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Summary of Paleozoic stratigraphy and history of western Colorado and eastern Utah

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1981, pp. 81-87. https://doi.org/10.56577/FFC-32.81

in:

Western Slope (Western Colorado), Epis, R. C.; Callender, J. F.; [eds.], New Mexico Geological Society 32 nd Annual Fall Field Conference Guidebook, 337 p. https://doi.org/10.56577/FFC-32

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SUMMARY OF PALEOZOIC STRATIGRAPHY AND HISTORY OF WESTERN COLORADO AND EASTERN UTAH

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INTRODUCTION

The area covered by this report extends from about Moab and Blanding, Utah on the west to Glenwood Springs and Gunnison, Colorado on the east (fig. 1). The Paleozoic Systems in this area are characterized by two different tectonic styles of sedimentation. The lower Paleozoic, Cambrian through Mississippian, consists of thin, stable shelf deposits that are commonly separated by major unconformities. The upper Paleozoic, Pennsylvanian and Permian, consist of thick basin deposits, a result of active tectonism.

The major structural elements of the region are shown on Figure 2. These structural elements are largely the product of Laramide deformation; however, the Paradox basin is a Paleozoic feature, and the Uinta and Uncompahgre Uplifts have influenced sedimentation throughout various parts of the Paleozoic (Baars, 1966; Baars and See, 1968; Lochman-Balk, 1972; Spoelhof, 1976; Weimer, 1980).

The stratigraphic terminology (fig. 3a, b) is from the San Juan Mountains for the area west of the Uncompahgre Uplift and from the White River Uplift for the area east of the Uncompahgre. East of the area discussed in this report in central Colorado, the stratigraphic sequence and terminology is somewhat different (Ross and Tweto, 1980; and DeVoto, 1980, a, b).

CAMBRIAN SYSTEM

The oldest Paleozoic rocks are in the subsurface along the western edge of the area. These are largely clastic rocks, medium to coarse quartz sandstones and some conglomerate, of probable Middle Cambrian age. To the east, the oldest Paleozoic rocks are of the same general lithology but are Late Cambrian, Dresbachian, age (Lochman-Balk, 1972). In the San Juan Mountains, these rocks are called the Ignacio Quartzite (fig. 3a) and in the White River

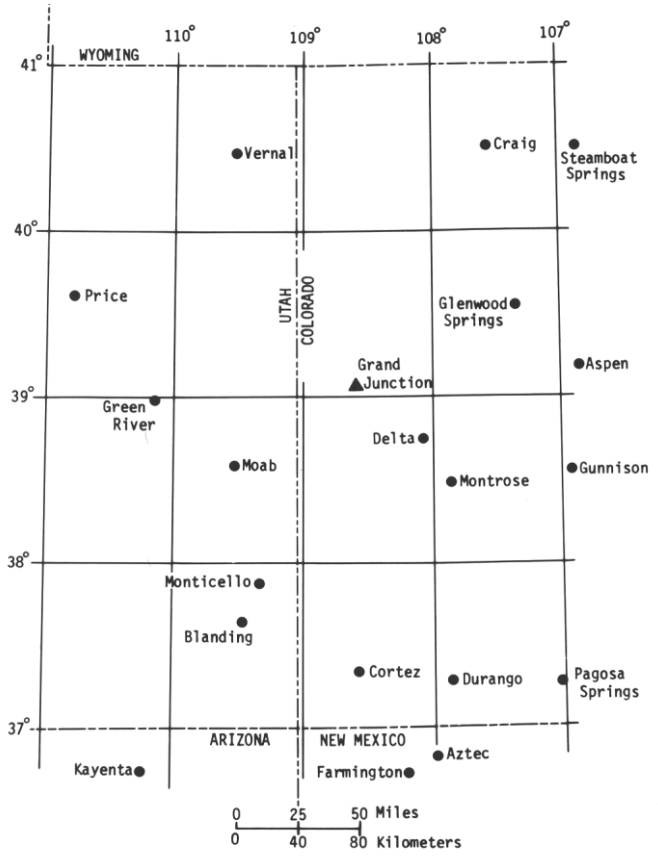


Figure 1. Index map, western Colorado and eastern Utah, showing area covered by this report.

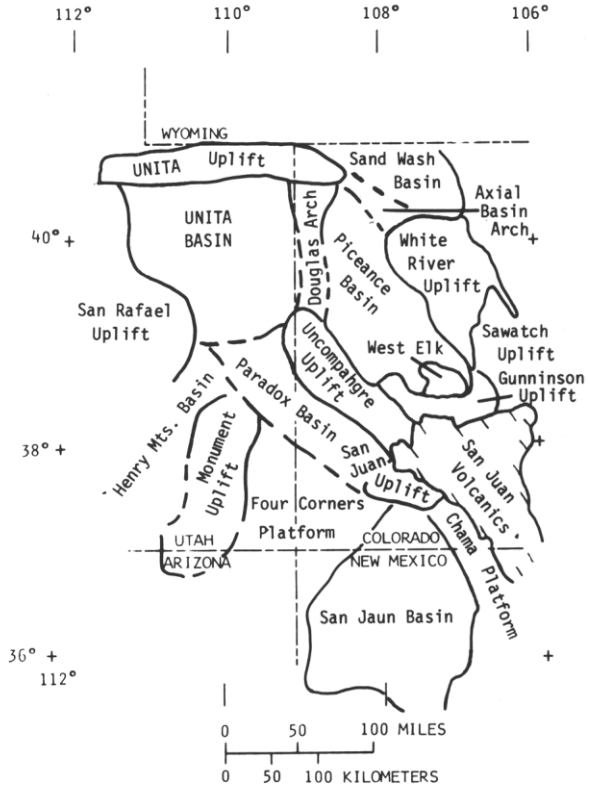


Figure 2. Major structural elements in western Colorado and eastern Utah (modified from Grose, 1972).

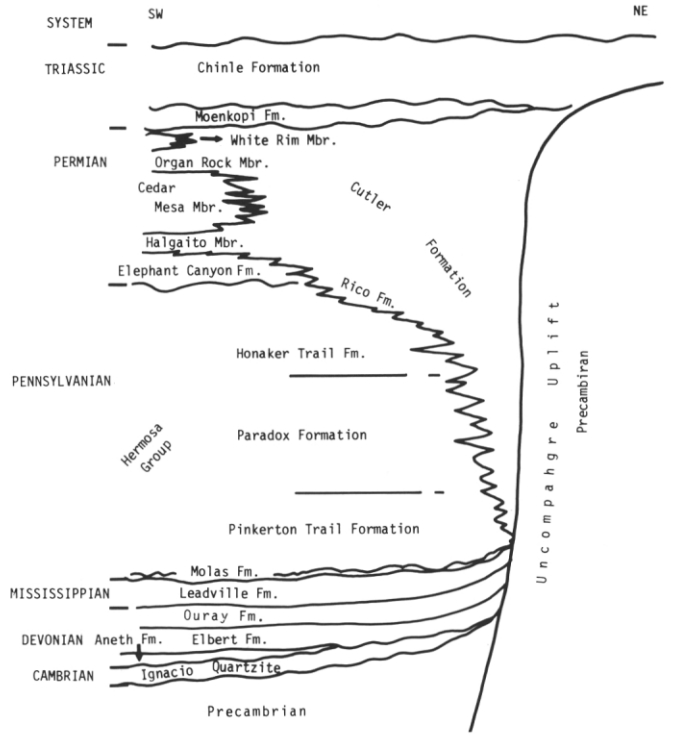


Figure 3a. Schematic stratigraphic section showing Paleozoic formations for the Four Corners area. No scale; thickness exaggerated for thinner units.

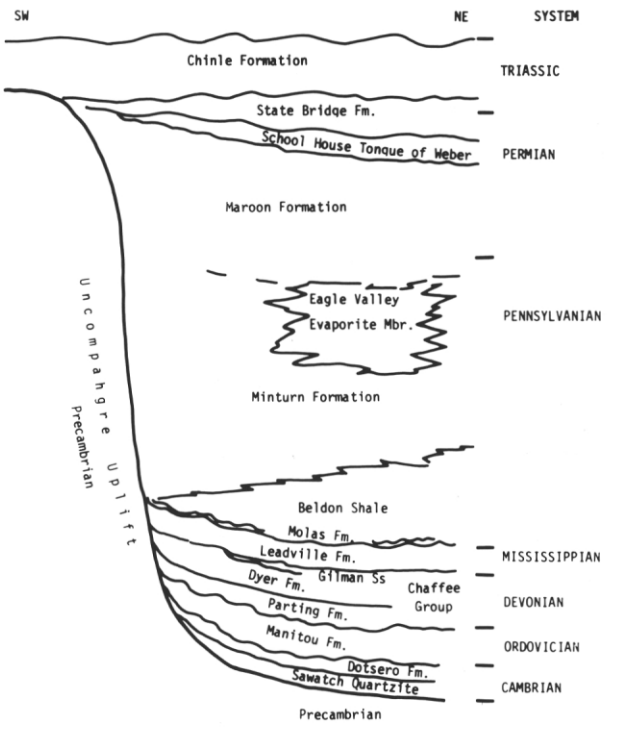


Figure 3b. Schematic stratigraphic section showing Paleozoic formations for the White River Uplift area. No scale; thickness exaggerated for thinner units.

Uplift and across the rest of Colorado, the Sawatch Quartzite (fig 3b). These rocks are probably in part Franconian age (Lochman Balk, 1972).

Late Cambrian, Trempealeauan, age rocks have been removec by erosion from most of western Colorado and eastern Utah ex cept in the area of the White River Uplift (fig. 2). Here, the latest stage of the Cambrian is represented by the Dotsero Formatior (Bass and Northrop, 1963). The Dotsero is composed of dolomite! and dolomitic limestone with abundant flat-pebble conglomerate, and an upper algal limestone member, all of intertidal and supra tidal origin (Tyler and Campbell, 1975; Tyler, 1976; Campbell, 1976).

The deposition of this sequence is a product of a slow, west tc east transgression of the Cambrian sea across low-lying, weath. ered Precambrian terrain. At the time of maximum transgression, the shoreline was to the east near the present Gore Range (Twetc and Lovering, 1977; Tweto, 1977). A series of low islands probably persisted to the north along the Colorado-Wyoming border (Loch. man-Balk, 1972; Bickford, 1974; Campbell and Bickford, 1976; along the axis of the Uinta peninsula (Lochman-Balk, 1972). Durin the maximum advance of the sea, the supply of detritus was cur tailed and a vast tidal flat existed across this area in which car. bonate sedimentation dominated (Campbell, 1972a; Tyler anc Campbell, 1975). A minor regression occurred at the end of Trem. pealeauan (Lochman-Balk, 1972; Campbell, 1976) to close Cam. Brian history in this area. The present thickness and extent of the Cambrian System are shown in Figure 4.

ORDOVICIAN SYSTEM

Figure 5 shows the present thickness and distribution of the Or dovician System in eastern Utah and western Colorado. Ordovi. clan rocks are not present in most of this area largely because 01

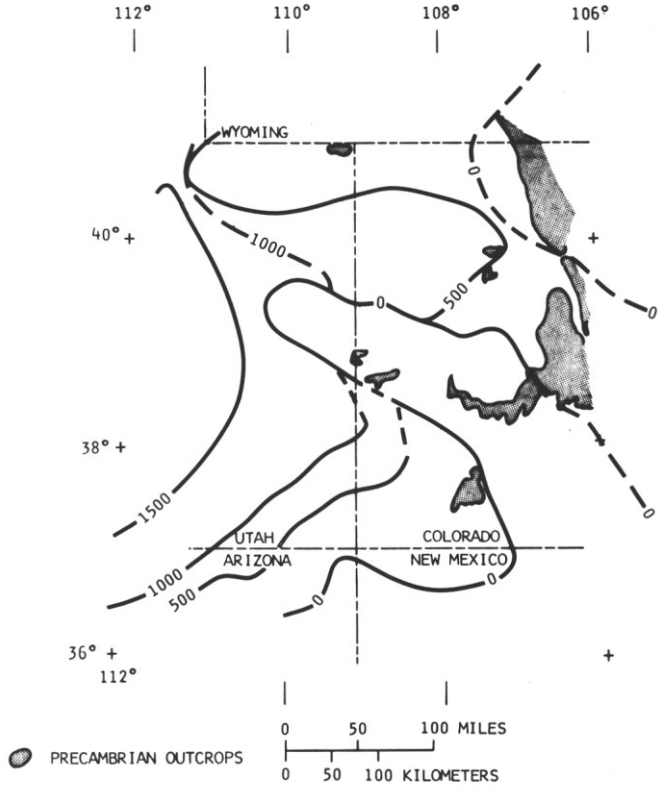


Figure 4. Isopach map of Cambrian System (modified from Lochman-Balk, 1972). Contour interval 500 ft (152 m).

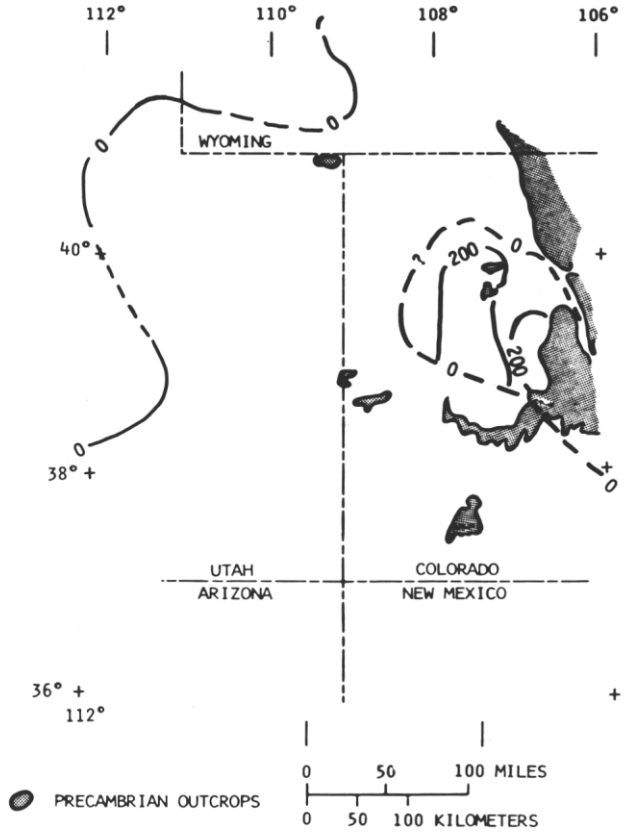


Figure 5. Isopach map of Ordovician System (modified from Foster, 1972). Contour interval 200 ft (61 m).

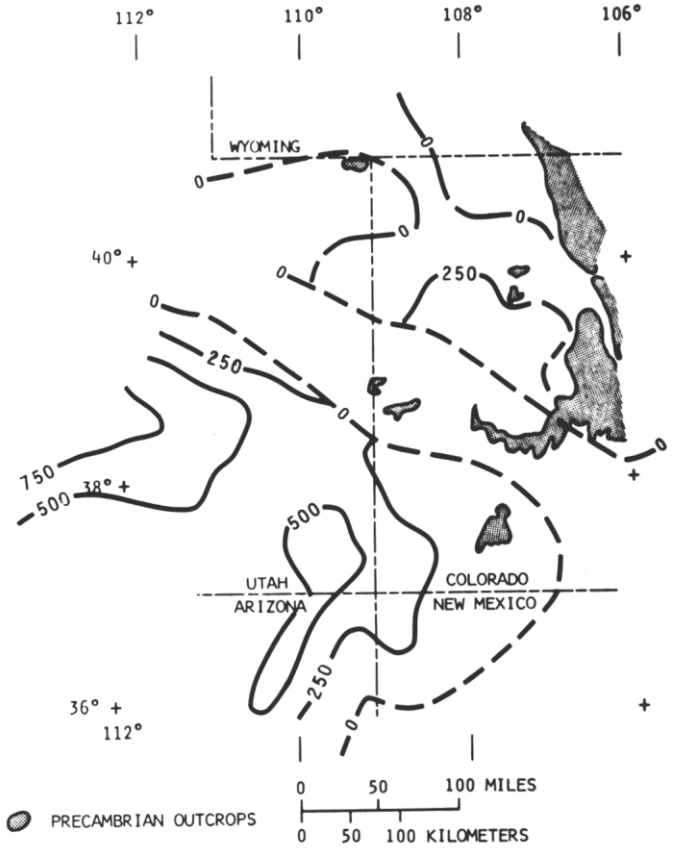


Figure 6. Isopach map of Devonian System (modified from Baars, 1972). Contour interval 250 ft (76 m).

several periods of pre-Devonian erosion. The lower Ordovician Manitou Formation is present in the White River Uplift area (Bass and Northrop, 1963), and Lower, Middle and Upper Ordovician rocks are present just east of the area of this report (Ross and Tweto, 1980).

The Manitou Formation is composed of dolomite and dolomitic limestone with abundant flat-pebble conglomerate very similar to the lithologies in the Dotsero Formation. The thickness of the Manitou varies considerabley in the White River uplift area due to pre-Devonian erosion. Fossils found by Bass and Northrop (1953) in the lower part of the Manitou indicate equivalence to zone B of the Canadian Series (Ross, 1951).

The fragmentary Ordovician record in Colorado indicates three periods of marine sedimentation separated by three periods of erosion. Only the earliest marine sequence is present in the White River Uplift area, and the nature of the carbonate sediments of the Manitou suggests intertidal and supratidal carbonate mud flats as the predominate environment (Campbell, 1972).

SILURIAN SYSTEM

The unconformity at the base of the Devonian represents about 100 million years, including all of Middle and Late Ordovician and Silurian and Early and Middle Devonian time. Rocks of Silurian age, as well as the other systems, could have been deposited and later removed by erosion. Although no Silurian rocks are known in this area, blocks of limestone that contain Middle and Upper Silurian brachiopods have been found in diatremes along the Colorado-Wyoming border south of Laramie, Wyoming (Chronic and others, 1969). No Silurian rocks are known within 480 km of these diatremes.

DEVONIAN SYSTEM

The oldest Devonian rocks in eastern Utah and westen Colorado are Upper Devonian, representing most of the Frasnian and Famennian Stages (Baars, 1971). Their present distribution and thickness across the area are shown in Figure 6.

The oldest Devonian stratigraphic unit southwest of the Uncompahgre Uplift is the Aneth Formation (fig. 3a). The Aneth is a dark colored, dense, argillaceous dolomite sequence that is present only in the subsurface in the Four Corners area (Baars, 1972). Conformably overlying the Aneth in the subsurface, and disconformably overlying the Cambrian Ignacio in exposures in the San Juan Mountains, are the sandstones, shales, and sandy dolomites of the Elbert Formation. The basal sandstone of the Elbert Formation is the McCracken Member. This sandstone is considered to be a product of a marine transgression with the source for the sand from local paleotectonic high areas (Baars and Campbell, 1968). Salt casts and stromatolitic dolomite suggest that much of the Elbert was deposited in an intertidal environment.

The oldest Devonian stratigraphic unit in the White River Uplift area consists of the sandstones, shales and thin stromatolitic dolomites of the Parting Formation, which is the basal formation of the Chaffee Group (Campbell, 1970a). Like the Elbert, the Parting consists of a basal sandstone unit, informally designated as Unit A, that is a product of marine transgression (Campbell, 1970a). Shallow marine to intertidal depositional environments are represented by the lithologies in the Parting (Campbell, 1967, 1970a, 1972b). The Aneth, Elbert and Parting Formations are of Frasnian age (Baars, 1972).

Conformably overlying the Elbert Formation in southwestern

Colorado is the Ouray Formation, and conformably overlying the Parting Formation in the White River Uplift area is the Dyer Formation (figs. 3a, b). Both the Ouray and Dyer are considered Famennian in age (Baars, 1972) with the upper part of Early Mississippian age (Baars, 1966; Baars and Campbell, 1968). The Ouray Formation is lime mudstone, pelletal lime mudstone and skeletal limestone that is locally dolomitized, and which formed in a quiet-water marine environment (Baars, 1966). The Dyer Formation consists of two carbonate members. The lower shallow marine fossilferous limestone is the Broken Rib Member and the upper intertidal to supratidal stromatolitic dolomite is the Coffee Pot Member (Campbell, 1970a, b). The Dyer Formation represents a regression of the Late Devonian-Early Mississippian sea from the White River Uplift area (Campbell, 1970a, b).

Unconformably above the Dyer Formation on the White River Uplift is a sandy dolomite that grades into a sandstone farther east, and which is unconformably overlain by the Leadville Formation. This is the Gilman Sandstone which Tweto and Lovering (1977) reassigned from the Leadville Limestone to the Chaffee Group because it is more closely related to the Dyer in composition and origin. The Chaffee Group thus consists of the Parting and Dyer Formations with the Gilman Sandstone at the top.

The depositional history of the Devonian consists of an initial west to east marine transgression over a highly weathered and eroded older Paleozoic terrain. Sources for sediment included local highs and the Front Range area to the east. With maximum transgression, sediment sources were covered or very low, and carbonate deposition prevailed. A minor regression occurred in the White River Uplift area with an influx of some sand which formed the Gilman Sandstone. At about this time, the diatremes in northern Colorado were formed (Naeser and McCallum, 1977).

MISSISSIPPIAN SYSTEM

The present distribution and thickness of rocks of Mississippian age are shown in Figure 7. These rocks, the Leadville Formation, are Early Mississippian in age, Kinderhookian and Osagean (Baars, 1966; DeVoto, 1980a). The Late Mississippian was a time of exposure, weathering and erosion of Lower Mississippian rocks across the area.

The Leadville Formation in southwestern Colorado consists of two informal members separated by an unconformity (Baars, 1966). The lower Kinderhookian-age member consists of stromatolitic dolomites, lime mudstones, and pelletal lime mudstones that are more fossiliferous to the west, and locally includes crinoidal biogenic banks adjacent to the Uncompahgre Uplift (Baars, 1966). It rests conformably on the Ouray Formation except in the vicinity of paleo-structures where local unconformities are present (Armstrong and Mamet, 1976). This member was deposited in intertidal to subtidal environments that persisted and expanded from Ouray time. Locally, over paleotectonic highs, the lower member thins or has been removed by pre-Osagean erosion (Baars, 1966; Armstrong and Mamet, 1976).

The upper member of Osagean age unconformably overlies the lower member, and consists of fossiliferous pelletal and oolitic limestone, and lime and dolomitic mudstone, with scattered crinoidal debris. As in the lower member, the carbonate facies changes on the flanks of the paleotectonic highs in the area (Baars, 1966).

Late Mississippian and Early Pennsylvanian time in this area was one of extensive weathering and erosion. Humid-climate solution erosion across the exposed Leadville Formation produced an extensive karst topography (DeVoto, 1980a). A residual *terra* rosa developed on the karst surface (Merrill and Winar, 1958). This

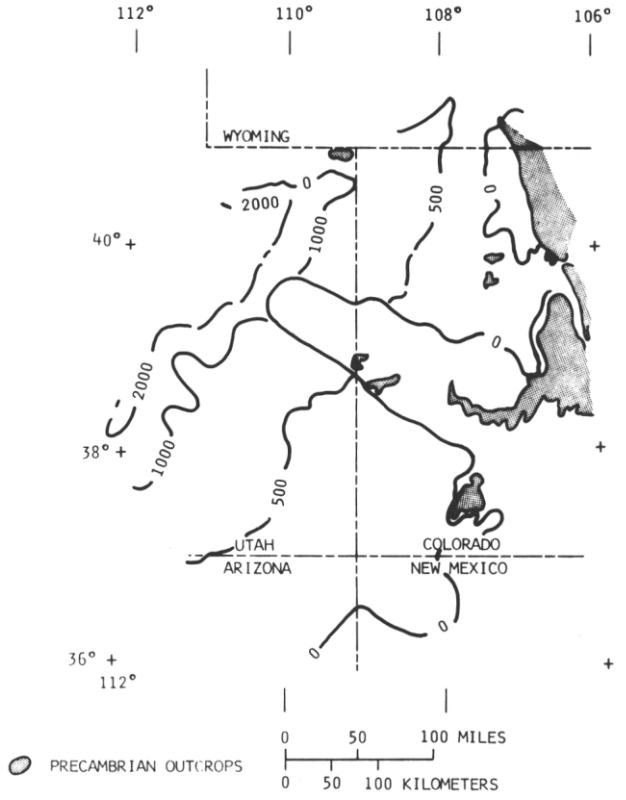


Figure 7. Isopach map of Mississippian System (modified from Craig, 1972). Contour interval 500 to 1000 ft (152 to 305 m).

regolith is the Molas Formation which is dated in part as Early Pennsylvanian (Merrill and Winar, 1958) but must have begun to form during Late Mississippian time.

A similar but simpler Mississippian sequence is present in the White River Uplift area. The lower part of the Leadville Formation, probably Kinderhookian in age (Conley, 1972; DeVoto, 1980a), consists of thin-bedded stromatolitic dolomite that is of intratidal to supratidal origin (Conley, 1972). The upper unit is Osagean in age (Conley, 1972; DeVoto, 1980a), and consists of oolitic limestone to the east and fossiliferous limestone to the west with increasing amounts of lime mudstone to the west (Conley, 1972). This sequence represents a single easterly transgressive sequence (Conley, 1972), in contrast to the two transgressive sequences separated by a period of erosion noted in southwestern Colorado. Solution weathering, erosion and the formation of a regolith over a karst surface developed over this area during Late Mississippian and Early Pennsylvanian time. This paleosoil also is called the Molas Formation (Bass and Northrop, 1963).

In the subsurface of the far western and northwestern part of the area covered by this report, a thicker and more complete sequence of Mississippian rocks is present. For a complete and detailed report on these rocks, see Craig (1972) and Craig and others (1979).

PENNSYLVANIAN SYSTEM

Mountain building, and the development of flanking basins that received almost 4000 m of fluvial and marine sediment, are the characteristics of the Pennsylvanian Period in western Colorado and eastern Utah (fig. 8). The Uncompahgre Uplift was activated

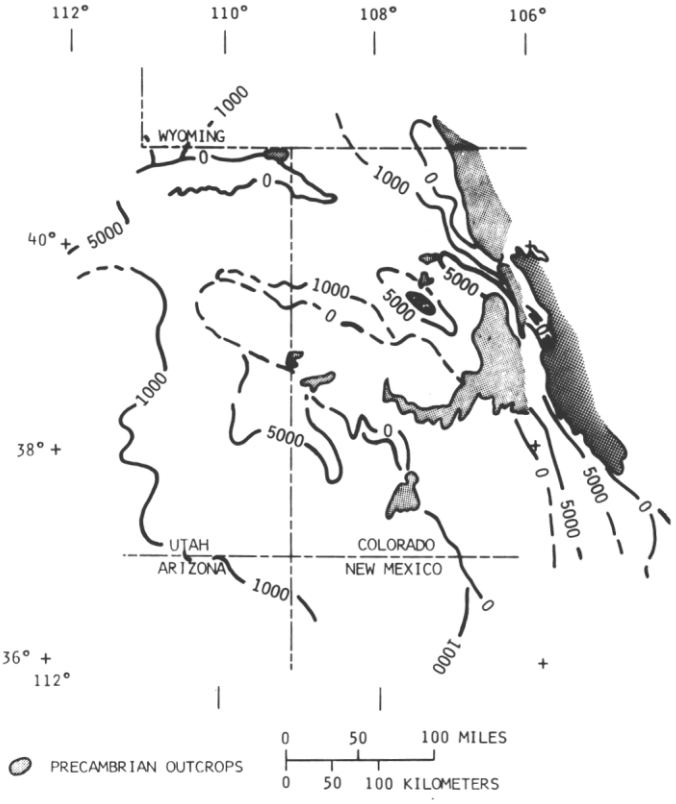


Figure 8. Isopach map of Pennsylvanian System. Central Colorado Trough is northeast of the Uncompahgre Uplift (modified from Mallory, 1972). Contour interval 1000 to 4000 ft (305 to 1219 m).

into a prominent mountain system, the Paradox Basin developed to the south and west, and the Central Colorado Trough developed to the north and east (figs. 2, 8). A number of excellent detailed reports are available on the tectonics and deposition in both of these basins including McKee and others (1967), Mallory (1972), McKee and others (1975), and DeVoto (1980b). A short summary of events is presented here.

Continued emergence and karst development characterized the early Pennsylvanian, most of Morrowan time, throughout the region (DeVoto, 1980b). Marine deposition commenced in Morrowan time in the Central Colorado Trough with the deposition of the black shales of the Beldon Shale (fig. 3b). This deposition continued into Atokan time, but coarse arkose became interbedded with the black shales in the upper part of the Beldon Shale as the Uncompahgre Uplift was slowly activated.

In southwestern Colorado, the Molas Formation continued to form during early Atokan time. However, the Atokan sea advanced across the weathered terrain reworking the upper Molas (Merrill and VVinar, 1958). Thus the Atokan strata include the upper Molas, and dark colored shales and limestone and dolomite of the Pinkerston Trail Formation of the Hermosa Group, which were deposited in the Paradox Basin as a product of this marine invasion.

In southwestern Colorado, the Paradox Basin contains a thick sequence of evaporites and black shales that formed during Desmoinesian time. Along the flanks of the Uncompahgre Uplift, thick sequences of arkose of the lower part of the Cutler Formation (fig. 3a) were deposited in response to tectonic activity (Wengerd, 1962; Mallory, 1972; Hite and Cater, 1972).

Desmoinesian strata in the Central Colorado Trough consist of thick arkoses of the Minturn Formation, deposited along the flanks of the Uncompahgre as well as the flanks of the Front Range Uplift to the east (fig. 3b). In the middle of the trough, in the White River Uplift area, a marine seaway persisted in which evaporites were deposited along with black shale and a few thin limestones. These deposits are called the Eagle Valley Evaporite Member of the Minturn Formation (Murray, 1958). This evaporite deposition occurred at about the same time as that in the Paradox Basin but the two basins were not connected (Mallory, 1972).

Evaporitic deposition ceased and normal marine deposition of limestones, with minor shale and sandstone, returned to the Paradox Basin in Late Desmoinesian time and continued through Missourian into Virgilian time (Mallory, 1972). Coarse fluvial arkose of the Cutler Formation continued to accumulate along the flanks of the Uncompahgre Uplift. These arkose sediments were deposited farther to the west late in Pennsylvanian and into early Permian time (fig. 3a). The transition between marine and fluvial sediments has been mapped by some geologists as the Rico Formation.

In the Central Colorado Trough, fluvial deposition dominated as the sea withdrew and the Maroon formation was deposited over the Eagle Valley Evaporite Member (fig. 3b). The lower part of the Maroon is considered to be Missourian and Virgilian in age; however, deposition of the Maroon continued into the Permian.

PERMIAN SYSTEM

The depositional patterns that were established in the Late Pennsylvanian in eastern Utah and western Colorado continued into the Early Permian. Although the depositional patterns are similar, an unconformity is present between the Pennsylvanian and Permian Systems in the Paradox Basin (Baars, 1962). Deposition close to the Uncompahgre Uplift and in the Central Colorado Trough was probably continuous, however. The fluvial sediments of Wolfcampian age in the trough are the upper part of the Maroon Formation (fig. 3b). Overlying the Maroon in the White River Uplift area is the School House Sandstone which is a tongue of the Weber Sandstone (Brill, 1952). Fryberger (1979) considers the Weber Sandstone in northwestern Colorado to be of eolian origin. The Weber thickens to the northwest, intertongues with and grades eastward into the Maroon, and represents Late Pennsylvanian, (Missourian and Virgilian) as well as Early Permian (Wolfcampian) time in northwestern Colorado and northeastern Utah (Rascoe and Baars, 1972).

The final Paleozoic deposition in the Central Colorado trough occurred during Guadalupian time. Shales, siltstones, fine grained sandstones and a thin dolomite unit comprise the State Bridge Formation which unconformably overlies the Maroon Formation. Most of Leonardian time is represented by the erosional unconformity between the Maroon and the State Bridge. The thin dolomite unit is the South Canyon Creek Member (Bass and Northrup, 1962) which probably correlates with the Park City Formation of southwestern Wyoming (Rascoe and Baars, 1972). The deposition of the State Bridge Formation was evidently in a shallow marine to intertidal environment representing a marine invasion of the trough from the north. An eolian sandstone is present at the base of the State Bridge in the White River Uplift area (Freeman, 1971), indicating initial continental deposition. Paleozoic history closes in the Central Colorado trough with erosion of part of the State Bridge Formation before Triassic deposition.

Southwest of the Uncompahgre Uplift, deposition of the fluvial Cutler Formation continued into Wolfcampian time. This deposition consisted of three large fluvial, or wet alluvial, fans (Campbell, 1979, 1980). In the southeastern and central part of the Paradox

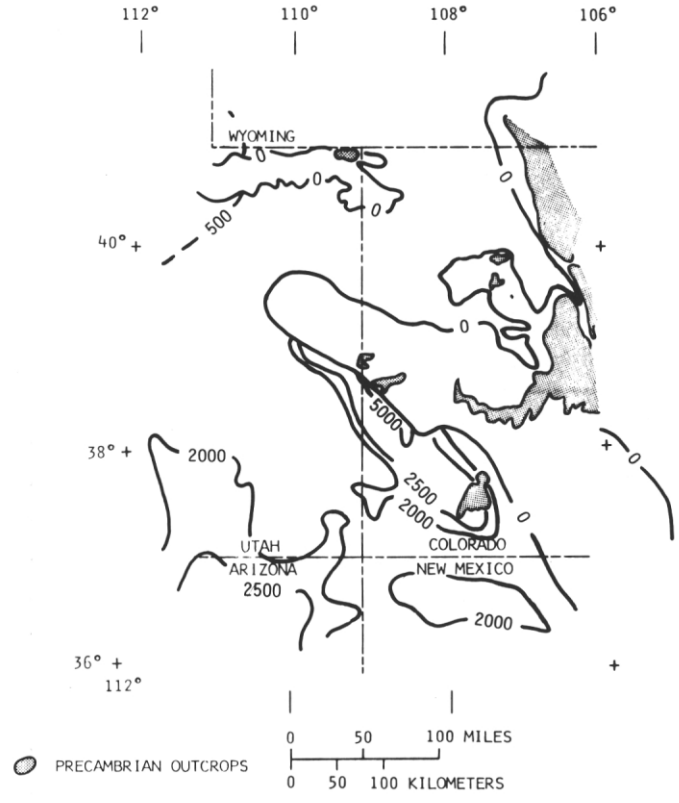


Figure 9. Isopach map of Permian System (modified from Rascoe and Baars, 1972). Contour interval 500 to 2500 ft (152 to 762 m).

Basin this fluvial deposition persisted, filling the basin. In the northwest during Early Wolfcampian, a sea was present to the west in which limestones, shales and sandstones of the Elephant Canyon Formation (Baars, 1962) were deposited. Rocks that were deposited along the distal margins of the northern fan are interbedded with the marine deposits (Campbell, 1979, 1980). Later in Wolfcampian time, a second sea was present in the northwestern part of the basin. Sandstones, shales and a few thin limestones of the Cedar Mesa Member of the Cutler Formation were deposited in shallow marine, marginal marine and eolian environments (Mack, 1977; Campbell, 1979, 1980). Once again, marine rocks are interbedded with distal fluvial sediments that were deposited along the margins of a large fluvial fan (Campbell, 1980). Red fluvial shales and sandstones that are present to the west between the Elephant Canyon Formation and the Cedar Mesa Member are the Halgaito Shale member of the Cutler, and fluvial red shales and sandstones that overlie the Cedar Mesa Member are the Organ Rock Shale Member of the Cutler Formation (fig. 3a). Final marine, and coastal dune deposition, probably in Leonardian time, along the western margin of the basin, produced the White Rim Sandstone Member of the Cutler Formation (Baars and Seager, 1970; Steele-Mallory, 1981). The basin was exposed to erosion during the remainder of Permian time and Paleozoic history for the Paradox Basin closes with an erosional unconformity. Present thickness and distribution of the Permian System are shown in Figure 9.

By the end of the Paleozoic, the Uncompahgre Uplift had been eroded, the basins filled, and the relief between the structural elements greatly reduced. Early Triassic erosion and deposition completed the leveling such that the fluvial Upper Triassic Chinle Formation was deposited across the area (MacLachlan, 1972).

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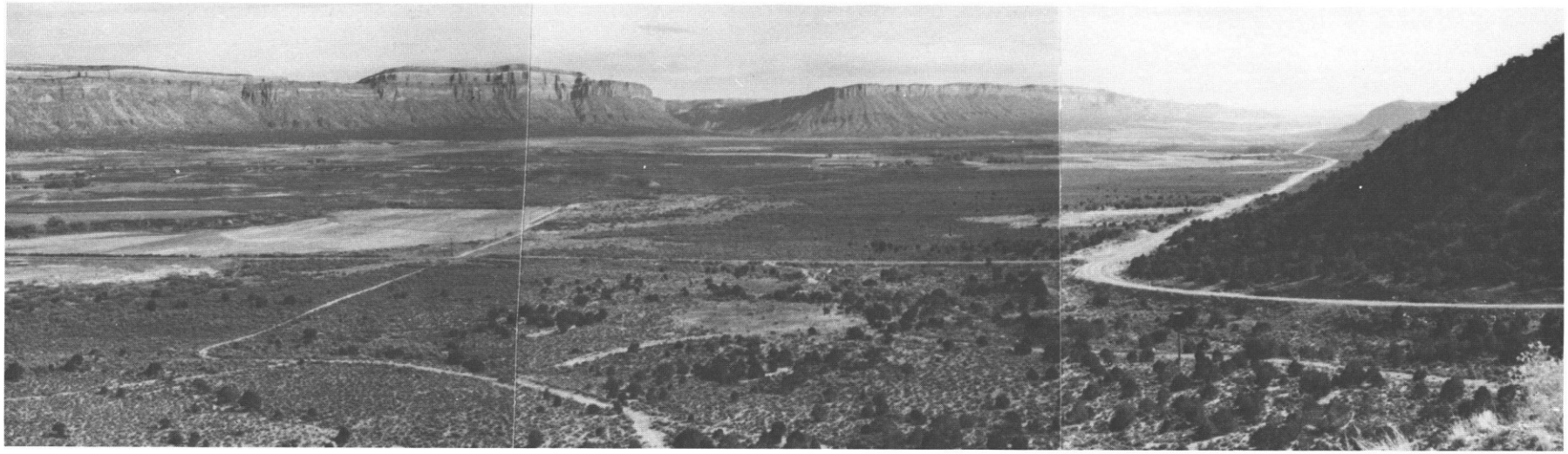
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Panorama of north end of Paradox Valley (C. M. Molenaar photo).



Panorama along and across Paradox Valley (C. M. Molenaar photo).