PENNSYLVANIAN OF NORTHWEST COLORADO

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Pennsylvanian stratigraphy of northwestern Colorado has long been considered very complex and results derived from studies are generally inconclusive. The red-beds lithology of much of the section and the resultant "downgrading" as probable oil producing horizons, have deprived these sediments of the attention given to other, more prosperous rock units.

When individual local sections are compared for purposes of correlation, the stratigraphy appears extremely variable, and because of lack of data and wide spacing of subsurface control, fully reliable correlations cannot be made. However, when the Pennsylvanian stratigraphic units of the region are considered as facies of a sedimentary epoch in a structural-depositional unit, these complexities appear to fall into place.

The Pennsylvanian history of northwestern Colorado is a good example of the structural-depositional history of a basin formed during a major deformational orogeny and subsequently filled by marine and later by non-marine sediments derived from surrounding uplifts. Thus, these complexities probably are more apparent than real when considered in the light of Pennsylvanian paleogeography. The following is an attempt to outline those major tectonic elements which must be considered in applying a paleogeographical approach toward reconciliation of stratigraphic vagaries.

During the Mississippian period there was widespread carbonate deposition throughout the Rocky Mountain province as well as over most of the North American continent. This period marks the last great carbonate deposition in northwestern Colorado. Though minor thicknesses of younger limestones and dolomites are present, the area of interest throughout post-Mississippian time has been close enough to major tectonic uplifts to receive predominantly clastic sediments.

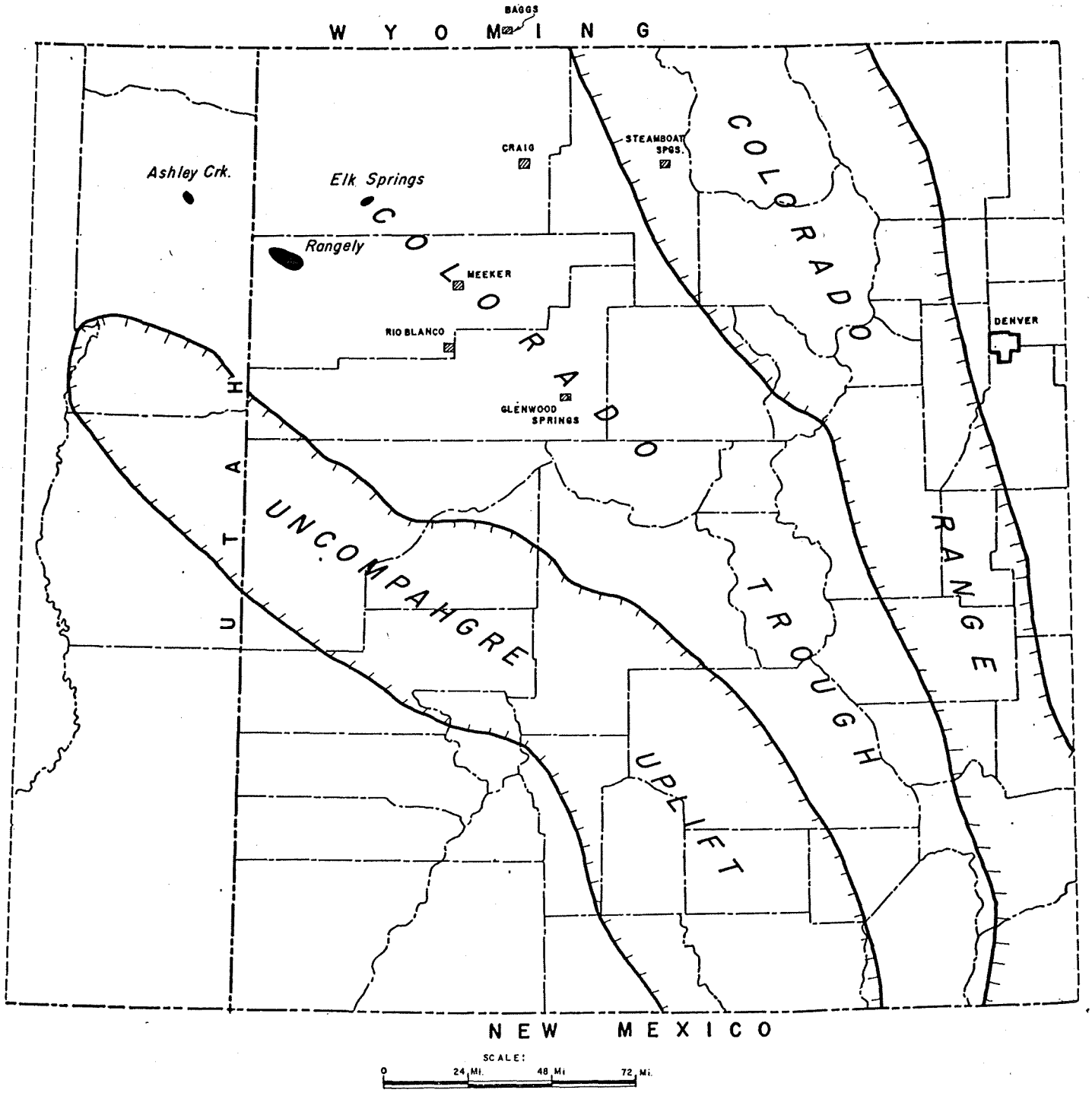
At the close of Mississippian time, gently regional uplift brought the sediments above sea level and a long period of gentle erosion followed. As a result, Mississippian sediments were deeply weathered and a topography of low relief developed.

Pennsylvanian seas, advancing over the deeply weathered carbonate-derived soils and rubble, reworked and stratified the material over which they advanced. Sediments from this ancient soil horizon, plus slight amounts of sediment from the incipiently developing highlands, form the Molas formation. As is to be expected under these conditions of sedimentation, the Molas is not everywhere present; its absence in local areas is due either to non-deposition over areas of slight topographic relief or to complete removal of the weathered zone by erosion prior to the deposition of sediments younger than Molas.

The formation is predominantly a variegated shale sequence with occasional thin limestone and sandstone stringers. It is generally less than 50 feet in thickness, though as much as 200 feet has been reported. In general, the thicker sections of Molas contain a larger percent of carbonates.

By the end of Molas time, the tectonic units which were to dominate the major portion of the Pennsylvanian and Permian were beginning to localize. The relative movement intensified, as indicated by the variety and limited areal distribution of those deposits immediately younger than Molas, namely, the Lower Morgan and Belden and, to the southeast in Central Colorado, the Kerber. Regional studies suggest the presence of four major geographic units which began development at this time and persisted throughout the Pennsylvanian and Permian. To the west of the area of interest was the great shifting orogenic belt of the "Cordilleran geosyncline". Trending southeast from this "deep" an arm of the sea extended into northwestern Colorado following a relatively narrow, trough-like depression which was being down-warped as the positive units of the Uncompahgre and Colorado Range were being elevated to the southwest and northeast. As Pennsylvanian time advanced the highlands continued to develop, ultimately exposing pre-Cambrian rocks to erosion. During middle or upper Pennsylvanian time the trough extended across what is now central Colorado, connecting with the seas advancing from the southeast.

The Morgan formation, as originally defined, included those sediments between the Mississippian and the base of the Weber. Blackwelder considered it to rest unconformably on the Mississippian and to pass transitionally upward into the base of the Weber. At its type locality, in Weber Canyon, Utah, it is predominantly soft, earthy, red sandstone. Some beds are shaly and some thin beds of gray, fossiliferous limestones are



ELEMENTS OF THE ANCESTRAL ROCKIES IN PENNSYLVANIAN

included. It was originally considered to be of probable terrestrial origin. The name Morgan has been retained, though concepts of the origin and lithology of the formation have changed radically with additional control.

The relative carbonate-clastic content of the Morgan changes rapidly with the distance from the uplifts bounding the trough of deposition. Near the center of the trough more than a thousand feet of limestone has been classed as Morgan. Near the uplifts this interval is predominantly clastic.

The lower Morgan, in general, consists of sandstone, sandy and argillaceous limestone and dolomite attaining a thickness of several hundred feet in wells near the axis of the trough. The Belden formation, believed correlative with the lower Morgan, due to its geographic

location of deposition, is composed, principally, of gray and dark shales with occasional limestone and sandstone stringers. This formation may reach a thickness of more than 1200 feet. Southeastward of the present area of interest the Belden grades into the Kerber formation, a contemporaneously deposited terrestrial facies. In view of rapid lateral facies changes, terminology becomes a problem and selection of a regional datum a virtual impossibility.

Middle Morgan time is characterized by a great increase in carbonate deposition in the northwestern part of the area. To the southeast, correlative sediments are red-beds and evaporites. Throughout most of the present area of interest the term Morgan is applicable.

The evaporite-redbed clastic facies of the Middle Morgan, known as the Minturn, attains thicknesses of 6000 feet or more in nearby areas to the southeast. The presence of this great thickness of gypsum, anhydrite and red silt in the middle of an otherwise normal sedimentary series poses intriguing questions bearing on the origin and stratigraphic and paleogeographic relationships of these deposits.

The Minturn consists of arkose, conglomerate, sand, shale and evaporites. Several limestone and dolomite members are present. The Minturn evaporite basin extends from southeastern Moffat County on the north to Fremont County on the south, a distance of approximately 175 miles. Evaporite deposition was not continuous over this entire distance. In most places evaporites are interstratified with clastics, indicating a periodic dessication of the waters in the semi-enclosed basins. Laterally the evaporites interfinger with, and are replaced by, clastics. During this period there was a constriction in the trough, which may have developed periodically into a bridge, in south-central Colorado. It is probable that the floor of the trough was higher in the northwestern part than in the more rapidly downwarping central area. Such conditions would account for observed variations in lithology.

The terrestrial type of deposition of much of the Minturn continued into the Maroon. As its name implies, the Maroon is predominantly dark red in color and consists of rocks of clastic origin—arkose, conglomerate, sandstone, silt and shale. The base of the Maroon is taken as the top of the Jacque Mountain limestone where that member is present. Elsewhere the base is called on a color change. The upper limit of the Maroon is the base of the Weber sandstone where that formation is present. Where the Weber is present as only a tongue it is considered as a member of the Maroon which then continues upward to the Phosphoria.

As a unit, the Maroon is a typically developed basin-filling formation with coarse clastics near the edges and much finer clastics nearer the center of the trough. The formation is in part equivalent to the Upper Morgan and Weber and interfingers with them. By the end of Maroon time the trough was essentially filled and peneplanation of the highlands almost completed. The highlands remained slightly positive into Triassic time, but by the upper part of Chinle time sediments were deposited across the uplifts, with the exception of a few local areas where the remnants of the ranges were not buried until the Jurassic. This type of sedimentation is not unique to this area of Colorado, but is duplicated in the Cutler formation, southwest of the Uncompahgre; the Sangre de Cristo formation, of south-central Colorado; and the Fountain formation, on the east side of the Colorado Range.

It is very probable that the Pennsylvanian-Permian boundary is in the Maroon formation. Conclusive evidence is lacking, but a summation of floral, faunal and paleogeographical indications, plus an attempt to fix the major regional diastrophic events, leads to the conclusion that both ages are represented.

Overlying the Maroon in much of the area of interest is the Weber sandstone. Its base is gradational with the Morgan formation which is of known Pennsylvanian age. The top of the Weber in the northwestern part of the area is marked by the Phosphoria formation of known Permian age. The Weber attains a maximum thickness of some 1300 feet in northwestern Colorado and southeastwardly it thins rapidly into, and is replaced by, redbeds of the Maroon formation.

In its typical development the Weber is a white to yellowish white, clean, quartz sandstone. As it approaches the transition zone into the Maroon formation, stringers of each type lithology are interfingered and the clean quartz sands become red and silty. At or near the top of the formation a thin tongue of typical Weber sand extends southward and southeastward beyond the present area of interest. In places this member, known as the Schoolhouse tongue, is overlain directly by the Phosphoria. To the southeast it is overlain by a thickness of Maroon redbeds which is, in turn, overlain by the Phosphoria or South Canyon Creek dolomite of Phosphoria age. It is believed here that the Schoolhouse tongue is of Permian age.

A preponderance of accumulating evidence indicates that the Weber, as developed in the present area of interest, was deposited from two sources. The clean, well sorted, typical Weber sands probably came from the west and northwest and represent the edge of the great sandstone deposits of the "Utah deep". Near the margins of this deposition the geography was such that the eastern limit of clean sand deposition coincided with the northwestern limit of Maroon deposition from

the Uncompahgre and Colorado Range highlands.

Oil production from Pennsylvanian sediments of the area of interest and the immediately adjacent region has been limited to Weber sand. Three fields, to date, have been discovered. They are Rangely and Elk Springs in Colorado and Ashley Valley in Utah. Rangely field is located, paleogeographically, at about the eastern limit of clean sand deposition and near the southwesterly margin of the trough. There is a notable difference in sand quality between the western and eastern ends of the field. In general, the farther east, the less the effective porosity and permeability and the greater the percentage of redbed, Maroon-type sediments. The Rangely field is ideally located for stratigraphic accumulation and it is possible that a major oil field would have been in the area regardless of the presence of the Rangely structure.

The paleogeographic location of the Elk Springs field is less favorable than that of Rangely, being located apparently in a deeper water facies of more silty texture. Average porosity is approximately three times as g in Rangely as in Elk Springs and average permeab ten times greater.

Many wells drilled in areas surrounding these fi have encountered saturated Weber, but have b non-productive, in most cases due to lack of adeq porosity and permeability. There has been no pene tion of the Weber in the central part of the tro southeast of the Rangely field. Possibilities for adeq sand conditions appear better here than higher on flanks of the trough on which considerable drilling been done, probably because of the admixture Maroon-type sedimentation coming from the bound highlands.

Other Weber fields will be found. To date, emphasis has been on structural traps. As informa accumulates, to the point that detailed stratigraphic lithologic trends can be mapped, production can expected from permeability traps as well as from st tural.