REGIONAL PHYSICAL STRATIGRAPHY OF THE TRIASSIC IN A PART OF THE EASTERN CORDILLERA

by

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BIOGRAPHICAL NOTE

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ABSTRACT

The Triassic strata of the Eastern Cordillera may be divided areally, by the Wasatch Line, into an eastern, shelf, facies and a western, miogeosynclinal, facies. Rock units in the shelf facies are the Moenkopi, Shinarump and Chinle formations aggregating about 1,000 feet in thickness. The units in the miogeosynclinal facies are the Dinwoody, Woodside, Thaynes and Timothy formations, which together form the Moenkopi group, and the Shinarump and Chinle formations, averaging 4,000 to 6,000 feet.

Isopach-lithofacies studies show an increase in limestones and finer clastics westward which is primarily due to the presence of the marine Thaynes formation.

Thaynes deposition west of the Wasatch Line was miogeosynclinal whereas all other Triassic units indicate deposition on a mildly unstable to stable shelf. Two moderally positive source areas in the region are indicated, one in Montana and Canada, the other in western Colorado.

Two Lower Triassic seas covered parts of the region; one, the Dinwoody Sea, was largely confined to the area west of the Wasatch Line, while the more extensive Thaynes Sea reached eastward to the southeastern Uinta Mountains and the San Rafael Swell.

REGIONAL PHYSICAL STRATIGRAPHY OF THE TRIASSIC IN A PART OF THE EASTERN CORDILLERA

INTRODUCTION

The Problem

The early geologic works containing stratigraphic data in the western United States have, with a few notable exceptions, been descriptive rather than interpretive and are usually confined to isolated districts or small areas. Investigators in these widely separated small areas of this patchwork pattern of geologic investigations have been reluctant, and properly so, to make long distant rock and time-rock correlations. These more or less local stratigraphic efforts, usually presented in a small section of a report primarily concerned with other aspects of geology, have frequently introduced purely local sets of stratigraphic names which later become unnecessary and undesireable synonyms.

A sufficient quantity of literature, supplemented in recent years by well logs, is now available to integrate and interpret this descriptive stratigraphic material in its regional aspects. During the past few years several excellent papers have been published dealing with the regional behavior of a few of the stratigraphic units in the western United States. Noteworthy examples of these are papers by Krumbein and Nagel (1953) on the Cretaceous, Andrichuk (1951) on the Devonian and Schmitt (1953) on the Jurassic. To date, however, no such regional interpretive study has been made for the Triassic, although, limited aspects of the problem have been treated by Moritz (1951) in southwestern Montana and Newell and Kummel (1942) in southeastern Idaho and southwestern Wyoming.

This study was undertaken in order to help fill a gap in our knowledge of the nature and behavior of the Triassic units in a part of the eastern Cordillera, to provide a more accurate and useable system of stratigraphic nomenclature, to give a better understanding of regional relationships and correlations, and in so doing to help provide a better basis for the interpretation of Triassic history, paleogeography and paleotectonics.

The Area

It was originally intended to limit the scope of this study to the critical transition area, between the shelf and miogeosynclinal environments, in northern Utah and northeastern Nevada and this is still the area of principal concern since most of the time in the field was spent in this region. However, as the work progressed, it seemed desireable in order to better understand the regional relationships of the Triassic strata, to visit and examine numerous other sections in southern and eastern Utah, western Colorado, Wyoming, southeastern Idaho, Montana, northern Arizona, and the Black Hills of South Dakota. To further understand the broad regional setting much of the Triassic literature for western North America was reviewed.

Previous Work

The Triassic sequence of the Colorado Plateau Province has for many years been well known and understood from the efforts of many fine geologists, among whom, Gilbert, Gregory, Baker and Gilluly have made outstanding contributions. Included in their reports one finds many good measured sections which are readily useable in interpretive studies. As a result of the relatively simple structure and excellent exposures in the Colorado Plateau region and the rather large areas covered in some of the studies, the regional relationships have been fairly well understood, and the same set of stratigraphic names has generally been used.

The units of the Colorado Plateau region have long been recognized in the Uinta Mountains, but the nomenclature has been unnecessarily revised in recent years by Williams (1945) and Thomas and Krueger (1946).

The work in western Utah and southeastern Idaho has largely been confined to isolated mining districts. Regional correlations are few and regional relationships are very poorly understood. Formational names are generally local and synonymous. Mansfield in southeastern Idaho and Boutwell in the Park City District, Utah have made the most significant contributions.

The Triassic of northeastern Nevada has been completely neglected in the past and, except for one locality reported by Smith (1932), was thought to be absent. Not a single measured Triassic section in northeastern Nevada has previously been available in the literature. It is interesting to note that the Geologic Map of the United States (Stose and Ljungstedt 1932) shows no Triassic in northeastern Nevada, and the paleogeographic map of Schuchert (1933) shows a Triassic positive in this area where the writer has measured several thousand feet of marine Triassic strata.

The fine works of J. P. Smith (1904, 1927, 1932) have provided invaluable information on the marine invertebrate faunas of the Cordilleran Region.

Designation of Unit

The Triassic sequence as used in this paper includes those strata which correspond as nearly as is known to the Triassic system, but since the exact time-stratigraphic position of both upper and lower system boundries is in question the writer prefers to use the non-standard term sequence as recommended by Wheeler et. al. (1950) rather than the standard designation, system. As thus defined the Triassic sequence includes all of the strata overlying the highest fossiliferous Permian rocks (Kaibab, Park City, Phosphoria, etc.) and underlying the massive Jurassic ? sandstones (Wingate, Navajo, Nugget) and includes the Moenkopi formation (or group), the Shinarump conglomerate, and the Chinle formation. The Triassic sequence in this region is therefore purely a rock unit and is in no sense an exact time-rock unit. The designation Triassic system has previously been used in the same sense as sequence is here applied.

Outcrops

Strata of the Triassic sequence crop out extensively in the Canyon Lands of the Colorado Plateau, particularly in the southern part. In the northern Canyon Lands the Triassic is exposed in the canyons of the Colorado and Green Rivers and in the center of the San Rafael Swell. A belt of Triassic strata extends along the south flank of the Uinta Mountains interrupted occasionally by Tertiary cover but well exposed at the east end of the range and in most of the canyons. In the Wasatch Mountains the Triassic is present in several of the canyons near Salt Lake City, namely Dry, Red Butte, Parley's, Mill Creek, and Big Cottonwood. Additional Wasatch Mountain exposures occur in the Park City District, and in the lower Weber River Canyon near Devil's Slide. The southeastern Idaho sections of the Fort Hall - Montpelier region are described by Mansfield (1927).

In the High Plateaus of Utah the Triassic for the most part is covered by younger strata but crops out in Spanish Fork Canyon near Thistle, Utah and on the west side of the Pavant Plateau near Fillmore, Utah and more extensively along the Hurricane Escarpment near Cedar City, Utah.

In the Basins and Ranges of western Utah and eastern Nevada, Triassic outcrops are scarce and scattered, and complete sections are almost entirely lacking. The only sections known to the writer occur in the Mineral Range near Minersville, Utah; the San Francisco Mountains west of Milford, Utah; the Confusion Range, Millard County, Utah; the Gold Hill District, Utah; the Muddy Mountains in southeastern Nevada; and Phelan Mountain near Phelans Ranch, Elko County, Nevada. A well exposed and almost complete section has been reported by Wheeler et. al. (1949) in Currie-Dolly Varden Valley north of Currie, Nevada, and these same strata extend northward along the east flank of the Pequop Range. An incomplete, poorly exposed and badly faulted, but previously unreported, section occurs about 20 miles south of the Wendover junction of Highways 50 and 40, Elko County, Nevada, along highway 50 between Gold Hill and Wendover.

Rocks which suggest uppermost Paleozoic or Triassic age occur at several other localities in northeastern Elko County, Nevada and have been called to the writer's attention by Harry E. Wheeler (personal communication). At one of these localities, a few miles north of Montello, Nevada several thousand feet of Lower Triassic strata are present and include an excellent Meekoceras zone ammonoid fauna. The writer has so far been unable to confirm a definite Triassic age for the other localities although rock types are suggestive of Triassic strata.

Field Work

The writer first became interested in the problems and aspects of the Triassic rocks in Utah during a summer field course with the University of Utah in 1940. A second summer field course in 1946 revived this interest and while engaged in commercial work during the latter part of the summer of 1946 and during the summers of 1947 and 1948 opportunity was provided to visit and examine many Triassic sections in Utah and Colorado. The summer of 1949 was spent in detailed examination and measurement of sections particularly in the Uinta and Wasatch Mountains of Utah and in northeastern Nevada. Further sections were examined and measured during the summers of 1950, 1951, 1952 and 1953.

All sections were measured by tape and brunton traverse and computed to true stratigraphic thicknesses. Fossils were collected wherever they could be found and their position in the section noted. The specimens are on file as Lot No. 1, University of Washington, Department of Geology, Thesis Collections. Several sections which have previously been measured and published were examined and paced to verify the published data.

GENERAL STRATIGRAPHY

Throughout Utah and eastern Nevada the Triassic sequence consists essentially of three litho-stratigraphic units, which from the base upward are the Moenkopi formation (or group), the Shinarump conglomerate, and the Chinle formation. The upper two units (Shinarump and Chinle), though they exhibit considerable local variations, maintain a remarkably uniform average regional thickness and lithologic aspect. The lowest unit (Moenkopi), on the other hand, shows general and considerable changes in thickness and lithologic aspect, principally due to the inclusion of marine sediments in the western area. These changes in lithofacies result from the differences in depositional environment from a shelf environment in the eastern part of the region to a miogeosynclinal environment in the western part. Thus, for convenience in discussion the region is separated into two parts, the eastern or <u>shelf facies</u> and the western or <u>miogeosynclinal facies</u>, although this separation in a strict sense is applicable only to the Moenkopi group. (Fig. 1, page 9.)

The lithologies and thicknesses typical of these two facies are shown in the generalized sections Fig. 2, page 10.

Shelf Facies

The area of the shelf facies includes, in general, the Colorado Plateau Province extending southward into Arizona, eastward into western Colorado, and northward to the eastern Uinta

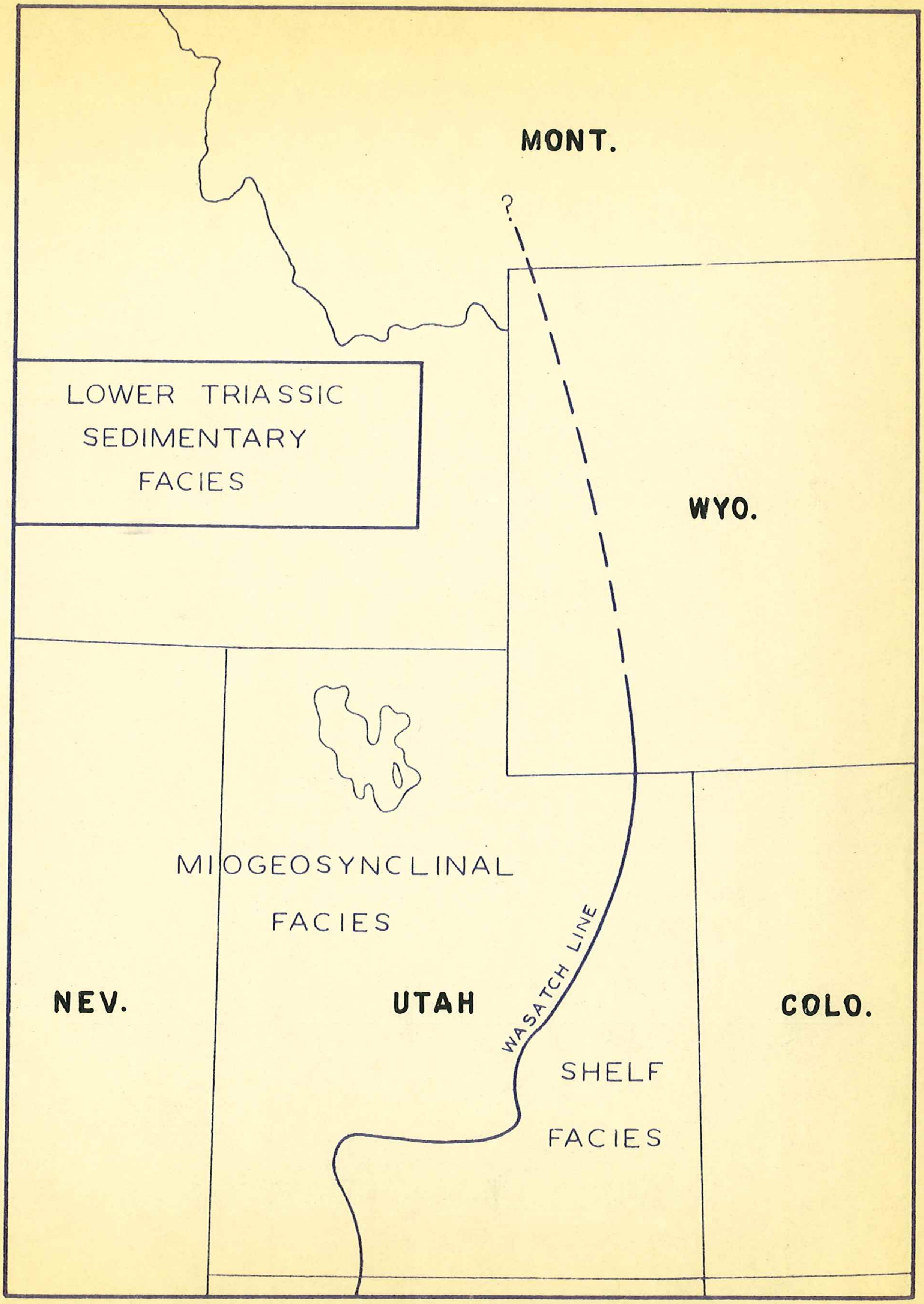


Fig. 1.--Distribution of Shelf and Miogeosynclinal Facies

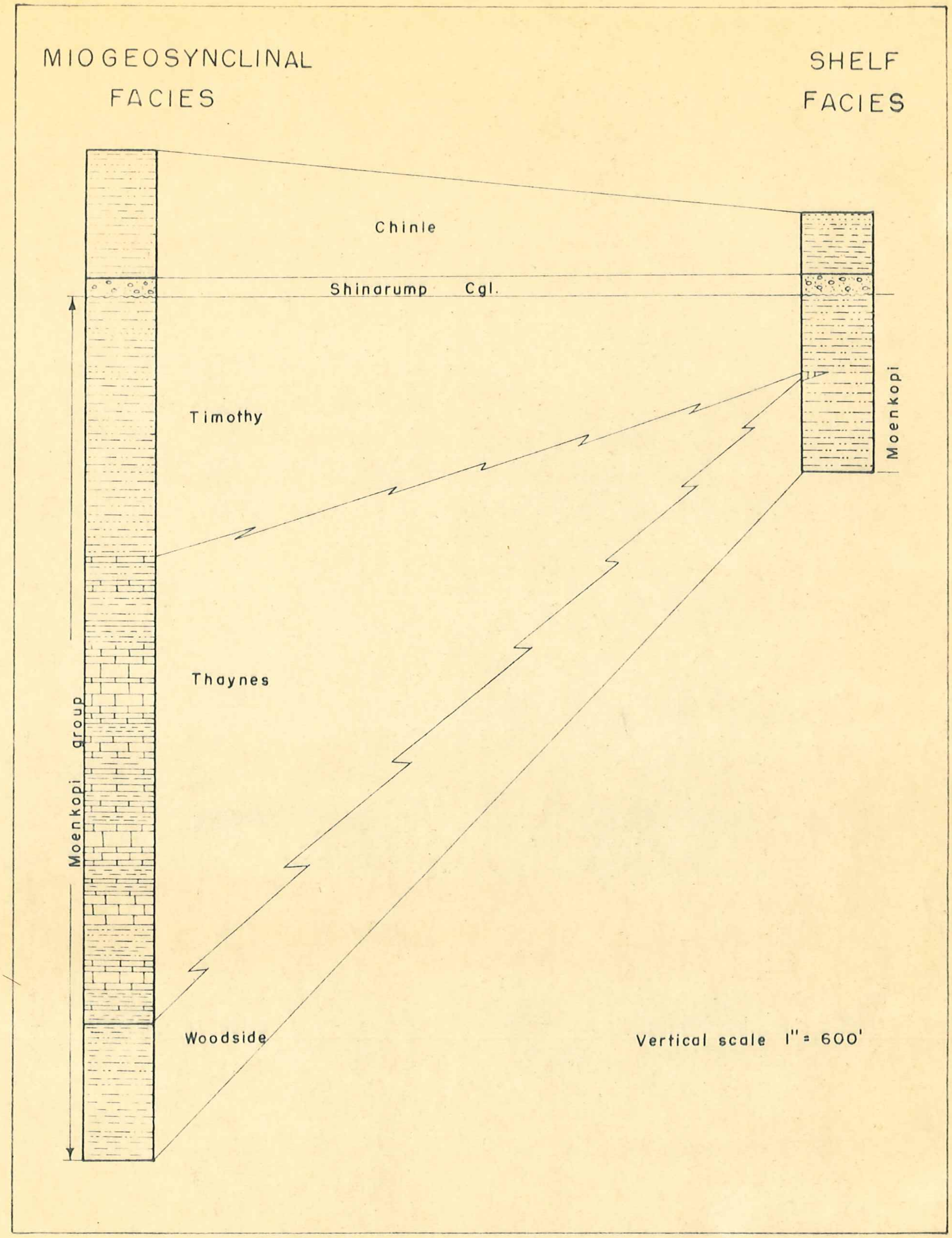


Fig. 2.--Generalized Sections Typical of the Shelf and Miogeosynclinal Facies.

Mountains, Wyoming and Montana. On the west the boundary between the shelf and the miogeosynclinal facies must be somewhat arbitrarily defined. A convenient and workable line of separation is the 1,000 foot isopach of the Moenkopi group. A line thus defined would generally follow the eastern margin of the High Plateaus of Utah, the eastern flank of the Wasatch Mountains, and pass through the center of the Uinta Mountains (see map Fig. 1, page 9). This boundary generally corresponds to the Wasatch Line of Kay (1947) and will be so referred to in this paper.

The Moenkopi formation of the shelf facies is widely exposed in the canyons of the Colorado Plateau and on the flanks of the eastern end of the Uinta uplift. The thickness of the formation ranges from 0 to 1,000 feet. Maximum thicknesses of the Moenkopi formation occur along the Wasatch Line at the western margin of the shelf facies while the formation wedges out to the eastward near the Utah-Colorado line. Baker (1933, p. 35) describes such thinning near Moab, Utah. From the maximum of 1,000 feet the thickness decreases, though not uniformly, toward the east. This decrease is accomplished largely by a thinning and lensing out of individual beds.

The predominant lithology of the Moenkopi is evenly thin bedded, dull reddish brown siltstone and mudstone with many thin beds of dusky red shale and silty sandstone. These are interbedded with more resistant, gray to yellowish gray, calcareous sandstones which form ledges. At some localities one or more silty, brownish gray limestone members are present. The sand and silt grains are principally subrounded quartz, cemented by ferric oxide and calcium carbonate. Feldspar, mica flakes and disseminated gypsum plates are common, greenish gray beds and spots probably resulting from the reduction of ferric oxides by organic material also appear frequently. Ripple marks of both the current and oscillation types are characteristic. Mud cracks (Dane 1935, p.52) and rain drop impressions (Longwell, et. al., 1923, p. 18) have been observed. Veinlets of gypsum are numerous and bedded gypsum also occurs (Baker, 1933, p. 34; Dane, 1935, p. 44).

In the flat lying strata of the Colorado Plateau the non-resistant beds of the Moenkopi formation characteristically form reddish brown slopes, laminated by frequent ledges of thin bedded, more resistant sandstone. These slopes generally steepen toward the top where they are capped by the more resistant Shinarump conglomerate. Along the flanks of the Uinta Mountains and in other folded areas the formation typically forms a red strike valley between the dip slope of the underlying Phosphoria and the hogback of the overlying Shinarump.

Throughout most of the shelf region the Moenkopi is disconformably underlain by the Kaibab limestone. In the Uinta Mountains the Phosphoria is the underlying formation and along the Utah-Colorado boundary the Moenkopi successively overlaps the Cutler, Rico and Hermosa formations (Baker, 1933, pp. 33-34; McKnight, 1940, p. 61). The unconformity at the base of the Moenkopi is angular in a few places along the Utah-Colorado line, but more commonly is represented by a channeled surface on the concordantly underlying Kaibab limestone. Locally, conglomerates at the base of the Moenkopi contain material derived from the underlying Kaibab. To the north and west the unconformity, if present, has not been distinguished by the writer.

The Shinarump conglomerate of the shelf facies crops out over considerable areas of the Colorado Plateau and along the flanks of the Uinta Mountains. The formation, which is remarkably persistent, varies in thickness from 0 to 200 feet. However, only rarely and locally does it exceed 100 feet, and most commonly its thickness is between 50 and 70 feet.

Lithologically, the Shinarump is usually composed of white, gray, or pale lavender gray, fine to coarse grained quartzitic sandstone with lenses of pebble conglomerate. The pebbles seldom exceed 3 inches in diameter and usually measure less than ½ inch. The pebbles are predominantly white quartz, red, gray, or white quartzite and chert, although occassional pebbles of clay, sandstone, and limestone are also present. Igneous derived rocks and feldspar have been reported by Baker (1933, p. 38) to occur in the Shinarump in the Moab Region. Lenses of shale and siltstone are common. Silicified wood, occuring as large logs, angular fragments and rounded pebbles or cobbles, is abundant. Cross bedding and ripple marks are numerous.

In the Colorado Plateau country the Shinarump commonly crops out as a conspicuous cliff capping the less resistant Moenkopi slope. A broad stripped surface is frequently developed on top of the Shinarump where the softer Chinle formation has been removed. In folded regions such as the Uinta Mountains the Shinarump normally forms a small white hogback between the red strike valleys of the softer Moenkopi and Chinle formations.

The contact between the Shinarump and underlying Moenkopi is a distinct erosional disconformity, exhibiting local relief of as much as 50 feet in a few miles. Locally, the basal Shinarump fills distinct channels cut into the upper surface of the Moenkopi. The Shinarump is everywhere overlain by the Chinle formation, the contact being conformable and generally gradational.

The Chinle formation is usually exposed in the Plateau region as a slope between the stripped Shinarump surface and the conspicuous overlying cliff of Jurassic ? sandstone. Where folded, the Chinle forms a red strike valley between Shinarump and Jurassic ? sandstone hogbacks.

In lithology the Chinle consists principally of variegated, light red, dark red, gray, green, calcareous shales and siltstones, and occasionally with thin beds of silty limestone, and lenses of pebble conglomerate. The red shales and siltstones are frequently mottled by green spots where the ferric oxides have been reduced around organic centers. The thin intercalated green layers probably owe their color to similar organic reduction. Ripple marks (both current and oscillation types) and mud cracks are common, silicified wood is abundant. The thickness of the formation varies from about 100 to 1,000 feet, but thicknesses of 400 to 500 feet are most common.

The contact between the Chinle and the overlying sandstones is sometimes sharp but more often gradational. In the latter case it is usually necessary to select a contact arbitrarily within a 20 to 30 foot sequence of interbedded shales and sandstones. The writer has been unable to find evidence of an unconformity between the Chinle formation and the overlying Jurassic ? sandstones.

Miogeosynclinal Facies

The known extent of the miogeosynclinal facies lies between the Triassic Wasatch Line on the east and eastern Nevada on the west. The nature and position of the boundary between the Triassic miogeosyncline and the eugeosynclinal sediments in Nevada are as yet unknown because of the apparent absence of Triassic outcrops in this critical region. Strata of the miogeosynclinal facies crop out in the western Uinta Mountains, the Wasatch Mountains, the basin ranges of western Utah and eastern Nevada and the mountains of southeastern Idaho.

The gross lithology, thicknesses, and other characteristics of the Chinle formation and Shinarump conglomerate are so similar to the description of these units in the shelf facies that the previous descriptions serve equally well here. The actively negative Triassic miogeosyncline which provides the basis for the differentiation of these two facies was present in this region only during the depositional interval of the Moenkopi group, which corresponds in a loose sense to Lower Triassic time.

The Moenkopi group of the miogeosynclinal facies differs from the Moenkopi formation of the shelf facies by its content of an appreciable thickness of marine sediments, and by the finer grain size of its clastic rocks. The formations of the Moenkopi group, from the base upward, are: (1) Woodside shale, 100 to 1,000 feet of remarkably uniform, red, silty shale and siltstone; (2) Thaynes formation, 100 to 4,000 feet of gray to pale brown, fossiliferous limestone, shaly limestone, shale, and calcareous sandstone; (3) Timothy formation, 200 to 1,500 feet of red shales and siltstones, with interbedded reddish purple and reddish brown sandstones.

The Woodside formation overlies the Phosphoria formation in northern Utah and disconformably overlies the Kaibab formation in central Utah. The disconformity is usually indicated by a weathered and silicified zone at the top of the Permian limestones, by some channeling on the limestone surface, and by the occasional presence of material derived from Permian limestones in the basal Woodside. The soft red shales and siltstones of the Woodside usually form strike valleys between the more resistant limestones of the Phosphoria and Thaynes formations, or in strata that dip less steeply, the Woodside beds form red slopes beneath cliffs of Thaynes limestone.

In southeastern Idaho and southern Wyoming the rocks occupying the same stratigraphic interval as the Woodside formation consist of greenish gray marine shales and thin, interbedded, brownish gray limestones. This unit has been designated the Dinwoody formation in southern Wyoming. The name Dinwoody is therefore extended to southeastern Idaho, and to those rocks of similar lithology and stratigraphic position in the Wasatch Mountains. The Dinwoody formation of these regions is regarded as a marine facies of the generally continental Woodside formation of northern Utah. Southward in Utah and in Nevada the Woodside and Dinwoody formations thin appreciably until rocks similar in lithology to the Thaynes rest directly upon the Permian. This relationship is encountered in the San Francisco Mountains of west-central Utah, in northeastern Nevada, and is reported by Longwell (1949, pp. 929-31) in the Muddy Mountains of southeastern Nevada.

The Thaynes formation, which contains appreciable amounts of limestone, commonly forms ridges and cliffs in the miogeosynclinal area. The Woodside-Thaynes contact is usually well defined though conformable, however, the adjacent parts of the two formations appear to intertongue laterally. In southern Utah and southern Nevada the lower part of the Moenkopi formation consists of marine sandstone, shale, and some Thaynes-like limestone. Although this lower member of the Moenkopi is undoubtedly a lithofacies of the basal Thaynes in this region, the difference in lithology is sufficiently great that a different designation is justified, and for the present, at least, the writer regards this unit as a lower marine member of the Moenkopi formation. This two fold separation of the Moenkopi is recognized by Gregory and Anderson (1939, pp. 183-4) and Longwell (1949, p. 931).

The Timothy formation usually forms a slope of red ledges beneath the more resistant Shinarump conglomerate, or with the Chinle formation, a red valley between hogbacks of Thaynes limestone and Jurassic? sandstone. The contact with the Thaynes is conformable and sharply defined where well exposed. The upper surface of the Timothy formation is an erosional disconformity showing about 100 feet of local relief due to Shinarump channeling. The Timothy is thin (200 to 800 feet) and consists predominantly of fine grained sandstone in southeastern Idaho but becomes much thicker (up to 1,300 feet) and includes more fine grained clastics in the Wasatch and Uinta Mountain regions.

The Thaynes formation thins and disappears to the east along the Uinta Mountains, and to the southeast in the Colorado Plateau. Beyond this wedge-edge of Thaynes the Timothy and Woodside lose their identity as separate formations and coalesce to constitute the Moenkopi formation.

NOMENCLATURE

Shelf Facies

The names applied to the rock units of the shelf facies have in general been correctly used since the Chinle was named by Gregory (1915). However, recent work by Williams (1945) and Thomas and Krueger (1946) has unnecessarily introduced new designations for these units in the Uinta Mountain area. The nomenclatural history of the shelf facies is summarized in Fig. 3, page 20.

Gilbert (1875, p. 175) and Howell (1875, p. 272) recognized the tripartite nature of the Triassic sequence in southern Utah. They referred to the lower red beds as the "Lower Shales", the conglomerate above as the Shinarump conglomerate, and the upper red beds as the "Upper Clay". Powell (1876), in the Uinta Mountains, called the whole sequence the "Shinarump Group" which he divided into "Lower Shinarump", Shinarump conglomerate, and "Upper Shinarump". Ward (1901), in the Little Colorado Region, designated the lower red sediments as the "Moencopi" beds, taking the name from Moencopi Wash in Arizona. The remaining units he designated as the Shinarump, dividing them into Shinarump conglomerate and "LeRoux" beds.

Gregory (1915) referred the lower two units to the Moenkopi and Shinarump, and introduced the name Chinle for the upper formation. In 1920 he further described them, although he

Rock	Gilbert 1875 S. Utah	Powell 1876 Uinta	Ward 1901 Little Colo.	Gregory 1915 Navajo	Williams 1945 E. Uinta	Thomas & Krueger 1945 E. Uinta	This Paper Shelf Facies
	Upper Clay	Upper Shinarump	Le Roux	Chinle	Chinle	Stanaker	Chinle
	Shinarump	Shinarump	Shinarump	Shinarump	Shinarump	Gartra	Shinarump
	Lower Shales	Lower Shinarump	Moencopi	Moenkopi	Red Wash	Woodside	Moenkopi

Fig. 3.--Nomenclatural History of the Shelf Facies

mistakenly regarded the Moenkopi as Permian and stated that it underlies the De Chelly sandstone. Later work by Baker and Reeside (1929) has shown that true De Chelly is a tongue of the Upper Coconino and is overlain by Moenkopi at Canyon De Chelly. Gregory did not explain the change in spelling of Moenkopi from Ward's original "Moencopi", but since the name of the type locality (Moenkopi Wash) appears on maps as Gregory spelled it, and since this spelling appears in the Lexicon of Stratigraphic Nomenclature (Wilmarth, 1938), the change now appears preferable. The "Le Roux" of Ward appears to have been a valid designation for the unit later called Chinle by Gregory, but in view of the wide usage and acceptance of the term Chinle it is undesirable at this late date to employ the prior term.

The names Moenkopi, Shinarump and Chinle have been widely employed in the Colorado Plateau by Baker (1936), Reeside (1929), Dane (1935), Gilluly (1929) among others, and are accepted by the Committee on Geologic Names of the United States Geological Survey (Wilmarth, 1938). These formations have been extended to the Uinta Mountains by Kinney (1947), Untermman (1949) and others. This extension is here accepted and recommended in the interest of unification of regional stratigraphic nomenclature.

Williams (1945) used Chinle and Shinarump for the upper units in the eastern Uinta Mountains but employed the new name "Red Wash" formation for beds previously designated as Moenkopi. He states (pp. 477-8):

> As the Woodside, Thaynes and Ankareh (restricted) formations are traced eastward along the south flank

> of the Uinta Mountains each becomes thinner, and in the vicinity of Whiterocks Canyon the Thaynes limestone tongue disappears completely. It is clear from these relationships that the red beds east of that point are in part equivalent to the Ankareh (restricted) sandstone and shale, and in part to the Woodside shale. Neither term alone can appropriately be applied to them however. These beds are sometimes designated the Moenkopi formation, but this name is not completely satisfactory because all of the Moenkopi, at least in the Zion Canyon Area, is younger than the Woodside shale, the Meekoceras zone lying at the base of the former in the Zion Canyon Area, (Newell and Kummel, 1942, p. 938), and above the latter (in the base of the Thaynes limestone) in southeastern Idaho (Kummel, 1943, p. 319).

Williams' objection to the use of either "Ankareh" or Woodside to designate this unit is perfectly valid and readily understandable, but his objection to the use of Moenkopi does not conform to the recommendations of The Stratigraphic Commission. (Ashley, et. al., 1933). Article 6 states in part (p. 432):

> It is not necessary that a formation be of precisely the same age at different localities, and there may be a marked difference in age from place to place.

Schenck and Muller (1941), Wheeler (1947), and many others have demonstrated the validity of using the same formational name for temporally transgressive rock units. Moreover, the presence of Meekoceras 15 feet above the Kaibab in the Zion Canyon area, as reported by Newell and Kummel, is neither a universal nor a common position for that genus. Gilluly (1929) reports Meekoceras in the "Sinbad" member of the Moenkopi in the San Rafael Swell, Utah, 183 feet above the top of the Kaibab, while McKnight (1940, pp. 57-8) reports Meekoceras? 220 feet above the base of the Moenkopi along the Green River in Utah.

Thomas and Krueger (1946, p. 1271) introduced the new name "Stanaker" to include the units formerly called Chinle and

Shinarump in the eastern Uinta Mountains, and recognized the "Gartra" grit (basal member of the "Stanaker") as the equivalent of Shinarump. They called the lower red bed member Woodside. The objection to the use of Woodside for this unit is pointed out by the quote from Williams above and is also recognized by Thomas and Krueger (1946, p. 1267) who say:

> East of the wedge-edge of the Thaynes, the single red-beds unit might be referred to as "Woodside-Ankareh," but the use of such hyphenated names is not in accord with the best principles of stratigraphic nomenclature.

They suggested the possibility of a new name for this unit but preferred the use of Woodside alone to avoid the introduction of a new name. Unfortunately they showed no such reluctance to introduce new terms in the case of the overlying "Gartra" and "Stanaker". They offered no reasons why the term Moenkopi is not acceptable for the unit which they called Woodside. Thomas and Krueger correlated their "Gartra" and "Stanaker" with Shinarump and Chinle but introduced the new names because of the possibility of slightly different ages of the units. The writer's objection to this line of reasoning is pointed out above in the case of Williams' "Red Wash".

In summary, the writer recommends the use of the names Moenkopi, Shinarump, and Chinle over the entire area of the shelf facies (as they generally have been employed) where the tripartite division is recognizable by reason of the presence of the Shinarump conglomerate. The recent revisions and the introduction of new formational names by Williams and by Thomas and Krueger in the eastern Uinta Mountains are considered neither necessary nor justified. Eastward in Colorado and northeastward in Wyoming this three-fold division becomes unrecognizable, due in part to the absence of the Shinarump and in part to the inclusion of older red bed units. Since these areas lie beyond the limits of the present study no recommendations are made for the nomenclatural treatment of Colorado and Wyoming Triassic.

Miogeosynclinal Facies

The formational names applied to the various units of the miogeosynclinal facies have been frequently revised and are not yet satisfactorily designated. The nomenclatural history of the miogeosynclinal facies is summarized in Fig. 4, page 25.

The units of this facies were first named by Boutwell (1907) in the Park City area. He recognized from the base upward: Woodside shale, Thaynes limestone, and "Ankareh" formation. The Woodside shale and Thaynes limestone as proposed by Boutwell are valid litho-stratigraphic units, but the "Ankareh" of Boutwell included four distinctly separate, easily recognized, mapable lithologic units; a lower red bed sequence, a thin conglomeritic sandstone, an upper red bed sequence, and at the top a thick massive sandstone. Veatch (1907) in southwestern Wyoming recognized Woodside and Thaynes, but applied the name Nugget with a basal red bed member for the same units called "Ankareh" by Boutwell. Gale and Richards (1910) in an attempt to reconcile the usages of Boutwell and Veatch restricted both Nugget and "Ankareh". The lower red bed units were called "Ankareh", and the massive sandstone at the top was called Nugget. Boutwell (1912 and 1933) accepted this revision and applied it to the

Rock	Boutwell 1907 Park City	Veatch 1907 SW. Wyo.	Gale & Richards 1910 SE. Idaho	Boutwell 1912 Park City	Mansfield 1916 SE. Idaho	Mansfield 1920&27 SE. Idaho	Mathews 1931 Wasatch	Williams 1945 Wasatch	Thomas & Krueger 1946 W. Uinta	This Paper Miogeosynclinal Facies
	Ankareh	Nugget: Yellow ss. memb.	Nugget	Nugget	Nugget: Main ss.	Nugget	Nugget	Nugget	Nugget	
		Nugget: Red Bed memb.	Ankareh	Ankareh	Nugget: Wood	Wood		Wood	Stanaker	Chinle
					Nugget: Deadman	Deadman				
					Nugget: Higham	Higham		Higham	Stanaker: Gartra	Shinarump
					Ankareh	Timothy		Ankareh	Ankareh	Moenkopi Group: Timothy
	Thaynes	Thaynes	Thaynes	Thaynes	Thaynes	Thaynes	Emigration	Thaynes	Thaynes	Moenkopi Group: Thaynes
							Pinecrest			
	Woodside	Woodside	Woodside	Woodside	Woodside	Woodside	Woodside	Woodside	Woodside	Woodside

Fig. 4.--Nomenclatural History of the Miogeosynclinal Facies

Park City Area. This revision was generally used by most authors until recently and is accepted by the Committee on Geologic Names of the United States Geological Survey (Wilmarth, 1938). Later work by Mansfield (1920, 1927), Williams (1945), Thomas and Kreuger (1946), and Scott (1950), has shown that the "Ankareh", even as revised, contains three distinct litho-stratigraphic units, upper and lower red bed units separated by a conglomeritic sandstone.

Mansfield (1916) further restricted the "Ankareh" to the red beds below the conglomeritic sandstone; while the term Nugget was applied to the conglomeritic sandstone and overlying rocks. His Nugget was subdivided into the following members: Higham grit, Deadman limestone, Wood shale, and Main sandstone (or "typical Nugget"). Mansfield (1920) later restricted the Nugget sandstone to what he had formerly called the Main sandstone or typical Nugget member and raised Higham grit, Deadman limestone, and Wood shale to formational rank. At the same time he abandoned the use of the much restricted "Ankareh" saying (p. 62):

> The term Ankareh shale cannot be retained in southeastern Idaho without confusion and is therefore dropped from the classification of that area.

He proposed the new name Timothy sandstone for the rocks occupying the interval between the top of the Thaynes limestone and the base of the Higham grit.

In some areas the Thaynes limestone may be separated into several units. Mansfield (1916) in the Fort Hall area of Idaho raised the Thaynes to group rank and recognized three formations, Ross limestone, Fort Hall formation, and Portneuf limestone. He later (1927) carried this nomenclature into the Montpelier area of southeastern Idaho. Mathews (1931) in the Wasatch Mountains also treated the Thaynes as a group with two formations, the Pinecrest and Emigration, basing his division on both lithologic and paleontologic evidence. The writer has been able to recognize a rough three-fold division of the Thaynes in the western Uinta Mountains and in the Park City district, where the formation comprises lower gray limestones, middle red argillaceous limestones and calcareous shales, and upper yellowish gray limestones. However, these units are not present in the Wasatch Mountains where the writer was unable to recognize with any assurance even the two fold division proposed by Mathews. On the basis of further work it may be possible to recognize a fundamental, three-fold, regional division of the Thaynes, but at the present time such attempt does not seem justified. Therefore, it is recommended that any subdivided units of the Thaynes that are useful locally should be regarded only as members of the Thaynes formation until a regional continuity can be demonstrated.

In an effort to apply valid litho-stratigraphic names for the three units formerly called "Ankareh", Williams (1945) proposed that "Ankareh" be restricted to the red beds above the Thaynes limestone and below the conglomeritic sandstone. He called the conglomeratic sandstone Higham grit, since it can be traced northward and is found to be identical with the type Higham. He further stated (p. 474):

> ....the grit may be recognized as the typical Shinarump conglomerate of the Colorado Plateaus province. That is the grit in the Ankareh formation of Boutwell, is

> the extension, into the area of the central Wasatch Mountains, of the Shinarump conglomerate.

The writer has confirmed the correlation of the Higham grit of southeastern Idaho with the grit in the "Ankareh" formation of Boutwell and this in turn with the Shinarump conglomerate of the Colorado Plateau. Williams, however, in extending the name Higham, has ignored the rule of priority and the principle of wider and greater usage, both of which favor the extension of Shinarump rather than Higham.

Since the red beds above the conglomeritic sandstone are lithologically similar to and occupy the same stratigraphic interval as the Wood shale in southeastern Idaho, Williams recommended the extension of this name into the Wasatch Mountains. He reported that this unit when traced along the south flank of the Uinta Mountains becomes the typical Chinle formation of the Colorado Plateaus.

Thomas and Krueger (1946) agreed with Williams in the restriction of the "Ankareh" to the red beds below the conglomeratic sandstone but proposed the new formational name "Stanaker" for the sandstone together with the overlying red beds. The name "Gartra" was proposed for the sandstone as the basal member of the "Stanaker formation." Regarding the correlation of the "Stanaker" they stated (p. 1275):

> In summary it may be said that lithologic and stratigraphic position favor a correlation of the Stanaker with the Shinarump and Chinle........

The proposal of new names for these two units appears to be without justification since by their own correlation Thomas and Krueger demonstrate that valid prior names exist for the units which they call "Stanaker" and "Gartra."

The writer is in close agreement with the efforts of Williams and of Thomas and Krueger to assign valid litho-stratigraphic names to the various units of the Triassic miogeosynclinal facies but is of the opinion that regional relationships and the "Stratigraphic Code" (Ashley et. al., 1933) require the assignment of a somewhat different nomenclatural scheme.

In recent years the use of the much restricted term "Ankareh" has become increasingly confusing, and it is usually necessary either to describe the rock units referred to, or refer to whose version of "Ankareh" is being used. This ambiguity indicates that the name has outlived its usefulness for which reason it is here recommended that the term "Ankareh" be dropped from the stratigraphic nomenclature of the region. The first valid name for the litho-stratigraphic unit between the top of the Thaynes limestone and the base of the thin conglomeritic sandstone is the Timothy sandstone, proposed by Mansfield (1920, p. 62) in southeastern Idaho. Although the Timothy of Mansfield's area is somewhat sandier than the unit occupying the same stratigraphic interval in the central Wasatch Mountains, intervening outcrops establish the continuity of the unit, and the change in lithology is one of facies magnitude. The exposures along the lower Weber River near Devil's Slide, Utah are intermediate in both location and lithology between the two areas. It is therefore recommended that the name Timothy be extended throughout the region for this unit wherever it may be recognized by virtue of the presence of the underlying Thaynes and overlying thin conglomeritic sandstone. W. W. Ruby (personal communication) has called attention to areas in southwestern Wyoming where the Timothy, as here extended, is no longer recognizable due to the absence of the thin conglomeritic sandstone. In such areas the red beds of the Timothy and those corresponding to the Wood shale of southeastern Idaho cannot be practically separated. Ruby suggests the possible use of "Ankareh" for this unit. Because this area is outside the limits of the present detailed investigation, no specific recommendation is made. However, since the type section of the "Ankareh" near Park City, Utah would no longer contain "Ankareh" as such, it seems inadvisable that this name be used in Wyoming. A better solution would be the use of a different name for this unit with an appropriate Wyoming type section. W. C. Knight (1901) and Williston (1904 and 1905) have used the name Popo Agie for a very poorly defined sequence of strata which appears to be included in the unit referred to above. It may be useful to adequately define Popo Agie to include those strata for which Ruby suggests the much abused name "Ankareh".

The thin conglomeritic sandstone unit above the Timothy in the Wasatch and Uinta Mountains is the litho-stratigraphic equivalent of the Higham grit of southeastern Idaho and the Shinarump conglomerate of the Colorado Plateau. This unit was called "Gartra grit" by Thomas and Krueger (1946), while Williams (1945) extended the use of "Higham grit" to include this unit in these Utah areas. Although both Williams and Thomas and Krueger recognize the correlation of this unit with the Shinarump of the Colorado Plateau, they have violated the rule of priority and the principle of wider usage. Therefore, following the recommendation of the Stratigraphic Committee (Ashley et. al., 1933, Article 9, p. 436) the older and more widely used term Shinarump conglomerate is here applied to this formation throughout its extent in the miogeosynclinal facies, and it is recommended that the names Gartra grit and Higham grit be dropped as undesireable and unnecessary synonyms.

The red beds between the Shinarump conglomerate and the Nugget sandstone are the litho-stratigraphic equivalent of the Wood shale of southeastern Idaho and the Chinle formation of the Colorado Plateau. The use of a name strictly on the basis of priority of publication would favor the extension of Wood shale, as done by Williams (1945). The term "Wood" (Mansfield, 1915) pre-dates the first published use of Chinle (Gregory, 1915) by one month. However, the writer prefers to extend the use of Chinle into the miogeosynclinal regions of Utah and Nevada because Chinle has been much more widely used and has been previously recognized over a much wider area. This preferance is justified in the "Stratigraphic Code" (Ashley et. al., 1933) which states (article 9, p. 436):

> In the application of names to formations, the rule of priority, that the first geographic name applied to any unit and duly published shall generally be observed; but a name which has become well established in use shall not be displaced, merely on account of priority, by a term not well known or only slightly used.

Eastward along the Uinta Mountains and southeastward in the San Rafael Swell the Thaynes limestone thins and finally disappears. Where this occurs the underlying Woodside and overlying Timothy combine to form the typical Moenkopi formation of the Colorado Plateau. Regarding the nomenclature of the areas where the Thaynes is present Thomas and Krueger (1946, p. 1268) state:

> It would be best to apply a group name to include the Woodside, Thaynes and Ankareh [Timothy] which could be used as a formation name where the Thaynes limestone is absent.

The writer is in complete agreement with this statement. Therefore, since Thomas and Krueger did not propose a name for this group, these formations (Woodside, Thaynes and Timothy) are here incorporated to constitute the Moenkopi group.

Near the wedge-edge of the Thaynes where the limestone is thin, as in the San Rafael Swell, the writer recommends that the unit be recognized as the Thaynes tongue of the Moenkopi formation rather than the "Sinbad" limestone member of Gilluly (1929, p. 85).

STRATIGRAPHIC SECTIONS

Sections of the units of the Triassic sequence were selected, and measured or examined, in order to best illustrate the spatial variations of the shelf and miogeosynclinal facies. Section localities are shown on the index map, page 34, and located in table 1, pages 93 to 105.

Chinle Formation

The Chinle formation is composed of red siltstones, dusky red, purple red shales, and light brown sandstones, the coarser clastics usually occuring near the top. The formation thickens gradually, but not remarkably toward the west from 161 feet at Cross Mountain, Colorado to 538 feet in the Wasatch Mountains, Utah.

The contacts with the overlying Jurassic? sandstone and the underlying Shinarump sandstone and conglomerate, are normal and transitional.

Cross Mountain (section 1)

The Chinle section at Cross Mountain, Moffat County Colorado, is well exposed on the west limb of the Cross Mountain anticline. Measurement was made along the east side of the Little Snake River near its junction with the Yampa in sec. 29, T. 7 N., R. 98 W. The Chinle at this locality is 161 feet thick and composed almost entirely of red siltstone.

Measured section:

NAVAJO SANDSTONE 552

CHINLE FORMATION

Sample No.	Description	Thickness feet
1	Siltstone, reddish brown with yellow mottling, thin bedded, calcareous	18
2	Siltstone, like 1	19
3	Siltstone, like 1 with interbedded sandstone, gray, coarse grained, silty, calcareous	33
4	Siltstone, like 1 but better cemented	25
5	Siltstone, like 4, platy	16
6	Siltstone, like 4	11
7	Siltstone, like 4	31
8	Limestone, yellowish gray, speckled, thin bedded, silty	3
9	Siltstone, like 4	5
	TOTAL CHINLE	161

SHINARUMP CONGLOMERATE 4

Split Mountain (section 2)

The Chinle section at Split Mountain, Dinosaur National Monument, Uintah County, Utah consists of 220 feet or red shale and siltstone with some interbedded, light gray, fine grained sandstone near the top. This section was measured just west of the Green River in sec. 30, T. 4 S., R. 24 E.

Measured section:

NAVAJO SANDSTONE 816

CHINLE FORMATION

Sample No.	Description	Thickness feet
1	Sandstone, light gray, thin to medium bedded, fine grained, with red siltstone laminations	31
2	Siltstone, reddish brown, thin bedded, soft, friable	24
3	Sandstone, similar to 1	10
4	Siltstone, similar to 2	9
5	Sandstone, reddish brown, thick bedded, cross bedded, fine grained	11
6	Sandstone, like 1	2
x	Covered	98
7	Shale, mottled dark reddish brown and gray, soft, crumbly, marly	10
x	Mostly covered, red soil indicates lithology similar to sample 7	25
	TOTAL CHINLE	220

SHINARUMP CONGLOMERATE 91

Vernal - Red Mountain (section 3)

A section of Chinle was measured along state highway 44 about 5 miles north of Vernal, Uintah County, Utah in sec. 5, T. 3 S., R. 22 E. The formation here is 259 feet thick and consists of interbedded gray, fine grained sandstone and red siltstone in the upper portion and yellow and red claystone in the lower portion.

Measured section:

NAVAJO SANDSTONE 712

CHINLE FORMATION

Sample No.	Description	Thickness feet
1	Sandstone, light reddish brown, thin to medium bedded, very fine grained, silty	23
2	Sandstone, like 1 but orange pink	29
3	Sandstone, light gray, medium bedded, fine grained	41
4	Sandstone, like 1	18
5	Siltstone, reddish brown, evenly thin bedded, chunky	11
6	Sandstone, light gray with red streaks, medium bedded, very fine grained, calcareous, silty	15
7	Siltstone, reddish brown with gray streaks, thin bedded	14
8	Sandstone, like 6, ripple marked	3
9	Siltstone, reddish brown, thin bedded, soft, chunky, ripple marked	11
10	Siltstone, like 9	13
11	Claystone, yellow, chunky, calcareous, contains limestone nodules	14
12	Claystone, like 11	18
13	Claystone, like 11	14
14	Siltstone, like 9	26
15	Claystone, dark purplish red, crumbly	9
	TOTAL CHINLE	259

SHINARUMP CONGLOMERATE 76

Whiterocks Canyon (section 4)

The Chinle section at Whiterocks Canyon, Uintah County, Utah is poorly exposed, but an accurate over-all thickness of 290 feet was obtained in sec. 19, T. 2 N., R. 1 E. The few outcrops and the soil development indicate a lithology similar to the sections at Vernal and Split Mountain.

Measured section:

NAVAJO SANDSTONE		934
CHINLE FORMATION		
Sample No.	Description	Thickness feet
x	Covered	10
1	Mudstone, reddish brown and greenish gray, thin bedded, soft, crumbly, slightly calcareous	2
x	Covered	38
2	Mudstone, reddish brown, thin bedded, soft, crumbly, calcareous	3
x	Covered	237
	TOTAL CHINLE	290
SHINARUMP CONGLOMERATE		53

Lake Fork Canyon (section 5)

At Lake Fork Canyon, Duchesne County, Utah a section of Chinle was measured in sec. 34, T. 2 N., R. 5 W. The Chinle at this locality is 402 feet thick and consists of red siltstone and gray, fine grained sandstone in the upper part with less resistant mostly covered, red, claystone and shale in the lower part.

Measured section:

NAVAJO SANDSTONE		Not measured
CHINLE FORMATION		
Sample No.	Description	Thickness feet
x	Covered	7
1	Siltstone and limestone; siltstone, reddish brown, chunky, interbedded with limestone and siltstone, light gray with green stains, medium bedded, fine grained	23
2	Siltstone and shale, dusky red, thin bedded	22
3	Sandstone, light gray with green stains, thin to medium bedded, very fine grained, calcareous	27
4	Siltstone, interbedded, dark reddish brown, light reddish brown and greenish gray, thin bedded, some beds calcareous	29
5	Siltstone, interbedded reddish brown and greenish gray, thin bedded, soft, chunky, calcareous	30
6	Siltstone, like 5	31
x	Covered, probably like 5	45
7	Spot sample, siltstone, reddish brown, soft, chunky, nodular	214 from top Chinle
8	Covered, soil sample, red silty and clayey soil indicates interbedded red shale and siltstone, some gypsum	188
	TOTAL CHINLE	402
SHINARUMP CONGLOMERATE		119

Duchesne River (section 6)

A section on the Duchesne River near Hanna, Utah was examined by the writer and the section measured by Huddle and

McCann (1947) near Squaw Creek in sec. 2, T. 1 S., R. 8 W. and sec. 35, T. 1 N., R. 8 W. seems to be essentially accurate. The Chinle here is about 340 feet thick and is composed of interbedded red siltstone and gray fine grained sandstone in the upper part and red mudstone in the lower.

The following section is modified after Huddle and McCann:

Unit	Description	Thickness feet
NAVAJO SANDSTONE		1,100
CHINLE FORMATION		
1	Siltstone, reddish brown, thin bedded	40
2	Sandstone, pale brown, medium bedded, very fine grained, quartz	30
3	Siltstone, like 1	25
4	Shale, brownish red, calcareous	15
5	Siltstone, light reddish brown, thin bedded	30
6	Shale, dusky red, calcareous	15
7	Mudstone, reddish brown, thick bedded	45
8	Siltstone, light reddish brown, thin to medium bedded	40
9	Mudstone, like 7	20
10	Sandstone, light greenish gray, medium bedded, very fine grained, quartz	10
11	Mudstone, like 7	70
	TOTAL CHINLE	340
SHINARUMP CONGLOMERATE		40

Upper Weber Canyon (section 7)

The section on the Upper Weber River above Oakley, Summit County, Utah contains 345 feet of reddish brown siltstone with grayish red and pale green shale and siltstone near the top. The section was measured in sec. 11, T. 1 S., R. 6 E.

Measured section:

NUGGET SANDSTONE — Not measured

CHINLE FORMATION

Sample No.	Description	Thickness feet
1	Shale, pale grayish red, with interbedded siltstone, pale green, thin bedded, slightly calcareous	53
2	Siltstone, pale green, thin bedded, soft, crumbly, slightly calcareous	4
3	Shale and siltstone, like 1	48
4	Siltstone, pale reddish brown with pale greenish gray spots, thin and medium bedded	80
5	Siltstone, similar to sample 4, mostly thin bedded to platy	160
	TOTAL CHINLE	345

SHINARUMP CONGLOMERATE — 110

Parley's Canyon (section 11)

The Chinle section at the mouth of Parley's Canyon, Salt Lake County, Utah was measured in sec. 24, T. 1 S., R. 1 E. The 538 feet of Chinle at this locality consists mainly of red shale and siltstone with some very fine grained sandstone.

Measured section:

NUGGET SANDSTONE — 1,677

CHINLE FORMATION

Sample No.	Description	Thickness feet
1	Shale, dusky red to purplish red with green spots and stringers, some thin bedded siltstone	12
2	Siltstone, light brownish red with green spots, thick bedded, cross bedded, ripple marked	19
3	Shale, purplish red, thin bedded, splintery and thin beds of gray siltstone	20
x	Covered, probably like 3	87
4	Siltstone, reddish brown, medium bedded, resistant, 2" greenish gray ripple marked layer at top	15
5	Siltstone, like 4, some softer interbedded, siltstone	14
6	Siltstone and shale, interbedded, reddish brown, purplish gray, light brown, thin bedded, splintery	15
7	Siltstone and mudstone, purplish gray to reddish brown, thin bedded	36
8	Siltstone, purplish red, medium to thick bedded	75
9	Siltstone, reddish brown with greenish gray spots, massive	64
10	Siltstone, purplish gray, medium bedded, micaceous, quartzitic	60
11	Sandstone, lavender gray, medium bedded, very fine grained, quartzitic	10
12	Limestone, lavender gray, medium bedded, fine grained, argillaceous, fresh water?	25
13	Siltstone and shale, purplish gray, thin bedded, splintery	40

CHINLE cont.

Sample No.	Description	Thickness feet
14	Siltstone, purplish brown, thin bedded, cross bedded, micaceous	46
	TOTAL CHINLE	538

SHINARUMP CONGLOMERATE 79

Currie - Dolly Varden Valley (section 15)

At Dolly Varden Valley north of Currie, Elko County, Nevada a section is exposed which in stratigraphic position and lithologic aspect appears to be the litho-stratigraphic equivalent of the Chinle formation. An incomplete section 581 feet thick was measured in secs. 8 and 9, T. 29 N., R. 64 E. It consists mainly of dark gray and green shales and yellowish brown argillaceous limestone in the upper part and red to gray siltstones in the lower part.

Measured section:

CHINLE? FORMATION, faulted, units 1 through 4 repeated, top not exposed

Sample No.	Description	Thickness feet
1	Shale, pale olive green, fissile	29
2	Shale, medium to dark gray, fissile	30
3	Limestone, pale yellowish brown, thin to medium bedded, very argillaceous	120
4	Siltstone and shale, grayish red, thin bedded, platy, micaceous	59
5	Sandstone, pale yellowish brown, thin bedded, very fine grained, platy	7
6	Limestone, like 3	4

A.--Strata at mouth of Parley's Canyon. Formations from right to left are: (1) Thaynes fm. far right, (2) Timothy fm., barren ridges, (3) Shinarump, narrow hogback ridge, (4) Chinle fm., bottom of canyon and (5) Nugget ss., far left.

B.--Closer view of Chinle and Shinarump.

Fig. 5.--Parley's Canyon (section 11)

A.--Detail of Chinle fm. at a point near the center of Fig. 5B.

B.--Close up of a part of Fig. 6A showing greenish gray reduction spots in red siltstone.

Fig. 6.--Chinle formation, Parley's Canyon

CHINLE? cont.

Sample No.	Description	Thickness feet
7	Siltstone and shale, like 4	155
x	Covered	100
8	Sandstone, pale yellowish gray, medium bedded, medium grained	12
9	Siltstone, light olive gray, thin bedded to platy, micaceous	65
	TOTAL CHINLE	581

SHINARUMP? CONGLOMERATE 42

Shinarump Conglomerate

The Shinarump conglomerate is a remarkable, thin blanket of quartzose sandstone and pebble conglomerate which formerly covered at least 100,000 square miles and possibly as much as 200,000 square miles in Utah, Arizona, Colorado, Wyoming, Idaho, and Nevada. This unit varies in thickness as much as 50 feet in a mile due to the erosional disconformity at its base, but average thicknesses are usually near 60 feet.

Cross Mountain (section 1)

At Cross Mountain, Moffat County, Colorado 4 feet of lighter colored more resistant siltstone between the Chinle and Moenkopi formations was questionably referred to the Shinarump. This locality is apparently near the eastern wedge-edge of Shinarump deposition.

Measured section:

CHINLE FORMATION 161

SHINARUMP? CONGLOMERATE

Sample No.	Description	Thickness feet
10	Siltstone, pale pink, thin bedded to platy, ripple marked, resistant calcareous	1
11	Siltstone, like 10 but light gray	3
	TOTAL SHINARUMP?	4

MOENKOPI FORMATION 720

Split Mountain (section 2)

At Split Mountain, Uintah County, Utah, the Shinarump already displays its normal development. The 91 foot section here consists of scattered pebbles and pebble conglomerate lenses in a sandstone matrix, containing more and larger pebbles toward the base.

Measured section:

CHINLE FORMATION 220

SHINARUMP CONGLOMERATE

Sample No.	Description	Thickness feet
8	Sandstone, light gray to pale yellowish gray, massive, cross-bedded, coarse grained with a few scattered quartz and quartzite pebbles up to ½" in diameter	13
9	Sandstone, like 8, yellowish-gray	34
10	Sandstone, like 8, with pebble conglomerate lenses, pebbles up to 1" in diameter	27
11	Sandstone, like 10, with pebbles to 1½"	17
	TOTAL SHINARUMP	91

- Disconformity -

MOENKOPI FORMATION 751

Vernal - Red Mountain (section 3)

A Shinarump section was measured along the Manila road (state Highway 44) near Ashley Creek north of Vernal, Uintah County, Utah in sec. 5, T. 3 S., R. 22 E. The unit consists of 76 feet of massive, cross bedded, light gray, fine grained sandstone with scattered pebbles and lenses of pebble conglomerate, the pebbles becoming more numerous and larger toward the base.

Measured section:

CHINLE FORMATION 259

SHINARUMP CONGLOMERATE

Sample No.	Description	Thickness feet
16	Sandstone, light yellowish gray, thick bedded to massive, cross bedded, coarse grained	19
17	Sandstone, like 16 with scattered pebbles up to ¼" in diameter	20
18	Sandstone, light gray with red streaks, medium bedded, fine grained, quartz	15
19	Sandstone, like 18	12
20	Sandstone, like 16, with pebble conglomerate lenses, quartz and quartzite pebbles, up to 2½" in diameter	10
	TOTAL SHINARUMP	76

- Disconformity -

MOENKOPI FORMATION 734

Whiterocks Canyon (section 4)

The Shinarump section in Whiterocks Canyon, Uintah County, Utah is well exposed in sec. 19 T. 2 N., R. 1 E., where

Fig. 7.--Shinarump resting disconformably upon Moenkopi, north of Vernal, Utah.

the formation is 58 feet thick and consists of quartz sandstone with scattered pebbles and lenses of pebble conglomerate.

Measured section:

CHINLE FORMATION 290

SHINARUMP CONGLOMERATE

Sample No.	Description	Thickness feet
3	Sandstone, light yellowish gray, massive, cross bedded, medium to very coarse grained with scattered quartz and quartzite pebbles and lenses of pebble conglomerate, pebbles up to ½" in diameter	36
4	Sandstone, and pebble conglomerate, like 3, but with finer grained matrix	10
5	Sandstone and pebble conglomerate, like 3, pebbles to 1"	12
	TOTAL SHINARUMP	58

- Disconformity -

MOENKOPI FORMATION 1,137

Lake Fork Canyon (section 5)

A good section of the Shinarump is exposed in Lake Fork Canyon, Duchesne County, Utah near the north end of Twin Pots Reservoir, sec. 34, T. 2 N., R. 5 W. The unit at this locality is 119 feet thick and consists of fine to coarse grained, yellowish gray, quartzose sandstone with pebble conglomerate toward the base.

Measured section:

CHINLE FORMATION 402

SHINARUMP CONGLOMERATE

Sample No.	Description	Thickness feet
9	Sandstone, yellowish gray with reddish brown stains, massive, cross bedded, fine to medium grained, well cemented toward top	20
10	Sandstone, light gray with some reddish brown stains, massive, cross bedded, medium to coarse grained	22
11	Sandstone, and pebble conglomerate, light gray to yellowish gray, massive, cross bedded, poorly cemented sandstone with pebbles of quartz, quartzite and chert to 1½" average ¼", generally coarser toward base	77
	TOTAL SHINARUMP	119

- Disconformity -

MOENKOPI GROUP 1,836

Duchesne River (section 6)

The section along the Duchesne River was measured by Huddle and McMann (1947) and examined by the writer near Hanna, Duchesne County, Utah. The 40 feet of fine to coarse grained, gray, quartzose sandstone with scattered pebbles to 1 inch in diameter resembles very closely the other sections along the Uinta Mountains described above.

Upper Weber Canyon (section 7)

Along the upper portion of the Weber River east of Oakley, Summit County, Utah, sec. 11, T. 1 S., R. 6 E., the Shinarump is 110 feet thick and consists of two units which grade into each other. The upper unit is very fine grained, brownish gray, quartzose sandstone and the lower unit is light brownish gray, medium and coarse grained quartzose sandstone and pebble conglomerate.

Measured section:

CHINLE FORMATION 345

SHINARUMP CONGLOMERATE

Sample No.	Description	Thickness feet
6	Sandstone, medium brownish gray, thin bedded, very fine grained, quartzose	70
7	Pebble conglomerate, grayish orange pink, to light brownish gray, massive, cross bedded, quartz and quartzite pebbles average 1/8" with maximum diameters of about 1"	40
	TOTAL SHINARUMP	110

- Disconformity -

MOENKOPI GROUP 2,515

Parley's Canyon (section 11)

The Shinarump crops out along highway 40 in the mouth of Parley's Canyon near Salt Lake City, Utah, sec. 24, T. 1 S., R. 1 E. The formation at this locality is finer grained and less conglomeritic than the normal development of the unit; however, the stratigraphic position, physiographic expression and general lithology leave no doubt that the unit is Shinarump.

Measured section:

CHINLE FORMATION 534

SHINARUMP CONGLOMERATE

Sample No.	Description	Thickness feet
15	Sandstone, pale lavender gray, thick bedded, cross bedded, very fine grained, quartzitic, lenses of coarse grained sandstone	19
16	Sandstone, like 15	8
17	Shale, purplish red, thin bedded, silty	5
18	Sandstone, pale lavender gray, massive, cross bedded, fine and coarse grained, quartzitic	47
	TOTAL SHINARUMP	79

- Disconformity -

MOENKOPI GROUP 3,669

Currie - Dolly Varden Valley (section 15)

A pebble conglomerate with the general lithologic aspect, physiographic expression, and stratigraphic position of the Shinarump occurs in the Dolly Varden section, Elko County, Nevada, secs. 8 and 9, T. 29 N., R. 64 E. This conglomerate is correlated, with only slight question, with the Shinarump conglomerate of the Colorado Plateau.

Measured section:

CHINLE? FORMATION 581

SHINARUMP? CONGLOMERATE

Sample No.	Description	Thickness feet
10	Pebble conglomerate, pale yellowish brown, massive, sub-rounded pebbles of quartz, quartzite, and chert in a matrix of very fine grained quartz sandstone and clay. Petrified wood	42
	TOTAL SHINARUMP	42

- Disconformity -

THAYNES? FORMATION 2,200

Moenkopi Formation and Group

The Moenkopi formation of the Colorado Plateau consists of reddish brown siltstones, mudstones, and fine grained sandstones. This unit which is generally less than 800 feet thick in the Plateau region thickens appreciably westward to over 4,000 feet in the Wasatch Mountains and about 5,000 feet in southeastern Idaho. As previously described the western or miogeosynclinal facies of this unit consists of three formations, the Woodside red beds, the Thaynes marine limestone, siltstone and sandstone, and the Timothy red beds which together constitute the Moenkopi group.

The following measured sections will serve to illustrate the character of the Moenkopi formation and group.

Cross Mountain (section 1)

The Moenkopi formation at Cross Mountain, Colorado is 720 feet thick and is composed of reddish gray and yellowish gray siltstone.

Measured section:

SHINARUMP? CONGLOMERATE 4

- Disconformity -

MOENKOPI FORMATION

Sample No.	Description	Thickness feet
12	Sandstone, yellowish gray, thin bedded, soft, very poorly consolidated, very fine grained	9

MOENKOPI cont.

Sample No.	Description	Thickness feet
13	Siltstone, reddish brown and yellowish gray, thin bedded, soft, crumbly	24
14	Siltstone, yellowish gray, thin bedded, calcareous, ledgy	37
15	Siltstone, light gray, thin bedded, calcareous	11
16	Siltstone, like 15	35
17	Siltstone, like 15, softer, gypsum float in soil	16
18	Siltstone, like 17	11
19	Siltstone, like 14	13
20	Siltstone, like 17	17
21	Siltstone, like 15	23
22	Siltstone, like 15, ripple marked	31
23	Siltstone, like 15	65
24	Siltstone, like 15	37
25	Siltstone, like 17	35
26	Siltstone, like 15, brownish gray	23
27	Siltstone, yellow, thin bedded, soft, slightly calcareous	118
28	Siltstone, like 27	28
29	Siltstone, like 27	51
30	Siltstone, like 27	18
31	Siltstone, light gray, thin bedded, chunky	8
32	Siltstone, like 31, brownish gray	28

MOENKOPI cont.

Sample No.	Description	Thickness feet
33	Siltstone, like 32	16
34	Siltstone, light gray, thin bedded, gypsiferous, calcareous	33
35	Siltstone, like 34	33
	TOTAL MOENKOPI	720

PARK CITY FORMATION 11

Split Mountain (section 2)

The Moenkopi formation was measured across Cottonwood Wash just west of Split Mountain Gorge in sec. 30, T. 4 S., R. 24 E., Uintah County, Utah. At this locality the Moenkopi is 751 feet thick and consists almost entirely of reddish brown siltstone with some veinlets and seams of gypsum.

Measured section:

SHINARUMP CONGLOMERATE 91

- Disconformity -

MOENKOPI FORMATION

Sample No.	Description	Thickness feet
12	Siltstone, reddish brown, thin bedded, chunky	24
13	Siltstone, like 12	22
14	Siltstone, like 12	27
15	Siltstone, like 12, softer, crumbly	33
16	Siltstone, like 12	31
17	Sandstone, reddish brown, medium bedded, very fine grained, friable, silty	20

MOENKOPI cont.

Sample No.	Description	Thickness feet
18	Siltstone, reddish brown, thin bedded, blocky, sandy	17
19	Siltstone, like 12	38
20	Limestone, light gray to white, with small dark brown spots, thin bedded, chalky, argillaceous	2
21	Siltstone, like 18, with some interbedded sandstone, more resistant, red, very fine grained	29
22	Siltstone, like 21, less resistant	18
23	Siltstone, like 21	22
23.5	Siltstone, like 12, some greenish gray streaks	20
24	Siltstone, like 21	24
25	Siltstone, reddish brown and pale greenish gray, thin bedded	40
26	Siltstone, like 18	32
27	Siltstone, like 21	32
28	Siltstone, like 21, micaceous	31
29	Shale, reddish brown, thin bedded, fissile, micaceous, silty	23
30	Sandstone, yellowish gray, with some black grains, thin bedded, fine grained	4
31	Shale, like 29, with some interbedded, fine grained sandstone	26
32	Siltstone, reddish brown, thin bedded, micaceous	19
33	Sandstone, yellow, thin bedded, fine grained	21

MOENKOPI cont.

Sample No.	Description	Thickness feet
34	Siltstone, pale gray, thin bedded, gypsiferous	17
35	Siltstone, reddish brown, thin bedded, soft, blocky	25
36	Siltstone, like 35	21
37	Siltstone, like 35, with interbedded yellow, fine grained sandstone	22
38	Siltstone, like 35, with gypsum veinlets and seams	22
39	Sandstone, yellowish pink, thin bedded, fine grained	19
40	Siltstone, like 38	8
41	Siltstone, pale brown, thin bedded	14
42	Siltstone, yellow to brown, thin bedded, platy	10
43	Siltstone, reddish brown, thin bedded, soft, chunky	38
	TOTAL MOENKOPI	751

PARK CITY FORMATION — Not measured

Vernal - Red Mountain (section 3)

The Moenkopi formation was measured down the north slope of Red Mountain in sec. 34, T. 2 S., R. 21 E., Uintah County, Utah. The section is composed of reddish brown and greenish gray siltstone with interbedded and disseminated gypsum.

Measured section:

SHINARUMP CONGLOMERATE — 76

- Disconformity -

MOENKOPI FORMATION

Sample No.	Description	Thickness feet
21	Siltstone, reddish brown, thin bedded to platy, calcareous	3
22	Siltstone, like 21 but non-calcareous, splintery	18
23	Siltstone, like 21	29
24	Siltstone, light gray, medium bedded, calcareous	13
25	Siltstone, like 21	35
26	Siltstone, like 21, but softer with thin interbedded gypsum	31
27	Siltstone like 26	25
28	Siltstone, like 26, but greenish gray	31
29	Siltstone, like 26, very soft	33
30	Siltstone, like 26	32
31	Siltstone, like 26	20
32	Siltstone, light reddish brown, thin bedded to platy with interbedded greenish gray shale	35
33	Siltstone, reddish brown, thin bedded, calcareous	68
34	Siltstone, like 33 with interbedded gypsum	29
35	Siltstone, like 34	27
36	Siltstone, like 34	23
37	Siltstone, like 34	33
38	Siltstone, like 34 with interbedded greenish gray sypsiferous siltstone	17
x	Covered, red silty soil and exposures along strike, indicate similar to 38, but softer	78

A.--Shinarump disconformably overlying Moenkopi north of Vernal, Utah.

B.--Red Mountain capped by Shinarump, light colored strata at base is Park City Formation.

Fig. 8.--Moenkopi formation Vernal-Red Mountain

MOENKOPI cont.

Sample No.	Description	Thickness feet
39	Siltstone, reddish brown, thin bedded, soft, chunky	10
40	Siltstone, greenish gray, medium bedded, resistant, gypsiferous	13
41	Siltstone, like 40	44
42	Siltstone, like 39, platy	39
43	Siltstone, like 39 and 40 interbedded	29
44	Siltstone, like 39	13
45	Siltstone, like 40	6
	TOTAL MOENKOPI	734

PARK CITY FORMATION Not measured

Whiterocks Canyon (section 4)

The Moenkopi section in Whiterocks Canyon, sec. 19, T. 2 N., R. 1 W., Uintah County, Utah is mostly covered, but scattered outcrops and soil development indicate a lithology similar to the sections at Split Mountain and Red Mountain. The section at Whiterocks is especially significant because it contains 20 feet of limestone near the middle. This limestone is regarded as the easternmost extension of the Thaynes formation along the south flank of the Uinta Mountains and may be referred to as the Thaynes tongue of the Moenkopi formation.

Measured section:

SHINARUMP CONGLOMERATE 58

– Disconformity –

MOENKOPI FORMATION

Sample No.	Description	Thickness feet
6	Shale and siltstone, reddish brown, thin bedded, micaceous, slightly calcareous, one thin bed of greenish gray siltstone	43
x	Covered, probably like 6	67
7	Shale and siltstone, like 6, more platy	2
x	Covered, probably like 6	450
8	Siltstone, reddish brown, thin bedded, soft, micaceous, calcareous	5
x	Covered	10
9	(Thaynes Tongue) Limestone, light gray, thin bedded, fine grained, argillaceous, lower part silty	20
x	Covered, red silty soil, probably like 8	540
	TOTAL MOENKOPI	1,137

PARK CITY FORMATION 245

Lake Fork Canyon (section 5)

At Lake Fork Canyon, secs. 26 and 35, T. 2 N., R. 5 W., Duchesne County, Utah, the silty limestones, and calcareous siltstone of the Thaynes are thick enough (179 feet) to be recognized as a distinct formation, and they separate the normal red beds of the Moenkopi into upper and lower red bed units, the Timothy and Woodside formations respectively. The three formations together constitute the Moenkopi group.

Measured section:

SHINARUMP CONGLOMERATE 119

- Disconformity -

MOENKOPI GROUP

TIMOTHY FORMATION

Sample No.	Description	Thickness feet
12	Mostly covered, scattered outcrops of reddish brown, thin bedded, platy siltstone and light gray, micaceous calcareous siltstone	49
13	Siltstone, reddish brown, thin bedded, platy, calcareous	24
14	Sandstone, moderate red, thick bedded, resistant, very fine grained, calcareous, silty	12
15	Siltstone, dusky red, thin bedded, platy, calcareous, some thin gray beds near top	80
16	Sandstone, light gray with brown spots, thin bedded, resistent, very fine grained, calcareous	12
17	Sandstone, like 16, but thick bedded and cross bedded	18
18	Siltstone, reddish brown, thin bedded, some beds platy, some chunky, some light gray, some calcareous	144
19	Siltstone, like 18, some ripple marked beds	14
20	Sandstone, light brownish gray with reddish brown spots, thin bedded, very fine grained, silty, calcareous; Siltstone, reddish brown, with green stringers and spots, medium bedded to thin bedded, ripple marked and interbedded; Shale, dusky red with green stringers and spots, chloritic and micaceous	80
x	Mostly covered, along strike rocks in this interval are exposed and are like sample 20	401

TIMOTHY cont.

Sample No.	Description	Thickness feet	
21	Spot sample; Shale, dusky red, thin bedded, slightly calcareous, micaceous	545 from top of Timothy	
22	Sandstone, like 20	111	
	TOTAL TIMOTHY		945

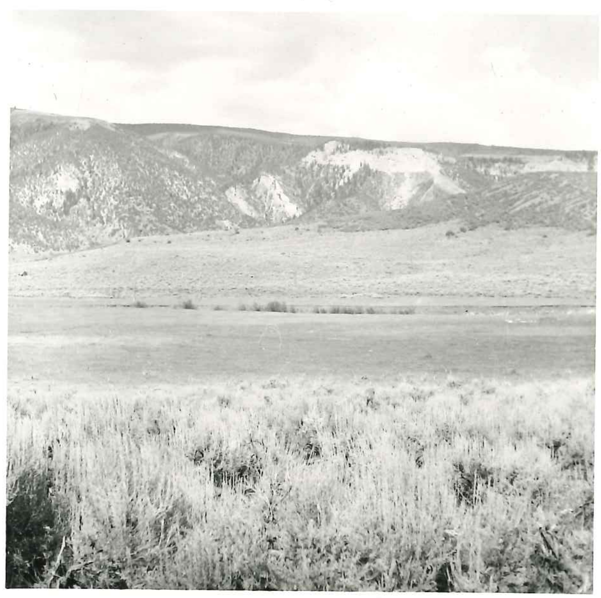
THAYNES FORMATION

Sample No.	Description	Thickness feet	
23	Siltstone, light gray, thin to medium bedded, slightly calcareous, with some dolomite, light brownish gray	44	
24	Siltstone, reddish brown, thin bedded, platy	13	
25	Limestone, light yellowish gray, fine grained, dolomitic	50	
26	Limestone, light yellowish brown, medium bedded, silty, dolomitic with two red siltstone layers near base	72	
	TOTAL THAYNES		179

WOODSIDE SHALE

Sample No.	Description	Thickness feet
27	Siltstone, reddish brown, thin bedded, slightly calcareous with interbedded shale, dusky red, platy, slightly calcareous	39
28	Siltstone and shale, like 27, with gypsum and thin bedded gray siltstone	74
29	Siltstone and shale, like 27	90
30	Siltstone, reddish brown and gray, thin to medium bedded, slightly calcareous	39
31	Siltstone, like 30	139
32	Siltstone, like 30, with greenish gray spots, ripple marks, and spots of secondary calcite	22

A.--Shinarump, Chinle and Nugget formations



B.--Park City fm. and Moenkopi group with Tertiary Uinta fm. nonconformably overlying

Fig. 9--Lake Fork Canyon (section 5)

WOODSIDE SHALE cont.

Sample No.	Description	Thickness feet	
33	Siltstone and shale, like 27, greenish gray spots, ripple marks	33	
34	Siltstone, reddish brown, thin bedded to platy, micaceous	54	
35	Mostly covered, scattered outcrops of Siltstone, like 34	53	
36	Covered, soil sample, like 34	70	
x	Covered, exposures along strike of Siltstone, similar to 34	99	
	TOTAL WOODSIDE		712
	TOTAL MOENKOPI GROUP		1,836
PARK CITY FORMATION			577

Duchesne River (section 6)

The Duchesne River section was examined (but not measured) by the writer near the town of Hanna along Farm Creek, secs. 31, 30, 29, 20, and 19, T. 1 N., R. 7 W., Duchesne County, Utah. The same units described in the Lake Fork Canyon section are present and are lithologically similar but thicker. Huddle and McCann (1947) report the following thicknesses: Woodside shale, 700 to 1,000 feet; Thaynes formation 550 to 650 feet; Ankareh (Timothy) formation 800 to 1,000 feet.

Upper Weber Canyon (section 7)

The three-fold division of the Moenkopi group is readily recognizable on the Upper Weber River above Oakley, Summit County, Utah in secs. 11 and 13, T. 1 S., R. 6 E.

Section measured down Swift Creek Canyon:

SHINARUMP CONGLOMERATE		40
- Disconformity -		
MOENKOPI GROUP		
TIMOTHY FORMATION		
Sample No.	Description	Thickness feet
6	Siltstone, pale grayish red, thin bedded, platy, ferric oxide cement	118
7	Siltstone, pale reddish brown, thin bedded to platy, friable ferric oxide cement, micaceous	590
8	Siltstone, like 7, but thinner bedded, shaly	35
9	Shale, pale reddish brown, thin bedded, micaceous, silty, many beds with fine (½") ripple marks	157
	TOTAL TIMOTHY	900
THAYNES FORMATION		
10	Limestone, very light brownish gray medium bedded, some cross bedding, flaggy, resistant, silty, cherty	60
11	Limestone and siltstone, interbedded, limestone, very light gray, fossiliferous, with unidentifiable pelecypod molds and siltstone, yellowish gray, calcareous	350
12	Limestone, light gray, weathers light brownish gray, massive, porous	25
	TOTAL THAYNES	435
WOODSIDE FORMATION		
13	Siltstone and shale, pale red, thin bedded to platy, micaceous	1,180
	TOTAL WOODSIDE	1,180
	TOTAL MOENKOPI GROUP	2,515

PARK CITY FORMATION Not measured

Lower Weber Canyon (section 8)

A good section of the Moenkopi group is exposed along the Union Pacific railroad tracks in the Lower Weber Canyon, between Morgan and Devil's Slide, secs. 23 and 24, T. 4 N., R. 3 E., Morgan County, Utah. The Timothy formation of the Lower Weber section is of special interest because it is composed of interbedded brownish gray, fine grained sandstone, which has the aspect of the type Timothy sandstone in southeastern Idaho, and reddish gray shale and siltstone, which have the aspect of the unit occupying the same position in the sequence near Salt Lake City and in the Uinta Mountains. This lithologic change from predominately sandstones in southeastern Idaho to interbedded sandstone, siltstone and shale in the Lower Weber Canyon to predominately siltstones and shale near Salt Lake City and in the Uinta Mountains is regarded as lithofacies of the same formation. This facies relationship plus the similar position in the sequence explains the extension of the name Timothy into northern Utah.

Measured section:

SHINARUMP CONGLOMERATE 76

- Disconformity -

MOENKOPI GROUP

TIMOTHY FORMATION

Sample No.	Description	Thickness feet
1	Sandstone, shale and siltstone, interbedded, sandstone, brownish gray, fine grained, quartz; and shale and siltstone, grayish red, micaceous. Individual beds vary from a few inches to about 6 feet; entire unit about 50% sandstone and 50% shale and siltstone	785
	TOTAL TIMOTHY	785

THAYNES FORMATION

Sample No.	Description	Thickness feet
2	Mostly covered, scattered outcrops indicate interbedded limestone, medium gray and shale, pale reddish purple and greenish gray	1,050
3	Shale, greenish gray, thin bedded	10
4	Limestone, medium gray, medium bedded, argillaceous	4
5	Shale, grayish red purple, thin bedded, calcareous, ripple marked	12
6	Limestone, like 4	36
7	Shale, like 3	25
8	Limestone, like 4	5
9	Shale, like 3 and 5	36
10	Limestone, like 4	7
11	Shale, like 3	25
12	Limestone, like 4	5
13	Shale, like 3 and 5	25
14	Mostly covered, scattered outcrops indicate interbedded limestone, and shale, like 3, 4, and 5	159
15	Limestone, like 4	8

THAYNES cont.

Sample No.	Description	Thickness feet
16	Shale, like 3	10
17	Limestone, like 4	8
18	Shale, like 3	15
19	Limestone, like 4	10
20	Shale, like 3	20
21	Limestone, like 4	15
22	Shale, like 3	5
23	Limestone, like 4	15
24	Shale, like 3	20
25	Limestone, medium gray, massive, medium grained	641
26	Shale, dark gray, thin bedded, calcareous	229
27	Limestone, medium gray to brownish gray, medium bedded to massive, medium grained, argillaceous	221
28	Limestone, like 27, fossiliferous, Meekoceras zone: ?Meekoceras gracilitatis	95
29	Limestone, like 27, fossiliferous, unidentifiable pelecypod molds	232
30	Limestone, like 27, some silty partings with ripple marks	300
	TOTAL THAYNES	3,243

WOODSIDE FORMATION

Sample No.	Description	Thickness feet
31	Shale and siltstone, interbedded; siltstone, pale grayish red purple, thin bedded, calcareous, and shale, grayish red, ripple marked	755
	TOTAL WOODSIDE	755
	TOTAL MOENKOPI GROUP	4,783

A.--Woodside formation

B.--Thaynes formation

Fig. 10.--Lower Weber Canyon (section 8)

Fig. 11.--Timothy formation in Lower Weber Canyon, note interbedding of red siltstones and lighter colored sandstones.

PHOSPHORIA FORMATION Not measured

Parley's Canyon (section 11) and

Red Butte Canyon (section 9)

A composite section of the Moenkopi group was obtained near Salt Lake City. The Timothy was measured in the mouth of Parley's Canyon, secs. 24, and 25, T. 1 S., R. 1 E., and the remaining formations of the group were measured at the top of Red Butte Canyon, secs. 10 and 15, T. 1 N., R. 1 E. The Red Butte section was measured along a dugway road which leads to a bulldozed trench in the Park City formation. This locality provides the best exposures of the Thaynes and Park City Formations known to the writer anywhere in the Wasatch Mountain region.

The section at the top of Red Butte is also of special interest because there are exposed 96 feet of greenish gray shale and gray limestone between the base of the Woodside and the top of the Park City. These shales occupy the same position in the sequence and are lithologically similar to the Dinwoody formation of southwestern Wyoming and are therefore considered by the writer to be the southernmost known extension of the Dinwoody formation.

Measured section:

SHINARUMP CONGLOMERATE

- Disconformity -

MOENKOPI GROUP

TIMOTHY FORMATION

Sample No.	Description	Thickness feet
19	Siltstone and sandstone, reddish to purplish brown, thin to medium bedded, some spots and zones reduced to greenish gray	65
20	Siltstone, like 19	33
21	Siltstone, like 19	30
22	Siltstone, like 19, micaceous	31
23	Siltstone, like 22	33
24	Siltstone, like 22	17
25	Siltstone, like 22	32
26	Siltstone, like 22	35
27	Siltstone, like 22	35
28	Siltstone, like 22	41
29	Siltstone, like 22	39
30	Siltstone, like 22	44
31	Siltstone, like 22	42
32	Siltstone, like 22	45
33	Siltstone, like 22	97
34	Siltstone, like 22	92
35	Siltstone, like 22	97
36	Siltstone, like 20	78
37	Siltstone, like 22	93
38	Siltstone, like 20, ripple marks	91
39	Siltstone, like 20	13
	TOTAL TIMOTHY	1,083

THAYNES FORMATION

Sample No.	Description	Thickness feet
1	Siltstone and limestone, siltstone yellowish gray, thin bedded to platy, very calcareous interbedded with limestone, brownish gray, medium bedded, with unidentifiable shell fragments. 75% siltstone	21
2	Siltstone and limestone, like 1, 50% siltstone	20
3	Siltstone and limestone, like 1, 70% siltstone	17
4	Siltstone, yellowish brown, thin bedded, platy, non-calcareous	72
5	Siltstone, light yellowish gray, thin bedded, calcareous	37
6	Siltstone and limestone, like 1	31
7	Siltstone, like 5	32
8	Shale and siltstone, yellowish gray, interbedded, thin bedded, non-calcareous	12
9	Limestone, light gray, medium bedded, medium grained	8
10	Limestone, yellowish gray (weathers yellow) medium bedded, blocky, very argillaceous	11
11	Limestone, light gray, medium bedded, fine grained and light yellowish gray, argillaceous	9
12	Limestone, like 11	30
13	Limestone, like 11, 90% argillaceous limestone	15
14	Limestone, like 13	45
15	Limestone, like 13	36

THAYNES cont.

Sample No.	Description	Thickness feet
16	Limestone, like 13	35
17	Limestone, like 13	29
18	Shale, reddish brown, splintery	8
19	Limestone, like 13	35
20	Limestone, like 13	33
21	Limestone, like 13	21
22	Shale and limestone, shale, reddish brown, interbedded with limestone, reddish brown, medium bedded, coarse grained, crystaline; and limestone, yellowish gray, argillaceous, 80% red shale	21
23	Limestone, like 13	28
24	Shale, reddish brown, thin bedded	15
25	Limestone, like 13	3
26	Shale, like 24	17
27	Limestone, medium gray, (weathers light gray), medium bedded, medium to fine grained, argillaceous; Unidentifiable fossil fragments	5
28	Shale and limestone, shale, reddish brown, splintery and limestone, medium gray, medium bedded, argillaceous; 90% shale	17
29	Limestone, interbedded, thin bedded, light gray, fine grained and yellowish gray, fine grained, argillaceous	14
30	Shale, brownish gray, splintery	11
31	Limestone, like 27	3

THAYNES cont.

Sample No.	Description	Thickness feet
32	Shale and limestone, shale, greenish gray to brownish gray, splintery, calcareous, and limestone, medium gray, medium bedded, argillaceous	9
33	Limestone, medium gray (weathers yellow), medium bedded, fine grained, argillaceous	8
34	Shale, brownish gray	12
35	Limestone, gray (weathers yellowish gray), thin to medium bedded, fine grained, argillaceous	28
36	Shale, like 34	20
37	Limestone, like 35	67
38	Limestone, like 35	36
39	Limestone, like 35	21
40	Shale and limestone; shale, greenish to yellowish gray, calcareous, and limestone, medium gray, medium bedded, argillaceous	17
41	Limestone, like 35	36
42	Shale and limestone, like 40	20
43	Limestone, like 35 with a few shale beds like 40	17
44	Limestone, medium gray (weathers brown to yellow), medium bedded, fine grained, argillaceous	10
45	Limestone, like 44 with greenish gray, very argillaceous, shaly limestone	10
46	Limestone, light gray (weathers yellowish gray), medium bedded, argillaceous	40

THAYNES cont.

Sample No.	Description	Thickness feet
47	Siltstone, medium brown, medium bedded, non-calcareous	16
48	Covered; Float sample, similar to 47 but calcareous where not weathered, interval probably contains mostly shale	74
49	Limestone, light gray, medium bedded, medium grained	39
50	Limestone, like 49, but brownish gray, with secondary chert	28
51	Limestone, brownish gray, thin bedded, fine grained, argillaceous, with a few beds like 49	31
52	Shale and siltstone interbedded, shale, reddish brown, platy, and siltstone, brownish gray, medium bedded, 70% shale	25
53	Shale and limestone; shale, greenish gray to brownish gray, splintery, calcareous, and limestone, medium gray, medium bedded, argillaceous	23
54	Limestone, like 46	10
55	Covered, float sample, probably like 56	39
56	Mudstone, reddish brown, thin bedded	42
57	Mudstone, similar to 56, weathers light reddish brown	47
58	Shale and limestone, shale, brownish gray and greenish gray, with interbeds of limestone, brownish gray (yellow weathering) silty, argillaceous	36
59	Limestone, light gray, medium bedded, shell coquina Terebratuloid brachiopods	13

THAYNES cont.

Sample No.	Description	Thickness feet	
60	Limestone, like 59 interbedded with greenish gray and brownish gray shale; 75% shale	43	
61	Limestone, like 59	19	
62	Shale, yellowish to greenish gray	42	
63	Shale, greenish to brownish gray, silty, calcareous	47	
64	Limestone, medium gray (weathers brownish gray), medium bedded, fine to medium grained, fossiliferous, <u>Meekoceras</u> zone: *Meekoceras gracilitatis* *Xenodiscus sp.* *Involtes sp.*	5	
65	Shale, yellowish brown, silty	35	
66	Limestone, like 64, fossils not identifiable	5	
67	Shale, like 65 with some very silty argillaceous limestone	62	
68	Shale and limestone, like 67	55	
69	Shale and limestone, like 67	24	
70	Shale and limestone, like 67, and some limestone like 66	48	
71	Shale and limestone, like 67	49	
72	Shale and limestone, like 67	41	
	TOTAL THAYNES		1,940

WOODSIDE FORMATION

73	Siltstone and shale, reddish brown, thin bedded, some beds micaceous	91	
74	Siltstone and shale, like 73	80	
75	Mostly covered, scattered sample, and float like 73	151	

WOODSIDE cont.

Sample No.	Description	Thickness feet
x	Covered, probably like 73	228
	TOTAL WOODSIDE	550
DINWOODY FORMATION		
76	Shale, green, thin bedded, in part elipsoidal	22
77	Shale, like 76	33
78	Shale, like 76, one 6" bed yellow, argillaceous limestone	24
79	Shale and limestone, interbedded, shale, greenish gray, like 76 and limestone, medium gray (weathers yellow), medium bedded, fine grained, argillaceous; 75% shale	17
	TOTAL DINWOODY	96
	TOTAL MOENKOPI GROUP	3,669
PARK CITY FORMATION		Not measured

Cephalopod Gulch (section 10)

A good section of the Moenkopi group is exposed along the Wasatch front between Dry Canyon and the mouth of Red Butte Canyon near Salt Lake City, in T. 1 N., R. 1 E. The lower part of the Thaynes formation at this locality contains several faults, and although considerable care was taken, some repetition and/or ommission of beds may have been overlooked.

Measured section:

SHINARUMP CONGLOMERATE

- Disconformity -

MOENKOPI GROUP

TIMOTHY FORMATION

Sample No.	Description	Thickness feet
2	Siltstone, pale reddish brown with spherical greenish gray spots, massive, calcareous	170
3	Sandstone, grayish red purple, massive, very fine grained, micaceous, quartz	300
4	Siltstone, pale reddish brown, thin bedded, calcareous, several ripple marked beds	845
	TOTAL TIMOTHY	1,315

THAYNES FORMATION

Sample No.	Description	Thickness feet
5	Limestone, light olive gray, massive, argillaceous, alternating thin bedded limestone and red siltstone near top	280
6	Limestone, shale and siltstone, interbedded; limestone, light brownish gray with crinoid stems, shale, light olive gray, splintery, and siltstone, pale reddish brown <u>Pentacrinus?</u>	178
7	Limestone, medium gray (weathers yellowish gray), platy, silty, fossiliferous, undeterminable cephalopods, <u>Lingula</u> <u>Monotis?</u>	375
8	Limestone, light gray, massive, fine grained, fossiliferous, Terebratuloid brachiopods, <u>Monotis?</u>	425
9	Limestone, medium gray (weathers yellowish gray), medium bedded, argillaceous, fossiliferous, <u>Pentacrinus</u>	412
10	Shale, yellowish gray, splintery, calcareous	50
11	Limestone, medium gray (weathers light gray), thin bedded, argillaceous	40

THAYNES cont.

Sample No.	Description	Thickness feet
12	Limestone, medium light gray (weathers light brownish gray), massive, cherty, fossiliferous, broken brachiopod fragments, Terabratuloidea?	100
13	Shale and limestone, interbedded; shale, yellowish gray, platy, and limestone, light gray, medium bedded, argillaceous.	360
14	Shale and limestone; shale, light olive gray, with a few beds of limestone, medium gray	40
15	Limestone, medium gray (weathers light olive gray) thin bedded	20
16	Shale, light olive gray (weathers brownish gray) micaceous	90
17	Limestone, medium light gray (weathers brownish gray), medium bedded, fossiliferous, <u>Meekoceras</u> zone at the base: <u>Meekoceras gracilitatis</u> <u>Anasibirites sp.</u> <u>Pseudomonotis sp.</u>	68
18	Limestone, medium light gray, massive	173
19	Siltstone, grayish orange pink to yellowish gray, massive, calcareous	25
	TOTAL THAYNES	2,636

WOODSIDE FORMATION

Sample No.	Description	Thickness feet
20	Shale and siltstone, pale grayish red, thin bedded, platy, gypsiferous	410
	TOTAL WOODSIDE	410
	TOTAL MOENKOPI GROUP	4,361

PARK CITY FORMATION — Not measured

Fig. 12.--Cephalopod Gulch (section 10), Moenkopi group forms barren slopes near center.

Gold Hill (section 13)

A poorly exposed and incomplete section of the lower Triassic is present in the Gold Hill District, about secs. 7 and 17, T. 7 S., R. 19 W., Tooele County, Utah. At this locality only the lower part of the section is present, the upper part has been eroded off and is nonconformably overlain by Tertiary. Both the Woodside and Thaynes formations are recognizable and the *Meekoceras* zone is present. Nolan (1935, p. 42) reports less than 50 feet of Triassic, but about one half mile north of the locality mentioned by him a greater thickness is present, the measured section of which is given below.

Measured section:

TERTIARY — Not measured

- Nonconformity -

MOENKOPI GROUP

THAYNES FORMATION

Sample No.	Description	Thickness feet
1	Limestone, medium gray to brownish gray (weathers brown), medium to thin bedded, medium grained, argillaceous, fossiliferous, *Meekoceras*?	6
2	Shale, pale green and brownish red, crumbly	6
3	Limestone, brownish gray (weathers brown), medium bedded, medium grained, argillaceous, fossiliferous, unidentified pelecypods	20
4	Shale, greenish gray, calcareous	17
5	Shale, brownish red, silty	17
6	Limestone, like 3	2

THAYNES cont.

Sample No.	Description	Thickness feet
7	Shale, like 5	29
8	Limestone, like 3, Terebratuloid brachiopods	6
	TOTAL THAYNES	103+

WOODSIDE FORMATION

Sample No.	Description	Thickness feet
9	Shale and siltstone, reddish brown, thin bedded, soft, crumbly	358
	TOTAL WOODSIDE	358
	TOTAL MOENKOPI GROUP	461+

PERMIAN — Not measured

Currie - Dolly Varden (section 15)

The most complete section of the lower Triassic sequence so far reported in Elko County, Nevada occurs in Goshute Valley about 6 miles north of Currie, Nevada near the Dolly Varden Anticline, approximately secs. 8 and 9, T. 29 N., R. 64 E. This section of definite miogeosynclinal aspect extends the miogeosynclinal facies farther west than has previously been demonstrated. The gray, yellowish gray and brownish gray limestones and the greenish gray shales have a Thaynes appearance and contain a typical Thaynes fauna. No units with the litho-straigraphic position and aspect of the Timothy, Woodside or Dinwoody are definitely recognizable although some of the greenish gray shales near the base suggest Dinwoody. However, similar shales occur in the Thaynes and the whole sequence is probably younger than youngest Dinwoody since the Meekoceras zone occurs only 81 feet above the base. The entire sequence below the Shinarump conglomerate and above the highest Permian strata is here tentatively referred to the Thaynes formation.

Measured section:

SHINARUMP? CONGLOMERATE 42

- Disconformity -

MOENKOPI GROUP

THAYNES? FORMATION

Sample No.	Description	Thickness feet
11	Dolomite, medium gray (weathers yellowish gray), medium bedded fine grained, saccharoidal	23
12	Limestone, medium dark gray, thin bedded, fine grained	18
13	Siltstone, yellowish olive gray to purplish red, thin bedded, platy	36
14	Dolomite and limestone, yellowish olive gray (weathers reddish brown), thin bedded, platy, silty, fossiliferous, <u>Monotis</u>?	180
15	Limestone, medium gray, medium bedded, fine grained	6
16	Limestone, light olive gray, thin to medium bedded, fine grained, very silty, fossiliferous, very abundant <u>Lingula</u>	289
17	Limestone, medium gray, medium bedded, coarse grained, fossiliferous; poorly preserved, unidentifiable cephalopods, <u>Pleurophorus bregeri</u>	87
18	Shale, greenish gray to yellowish gray, soft, crumbly	128
19	Limestone, yellowish olive gray, medium bedded, silty	177

THAYNES? cont.

Sample No.	Description	Thickness feet
x	Covered, probably soft shale and/ or siltstone	7
20	Limestone, like 19	21
21	Covered, float of limestone, yellowish gray, thin bedded, silty, and siltstone, light brownish gray, platy	319
22	Limestone, medium gray to light olive gray, medium bedded, fine grained, silty	117
23	Shale and siltstone, light olive gray to medium olive gray, platy	105
24	Limestone, medium gray with brown streaks, medium bedded, medium grained	27
25	Shale and siltstone, greenish gray, thin bedded, platy	60
26	Limestone, light olive gray with brown mottling, medium bedded, coarse grained, fossiliferous; unidentifiable shell fragments, probably brachiopods	28
27	Shale and siltstone, like 25	47
28	Limestone, light olive gray with brown mottling, medium bedded, coarse grained	5
29	Shale and siltstone, like 25	23
30	Limestone, like 28	3
31	Siltstone, yellowish gray, thin bedded, platy, micaceous, calcareous	27
32	Limestone, medium gray with brown mottling, medium bedded, medium grained silty	13
33	Siltstone, like 31	10

THAYNES? cont.

Sample No.	Description	Thickness feet
34	Limestone, like 28	2
35	Limestone, like 28, fossiliferous, *Pseudomonotis?* *Terebratula thaynesiana*	18
36	Siltstone, like 31	11
37	Limestone, like 28, very fossiliferous *Pseudomonotis?* *Terebratula thaynesiana*	8
38	Siltstone, like 31	30
39	Limestone, medium light gray with brown streaks, medium bedded, medium grained, fossiliferous, *Pseudomonotis?*	11
40	Siltstone, yellowish gray to light brown, thin bedded, platy micaceous, very calcareous	20
41	Limestone, very light gray with brown streaks, medium bedded, very fine grained	10
42	Mostly covered, scattered outcrops and float of light greenish gray, calcareous shale and grayish orange pink, calcareous siltstone	243
43	Limestone, medium dark gray with brown mottling (weathers brown) medium bedded, medium grained, argillaceous, fossiliferous, *Meekoceras* zone: *Meekoceras gracilitatis* *Xenodiscus waageni?* *Xenodiscus* cf. *intermontanus* *Ophiceras?* *Pseudomonotis?*	10
44	Mostly covered, shale and siltstone like 42	81
	TOTAL THAYNES	2,200
FOSSILIFEROUS PERMIAN		Not measured

Fig. 13.--Currie-Dolly Varden (section 15). Uppermost Permian on extreme right, Meekoceras zone at three small Juniper trees near center, alternating limestone and siltstone on ridge at extreme left represent samples 34 to 41 in measured section.

Pequop Range (section 16)

A fair but incomplete Triassic section was measured on the east flank of the south end of the Pequop Range, Elko County, Nevada, approximately sec. 25, T. 31 N., R. 64 E. and sec. 30, T. 31 N., R. 65 E. This section was first discovered by Professor Harry E. Wheeler of the University of Washington while he was engaged in geological reconnaissance for Phillips Petroleum Company. The section was measured by Professor Wheeler and the writer.

This section, though incomplete, was important in pointing out the occurance of a considerable thickness of Triassic sediments in northeastern Nevada and stimulated the search which led to discovery by Wheeler of the more complete Dolly Varden Valley section (section 15) and several (as yet unmeasured) sections in northern Elko County.

Measured section:

- Fault contact -

THAYNES? FORMATION

Sample No.	Description	Thickness feet
1	Sandstone and siltstone, reddish gray (weathers reddish brown), medium to thin bedded, fine grained, with a few 6" to 1' beds of medium gray, medium grained limestone	165
2	Siltstone and limestone, siltstone, medium brownish red, thin bedded, sandy, interbedded with limestone, brownish gray, fine grained, argillaceous, silty	478
3	Sandstone and siltstone, medium to light gray, thin bedded, very	97

THAYNES? cont.

Sample No.	Description	Thickness feet
3 cont.	fine grained calcareous	
4	Shale, drab greenish gray, laminated, splintery	144
5	Siltstone, light gray (weathers brownish gray) irregularly thin bedded	48
6	Sandstone and siltstone, medium gray to reddish gray, thin bedded, fine grained	153
7	Limestone, yellowish gray to greenish gray, medium bedded, fine grained, argillaceous, silty, fossiliferous, unidentified cephalopods	200
x	Covered, probably like 6	185
8	Limestone, medium to dark gray, medium to thick bedded, medium grained	39
9	Siltstone and sandstone, medium gray (weathers reddish gray) thin bedded to platy, fine grained	94
10	Shale and siltstone; shale, drab green, laminated micaceous, silty, interbedded with siltstone, medium to light gray (weathers reddish gray), arenaceous, calcareous	147
11	Limestone, medium to dark gray, medium bedded, fine to medium grained, argillaceous	80
12	Limestone, medium to dark gray (weathers greenish gray) thin bedded, fine grained, argillaceous, silty	97
13	Limestone, light to medium gray, medium bedded, fine to medium grained, porous	30

THAYNES? cont.

Sample No.	Description	Thickness feet
14	Sandstone, brownish red to brownish gray, thin bedded to platy, fine grained, silty	38
15	Sandstone and limestone; sandstone, medium to light gray (weathers reddish gray), thin bedded, fine grained, silty, calcareous, interbedded with limestone, medium gray, thin bedded, fine grained, argillaceous	170
x	Covered, probably similar to 15	140
16	Limestone, brownish gray, medium bedded, medium to fine grained, argillaceous, fossiliferous, *Meekoceras* zone: *Meekoceras gracilitatis*	2
x	Covered, probably similar to 15	68
	TOTAL THAYNES?	2,375

- Disconformity -

PHOSPHORIA? — Not measured

TABLE 1

LOCATION AND SOURCE OF SECTIONS

Section No.*	Section Name	Location	Source
1.	Cross Mountain	Sec. 29, T. 7 N., R. 98 W., Moffat Co., Colo.	This paper
2.	Split Mountain	Sec. 30, T. 4 S., R. 24 E., Uintah Co., Utah	This paper
3.	Vernal-Red Mountain	Sec. 5, T. 3 S., R. 22 E., Uintah Co., Utah	This paper
4.	Whiterocks Canyon	Sec. 19, T. 2 N., R. 1 E., Uintah Co., Utah	This paper
5.	Lake Fork Canyon	Sec. 26, 34, and 35, T. 2 N., R. 5 W., Duchesne Co., Utah	This paper
6.	Duchesne River	Sec. 2, T. 1 S., R. 8 W., Duchesne Co., Utah	Huddle, J. W., and McCann, F. T. (1947) "Geologic Map of Duchesne River Area, Wasatch and Duchesne Counties, Utah", <u>U. S. Geol. Survey Prelim. Map</u> 75, Oil and Gas Inves. Ser.
7.	Upper Weber Canyon	Sec. 11 and 13, T. 1 S., R. 6 E., Summit Co., Utah	This paper

*see index map page 34

TABLE 1—*Continued*

Section No.	Section Name	Location	Source
8.	Lower Weber Canyon	Secs. 23 and 24, T. 4 N., R. 3 E., Morgan Co., Utah	This paper
9.	Red Butte Canyon	Unsurveyed. Approx. secs. 17 and 20, T. 1 N., R. 2 E., Salt Lake Co., Utah	This paper
10.	Cephalopod Gulch	Unsurveyed. Approx. sec. 34, T. 1 N., R. 1 E., Salt Lake Co., Utah	This paper
11.	Parley's Canyon	Secs. 24 and 25, T. 1 S., R. 1 E., Salt Lake Co., Utah	This paper
12.	Cottonwood Canyon	Secs. 14 and 15, T. 2 S., R. 3 E., Salt Lake Co., Utah	Calkins, F. C., and Butler, B. S. (1943), "Geology and Ore Deposits of the Cottonwood-American Fork Area, Utah", *U. S. Geol. Survey Prof. Paper* 201.
13.	Gold Hill	Secs. 8 and 17, T. 7 S., R. 19 W., Tooele Co., Utah	This paper

TABLE 1--Continued

Section No.	Section Name	Location	Source
14.	Highway 50	Along Hy. 50 about 20 mi. S. of its junction with Hy. 40 at Wendover, Utah, Elko Co., Nevada	Field examination of unpublished section.
15.	Dolly Varden Valley	Approx. secs. 8 and 9, T. 29 N., R. 64 E., Elko Co., Nevada	This paper
16.	Pequop Range	Approx. sec. 25, T. 31 N., R. 64 E. and sec. 30, T. 31 N., R. 65 E., Elko Co., Nevada	This paper
17.	Confusion Mountains	T. 16 S., R. 16 W., Millard Co., Utah	Bacon, G. S. (1948), "Geology of the Confusion Range, West-Central Utah", Geol. Soc. Am. Bull., Vol. 59, No. 10.
18.	San Francisco Mountains	Secs. 17 and 18, T. 28 S., R. 11 W., Beaver Co., Utah	Butler, B. S. (1913), "Geology and Ore Deposits of the San Francisco and Adjacent Districts, Utah", U. S. Geol. Survey Prof. Paper 80.
19.	Mineral Mountains	2 mi. N. E. of Minersville, Beaver Co., Utah	Field examination of unpublished section.

TABLE 1--Continued

Section No.	Section Name	Location	Source
20.	Pavant Range	Approx. secs. 25 and 35, T. 21 S., R. 4 W., Millard County, Utah	Maxey, George B. (1946), "Geology of part of the Pavant Range, Millard County, Utah", Am. Jour. of Sci., Vol. 244, pp. 324-56.
21.	Gordon Creek	Sec. 24, T. 14 S., R. 7 E., Carbon Co., Utah	Well log, Pacific Western Oil Co., Gordon Creek Well.
22.	Spanish Fork	Sec. 21, T. 9 S., R. 4 E., Utah Co., Utah	Baker, A. A., (1947) "Stratigraphy of the Wasatch Mountains in the Vicinity of Provo, Utah", U. S. Geol. Survey Prelim Chart 30, Oil and Gas Inves. Series.
23.	Scott's Draw	Sec. 17, T. 4 S., R. 4 E., Wasatch Co., Utah	Ibid.
24.	Temple Mountain	T. 24 S., R. 11 E., Emery Co., Utah	Baker, A. A. (1946), "Geology of the Green River Desert - Cataract Canyon Region, Emery, Wayne, and Garfield Counties, Utah", U. S. Geol. Survey Bull. 951.

TABLE 1--Continued

Section No.	Section Name	Location	Source
25.	San Rafael Swell	T. 20 S., R. 11 and 12 E., Emery Co., Utah	Gilluly, James (1929), "Geology and Oil and Gas Prospects of Part of the San Rafael Swell, Utah", U. S. Geol. Survey Bull. 806.
26.	Thompson	Sec. 33, T. 21 S., R. 21 E., Grand Co., Utah	Well log, Pacific Western and Equity Oil Companies, Thompson Unit #1.
27.	Salt Valley	T. 23 S., R. 24 E., Grand Co., Utah	Dane, C. H. (1935), "Geology of the Salt Valley Anticline and Adjacent Areas, Grand Co., Utah", U. S. Geol. Survey Bull. 863.
28.	Salt Valley	Sec. 17, T. 24 S., R. 26 E., Grand Co., Utah	Ibid.
29.	Asbury Creek	Sec. 14, T. 9 S., R. 101 W., Mesa Co., Colo.	Well log, Amerada Oil Co., Asbury Creek Well.
30.	Wilson Creek	Sec. 34, T. 3 N., R. 94 W., Rio Blanco Co., Colo.	Well log, Texas and California Oil Companies, Wilson Creek Unit #1.

TABLE 1--Continued

Section No.	Section Name	Location	Source
31.	Cane Creek	Sec. 22, T. 26 S., R. 20 E., Grand Co., Utah	McKnight, E. T., (1940) "Geology of Area between Green and Colorado Rivers, Grand and San Juan Counties, Utah", U. S. Geol. Survey Bull. 908.
32.	Moab	Sec. 27, T. 29 S., R. 20 E., San Juan Co., Utah	Baker, A. A. (1933), "Geology and Oil and Gas Possibilities of the Moab District, Grand and San Juan Counties, Utah", U. S. Geol. Survey Bull. 841.
33.	Stillwater Canyon	T. 27 S., R. 17 E., San Juan Co., Utah	McKnight, E. T., op. cit.
34.	Cove Canyon	S. end of South Block Cove Canyon, Garfield Co., Utah	Baker, A. A. (1946), "Geology of the Green River Desert - Cataract Canyon Region, Emery, Wayne and Garfield Counties, Utah", U. S. Geol. Survey Bull. 951.
35.	Rasp Trail	Along Rasp Trail, 5 mi. above mouth of White Canyon, San Juan Co., Utah	Gregory, H. E. (1938), "The San Juan Country", U. S. Geol. Survey Prof. Paper 188.
36.	Rock Springs	Rock Springs, White Canyon, San Juan Co., Utah	Ibid.

TABLE 1--*Continued*

Section No.	Section Name	Location	Source
37.	Circle Cliffs	East side of Circle Cliffs, Garfield Co., Utah	Gregory, H. E., and Moore R. C., (1931), "The Kaiparowits Region", *U. S. Geol. Survey Prof. Paper* 164.
38.	Kaibab Gulch	T. 42 S., R. 2 W., Kane Co., Utah	Ibid.
39.	Hurricane Cliffs	Taylor Creek, Washington Co., Utah	Gregory, H. E. (1950), "Geology of Eastern Iron County, Utah", *Utah Geol. and Mineral Survey Bull.* 37.
40.	Zion Park	Camp Creek, Zion National Monument, Washington Co., Utah	Gregory H. E., and Williams, N. C., (1947), "Zion National Monument Utah", *Geol. Soc. Am. Bull.*, Vol. 58, No. 3.
41.	Muddy Mountains	Valley of Fire, South of Moapa, Clark Co., Nevada	Longwell, C. R. (1928) "Geology of the Muddy Mountains Nevada", *U. S. Geol. Survey Bull.* 798.
42.	Lee's Ferry	Lee's Ferry, Colorado River, Coconino Co., Arizona	Gregory, H. E., and Moore, R. C. (1931), op. cit.

TABLE 1—Continued

Section No.	Section Name	Location	Source
43.	Monument Valley	Sec. 35, T. 43 S., R. 15 E., San Juan Co., Utah	Baker, A. A. (1936), "Geology of the Monument Valley-Navajo Mountain Region, San Juan County, Utah", U. S. Geol. Survey Bull. 865.
44.	Dove Creek	Sec. 3, T. 38 N., R. 19 W., Montezuma Co., Colo.	Well log, Western Natural Gas Co. and Byrd-Frost, Inc., No. 1, Driscoll well.
45.	Elk Creek	Approx. sec. 31, T. 35 N., R. 4 W., Archuleta Co., Colo.	Read, C. B., et. al. (1949), "Stratigraphy and Geologic Structure in the Piedra River Canyon, Archuleta County, Colorado", U. S. Geol. Survey Prelim. Map 96, Oil and Gas Inves. Ser.
46.	Davis Creek	Approx. sec. 15, T. 36 N., R. 4 W., Archuleta Co., Colo.	Ibid.
47.	Montpieler Canyon	Secs. 32-34, T. 12 S., R. 34 E., Bear Lake Co., Idaho.	Mansfield, G. R. (1927), "Geography, Geology, and Mineral Resources of Part of Southeastern Idaho", U. S. Geol. Survey Prof. Paper 152.

TABLE 1--Continued

Section No.	Section Name	Location	Source
48.	Henry Quadrangle	Sec. 18, T. 6 S., R. 41 E., Caribou Co., Idaho	Ibid.
49.	Teton Basin	Sec. 17, T. 2 N., R. 46 E., Bonneville Co., Idaho	Gardner, Louis S. (1944), "Phosphate Deposits of the Teton Basin Area, Idaho and Wyoming", U. S. Geol. Survey Bull. 944-A.
50.	Gros Ventre River	Sec. 5, T. 42 N., R. 114 W., Teton Co., Wyoming	Love, J. D., et. al. (1951), "Geologic Map of the Spread Creek-Gros Ventre River Area, Teton County, Wyoming", U. S. Geol. Survey Prelim. Map 118, Oil and Gas Inves. Ser.
51.	Wind River	T. 37 N., R. 109 W., Sublette Co., Wyoming	Richmond, G. M., (1945), "Geology of Northwest End of the Wind River Mountains, Sublette Co., Wyoming", U. S. Geol. Survey Prelim. Map 31, Oil and Gas Inves. Ser.

TABLE 1--Continued

Section No.	Section Name	Location	Source
52.	Sage Creek	Sec. 27, T. 1 N., R. 1 W., Fremont Co., Wyoming	Sharkey, H. H. (1946), "Geology and Structure Contour Map of Sage Creek Dome, Fremont County, Wyoming", U. S. Geol. Survey Prelim. Map 53, Oil and Gas Inves. Ser.
53.	Boysen	T. 6 N., R. 4 E., Fremont Co., Wyoming	Tourtelot, H. A. and Thompson, R. M. (1948) "Geology of the Boysen Area, Central Wyoming", U. S. Geol. Survey Prelim. Map 91, Oil and Gas Inves. Ser.
54.	Wind River Basin	T. 33 N., R. 87 W., Natrona Co., Wyoming	Hares, C. J., et. al. (1946), "Geologic Map of the Southeastern Part of the Wind River Basin and Adjacent Areas in Central Wyoming", U. S. Geol. Survey Prelim. Map 51, Oil and Gas Inves. Ser.
55.	Hartville Uplift	Approx. sec. 32, T. 29 N., R. 67 W., Platte Co., Wyoming	Denson, N. M., and Botinelly, T. (1949) "Geology of the Hartville Uplift, Eastern Wyoming", U. S. Geol. Survey Prelim. Map 102, Oil and Gas Inves. Ser.

TABLE 1--Continued

Section No.	Section Name	Location	Source
56.	Mush - Osage	T. 41 S., R. 60 W., Weston Co., Wyoming	Dobbin, C. E., and Horn, G. H. (1949), "Geology of the Mush Creek and Osage Oil Fields and Vicinity, Weston County, Wyoming", U. S. Geol. Survey Prelim. Map 103, Oil and Gas Inves. Ser.
57.	Black Hills	T. 6 N., R. 2 E., Lawrence Co., South Dakota	Darton, N. H. (1909), "Geology and Water Resources of the Northern Portion of the Black Hills and adjoining Regions," U. S. Geol. Survey, Prof. Paper 65.
58.	Worland Area	Approx. sec. 23, T. 49 S., R. 89 W., Big Horn Co., Wyoming	Rogers, C. P., et. al. (1948) "Geology of the Worland-Hyattville Area, Big Horn and Washakie Counties, Wyoming," U. S. Geol. Survey Prelim. Map 84, Oil and Gas Inves. Ser.
59.	Clark Fork	Sec. 6, T. 56 N., R. 103 W., Park Co., Wyoming	Scott, W. F. (1952), Unpublished report to Gulf Oil Corp.

TABLE 1--Continued

Section No.	Section Name	Location	Source
60.	Fossil Creek	Sec. 4, T. 12 S., R. 2 W., Madison Co., Montana	Moritz, C. A. (1951), "Triassic and Jurassic Stratigraphy of Southwestern Montana", Bull. Amer. Assoc. Petrol. Geol. Vol. 35, No. 8.
61.	Blacktail Creek	Sec. 23-26, T. 12 S., R. 6 W., Beaverhead Co., Montana	Ibid.
62.	Livingston	Secs. 26, 35, 36, T. 2 S., R. 9 E., Park Co., Montana	Hadley, H. D., et. al. (1945), "Graphic Sections of Mesozoic and Paleozoic Rocks that Underlie the Basin Areas in Southcentral Montana", U. S. Geol. Survey Prelim. Chart 19, Oil and Gas Inves. Ser.
63.	Picket Pin Creek	Sec. 36, T. 4 S., R. 14 E., Sweetgrass Co., Mont.	Gardner, L. S., et. al. (1945), "Columnar Sections of Mesozoic and Paleozoic Rocks in the Mountains of South-central Montana", U. S. Geol. Survey Prelim. Chart 18, Oil and Gas Inves. Ser.
64.	Dry Creek	Sec. 3, T. 7 S., R. 21 E., Carbon Co., Mont.	Well log, The Ohio Oil Co., N. P. # 18.

TABLE 1--Continued

Section No.	Section Name	Location	Source
65.	Bighorn Canyon	Sec. 7, T. 6 S., R. 31 E., Big Horn Co., Mont.	Richards, P. W., and Rogers, C. P. (1951) "Geology of the Hardin Area, Big Horn and Yellowstone Counties, Montana", U. S. Geol. Survey Prelim. Map 111, Oil and Gas Inves. Ser.
66.	Little Beaver	Sec. 13, T. 4 N., R. 61 E., Fallon Co., Mont.	Well log, Shell Oil Co., Little Beaver.
67.	Boundary Dome	Sec. 4, T. 2 S., R. 27 E., Yellowstone Co., Mont.	Well log, Mid-Northern Oil Co., Crow Reservation No. 1.
68.	Crooked Creek	Sec. 15, T. 4 N., R. 26 E., Yellowstone Co., Mont.	Well log, Carter Oil Co., N. P. No. 1.
69.	Big Lake Field	Sec. 25, T. 1 N., R. 21 E., Stillwater Co., Mont.	Well log, I. T. I. O. Co., Hepp No. 2 c.
70.	Big Snowy Mountains	Sec. 32, T. 11 N., R. 21 E., Golden Valley Co., Mont.	Field examination of unpublished section.
71.	Garrison	Sec. 19, T. 10 N., R. 9 W., Powell Co., Mont.	Field examination of unpublished section.

REGIONAL ROCK CORRELATION

The regional rock unit relationships are shown by the stratigraphic cross sections pages 107 and 108.

Moenkopi Formation and Group

The typical Moenkopi formation of the Colorado Plateaus can be traced in almost continuous outcrops along the south flank of the Uinta Mountains where the marine tongue of the Thaynes formation separates the red beds of the Moenkopi into upper and lower red bed units, the Timothy and Woodside formations respectively. These three formations of the miogeosynclinal facies, Timothy, Thaynes and Woodside, have been designated by the writer (1950) as the Moenkopi Group. The validity of this rock unit correlation is further substantiated by the presence throughout the area of the overlying Shinarump conglomerate and the underlying Park City, Phosphoria or Kaibab formations.

Shinarump and Chinle Formations

The Shinarump and Chinle formations can be recognized throughout all of Utah and parts of northern Arizona, western Colorado, eastern Nevada, southwestern Wyoming and southeastern Idaho. The stratigraphic position and lithologic identity remain very much the same over the entire area. The thickness of the Chinle increases slightly, but not remarkably, westward.

In southeastern Idaho Mansfield (1927) has used the

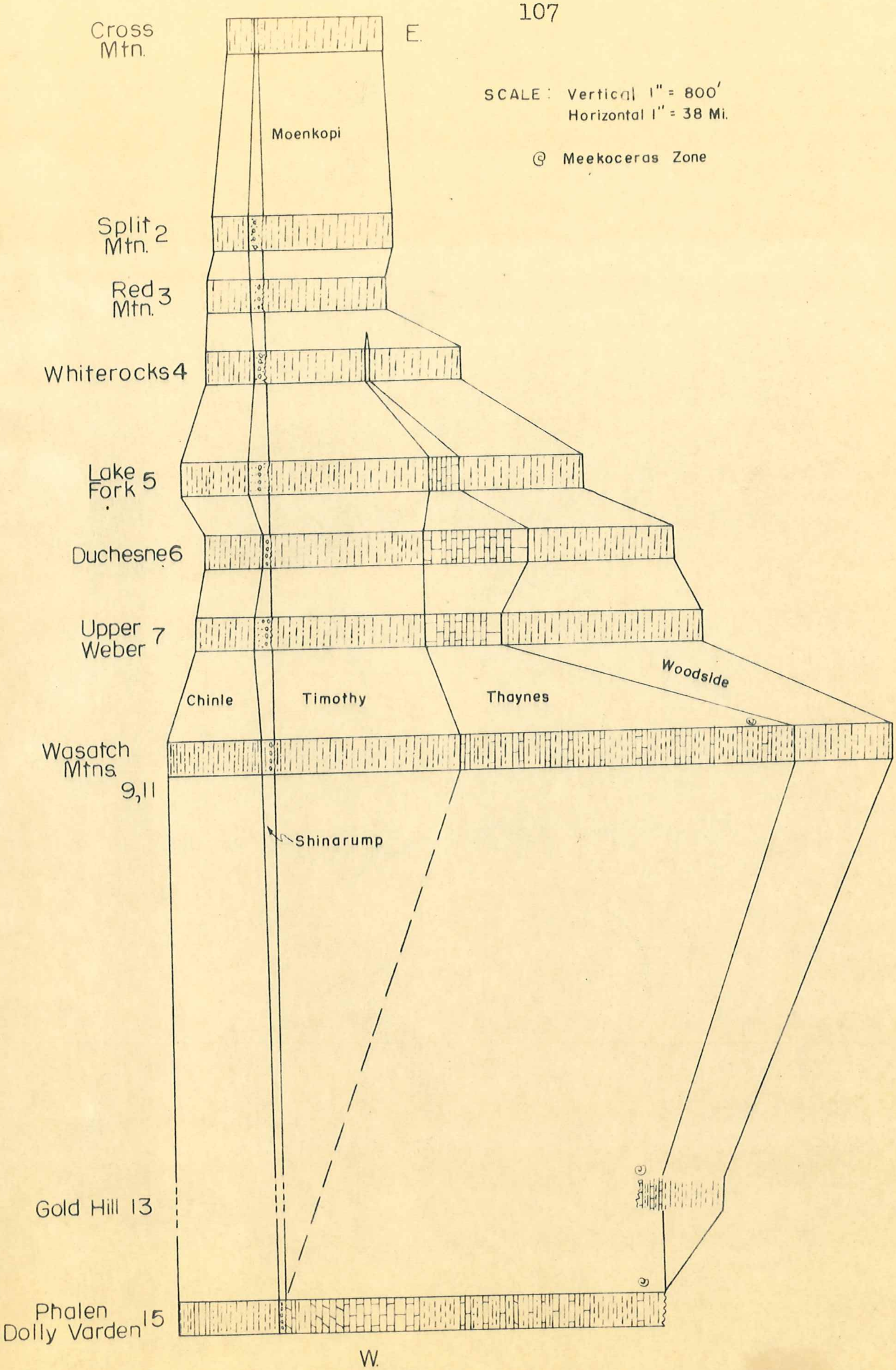


Fig. 14.--E.-W. Stratigraphic Cross Section from Northwestern Colorado to Northeastern Nevada

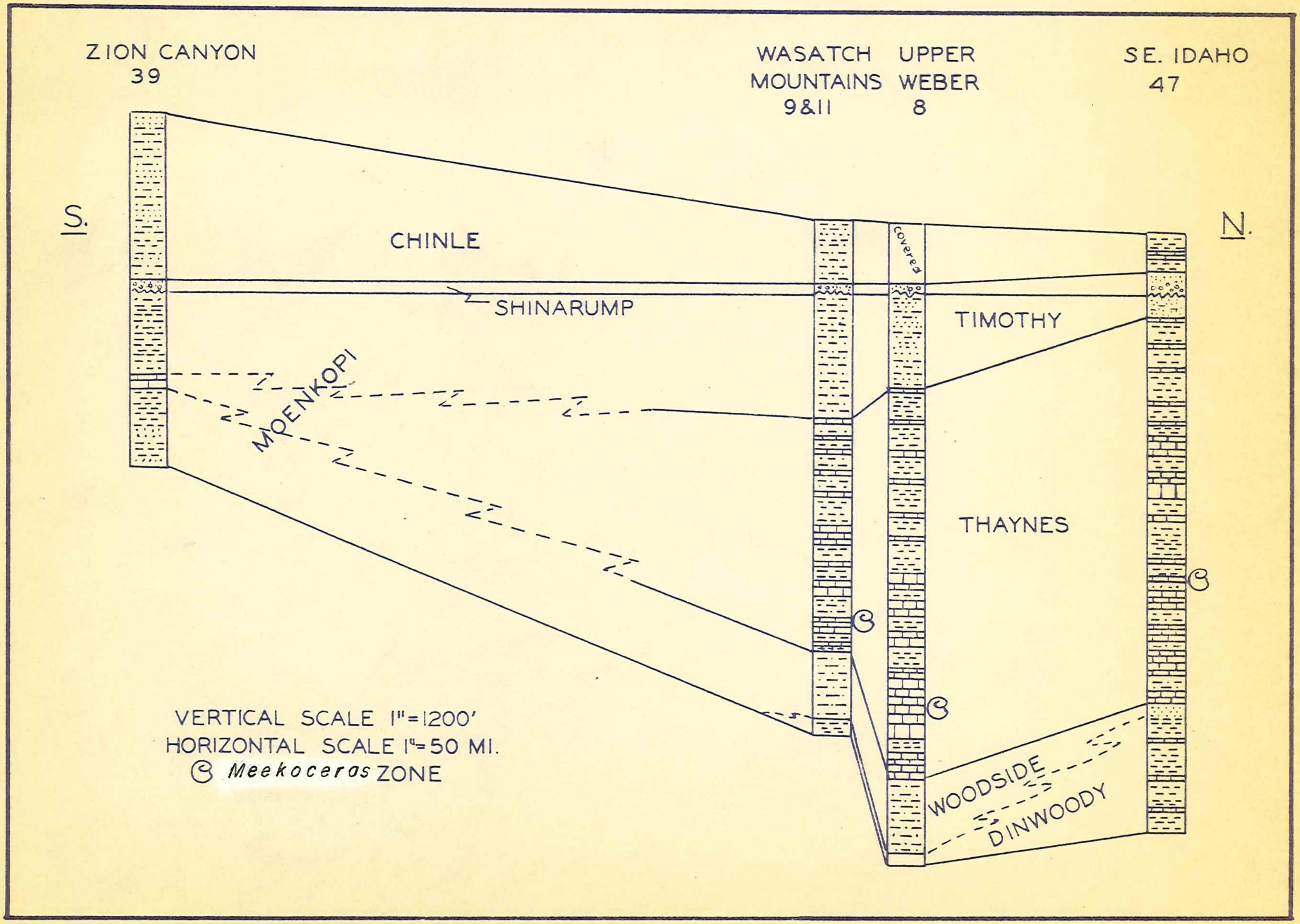


Fig. 15.--N.-S. Stratigraphic Cross Section from Southeastern Idaho to Southwestern Utah

names Higham grit, for those strata called Shinarump elsewhere, and Deadman limestone and Wood shale for the rock correlatives of the Chinle. This seemingly unnecessary duplication of names has already been discussed in the section on nomenclature.

Spearfish and Chugwater Formations

Northeastward in central and eastern Wyoming both the Thaynes formation and Shinarump conglomerate tongue out leaving the Chinle superimposed upon the Moenkopi to form an inseparable succession of red beds. This single red bed unit is called the Chugwater formation in Wyoming and the Spearfish formation in South Dakota. The name Spearfish, having priority, should perhaps be used in lieu of Chugwater in Wyoming; however, this suggestion is not offered as a specific recommendation at this time.

Popo Agie and Jelm Formations

In parts of western Wyoming the Shinarump conglomerate cannot be recognized, but the Thaynes formation is present. This leaves an uninterrupted sequence of red beds, between the Thaynes and Nugget formations, which contains the rock equivalents of both the Chinle and Timothy formations.

The name Popo Agie was used by W. C. Knight (1901, p. 359) to refer to some of the beds contained in this unit, but the exact content of rock included was not, and has never been adequately defined. Wilmarth (1938, p. 1042) recommends that the name Jelm as proposed in an abstract by S. H. Knight (1917, p. 168) be used instead of Popo Agie, "because of objectional pronunciation and inadequate definition".

It is the writer's opinion that neither Jelm nor Popo Agie have been adequately defined and that "objectional pronunciation" is not sufficient grounds for discarding an otherwise proper name. If either Popo Agie or Jelm is to be used they must be more exactly defined. The Popo Agie could be redefined to include the red beds between the Thaynes formation and the Nugget sandstone where the Shinarump is absent. If such redefinition were objectionable then a new name would be required for this unit. However, the writer presently does not feel justified, without more field work in the area concerned, in proposing a specific solution to this problem.

TEMPORAL CONSIDERATIONS

The Base of the Triassic

A satisfactory time rock base for the Triassic system has not yet been determined in the Rocky Mountain Region. The Triassic-Permian boundary is usually placed between the limestones of the Kaibab-Park City-Phosphoria sequence and the shales and siltstones of the Woodside-Dinwoody-Moenkopi lithologies.

The Permian limestones immediately below this boundary usually contain upper (but not uppermost) Permian fossils. The shales and siltstones of the Woodside and the Moenkopi are usually devoid of fossils. A few fossils classified as Triassic have been reported from the Dinwoody by Newell and Kummel (1942), but these do not occur near the base of the formation. In most sections the lowest good diagnostic Triassic fossils occur in the *Meekoceras* zone which is usually several hundred feet above strata containing diagnostic Permian fossils.

A disconformity sometimes occurs at the base of the Moenkopi, and it has been common practice to assign the missing uppermost Permian interval to the hiatus at the base of this disconformity. However, in most localities the writer has found little real evidence for this disconformity; it is his belief that a hiatus is more often placed here in the section to account for the missing time rather than because of any physical evidence of a disconformity.

Is it necessary to account for the missing upper Permian interval by a hiatus? Not necessarily. It is true that a fairly abrupt change in lithology occurs, and that the beds above this change closely resemble those lithologies higher in the section which are demonstrably Triassic. However, this change in lithology (and therefore in sedimentary environment) did not necessarily occur at precisely the beginning of the Triassic Period, in fact, it would be the oddest kind of coincidence if it had. Therefore, it must be recognized that the exact position of the Permo-Triassic boundary is not known and that with our present methods it cannot be accurately determined. One possibility of determining a bio-stratigraphic base for the Triassic is in northeastern Nevada, where H. E. Wheeler (personal communication) reports a considerable thickness of fossiliferous, pre-*Meekoceras*, Triassic strata.

Until more suitable criteria (biologic or other) are available it seems advisable to continue to place the Permian-Triassic boundary between the Kaibab-Park City-Phosphoria units and the Moenkopi-Woodside-Dinwoody lithologies, but always with question and with the realization that the lower part of these so called Triassic units probably contains some beds which were deposited during late Permian time.

Lower Triassic

The Moenkopi formation and group is principally Lower Triassic although the lowermost part may extend down into Upper Permian, as discussed above, and the uppermost part may extend into Middle Triassic.

The only diagnostic fossils are contained in the Thaynes formation, and these appear to be entirely Lower Triassic. Mathews (1931) identified some Middle Triassic cephalopods from the upper part of the Thaynes formation in the Wasatch Mountains, but Smith (1914 and 1932), and the writer have been unable to confirm this designation.

The Timothy formation and the upper part of the Moenkopi formation contain no diagnostic fossils and are questionably regarded as Lower Triassic solely on the basis of stratigraphic position although these formations may very possibly extend into Middle Triassic.

Middle Triassic?

Since no diagnostic fossils of Middle Triassic age have yet been discovered in the region, the presence, or absence, of Middle Triassic strata must be inferred from the stratigraphic position and depositional history of the strata between the faunally "dated" Lower Triassic Thaynes formation and Upper Triassic? Chinle formation and, of course, be subject to considerable question. The formations occupying this interval are the Timothy formation, its equivalent upper portion of the Moenkopi formation, and the Shinarump conglomerate.

In the preceding paragraph the possibility of the Timothy formation and the upper portion of the Moenkopi formation extending into Middle Triassic time is recognized. However, it is also possible, if not probable, that the Shinarump conglomerate, or the unconformity at its base, accounts for at least a part of Middle Triassic time. Therefore, a brief discussion of the Shinarump problem is given below.

Origin and Age of the Shinarump Conglomerate

The Shinarump conglomerate is a remarkably thin, widespread, blanket-like, fine to coarse grained quartzose sandstone with scattered stringers and lenses of pebble conglomerate and with numerous isolated pebbles in the sandstone matrix. The vast majority of Shinarump pebbles are composed of quartz, quartzite, and chert, usually less than one inch in diameter. However, some gravel occurs and cobbles up to seven inches have been reported by Gregory (1917) in the Navajo country.

The larger pebbles and gravels occur near the base of the unit with the formation as a whole becoming finer grained upward. No lateral trend of increasing or decreasing grain size has been observed. However, this may be due to the lack of sufficiently accurate observations.

The sandstones are very frequently cross bedded and ripple marked. A distinct disconformity occurs at the base of the Shinarump and numerous less distinct, but perhaps equally significant, disconformities or diastems are present within the formation. Regarding the Shinarump in the San Rafael Swell, Gilluly and Reeside (1928, p. 67) state:

> Everywhere the Shinarump is clearly recognizable as an interfingering series of lenticular gritty sandstones, conglomerates, clean sandstones, variegated mudstones and even shale--a series cut by hundreds of channel unconformities within itself and composed of lenses which thicken and thin with bewildering rapidity.

The Shinarump is everywhere conformably overlain by the Chinle formation into which it grades.

Fossils, except for petrified wood which can be found at almost every locality, are rare. Logs fifty feet long and two and one-half feet in diameter and fern impressions are reported by Gregory and Moore (1931, p. 52) in the Kaiparowits region. In Monument Valley, Utah, Baker (1936, p. 46) reports logs twenty to thirty feet long and two to three feet in diameter, together with cycad fronds. In the Navajo country Gregory (1917) reports logs, cycad leaves, unidentifiable bone fragments and at one locality, pelecypods. Regarding the pelecypods, Gregory (p. 41) quotes a personal communication from T. W. Stanton in which Stanton states that one specimen "is almost certainly marine." However, Reeside, in Gilluly and Reeside (1928, p. 67), restudied this specimen, and concludes that it is, like the others in the original collection, a fresh water form.

All investigators who have studied the Shinarump have concluded that the formation represents deposition by streams on a surface of low relief. Gregory's ideas are put forth in several of his papers and are perhaps best summed up in his work on the San Juan country (1938, p. 49) where he states:

> The physiographic conditions under which the Shinarump was deposited are difficult to visualize. What conditions could be so persistant and so uniform as to permit the deposition of a thin sheet of material essentially alike over thousands of square miles in Utah, Arizona, and Nevada? The lenticular bedding, the abrupt lateral and vertical changes in composition and texture, and the absence of thick deposits point to a land surface of slight relief over which intermittent and ephemeral streams, perhaps also perennial streams of fluctuating volume, all flowing in poorly defined channels, transported and deposited material available for distribution.

Gilluly and Reeside (1928) ascribe a continental origin to the Shinarump and state (p. 67):

> The numerous lateral and vertical variations of the Shinarump conglomerate and its apparently conformable position beneath the Chinle formation, which is definitely continental, point to a continental origin for the Shinarump conglomerate also. The evidence is not conclusive, but the improbabilities that arise on a postulate of marine origin seem so great that the evidence cited appears sufficient. A marine transgression extending over 100,000 square miles (the minimum areal extent of the Shinarump conglomerate) would be expected to leave offshore sediments and marine fossils.

Baker (1946) agrees with Gregory. He summarizes (p. 60):

> This widespread relatively thin formation with its coarse sediments, irregular bedding, and cross bedding appears to have been deposited by shifting streams upon a surface of slight local relief; the source of the sediments is not known.

Stokes (1950) regards the Shinarump conglomerate as fluvial and postulates its origin as an extensive pediment deposit.

Although each of the above writers are in general agreement regarding the origin of the Shinarump, they are also impressed by the thinness, uniformity, and areal extent of the deposit and all regard it as an unusual if not unique example of fluvial deposition. This unusual aspect of the Shinarump requires the brief consideration of other possible origins.

The sand deposits upon modern beaches and ancient deposits, such as the Saint Peter sandstone of the northern mid-continent region and its lateral equivalents, and the Tensleep sandstone of Wyoming and its lateral equivalents, which have long been regarded as the beach facies of transgressive or regressive seas, are not altogether unlike the Shinarump in some of their general aspects. However, most modern beach sands and both the Saint Peter and the Tensleep are much better sorted than the Shinarump. Both the Saint Peter and the Tensleep thicken and grade into finer clastic and carbonate lithologies; such lateral thickening and gradation has not been observed in the Shinarump, although its original western margin is as yet unknown. Lamar (1927) reports that cross bedding and ripple marks, though present, are rare in the Saint Peter. Thiel (1935) states that minor disconformities within the Saint Peter are suspected, but have not been observed. Berkey (1906) reports a considerable marine fauna from the Saint Peter at several localities in Minnesota, Wisconsin, and Missouri. P. C. Wilson (personal communication) has collected fusulinids from several localities in the Tensleep. The above characteristics of the Saint Peter and Tensleep are sufficiently different from those of the Shinarump to suggest that the physical environments of deposition were not entirely the same. It is also quite possible that portions of these units were formed in ways other than beach sand deposition.

The deposition of the uniform blanket-like Shinarump on a stable bottom (marine or lacustrine) as a subaqueous sand desert, worked and reworked by waves and currents, would explain the lithologic characteristics of the formation better than the transgressive or regressive beach sand hypothesis. On such a stable bottom the available rock waste would be shifted about by waves and currents, the unstable minerals destroyed, and the finer clastic material would be winnowed out and carried to an area of quieter water and perhaps greater subsidence before being deposited.

Such subaqueous deserts of shifting sands would not support an abundant benthonic fauna; those which were present, and the pelagic forms, would likely be destroyed by the abrasive action of the shifting sands, thus accounting for the lack of fossils in the Shinarump. Drifting trees which eventually become waterlogged could explain the abundance of petrified wood.

As seen from the above discussions, the exact nature of the physical depositional environment of the Shinarump formation remains undetermined; this is perhaps due to the fact that tectonic stability may play a more important role in the formation of such quartzose blanket sands than does the specific nature of the physical environment. Under tectonic conditions of extremely stable shelves, where rock debris moves slowly over the depositional interface and is subjected to constant reworking, where very slight and very slow subsidence prevents the accumulation of thick deposits, blanket quartzose sandstones similar to the Shinarump are likely to be formed, even though specific physical environments of deposition may vary.

From the observations thus far made the following general conclusions regarding the origin of the Shinarump may be drawn: (1) the Shinarump appears to have been deposited on a shelf of extreme tectonic stability; (2) the lithology, internal structures, and fossil content have suggested deposition by streams on a plain of low relief to previous investigators and no evidence observed by the writer tends to negate this theory.

However, other possible physical environments, especially stable bottom deposits, cannot be entirely discounted, and the Shinarump may include areas where the specific depositional environments differ from one another.

Most stratigraphers who have concerned themselves with the problem of the age of the Shinarump have assigned all of Middle Triassic time to the hiatus represented by the disconformity at the base of the Shinarump and have regarded the formation itself as the "basal conglomerate" of the Upper Triassic cycle of deposition. This implies that the Shinarump is a two process type of conglomerate, deposited as a separate episode and at a later date than the lateral corrasion surface upon which it rests.

Gilluly and Reeside (1928, p. 67) and the writer have noted numerous minor disconformities or diastems within the unit. It is the writer's opinion that these disconformities within the unit, individually or collectively, may have as much or more time significance as the more apparent disconformity at the base, and that the Shinarump is a "one process" type of conglomerate such as described by Mackin (1950, p. 62) rather than a "two process" type. This opinion is also held by Stokes (1950, p. 97) who states:

> It is illogical to assign the unconformity to one period and the gravel sheet to a much later period just as it is illogical to assume that cutting of a pediment surface precedes in its entirety the production and dispersal of the gravel sheet which covers it. The lapse of time is represented by both the unconformity and the gravel sheet. In the case of the Shinarump it would seem best to assign it to a Middle Triassic age rather than to assume widespread uniform erosion for this interval.

The writer believes that the Shinarump conglomerate, together with the disconformities or diastems both at its base and within, represent a locally intermittent stratigraphic record. The duration of accumulation of this record, in spite of its universal thinness, appears to have been relatively long. On this basis the Shinarump interval may include most of, all of, or more than all of the Middle Triassic epoch.

Upper Triassic?

The contact between the Shinarump conglomerate and the overlying Chinle formation is gradational and represents a gradual change from the environment responsible for the deposition of the Shinarump to that responsible for the formation of the Chinle. If the forgoing reasoning regarding the age of the Shinarump is correct then the Chinle by virtue of its stratigraphic position is no older than Middle Triassic and may represent deposition during all or a portion of Upper Triassic time. This age assignment is substantiated by Upper Triassic vertebrate fossils collected from the Chinle in Arizona (Gregory 1917, pp. 46-47).

The Top of the Triassic

The Triassic-Jurassic boundary is even more indefinite than the Permo-Triassic boundary. The base of the Jurassic must occur somewhere between the Chinle formation, which is dated as Upper Triassic? on rather sparse evidence, and the Carmel-Twin Creek formations which contain a Middle Jurassic fauna. Between these two "dated" formations occurs a considerable thickness of sandstone of the Nugget-Navajo formations and to the south the Kayenta and Windgate formations are also included.

It has been common practice among most investigators to place the Triassic-Jurassic boundary at the Chinle-(Nugget-Navajo) contact or at the Chinle-Windgate contact where the latter formation is developed.

Since the Chinle-(Nugget-Navajo-Windgate) contact is gradational, and there appears to be no disconformity to account for lower Jurassic time, it seems logical to assume that at least part of the Nugget-Navajo and possibly Windgate formations were deposited during the lower Jurassic.

The placing of the Triassic-Jurassic boundary precisely at the Chinle-(Nugget-Navajo-Windgate) contact is purely an arbitrary solution and is almost surely in error. However, this solution is one of practical convenience, and it is recommended that the practice of placing the boundary at the top of the Chinle be continued, at least until better evidence for its position is found, but always with question and with full realization that Jurassic time may have begun somewhere within the Chinle formation or, on the other hand, that Triassic time may have continued well into the overlying sandstone formations.

REGIONAL STRATIGRAPHIC ANALYSIS

Isopach-Lithofacies Maps

Isopach-Lithofacies maps of the general type proposed by Sloss, Krumbein and Dapples (1949) were prepared for the total Triassic sequence, the Moenkopi group (essentially the Lower Triassic sequence), and the Thaynes formation. These maps appear on pages 123, 127 and 129. The data for the maps were based upon seventy-one sections, of which fourteen sections were measured in the field by the writer, fifteen were published sections examined in the field by the writer, four were unpublished sections examined in the field by the writer, twelve were from well logs, and twenty-six were from published sections not examined in the field. The greatest number of control sections were taken in Utah, of the seventy-one sections thirty-five were in Utah, four in eastern Nevada, nine in Wyoming, twelve in Montana, three in eastern Idaho, six in western Colorado and one each in South Dakota and Arizona.

For each of these sections the total thickness of the unit and the total thickness of each separate lithology was determined. The lithologic data were then resolved into clastic ratio and sand-shale ratio values. These ratios together with the total thickness were plotted on a base map and were used as control points to construct isopach, "isoclastic" and "isosand-shale" lines.

The Middle and Upper Triassic sequences are not shown on separate maps because thicknesses and lithologies would show very little variation, in fact, the variations on the total Triassic map are largely a reflection of those of the Lower Triassic, somewhat masked by the relatively uniform values of the overlying strata.

The map of the Thaynes formation has no time-rock significance but is an effort to show only that Triassic unit which was deposited in a predominantly marine environment.

Moenkopi Group

The Moenkopi Group map, page 123, is confined almost entirely to the state of Utah since the group becomes unrecognizable to the north due to the absence of the Shinarump conglomerate, and little data were collected to the south.

Isopach Pattern

The isopach pattern shows a gradual thickening of the unit westward from the zero isopach, around isolated positives in western Colorado, to the Wasatch Line (approximately the one thousand foot isopach). From the Wasatch Line westward into western Utah the rate of increase in thickness is greatly accelerated. It will be noted that the two hundred foot isopachs east of the Wasatch Line have about the same spacing as the one thousand foot isopachs west of the line. This indicates that the ratio of increase in thickness is about five to one. This rapid increase in thickness and the maximum thicknesses in excess of five thousand feet in southeastern Idaho indicate a geosynclinal trough whose axis trends slightly east of north from the common corner of Utah, Arizona and Nevada to southeastern Idaho.

Lithofacies Pattern

Only those gross lithologies represented in the Moenkopi group are colored in the lithologic triangle of the map on page 123. It can be seen from the colored portions of this triangle that the unit is everywhere predominantly clastic. At no point in the area is the clastic ratio less than one. The dominant clastic rock type in the unit is siltstone which was treated as having a sand-shale ratio of one. However, in the eastern part of the area there is an excess of sandstone over shale while to the west there is an excess of shale. The area in which the gross lithology is sand-shale (a mixture of sand and shale with an excess of sand and no appreciable amount of limestone) is shown on the map in yellow, and the area of shale-sand lithology is shown in red. Two major areas of coarser clastic (yellow) deposition, one in southwestern Wyoming and northeastern Utah and the other in western Colorado and southeastern Utah, appear partially separated by an eastward projecting finger of finer clastic (red on map) material. This pattern suggests the influence of two distinct source areas, one to the north probably in northern Montana and the other to the southeast in western Colorado.

Westward in western Utah and eastern Nevada there is a large area where the gross lithology is shale-lime (magenta on the map), that is, a mixture of shale and sandstone with an excess of shale over sand and with appreciable amounts (but less than fifty per cent) of limestone. This lithology is largely due to the presence of the thick predominantly marine Thaynes formation in the miogeosynclinal area since the units of the Moenkopi group, exclusive of the Thaynes, exhibit much the same lithologic aspect as those on the shelf farther to the east.

The small area of sand-lime deposition (green on the map) in the northern part of the area is due to the dual effect of the near proximity of the Montana source area and the Thaynes marine environment.

The lithologic patterns displayed and the total thickness of sediments together with the ratio of thickness increase indicate that western Utah and southeastern Idaho were a part of a Lower Triassic miogeosyncline. Eastward in eastern Utah and western Colorado the lithologic aspect and relatively slow rate of thickening together with general thicknesses of less than one thousand feet suggest an area of unstable shelf deposition.

Total Triassic

The isopach and lithofacies patterns of the total Triassic map which appears on page 127 are essentially a reflection of the Moenkopi group variations masked by the addition of three hundred to four hundred feet of mainly siltstones of the Chinle formation and fifty to one hundred feet of mainly sandstones of the Shinarump. However, the same general patterns and trends are reflected with slight modification. The indication of dual source areas is shown by the projection of sand-shale (yellow) tongues into northeastern and southeastern Utah and the corresponding eastward projecting shale-sand (red) tongues into northwestern and southwestern Colorado.

Sufficient control was obtained to partially outline these source areas by means of incomplete zero isopachs in Montana and southwestern Colorado.

Thaynes Formation

The map of the Thaynes formation, page 129, is of special interest since it represents the only predominantly marine Triassic unit in this area.

Isopach Pattern

The zero isopach of the Thaynes formation represents, except in Montana where Late Triassic post depositional removal has probably occured, the maximum strand line of the Middle Lower Triassic Thaynes Sea. The isopach pattern of the Thaynes resembles that of the total Triassic less about one thousand to fifteen hundred feet of thickness. If an isopach map of the total Triassic exclusive of the Thaynes formation were made it would show a rather uniform thickness throughout the area with a slight but unimpressive increase westward into central Utah and then a decrease westward into eastern Nevada. It is only the presence of the Thaynes formation in the Triassic map that gives it a trough-like or geosynclinal appearance, therefore, it was only in "Thaynes time" that a Triassic geosyncline existed in this area of western United States.

Lithofacies Pattern

The clastic ratio of the Thaynes, except in the extreme southeast is slightly less than one. The large area of lime-shale lithologic aspect (violet on the map) indicates a limestone content of greater than fifty per cent and an excess of shale over sand. The lime-sand lithology (blue on the map) is probably a result of coarser clastics from the nearby Montana source while the shale-lime (magenta on the map) appears to be a reflection of the southwestern Colorado source.

If a lithofacies map of the total Triassic exclusive of the Thaynes formation were made it would show everywhere a clastic ratio near infinity and a sand-shale ratio near one. Therefore, most of the lithologic variations seen on the maps of the total Triassic and the Moenkopi Group are due to the presence of the Thaynes formation which contributes nearly all of the limestone and most of the shale to the sections.

PALEOTECTONICS

A study of the isopach-lithofacies maps permits, in a general way, the reconstruction of Triassic tectonics. The paleotectonic map on page 132 is a generalized reconstruction of the Lower Triassic tectonic elements.

Lower Triassic

The Triassic period began with most of the area an unstable shelf and with neutral or mildly positive areas to the north, probably in Canada, and to the east in Colorado. The area west of the Wasatch Line had a slight tendency to greater instability and more pronounced subsidence. During this phase the Woodside, Dinwoody, lower Moenkopi formations and their time rock equivalents were deposited.

In Middle? Lower Triassic, "Thaynes time", the tendency of the area west of the Wasatch Line to subside became much more pronounced and a true miogeosynclinal trough was developed in approximately the same area as earlier Late Paleozoic geosynclines. East of the Wasatch Line deposition continued on an unstable shelf. During this phase the Thaynes formation and its time-rock equivalents were deposited.

Unstable shelf conditions again prevailed over most of the area during the Late? Lower Triassic while the Timothy, Upper Moenkopi formations and their time rock equivalents were being deposited. The true miogeosyncline of western Utah and

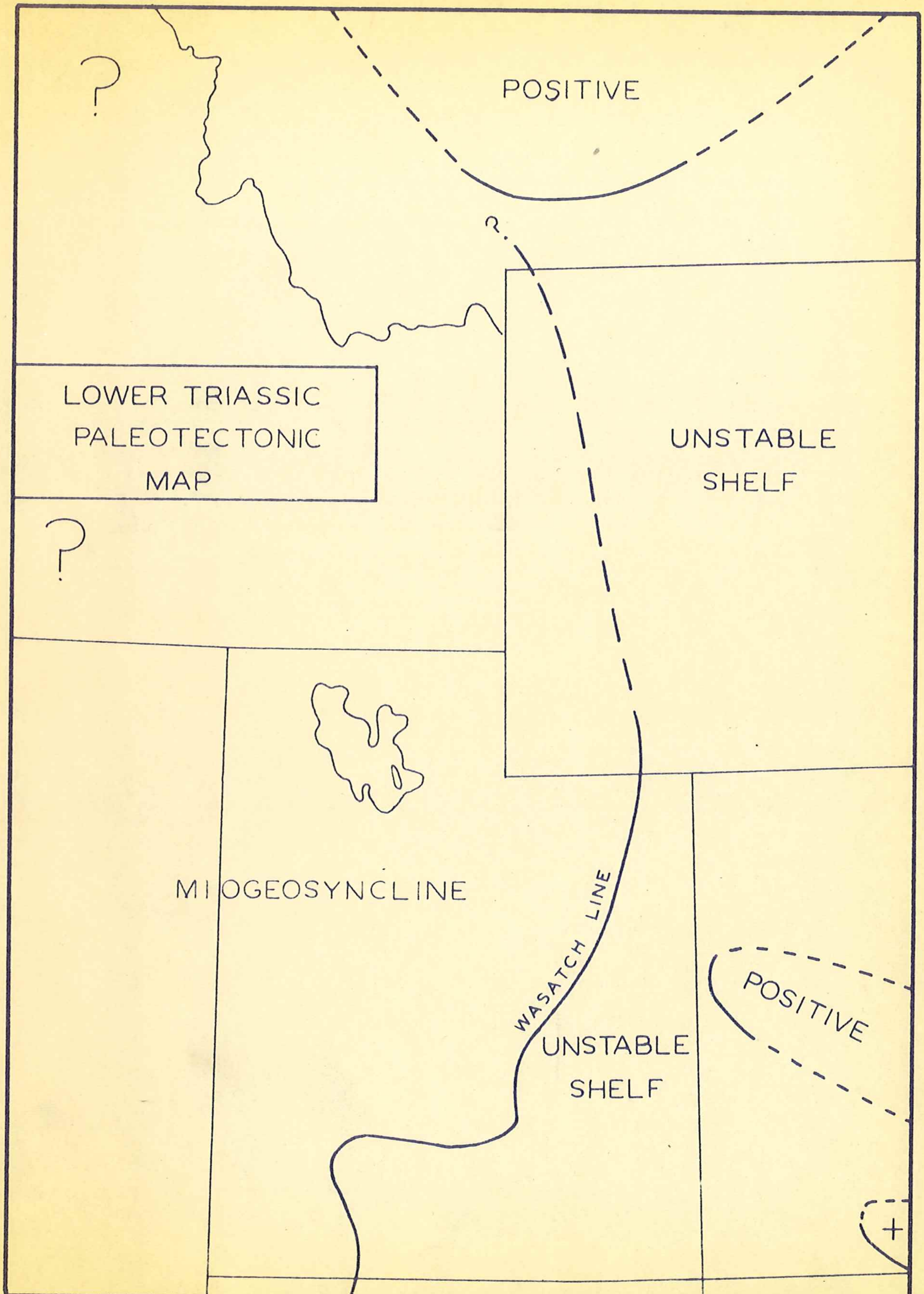


Fig. 16.--Lower Triassic Paleotectonic Map

eastern Nevada which had been a dominant tectonic element throughout the Paleozoic and during "Thaynes time" ceased to exist and was not again reestablished during the Triassic.

Middle Triassic?

Following the deposition of the Lower Triassic Moenkopi group, the region apparently entered a period of extreme tectonic stability, "Shinarump time", during which the clean, blanket like sands and pebble conglomerates of the Shinarump conglomerate were deposited. These deposits are characteristic of extremely stable shelves.

The exact dating of this episode of tectonic stability is questionable, but, as discussed in the section on Temporal Consideration, it seems probable that it included at least a part of Middle Triassic time.

The Montana positive was probably very gently uplifted during this time and continued to be during the later Triassic.

Upper Triassic?

The red siltstones and shales of the Chinle formation indicate deposition on a slightly unstable shelf during Upper Triassic? time.

The absence of Upper Triassic sediments in most of Montana and parts of central Colorado and the truncated edges of the Lower Triassic with the Jurassic resting unconformably on strata from Lower Triassic to Lower Mississippian in age indicate an active but moderate uplift in these areas during the late Triassic.

PALEOGEOGRAPHY

Lower Triassic

During the late Permian and/or early Triassic the Phosphoria Sea retreated westward to where, during the earliest Triassic, the eastern shore of this Dinwoody Sea was in the vicinity of the Wasatch Line. These earliest Triassic deposits are represented by the marine Dinwoody green shales and gray limestones of the western facies and the red beds of the Woodside and lower Moenkopi formations of the eastern facies. Features such as the red color, petrified wood, reptile tracks and bones, oscillation ripple marks, and mud cracks suggest that the Woodside and lower Moenkopi red beds were continental for the most part and were probably deposited on a broad newly emergent coastal plain with numerous lakes and marshes which may have been briefly covered by shallow marine waters occasionally, due to mild tectonic oscillations, thus accounting for occasional drab beds and evaporites.

During this early Lower Triassic stage there was a gradual oscillatory encroachment of the continental red beds westward causing an interfingering of Woodside red beds and Dinwoody green shales and finally in southeastern Idaho and the Wasatch Mountains of Utah the Woodside red beds overlie the Dinwoody.

In Middle? Lower Triassic time there was an eastward readvance of the sea, the Thaynes Sea, which deposited the drab siltstones, shales and limestones of the Thaynes formation and reached eastward, at its maximum extent, as far as Whiterocks Canyon, (section 4), the San Rafael Swell (section 25) and east of Zion Canyon. The extent of this sea, at its maximum, is the same as the extent of the Thaynes formation which is shown on the lithofacies map page 129.

In the Late, Lower Triassic the sea again retreated westward and the Timothy red beds were deposited, interfingering with the Thaynes formation and finally overlying it.

The Lower Triassic epoch in Eastern Nevada is represented by a continuous series of marine strata, (siltstones, shale and limestone) all of which are lithologically similar to the Thaynes formation, but representing a longer time span than the Thaynes at its type locality in the Wasatch Mountains. In Southeastern Idaho and in the Wasatch Mountains of Utah the Lower Triassic displays, from the base upward, the marine shales of the Dinwoody, the continental red beds of the Woodside, the marine beds of the Thaynes, and the continental red beds of the Timothy; while in eastern Utah the Lower Triassic series is represented by a continuous succession of continental red beds of the Moenkopi formation.

Middle Triassic?

The paleogeographic picture during the Middle Triassic? is somewhat uncertain due to the unsolved question of the origin of the Shinarump conglomerate. However, the region must have been one of low relief, extreme tectonic stability, and near sea level. It may possibly have been covered by a shallow sea which deposited the Shinarump as beach sands and gravels or distributed the uniform blanket of sand by fluctuating currents on a stable bottom as a "marine or lacustrine desert". But, as discussed previously under the origin of the Shinarump, the weight of opinion favors a fluvial origin for the formation. In this case the Middle Triassic? paleogeographic picture would be one of a vast continental plain near sea level, perhaps a piedmont plain, interlaced with numerous shifting stream channels, and possibly covered in part by lakes.

Upper Triassic?

The red beds of the Upper Triassic Chinle formation indicate a return of the great Shinarump stable shelf plain from a condition of stability to one of slightly increased subsidence and continental deposition very similar to the environment of the Woodside, Timothy and Moenkopi formations occured. These Chinle red beds extend westward at least as far as northeastern Nevada and so indicate a broad low lying coastal plain in the Rocky Mountain-Eastern Cordilleran Region during Upper Triassic? time.

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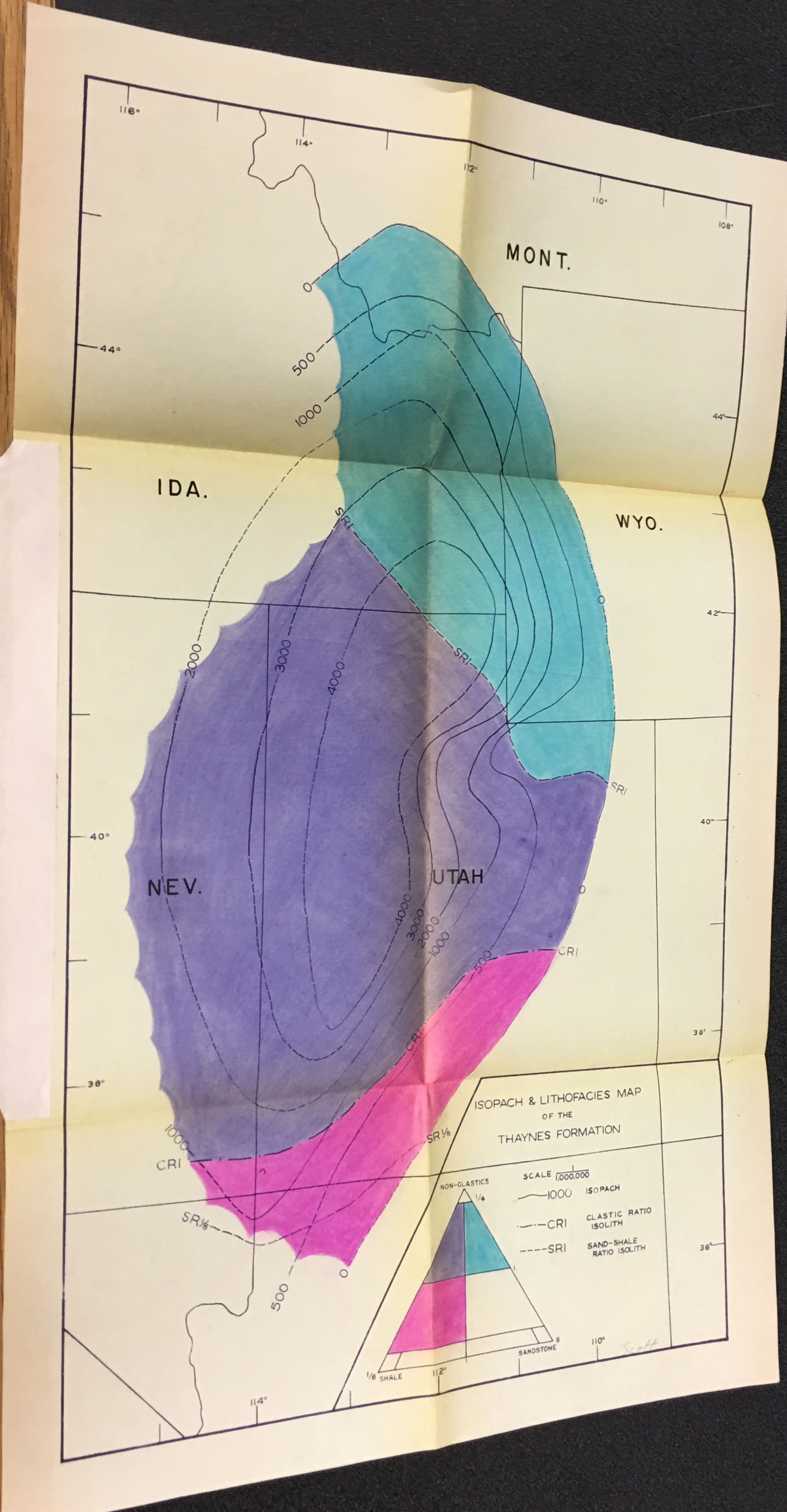
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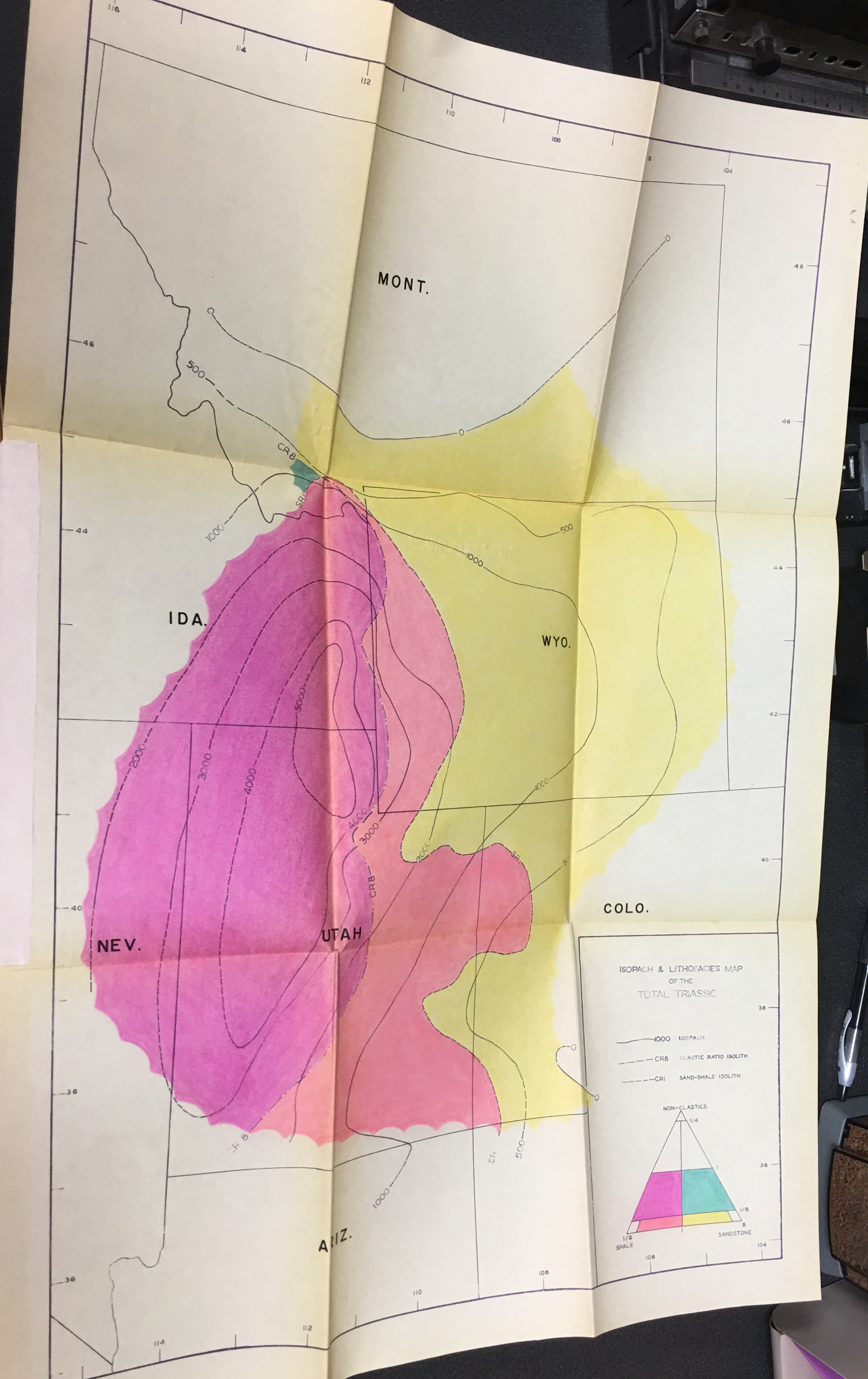

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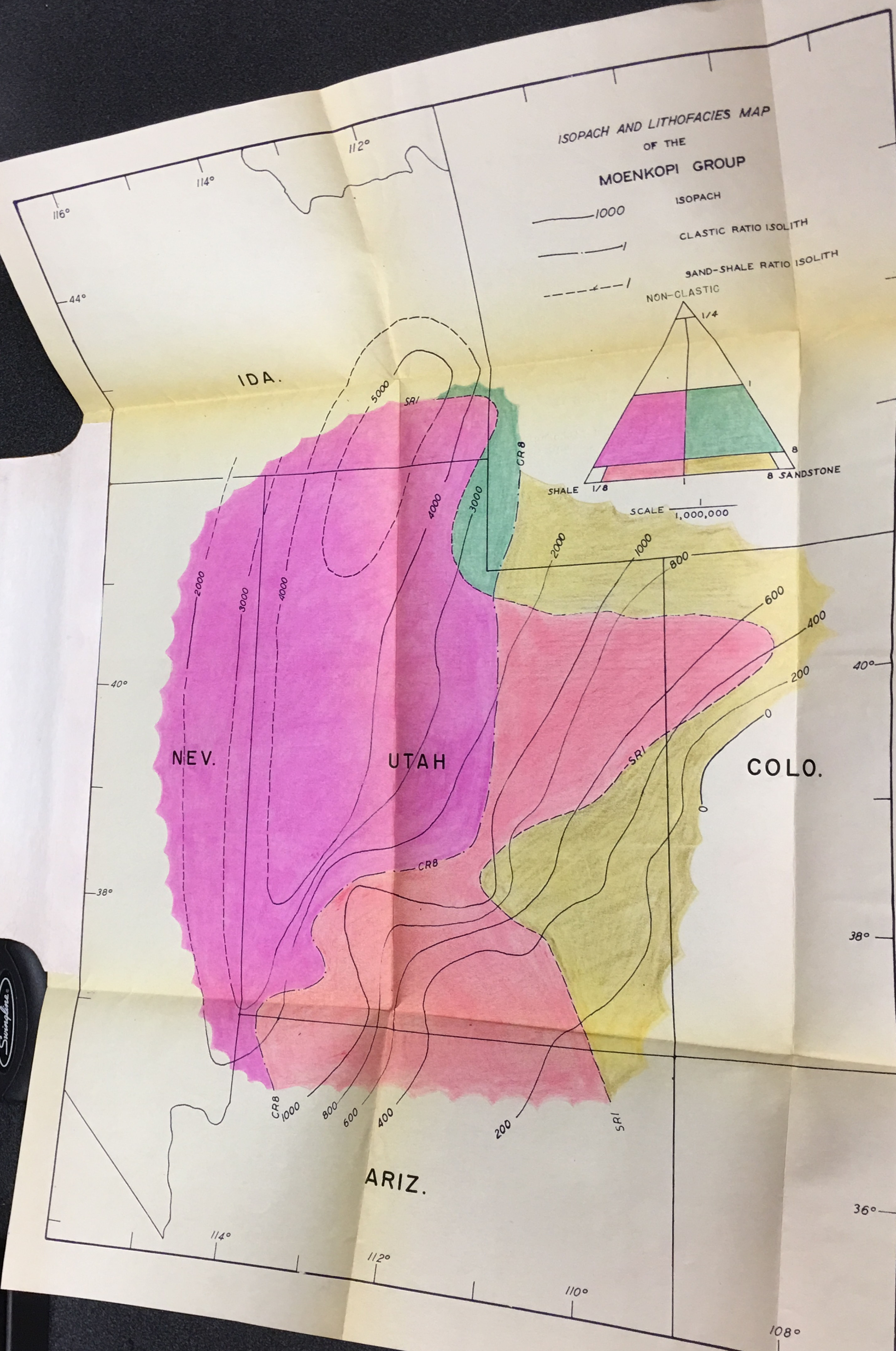
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