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PENNSYLVANIAN PALEOGEOGRAPHY OF ARIZONA

by KAY HAVENOR[1] and WILLARD D. PYE[2]

INTRODUCTION

The "Frame-work" project now underway at the University of Arizona is designed to systematically develop the basic information concerning each period within Arizona and the adjacent regions. The stratigraphy, lithology, paleogeologic and paleogeographic relationships and economic possibilities for each series of rocks are being developed. This basic information is being supplemented by detailed lithologic, paleontologic, insoluble residue, sedimentary analysis, stratigraphic analysis, porosity and permeability studies, and similar investigations of individual formations, parts of formations or localized areas of the regions.

For the purposes of the discussion, Arizona can be divided roughly into four general geological regions which correspond to four geographical areas. These regions are:

(1) Northwestern Arizona which is dominated by the Cordilleran geosyncline and the adjacent shelf area of Arizona and is characterized by marine and interfingering marine and red bed sections.

(2) Northeastern Arizona which is dominated by the Arizona shelf area and by the Paradox basin and adjacent uplifts, most important of which are the Defiance and Uncompahgre, and which is characterized by marine, evaporite, tidal, wind and interfingering shallow marine and red bed deposits.

(3) Southeastern Arizona which is dominated by marine deposits associated with seas from the south.

(4) Southwestern Arizona which is characterized by a general lack of Pennsylvanian sediments and a lack of geological information.

PRE-PENNSYLVANIAN

The Arizona region was broadly uplifted at the end of Middle (?) Mississippian time. This resulted in almost a complete retreat of the seas which covered the State. However, there is no evidence of extensive tectonic activity and presumably the region was of low relief and of not great elevation. On this low-lying land, mainly underlain by Mississippian limestones, a karst topography developed and a fairly deep soil cover formed. This flat lying land controlled the advance of the mid-Pennsylvanian seas.

Two small areas of southeastern Arizona remained down-warped and marine conditions persisted into the Late Mississippian time. Any draining of the area was for a limited duration and Early Pennsylvanian seas reoccupied the basins.

Much the same condition existed in northwestern Arizona and southern Nevada where seas persisted in the area until Late Mississippian time. Following a brief retreat into the Cordilleran geosyncline, the seas again began to spread out upon the Arizona shelf in Early Pennsylvanian time.

PENNSYLVANIAN

At the beginning of Pennsylvanian time Arizona was essentially a stable platform probably with little relief and not elevated much above sea level. Except in southeastern Arizona and southern Nevada, where Early (?) Pennsylvanian beds were deposited on Late Mississippian limestones in nearly conformable relationships, the rest of the area shows Middle Mississippian limestones disconformably overlain by Pennsylvanian rocks of Desmoinesian age. The contact of the Pennsylvanian section with the overlying Permian beds is everywhere conformable. Frequently the contact is gradational and often occurs within lithologically similar beds.

The one characteristic feature throughout Pennsylvanian times was the positive Defiance-Zuni uplift. At no time was this an area of great relief or elevation. It furnished little detrital sediment, but acted as a barrier to Pensylvanian seas and as a land mass against and around which various sedimentary facies developed.

Northwestern Arizona

In northwestern Arizona and southern Nevada the Pennsylvanian section is represented by the Pennsylvanian and Permo-Pennsylvanian Callville limestone, the Bird Spring limestone, and the Supai formation, which disconformably overlie Early to Late Mississippian limestones (fig. 1).

Morrowan fossils have been found in the western part of this area. As time progressed, the Pennsylvanian seas spread eastward and southeastward from the Cordilleran geosyncline so that by late Virgil time the seas had transgressed southward to at least the Peach Springs and Chino Valley region. There, limestones of Callville lithology interfinger with red beds of Supai lithology. A similar interfingering of limestones and red beds has been reported from several wells east of the Peach Springs and Chino Valley areas.

The Supai formation in the Chino Valley area is Permo-Pennsylvanian in age with the lower or "C" unit being of Pennsylvanian age and the upper two units Permian in age. In the Goodsprings area the base of the Supai formation is considerably younger than to the east, and indicates the westward migration of the Supai depositional environment during Late Pennsylvanian and Early Permian time.

The interfingering of the Callville limestone and the Supai formation, the absence of marine limestones to the east and southeast and the thick accumulations of marine limestones to the west suggests that northwestern Arizona was a relatively stable platform in close proximity to the Cordilleran geosyncline. The platform was undergoing repeated inundations by very shallow Virgilian seas and there was a close balance between marine limestone and red bed environments.

Northeastern Arizona

In northeastern Arizona and northward through the Paradox basin, the Pennsylvanian rocks are represented by the Molas, Pinkerton Trail, Paradox, Hermosa, Rico, and under some definitions, part of the Cutler formations.

The oldest rocks are the Molas. This formation may be considered the result of a reworked limestone regolith by Morrowan and Lampasan seas. The regolith was developed during the later portion of the Mississippian and early part of the Pennsylvanian periods, on top of the extensively exposed Mississippian limestones.

The oldest Pennsylvanian fossils found in the Molas formation are from northwestern New Mexico and indicate a Morrowan age. The general thickening trend of the

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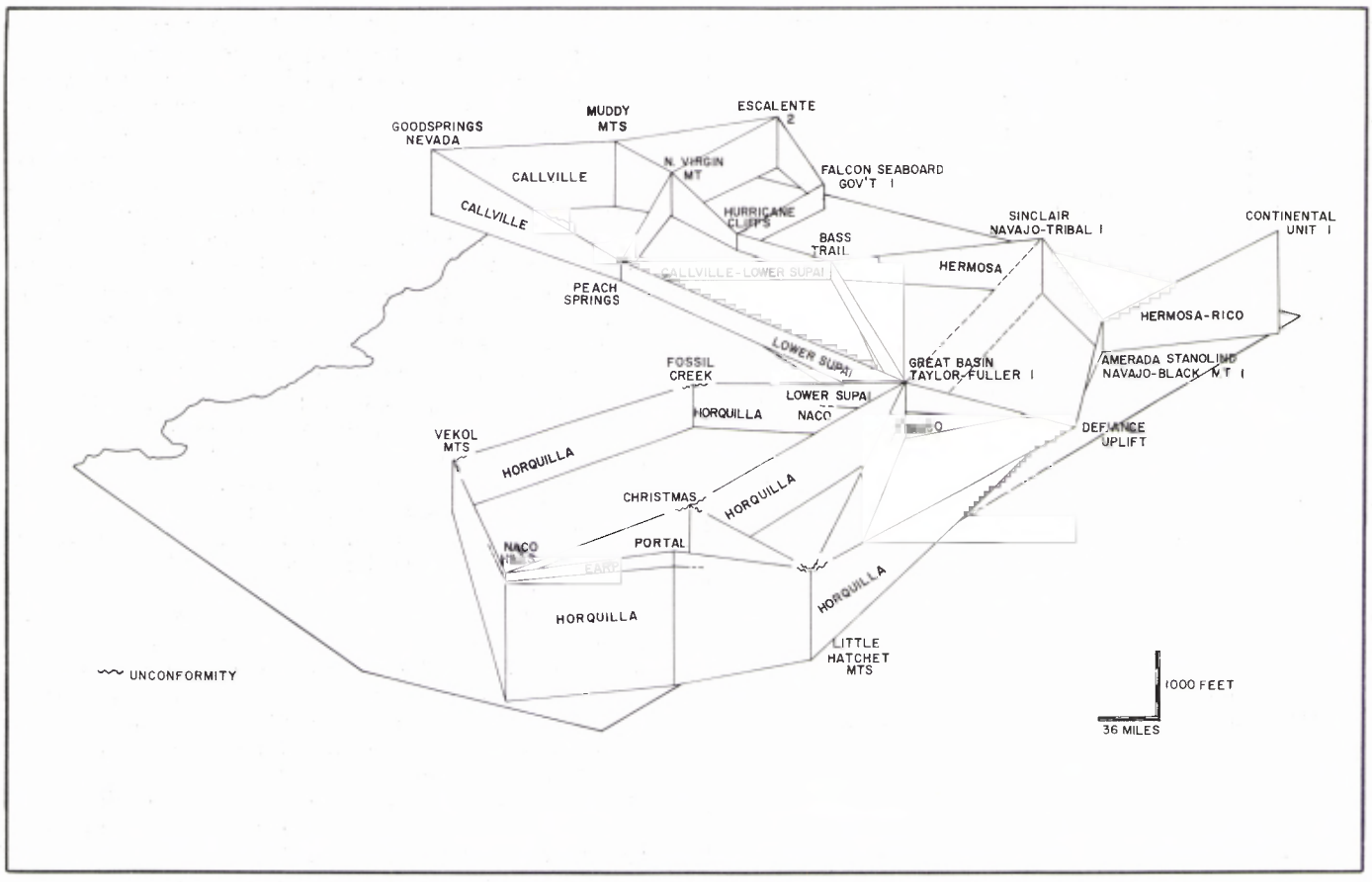


FIGURE 1. Fence diagram of the Pennsylvanian system in Arizona.

formation and increase in clastic content toward the present location of the Monument upwarp is suggestive of a positive tending feature to the southwest of the Paradox basin. Residual Mississippian fossils may be found in the formation; Pennsylvanian fossils range from Morrowan to Desmoinesian in age.

The Pinkerton Trail formation also is observed to thicken and become more clastic to the southwest of the Paradox basin. The fact that the eastern portion of the Pinkerton Trail limestone contains no coarse clastic material is indicative that the Uncompaghre area had not yet been subjected to the tectonic disturbances which are well recorded in the Desmoinesian and throughout the remaining Paleozoic era.

Following Pinkerton Trail time, the existence of a major restricted basin of deposition to the northeast of Arizona is evidenced by the thick accumulations of limestone, dolomite, black shale, salt, gypsum, and anhydrite. These marine and evaporite beds grade eastward into coarse clastics derived from the actively rising Uncompahgre-San Luis uplift of Colorado and New Mexico. Constriction of the Paradox basin was by the Uncompahgre uplift, the gently shelving San Juan basin, the Nacimiento uplift and the Defiance-Zuni uplift; these tectonic barriers may have been supplemented by deposition barriers such as reefs, bars and deltas.

Connection of the Paradox basin with the open seas has been considered as southward across New Mexico to the Gulf of Mexico and/or northwestward across Utah to the Cordilleran geosyncline. The connection apparently did not extend westward across northern Arizona to the Cordilleran geosyncline as is evidenced by the age, lithology, thinning, and increase in sand content of the Pennsylvanian rocks in that area and by the presence of a positive tending area in northcentral Arizona in the vicinity of the Grand Canyon. The positive Defiance-Zuni uplift cut off the basin from Pennsylvanian seas to the south, although a narrow connection may have existed between the two mentioned uplifts.

The marine Hermosa limestones, which overlie the Paradox formation, resulted from the flooding of the basin during Late Pennsylvanian time by seas extending eastward and southeastward across central and northern Utah from the Cordilleran miogeosyncline, and by seas extending northward from the Mexican or Sonoran geosyncline.

The final regression of Pennsylvanian and earliest Permian seas is recorded in the complex interfingering of marine limestones and red beds of very shallow marine, tidal, deltaic, and continental origin which become progressively younger at the top toward the west and northwest.

Within Arizona the regression of the Pennsylvanian seas from the northeastern part of the state was related to the general withdrawal of the epeiric seas caused by renewed uplift of the already high Uncompahgre-San Luis and other positive areas.

Southeastern Arizona

The thickest section of Pennsylvanian beds in Arizona is found in the southeastern part of the state. There beds of Middle Mississippian, and, in limited areas, beds of

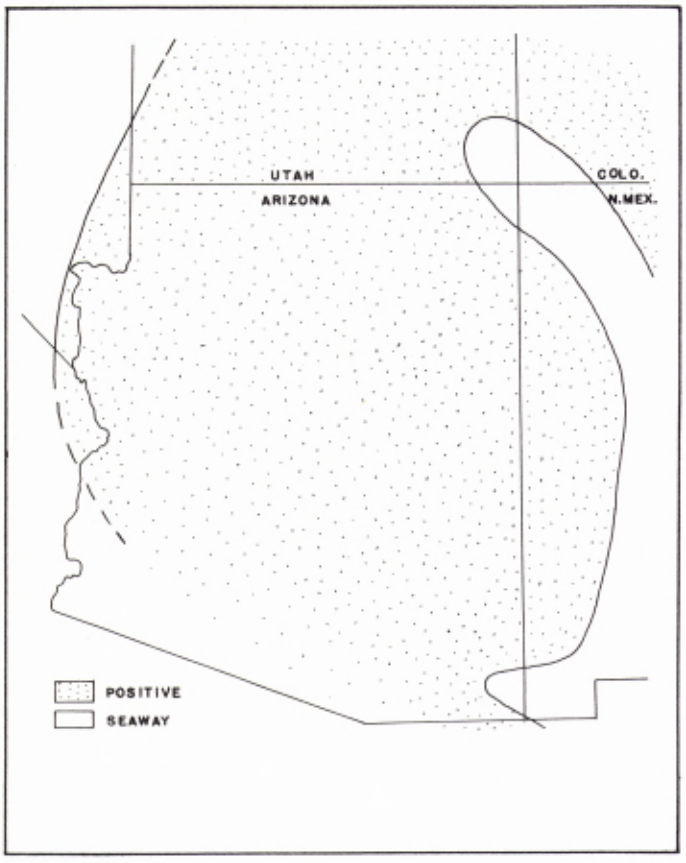


FIGURE 2. Distribution of Morrowan seas.

Upper Mississippian age are overlain disconformably by the Horquilla limestone (Naco of older reports). This limestone is overlain by a transitional Permo-Pennsylvanian group of shales, sandstones, conglomerates, impure limestones, gypsum and marl. The Permo-Pennsylvanian boundary lies within this upper group of beds.

During this Permo-Pennsylvanian interval, southeastern Arizona was a negative region receiving marine deposits for most of Pennsylvanian and Permian times. The apparent double-pronged basin of Mississippian sedimentation in southeastern Arizona may have persisted into Pennsylvanian time as two separate basins or the basins may be merged into one.

Southwestern Arizona

Very little is known concerning the Pennsylvanian, or in fact, any of the stratigraphy of southwestern Arizona, both because of lack of exposures and because of lack of study of the geology of the area. Although it is known that Pennsylvanian beds are present in some localities, most of the sections are involved in complex structure and insufficient work has been done on them. In other areas where no Pennsylvanian strata yet have been reported, boulders derived from Pennsylvanian rocks have been found in Tertiary (?) and Cretaceous (?) conglomerates. Some of these boulders are quite large and angular and indicate little transportation. Pennsylvanian beds were undoubtedly present at not too great a distance.

It is presumed that Pennsylvanian and Permian seas covered the region and conditions of sedimentation were similar either to those of southeastern Arizona or to those of northwestern Arizona.

CLOSE OF PENNSYLVANIAN PERIOD

Pennsylvanian time merged into Permian time with no great change in conditions of deposition. Where Pennsylvanian deposition was marine, Permian deposition was marine of a generally similar lithology; where oscillating shore and sea conditions existed in Pennsylvanian time, those conditions persisted into Permian time; where continental types of Pennsylvanian deposits were forming, similar patterns of sedimentation of Permian age occurred. For mapping purposes, the Permo-Pennsylvanian boundary is usually rather arbitrarily drawn "by definition," since in many cases faunal evidence shows the time boundary to be within a relatively uniform formation or as occurring between beds of somewhat similar lithologies.

DISTRIBUTION OF PENNSYLVANIAN SEAS

Seas probably entered Arizona from both the Cordilleran geosyncline and from the Mexican or Sonoran geosyncline. Those seas probably were not connected, unless westward through southern Arizona or Mexico, until Desmoinesian and Virgilian times. Even during those times owing to local constrictions, the connections were never very effective.

Paleontological evidence indicates progressively younger beds at the base of the Pennsylvanian section both westward and northward from southeastern Arizona, as well as eastward and southward from northwestern Arizona and Nevada. Likewise, at the top of the section, paleontological evidence indicates that the Late Pennsylvanian and Early Permian formations become progressively younger at their tops westward and southward from northeastern Arizona and the Defiance uplift as the marine basins became filled. The continued uplift of areas adjacent to the northeast corner of Arizona raised that part of Arizona and covered it with detritus which was deposited largely under transitional marine-nonmarine environments.

Morrowan Seas

Within Arizona there are no fossils reported that are of unquestioned Morrowan age, although that age has been assigned to the lowermost beds of the Horquilla limestone in southeastern Arizona. In northwestern New Mexico adjacent to the Arizona boundary, the Molas formation has yielded fossils ranging in age from Morrowan to Desmoinesian. In southern Nevada near the margins of the Cordilleran geosyncline, rocks of similar age have been reported, but the Morrowan seas in which they were deposited may not have extended into northwestern Arizona.

This absence of Morrowan fossils near the base of the Pennsylvanian section throughout most of Arizona is believed to be due to non-deposition rather than erosion. The paleogeographic map (fig. 2) is drawn showing Arizona as a land area, except for a narrow margin along the eastern part of the state. Nothing is known of sea and land distribution in the southwestern part of Arizona.

Desmoinesian Seas

The occurence of rocks of Desmoinesian age throughout eastern Arizona indicates that the eastern part of the state may have been widely flooded by seas which may have spread eastward from the Cordilleran geosyncline or northward from the Sonoran or Mexican geosyncline (fig. 3).

In northeastern Arizona, Desmoinesian strata are found on the northern flank of the Defiance uplift but did not cross it. Desmoinesian rocks also appear to wedge out by overlap on a mildly positive area to the west.

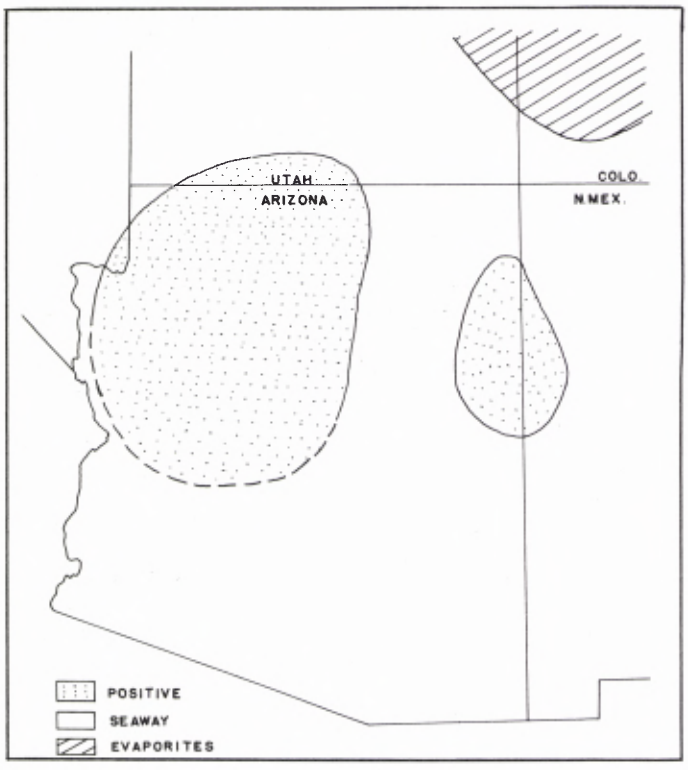


FIGURE 3. Distribution of Desmoinesian seas.

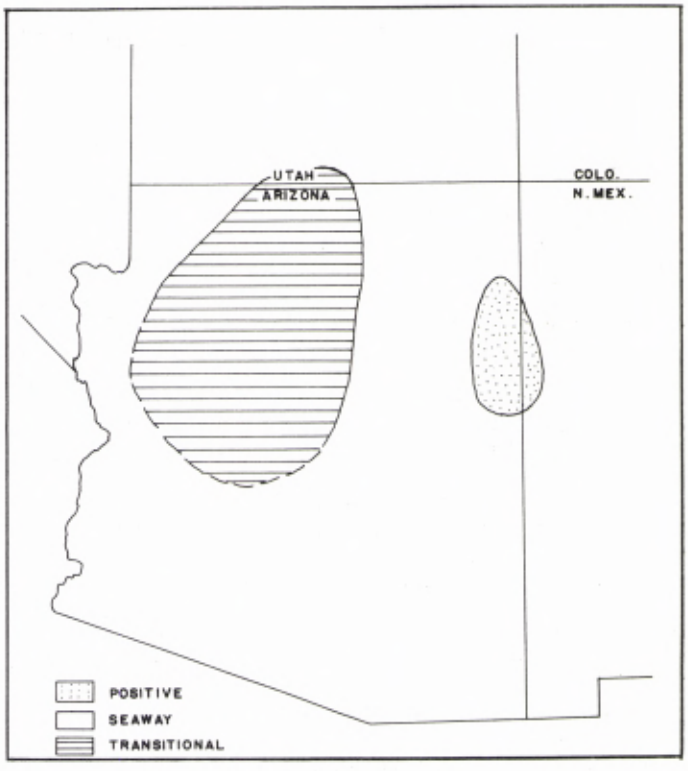


FIGURE 4. Distribution of Virgilian seas.

Thickness distribution indicates that there probably was a shallow connection between the Pennsylvanian seas in northern Arizona and those in southern Arizona, and that this connection was somewhere between the Defiance uplift and a mildly positive area in the Grand Canyon region. Subsurface information is needed to prove this. Northwestern Arizona appears to have been a shoal area subject neither to active erosion nor deposition throughout this epoch. Marine rocks of Desmoinesian age are found in south central Arizona but their extent farther westward is unknown. Nowhere in Arziona were there pronounced uplifts such as were forming north and east of the State.

Virgilian Seas

Rocks of Virgil age are known to occur in northwestern, northeastern and southern Arizona. This wide distribution suggests that the Pennsylvanian seas reached their maximum extent during this time (fig. 4). During this epoch, as was true throughout Pennsylvanian time, the Defiance uplift remained positive. Other areas of low relief in the Virgilian seas were probably ephemeral in nature since the very shallow seas of Late Pennsylvanian and of Early Permian times characteristically transgressed and regressed across the gently sloping, slightly rolling shelf. Except for the Defiance uplift, Arizona was probably almost completely covered at numerous times by these shallow seas flooding the lower areas; the higher areas formed shoals and areas of non-marine or near shore deposits These relationships produced the repeated interfingering of marine limestones and red beds.

SUMMARY

Pennsylvanian time started in Arizona with a generally emergent condition. As time progressed, seas spread across the State both from the northwest and from the southeast. The State in pre-Desmoinesian time was essentially a stable shelf, but starting with Desmoinesian time individual basins and restrictions of sea-ways developed. These were related to the uplifts in adjacent areas such as the Uncompahgre, San Luis, Zuni Mountains, and Pedernal positive areas and the Ancestral Rocky Mountains. By the close of Pennsylvanian time, detritus from these uplifts had filled the marine basins in the northeastern part of Arizona with coarse clastics, near shore deposits, red beds, continental beds, and wind deposits.

Shore lines oscillated as the seas transgressed and regressed across the shelf area giving rise to interfingering marine and red beds and thick accumulations of cross-bedded sands.

Within Arizona proper the only definite positive area was the Defiance uplift, and it apparently was not of great relief. Pennsylvanian time ended with a transition into Permian time with no great change in conditions of deposition.

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