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An Isopach Map and Discussion of Triassic Strata in Southern Montana and Wyoming

Robert G. Thompson

AN ISOPACH MAP AND DISCUSSION OF TRIASSIC STRATA IN SOUTHERN MONTANA AND WYOMING

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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 in Geological Engineering

MONTANA SCHOOL OF MINES
Butte, Montana
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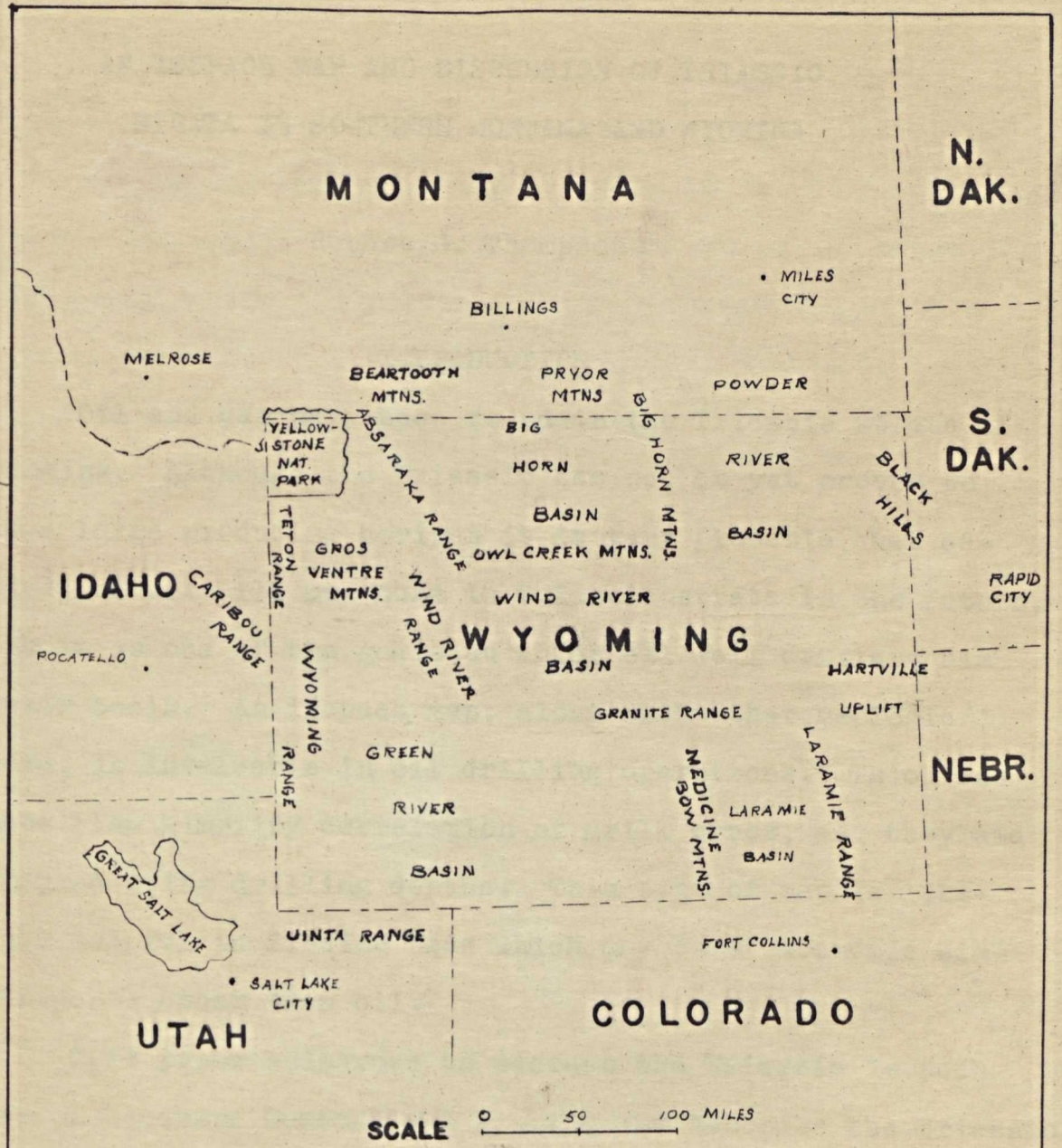
TABLE OF CONTENTS

ILLUSTRATIONS



INDEX MAP OF SOUTHERN MONTANA AND WYOMING

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INTRODUCTION

Oil and gas have been found in the Triassic strata of Wyoming. Although the Triassic has not as yet proven to be a large producing horizon it is very probable that additional oil will be found in Triassic strata in the future, and it is one of the goals at which oil well drillers aim their tools. An isopach map, along with other geologic data, is invaluable in oil drilling operations. Thickness maps also simplify correlation of drill cores, and they aid in predicting drilling depths. This type of map is likewise helpful in finding beds which may be of economic significance other than oil.

This paper endeavors to discuss the Triassic isopach map of southern Montana and Wyoming and describe the Triassic strata of the region. Material has been compiled from previously published literature from the Montana School of Mines library. Because of the complexity and incompleteness of data in southwestern Wyoming, southeastern Idaho, and adjacent areas they will not be covered in this report.

With these views in mind, the writer has undertaken as an undergraduate thesis to construct and discuss an isopach

map of southern Montana and Wyoming. To the writer's knowledge such a map does not exist in present literature.

Thanks and appreciation are given to Dr. E. S. Perry of the Geological Department of Montana School of Mines for his generous aid and guidance in the preparation of this paper. The writer also wishes to express gratitude to the librarians for their able assistance.

GENERAL STATEMENT

Triassic signifies threefold as used in the type section in Germany. Although a threefold division is not applicable to other parts of the world, the name has been adopted throughout the world. In the Rocky Mountain region Triassic rocks are widely distributed. Idaho, southern Montana, Wyoming, Utah, Colorado, Arizona, New Mexico, and western Texas contain the greatest areal distribution of continental Triassic beds in North America. It is with the north-central part of this region that this report is concerned.

As stated by Moore 29/*, this region seems to have been a nearly featureless vast lowland plain throughout the Triassic period. It is thought that most of the region sloped gently toward the seas of the Cascadian geosyncline. Sluggish streams depositing sediments formed coalescent alluvial deposits which were composed of oxidized materials. The typical red color is derived from iron oxides distributed through the sediments. Horizontal uniform beds suggest deposition

* Numbers in shelves refer to Bibliography

in standing water. Triassic deposits of this region are generally unfossiliferous due to repetitious exposure of sediments to the atmosphere.

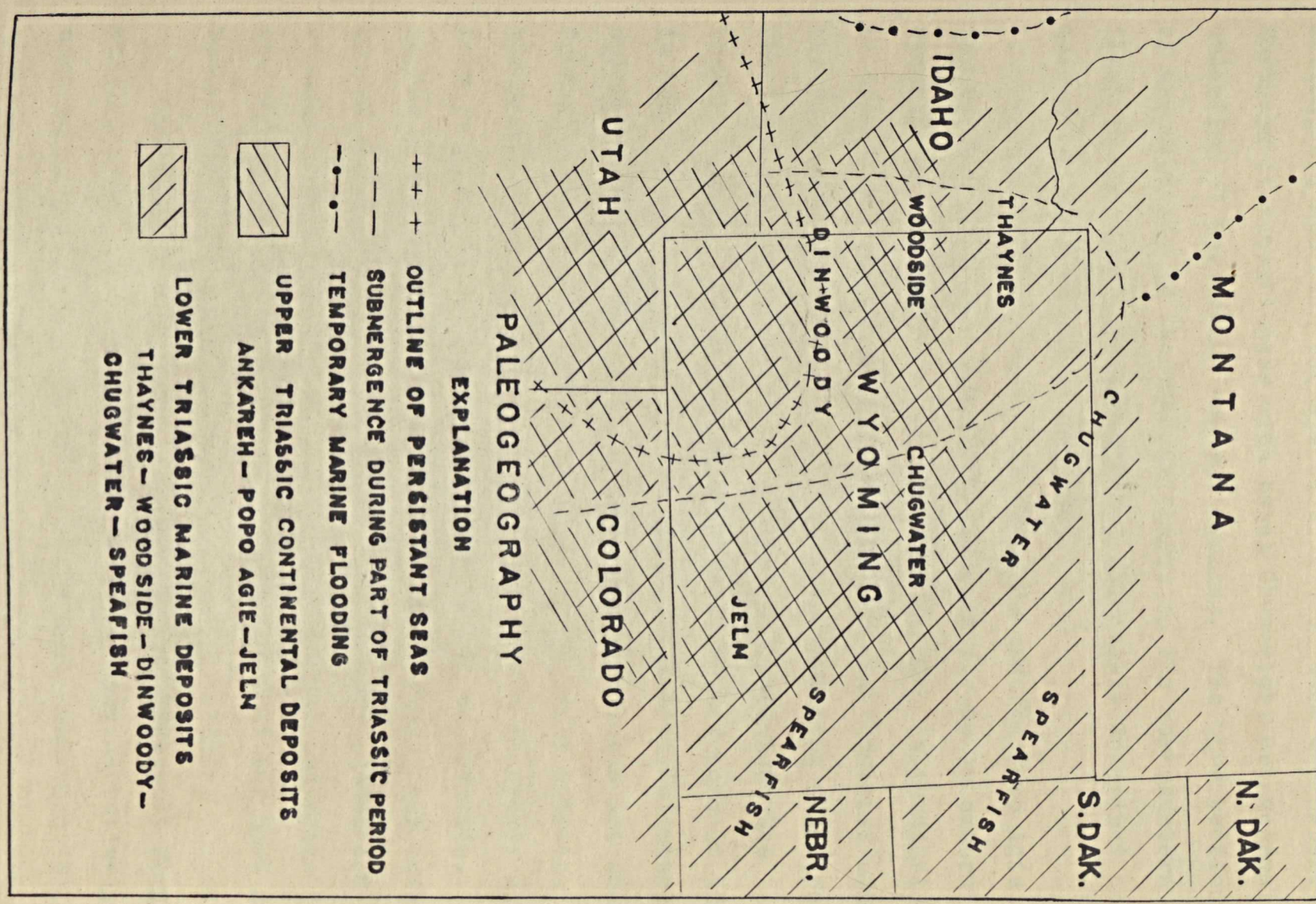
NOMENCLATURE AND CORRELATION

Lower Triassic

Plate II-B shows an east-west generalized cross section showing correlation of Triassic stratigraphy. In the extreme eastern part of the region the Lower Triassic is represented by the Spearfish formation, named by Darton 14/ from the excellent exposures in the Black Hills of western South Dakota. Spearfish is equivalent in terms of time to the widely distributed Chugwater of Wyoming and southern Montana. The name Chugwater has been used as both a group and a formational name by various investigators, and was first described by Darton 14/. The name was derived from Chugwater Creek in the Laramie Range of southeastern Wyoming. A recent U. S. Geological Survey publication 27/ has divided the Chugwater into three members which are distinctive and sufficiently widespread for regional work. As shown on Plate II, these are the Red Peak, Alcova, and Popo Agie members in order of decreasing age, and they will also be referred to as lower, middle, and upper Chugwater. In southeastern Wyoming Thomas 38/ has described the intertonguing of the basal member of the Chugwater with upper Phosphoria sediments.

The Dinwoody formation of western Wyoming and southern Idaho exhibits overlapping relations with the Woodside for-

Plate II-A



GENERAL STRATIGRAPHIC CORRELATION

	SE. IDAHO MONPELIER	WESTERN WYO. DINWOODY CA. GOS VENTRE	W–CENT. WYO. LANDER	CENTRAL WYO. RATTLESNAKE HILLS	EAST–CENT. WYO. ALCOVA	EASTERN WYO. DOUGLAS	S. DAKOTA S. SECT OF BLACK HILLS
Jr	NUGGET						
U. Tr	ANKAREH? TIMOTHY?	ANKAREH	POPO AGIE (U. CHUG.)	JELM	GYPSUM SPRINGS		SUNDANCE
	THAYNES		ALCOVA (M. CHUG.)				
L. Tr	WOODSIDE		RED PEAK (L. CHUG.)				SPEARFISH
	DINWOODY			LITTLE MEDICINE TONGUE			
P	PHOSPHORIA			ERVAY / FORELLE	INTER–TONGUING OF CHUG.–SPEAR. AND PHOS.	MINNEKAHTA	OPECHE

NORTHERN SECTION

	EAST IDA.	SW. MONT.	S–C. MONT.	N. WYOMING	NE. WYO.	SW. N. DAK.–NW. S. DAK.
U. Tr	ANKAREH? TIMOTHY?					GYPSUM SPRINGS
L Tr	THAYNES WOODSIDE DINWOODY	WOODSIDE DINWOODY	CHUGWATER	CHUGWATER	SPEARFISH	SPEARFISH

Plate II-B

mation, and has been correlated with the lower Chugwater. Eastward it interfingers with basal Chugwater, and generally underlies it throughout central Wyoming. The type section of the Dinwoody is in Dinwoody Canyon on the northeastern flank of the Wind River Mountains, originally described and defined by Blackwelder (4, p. 425).

As the strata between the Dinwoody and the Popo Agie (Upper Chugwater) are generally unfossiliferous in central Wyoming, and the age of each is questionable, it is difficult to definitely correlate the main body of the Chugwater with the fossiliferous marine rocks of western Wyoming and Idaho. The lower Chugwater has been followed westward into the Thaynes group, but until detailed stratigraphic work is done in west-central Wyoming this formation cannot be definitely correlated. Love 26/ states, "When Triassic rocks are studied further afield, the picture becomes increasingly complex. In the Snake River Canyon of western Idaho there is nearly 25,000 feet of rocks which have been considered to be Triassic. This series consists of rhyolites, phyroclastic rocks, red beds of gypsum, conglomorates, and 20,000 feet of clay slates and limestones. The occurrence of red beds and gypsum indicates that the Chugwater type of environment extended that far west during Triassic time."

The Woodside and Thaynes formations of southwest Montana, and along the Idaho-Wyoming border region, are tentatively correlated with lower and middle Chugwater. The Woodside shale was named by Boutwell 5/ from Woodside gulch in the

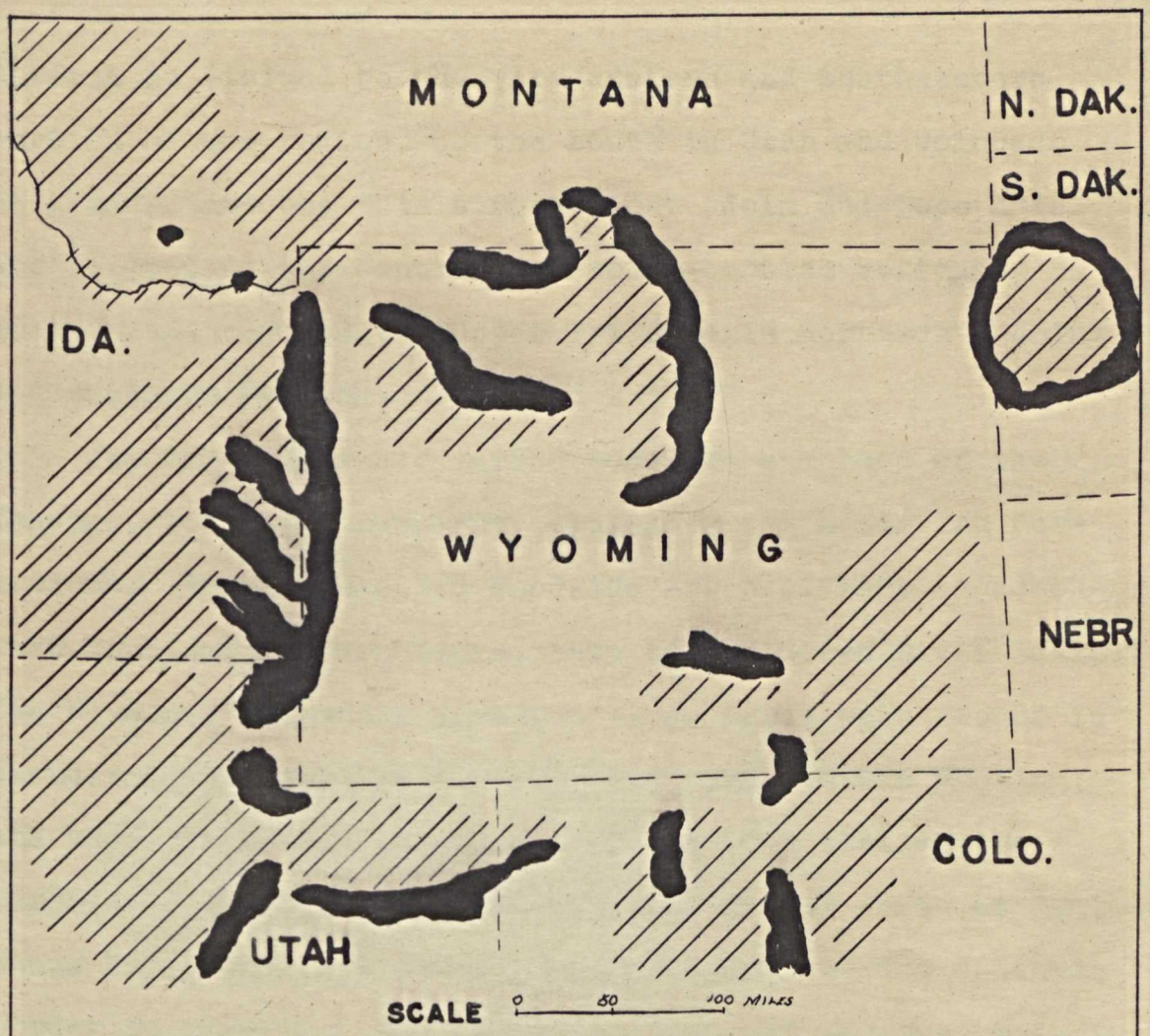
Park City, Utah, mining district. The Thaynes formation was likewise named by Boutwell from a canyon in the same vicinity.

Upper Triassic

Ankareh, Jelm and Popo Agie are representative of Upper Triassic formations. Ankareh is a name generally used in southwestern Wyoming, and the literature is rather indefinite on it. Horberg 19/ in his description of the Teton Pass area states that the Ankareh is composed of continental beds and lies unconformably on the Dinwoody. The type area of the Popo Agie member is near Lander, Wyoming, and that of the Jelm formation is in southeastern Wyoming. The Jelm is named after Jelm Mountain in the Laramie Quadrangle by Knight (20, p. 120). Because of lithologic changes in central Wyoming, Popo Agie is used instead of Jelm in more recent literature.

Distribution

A general regional distribution of Triassic outcrops is shown in Plate III, whereas continental and marine deposits are shown in Plate II-A. The continental deposits are somewhat limited in areal distribution as compared to those of marine origin in this region. The Ankareh, Popo Agie (Upper Chugwater), and Jelm comprise the land deposits. The boundaries of these formations are only approximate, as definite information on such was not found in the literature. The



GENERAL DISTRIBUTION OF TRIASSIC OUTCROPS

EXPLANATION

POST TRIASSIC

TRIASSIC

PRE TRIASSIC

Ankareh is limited to the very western and southwestern portion of the region, to the south in Utah and Colorado it grades into the Chinle formation. Jelm and Popo Agie are limited to the central and south-central regions. Erosion has removed the Upper Triassic in northern Wyoming and southern Montana.

The Lower Triassic marine beds are composed of the Thaynes, Woodside, Dinwoody, Chugwater and Spearfish formations. The Thaynes and Woodside are prevalent in southwest Montana, eastern Idaho, east to the Green River Basin. The Dinwoody formation covers a large area, being found in eastern Idaho, southwestern Montana, and western Wyoming; and there is a thin tongue reaching as far east as the Laramide Range, Wyoming. It is found as far north as Yellowstone Park, and it gradually pinches out near the southern border of Wyoming. The Chugwater with its various members is even more widely distributed than the Dinwoody formation. The Chugwater is found in the Green River Basin and east to the vicinity of the Hartville uplift. To the north the Chugwater pinches out in southern Montana north of Billings. The Spearfish is found predominantly in the Black Hills, in southern North Dakota, and south in Nebraska. The Spearfish formation is also widespread in southern Montana, and also east of the Hartville uplift in Wyoming.

GENERAL STRATIGRAPHY AND LITHOLOGY

CENTRAL WYOMING

The following is a condensation of U. S. Geological Survey Preliminary Chart No. 17 27/, and is used since it represents a detailed description of Triassic strata completed by the authors of the chart.

Dinwoody Formation

The Dinwoody formation is present throughout central Wyoming and consists of 50 to 250 feet of greenish-gray, hard, tight, fine, sandy, dolomitic siltstones, silty greenish-gray shales, and thin slabby sandstones, commonly oil stained. The sandstones characteristically weather into thin, hard slabs with a brownish stain on the surfaces. The lithology shows little variation, except in the eastern part of the Wind River Basin where greenish-gray sandy siltstones intertongue with silty red shales and anhydrite beds, and along the southwestern margin of the Wind River Basin where lenticular anhydrite and gypsum beds are present. The Phosphoria formations are not cherty.

The Dinwoody formation overlies the Phosphoria formation with such a slight unconformity that it is apparent only in regional studies. The contact between the Dinwoody formation and younger Triassic rocks is marked by a slight lithologic change, and in some places by a color change from greenish-gray below to red above.

Chugwater Formation

The basal member of the Chugwater (Red Peak member), comprises about 800 to 1,000 feet of red siltstones, shales and silty sandstones, generally overlying the Dinwoody formation. The sequence is monotonous with only minor gradational changes in lithology. The lower part of the Red Peak member is much more shaly and finely silty than is the upper part, which grades from red shaly siltstones to red silty sandstones with thin shale partings. The boundary between the Dinwoody formation and Red Peak member of the Chugwater formation is marked by a color change from greenish-gray below to red above, and by a lithologic change from hard, dolomitic siltstones below to soft, non-dolomitic shales and siltstones above. The color change is not always consistant, therefore the lithologic change is more significant.

The Alcova limestone member of the Chugwater consists of a single limestone bed, with a thickness ranging from a wedge-edge up to 15 feet overlying the Red Peak member. This is the only limestone in the Chugwater in central Wyoming. The Alcova limestone member is one of the most useful datum horizons for structural work in central Wyoming, because it is so widespread, so thin, and so easily recognized, both on the surface and in the subsurface. The limestone is commonly gray to a slightly pinkish color, hard, finely crystalline, thin-bedded, and comparatively pure. The limestone has been called Upper Triassic by some investigators, although fauna found in it are similar to Lower Triassic fauna. In some

areas a local sandstone facies named the Crow Mountain member overlies the Alcova.

The sandstone above the Alcova limestone contains fragments of limestone and also comparatively large, rounded, frosted sand grains. It has been confused with several Jurassic sandstones by some investigators. The Popo Agie, the youngest member of the Chugwater, consists of 100 to 200 feet of ocher-colored, oolitic, siliceous, dolomitic claystone; limestone-pellet conglomerate; purple and red shale; and red silty sandstone. A widespread zone of highly siliceous bright ocher-colored dolomitic claystone is present near the top of the member.

In the western half of the Wind River Basin, Popo Agie lithology is distinctive. However, in the eastern section of the Basin there are only a few feet of beds similar to those of the Red Peak member. Southwest of the Wind River Basin, Popo Agie lithology is well developed, but southeast of the Basin it is lacking in several areas. No consistant base to the Popo Agie has yet been found, either on the surface or the subsurface, or in electric logs.

The name Popo Agie is used in central Wyoming in preference to the Jelm. Any identification of the Jelm formation in central Wyoming is made uncertain by the lack of Jelm lithology in intermediate areas. The correlation of the Popo Agie and Jelm rocks has neither been definitely established or disapproved.

Southern Montana

The Chugwater formation is present in southern Montana, but pinches out in subsurface a few miles north of Billings, probably because of pre-Ellis erosion. The thickness of the formation ranges from over 600 feet at the Montana-Wyoming border to zero feet north of Billings.

According to a description taken from a U. S. Geological Survey paper 16/, "The formation consists of red and brown sandstone, siltstone and some shale. Gypsum is common at the base, and some thin beds of limestone occur in the middle and lower parts. The sandstone beds are massive and resistant. The base of the Chugwater is distinct where it rests on the Tensleep sandstone, but it is less distinct where Permian beds intervene, because beds at the base of the Chugwater formation probably interfinger with beds in the Permian Embar formation. The Chugwater-Embar contact is arbitrarily placed at a horizon marked by a change from red siltstone and sandstone above to yellow-gray or yellowish brown calcareous sandstone and limestone below." According to Bartram 2/, upper Chugwater units are absent in southern Montana due to erosion in Upper Triassic time.

Southwest Montana

In southwestern Montana over 500 feet of Triassic sediments are found as far north as Melrose. These were originally described and defined as Woodside by Richards and

Pardee 34/ as limey shale, limestone, and sandstone characterized by prevailing brown weathered surfaces, which when freshly broken run in color from buff to bluish gray and greenish gray. At least half of the thickness is composed of shale with limestone being next in abundance. Condit 13/ found over 100 feet of brown-weathering shale and limestone Triassic sediments along Indian Creek.

Newell and Kummel 31/, largely through characteristic faunal evidence, have classified the Triassic beds near Trapper Creek, west of Melrose, as the Dinwoody formation. They state that under the Kootenai formation lies 638 feet of shale, limestone and sandstone beds. The beds are of tones of gray to light buff, and lithologically similar to the Dinwoody in Idaho and western Wyoming. From the evidence at hand it seems reasonable to assume that south from Melrose the thicker Triassic sediments contain Thaynes, Woodside and Dinwoody formations.

Love 26/ states, "The Dinwoody has been recognized in Yellowstone Park and northwestward. There seems to be general agreement that the Dinwoody correlates with at least part of the Woodside, but the age of the latter is also not settled.

Western Section

Along the Idaho-Wyoming border the Dinwoody reaches a thickness of around 650 to 700 feet. Newell and Kummel 31/ have divided the Dinwoody of this area into three units.

The lower base unit consists of 50 to 175 feet of friable unfossiliferous buff siltstones to the west, and pinches out a few miles east of the Idaho-Wyoming border line. The second unit (Lingula zone) has abundant Lingula and the beds consist dominantly of silty olive-buff to gray shales interbedded with blockey-brown to bluish-gray limestones. The Lingula zone reaches a thickness of between 250 to 350 feet a few miles east of the Idaho-Wyoming border, and gradually pinches out a short distance east of Lander, Wyoming. The upper unit (Claraia zone) is the most extensive, and corresponds to the Dinwoody of central Wyoming. It consists of largely resistant, light brown, calcareous siltstones, with intermittant light colored massive limestone facies. In the Wind River and Owl Mountains the Claraia zone ranges from 30 to 100 feet in thickness. Eastward equivalents of the Dinwoody change to red silty shales, except for a brief calcareous and gypsiferous zone near the top. In south-central Wyoming, Thomas 38/ has given the name Little Medicine Tongue to these non-red rocks. It seems likely that they correspond to the upper part of the Claraia zone.

West of the Gros Ventre Mountains are several hundred feet of red shaly siltstones and sandstones of the Woodside formation which are equivalent to lower Chugwater beds. According to Newell and Kummel 31/, "These red beds belong to the same facies as the type Woodside, but apparently correspond stratigraphically on to about the upper half of typical Woodside as defined in the Park City area".

In western Wyoming near the Hoback Mountains the Thaynes formation is over 1,000 feet in thickness and lies conformably on the Woodside formation. The basal unit is made up of a massive, cliff-forming gray and white limestone. The upper section is composed of silty limestones and buff shales, with minor quantities of red beds. Eastward these grade into red beds with relatively inconspicuous purple to white dolomitic limestones. Some of these limestones are lithologically the same as the persistent Alcova limestone to the east.

Along the southern margin of the Absaroka Range in an area where the Nugget sandstone is missing, Love 26/ has included the Gypsum Spring member as the upper unit of the Chugwater formation. This unit is composed of a sequence of red shales and siltstones interbedded with gypsum, limy sandstones, and slabby limestones. This member has a thickness of about 180 feet in this region. Along the northeastern border of the Wind River Basin is a similar case. According to the writers of the U. S. Geological Survey paper 27/, "The Gypsum Spring formation has been included in the Chugwater formation by many investigators, and in the Sundance formation by others".

In the Teton Pass area Horberg 19/ states, "The Ankareh forms a clearly recognizable unit of red beds, about 100 feet thick, overlying the Dinwoody formation. The Ankareh is entirely composed of continental deposits considered time equivalent of marine Upper Triassic of southern Idaho". To

the east the Ankareh is correlated with upper Chugwater or Jelm.

In southwestern Wyoming, Mansfield 28/ states, "The stratigraphic limits of the Triassic in southwestern Wyoming are essentially the same as in southern Idaho". There has been some difficulty in agreement on formations in this region, and for this reason further correlations will not be taken up in this paper.

Eastern Section

Eastward in Wyoming the Chugwater passes into the Spearfish formation. A thin finger of the Dinwoody extends as far east as the Hartville Uplift, where in the vicinity of Iron Mountain, Condra (11, p. 14) has measured 2 feet or more of Dinwoody strata. The Spearfish has been redefined from Darton's original definition to apply to the section between the Phosphoria group and the Sundance by Condra, Reed and Scherer 11/. The Spearfish formation is widespread covering southeastern Montana, northeastern, eastern and southern Wyoming, North Dakota, the Black Hills region, and northwest Nebraska.

The Spearfish ranges from 300 to 700 feet in thickness, and consists largely of bright red shale and gray to black shale, sandstones and light limes. Some gypsum is present. In Bartram's 1/ description, "The Spearfish formation is 700 feet thick in the north end of Black Hills and thinner to the south. It consists mostly of brick-red, sandy shales

that are maroon in well cuttings, and near the base has a thick evaporite section with much salt in eastern Montana. In the north end of the Black Hills there is a gypsum at the top of the Spearfish." This formation is persistent in all sections and is overlaid unconformably by the Jurassic Sundance formation. No physical break occurs between the Spearfish and Phosphoria formations except in areas where the thin lense of the Dinwoody is found. Little information has been published concerning the Spearfish in northeastern Wyoming and southeastern Montana.

In southeastern Wyoming in the Laramie Basin, the Chugwater formation is overlaid by approximately 250 feet of Upper Triassic rocks which are called the Jelm formation by Knight 20/. The Jelm unconformably underlies Jurassic Sundance formation and consists of a massive, orange-colored cross-bedded sandstone occurring along the Laramie and Rocky Mountain fronts. Lee 24/ states, "Their massive cross-bedded character, the inclusion of lenses of pellet conglomerate which may have originated as the filling of stream channels, and non-marine fossils, indicate the formation may be of fluviable origin and may not be continuous from place to place". The Jelm is not found east of the Laramie Range. Underneath the Jelm is found red beds comparable to the Red Peak member of lower Chugwater, which eastward are called the Spearfish formation.

PALEOGEOGRAPHY

Lower Triassic

During Triassic time the Pacific Coast geosyncline was inside the margin of the continent, running parallel to the present coastline from California to Alaska. The geosyncline was quite extensive during the latter part of the period. In the Rocky Mountain region Heaton 18/ states that in Lower Triassic time there began a slow oscillatory marine invasion from the west, resulting in the laying down of sandstones, limestones, shales, and gypsum. These marine invasions were probably fairly shallow seas near a lowland area which Heaton 18/ thinks was to the south. It is likely that true marine conditions prevailed in the western part of the area with gypsiferous red shales and sands replacing the limestones eastward. Schuchert & Dunbar 35/ write that the gypsum in Wyoming represents evaporation in lagoons where the marine water spreads temporarily from the west.

The approximate extent of the Lower Triassic seas is shown on Plate II-A. Heaton has postulated that the highest land was probably in southern Idaho, as thick sediments (Thaynes limestones and Woodside silty sandstones) are around it. Eastward the sandstones, siltstones and shales of the Dinwoody, Chugwater and Spearfish formations were deposited. Some of the land-derived material probably came from this positive area. Lower Triassic time ended with the gradual withdrawl of these oscillating seas and redeposition over limestone of additional sandstones, shales and gypsum beds.

Upper Triassic

Following the withdrawl of Lower Triassic seas came an interval of erosion, with the high area in southern Idaho extending southward. In the southwest region Upper Triassic sediments thicken and are of fluviatile origin. Plate II-A shows the areal distribution of Upper Triassic sediments in the northern section, which are the Popo Agie and Jelm formations of central and southeastern Wyoming. Triassic strata in southwestern Wyoming and Idaho are represented by the Ankareh formation.

According to Heaton 18/, "The red beds of Triassic do not necessarily indicate an arid climate, because the color is the result of the hydration of certain ferric oxide compounds which takes place most rapidly in warm, moist climates. The red ferruginous soils thus formed were redeposited on river deltas, flood plains, and in lagoons. Doubtless considerable percentages of the red beds are the result of a redeposition of earlier reds."

CHARACTERISTIC FOSSILS

Dinwoody Fauna

In central Wyoming the Dinwoody formation contains abundant pelecypods and Phosphatic brachiopods of a nondescript, Lower Triassic marine fauna. Lingula is well preserved and abundant in various areas through the Dinwoody formation. Newell and Kummel (31, p. 949) state,

"So little is known about the earliest Triassic faunas of the world, as well as the latest Permian faunas, that part of the apparent dissimilarities between late Paleozoic and early Mesozoic faunas is due to lack of fossil records near the boundary between rocks of the two eras".

In western Wyoming the Dinwoody fauna consists of cephalopods, a few species of brachiopods, several pelecypod species, and one gastropod species. Newell and Kummel (31, p. 952) constructed a table showing the distribution of Dinwoody and Woodside fauna in southeastern Idaho, western Wyoming, and southwestern Montana. The species with asterisks are similar to those recognized by Girty 28/ as Lower Triassic fauna. "x" indicates presence of fossil.

	Lingula Zone	Claraia Zone	Woodside Tongue Equivalent
Discophiceras subkyokticum Spath (4)	x		
Metophiceras subdemissum Spath (4)	x		
Mentzelia sp ? (1)	x		
*Spiriferina mansfield	x		
*Mytilus? postcarbonicus Girty (3)	x		
*Pleurophorus? bregeri Girty (3)	x		
Lingula borealis Bittner (1)	x	x	
Myalina putiatinensis Kiparisova (3)	x		
*Myalina spathi, n. sp. (3)	x	x	x
Claraia clarai occidentalis, n. var.(3)		x	
Claraia stachei Bittner (3)	x	x	x
Claraia mulleri, n. sp. (3)		x	
Eumorphotis multiformis Bittner (3)		x	
Eumorphotis iwanowi Bittner (3)			x
*Myophoria, sp?		x	x
Anodontophora fassaenis Wissmann (3)		x	
Anodontophora canelensis Catullo? (3)		x	
Gervilleia assurica Kiparisova (3)		x	
Terebratula margaritowi Bittner (1)			x
*Bellerophon Bittner, n. sp. (2)		x	

(1) Brachiopoda
(2) Gastropoda
(3) Pelecypoda
(4) Cephalopoda

Woodside Fauna

In southwest Montana Richards and Pardee 34/ found abundant phosphatic pelecypod Lingula and fossils which were determined by Girty to belong to the Lower Triassic of Idaho, which has been suggested to be a Dinwoody, or possibly Dinwoody Woodside intertongues by Newell and Kummel 31/. Condit 13/ found Lingula in limestones along Indian Creek. A specimen of discophiceras was found in the Woodside near Melrose, Montana. Other Woodside fauna of Idaho and western Wyoming are listed on page 18 in column of Woodside Tongue Equivalent. Mansfield 28/ stated that the age determination of the Woodside and Thaynes formations is based upon Ammonite zones occurring over 1,000 feet above the top of the Paleozoic formations. He thus placed the upper limit of the Woodside formation as below the Meekoceras zone of the Thaynes formation.

Thaynes Fauna

As noted in the preceding paragraph, Mansfield placed the base of the Thaynes formation in the Meekoceras zone. Kummel 21/ lists Thaynes fauna of the western section in older to younger zones. In the Meekoceras unit cephalopods, pelecypods and lingulas are found. Above this is the Tiroletes zones containing myriads of brachiopods, pelecypods and ossicles of Pentacrinum. Lying above this is the Columbites shale zone containing abundant cephalopod-bearing concretions and pelecypods, overlain by a siltstone containing

interbedded limestones with sparse brachiopods and pelecypod fauna. Above this sparse amounts of small brachiopods are found.

Chugwater Fauna

The fossils in the Chugwater formation include marine invertebrates, land vertebrates, and fresh water invertebrates. Very few fossils have been found in the Red Peak member (Lower Chugwater). According to Love 25/, a poorly preserved Monotia, identified by J. R. Reeside, Jr., was found in the Wind River Basin. In the Alcova (Middle Chugwater) Branson and Branson 8/ state that a marine nothosour was found near Casper, Wyoming. Lee 24/ remarks that in several areas fossil invertebrates identified as Naiadites? and Natica lelia were found in the Alcova limestone.

In the Absaroka Range labyrinthodant teeth and bones were found in the Popo Agie (Upper Chugwater) by Collier 10/. Fragments of plant fossils and labyrinthodant teeth and bones were found in the Popo Agie member in the Absaroka Range, Love 26/. Near Lander, Wyoming, Berry 3/ described fossil plants and mentioned the common occurrence of several species of Unio, one of which was identified as Unio dumblie.

Love 26/ writes, "The presence of algae heads in the upper part of the Gypsum Spring member indicates that shallow-water conditions prevailed at that time and that the water was not saline enough to prohibit life".

Jelm and Spearfish Fauna

According to Lee 24/, the Jelm contains bones of Triassic vertebrates in beds of pebble conglomerate composed of small limestone pellets, wood fragments, and other unclassified material in the Laramie Basin. He also notes that similar material was found north of Medicine Bow. The Spearfish formation, as noted by Wilson 40/, is generally barren of fossils.

Structural Geology

The structural geology of Triassic strata is simple and of minor importance. Generally speaking, sometime during Upper Triassic time the region was gently warped and the strata somewhat beveled by erosion. With recurrent uplift and continued erosion, the Triassic sediments thinned to the north. Thus, toward the northern section, Upper Triassic strata is absent and north of south-central Montana all Triassic strata is missing.

Economic Geology

Oil or gas has not been found in the Chugwater formation in Montana, although the porous sandstones in this formation would make favorable reservoirs for oil or gas. It is thought that the northward thinning out of the Chugwater in south-central Montana is suggestive of the possible existence of stratigraphic traps in the zones of pinch outs, U. S. Geological Survey paper 16/.

Along the western margin of the Wind River Basin the isopach map indicates that there was an area of recurrent gentle folding trending northwest in this region, involving Lower and Upper Triassic strata. Since it is likely that this was not an early phase of the Laramide orogeny that formed the Wind River Mountains it is possible that the gentle folding may have influenced the accumulation of oil.

In various areas throughout Wyoming the Dinwoody formation has shown some oil stains, both on the surface and in subsurface sections. In fact, small amounts of black oil have been found in the sandstones of the Chugwater formation in some anticlines in western Wyoming. These shows of oil are found in various parts of the formation. U. S. Geological Survey Preliminary Chart 27/ states, "In most subsurface, and in some surface sections, however, there is oil standing in the sandstone directly overlying the Alcova limestone member. The Popo Agie member rarely has any oil staining, even on top of producing structures".

La Fleiche 22/ writes, "The Chugwater is productive in isolated cases in western Bighorn Basin fields, but the accumulation in sands of this series is thought to have migrated through fissure and faults from lower beds".

Of the Triassic formations the Dinwoody is the most important source zone. Under very favorable conditions it is possible for some of the Chugwater sandstones to produce commercial quantities of oil. However, generally these sandstones are of the silty type, having low porosity and

permeability, producing a black asphaltic oil that is hard to extract. According to State Map of Wyoming 33/, fields in Wyoming having productive formations in the Triassic are: The East Ferris, Garland, Grass Creek, Hamilton Dome, North Oregon Basin, and the Sage Creek Field.

Commercial deposits of gypsum are found in the Chugwater formation in Montana 35/. These are located in Carbon and Madison Counties and have not been extensively exploited. In Wyoming the workable gypsum deposits are found in the Chugwater and Spearfish formations. The Triassic gypsum beds in Wyoming have been used commercially since 1890, and as stated by Stone 35/, "The gypsum beds in Wyoming are so numerous and of such extent and purity that with proper facilities for transportation an enormous industry could be supplied".

ISOPACH MAP

Discussion

In the construction of the isopach map (Plate IV), equal thickness lines were drawn as though the area were a level surface with no interruptions. It is actually a plan drawing of the various thicknesses of the strata. The equal thickness lines begin in southern Montana at zero and continue to over 5,500 in eastern Idaho. The heavier lines are of 500 foot intervals, and the lighter lines represent 100 foot intervals. The dashed lines cover areas in which the writer found no thickness data, and are drawn according

to the general trends. The map is drawn as though the beds are continuous and uniform, with no allowance made for localities where beds are missing because of being truncated by uplift or other geologic structures.

Southwestern Wyoming and eastern Idaho show the greatest accumulation of Triassic strata. West of Lander, Wyoming, the sediments thicken rapidly over a short distance. Eastward the strata thins gradually, except in the Black Hills region where there is a slight thickening of beds. North toward southern Montana the strata uniformly decreases in thickness until an area is reached north of Billings where Triassic deposits are entirely missing in Montana. The irregularily of the thickness lines northwest of Lander suggest an area of recurrent gentle folding.

The general pattern of the isopach map seems to verify the history of Triassic strata. Triassic seas invaded the area from the west and southwest with the shoreline lying to the east. The thickest deposits lie to the southwest, reaching a thickness of over 25,000 feet in central Nevada. As shown on the map, the fairly rapid increase in thickness of strata over a short distance in southwest Wyoming would indicate a land area nearby. This was probably to the southwest in southern Idaho or in northern Utah.

The decrease in thickness of strata from southern Montana to central Montana represents a pinching out, or beveling of the strata due to erosion, probably caused by uplift with the upper beds being eroded during the latter

part of the period. The increase in thickness in strata in the Black Hills area was likely due to lagoonal deposition, as the marine seas of Triassic were oscillatory and this area represented one or more tongues of a marine sea that invaded a basinal area, leaving a lagoon as it withdrew.

SUMMARY

The Lower Triassic marine beds are composed of the Thaynes, Woodside, Dinwoody, Chugwater and Spearfish formations representing oscillatory marine invasions from the west and southwest. Sandstones, limestones, shales and gypsum were deposited and with the gradual withdrawl of the oscillating seas there was redeposition of tongues of limestones, shales and gypsum beds. Continental deposits (Rocky Mountain area), although limited as compared to marine sediments in this area, represent the largest land deposits in North America in Triassic time. The continental deposits of this area are represented by the Ankareh, Upper Chugwater and Jelm formations. The color of the red beds is due to hydration of certain ferric oxide compounds found in the beds, and their predominance is due to considerable redeposition of earlier beds. The isopach map was constructed as an aid to those concerned with Triassic strata, either through drilling operations or in correlation of strata. Some oil has been found in Triassic strata in Wyoming. Its importance lies in the possibility of oil being found in the future in Triassic rocks. The Triassic contains large quantities of commercial grade gypsum and is an important source of ground water in some areas.

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ISOPACH MAP OF TRIASSIC STRATA IN SOUTHERN MONTANA AND WYOMING

SCALE 0 10 20 30 40 50 60 MILES

R. G. THOMPSON APRIL, 1949

GREAT FALLS
BUTTE
BOZEMAN
BILLINGS
MILES CITY
DICKINSON
DILLON
LODGE GRASS
N. DAK.
S. DAK.
MONT.
WYO.
YELLOWSTONE NAT. PARK
CODY
SHERIDAN
DEADWOOD
RAPID CITY
IDA.
IDAHO FALLS
THERMOPOLIS
POCATELLO
LANDER
CASPER
NEBR.
SCOTTSBUFF
KEMMERER
RAWLINS
UTAH
GREAT SALT LAKE
SALT LAKE CITY
CHEYENNE
COLO.
FT. COLLINS