

In late Middle Pennsylvanian (Des Moinesian) time, the tectonic setting changed. The Copper Basin highland (figs. 13, 14) rose and contributed minor coarse detritus to a newly formed Wood River basin on the west, to the Snaky Canyon Formation area on the east, and to the Oquirrh Formation on the south. The Bannock highland in southeastern Idaho, which had been emergent through Late Mississippian and Early Pennsylvanian time (Williams, 1962; Sando, 1976a), submerged and received sediment. At the same time, floods of very fine to fine-grained sand were deposited in the Wood River, Sublett, Oquirrh, and Quadrant basins.

Ketner (1977) recently defined the Humboldt orogeny in Nevada to include the late Paleozoic orogenic events that affected parts of the Great Basin from late Middle Pennsylvanian time through Early Permian time. The axis of the north-trending Humboldt highland of western Nevada, which shed detritus both east and west, was west of the axis of the former Antler highland, according to Ketner (1977). Poole and Wardlaw (1978) described the highland as a series of Pennsylvanian flysch basins and emergent ridges or islands in central Nevada. They considered the highland to have been along the western side of the former Antler orogenic highland.

Extension of the Humboldt highland into southern Idaho is tenuous because the Idaho batholith occupies the probable position of this inferred orogenic belt. Paleocurrent evidence of a western or southwestern source terrane for the bulk of Wood River Formation detritus (Thomasson, 1959) is compatible with the idea of a highland in western Idaho. The major problems with this interpretation are (1) the mineralogy of the Wood River sandstones, which suggest a cratonic basement source (Hall and others, 1974), and (2) the similarity between Oquirrh basin and Wood River basin sedimentary rocks, even though the Oquirrh basin formed earlier. The Oquirrh basin probably also was filled with detritus derived from cratonic sources (Bissell, 1974).

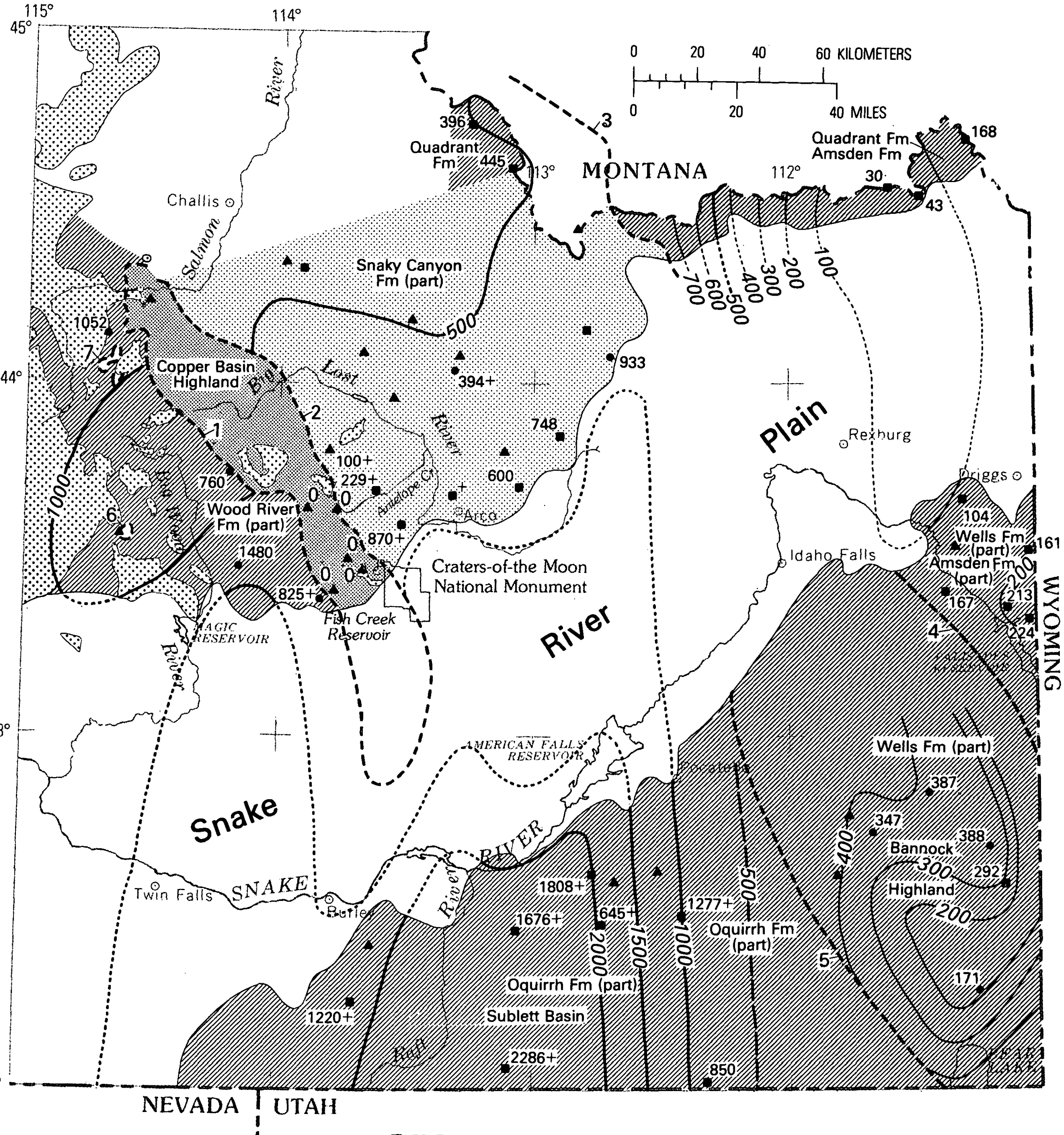
North of the plain, throughout Pennsylvanian time, the Copper Basin highland remained an effective barrier between the Wood River basin on the west and the depositional area of the Snaky Canyon Formation on the east. South of the plain, no such barrier existed; instead, an area of subsidence and basin filling, referred to as the Sublett basin (Cramer, 1971; this report figs. 13, 14), formed as a northern extension of the Oquirrh basin during Pennsylvanian and Permian time. Minor granule and pebble conglomerate in the Pennsylvanian part of the Oquirrh Formation of the Black Pine and Sublett Ranges, and the Deep Creek Mountains (J. F. Smith, Jr., written commun., 1976; R. L. Armstrong, written commun., 1976; Trimble and Carr, 1976), probably was derived from the Copper Basin highland to the north.

The depositional framework established during Middle Pennsylvanian time persisted into the Permian.

UNDERLYING ROCKS

North of the plain, upper Middle Pennsylvanian rocks rest in thrust contact on the Devonian Milligen Formation in the Wood River basin (fig. 8; Sandberg and others, 1975), but the Wood River is interpreted as having been deposited unconformably on the Milligen. The Milligen Formation is part of the complex that constituted the Late Devonian-Early Mississippian Antler orogenic highland (Poole, 1974; Sandberg and others, 1975). East of the Copper Basin highland, the Pennsylvanian-Mississippian contact is gradational, and its position in the stratigraphic sections is defined on the basis of contained faunas. East of the inner cratonic platform margin, the Amsden Formation unconformably overlies Upper Mississippian rocks in the vicinity of the Centennial Mountains and Henrys Lake Mountains (localities 29, 30, and 30a).

South of the plain, the Mississippian-Pennsylvanian contact is considered to be conformable within the Amsden Formation where the Amsden is present. Elsewhere, except for the area of the Bannock highland, where Middle Pennsylvanian rocks rest on Upper Mississippian strata, the lithologic transition from the Mississippian to Pennsylvanian Systems is within the Manning Canyon Shale. Through much of southern Idaho, however, the transition is not actually observed, because uppermost Mississippian shale formed a zone of structural weakness along which Mesozoic thrusting took place (S. S. Oriel and L. B. Platt, unpub. data, 1978). Mississippian rocks are exposed only in structural windows in the Black Pine and Sublett Ranges (figs. 2, 4; J. F. Smith, Jr., M. H. Hait, Jr., and R. L. Armstrong, unpub. data).



EXPLANATION

- Tertiary and Cretaceous intrusive rocks
- Mostly cherty or sandy limestone, minor sandstone or quartzite
- Mostly calcareous or quartzitic sandstone, with sandy limestone and minor granule- to cobble- sized conglomerate and shaly mudstone in places
- Emergent area

—*500*— Isopachs (partly restored) in 500-m and 1000-m intervals—Dashed where inferred; dotted across Snake River Plain

—*100*— Isopachs (partly restored) in 100-m intervals—Dashed where inferred; dotted across Snake River Plain

- - -1- - - Structural element or boundary described in caption

■ ▲ ●1052 Sample localities—Same as on figure 4. Thicknesses in meters

OVERLYING ROCKS

North of the Snake River Plain and west of structural element 3 (fig. 13), rocks of Pennsylvanian age are overlain gradationally by Permian strata except in the area of the Copper Basin highland where neither Pennsylvanian nor Permian rocks have been recognized. The Pennsylvanian-Permian boundary lies within the Wood River and Snaky Canyon Formations. Because of the gradational nature of the contact, some Permian rocks are shown as combined with Pennsylvanian rocks in figure 2. In the central Beaverhead Mountains (localities 27 and 28), sandstone and limestone assigned to the Quadrant Formation correlate with the lower part of the Snaky Canyon Formation and are overlain gradationally by carbonate rocks assigned to the Grandeur Member of the Park City Formation (Ruppel, 1968), which probably correlates with the upper part of the Snaky Canyon Formation. The Pennsylvanian-Permian boundary may be within the lower beds of the Park City Formation as defined in these areas, though no faunal data are available at this time. Only beds assigned to the Quadrant Formation have been included on the isopach map (fig. 13).

The Quadrant Formation, which crops out in Idaho east of structural element 3, is no younger than Middle Pennsylvanian in age on the basis of fusulinids obtained from the nearby type section (Thompson and Scott, 1941); it is unconformably overlain by the Phosphoria Formation of Permian age (fig. 8).

South of the plain, the Pennsylvanian-Permian boundary is gradational in all areas of outcrop and is present within both the Oquirrh and Wells Formations.

THICKNESS

Pennsylvanian rocks generally thicken to the south and west across Idaho, a very different trend from that of thicknesses within the Mississippian System. The thickest sequences (Oquirrh Formation), more than 2,286 m, are present in the Sublett and Black Pine Ranges—a northern extension of the Oquirrh basin of Utah. The oldest upper Paleozoic rocks found to date in the Cassia Mountains (fig. 4), west of the Albion Range, are of Permian age (Morgan, 1977). The strata so resemble the upper part of the Wood River Formation north of the plain that Pennsylvanian rocks are assumed to be present in the subsurface.

Observed thicknesses in the Wood River area range from 760 to 1,480 m; thinnest sequences are in the center of the area of outcrop (W. E. Hall, unpub. data; fig. 13). No Pennsylvanian rocks have been reported from the area of the Copper Basin highland. East of the highland, the Pennsylvanian part of the Snaky Canyon Formation ranges from 600 to about 1,100 m in thickness. Strata assigned to the Quadrant Formation in the Beaverhead Mountains (localities 27 and 28) are about 400 m thick. East of the outer cratonic platform, Pennsylvanian rocks thin to as little as 30 m (locality 29).

South of the plain and east of the Sublett basin, on the Bannock highland (fig. 13), the thickest sequences assigned to the Wells Formation, 388 m and 387 m, are in the Preuss and Wooley Ranges (Peale Mountains) (localities 49 and 45) of southeasternmost Idaho. In the area of Amsden Formation south of the plain, a maximum of 224 m of Wells Formation is reported in the Snake River Range (locality 42).

FORMATIONS INCLUDED

Rocks of Early to latest Pennsylvanian age are included between line I and rocks above the Pennsylvanian System at the top of the correlation chart (fig. 8). Cratonic-platform basin and restricted-marine or lagoonal depositional environments are represented.

North of the plain, the lower parts of the Wood River and Snaky Canyon Formations make up the interval in most areas. Rocks assigned to the

FIGURE 13.—Total isopach map of Pennsylvanian rocks showing Middle and Upper Pennsylvanian lithofacies, provincial formation names, location of Copper Basin highland, and position of Lower Pennsylvanian Bannock highland.

1. Structural eastern limit of Wood River Formation and western edge of Copper Basin highland.
2. Structural eastern edge of Copper Basin highland and western limit of Snaky Canyon Formation.
3. Structural eastern limit of Snaky Canyon Formation and western limit of Amsden Formation.
4. Structural western limit of Amsden Formation and eastern border of Bannock highland (modified from Williams, 1962, and Sando, 1976a).
5. Western limit of Wells Formation and approximate western border of Bannock highland.
6. Structural window of Mississippian(?) rocks.
7. Structural windows(?) of Mississippian(?) rocks.

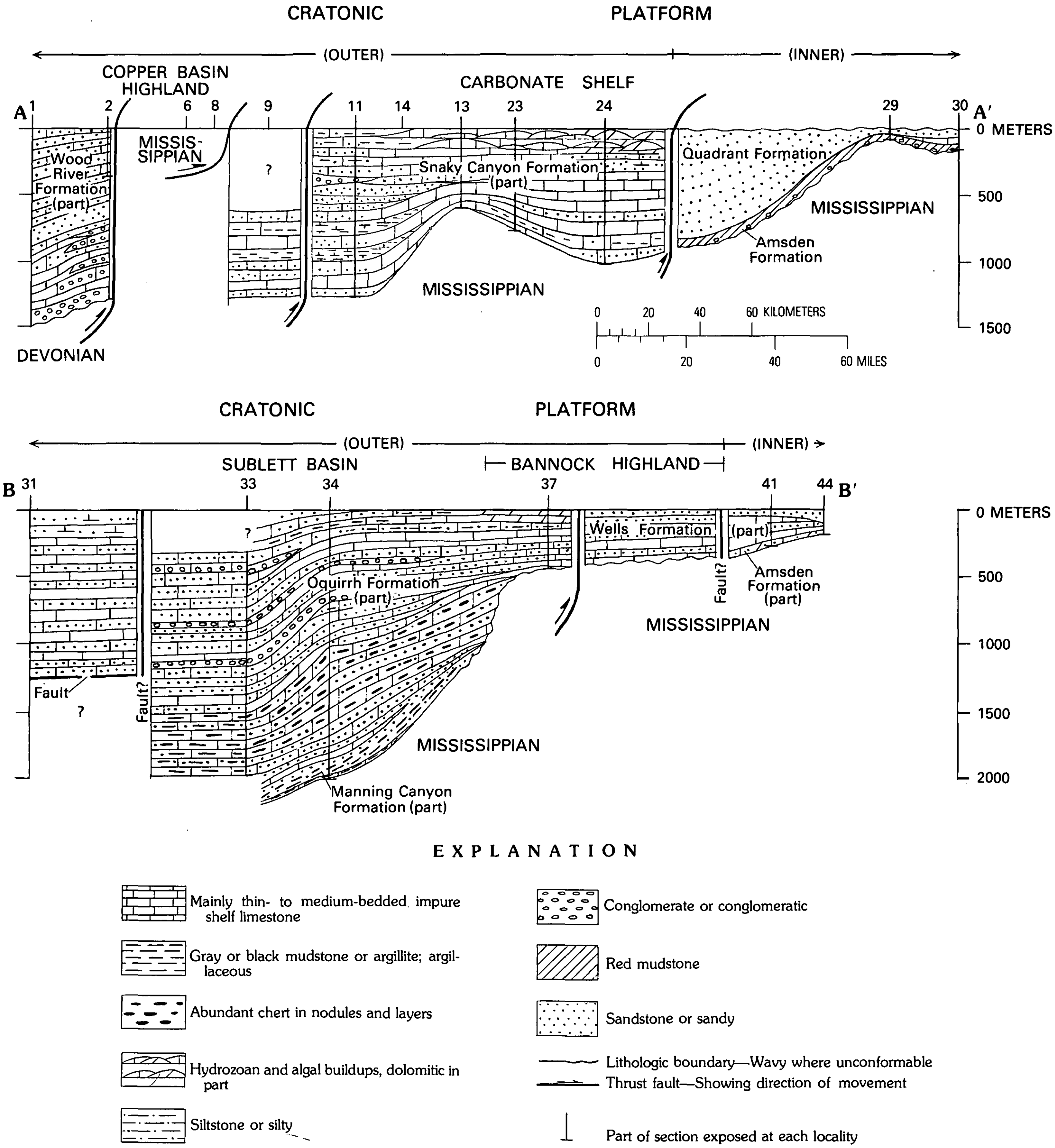


FIGURE 14.—Cross sections showing stratigraphic and structural relations of Pennsylvanian rocks in Idaho north of the Snake River Plain (*A–A′*) and south of the plain (*B–B′*). Locations of cross sections are shown on figures 2 and 4. Locations of stratigraphic sections are shown on figure 4. Datum is the top of the Pennsylvanian.

Quadrant Formation in the Beaverhead Mountains (localities 27 and 28) are correlatives of the Snaky Canyon Formation. The Amsden and Quadrant Formations constitute the Pennsylvanian System east of structural element 3 (fig. 13) on the cratonic platform.

South of the plain, the upper part of the Amsden Formation and the lower part of the Wells Formation constitute the Pennsylvanian System in the eastern part of the outcrop area. To the west, Pennsylvanian strata are represented in the upper part of the Manning Canyon Shale and the lower part of the Oquirrh Formation as far west as the Black Pine Range (locality 32).

WOOD RIVER FORMATION (PART)

The Pennsylvanian part of the Wood River Formation includes the Hailey Conglomerate Member (unit 1) at the base, overlying units 2, 3, 4, 5, and slightly less than half of unit 6 (Hall and others, 1974; fig. 8). This part of the formation is 1,480 m thick at the type section (locality 1) and 760 m thick at Wilson Creek to the north (locality 1a). The base of the Hailey Conglomerate Member is the sole of a major thrust; it is strongly sheared and detached into boudins where it is present (fig. 14). The Wood River rests on the Devonian Milligen Formation through much of its outcrop area and overrides the Mississippian Copper Basin Formation and a sequence of Ordovician through Devonian rocks (Dover and others, 1976) along its eastern outcrop margin (structural element 1, fig. 13). The Wood River Formation may rest on the Copper Basin in the White Cloud Peaks area (structural element 7, fig. 13). The Pennsylvanian part of unit 6 appears to be overlain conformably by beds of Wolfcampian (Early Permian) age.

The Hailey Conglomerate Member (unit 1), which consists of chert- and quartzite-pebble to -cobble conglomerate and quartzite interbedded with brown, partly algal, limestone, is about 120 m thick at locality 1 (fig. 4) and in its type section near the town of Hailey. Faulting and folding in the type locality has duplicated the section, which was reported by Thomasson (1959) to be 986 ft (300 m) thick. Though no studies of clast-size distribution or sedimentary structures within the sheared basal conglomerate have been made, it now seems likely that the chert and quartzite clasts were derived from the emergent eastern Copper Basin highland (fig. 13). The basal conglomerate is overlain by more than 1,000 m of interbedded sandstone, quartzite, sandy and argillaceous limestone, and minor easterly derived turbidite conglomerate (Hall and others, 1974; Skipp and Hall, 1975a; Skipp, 1975).

The bulk of the formation consists of very fine to fine-grained, slightly feldspathic, quartzose limy sandstone and sandy limestone that had a source different from that of the conglomerate. The craton (Hall and others, 1974; Skipp and Hall, 1975a) and the Humboldt highland (Ketner, 1977) have been suggested as possible source terranes. South to southwest and a few northwest current directions were measured in the Wood River Formation by Thomasson (1959), who also noted that sand in the Slate Creek section (locality 17) is coarser, fine to medium grained, and more abundant than in the type section (locality 1) to the south.

The Pennsylvanian part of the formation ranges in age from Middle (Des Moinesian, possibly Atokan) through Late (Virgilian) (Bostwick, 1955; Hall and others, 1974). No Missourian faunas have been recovered from the Wood River Formation. About 61 m of strata occur between fusulinid faunas of Des Moinesian and Virgilian age in the type section, but no fault or unconformity has been recognized in the poorly exposed interval (Hall and others, 1974). Whether the Missourian stage is condensed in this interval or is missing altogether is not known.

Pennsylvanian rocks south of the plain informally have been called Wood River Formation because of their lithologic resemblance to units 2 through 6. These rocks are assigned to the Oquirrh Formation. Permian rocks in the Cassia Mountains (fig. 4) bear a strong resemblance to the Permian part of the Wood River Formation (Morgan, 1977), and it seems obvious that Pennsylvanian and Permian sedimentation took place between these areas now separated by the Snake River Plain.

The Wood River Formation is distinguished by its locally abundant fusulinid faunas (Bostwick, 1955; Hall and others, 1974), particularly in unit 6, but other faunal and floral groups are present, including crinoidal debris, bryozoans, brachiopods, corals, nonfusulinid foraminifers, and algae.

SNAKY CANYON FORMATION (PART)

East of the Copper Basin highland and north of the Snake River plain the Pennsylvanian System is represented by the lower part of the recently defined Snaky Canyon Formation (Skipp and others, 1979 which includes the basal Bloom Member overlain by the Gallagher Peak Sandstone Member and the lower beds of the Juniper Gulch Member. At the type section in the southern Beaverhead Mountains (localities 24 and 25), the Pennsylvanian part of the formation is about 900 to 1,000 m thick. The formation is more than 870 m thick at Timbered Dome (locality 11) and as little as 600 m thick in the Arco Hills-Howe Peak area (locality 13).

The Bloom Member in the Lost River and Lemhi Ranges and the Beaverhead Mountains consists of medium-bedded gray limestone, much of it sandy or silty, interbedded with thin beds of very fine grained, yellowish-brown-weathering sandstone and siltstone. Nodules of incipient chert (rims of brown-weathering silicified material enclosing gray limestone), as well as concentrically laminated stromatolitic mounds, are common. Impure wackestones, packstones, and lesser amounts of calcareous mudstone are the chief carbonate rocks. Fossils are fairly common and include small fusulinids and other foraminifers, brachiopods, corals, bryozoans, crinoid columnals, and abundant encrinitic debris. The base of the Bloom Member east of the White Knob Mountains is probably near the Late Mississippian-Early Pennsylvanian boundary, and the top is probably Missourian in age (fig. 8).

The Gallagher Peak Sandstone Member consists largely of very fine grained calcareous sandstone. It is less than 60 m thick, appears to thin westward, and has not been recognized with certainty in the White Knob Mountains. The member is of probable Missourian age.

The lower part of the Juniper Gulch Member consists of interbedded sandy and cherty, generally light-gray-weathering, thin- to thick-bedded limestone and dolomite. The sand and chert is mainly in the basal 100 m. The Pennsylvanian-Permian boundary is near the middle of the member in hydrozoan(?)-algal carbonate buildups, 100 to more than 200 m thick. The buildups were described in detail by Breuninger (1976), who suggested that lenticular buildups stood topographically above the adjacent sea floor while they formed (fig. 14). Other fauna associated with the buildups include common encrusting foraminifers and bryozoans and less common gastropods, crinoids, and brachiopods. Fusulinid foraminifers are sparse, although they have been found throughout the lower part of the member and date it as mostly of Missourian and Virgilian age (Shannon, 1961; Breuninger, 1976; R. C. Douglass, written commun., 1976; fig. 8). The Juniper Gulch Member also has not been recognized in the White Knob Mountains area.

In the White Knob Mountains (localities 11 and 12), the Snaky Canyon Formation consists of basal thick-bedded sandy limestone overlain by interbedded thin- to medium-bedded, fossiliferous, argillaceous and silty limestone, calcareous shale, siltstone, and very fine grained sandstone. The limestone is mostly impure carbonate mudstone and wackestone containing abundant calcareous sponge spicules and lesser amounts of bryozoan, molluscan, and brachiopod debris. Minor sandy limestone, together with quartz and chert sand of medium grain size, and granule limestone conglomerate are present locally. At Timbered Dome (locality 11), a chert-quartzite pebble- to cobble-conglomerate bed, 14 m thick containing fragments as large as 10 cm in diameter, crops out about 700 m above the base. The conglomerate, which was derived from the Copper Basin highland, is assigned to the Middle Pennsylvanian (fig. 8), on the basis of silicified brachiopods identified by J. T. Dutro, Jr. (written commun., 1978), from beds 15 m below.

Strata that correlate with the Snaky Canyon Formation have been called Quadrant Formation in the central Beaverhead Mountains (localities 27 and 28). These Quadrant sections contain about 50 percent (locality 28) or more (locality 27) quartzitic and calcareous sandstone (fig. 13). The increase in percentage of sand to the north probably indicates a northern or northeastern source for the detritus (Lucchitta, 1966). The sandstone is fine to very fine grained, clean, and thick bedded and is interbedded with locally sandy limestone and dolomite and minor black shale and mudstone (Lucchitta, 1966; Ruppel, 1968). The carbonate rocks contain nodules of incipient chert and stromatolitic mounds resembling those described in the Snaky Canyon Formation, and numerous fragments of brachiopods, bryozoans, corals, crinoids, and a few small fusulinids. The sequences are poorly dated but are thought to represent most of the Pennsylvanian System.

AMSDEN (PART) AND QUADRANT FORMATIONS

East of structural element 3, and north of the Snake River Plain, the Amsden and Quadrant Formations constitute the Pennsylvanian System. In the Henrys Lake Mountains (locality 30), the Amsden Formation is 84 m thick and consists of a basal limestone conglomerate overlain by red claystone, dark-gray limestone, banded red chert, dolomite breccias, sandy dolomite, and dolomitic sandstone at the top (E. K. Maughan, written commun., 1977). The limestones contain bryozoans, echinoderms, mollusks, conodonts, hydrozoans, and calcareous foraminifers. Lithologies of the Amsden represent a shallow-marine environment. Terrigenous detritus in the Amsden may have been derived from local uplifted areas of the Big Snowy Formation within the Montana-Dakota region (Maughan, 1975).

The Amsden Formation is overlain by the Quadrant Formation, which is dominated by thick-bedded fine-grained quartzose sandstone, locally quartzitic; thin lenticular sandy dolomite beds are interleaved in the basal and upper parts. The Quadrant is believed to overlie the Amsden Formation conformably in the Henrys Lake Mountains (E. K. Maughan, written commun., 1976). The Quadrant is thin, 84 m (locality 30) and 24 m (locality 29) thick in easternmost Idaho, but is known to be about 800 m thick in southwestern Montana, just north of the Idaho border and east of structural element 3 shown in figure 13 (Sloss and Moritz, 1951; Scholten and others, 1955). Emergent land sources to the north-northwest and northeast have been suggested for the multicycle deposits of the Quadrant Formation (Mallory, 1967; Maughan, 1975). Fusulinids from the type section in Wyoming, just northeast of the northeast corner of Idaho, indicate a Des Moinesian and possibly Atokan, age for the formation (Thompson and Scott, 1941; fig. 8).

RANCHESTER LIMESTONE MEMBER OF AMSDEN FORMATION

The upper part of the Amsden Formation, which is probably of Early Pennsylvanian age, is included in the discussion of Upper Mississippian rocks south of the plain. The Amsden is recognized east of structural element 5 (fig. 13), where it is composed largely of the Ranchester Limestone Member (Sando and others, 1975; Sando, this volume), which probably is less than 30 m thick. The Ranchester is a sequence of interbedded cherty dolomite and limestone, sandstone, and shale.

WELLS FORMATION (PART)

South of the plain, the lower part of the Wells Formation makes up approximately the eastern half of the outcrop area of Pennsylvanian rocks in Idaho. The Wells Formation was named by Richards and Mansfield (1912) for exposures in Wells Canyon, which is 2 miles south of locality 46 (fig. 4). The Wells is divided into two members, a lower and an upper. Fusulinids from sections near locality 45 in the Wooley Range of the Peale Mountains, date the lower member of the Wells as Middle Pennsylvanian (Atokan and Des Moinesian), and the lower part of the upper member as Des Moinesian or younger. Permian fusulinids have been collected 300–400 ft (100–120 m) above the base of the upper member (Cressman, 1964).

No faunas of Morrowan age have been recovered from these sequences, and, on this basis, an Early Pennsylvanian high or neutral area (the Bannock highland) was proposed by Williams (1962); this area is outlined in modified form on figure 13 (structural element 5).

At present, there is no record of Late Pennsylvanian faunas from the Wells Formation, and several authors have suggested an hiatus at this level (Mallory, 1975; Rich, 1977). A Late Pennsylvanian fauna was reported in the Tensleep Sandstone in central westernmost Wyoming (Love, 1954; Wanless and others, 1955) from sandstone tentatively correlated with beds in the lower part of the upper member of the Wells Formation (Cressman, 1964). This correlation is used in this report in the absence of new data (fig. 8).

The formation ranges in thickness from 104 m (locality 39) in the east to about 405 m (locality 37a) in western exposures.

In the type area, the lower member of the Wells Formation consists of a basal very fine grained to fine-grained quartzose sandstone bed, 30–100 m thick, overlain by medium gray sandy and minor oolitic limestone, interbedded with relatively thin, fine-grained sandstone beds as much as 3 m thick. Chert nodules and layers occur throughout. Phosphatic rocks and a thin black shale are present locally at the top of the member (Cressman, 1964). The lower part of the upper member consists of yellowish-brown and light-gray thick-bedded, very fine to fine-grained calcareous quartzose sandstone containing thin (2–5 m) beds of gray limestone, calcareous sandstone, and dolomite (Cressman, 1964; Montgomery and Cheney, 1967).

In the Snake River Range (locality 44) and Big Hole Mountains (locality 39), the Wells consists of a lower thin to irregularly bedded brownish-gray cherty limestone, minor limestone breccia, and thin sandstone interbeds overlain by fine-grained well-sorted quartzite.

On the basis of published descriptions, the total amount of sandstone and/or quartzite in the Pennsylvanian part of the Wells Formation is extremely variable—50 to 75 percent at localities 45, 46, and 49 near the type section and less than 20 percent at locality 37a in the Chesterfield Range and locality 41 in the Snake River Range. At localities 42, 44, and 47 in the Snake River Range and Caribou Range, the amount is close to 50 percent. An average of about 50 percent is used on figure 13.

Sparse fossils in the Wells include crinoid plates, brachiopods, corals, fusulinids, and other foraminifers.

MANNING CANYON SHALE (PART)

An interval of quartzite and sandstone, limestone, siltstone, and shaly argillite, 220 m thick, assigned to the upper part of the Manning Canyon Shale in the northern Deep Creek Mountains (locality 34), is included in the Pennsylvanian part of the Manning Canyon Shale. A similar thickness (186 m) is present in the southwestern part of the Bannock Range (locality 48). Elsewhere south of the plain, the incomplete Manning Canyon is exposed in structural windows in the southern Deep Creek Mountains (locality 35), the Black Pine Range (locality 32), and the Sublett Range (locality 33), and neither thicknesses nor age determinations are available.

OQUIRRH FORMATION (PART)

Strata assigned to the lower part of the Oquirrh Formation occur at Samaria Mountain (locality 36), in the Deep Creek Mountains (locality 34), and into the Albion Range (locality 31). They also are presumed to be present in the subsurface as far west as the Cassia Mountains (fig. 4; see discussion of Wood River Formation). Thicknesses within the Sublett basin (fig. 13) range from about 850 m at Samaria Mountain to more than 2,286 m in the Black Pine Range (locality 32).

At Samaria Mountain, the limestone member (= West Canyon Limestone Member of Beus, 1968) and the lower 400 m of the overlying sandy member are included within the Pennsylvanian part of the Oquirrh Formation (Platt, 1977). The limestone member consists of interbedded brown to gray quartz sandstone, gray calcareous sandstone, and limestone. The sandy member is made up of sandstone and minor chert-granule to cobble-conglomerate beds in the Upper Pennsylvanian part of the sequence. The sequence is composed of more than 50 percent sandstone. Scattered fusulinid faunas indicate that Lower through Upper Pennsylvanian beds representing the five stages are present (Beus, 1968; Platt, 1977).

In the northern Deep Creek Mountains (locality 34), a nearly complete sequence of the lower part of the Oquirrh Formation (1,710 m thick) is assigned to the Pennsylvanian (fig. 15; Trimble and Carr, 1976). Units A, B, C, and the lower part of D consist of sandy or silty limestone and minor quartzite, bedded chert, and chert-granule to pebble conglomerate representing late Atokan through Virgilian time. The base of the sequence is faulted. Conglomerates occur in Middle and Upper Pennsylvanian beds. Bedded chert is restricted to the Upper Pennsylvanian part. Sandstone and quartzite make up a minor part of the sequence. Fusulinids, corals, brachiopods, gastropods, and bryozoans locally are abundant in the formation.

A thick (more than 1,676 m) incomplete section of the Oquirrh Formation in the northern Sublett Range (locality 33; R. L. Armstrong, written commun., 1977) has been assigned to the Pennsylvanian System. The lower part of the sequence consists of interbedded silty, sandy, or cherty limestone and calcareous sandstone, overlain by quartzite and calcareous sandstone, sandy and cherty limestone, and thin interbeds of chert-granule conglomerate. Chert-granule conglomerate is more common in the northern part of the range than in the central part, suggesting a northern source for the detritus, such as the Copper Basin highland. Fusulinids are abundant locally.

The thickest Pennsylvanian Oquirrh sequence (more than 2,220 m thick) has been reported from the Black Pine Range (locality 32). Limestone and sandy limestone, sandstone or quartzite, sandstone breccia, and local limestone and chert-pebble conglomerate are present in many fault slices (J. F. Smith, Jr., written commun., 1976). Scattered fusulinids, corals, and mollusks date the incomplete sequence.

In the Albion Range (locality 31), an allochthonous sheet of unmetamorphosed sandy limestone and calcareous sandstone assigned to the Oquirrh Formation has been thrust over Paleozoic metasedimentary rocks (Armstrong, 1968). The limestone and sandstone, which are several thousand feet thick, resemble Oquirrh strata in the Sublett Range and are, in part, of Pennsylvanian age.

DEPOSITIONAL HISTORY

During Pennsylvanian time, sandy carbonate rocks together with minor conglomerates were deposited in several cratonic basins across the area of outcrop in southeastern Idaho. In Early and early Middle Pennsylvanian time, shallow-water carbonate deposits and sandstones were laid down on the carbonate shelf east of the site of the Mississippian flysch trough north of the plain and east of the inner cratonic platform margin. The inner cratonic platform may have been emergent part of the time and then was inundated slowly by poorly circulating marine waters by the end of Morrowan time. South of the plain, the low-lying Bannock highland separated the shallow offshore marine depositional site of the Ranchester Limestone Member of the Amsden Formation on the east from the restricted-marine en-

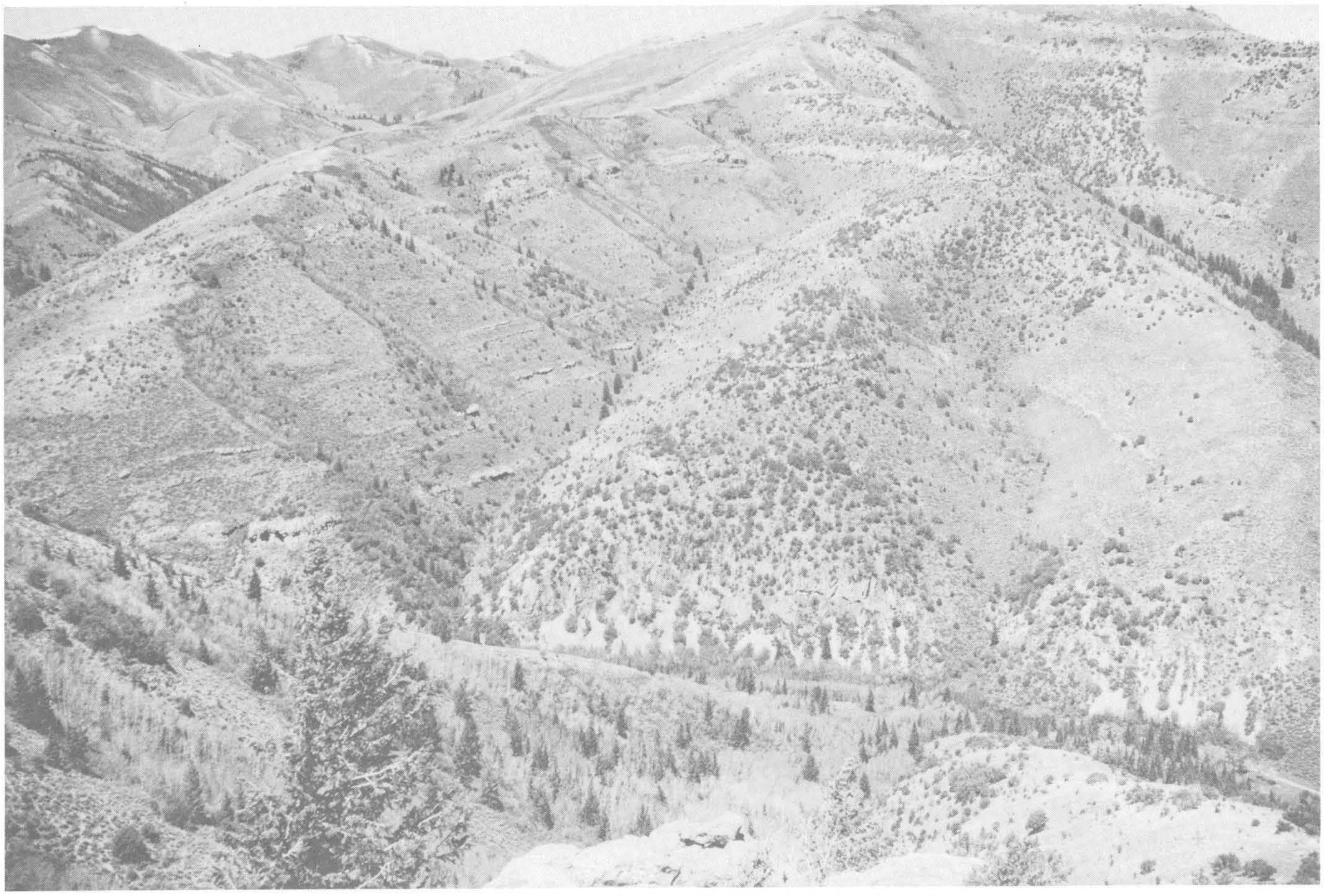


FIGURE 15.—Anticline in Pennsylvanian part of Oquirrh Formation in northern Deep Creek Mountains near locality 34 (fig. 4). Base of unit C is at base of conspicuous ledge that crosses upper part of draw in central part of picture. From Trimble and Carr (1976, p. 31, fig. 8).

vironment of deposition of the upper part of the Manning Canyon Shale. Both sequences contain sand derived principally from a cratonic source (L. D. Cress, unpub. data, 1978).

In late Atokan and/or Des Moinesian time, the tectonic setting that had been inherited from the Mississippian System changed drastically. North of the plain, Wood River sediments began to accumulate on the former site of the Antler orogenic highland. Sediments of the Mississippian flysch trough became emergent, probably because of faulting, and provided chert- and quartz-pebble and granule detritus to areas west, east, and south (Skipp, 1975; Skipp and others, 1979. At the same time, large volumes of fine-grained quartz sand flooded the basins north and south of the plain. Less sand reached the area of accumulation of the Snaky Canyon Formation, in which intermittently emergent carbonate buildups, composed of hydrozoans and algae, formed.

South of the plain, in late Atokan or Des Moinesian time, the Bannock highland was completely submerged, and shallow-water-marine sandy carbonate, calcareous sandstone, and noncalcareous sandstone were deposited in the rapidly subsiding Sublett basin, a northern extension of the Oquirrh basin, and in the area of the Wells Formation. Minor granule to pebble conglomerate reached the area of the Sublett basin from the Copper Basin highland to the north.

Sources for the tremendous volumes of Middle and Upper Pennsylvanian sand in the cratonic-platform basins of Idaho, Montana, and Utah remain elusive. Petrography of the fine-grained sand, of probable second- or third-cycle origin, suggests a cratonic rather than a western orogenic source; hence, the northeasterly, easterly, and southeasterly source areas proposed by Bissell (1974) appear to be the most reasonable for southern Idaho.

The influence of detritus shed eastward from a possible western Humboldt highland (Ketner, 1977) is not clear. Perhaps the record of this material is lost in the area of the Idaho batholith. Possibly, more petrographic work will show that both cratonic and western orogenic source terranes provided material for some of the Pennsylvanian and Permian basins.

PLATE-TECTONIC MODELS

Major changes in the structural settings for deposition of Carboniferous rocks in Idaho took place in latest Devonian to earliest Mississippian time. These periods are coincident with major plate-boundary tectonic events along the western margin of the proto-North American continent.

A postulated plate-tectonic model for the Antler orogeny is that of back-arc thrusting during a period of increased plate motion in which the sediments of an inner-arc basin were obducted onto the continental margin east of an offshore island arc; west of the island arc was an east-dipping subduction zone (fig. 16). The obducted inner-arc basin sediments in this model make up the Antler orogenic belt (Burchfiel and Davis, 1972, 1975; Poole, 1974; Poole and Sandberg, 1977; Dickinson, 1977). In this model, the inner-arc basin continued to close during Pennsylvanian and Permian time, and the island arc (Klamath-North Sierran arc of Poole and Sandberg, 1977, p. 82, fig. 8) collided with the proto-North American continent in Triassic time (Silberling, 1973) and became welded to the continent. This interpretation was used to construct model I of Paleozoic plate-tectonic events (fig. 16).

Dickinson (1977) noted the short duration of the Antler orogeny and pointed out that flysch deposition was not followed by molasse accumulation but by a return to modified shelf conditions. Carboniferous rocks in Idaho record exactly this sequence of events. Dickinson suggested that, perhaps, mid-Carboniferous rifting broke up the Antler orogen and interrupted the maturing process, producing instead a fault-controlled rift topography on which the many basins and intervening local highlands of the Pennsylvanian and Permian Systems formed. In this model, the Humboldt highland in Nevada might be a westward-rifted and uplifted remnant of the old Antler highland. A postulated model (model II) of this concept of plate-tectonic events is presented in figure 17. In this reconstruction, the Antler orogeny is the result of an arc-continent collision along a west-dipping subduction zone (Dickinson, 1977). The Antler collision was followed by a period of rifting during which fault-bounded basins and highlands formed on the cratonic platform. In Permian time, a volcanic arc again approached the proto-North American continent and was welded to it in mid-Triassic time (Dickinson, 1977).

ECONOMIC GEOLOGY

Carboniferous rocks in Idaho had not produced any coal or petroleum to date (1977). Minor coaly beds like those in the upper part of the Copper Basin Formation are present but are neither extensive enough nor of high enough rank to be commercial deposits.

Petroleum exploration in the overthrust belt of eastern Idaho is in progress, and the area is considered potentially productive (Monley, 1971; Royse and others, 1975; Powers, 1977). Mississippian carbonate-shelf complexes (Rose, 1976), and the sandstones and carbonate rocks of the Pennsylvanian cratonic-platform-basin sequences are potential reservoir rocks. The starved-basin facies of the Deep Creek and Little Flat Formations (Poole and Sandberg, 1977; Sandberg and Gutschick, 1977) and the phosphatic shales and interbedded quartzites of the Big Snowy Formation and the Manning Canyon Shale are both potential source and reservoir rocks. The structurally complex setting of these rocks discouraged earlier exploration, but the present need for more domestic hydrocarbons has opened the area to the search for gas and oil.

Metalliferous deposits have a long history of exploitation in Idaho; a description by W. E. Hall of known deposits associated with Carboniferous rocks follows.

Mississippian and Pennsylvanian carbonate rocks are also a valuable resource in Idaho, and a summary of their economic potential is included.

METALLIFEROUS DEPOSITS

Carboniferous rocks in central and south-central Idaho contain many metalliferous deposits that have been exploited sporadically since the 1880's. The mineral resources, listed in approximate decreasing order of economic significance, include deposits of lead, silver, molybdenum, copper, zinc, barite, gold, tungsten, and subeconomic tin. Although the deposits in general are small and the production moderate (estimated at approximately $20 million, fig. 18), several very large low-grade deposits are known, but they have not been developed extensively.

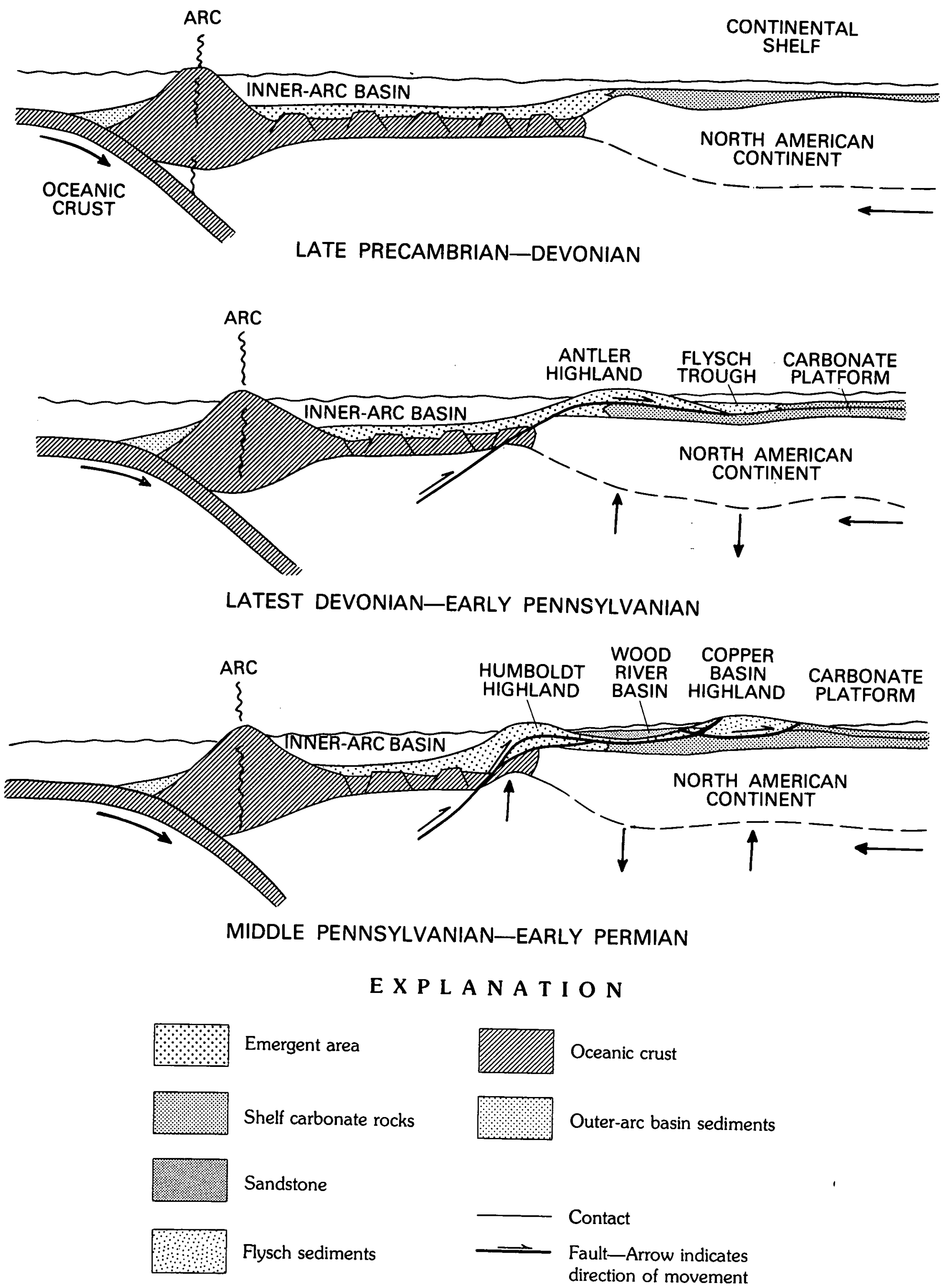


FIGURE 16.—Model I of plate-tectonic events along western margin of proto-North American continent showing an east-dipping subduction zone west of an island arc and a gradually closing inner-arc basin. Modified from Poole (1974) and Poole and Sandberg (1977).

Most favorable sites for ore in the Carboniferous are in contact-metamorphosed calcareous beds beneath thrust faults and near leucocratic granitoid or porphyritic stocks, sills, or dikes of Cretaceous or Eocene age. The Copper Basin Formation of Mississippian age, the White Knob Limestone of Late

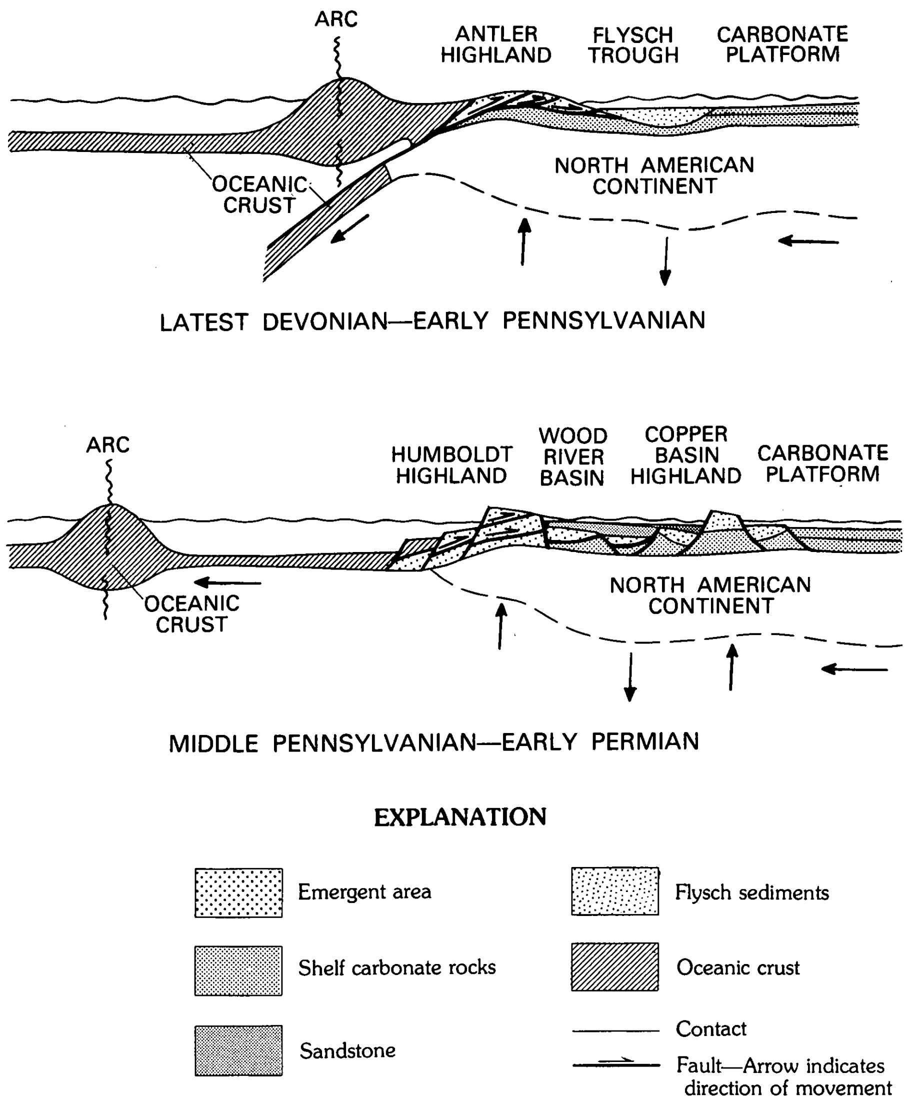


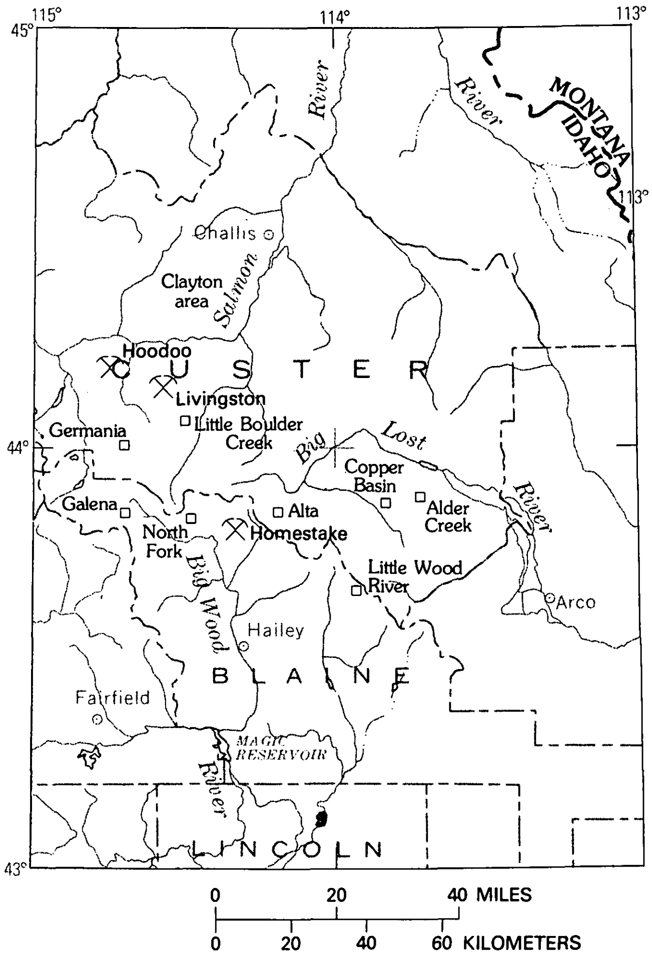
FIGURE 17.—Model II of plate-tectonic events along the western margin of proto-North American continent showing an arc-continent collision along a west-dipping subduction zone, an event that produced the Antler orogeny. This orogeny was followed by mid-Carboniferous rifting (Dickinson, 1977).

Mississippian age, and the Wood River Formation of Pennsylvanian-Permian age each host significant deposits.

Ore occurs in the Copper Basin Formation, in the more calcareous sequences where cut by intrusive masses in the Little Wood River and Alta mining districts and, according to C. M. Tschanz (written commun., 1977), at the Hoodoo and Livingston mines at the north end of the Boulder Mountains and at the Twin Apex and Bruno mines in the Clayton area, where the deposits are controlled by a thrust fault at the base of the Copper Basin Formation (S. W. Hobbs, oral commun., 1977). The Little Wood River district contains small but high-grade lead-silver and some barite and zinc deposits (Anderson and Wagner, 1946), and the Alta district has small lead-silver-gold deposits (Umpleby and others, 1930; U.S. Geol. Survey and U.S. Bur. Mines, in press). The Livingston and Hoodoo mines have produced substantial amounts of zinc as well as some lead, silver, and gold (Tschanz and others, 1974), and the Twin Apex and Bruno mines have produced lead, zinc, and a little silver and gold.

The White Knob Limestone is the host rock in the Alder Creek district near Mackay and at the Copper Basin mine. About 90,000 kg of copper was produced from replacement deposits in quartzite and limestone in the Copper Basin district (Umpleby, 1917; Vhay, 1964, p. 71). The Alder Creek district has yielded 26 million kg of copper as well as appreciable amounts of lead, silver, and gold (Nelson and Ross, 1968, p. A29–A30). The ore deposits are in irregular replacement bodies in granite porphyry and in tactite from contact-metamorphosed White Knob Limestone.

The Wood River Formation at its type locality in the vicinity of the Big Wood River valley is an unfavorable host for metalliferous deposits, and nearly all the ore in that area has a structural control in the Devonian Milligen Formation beneath the Wood River thrust (Anderson and others, 1950, p. 10; Hall and Czamanske, 1972, p. 350). However, in the Boulder Mountains, the Wood River Formation is the host rock for many deposits (Tschanz and others, 1974). These include the small high-grade lead-silver deposits in the North Fork, Galena, and Germania districts and the large low-grade disseminated molybdenum deposit at the southeast end of the White Cloud stock in the Little Boulder Creek district. In addition, tin occurs in subeconomic amounts in the lead-silver deposits in an arcuate north-trending belt about 30 miles long and 4 miles wide along the crest of the Boulder Mountains (Tschanz and others, 1974, p. 251). Locally, the concentrations of tin are high, and the potential tin resource is certainly significant.



Production

	$ Million
Livingston mine	2.3
North Fork and Galena districts	1.4
Hoodoo mine	.6
Little Wood River district	.2
Germania district	.45
Alder Creek district	12.7
Alta district	.1
Homestake mine	.2
Total	17.95 (≈$20M)

FIGURE 18.—Locality map and production figures, in millions of dollars, for major metalliferous deposits related to Carboniferous rocks in Idaho.

CARBONATE ROCKS

Idaho contains large reserves of carbonate rocks; many of these are present in the marine Carboniferous rocks of the south, south-central and southeastern parts of the State. Although Idaho's production of limestone has remained small, the widespread distribution of relatively pure calcium carbonate limestone of Pennsylvanian and Mississippian formations—such as the Scott Peak and Surrett Canyon, the Madison Group, and parts of the Oquirrh and Wells Formations—provides potential resources for cement, agricultural and industrial lime, flux, and the manufacture of paper, vinyl, and glass (Savage, 1969).

Small quantities of limestone and marble are used in construction as both dimension and broken stone.

More carbonate rock could be used in road construction, where strategically located, but roadbuilders in southern Idaho have tended to rely upon basalt aggregate from the vast resources of the Snake River Plain rather than the local limestone. A comprehensive region-by-region review of carbonate rocks and their economic potential in Idaho has been prepared by Savage (1969).

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The Mississippian and Pennsylvanian (Carboniferous) Systems in the United States

GEOLOGICAL SURVEY PROFESSIONAL PAPER 1110–M–DD

ON THE COVER

Swamp-forest landscape at time of coal formation: lepidodendrons (left), sigillarias (in the center), calamites, and cordaites (right), in addition to tree ferns and other ferns. Near the base of the largest *Lepidodendron* (left) is a large dragonfly (70-cm wingspread). (Reproduced from frontispiece in Kukuk, Paul (1938), "Geologie des Niederrheinisch-Westfälischen Steinkohlengebietes" by permission of Springer-Verlag, New York, Inc.)

The Mississippian and Pennsylvanian (Carboniferous) Systems in the United States—

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N. Missouri, by Thomas L. Thompson
O. Arkansas, by Boyd R. Haley, Ernest E. Glick, William M. Caplan, Drew F. Holbrook, and Charles G. Stone
P. Nebraska, by R. R. Burchett
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CECIL D. ANDRUS, *Secretary*

GEOLOGICAL SURVEY

H. William Menard, ***Director***

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FOREWORD

The year 1979 is not only the Centennial of the U.S. Geological Survey—it is also the year for the quadrennial meeting of the International Congress on Carboniferous Stratigraphy and Geology, which meets in the United States for its ninth session. This session is the first time that the major international congress, first organized in 1927, has met outside Europe. For this reason it is particularly appropriate that the Carboniferous Congress closely consider the Mississippian and Pennsylvanian Systems; American usage of these terms does not conform with the more traditional European usage of the term "Carboniferous."

In the spring of 1976, shortly after accepting the invitation to meet in the United States, the Permanent Committee for the Congress requested that a summary of American Carboniferous geology be prepared. The Geological Survey had already prepared Professional Paper 853, "Paleotectonic Investigations of the Pennsylvanian System in the United States," and was preparing Professional Paper 1010, "Paleotectonic Investigations of the Mississippian System in the United States." These major works emphasize geologic structures and draw heavily on subsurface data. The Permanent Committee also hoped for a report that would emphasize surface outcrops and provide more information on historical development, economic products, and other matters not considered in detail in Professional Papers 853 and 1010.

Because the U.S. Geological Survey did not possess all the information necessary to prepare such a work, the Chief Geologist turned to the Association of American State Geologists. An enthusiastic agreement was reached that those States in which Mississippian or Pennsylvanian rocks are exposed would provide the requested summaries; each State Geologist would be responsible for the preparation of the chapter on his State. In some States, the State Geologist himself became the sole author or wrote in conjunction with his colleagues; in others, the work was done by those in academic or commercial fields. A few State Geologists invited individuals within the U.S. Geological Survey to prepare the summaries for their States.

Although the authors followed guidelines closely, a diversity in outlook and approach may be found among these papers, for each has its own unique geographic view. In general, the papers conform to U.S. Geological Survey format. Most geologists have given measurements in metric units, following current practice; several authors, however, have used both metric and inch-pound measurements in indicating thickness of strata, isopach intervals, and similar data.

FOREWORD

This series of contributions differs from typical U.S. Geological Survey stratigraphic studies in that these manuscripts have not been examined by the Geologic Names Committee of the Survey. This committee is charged with insuring consistent usage of formational and other stratigraphic names in U.S. Geological Survey publications. Because the names in these papers on the Carboniferous are those used by the State agencies, it would have been inappropriate for the Geologic Names Committee to take any action.

The Geological Survey has had a long tradition of warm cooperation with the State geological agencies. Cooperative projects are well known and mutually appreciated. The Carboniferous Congress has provided yet another opportunity for State and Federal scientific cooperation. This series of reports has incorporated much new geologic information and for many years will aid man's wise utilization of the resources of the Earth.

H. William Menard
Director, U.S. Geological Survey

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