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

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With a section on Paleontology

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GEOLOGICAL SURVEY PROFESSIONAL PAPER 1110-BB

Prepared in cooperation with the
Nevada Bureau of Mines and Geology

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

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1979

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

By E. R. LARSON[1], and RALPH L. LANGENHEIM, JR.[2]

ABSTRACT

The entire Carboniferous is represented in discontinuous exposures of clastic and carbonate sedimentary rocks in eastern Nevada, but eugeosynclinal assemblages (shale, chert, turbidites, volcanic rocks) in thrust slices in central Nevada may lack parts of the system.

Mississippian clastic rocks derived from the north-trending Antler orogenic highlands in central Nevada are as much as 2,500 m thick. They are coarsest in central Nevada, but are fine and thin eastward through a starved basin to a carbonate-bank assemblage in central Utah and southeast Nevada. Mississippian eugeosynclinal rocks consist of chert, shale, turbidites, and lesser volcanic rocks thousands of meters thick in thrust slices in central Nevada.

Pennsylvanian rocks are primarily limestone in eastern Nevada and coarse clastic facies near the Antler belt. Thickest accumulations are in the Bird Spring-Ely Basin, farther east than the Mississippian maximum. Widespread disconformities in both Mississippian and Pennsylvanian rocks in eastern Nevada reflect continued instability in the Cordilleran miogeosyncline throughout the Carboniferous.

Pennsylvanian eugeosynclinal rocks deposited in a trough west of the Antler belt are contemporaneous deposits of shale, chert, and volcanic rocks (Pumpernickel Formation) and turbidites together with lesser chert and some limestone (Havallah Formation). These beds are as much as 5,000 m thick in incomplete sequences in western-derived thrust slices in north-central Nevada.

Carboniferous faunas in the carbonate belt have been well studied and allow good paleontologic control. Brachiopods are common throughout the Carboniferous, but mollusks are more abundant in the clastic sequences. Fusulines are abundant and diagnostic in the Pennsylvanian rocks in the carbonate belt but are less common in the lenticular limestone of the eugeosynclines. Conodonts are widespread and distinctive. Their presence in both clastic- and carbonate-facies rocks has allowed reliable interfacies correlations.

INTRODUCTION

Carboniferous beds (figure 1) were recognized in the Spring Mountains in southern Nevada by the Wheeler Survey of 1872–1873 (Wheeler, 1875) and in eastern Nevada by the 40th Parallel Survey (King, 1878), 1870–1878. Study of the Eureka district, begun by Hague and Emmons (1877) as a part of the 40th Parallel Survey, was continued by Hague (1883), whose monograph on the Eureka district (1892) established much of the Paleozoic stratigraphic terminology of east-central Nevada. Modern stratigraphic studies have brought many new subdivisions, but only a few detailed regional studies that synthesized Carboniferous paleontology, sedimentology, and stratigraphic relationships have been made (Bissell, 1964; Dott, 1955; Smith and Ketner, 1975; Steele, 1960). None of these was on a statewide basis. Figure 2 outlines the development of Carboniferous stratigraphic terminology in the State. Apparent duplication of names is due in part to scattered exposures and uncertainties of correlation.

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 Nevada Bureau of Mines and Geology.

The facies and the original distribution of Carboniferous strata in Nevada were determined by the prior depositional-tectonic history of the State. Beginning in the late Precambrian and continuing to the middle Paleozoic, carbonate sedimentary rocks and lesser shale and orthoquartzite formed a thick wedge on the western margin of the North American craton—the Cordilleran miogeosyncline. This carbonate assemblage graded west into deep-water deposits of dark shale, bedded chert, medium clastic materials, turbidites, and volcanic rock—the Cordilleran eugeosyncline. Eugeosynclinal rocks were carried eastward onto the miogeosyncline by the Roberts Mountain thrust during the late Devonian-early Mississippian Antler orogeny. This orogenic activity formed the north-trending Antler orogenic belt, an uplifted area through central Nevada that separated an eastern foreland basin containing clastic and carbonate rocks from a western shale-

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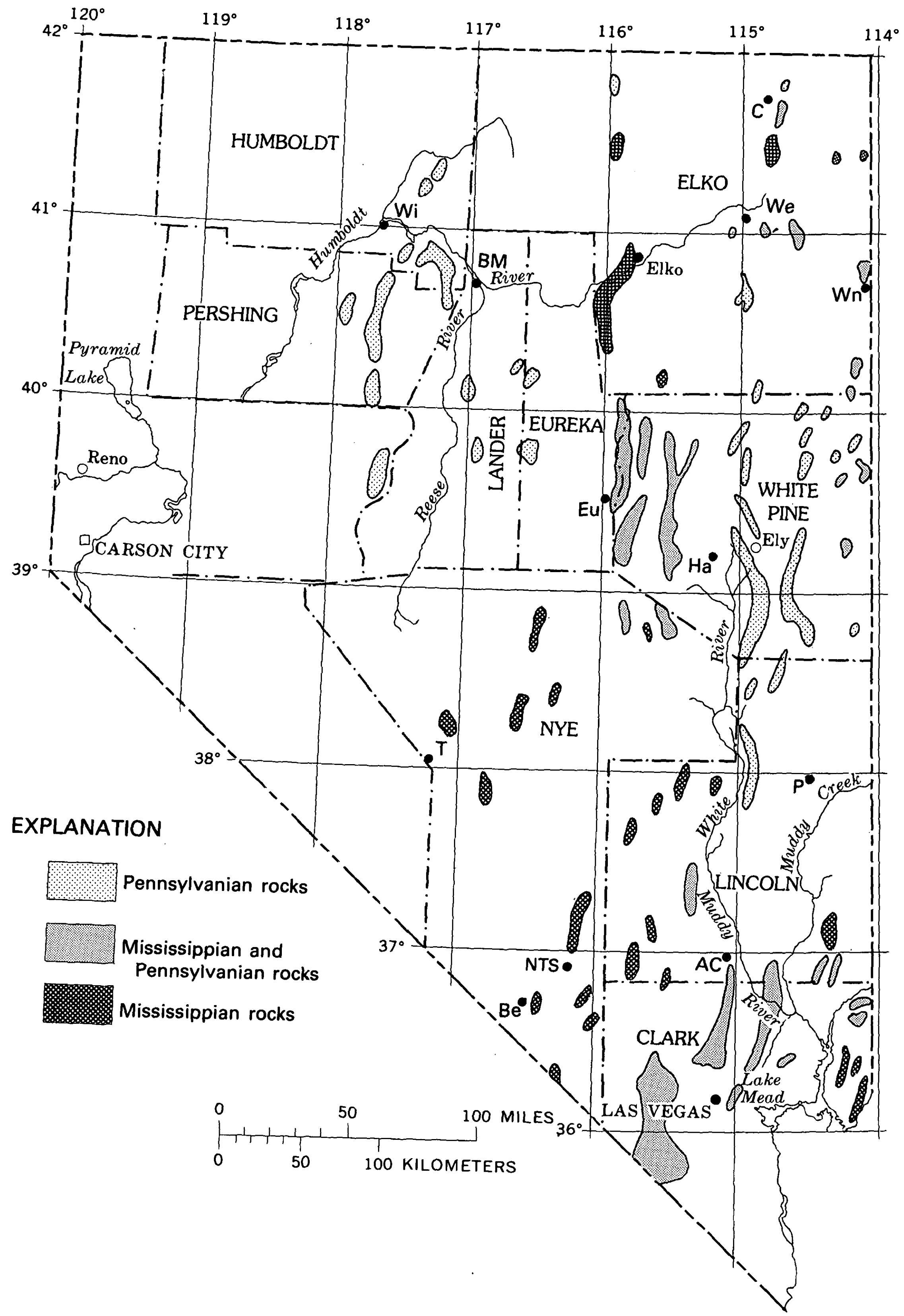
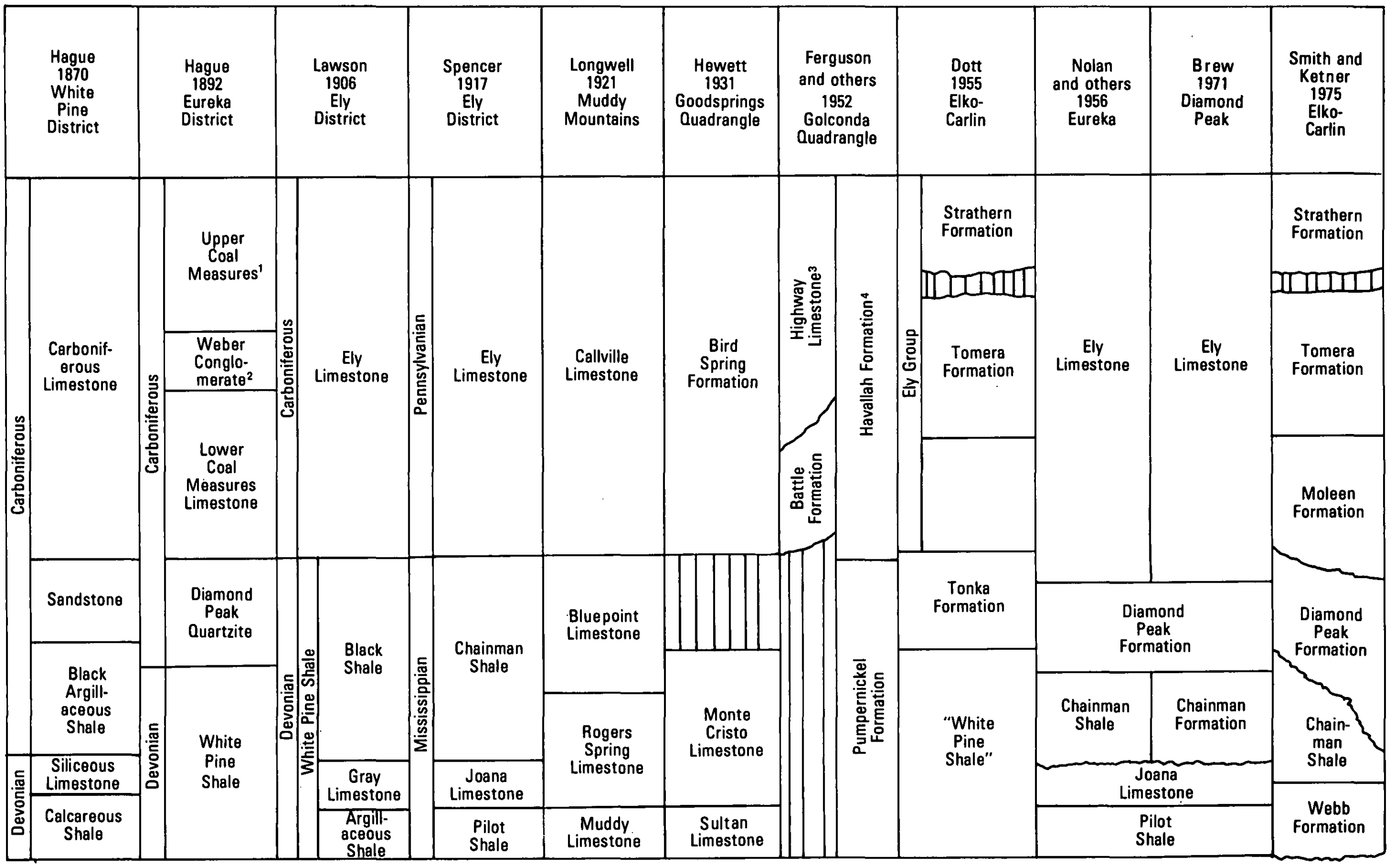


FIGURE 1.—Carboniferous outcrops. Localities: AC, Arrow Canyon Range; Be, Beatty; BM, Battle Mountain; C, Contact; Eu, Eureka; Ha, Hamilton; NTS, Nevada Test Site; P, Pioche; T, Tonopah; We, Wells; Wi, Winnemucca; Wn, Wendover.



¹Fault block of Lower Pennsylvanian
²Cretaceous
³Autochthonous
⁴Allochthonous

FIGURE 2.—Development of Carboniferous terminology in Nevada.

volcanic sequence. The Antler belt was an active source of clastic sediments during the Permo-Carboniferous. Figures 3 and 4 show the stratigraphic belts and representative stratigraphic columns from them.

The stratigraphy of the foreland belt is well known but is complicated by facies differences and later tectonic displacements.

The eugeosyncline (shale-volcanic belt) can only be interpreted from strata preserved in klippen that lie on the foreland-basin sequence or on the Antler belt.

The original distribution of Carboniferous rocks has been modified by major west-to-east thrusting during the lower Triassic (Golconda thrust) and middle Cretaceous through lower Tertiary Sevier and Laramide orogenies. Middle Tertiary through Holocene block faulting (Basin and Range province) has segmented all older structures. Major strike-slip faults (Death Valley-Furnace Creek shear zone, Las Vegas shear, Wells fault; the last two features shown on fig. 5) have displaced Carboniferous sedimentary rocks tens of kilometers.

MISSISSIPPIAN SYSTEM

MISSISSIPPIAN FORELAND BASIN

LOWER MISSISSIPPIAN

Lower Mississippian (Kinderhookian, Osagean, lower Meramecian) beds are 1,000 m thick in a north-trending belt from Elko to Beatty (fig. 5). These deposits thin abruptly westward to zero on the eastern edge of the Antler belt and thin gradually to a few hundred meters in eastern Nevada, where they may be locally absent. The area of thickest sedimentary rocks first received western-derived medium- and fine-grained clastic deposits. In the Eureka area (fig. 4), the black Pilot Shale conformably overlies the Nevada Formation of Devonian age. Conodonts indicate that the Devonian-Mississippian boundary is within the shale. To

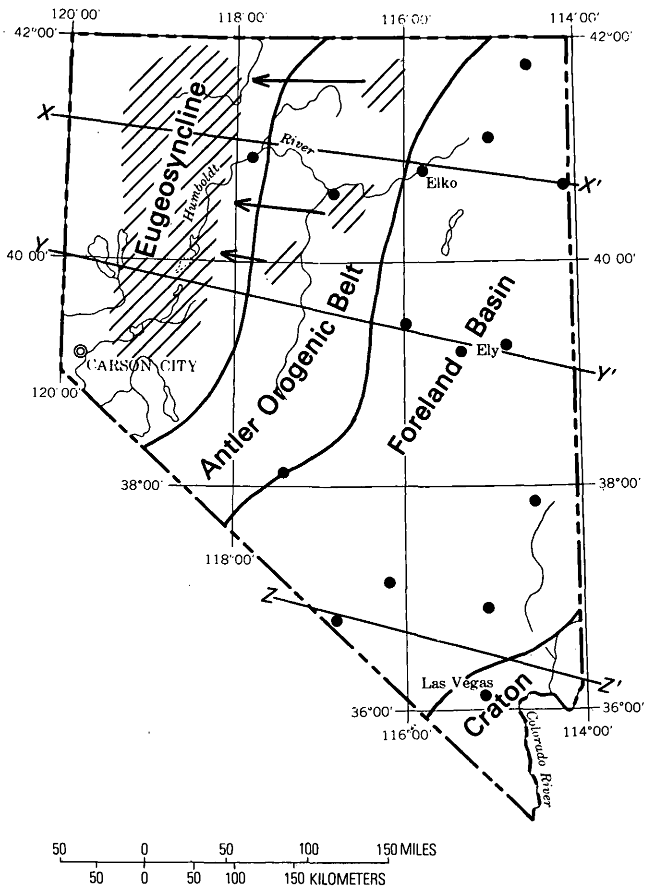


FIGURE 3.—Paleotectonic map of Carboniferous elements in Nevada. Original site of deposition of allochthonous eugeosynclinal units indicated by ruled pattern. *X–X'*, *Y–Y'*, and *Z–Z'* are lines of restored sections (block diagrams) shown in figure 9.

the east near Ely, the Pilot Shale is discontinuous, the result of post-Pilot warping and erosion (Langenheim, 1960, 1961).

Fine arenites in the Pilot Shale near Wendover (figs. 5, 6) have Buoma sequences in which all elements are present. These rocks are interpreted as proximal turbidites (Poole, 1974, p. 66), part of a submarine fan that extended southward from Idaho. Graded beds are again present in the Eleana Formation near Beatty in southern Nevada (Barnes and others, 1963) (fig. 6). These Lower Mississippian turbidites are the early flysch deposits of the Antler orogeny.

The Joana Limestone, which overlies the Pilot Shale in the Eureka-Ely area, is continuous to the east and southeast with the lower part of a carbonate bank that extends southwest from central Utah to southern Nevada (figs. 6, 9). The relationship of the Joana to contiguous beds is complex and is generally disconformable. Near Ely, the Joana lies on the Pilot Shale or directly on the Devonian Guilmette Formation as the result of regional warping and erosion (Langenheim, 1960, 1961). Near Eureka, the Joana lies disconformably (Langenheim, 1961) or conformably (Nolan and others, 1956) on the Pilot. The pattern seems to be one of regional disconformity.

The Joana Limestone thickens from 100 m at Ward Mountain near Ely (Langenheim, 1960) to 300 m near Pioche and is laterally continuous with the Dawn Limestone of the Monte Cristo Group in the Arrow Canyon Range (fig. 6). The contact of the Joana with the overlying Chainman Formation is a regional disconformity according to MacKenzie Gordon, Jr. (*in* Brew, 1971, p. 35), on the basis of limited faunal evidence, but Rose (1976, fig. 3) has interpreted the Joana and Chainman as a continuous sequence that reflects deposition on a carbonate bank and adjacent basin. The Joana is locally absent east of Eureka (Nolan and others, 1956), and changes in thickness from 50 to 150 m in 5 km have been observed (Larson and Riva, 1963; Brew, 1971). Joana time was one of minimum influx of clastic sediments into the foreland basin. The post-Joana hiatus that represents most of the Meramecian in eastern Nevada (Mackenie Gordon, Jr., *in* Brew, 1971, p. 34-77) resulted from uplift in the Antler area and warping in the basin. The upward-coarsening flysch deposits of the overlying Chainman Formation indicate progressive uplift in the Antler source area.

In the Elko-Carlin area, the Kinderhookian Webb Formation (Smith and Ketner, 1975, A38) is a laminated to thin-bedded claystone containing limestone lenses equivalent to the upper Pilot Shale and the Joana Limestone. The Webb lies on both autochthonous Devonian Limestone and allochthonous Ordovician eugeosynclinal deposits (Valmy Formation). The lithology of the Webb indicates that the formation was deposited nearer to an active source of fine clastic materials than were the Pilot and Joana, a condition that is emphasized in the succeeding Chainman and Diamond Peak Formations.

Glauconitic black shale that overlies the Joana Limestone in easternmost Nevada and adjacent Utah was deposited in a starved basin between the toe of the Antler flysch wedge and the central Utah carbonate bank (Poole and Sandberg, 1977) (figs. 5, 6). A carbonate buildup of the Joana Limestone isolated the basin from a western source of sediments, so that the black shale was largely of eastern origin (Poole, 1974).

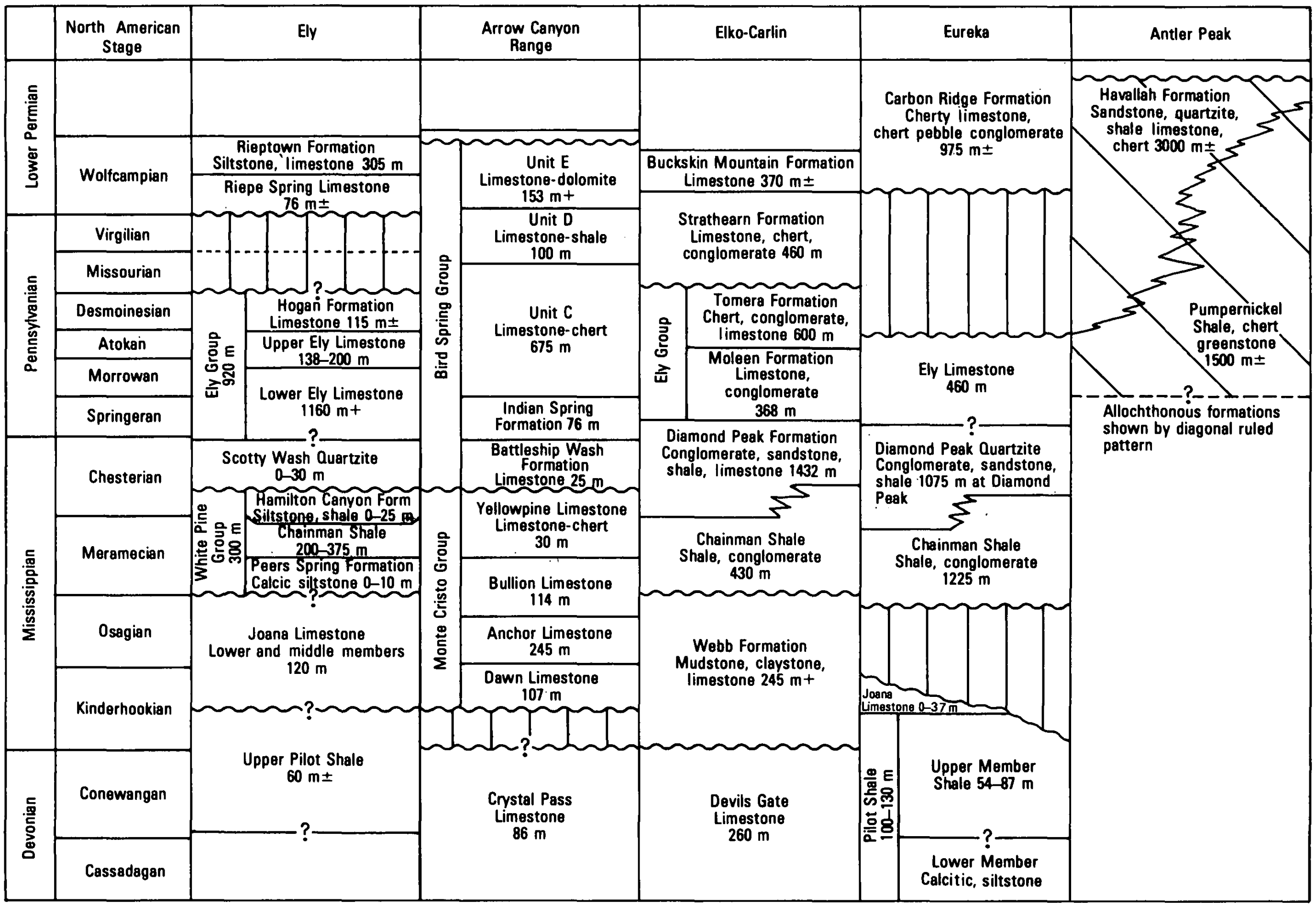


FIGURE 4.—Correlation chart of representative Carboniferous assemblages from stratigraphic belts.

UPPER MISSISSIPPIAN

Upper Meramecian and Chesterian deposits in eastern Nevada, the flysch and molasse of the Antler orogeny, are thickest adjacent to the Antler belt, reaching a thickness of more than 1,500 m near Elko and Beatty (fig. 7). The thickest deposits contain thick conglomerate sequences (Diamond Peak Formation) that overlie and interfinger eastward with a shale-arenite formation (Chainman). The terminology of the upper Mississippian has been the source of much discussion. Because of the eastward transgression of the Diamond Peak, the formation boundaries are not time horizons and are recognized differently by various workers.

The name Illipah has been used for arenites that occupy the position of the Diamond Peak Formation in the Ely area and in exploratory oil wells drilled near Hamilton, but the name is not recognized by the U.S. Geological Survey. Humphrey (1960) applied the name Illipah to Eocene deposits in the White Pine mining district.

The Chainman Shale (Formation) is approximately 100 m of generally gray to greenish-gray silty and sandy shale that disconformably overlies the Joana Limestone near Ely, the type area (Spencer, 1917). Westward, in the Eureka-Hamilton area, the Chainman overlies the Joana Limestone (locally on the Pilot); near Elko and Carlin, it overlies the Webb.

Graded sandstone turbidites in the Chainman were deposited in deep water, attested to by meandering trails (*Nereites*) on bedding surfaces. Pebbly mudstones near Elko (Smith and Ketner, 1975) contain well-rounded chert and quartzite cobbles, indicating proximity to the source, but those near Eureka have only chert pebbles, indicating a more distal deposit.

DIAMOND PEAK FORMATION

Maximum elevation of the Antler belt is marked by conglomerate of the Diamond Peak Formation, which is the molasse of the Antler orogeny. This

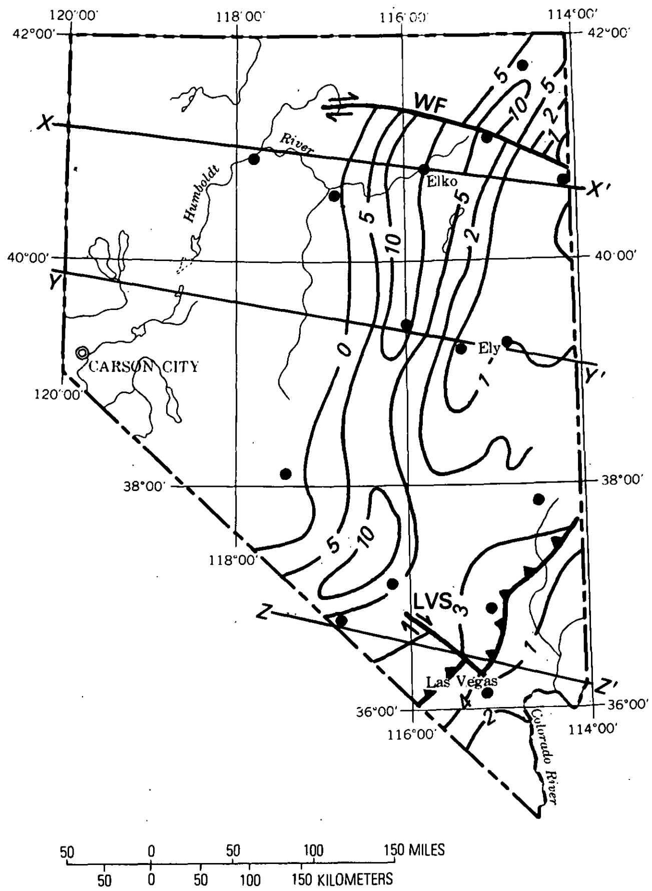


FIGURE 5.—Thickness of Lower Mississippian (Kinderhookian, Osagean, lower Meramecian) rocks. Isopachs in hundred of meters. Allochthonous rocks are restored to the site of original deposition. Faults: LVS, Las Vegas shear; WF, Wells fault. *X–X'*, *Y–Y'*, and *Z–Z'* are lines of restored sections (fig. 9). Modified from Poole and Sandberg (1977).

assemblage of coarse to fine clastic deposits and some limestone is more than 1,000 m thick in the Eureka-Elko-Carlin belt, but it thins rapidly eastward and cannot be recognized with certainty east of Hamilton. The proportion of conglomerate in the upper Mississippian decreases eastward and southeastward from near 50 percent near Elko to less than 2 percent near Ely (fig. 8).

The Diamond Peak is Meramecian and Chesterian and contains the Mississippian-Pennsylvanian boundary near Elko (Mackenzie Gordon, Jr., *in* Brew, 1971, p. 34–55; fig. 11). It is entirely Meramecian and Chesterian near Eureka, but is only upper Chesterian near Hamilton (Mackenzie Gordon, Jr., *in* Brew, 1971, p. 34–77). Upper Chesterian arenites near Pioche (Scotty Wash Formation) have been correlated with the Diamond Peak, but may have been derived from the east (James, 1954).

It is reasonable that the upper limit of the Diamond Peak is younger toward the north than near Eureka, which is farther from the principal source of clastic sediments.

Lenticular bodies of conglomerate in the upper Chainman-lower Diamond Peak both in the Carlin area and near Eureka are debris flows and distributary channels on a submarine fan that extended southeast from the northern extension of the Antler belt (Rose, 1976). These lenticular bodies—cross sections of channel fillings as much as 500 m wide and 20 m thick—are well seen on the western slope of the Diamond Mountains near Eureka. Well-washed chert pebble conglomerates are in a series of overlapping channels near the base of the Dia-

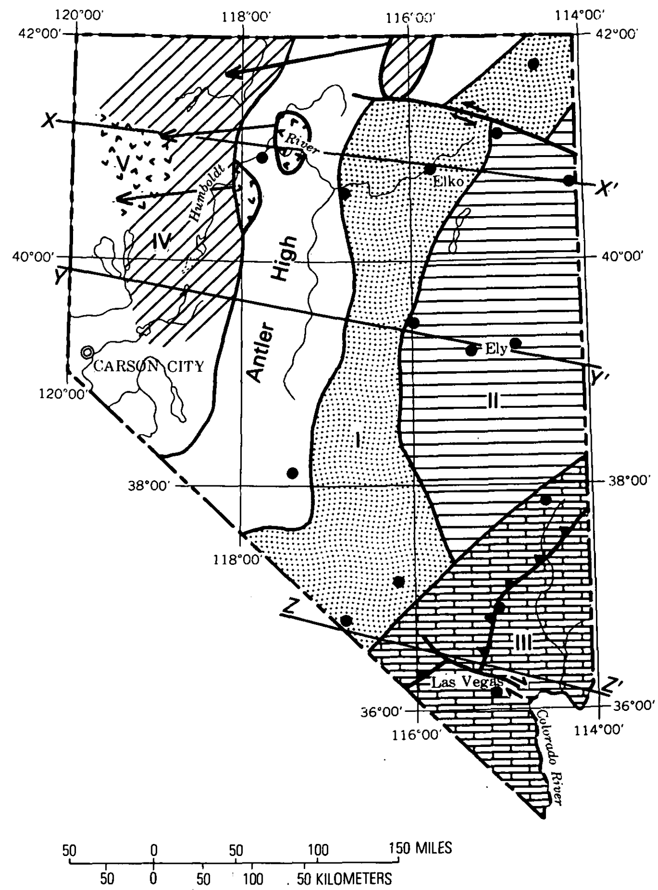


FIGURE 6.—Lower Mississippian (Kinderhookian, Osagean, lower Meramecian) lithofacies. Lithologies: I, clastic wedge—shale, sandstone, conglomerate; II, starved basin—shale, limestone; III, platform carbonate rocks—limestone; IV, eugeosynclinal rocks—shale, graywacke, bedded chert; V, volcanic rocks. *X–X'*, *Y–Y'*, and *Z–Z'* are lines of restored sections (fig. 9). Arrows show direction of restoration of eugeosynclinal rocks in klippen. Keystone-Muddy Mountain thrust indicated by sawteeth. Modified from Poole and Sandberg (1977).

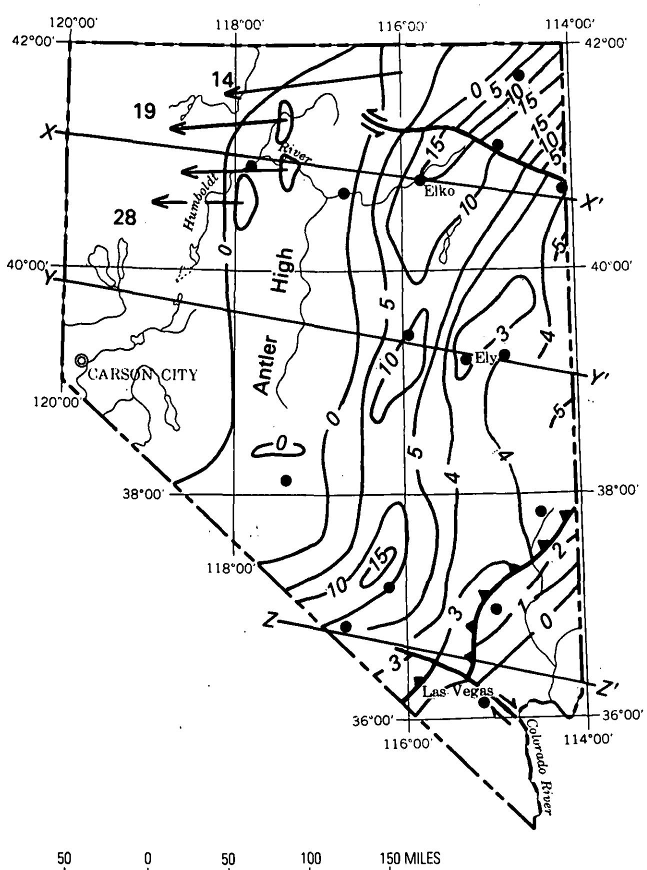


FIGURE 7.—Thickness of Upper Mississippian (upper Meramecian, Chesterian) rocks. Isopachs in hundreds of meters. Allochthonous rocks are restored to the original site of deposition. *X–X'*, *Y–Y'*, and *Z–Z'* are lines of restored sections (fig. 9). Modified from Poole and Sandberg (1977).

mond Peak Formation at Buck Mountain east of Eureka (Blomquist, 1971). Crossbeds that dip approximately 30° indicate southward transport. Regional studies of directional features in the Diamond Peak (fig. 8) indicate dominant southward transport, but some transport was from the east or the northeast, suggesting control of currents by a high area near Ely (Ely high).

Faunas in the Chainman-Diamond Peak transition zone in the Diamond Mountains north of Eureka are productoids, pelecypods, echinoids, crinoids, and trilobites. This assemblage is in muddy beds interlayered with pebble and cobble conglomerates. The depositional environment is interpreted as having been relatively shallow but below the zone of wave action, in contrast to the deep-water depositional site of the pebbly mudstones in the lower Chainman. This change indicates eastward filling of the foreland basin. Upper Mississippian deposits spread progressively eastward and cover the lower Mississippian starved basin, which was reduced to a small area on the Utah-Nevada border in Chester time (fig. 8).

The contact of the Diamond Peak and the Pennsylvanian Ely Limestone is in a zone of interbedded limestone, conglomerate, and finer clastic materials (Brew, 1971). The horizon chosen in a local area cannot be traced widely, and different limits have been used by different workers in the same area. The type Diamond Peak Formation has been variously interpreted as entirely Chesterian (Nolan, 1956; Brew, 1971) or as including basal Pennsylvanian strata (Dott, 1955, fig. 13; Easton, 1953; Langenheim and Larson, 1973). Arnold and Sadlick (1961) defined the Mississippian-Pennsylvanian

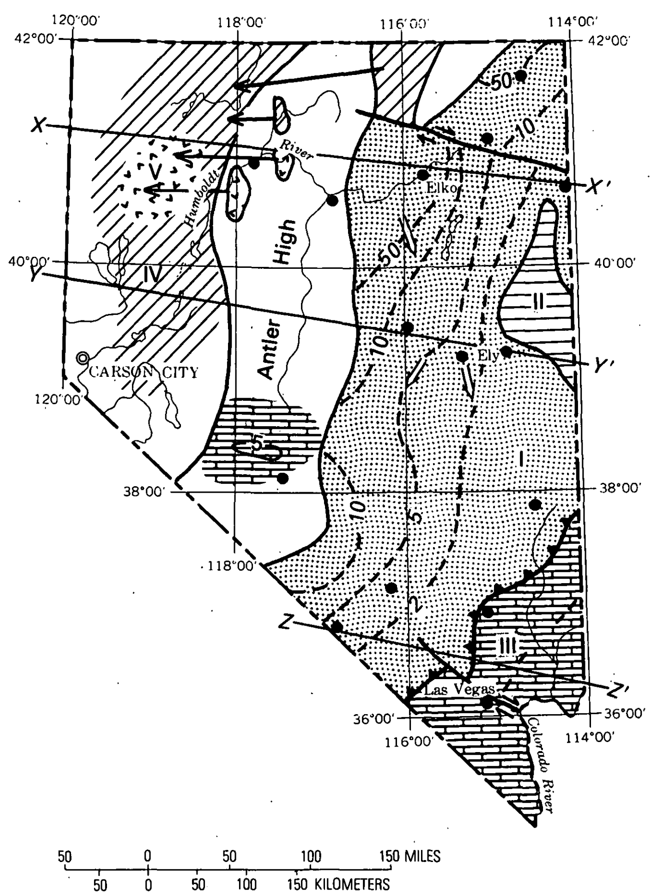


FIGURE 8.—Upper Mississippian (upper Meramecian, Chesterian) lithofacies. Allochthonous units are restored to site of deposition indicated by arrows. *X–X'*, *Y–Y'*, and *Z–Z'* are lines of restored sections (fig. 9). Lithologies: I, clastic wedge (isopleths indicate percent of conglomerate); II, starved basin, phosphatic shale, limestone; III, limestone; IV, eugeosynclinal sedimentary rocks; V, eugeosynclinal volcanic rocks. Double-shafted arrows indicate current directions from cross-lamination and bedding surfaces. Modified from Poole and Sandberg (1977).

transitional sequence of limestone, shale, and quartz arenite between the Chainman and the Ely in the Wendover area as the Jensen member of the Chainman. The Jensen was widely recognized by Bissell (1964, fig. 3).

Mississippian clastic-wedge sedimentary rocks in southern Nevada constitute the Eleana Formation, a 2,000-m thick unit of turbidites and lesser chert and shale, which extends from the vicinity of Goldfield and Beatty eastward toward Las Vegas. Turbidites suggest deposition in deep water (Poole and others, 1965; Poole and Sandberg, 1977). The age relations of the Eleana are not well known, but the formation evidently encompasses the entire Mississippian. The lithology of the beds indicates that deposition was well removed from a source of coarse clastic sediments, but some pebble beds have been observed in the vicinity of Beatty (figs. 7, 8, and 9, Z–Z′).

Mississippian formations in southeast Nevada comprise the Monte Cristo group and the lowermost Bird Spring group (see fig. 4). These units are a part of the carbonate bank that extended from central Utah southwestward through southern Nevada. A minor disconformity that separates the upper Monte Cristo (Yellowpine Limestone) from the uppermost Mississippian Battleship Wash Formation in the Arrow Canyon Range is within a single conodont zone.

MISSISSIPPIAN EUGEOSYNCLINE

Mississippian shale-volcanic-assemblage rocks in klippen of the Golconda thrust near Elko and Winnemucca are samples of the eugeosyncline that was to the west during the Carboniferous. North of Elko, the Schoonover Formation (Fagan, 1962) is 2,500 m of radiolarian chert, turbidite, and shale that has volcanic rock near the base. The Schoonover is now dated as Late Mississippian in age (Poole and Sandberg, 1977). Fagan (1962) believed that the formation is composed of deep-water sediments derived from a sourceland toward the west within the eugeosyncline.

The Gogh Canyon Formation in the Osgood Mountains northeast of Winnemucca is 1,500 m of pillow lava and volcanic breccia (Hotz and Willden, 1964). These early Osagean or late Kinderhookian rocks are believed to be shallow-water volcanic rocks and shallow siltstone (Hotz and Willden, 1964). The Inskip Formation in the East Range near Winnemucca resembles the Gogh Canyon.

Figure 9, a palinspastic interpretation of Mississippian rocks along a series of sections in southern, central, and northern Nevada, indicates the original position of the now-displaced facies belts and the role of the Antler orogenic belt.

PENNSYLVANIAN SYSTEM

PENNSYLVANIAN FORELAND BASIN

INTERVALS A, B, AND C

Mississippian clastic wedge sedimentary rocks in eastern Nevada are succeeded by the limestones of the Ely Formation in the northern part of the State and by the Bird Spring Group in the south. This carbonate deposition continued without significant interruption through Morrowan and Desmoinesian time (intervals A, B, C), the principal accumulation being in the southwest-plunging Ely-Bird Spring Basin in Clark, Lincoln, and southern White Pine Counties (figs. 1, 10). These rocks are thinner on the Ely Platform, which separates the southern basin from the supposed Butte Basin in the north in Elko County. These regional variations in the thickness of contemporaneous strata reflect continued warping of the Cordilleran miogeosyncline.

The Mississippian-Pennsylvanian boundary in the heart of the miogeosyncline has been well documented as occurring in the lower part of unit "C" of the Bird Spring Group or within the lowermost Ely Formation, or their temporal equivalents. On the western margin of the foreland basin or miogeosyncline, the systemic boundary is within the Diamond Peak Formation in some areas, as near Elko (fig. 9, Elko-Carlin section), where conditions controlling Diamond Peak deposition prevailed from the middle Mississippian into the Pennsylvanian. Middle Pennsylvanian strata near Elko contain lenses of chert pebble conglomerate like those of the Diamond Peak.

Morrowan through Atokan parts of the Bird Spring Group are characterized by cyclically alternating layers of argillaceous fine-grained limestone, nodular limestone, and thicker bedded, cherty, arenaceous medium-grained limestone in the southern part of the Ely-Bird Spring Basin (fig. 11). Desmoinesian parts of the Bird Spring Group here are somewhat more arenaceous. In the northern part of the basin and on the Ely Platform, the Morrowan through Atokan Ely Limestone consists of thick-bedded, more argillaceous and silty limestone and has been referred to as the Hogan Formation. The eastern part of the Butte Basin is occupied by rocks referred to as the Ely Limestone and Hogan Formation (Bissell, 1964); sandy and conglomeratic mid-

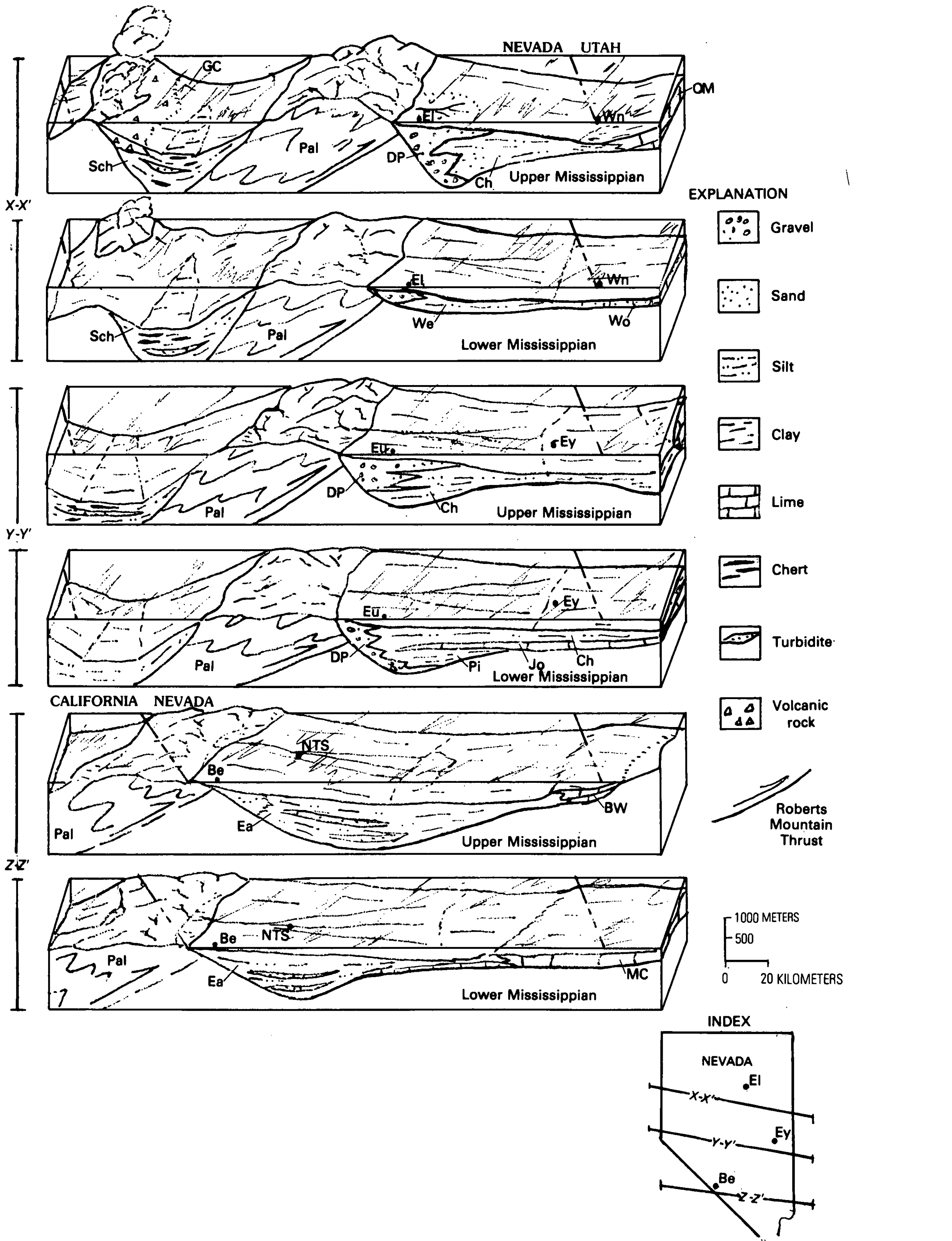


FIGURE 9.—Paleotectonic block diagrams of Mississippian rocks. Localities: Be, Beatty; El, Elko; Eu, Eureka; Ey, Ely; NTS, Nevada Test Site; Wn, Wendover Formation; BW, Battleship Wash Formation; Ch, Chainman Shale; DP, Diamond Peak Formation; Ea, Eleana Formation; GC, Gogh Canyon Formation; Jo, Joana Limestone; MC, Monte Cristo Formation; OM, Ochre Mountain Limestone; Pal, lower Paleozoic allochthon; Pi, Pilot Shale; Sch, Schoonover Formation; We, Webb Formation; Wo, Woodman Formation. (Diagram by E. R. Larson.)

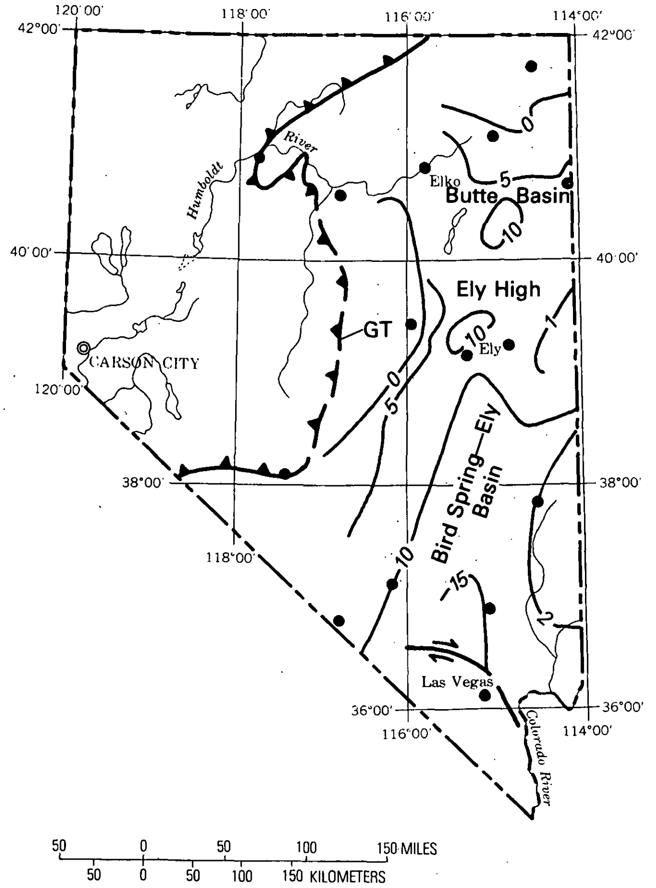


FIGURE 10.—Thickness of Pennsylvanian intervals A, B, C (Morrowan-Desmoinesian). Isopachs in hundreds of meters. GT, Golconda thrust. Modified from McKee and others (1975).

dle Atokan through Desmoinesian rocks to the west have been separately described as the Tomera Formation of the Ely Group (Dott, 1955). The underlying Morrowan and early Atokan Moleen Formation resembles the lower part of the Ely Limestone to the east.

Arenaceous and oolitic limestones, which are partially dolomitized, characterize the Callville Platform in southern Clark County and are assigned to the Callville Formation. Here, the Morrowan through Desmoinesian interval is broken by a hiatus representing Atokan time.

Pennsylvanian strata in north-central Nevada reflect the influence of the Antler orogenic belt. During the Mississippian and lower Pennsylvanian, this belt had acted as a barrier between sedimentary basins in eastern and western Nevada, but during the Atokan, the barrier was breached. The resulting islands were rugged enough to act as sources of coarse clastic material.

The Battle Formation, 730 m thick in the type section at Battle Mountain, has a 150-m basal conglomerate unit that reflects the composition of subjacent beds; a middle part consisting of *Fusulinella*- and *Chaetetes*-bearing limestone and conglomerate and ridge-forming sandstone; and an upper part of sandstone, siltstone, and conglomerate (Roberts, 1964, p. A29).

Lawson (1913) described these rocks as a fanglomerate, implying continental deposition. The formation as understood today represents marine deposition adjacent to a rugged source terrane. Recent studies by Drowley (1973) have shown that the beds included in the Battle Formation are isolated clastic accumulations deposited quite separately where gravel, boulders, and sand were being carried into a marine environment (fig. 12). To the west, the Battle Formation is overlain by the Highway Limestone of the same age, suggesting an interfingering relationship (fig. 12).

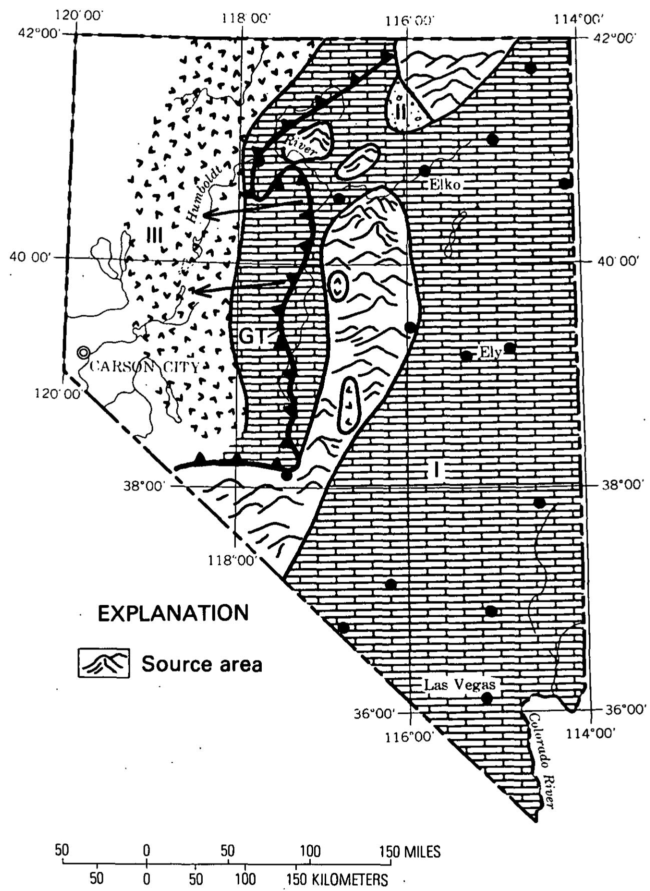


FIGURE 11.—Distribution of lithologies in Pennsylvanian intervals A, B, C (Morrowan-Desmoinesian). GT, Golconda thrust. Lithologies: I, limestone; II, conglomerate fan; III, eugeosynclinal rocks. Modified from McKee and others (1975).

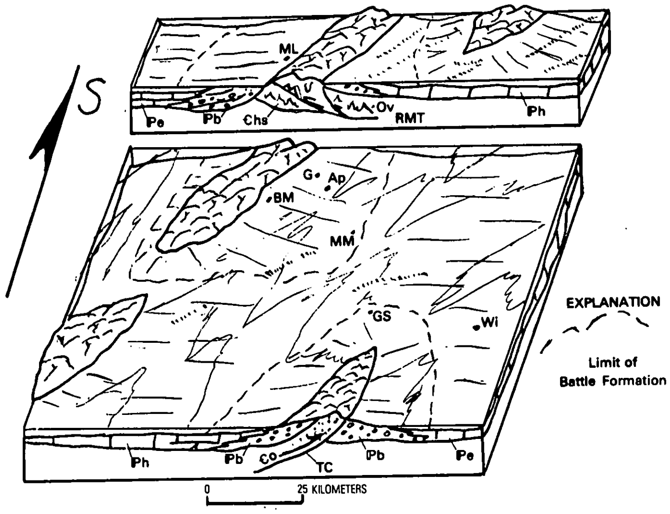


FIGURE 12.—Sites of deposition of Battle Formation. Localities: AP, Antler Peak; BM, Battle Mountain; G, Galena; GS, Golconda Summit; ML, Mount Lewis; Wi, Winnemucca. Formations: -Chs, Cambrian Harmony and Scott Canyon formations; -Co, Cambrian Osgood Mountain Quartzite; Ov, Ordovician Valmy Formation; IPb, Pennsylvanian Battle Formation; IPe, Pennsylvanian Etchart Limestone; IPh, Pennsylvanian Highway Limestone; RMT, Roberts Mountain thrust; TC, Twin Canyon fault. (Diagram by E. R. Larson.)

To the east, pebbly limestone of the Moleen Formation (Dott, 1955) contains the *Chaetetes-Fusulinella* zone like the Battle and is its eastward equivalent.

INTERVALS D AND E

Desmoinesian rocks are separated from later Pennsylvanian rocks or from Permian rocks by a disconformity that is well documented throughout most of the miogeosyncline and shelf in Nevada. During the Missourian and Virgilian, the Butte Basin was divided by a northeast-trending positive area that shed sediments into the remaining part of the basin on either side. This positive area and the still-extant Ely Platform outlined a trough that extends from the Oquirrh Basin of Utah near Wendover southwestward toward central Nevada (fig. 13). The Strathern Formation, occupying the northwestern part of the Butte Basin, consists of chert-pebble conglomerate, silty limestone, and sandstone of Missourian through Wolfcampian age. It rests disconformably on Desmoinesian rocks of the Tomera Formation in the central part of the basin. Near Carlin, the Strathern forms a spectacular angular unconformity with the Diamond Peak Formation (Mississippian) and with pre-Strathern Pennsylvanian strata.

On the ridge between the basins, Wolfcampian rocks rest on formations as low in the section as Diamond Peak.

South of the Butte Basin on the Ely Platform, Missourian and Virgilian rocks are absent in White Pine and northern Lincoln Counties (fig. 13). Here the Wolfcampian Riepe Springs Limestone rests directly on Desmoinesian rocks. In the Bird Spring Basin, Missourian and Virgilian rocks of the Bird Spring Group, lithologically much like those below, are succeeded by Wolfcampian rocks variously assigned to either the Bird Spring Group or the Pakoon Formation. On the Callville Platform, Missourian rocks are absent in the Callville Formation, but the upper part of the formation is of Virgilian age. Wolfcampian rocks of the Pakoon Formation, a thick-bedded dolomite, succeed the Callville Formation disconformably.

Carbonate rocks also accumulated northwest of the Antler belt during Late Pennsylvanian and Early Permian time. Limestone-pebble and chert-

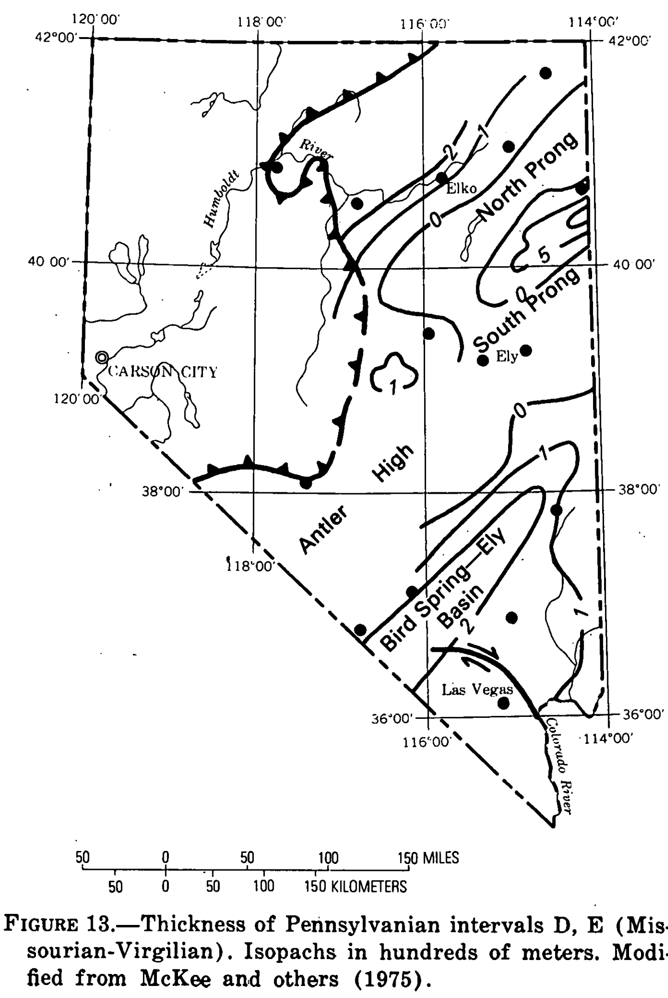


FIGURE 13.—Thickness of Pennsylvanian intervals D, E (Missourian-Virgilian). Isopachs in hundreds of meters. Modified from McKee and others (1975).

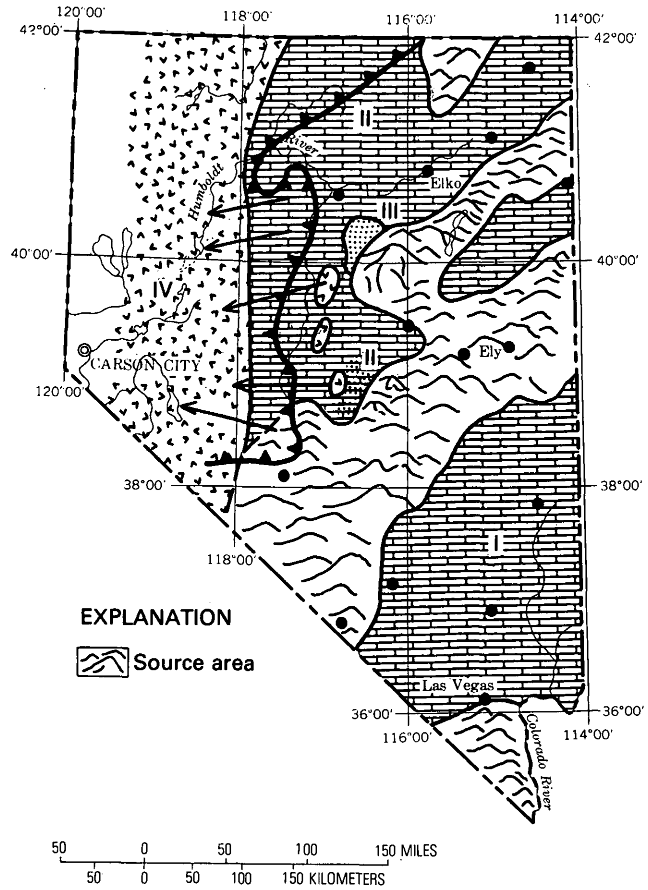


FIGURE 14.—Distribution of lithologies in Pennsylvanian intervals D, E (Missourian-Virgilian). Lithologies: I, limestone; II, conglomerate and limestone; III, sandstone; IV, eugeosynclinal rocks. Modified from McKee and others (1975).

pebble conglomerate and chert pebbly limestone (Wildcat Peak Formation) were deposited in the area of the Toquima Range west of Eureka (fig. 14). *Triticites* of possible Late Pennsylvanian age have been found in the lowermost beds of the formation (Kay and Crawford, 1964, p. 443; McKee, 1976, p. 23), but the formation has been dated as earliest Permian by Laule (1978) on the basis of a fusuline and coral fauna of Asiatic affinity.

PENNSYLVANIAN EUGEOSYNCLINE

Atokan through lower Permian sediments seen in klippen in the Battle Mountain-Winnemucca area (Roberts, 1964; Roberts and others, 1958; Ferguson and others, 1952; McMillan, 1974) and southward to Tonopah (Speed, 1971; Wilson, 1975) were deposited in a continuing eugeosynclinal system in western Nevada. These deposits of shale, chert, and volcanic rocks (Pumpernickel Formation), turbidites, and lesser limestone (Havallah Formation), originally thought to be sequential deposits (Ferguson and others, 1952), are now recognized as partly contemporaneous facies reflecting different source areas (figs. 4, 11, 13, 15). The poorly fossiliferous Pumpernickel Formation contains Atokan fusulines in limestone lenses, but the major lithology is bedded chert containing tubes and trails (lebensspoor) attributed to deep-water marine worms. Associated spilite is from submarine effusions or volcanic islands (fig. 15).

The Havallah Formation, which overlies the Pumpernickel in many areas, is Atokan to Leonardian. The graded arenite of the Havallah is believed to have been derived from the Antler belt and transported westward into an inner-arc basin (fig. 15). Figure 15 is a palinspastic synthesis of mid-Pennsylvanian relationships in northern Nevada.

The Carboniferous strata in Nevada reflect the tectonic development of the area that controlled the locus of source lands, sites of deposition, and the facies of the system. Continuing deformation is responsible for the present distribution of Carboniferous strata, and many of the problems of interpretation and reconstruction are still unresolved.

REPRESENTATIVE STRATIGRAPHIC SECTIONS

1. Monte Cristo-Bird Spring exposures on Nevada State Route 16, from crest of Spring Mountain Pass east to the valley floor. (Geologic map of Clark County (Longwell and others, 1965).)
2. A similar section along State Route 9, just northwest of the irrigated area in Muddy Valley.
3. Joana Limestone, White Pine Group, and Ely Limestone on U.S. Highway 50, beginning at Conners Pass and extending westward. (Connors Summit 15-minute quadrangle topographic map and White Pine County geologic map (Hose and Blake, 1976).)
4. A complete Joana-Chainman-Ely sequence on U.S. Highway 50 between Moorman Ranch and Antelope Summit. (Illipah 15-minute quadrangle topographic map and White Pine County geologic map (Hose and Blake, 1976).)
5. A well-exposed angular unconformity between the Diamond Peak Formation (Tonka of Dott, 1955) and the Strathern Formation at the west end of the tunnels on Interstate 80 east of Carlin. Post-Diamond Peak—pre-Strathern beds are exposed along old U.S. Highway 40 north of the Humboldt River.

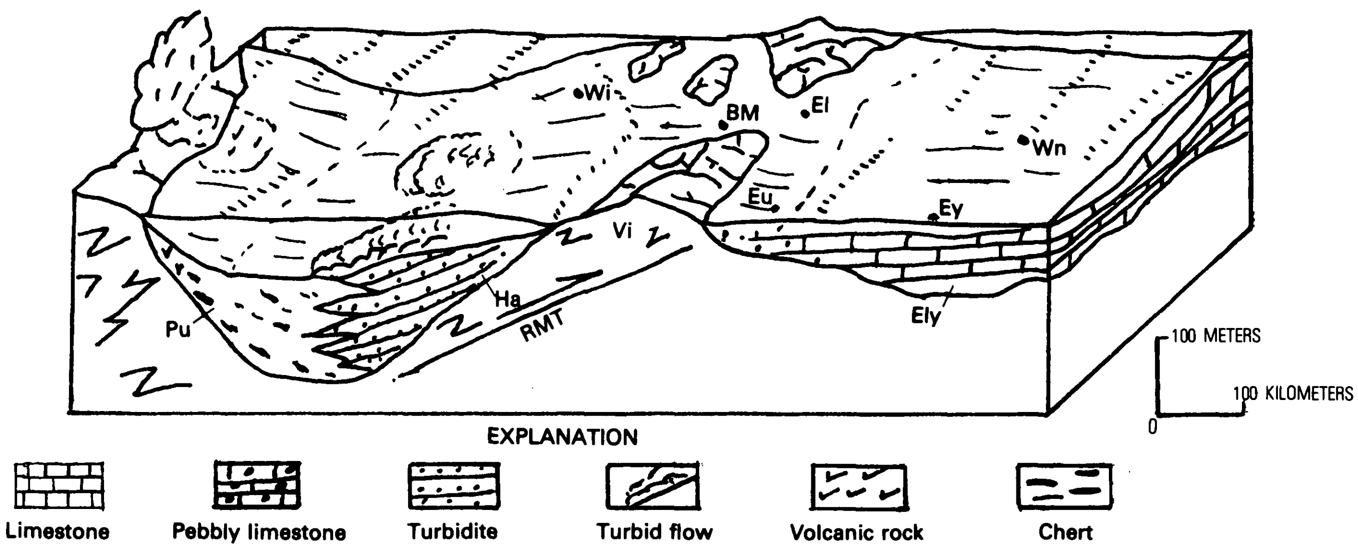


FIGURE 15.—Paleotectonic block diagram of Middle Pennsylvanian rocks. Localities: BM, Battle Mountain; El, Elko; Eu, Eureka; Ey, Ely; Wn, Wendover; Wi, Winnemucca. Formations: Ely, Ely Limestone; Ha, Havallah Formation; Pu, Pumpernickel Formation; Vi, Vinini Formation. RMT, Roberts Mountain thrust. (Diagram by E. R. Larson.)

6. Joana Limestone, Chainman Shale, and younger rocks on Interstate 80 east of Wells at Pequop Summit.
7. Pumpernickel and Havallah Formations at and near the Marigold mine. Take the Valmy turnoff approximately 15 miles (24 km) west of Battle Mountain (see Antler Peak geologic map (Roberts, 1964)). Pumpernickel chert and Havallah Formation together with turbidites in W. ½ Sec. 12, Havallah Formation Sec. 13. Badly silicified Battle Formation forms rusty ridges at the mine.
8. Antler Peak Limestone in good exposures in roadcuts on old U.S. Highway 40 west of Golconda Summit (SW, SW, Sec. 6, T. 35 N., R. 41 E.; Golconda Summit geologic map (Erickson and Marsh, 1974).)
9. Pumpernickel Formation exposed in borrow pits on the north side of Interstate 80, 1 mile (1.6 km) west of Golconda Summit.

PALEONTOLOGY

By JOSEPH LINTZ, JR.[3]

During the Carboniferous, sedimentation was nearly continuous in eastern Nevada, and all the widely recognized stages are represented (fig. 16). Poorly exposed eugeosynclinal assemblages in western Nevada are essentially nonfossiliferous, although scattered faunules have permitted a rough correlation of these beds with their eastern analogs.

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Most of the paleontologic discussion here is limited to the eastern part of the State; Carboniferous fossils have been relatively well studied there, and a considerable literature has accumulated. The fossils suggest a shelf area in southern Nevada and a shift to miogeosynclinal conditions farther north.

FAUNAL ZONES

The faunal zonation is shown in table 1. A few comments are in order. The Foraminifera are common throughout Nevada but are abundant on the craton in the southern part of the State. Douglass (1974) has given an excellent summary of fusulinid occurrences in Nevada. Local fusulinid faunules have been described by Cassity and Langenheim (1966), Rich (1961), and Slade (1961).

For the Mississippian stages, the ammonoids offer the best correlations for those parts of Nevada in deeper basins near the margins of the cratonic block (Gordon, 1970). Mississippian foraminifers, usually endothyrids (Brenckle, 1973), are also present and offer good control. The longer ranging corals, brachiopods, and bryozoans are frequently found, but their long ranges reduce their value as stratigraphic indicators.

For the Pennsylvanian stages, the fusulinids are nearly ubiquitous and are the most treasured stratigraphic indicators. Occasional marker horizons, such as the *Chaetetes-Rhipidomella* zone, are widely recognizable by the unusual abundance of the named taxa. Common faunal elements of less stratigraphic

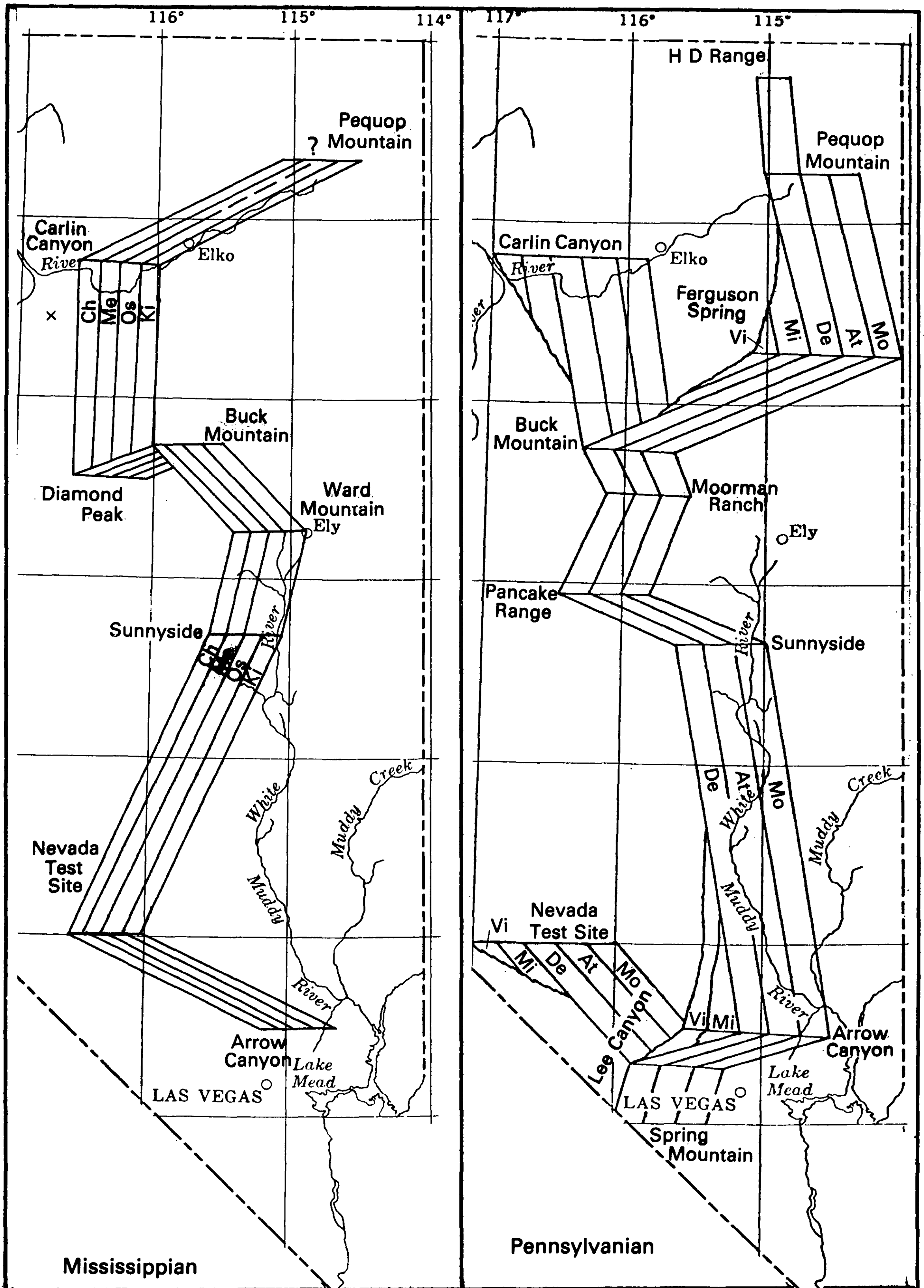

FIGURE 16.—Carboniferous stages in Nevada. Mississippian stages: Ki, Kinderhookian; Os, Osagean; Me, Meramecian; Ch, Chesterian. Pennsylvanian stages: Mo, Morrowan; At, Atokan; De, Desmoinesian; Mi, Missourian; Vi, Virgilian.

TABLE 1.—*Carboniferous index fossils of Nevada*

Period and Epoch	Foraminifers	Ammonoids	Conodonts	Other fossils
		Pennsylvanian		
Virgilian	*Triticites cullomensis* *T. kellyensis* *T. hobblensis* *T. plummeri* *T. ventricosus* *Dunbarellinella hughesensis*	----------	----------	----------
Missourian	*Triticites provoensis* *T. springvillensis* *Kansanella (Kansanella) grangerensis*	----------	----------	----------
Desmoinesian	*Fusulina megista* *Wedekindellina euthysepta*	----------	----------	*Hystriculina* spp. *Desmoinseia muricatina*
Atokan	*Fusulinella devexa* *F. acuminata* *F. fugax* *Profusulinella decora* *P. apodacensis* *P. copiosa*	*Pseudoparalegoceras kesslerense*	----------	*Multithecopora cannia* *Chaetetes favosus* *Komia* spp. *Chaetetes* sp. *Caninia torquia*
Morrowan	*Millerella marblensis* *Staffella expansa* *Paramillerella circuli*	*Gastrioceras branneri* *Diaboloceras* aff. *D. neumeieri* *Syngastrioceras* sp. *Stenopronorites* sp.	*Streptognathodus noduliferus* *Idiognathoides convexa* *I. parva*	*Caninostrotion* spp. *Hustedia miseri* *Rhipodomella nevadensis* *Flexaria* spp.
		Mississippian		
Chesterian	*Atesuella meandra* *Plectogyra* sp.	*Cravenoceras hesperium* *C. merriami* *Eumorphoceras bisulcatum* *Mooreoceras* sp.	*Gnathodus bilineatus*. *G. girtyi simplex*	*Faberophyllum* sp. *Ekvasophyllum* spp.
Meramecian	*Endothyra symmetrica* *Plectogyra* spp. *Granuliferella* spp. *Endothyra spiroides*	----------	*Taphrognathus varians* *T. varians/ Polygnathus mehli* *Eotaphrus burlingtonensis* *Polygnathus communis communis/ Eotaphrus* sp.	----------
Osagean	*Plectogyra tumula* *P. anteflexa* *Endothyra* spp.	----------	*Pseudopolygnathus triangulus nudus* *Gnathodus bilineatus/ G. cuneiformis* *G. semiglaber/ Pseudopolygnathus marginatus* *Polygnathus communis communis*	----------
Kinderhookian	*Granuliferella* spp.	*Protocanites lyoni*	*P. communis communis/ Pseudopolygnathus dentilineatus*	*Torynifer* aff. *T. cooperensis*

value in the Pennsylvanian are the associations of corals, brachiopods, and bryozoans.

Pennsylvanian mollusks, especially ammonoids, are less frequently found than are those of the Mississippian. Gastropods are present in moderate quantity, but pelecypods are less common. Gordon (1970) has reviewed Carboniferous ammonoid zonation in the Western United States, and Gordon and others (1957) have established goniatite zones in the Chainman Shale equivalents of western Utah.

Conodonts have been recognized in both argillaceous and carbonate rocks in eastern Nevada and in the generally nonfossiliferous allochthonous eugeosynclinal sequences in central Nevada. They have proved invaluable in regional correlation and classification.

Carboniferous conodont faunas in Nevada have been described by Dunn (1965), Pierce and Langenheim (1974), and Rice and Langenheim (1974). Webster (1969) showed the relation of conodonts to fusuline zones.

Brachiopods are typical of the Carboniferous. A representative collection will contain many of the major taxa, including spiriferids, productids, rhynchonellids, and strophomenids. Brachiopods are almost always the dominant forms of any collection from either Mississippian or Pennsylvanian sedimentary rocks.

Trilobites are poorly represented in the Carboniferous faunas of Nevada. After the abundance of phacopids in the Devonian, trilobites were greatly reduced in numbers; a gradual diminution took place throughout the Mississippian and Pennsylvanian and into the Permian. Carboniferous trilobites from Nevada are members of the less exotic, more conservative stocks, such as the proetids.

Echinodermata are abundant but almost always consist of the ubiquitous columnals. Calices are rarities, except in the cratonic area, where Webster and Lane (1970) have described several genera and species. *Pentremites,* so abundant in the Mississippian of the Mississippian River valley, is essentially unknown in Nevada.

SELECTIVE LIST OF COLLECTING LOCALITIES

The purpose of this list is to enumerate some localities where representative collections might be made by interested persons. In selecting the localities, accessibility has been considered. Thus, localities within the Nevada Test Site are omitted because access to that rather large area of south-central Nevada is restricted. The order of presentation is generally from south to north along the eastern part of Nevada.

Spring Mountains (SW. Clark County).—Spring Mountains, the type locality of the Bird Spring Formation, is northeast of the town of Goodsprings and is best reached over unpaved roads from the Blue Diamond-Arden Highway. A complete sequence of Pennsylvanian fusulinids is available, plus other common invertebrates that have yet to be catalogued in the literature. (Goodsprings 15-minute quadrangle topographic map.)

Arrow Canyon (E. Clark County).—Arrow Canyon has become well known through the field studies of R. L. Langenheim, G. D. Webster, N. G. Lane, and their students. Located on the Arrow Canyon 15-minute quadrangle topographic map, the area has easy access from Las Vegas and contains a superior sequence of fossils from Kinderhookian into the Wolfcampian. Ample papers have described the sites and the fauna in detail (Langenheim and Langenheim, 1965).

Shingle Pass (NW. Lincoln County).—Shingle Pass, a less accessible site in the southern Egan Range between State Route 38 and U.S. Highway 93, is near Sunnyside at Whipple Ranch. Good Pennsylvanian exposures are on the north side of the pass. This site has a good Pennsylvanian fauna (Kellogg, 1963) of fusulines and of generally undescribed larger invertebrates (Shingle Pass 7½-minute topographic map.)

Dutch John Mountain (N. Lincoln County in T. 8 N., R. 65 E., projected).—Dutch John Mountain is one of the best localities for Mississippian faunas, being accessible from U.S. Highway 93, approximately 12 miles (20 km) south of Geyser maintenance station. This site is on the geologic map of Lincoln County (Tschanz and Pampeyan, 1970).

Ward Mountain (central White Pine County).—On the outskirts of Ely, Ward Mountain has a complete Mississippian to mid-Pennsylvanian-Desmoinesian section. Lithologies are typical for eastern Nevada. The Mississippian black shale is poorly fossiliferous, but good collections can be obtained from the Joana Limestone (Mississippian) and Ely Limestone (Pennsylvanian). (Ely 15-minute quadrangle topographic map and White Pine County geologic map (Hose and Blake, 1976).)

Duckwater (NE. Nye County).—Duckwater is mentioned because of the *Cravenoceras* faunule (Chesterian) described by Youngquist (1949). Very accessible black-shale exposures are east of Duckwater. (Duckwater 15-minute quadrangle topographic map.)

Buck Mountain (W. White Pine County).—Buck Mountain has fossils ranging in age from Kinderhookian to Desmoinesian. It is reached by a gravel road leading north from U.S. Highway 50, 3 miles (4.8 km) east of Pancake Summit. (Buck Mountain and Pancake Summit 15-minute quadrangle topographic maps and geologic map of White Pine County (Hose and Blake, 1976).)

Carbon Ridge (W. White Pine County).—Carbon Ridge is one of the better exposures of the Diamond Peak conglomerate and its Chesterian faunule. The preservation is good, although fossils have a tendency to split between shell layers. Accessibility is excellent. Turn south off U.S. Highway 50 onto State Route 20, proceed about 1 mile (1.6 km), then turn right onto the gravel road leading up Secret Canyon. A little more than 2 miles (3.2 km) from the turnoff at the cattle guard are conspicuous hogbacks of chert pebble conglomerate. The fossils are in the softer sedimentary rocks between the conglomerates. (Pinto Summit 15-minute quadrangle topographic map and Nolan and others, 1974.)

Carlin Canyon (SW. Elko County).—Fossil localities in the Carlin Canyon are numerous, both Mississippian and Pennsylvanian Systems being well represented. The structures are somewhat complicated by extensive faulting, so that beds are seldom continuous over any distance. Conglomerates predominate, and one should seek the finer clastic rocks and limestone. The area is adjacent to Interstate 80 and is readily reached via old U.S. Highway 40. Carlin Canyon extended would include Grindstone Mountain. This place is one of the few in northern Nevada that has Missourian and Virgilian faunas. (Carlin and Dixie Flats 15-minute quadrangle topographic maps (Dott, 1955; Smith and Ketner, 1975).)

South Doby Summit (Elko County).—The well-known locality at South Doby Summit is 7 miles (11.2 km) north of Elko on State Route 51. On the right side of the road is a black-shale borrow pit containing a very good Chesterian faunule. The shale is soft and the fossils are silver hued, producing showy specimens. However, the specimens are as fragile as the shale, and care must be taken to prevent a high attrition rate. (Elko West 7.5-minute quadrangle topographic map and Smith and Ketner, 1975.)

Pequop Mountains (central Elko County).—Twenty-two miles (35 km) east of Wells, Interstate 80 crosses the Pequop Mountains. At the summit are excellent Mississippian and Pennsylvanian faunules. The literature contains no report of the presence of the middle Mississippian, but Kinderhookian and Chesterian fossils and a complete Pennsylvanian section have been reported. (Pequop Summit 7.5-minute quadrangle topographic map and Thorman, 1970.)

Ferguson Springs (E. Elko County).—Some 14 miles (22.4 km) south of Wendover on U.S. Highway 50 Alternate is a highway maintenance station. To the west, on the east flank of the Goshute Mountains, are Pennsylvanian and Permian limestones. The Pennsylvanian is complete here. Access is easy and the excellent fauna includes fusulinids, brachiopods, bryozoans, rugose and tabulate corals, and mollusks. (Ferguson Mountain 7.5-minute quadrangle topographic map.)

NOTABLE FOSSIL TAXA

Like every other region, Nevada has unusual finds from Carboniferous sedimentary rocks. Any listing of such a group is inescapably arbitrary and subjectively incomplete.

Dimegalasma eurekensis.—Dimegalasma eurekensis, from the Chesterian Diamond Peak Formation and equivalents, is possibly the largest spiriferid known. G. A. Cooper, upon receipt of the holotype at the U.S. National Museum, said that it was the second largest brachiopod he had seen (Lintz and Lohr, 1958).

Komia eganensis.—Komia was originally described by Korde (1951) as an alga. Wilson and others (1963), on the basis of their work describing *Komia eganensis,* using specimens from Nevada, concluded that the genus *Komia* should be assigned to the Stromatoporoidea. *Komia eganensis* is known from Arrow Canyon, Sunnyside, Ward Mountain, and Moorman Ranch, occurring in association with *Fusulinella acuminata* about 50 m above the *Profusulinella/Chaetetes* marker horizon (Wilson and others, 1963).

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2001

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.)

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M. Iowa, by Matthew J. Avcin and Donald L. Koch
N. Missouri, by Thomas L. Thompson
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P. Nebraska, by R. R. Burchett
Q. Kansas, by William J. Ebanks, Jr., Lawrence L. Brady, Philip H. Heckel, Howard G. O'Connor, George A. Sanderson, Ronald R. West, and Frank W. Wilson
R. Oklahoma, by Robert O. Fay, S. A. Friedman, Kenneth S. Johnson, John F. Roberts, William D. Rose, and Patrick K. Sutherland
S. Texas, by R. S. Kier, L. F. Brown, Jr., and E. F. McBride
T. South Dakota, by Robert A. Schoon
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V. Colorado, by John Chronic
W. New Mexico, by Augustus K. Armstrong, Frank E. Kottlowski, Wendell J. Stewart, Bernard L. Mamet, Elmer H. Baltz, Jr., W. Terry Siemers, and Sam Thompson III
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DD. Alaska, by J. Thomas Dutro, Jr.

GEOLOGICAL SURVEY PROFESSIONAL PAPER 1110-M-DD

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1979

UNITED STATES DEPARTMENT OF THE INTERIOR

CECIL D. ANDRUS, *Secretary*

GEOLOGICAL SURVEY

H. William Menard, *Director*

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402

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

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

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