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A Discussion of the Geology and an Isopach Map of the Pennsylvanian System in Wyoming and Adjacent Areas

B. R. Alto

A DISCUSSION OF THE GEOLOGY AND AN ISOPACH MAP OF THE PENNSYLVANIAN SYSTEM IN WYOMING AND ADJACENT AREAS

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A Thesis

Submitted to the Department of Geology

in partial fulfillment of the requirements

for the Degree of Bachelor of Science

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INTRODUCTION

Pennsylvanian strata in Wyoming and adjacent areas have been the subject of much work and discussion. Most of the work has been due to the economic importance of the system as an oil producer in this region. Oil production from strata of Pennsylvanian age is rather recent history; and therefore, much of the available information is localized and incomplete.

Problems of Pennsylvanian stratigraphy and correlation have been attacked by many geologists, and the results of the studies are in many instances conflicting. In many of the structural basins of Wyoming and Montana, rocks of Pennsylvanian age do not crop out for great distances, and the shallow wells in these basins do not penetrate Paleozoic strata. Reports of deep well tests were encountered in the literature, but logs of most of these wells were not available to the writer. Hence, it became apparent to the writer in the compiling of this report that an isopach map would be generalized and in many areas it would be incomplete.

The information for this report was gathered from reports of State and Federal Surveys, from well logs on

file at the Montana School of Mines, and from publications of numerous technical and professional societies.

At this point the writer wishes to express his gratitude and appreciation for the help given in the preparation of this thesis by Dr. Eugene S. Perry and Mr. Alvin M. Hanson of the Geology Department of the Montana School of Mines. The efforts of Mrs. Loretta B. Peck, Librarian at the Montana School of Mines, for her assistence in the research of the literature are also greatly appreciated.

STRATIGRAPHY

The stratigraphy and formations of the Pennsylvanian system will be discussed as they appear at their type localities. The nomenclature of the Pennsylvanian formations differs to a great extent in the region discussed in this report. The map which accompanies this report as Plate II, shows the approximate distribution and names of these formations; and the correlation chart Plate I, taken from Branson (Ref. 2, p. 1223), has been somewhat modified by this writer.

Quadrant formation:

The Quadrant formation was so named by Iddings and Weed for exposures found on Quadrant Mountain in Yellowstone National Park. The formation is widespread in southwestern Montana and crops out in many localities.

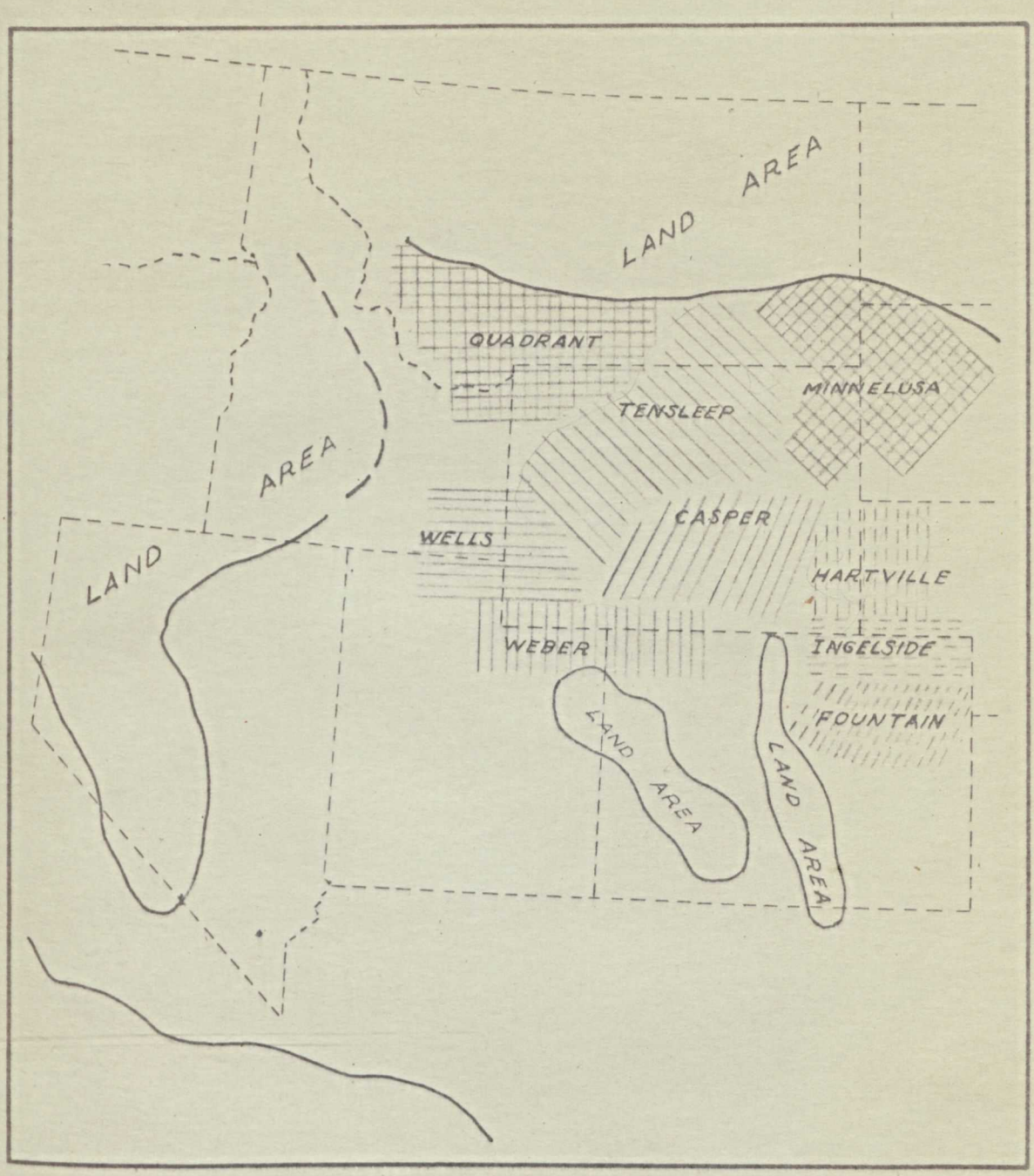
At the type section on Quadrant Mountain, the for-

		Southern Montana	Central Wyoming	Black Hills South Dak.	Hartville Uplift	Eastern Wyoming	Eastern Utah	Eastern Idaho
Permian		Embar	Embar	Minnekahta Opeche	Minnekahta Opeche	Forelle Satanka	Phosphoria	Phosphoria
Pennsylvanian	Missouri			Minnelusa	Hartville I, II	Casper		Wells
	Des Moines	Quadrant U. Amsden	Tensleep		Hartville III, IV, V		Weber Morgan	
Miss.		L. Amsden	L. Amsden	L. Amsden				
		Madison	Madison	Pahasapa	Gurnsey	Madison	Madison	Madison

CORRELATION TABLE OF PENNSYLVANIAN FORMATIONS

PLATE I

PLATE II



Paleogeographic Map During Pennsylvanian Time

in the Northern Rockies

Showing Distribution of Pennsylvanian Formations

(Modified after Branson)

mation as measured by Scott (Ref. 13, p. 1017) was found to be 233 feet thick. The basal 116 feet of the formation consists mainly of cross-bedded gray quartzite, loosely cemented at the base and calcareous toward the top. Above this basal member is a series of quartzites, sandstones, and thin beds of limestone. The sandstones and quartzites, are generally saccharoidal and commonly display cross bedding and ripple marks. The thin bands of limestone are cherty and siliceous, and toward the top of the formation they may contain brachiopod fragments and foraminifera. The predominance of quartzites in the formation has led to the name Quadrant quartzite, which is often applied to the formation.

A distinctive feature of the Quadrant is its almost consistent lithology. In south central Montana the formation is primarily a well-bedded white to pink quartzite ranging from fine to medium in grain size. To the west, toward the Idaho border, calcareous zones and limestone become more predominant, and the formation also becomes thicker. Eastward the limy lenses become less important, and the formation grades into the Tensleep sandstone in the vicinity of the Bighorn basin.

Uniformity of grain size and steep cross bedding of the basal Quadrant indicates a possible eolian origin. The upper calcareous zones are believed to result from marine deposition, and reworking of underlying material.

The Quadrant formation as such, is not found in cen-

tral or northern Montana. However, in a few areas in central Montana small thicknesses of the distinctive quartzite have been found. These scattered outliers do not have a great areal extent, and are probably erosional fringes of the main Quadrant area extending southward. In general the formation wedges out before reaching central Montana.

The age of the Quadrant formation, as given in earlier work, had been based largely upon stratigraphic relationships. The Permian Phosphoria formation overlies the Quadrant unconformably in southwest Montana and northwest Wyoming. The Quadrant rests disconformably upon the Amsden formation which is thought to be Mississippian in age. Fossils are rare in the Quadrant, although a few microfosils and fragments of megascopic fossils have been found in the calcareous zones. Thompson and Scott (Ref. 15 p. 349) have made a study of the microfossils. The discovery of species of the fusulinid genera Wedekindellina and Fusulina from the upper Quadrant indicates a middle Des Moinsean age for the formation.

Amsden formation:

To properly discuss Pennsylvanian stratigraphy in Montana it is necessary to consider the Amsden formation. The age of this formation is very controversial, and much work has been, and is being done, to correct the ambiguity. The Amsden underlies the Quadrant in both Montana and Wyoming. Red shales, sandstones, and limestones averaging 200 feet in thickness are the principle lithologic features of the formation.

Scott (Ref. 13, p. 1022) describes Amsden fauna, and lists Composita trinuclea, Composita subquadrata, and Productus inflatus as being present. This assemblage indicates that the Amsden must be middle or upper Chester in age. Sloss (Ref. 14, p. 6-11) in his studies of the Amsden fauna suggests that the lower two-thirds of the formation, be assigned to upper Chester on the basis of such fossils as Productus elagans, Chonetes chesterensis, and Caninia cornucopiae; and that the upper one-third as observed in northern Wyoming may be Pennsylvanian in age. Lack of a good fossil record from the upper one-third of the Amsden prevents the accurate correlation of this member.

In north central Wyoming, Branson (Ref. 2, p. 1201) has found that upper Amsden fauna include Derbya sp., Orthotetina sp., and Bellerophon sp. Therefore, he regards the upper Amsden as being Pennsylvanian in age. The lower Amsden is considered by Branson (Ref. 3, p. 652) to be of Mississippian age. In the Wind River Mountains where the studies were made he further divides the lower Amsden into Chester and Ste. Genevieve ages. The lowest portion, which contains such Ste. Genevieve fauna as Composita trinuclea, Spirifer pellensis, and Cliothyridina hirsuta, has been given the formational name of Sacajawea formation. Hence comes the paradox of a single formation being of two different geologic ages.

In Montana the Amsden formation is recognized as a mappable unit, it is a recognizable unit in well records, and it serves very well as a formational name for these

strata. In the opinion of the author the Amsden should be considered as a transitional series of similar strata containing fauna of both Mississippian and Pennsylvanian age.

Tensleep formation:

The name of this formation comes from Tensleep Creek in the Bighorn Mountains of Wyoming, where good exposures are found. The Tensleep is widespread over central and northern Wyoming and in southern Montana. In northern Wyoming the formation grades westward into the Quadrant formation.

The Tensleep is essentially a very pure sandstone, and uniform lithologic characteristics are maintained over a widespread area. The sands of the Tensleep are fairly uniform in size, ranging from 0.2 to 0.08 mm. in diameter. Some frosting is noted in the grains which are for the most part poorly rounded. A study made by A. W. Quinn (Ref. 2, p. 1214) reports that the heavy mineral content of the Tensleep sands is very small. The purity and uniformity of the Tensleep formation, and the sphericity of grains, indicates that the sediments were derived from older sandstones or quartzites or that the sands forming the formation were subjected to unusually long and vigorous abrasion.

As in the Quadrant formation, the Tensleep likewise shows cross bedding and ripple marks, again indicating a a shallow water depositional enviornment, and possibly desert deposition. In some areas the basal Tensleep contains thin beds of shale. The upper portion of the forma-

tion has massive beds of dolomite in central Wyoming. The clean white sands of the Tensleep are easily recognized in well cuttings and hence serves as a horizon marker which facilitates correlation.

Branson (Ref. 2, p. 1217) has recognized the following fossils from the Tensleep; Lingulidicina sp., Derbya crassa, Chonetes granulifer, and Spirifer rockymontanus. This assemblage establishes the age of the Tensleep as Des - Moinsean which makes it contemporaneous with the Quadrant.

Minnelusa formation:

The Minnelusa formation crops out in the Black Hills of South Dakota and Wyoming. The thickness of the formation is approximately 500 feet in the vicinity of the Black Hills, but it thickens rapidly to the south. Early studies of the Minnelusa did not establish the age of the formation, however, later work has definitely dated it as being Pennsylvanian.

On the basis of lithology, and to some extent on fossil content, the Minnelusa can be divided into three units. The lower 100 feet consists of red shales, arenaceous shales, dolomitic limestones, and a few thin laminations of black shale. Des Moinsean fossils are found in this lower member. Fossils of Missourian age are found in the middle unit of the formation which consists of 200 feet of sandstones and sandy dolomites. The upper 100 feet consists mainly of sandstone, and is also Missourian in age.

In the Lance Creek area in the eastern part of Wyoming, the Minnelusa again has three distinctive sandstone members.

One of these members, occuring in the upper portion of the formation, is known as the "Converse" sand. Another member, occuring in the middle of the Minnelusa, is known by the local name of "Leo" sand. The "Bell" sand occurs at the base of the Minnelusa. Also in this area the Minnelusa is characterized by anhydrite and dolomites. Near Lance Creek the Minnelusa has thickened to about 800 feet as shown in well records.

A changing in lithology southward from the Black Hills can be determined in the Minnelusa. To the north the basal portion of the formation shows a greater preponderance of coarse clastics than it does to the south and west. This may perhaps suggest that a land mass existed to the north and east in Pennsylvanian time.

Hartville formation:

The Hartville is the name given to strata of Pennsylvanian age in the vicinity of the Hartville uplift in eastern Wyoming. Condra and Reed (Ref. 5, p. 75) have divided the Hartville into six divisions. The lowest member, division VI, is of uncertain age being either upper Mississippian or lower Pennsylvanian. The youngest member, division I, is thought by some geologists to be lower Permian.

In the vicinity of the Guernsey Dam in Platte County, Wyoming good exposures of the Hartville formation are found. The Hartville, in this area overlies the Mississippian Guernsey formation with a very apparent unconformity. The basal Hartville averages 50 feet in thickness, and fills

channels in the deeply eroded Mississippian limestone. Division VI of the Hartville consists mainly of a red, medium-grained quartz sandstone. The next number of the formation, division V, is principally a series of red shales and dark limestones. Division IV is primarily a red shale. In division III siltstones and sandstones are found to a thickness of about 100 feet. Division II is the thickest member of the Hartville formation with a series of limestones, dolomites, and shales totaling to more than 200 feet.

Branson (Ref. 2, p. 1219) has collected Composita subtilita, Spirifer rockymontanus, and Neospirifer dunbari from divisions III and IV of the Hartville formation. These and other fauna are Des Moinsean in age and are in many ways typically Tensleep. Division II can also be correlated with the Tensleep formation on the basis of fossils.

Casper formation:

The Casper formation crops out in the Laramie Mountains of Wyoming. On the east slope of the Laramie Range the Casper is similar to the Hartville, in fact the two formational names in this area refer to the same strata.

On Casper Mountain the formation has been studied and the following lithology noted: a basal red shale, 100 feet of limestone and shale, 100 feet of brown sandstone, and the upper 215 feet of massive cross-bedded sandstone. Branson (Ref. 2, p. 1218) considers the lower red shales as being Mississippian in age. If this is the case then the Casper is 415 feet thick in the Laramie Mountains.

The limestone member of the Casper contains a typical Tensleep fauna. Branson collected many Des Moinsean fossils from the middle of the formation. Chonetes granulifer, Ambocoelia planoconvexa, and Composita subtilita are a few of the common brachipods found in the Casper formation, and it may be considered equivilant to the Tensleep for the greater part, with perhaps the uppermost portion being somewhat younger.

To the south in southern Wyoming and northern Colorado the Casper formation grades into the Ingleside formation. The Ingleside in central Colorado grades into a very thick series of arkosic sediments known as the Fountain formation. The Fountain is Pennsylvanian in age and represents terrestrial deposits from a land mass of some magnitude.

Wells formation:

The Wells formation was named from Wells Canyon in the Webster Mountain Range in southeast Idaho.

The formation at its type section can be divided into three fairly distinct parts. The lower section consists of 750 feet of sandy and cherty limestones with interbedded sandstones. A section about 1700 feet thick, consisting mainly of sandy limestones with a few thin beds of quartzite and sandstone, makes up the middle portion of the formation. The upper member is a sandy limestone and has an average thickness of 75 feet. The entire Pennsylvanian system, therefore, is over 2400 feet thick in this area.

The age of the Wells has been established as Pennsyl-

vanian by Girty on the basis of fossils collected by Mansfield (Ref. 11, p. 73) Although the Wells is not particularly fossiliferous, certain distinctive Pennsylvanian fossils such as Fusulina secalica, Bellerophon sp., and Productus coloradoensis have been found. Girty believes that the Wells is lower and middle Pennsylvanian in age and does not range very far into the upper portion of the period.

Weber and Morgan formations:

The Pennsylvanian system is represented by two formations in north-eastern Utah. The combined thickness of these two is greater than 4000 feet in some places.

The Morgan is the basal formation of the system. The type locality of the Morgan is in Weber Canyon where it attains a thickness of more than 1000 feet. In regions nearby, thicknesses greater than 3000 feet have been measured. At the type section the Morgan is a terrestrial deposit and consists principally of red-beds. In many of the sections of the area, sandstones and shaly sandstones make up the formation. Cross-bedding is common in many of the sandstone beds. Minor amounts of limestone are found in a few areas.

A red bed formation in the Uinta Mountains containing some limestone is thought by Williams (Ref. 16, p. 614) to be equivalant to the Morgan. He describes a coquina formed largely of the tests of Fusulinella sp., which would indicate a Lampasan age for this formation. The presence of

Branneroceras and Spirifer occidentalis substantiates the the lower Pennsylvanian age of the Morgan formation.

The Weber formation, which overlies the Morgan, consists predominantly of sandstones with a few limestones and dolomite members. The beds are generally thick and massive, and are often cross-bedded. Minor members of limestones and dolomites are often cherty and sandy. The thickness of the formation differs greatly within short distances. A maximum thickness of 3300 feet is found in Weber Canyon.

Fossils collected from the Weber include Mesolobus mesolobus, Dictyoclostus, and Spirifer rockymontanus. This assemblage indicates a lower Pennsylvanian age and Williams (Ref. 16, p. 615) suggests that the greatest portion of the Weber formation is probably of Des Moines age.

HISTORICAL GEOLOGY

Paleozoic history, until the beginning of Pennsylvanian time, has been represented in the western United States principally by marine deposition of limestones, dolomites, and shales. in late Mississippian time, slow uplift began to take place in the so called "Ancestral Rockies" and also in the ancient land area of "Cascadia". This condition is shown on the map on Plate II which is modified after Branson. (Ref. 2, p. 1222)

The "Ancestral Rockies" or "Colorado Mountains", as they are called by some writers, were located in what is now

the state of Colorado. Rapid erosion did not begin in earliest Pennsylvanian time, because uplift was not enough to provide the necessary high relief. Therefore, strata of earliest Pennsylvanian time, Morrow and Lampasan, are not represented in the area discussed in this report, with the exception of the Uinta Mountains of northern Utah.

The earliest Pennsylvanian rocks found in this area; equivalents of the upper Amsden, the lower Minnelusa, and lower Hartville; are comparatively thin. These strata are predominantly red beds. It is believed that the clastic beds found in these strata were derived from the low lying pre-Cambrian shield area far to the northeast.

After the deposition of the earliest Pennsylvanian strata the land mass to the northwest of the epi-continental sea began to furnish vast quantities of sediments. The area of deposition lies in western Montana and Wyoming, eastern Idaho, and northern Utah. The land mass had risen relatively high and continued uplift was accompanied by rapid erosion. Sediments deposited in this area were for the greater part light-colored, fine-grained, quartz sands. The depositional enviornment was essentially marine, but limestones were subordinate with shales being practically non-existent.

The pure sandstones and quartzites found in this area are quite thick in the west, which would indicate that the source of material was from a westerly direction. Locally the Pennsylvanian sediments developed tremendous thicknesses. In the Oquirrh and Wasatch Mountains of northern

Utah several thousand feet of strata are reported to be present. Williams (Ref. 16, p. 591). A rapidly sinking basin and two nearby sources of sediments, the Ancestral Rockies and the western land mass, would account for the great thicknesses.

The presence of such huge quantities of almost pure quartz sands without other detrital material indicates that the source must have consisted of almost pure sandstones and quartzites. Heaton, (Ref. 8, p. 138) believes that the sediments were derived from the vast thicknesses of pre-Cambrian (Belt) sediments present in western Montana, Idaho, and Utah. These Pennsylvanian light-colored sands were not widespread during the earliest period of deposition, but were later laid down as thick beds to the west.

Contemporaneous with the erosion in the west, the Ancestral Rockies also began to supply sediments to the nearby basins. In northern Colorado, the Fountain, a thick red arkosic formation composed of terrestrial deposits, was laid down on large flood plains and in deltas. Further to the north the terrestrial sediments began to interfinger with the marine Ingleside formation, which consists of cross-bedded red sandstones and some limestones. Still further to the north, the Ingleside grades into the east-central Wyoming formations, the Hartville and Casper. Lithologic correlation in this area becomes confusing because the central Wyoming area was also receiving sediments from the pre-Cambrian shield area to the north east.

In Des Moines time, middle Pennsylvanian, the epicontinental sea began to withdraw slowly; and large areas of newly deposited sandstones were exposed in northern Wyoming and in southern Montana. Uplift continued, and redistribution of these sands was initiated. This spreading of sands in the wake of the retreating Pennsylvanian seas is now manifested in the Quadrant and Tensleep formations. That oscillation of the retreating seas ocurred, is evidenced by thin beds of marine limestones found in the Quadrant and Tensleep. Shallow water conditions also existed, with temporary emergences followed by submergence and more deposition. During the periods of emergence wind action was important, as is shown in the eolian cross-bedding so common to the Tensleep sandstone.

By late Pennsylvanian time the uplift in the Ancestral Rockies had ceased, the land surface was brought to base level, and sedimentation decreased. To the west the epicontinental sea had retreated and the land surface lay emergent until the transgression of Permian seas.

It is believed by some geologists that a seaway existed to the north through northern Montana. (See Plate II). No Pennsylvanian rocks are found in this area but it is believed that middle and upper Pennsylvanian or later erosion may have removed the strata.

ECONOMIC GEOLOGY

With the ever expanding program of exploration for new

oil horizons, the deeper lying strata of Wyoming and adjacent areas have become very important. At the present time much attention is focused upon the Pennsylvanian strata which in some fields are already the major oil producing horizons.

The Elk Basin field, the Lance Creek field, and the Salt Creek field are but a few in which important production comes from strata of Pennsylvanian age. The sands of the Tensleep and Minnelusa are excellent reservoir rocks for oil and gas, and in all probability will be found to yield oil or gas in many of the existing structures which at present are producing from shallow horizons.

Many of the large structural basins of Wyoming and Montana have not been explored to great depths, and in these areas the Pennsylvanian strata are of great potential importance. It is in these basins where the greatest amount of exploration is being carried on at present.

A DISCUSSION OF THE ISOPACH MAP

Upon examination of the isopach map (Plate III, following page 21) it can be seen that the Pennsylvanian sediments pinch out along a gently curving line through southern Montana. North of this line, in a few local isolated areas not shown on the map, the Quadrant formation with very minor thicknesses has been identified. This indicates that at one time the Quadrant extended further north than it does at the present time. Hence, it is believed that the northern exposures of the Quadrant are erosional remnants beyond the

thinning edge of Pennsylvanian strata. Late Pennsylvanian erosion and reworking of sands has been discussed in the section on historical geology.

From the margin of the area in Montana, the strata thicken rather uniformly to the south. In the Powder River Basin in eastern Montana and Wyoming and eastward toward the Black Hills, the sediments become thicker at a rapid rate. Some doubt exists as to the thickness of the strata in this area as is evidenced by the dashed lines. Since the strata do not crop out in the wide Powder River Basin, and since no well logs were available to the writer, the thickness lines were drawn from known points near the area, and follow the general configuration of the basin of deposition.

In southwestern Wyoming very little definite information was found that could be applied to the map. Therefore, rather than to plot a few uncertain thicknesses, which might easily give an incorrect picture, this area was not completed.

In western Montana and eastern Idaho the sediments are much thicker and indicate a steady increase in the thickness to the west. Very little work has been done in this area and the correlations of the Pennsylvanian strata have not been worked out except at their type localities. Much of the stratigraphy is obscured by complex faulting in this mountainous area.

In southeastern Idaho and northeastern Utah the Pennsylvanian strata assume great thicknesses as is shown on the map by several thicknesses which are indicated in that

area. It was not possible to correlate these thicknesses with other areas because of the great intervening distances over which no information was available.

From the information which is shown on the map, however, the following generalizations can be made. In the west and southwest great thicknesses of Pennsylvanian sediments were deposited in what was probably the geosynclinal trough at that time. In all probability a narrow seaway extended to the north to Canada but erosion has removed all of the evidence. An epi-continental sea existed in southern Montana, not as a deep body of water; but rather as a shallow constantly oscillating sea. In eastern Wyoming a deeper portion of the sea existed as is shown by the thickening of sediments.

SUMMARY

Pennsylvanian strata in the northern Rocky Mountain region are characterized by being principally a series of clastics. Large areas in northern Wyoming and southern Montana are underlain by relatively pure sandstones and quartzites of Pennsylvanian age. In central Colorado thick deposits of terrestrial and delta sediments are found. To the east in Utah and Idaho, large thicknesses of Pennsylvanian strata are found which indicates deposition in a geosyncline. The Pennsylvanian strata wedge out in southern Montana. This thinning out probably represents the northern extent of the Pennsylvanian seas. A seaway may

have existed through western Montana into Canada but geologic evidence of this condition is lacking.

The opinions of geologists, who have worked in the area, are varied as to the correlation of the Amsden formation. The Amsden formation in the opinion of this writer is transitional and represents deposition in both Mississippian and Pennsylvanian time. The problem of correlation and also the lack of information over widespread areas proposes a difficult problem when an isopach map of the system is attempted.

Pennsylvanian strata in Wyoming and adjacent areas are important to the petroleum industry; and the accelerated exploration at present and in the future will disclose much new information about the system.

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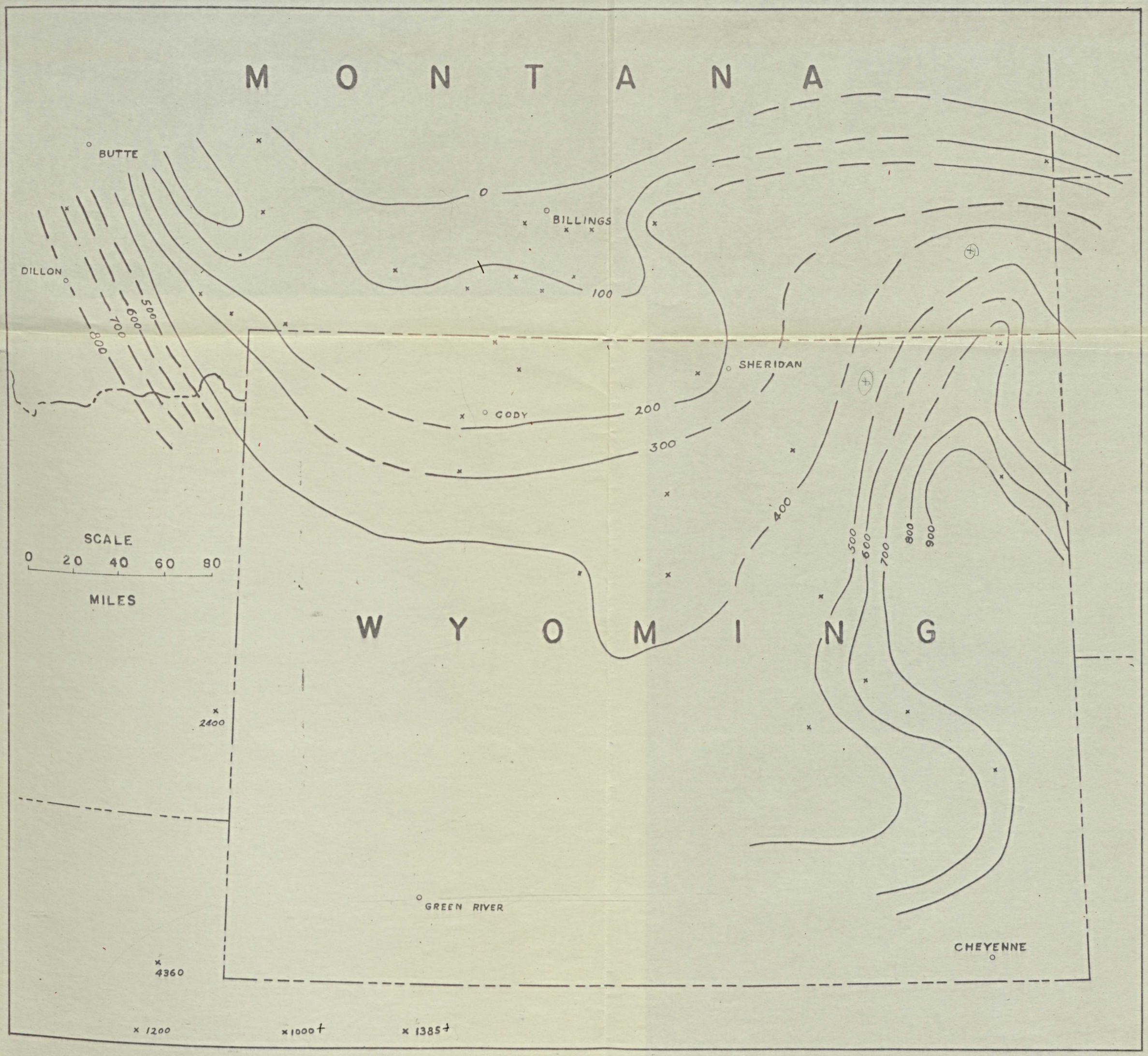
PLATE III



ISOPACH MAP OF PENNSYLVANIAN STRATA SOUTHERN MONTANA AND NORTHERN WYOMING

B.R. ALTO - APRIL 1948