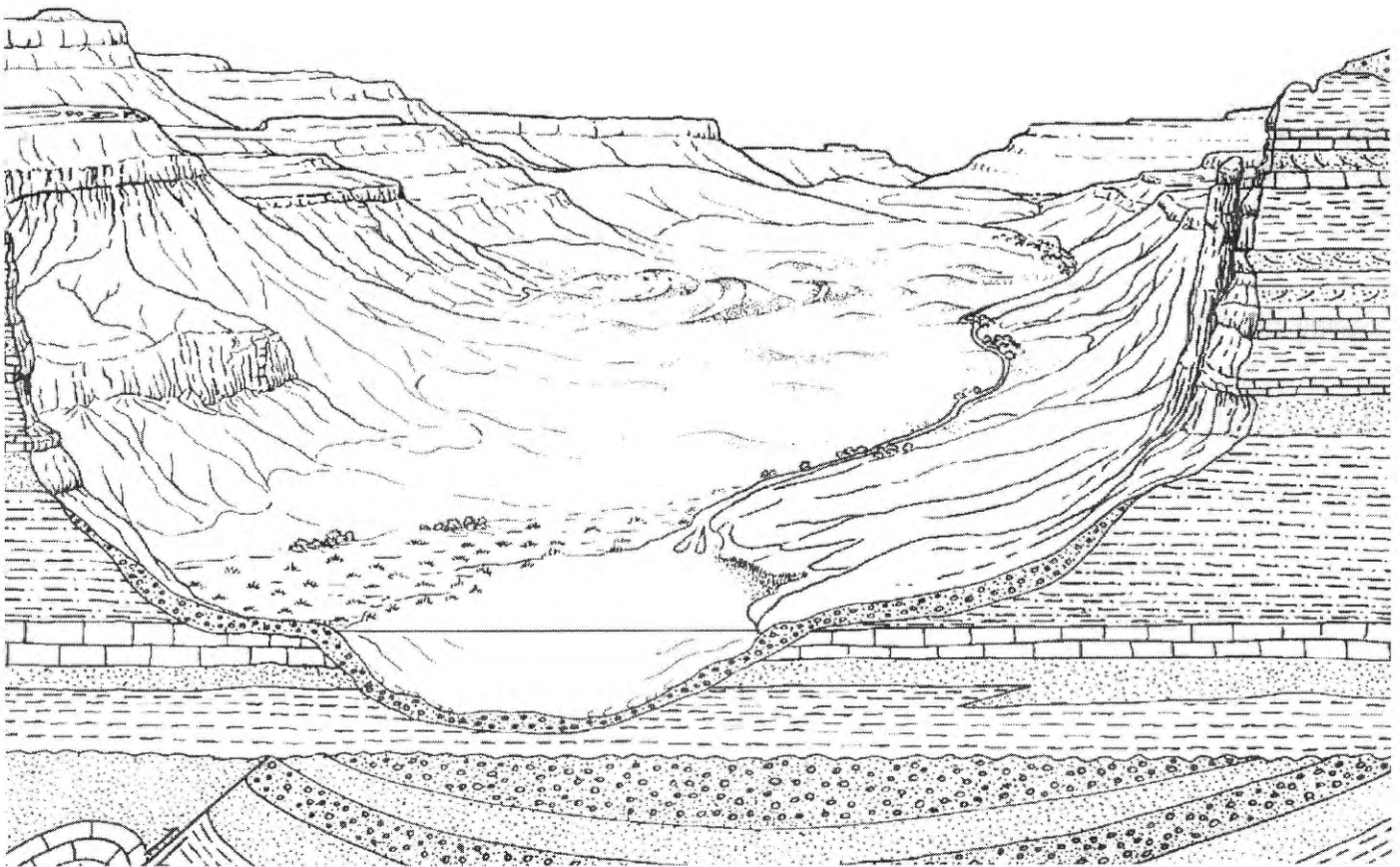


Sedimentology and Depositional History of the Upper Triassic Chinle Formation in the Uinta, Piceance, and Eagle Basins, Northwestern Colorado and Northeastern Utah

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Chapter W

Sedimentology and Depositional History of the Upper Triassic Chinle Formation in the Uinta, Piceance, and Eagle Basins, Northwestern Colorado and Northeastern Utah

By RUSSELL F. DUBIEL

A multidisciplinary approach to research studies of sedimentary
rocks and their constituents and the evolution of sedimentary
basins, both ancient and modern

U.S. GEOLOGICAL SURVEY BULLETIN 1787

EVOLUTION OF SEDIMENTARY BASINS—UINTA AND PICEANCE BASINS

U.S. DEPARTMENT OF THE INTERIOR
MANUEL LUJAN, JR., Secretary



U.S. GEOLOGICAL SURVEY
Dallas L. Peck, Director

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EVOLUTION OF SEDIMENTARY BASINS—UINTA AND PICEANCE BASINS

Sedimentology and Depositional History of the Upper Triassic Chinle Formation in the Uinta, Piceance, and Eagle Basins, Northwestern Colorado and Northeastern Utah

By Russell F. Dubiel

Abstract

Lithofacies analysis was used to examine depositional systems of the Upper Triassic Chinle Formation in the Uinta, Piceance, and Eagle basins in northwestern Colorado and northeastern Utah. Lithofacies analysis identified deposits of valley fills and active channel fills, point bars of moderate- to high-sinuosity fluvial systems, floodplains containing paleosols and rhizoliths, lakes and lacustrine deltas, and eolian sand sheets.

Lateral facies relations determined from field relations and stratigraphic cross sections depict the paleogeography at the time of Chinle deposition. The ancestral Uncompahgre and Front Range uplifts in Colorado supplied clastic detritus to the depositional basin. Fluvial systems flowed west and northwest from the bounding highlands and deposited sediment within paleovalleys and channels and on associated floodplains. Fluvial systems graded distally into lacustrine and lacustrine-deltaic systems in the southern and eastern Uinta and Piceance basins. In the Eagle basin, the close of Chinle time is marked by eolian sand-sheet deposition, reflecting the change from a tropical monsoonal climate earlier in the Late Triassic to drier conditions at the close of the Late Triassic.

INTRODUCTION

The Upper Triassic Chinle Formation is a sequence of continental rocks that was deposited in a back-arc cratonic basin (Dickinson, 1981). A magmatic-volcanic arc on the western and southwestern margin of the Triassic continent provided both volcanic ash and clastic detritus to the Chinle

depositional basin, which encompassed a large part of the Colorado Plateau and the regions adjacent to it. The Chinle depositional basin can be subdivided in this area into a major and a minor depocenter.

The major part of the Chinle depositional basin was centered near the Four Corners area of Colorado, Utah, Arizona, and New Mexico and was north of the Mogollon Highlands and south of the ancestral Rocky Mountains (fig. 1) (Stewart and others, 1972; Blakey and Gubitosa, 1983; Dubiel, 1983, 1989a, b; Busbey-Spera, 1988). Detritus was shed northward and westward into this part of the Chinle basin from the Mogollon Highlands, which lay to the south, and southward and westward off the ancestral Rocky Mountains, which lay to the north. The ancestral Rocky Mountains consisted of the ancestral Uncompahgre Highlands and the ancestral Front Range and several minor ranges. Fluvial and lacustrine-deltaic depositional systems flowed north and west off of the Mogollon Highlands and south and west off of the ancestral Uncompahgre and Front Range highlands into the southern part of the Chinle depositional basin. A second smaller part of the Chinle depositional basin was coincident with the areas of the present-day Eagle basin in western Colorado and Uinta and Piceance basins in northwestern Colorado and northeastern Utah. The ancestral Uncompahgre Highlands and the ancestral Front Range also contributed clastic detritus northward and westward to this smaller part of the Chinle depositional basin.

Considerable effort has been focused on delineating stratigraphic and sedimentologic relations within the Chinle Formation of southeastern Utah, northern Arizona, and northern New Mexico (for example, Stewart and others, 1972; Blakey and Gubitosa, 1983; Dubiel, 1987a, b, c,

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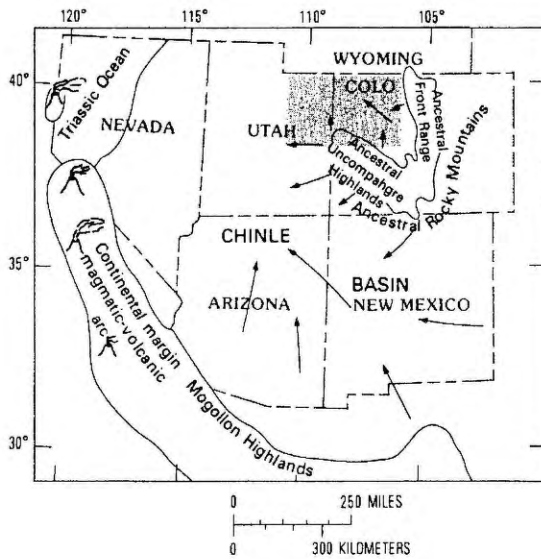


Figure 1. Schematic reconstruction of Late Triassic paleogeography on the Colorado Plateau and adjacent regions. Arrows depict general transport directions of clastic sediment. Details of study area (shaded) are in figure 2.

1989a, b; Lucas and Hayden, 1989); however, few research efforts employing modern sedimentologic techniques have been applied to the Chinle in northwestern Colorado and northeastern Utah.

This study examined the sedimentology and depositional history of the Chinle Formation in outcrops in the Uinta, Piceance, and Eagle basins of northwestern Colorado and northeastern Utah (fig. 2). Upper Triassic rocks are exposed in four widely separated areas within the broad region outlined for this study: (1) the Eagle basin and White River uplift in western Colorado, (2) the Uinta and Piceance basins in northwestern Colorado and northeastern Utah in the vicinity of Dinosaur National Monument and the Uinta Mountains, (3) the San Rafael Swell in east-central Utah, and (4) western Colorado and eastern Utah in the canyon country near Moab, Utah. This report presents the results of detailed sedimentologic examination of outcrops in the Uinta, Piceance, and Eagle basins and some preliminary data from the San Rafael Swell and near Moab.

Stratigraphy of the Chinle Formation and related Upper Triassic strata on the Colorado Plateau and correlations with Upper Triassic rocks northward into Wyoming are complicated by a combination of varied historical stratigraphic nomenclature, a lack of stratigraphic and biostratigraphic marker horizons within the continental strata, and the laterally persistent, but generally poorly exposed character of the Chinle. Exact stratigraphic relations between units are further complicated by rapid lateral facies changes typical of continental rocks. This

report does not establish new stratigraphic nomenclature but rather discusses the units in terms of genetic sedimentologic units and previously published stratigraphy.

Acknowledgments.—This paper has benefited from constructive reviews by Samuel Johnson and Robert B. O'Sullivan, U.S. Geological Survey. Gary Skipp, U.S. Geological Survey, provided invaluable assistance in the field. Steven C. Good, University of Colorado at Boulder, and J. Michael Parrish, Northern Illinois University, provided identifications of invertebrate and vertebrate fossils, respectively, and both collaborated on discussions and additional aspects of cooperative interdisciplinary research. The work on which this report is based was supported by the U.S. Geological Survey Evolution of Sedimentary Basins Program.

PREVIOUS WORK

The Chinle Formation has been the focus of many reports related to Triassic stratigraphy, Late Triassic paleontology, and economic uranium-vanadium deposits. Many of those reports discuss that part of the Chinle deposited in and around the Four Corners region of Utah, Colorado, New Mexico, and Arizona. An inclusive review of previous literature on the Chinle Formation and related Triassic rocks on the Colorado Plateau is in Stewart and others (1972). More recent reports, particularly those related to sedimentologic studies, are summarized in Dubiel (1987a, c, 1989a, b), Dubiel, Good, and Parrish (1989), and Dubiel and Skipp (1989).

In contrast to the many publications on the Chinle in the Four Corners region, relatively few publications deal with the Chinle Formation of northwestern Colorado and northeastern Utah. Despite being few in number, these publications describe the complex stratigraphy of Upper Triassic rocks and provide the basis for subsequent detailed studies both in the northern part of the Colorado Plateau and farther to the north in Wyoming. The Shinarump Member and Chinle Formation were recognized by most geologists working in the region (see, for example, Thomas and others, 1945; Kinney, 1955). Thomas and Krueger (1946) first used the terms Stanaker Formation and Gartra Grit Member for the Upper Triassic rocks of the Uinta Mountains that they considered lithologically distinct from the Chinle. Keller (1952, 1953) suggested that the presence of analcime in the Chinle near Vernal, Utah, indicates that those rocks are correlative with the analcime-bearing Upper Triassic Popo Agie Formation in Wyoming. MacLachlan (1957) discussed Triassic stratigraphy in parts of Utah and Colorado. Poole and Stewart (1964) extended correlations of Upper Triassic strata on the Colorado Plateau northward into the Uinta Mountains. Sikich (1965) briefly discussed Upper Triassic stratigraphy in the eastern Uinta Mountains. High and Picard (1967), McCormick and Picard (1969), and High and others (1969) supported Keller's contention and extended

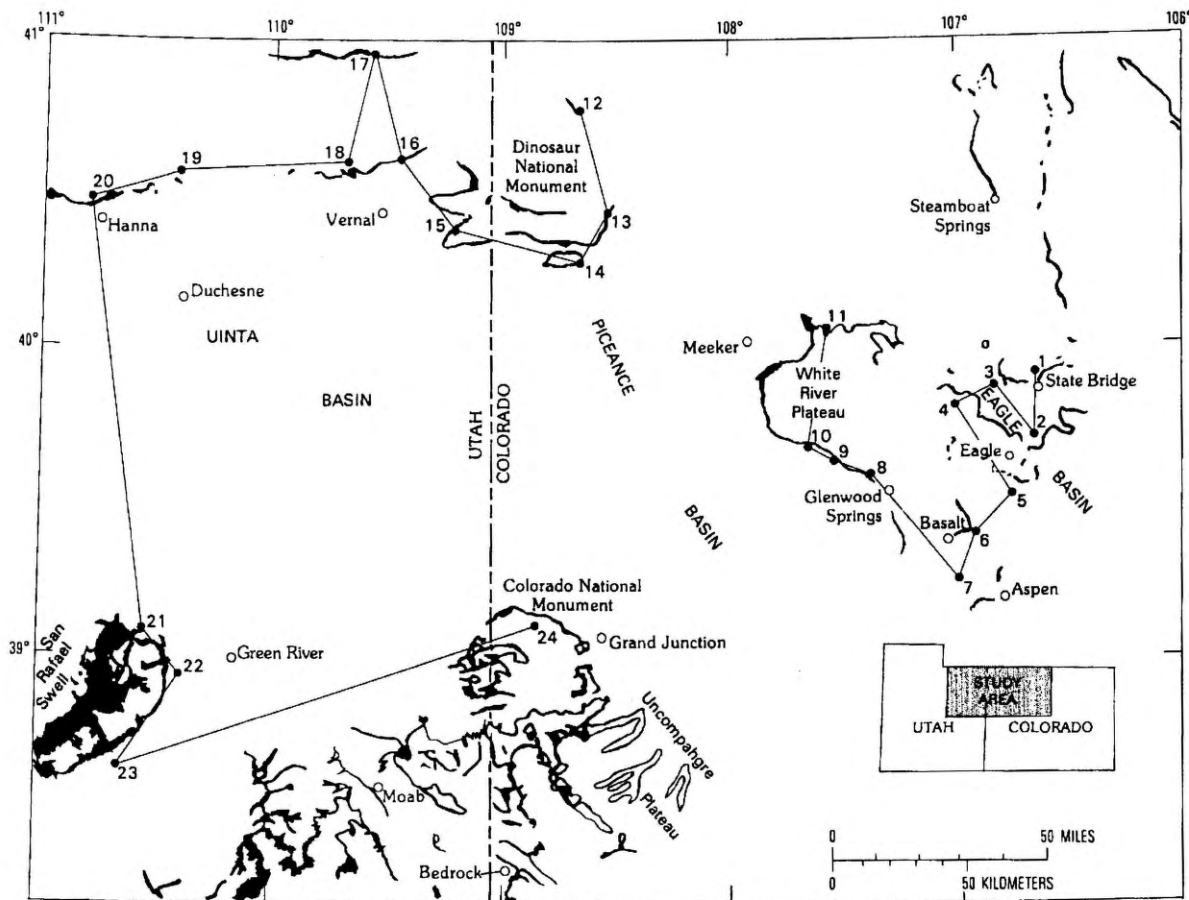


Figure 2. Map of the study area in northwestern Colorado and northeastern Utah showing geographic features, measured sections (numbered circles), and lines of cross sections referred to in text (see fig. 4). Outcrops of Chinle Formation shown in black. Modified from Stewart and others (1972) and Dubiel and Skipp (1989).

the Wyoming nomenclature to the Uinta Mountains area. Pippingos (1968) described correlations and nomenclature of Triassic rocks in south-central Wyoming. Pippingos and others (1969) discussed the stratigraphy of the Chinle Formation in north-central Colorado, just north of the Eagle basin. Pippingos, *in* Segerstrom and Young (1972), described correlations of the Chinle and Popo Agie from north-central Colorado northward into Wyoming. Building on several earlier reports on Triassic stratigraphy, Stewart and others (1972) provided correlations and interpretations of depositional environments of the Chinle Formation and related Triassic strata throughout the Colorado Plateau and extended Chinle nomenclature into the Uinta Mountains in northeastern Utah and into northwestern Colorado.

Reports specifically describing the region of this report include several stratigraphic studies and only a few sedimentologic studies. Shropshire (1974) studied the stratigraphy and depositional environments of the Chinle and Jelm Formations in north-central Colorado. Red-bed

formations near Aspen, Colorado, including the Chinle, were briefly described by Freeman and Bryant (1977). Principal Triassic unconformities of the Western Interior of the United States are summarized in Pippingos and O'Sullivan (1978), along with a discussion of Triassic correlations relevant to the present study. Lupe (1977, 1979) interpreted depositional environments and measured stratigraphic sections of the Chinle in Utah from the San Rafael Swell to the Moab area. The sedimentology of the Upper Triassic Dolores Formation in southwestern Colorado, a correlative of the Chinle, was studied by Blodgett (1984, 1988). Lungfish burrows and possible freshwater crayfish burrows have been described from Chinle outcrops within the study area (Dubiel, Blodgett, and Bown, 1987, 1988, 1989; Hasiotis and Mitchell, 1989). Several reports discuss fossil fish (Schaeffer, 1967; Elliot, 1983, 1987) and the sedimentology and paleoecology of Chinle outcrops (Dubiel, Good, and Parrish, 1989; Parrish and others, *in press*) near Bedrock in western Colorado.

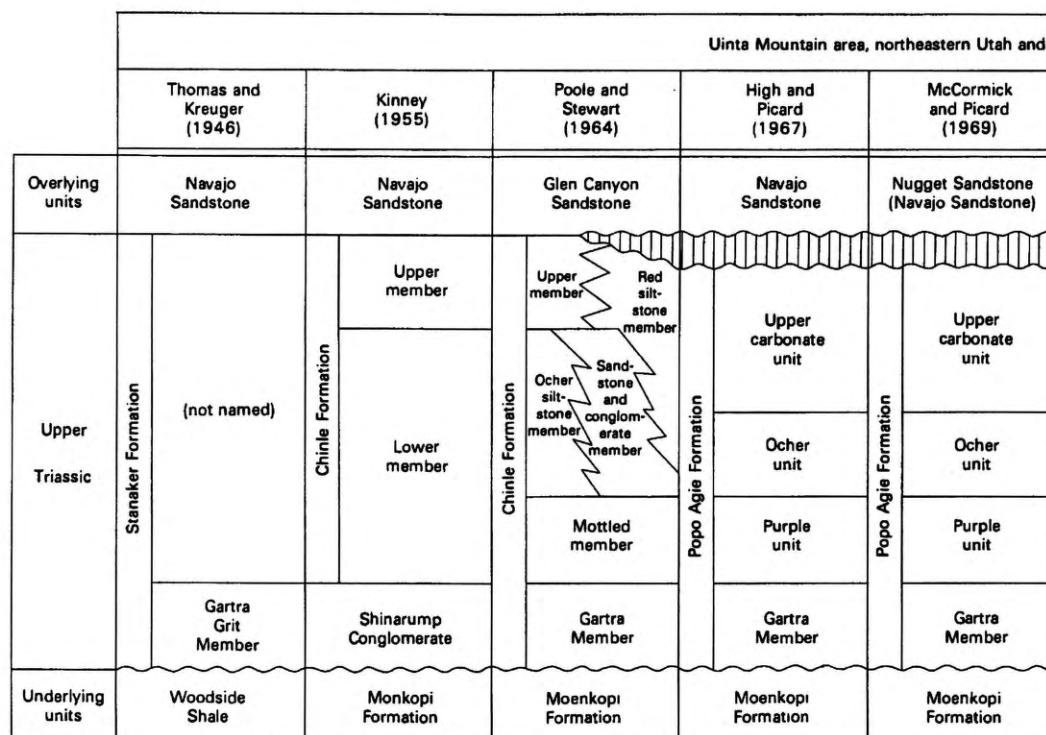


Figure 3 (above and facing page). Diagram showing correlation of stratigraphic nomenclature of Upper Triassic strata in Colorado, Utah, and Wyoming.

Dubiel and Skipp (1989) reported on preliminary stratigraphic and sedimentologic studies of the Chinle Formation in the Eagle basin of western Colorado.

GEOLOGIC SETTING

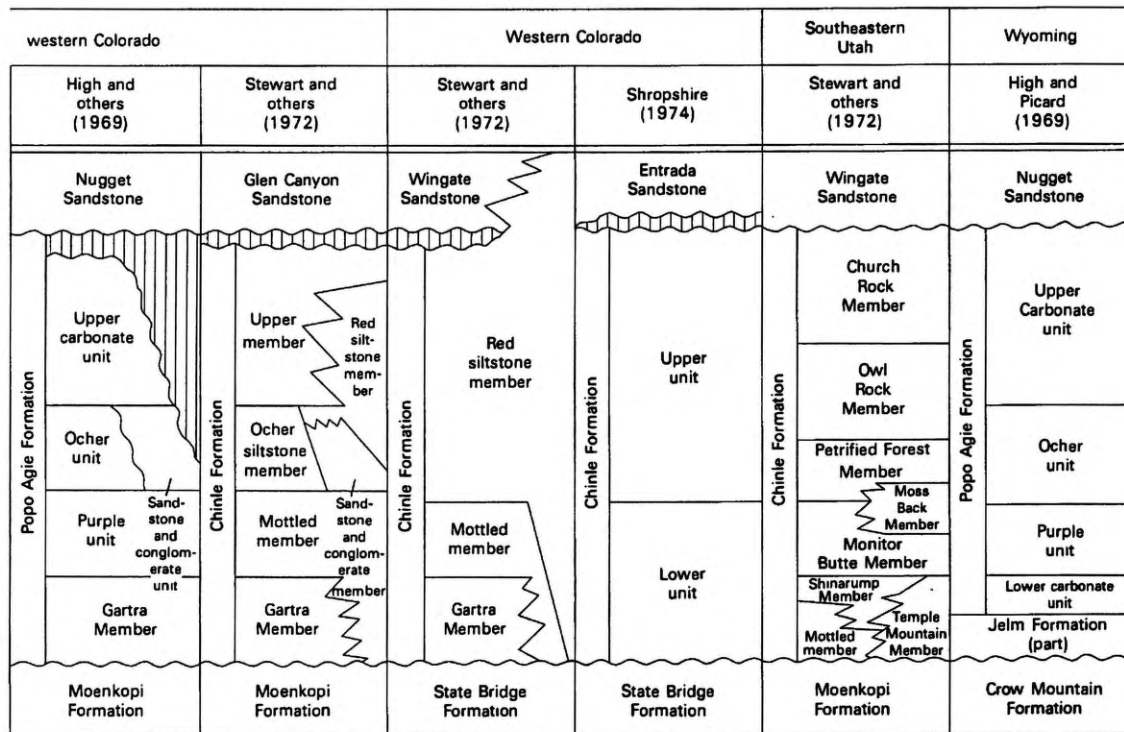
The ancestral Rocky Mountains, which included the ancestral Uncompahgre and Front Range highlands, were uplifted in the Pennsylvanian and Early Permian (for example, Mallory, 1972; Kluth and Coney, 1981) and continued to provide clastic detritus to the Chinle depositional basin during the Late Triassic (fig. 1). Paleozoic and Early Mesozoic sedimentary strata deposited adjacent to the uplifts were eroded, reworked, and incorporated into the Chinle.

In the Eagle basin, the Chinle Formation unconformably overlies the Pennsylvanian and Permian Maroon Formation, including the Permian Schoolhouse Member (previously called the Schoolhouse Tongue of the Weber Sandstone; Johnson and others, 1990), or the Permian and Triassic State Bridge Formation (Stewart and others, 1972; Tweto and others, 1978; Johnson, 1987; Dubiel and Skipp, 1989). On a regional scale, the unconformity is angular, in that the Chinle overlies progressively older strata in areas on or near the ancestral uplifts (Tweto and others, 1978). At Colorado National Monument, on the northeastern flank of

the present Uncompahgre uplift, the Chinle unconformably overlies Precambrian crystalline rocks.

In the area around Dinosaur National Monument, in the Uinta Mountains of northeastern Utah and northwestern Colorado, and in the San Rafael Swell and near Moab in eastern Utah, the Chinle Formation rests unconformably on the Lower and Middle (?) Triassic Moenkopi Formation (Stewart and others, 1972; Pipiringos and O'Sullivan, 1978).

In the northern part of the study area, near the Uinta Mountains and Dinosaur National Monument, the Chinle Formation is unconformably overlain by an eolian unit that historically has been assigned to the Triassic (?) and Jurassic Nugget Sandstone (Pipiringos and O'Sullivan, 1978), or the Lower Jurassic Navajo Sandstone, or the Glen Canyon Sandstone. Recent work suggests that the lower part of this eolian unit is correlative with the Lower Jurassic Wingate Sandstone of the Glen Canyon Group farther to the south in the San Rafael Swell and near Moab (Peterson, 1988). Observations made during the present study indicate that the thin eolian unit immediately overlying the Chinle can be distinguished from an overlying eolian unit that is probably correlative with the Navajo Sandstone and the Nugget Sandstone. The results of the present study support Peterson's (1988) assignment of the lower thin eolian unit to the Wingate Sandstone. In the San Rafael Swell and near



Moab, the Chinle is unconformably overlain by the Lower Jurassic Wingate Sandstone. In part of western Colorado, the Chinle is unconformably overlain by the Middle Jurassic Entrada Sandstone.

STRATIGRAPHY

Stratigraphy of the Chinle Formation in the large area encompassed by the present study is complicated by the designation of different formal and informal nomenclature by several workers for exposures in widely separated regions (fig. 3). Stewart and others (1972) summarized the stratigraphic nomenclature of the Chinle on the Colorado Plateau, and those designations are followed in this report. In the San Rafael Swell and near Moab, the Chinle consists, in ascending order, of the Temple Mountain Member, mottled member, and Shinarump, Monitor Butte, Moss Back, Petrified Forest, Owl Rock, and Church Rock Members. For the area around Moab, Blakey and Gubitosa (1983) applied the name Kane Springs strata to lateral facies equivalents of the Petrified Forest and Owl Rock Members.

The issue is complicated, however, with the application by some workers of the name Popo Agie Formation, which is used in Wyoming, for Upper Triassic strata in the Uinta Mountains (High and Picard, 1967; High and others, 1969; McCormick and Picard, 1969). Despite the discrepancy over whether the rocks are assigned to the

Chinle Formation or the Popo Agie Formation, informally designated stratigraphic units and their lateral and vertical relations around the Uinta Mountains are common to each of the reports (fig. 3). The descriptive informal names of the subdivisions are virtually identical in each report. The Gartra Member is generally accepted in each report as the conglomeratic sandstone at the base of the Chinle or Popo Agie, although Kinney (1955) termed this unit the Shinarump Conglomerate. Overlying the Gartra is either a mottled member or a purple unit, clearly referring to the same stratigraphic unit. Shropshire (1974) provided the basal deviation from this scheme, grouping the basal conglomerates and the mottled units directly above them into the lower unit and the remainder of the Chinle into an upper unit (fig. 3). As discussed in the sedimentology section later in this report, Shropshire's subdivisions have some validity because the present study interprets the mottled coloration to be the result of pedogenic or early diagenetic alteration that affected both the Gartra and the overlying siltstones and mudstones.

Above the Gartra Member, one or more fine-grained units of the Chinle Formation is recognizable as distinct lithostratigraphic units, and they have similar informal names (fig. 3). In northwestern Colorado, the red siltstone member constitutes the entire upper Chinle. In the eastern part of Dinosaur National Monument, the middle part of the Chinle contains a sandstone and conglomerate member that interfingers with the overlying red siltstone member and the

equivalent ocher siltstone member. The middle part of the Chinle is overlain and interfingers with the upper member, also referred to as the upper carbonate unit. Each of these previously named units or members was recognized in the present study, and the general stratigraphic relations are supported by the sedimentology study.

The relationship between the Chinle Formation and the various overlying rocks that are referred to as the Nugget Sandstone, Navajo Sandstone, Glen Canyon Sandstone, or Wingate Sandstone has been described as interfingering, unconformable, or an angular unconformity (fig. 3). The present study indicates that in the Uinta Mountains and in Dinosaur National Monument the Chinle Formation is unconformably overlain by eolian sandstones equivalent to the Lower Jurassic Wingate Sandstone, which unconformably overlies the Chinle in the San Rafael Swell and near Moab. Peterson (1988) assigned the eolian sandstone overlying the Chinle in the Uinta Mountains and around Dinosaur National Monument to the lower part of the Nugget Sandstone and stated that it is equivalent to the Wingate Sandstone farther to the south in Utah. Observations on grain size, lithology, and bedding made in the present study indicate that the eolian rocks unconformably overlying the Chinle in the Uinta Mountains can be subdivided into two distinct eolian units. The lower eolian unit is thin (10–30 ft, 3–10 m) and probably is equivalent to the Wingate Sandstone, whereas the upper eolian unit is much thicker and lighter in color and probably correlates with the Navajo Sandstone, supporting Peterson's (1988) conclusions. In western Colorado, the Chinle is unconformably overlain by eolian strata of the Middle Jurassic Entrada Sandstone. Despite the large-scale angular unconformity indicated by these regional relationships, on a local scale beds appear conformable, and there appears to be no angular unconformity between the Popo Agie and the overlying Nugget Sandstone as reported by High and others (1969) and Picard (1975). The contact shown in photographs of those reports most likely depicts a diastem within Chinle strata typical of a crevasse splay or lacustrine delta rather than an angular contact between the Chinle and the Nugget.

SEDIMENTOLOGY

In the study area, the Chinle Formation consists of as much as 1,000 ft (300 m) of predominantly dark-reddish-brown to moderate-reddish-orange, fine-grained sandstone, siltstone, and mudstone and lesser amounts of dark-gray to reddish-purple conglomeratic sandstone, limestone-pebble conglomerate, sandstone, and gray limestone. Stratigraphic sections of the Chinle Formation (fig. 4, table 1) were measured to record data on composition, color, grain size, bedding, physical sedimentary structures, and lithosome geometry. These data and additional observations on paleosols and biogenic sedimentary structures, including trace fossils and rhizoliths, were utilized to designate lithofacies

in the Chinle. Lithofacies then were grouped into lithofacies assemblages on the basis of rock type, lithosome geometry, sedimentary structures, fauna and flora, and repetition of the sequences. Each lithofacies assemblage represents a particular depositional environment (fig. 4).

This study utilized the concept of lithofacies analysis, rather than the traditional descriptive approach of lithostratigraphy, to decipher the depositional history of the Chinle in the Uinta, Piceance, and Eagle basins. Because of the lack of physical and biostratigraphic markers in the continental rocks of the Chinle, the lithofacies approach was deemed more suitable for correlating measured sections and for interpreting the succession of depositional environments and depositional history. Sections are not hung on a specific horizontal datum because no such datum exists within the Chinle to correlate definitively the laterally variable continental depositional facies. Because unconformities mark both the lower and upper contacts of the Chinle, those horizons also do not provide suitable datums for correlating Chinle strata. The method employed herein utilizes facies concepts and the application of Walther's Law, together with facies relations provided by sedimentologic studies of ancient and modern continental systems (for example, Reading, 1978; Miall, 1984), to make reasonable correlations of Chinle lithofacies assemblages (fig. 4). Where available, beds and units that can be identified from section to section were used as local stratigraphic markers. Because strata change facies in several areas, individual beds may not correlate precisely between sections; the lithofacies assemblages and transitions shown, however, provide the most reasonable and accurate correlations possible for depicting the Chinle depositional system.

Lithofacies and Depositional Environments

The lower part of the Chinle Formation fills local scours and large swales eroded into the underlying rocks. The contact is generally sharp and irregular, but it is difficult to pick in places where conglomeratic units of the Chinle overlie compositionally similarly conglomeratic strata of the Maroon or State Bridge Formations. The upper part of the Chinle is characterized by a variety of lithofacies that includes several lithologies and associated biogenic and physical sedimentary structures. The following lithofacies assemblages were designated to describe the different depositional environments of the Chinle in the study area (fig. 4).

Valley-Fill and Active Channel-Fill Deposits

The basal part of the Chinle Formation consists of as much as 60 ft (18 m) of gray to yellow and dark-

reddish-brown or dark-reddish-purple conglomerate, conglomeratic sandstone, and sandstone containing pebbles of quartz, granite, and gneiss as large as 4.5 in. (11 cm) in diameter (fig. 5). Freeman (1971) reported 388 ft (117 m) of a unit he termed the "coarse unit of Toner Creek" of the State Bridge Formation. In the same area near Toner Creek, S.Y. Johnson (U.S. Geological Survey, written commun., 1989) measured about 170 ft (52 m) of conglomerate that he believed correlates with Freeman's unit but that should be assigned to the Chinle. It was not possible to corroborate this observation at Toner Creek during the present study. Conglomeratic units are medium to thick bedded and exhibit medium- to large-scale trough and planar crossbeds, or they are massive. Sandstone strata are coarse to fine grained, are thin to medium bedded, and contain planar and trough crossbeds, climbing-ripple laminations or horizontal laminations. In general, both the grain size and the scale of the sedimentary structures decrease upward within this unit.

Conglomeratic units at the base of the Chinle are generally assigned to the Gartra Member in northwestern Colorado and northeastern Utah and to the Temple Mountain and Shinarump Members in the San Rafael Swell. At Derby Junction (figs. 3, 4), the Gartra contains blocks of eolian sandstone from the underlying State Bridge Formation that are as large as 1.5 ft (0.5 m), indicating lithification of the underlying strata prior to erosion and redeposition within the Chinle. At East Brush Creek (figs. 3, 4), the Gartra contains clasts of silicified wood that are as long as 2 ft (0.6 m). Plots of the maximum pebble size in the Gartra Member (Shropshire, 1974), coupled with data on pebble sizes in basal units of the Chinle from the present study, indicate a general decrease in maximum size of siliciclastic pebbles toward the northwest and away from the area of the ancestral Uncompahgre and Front Range uplifts. The size distribution and composition of the clasts indicate a highland source for the clasts. Paleocurrent indicators in the Gartra (Stewart and others, 1972; Shropshire, 1974) suggest that deposition was generally away from the bounding uplifts and toward the northwest into the Uinta, Piceance, and Eagle basins.

The grain size, sedimentary structures, and overall geometry of coarse-grained deposits in the Gartra, Temple Mountain, and Shinarump Members resemble those described for modern and ancient fluvial sequences (for example, Allen, 1965a, b; Harms and others, 1975). The massive conglomeratic and planar crossbedded sandstones represent fluvial bedload deposition. The large variations in thickness observed on outcrops and between measured sections, and the erosional contact with significant relief cut into underlying units, indicate that the basal conglomerates are valley fills. The grain size and sedimentary structures suggest that deposition was by fluvial systems on in-channel bars (Rust, 1978). The upward transition to finer grained

sandstone containing trough crossbedding and horizontal and climbing-ripple laminations reflects fluvial bedload deposition by migrating dunes, ripples, and plane beds (Jackson, 1976).

The upper part of the Gartra Member, the lower part of the overlying red siltstone member, and the Temple Mountain Member of the Chinle Formation (fig. 3) are locally mottled purple and white (fig. 6). In western Colorado, these mottled strata were termed the mottled member by Stewart and others (1972), but Shropshire (1974) included the mottled rocks along with the Gartra in his lower unit of the Chinle. The present study recognizes a gradational contact between the Gartra Member and the mottled strata and a gradational contact between the mottled strata and the overlying red units of the Chinle. In places, each unit intertongues with the others. There is a gradual change in grain size and sedimentary structures upward through the units that reflects a transition of depositional environments. In the San Rafael Swell, mottled strata of the Temple Mountain Member generally underlie the Shinarump Member, but, locally in the San Rafael Swell, mottled strata are present stratigraphically higher in the Chinle.

The mottled coloration of these units is thought to reflect alteration and translocation of iron-bearing minerals in the rocks, similar to the purple mottled unit of the Monitor Butte Member of the Chinle Formation in southeastern Utah (Dubiel, 1987a, b, c). Many of the mottled units contain ubiquitous, large-diameter, cylindrical trace fossils interpreted as lungfish burrows (fig. 6) (Dubiel, Blodgett, and Bown, 1987, 1988, 1989) and as freshwater crayfish burrows (Hasiotis and Mitchell, 1989). The mottles probably represent relocation of iron due to fluctuating water tables penecontemporaneous with deposition; thus, the strata represent a gleyed paleosol. Both the mottles and the long trace fossils reflect fluctuating water tables. A similar interpretation is proposed for the development of the mottled coloration in the Gartra Member and the Temple Mountain Member and associated rocks in this study.

Lateral-Accretion Deposits

The largest part of the upper part of the Chinle Formation overlying the conglomerates and sandstones of the Gartra, the Shinarump, and the Temple Mountain Members consists almost entirely of dark-reddish-brown to reddish-orange, very fine to fine grained, thin- to thick-bedded sandstone, siltstone, and mudstone. The fine-grained units are assigned to the red siltstone member in the Eagle basin, to the red siltstone member and the upper member or unit in the Uinta Mountains and near Dinosaur National Monument, and to the Moss Back and the Church Rock Members in the San Rafael Swell and near Moab (figs. 2, 3).

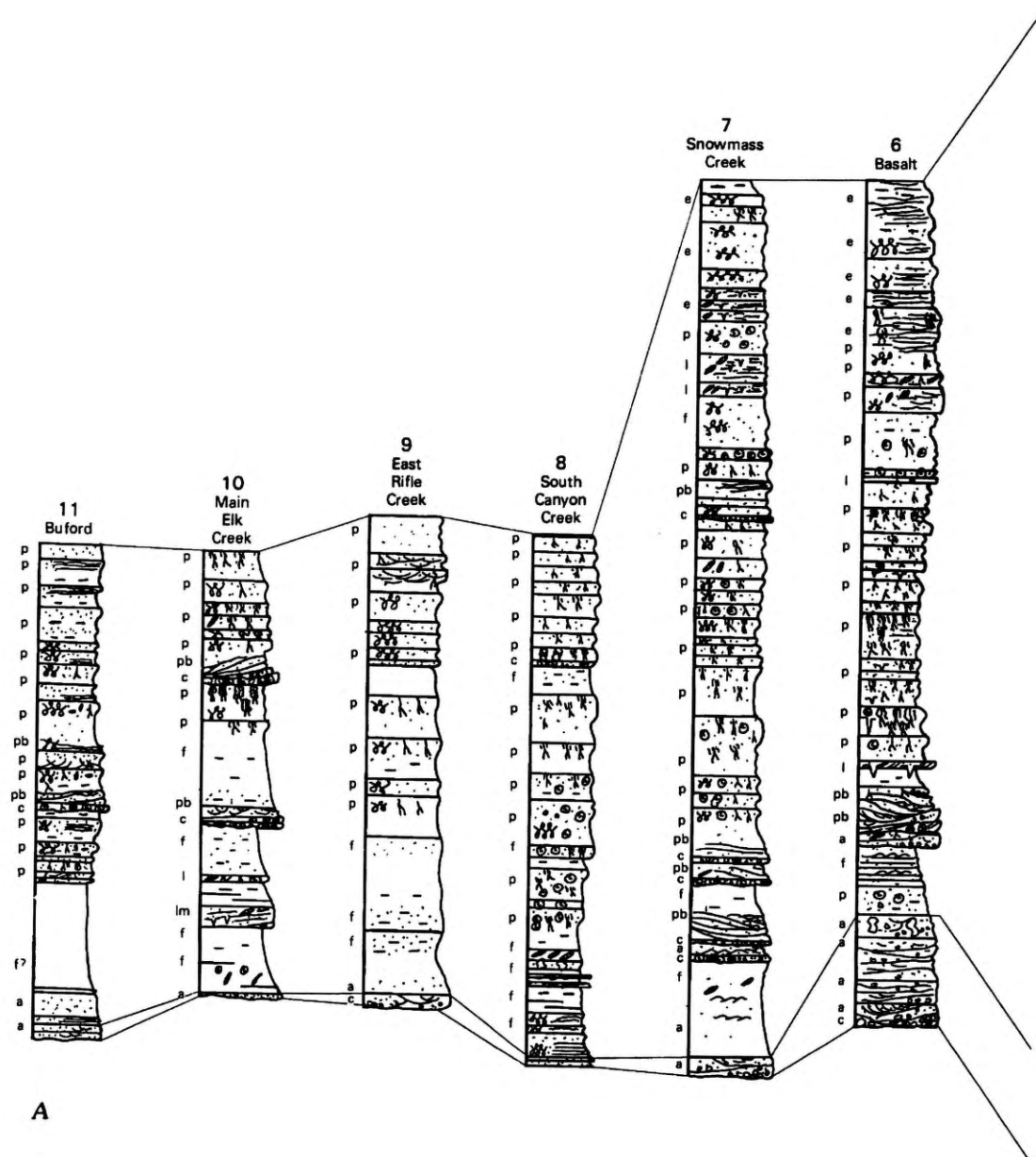
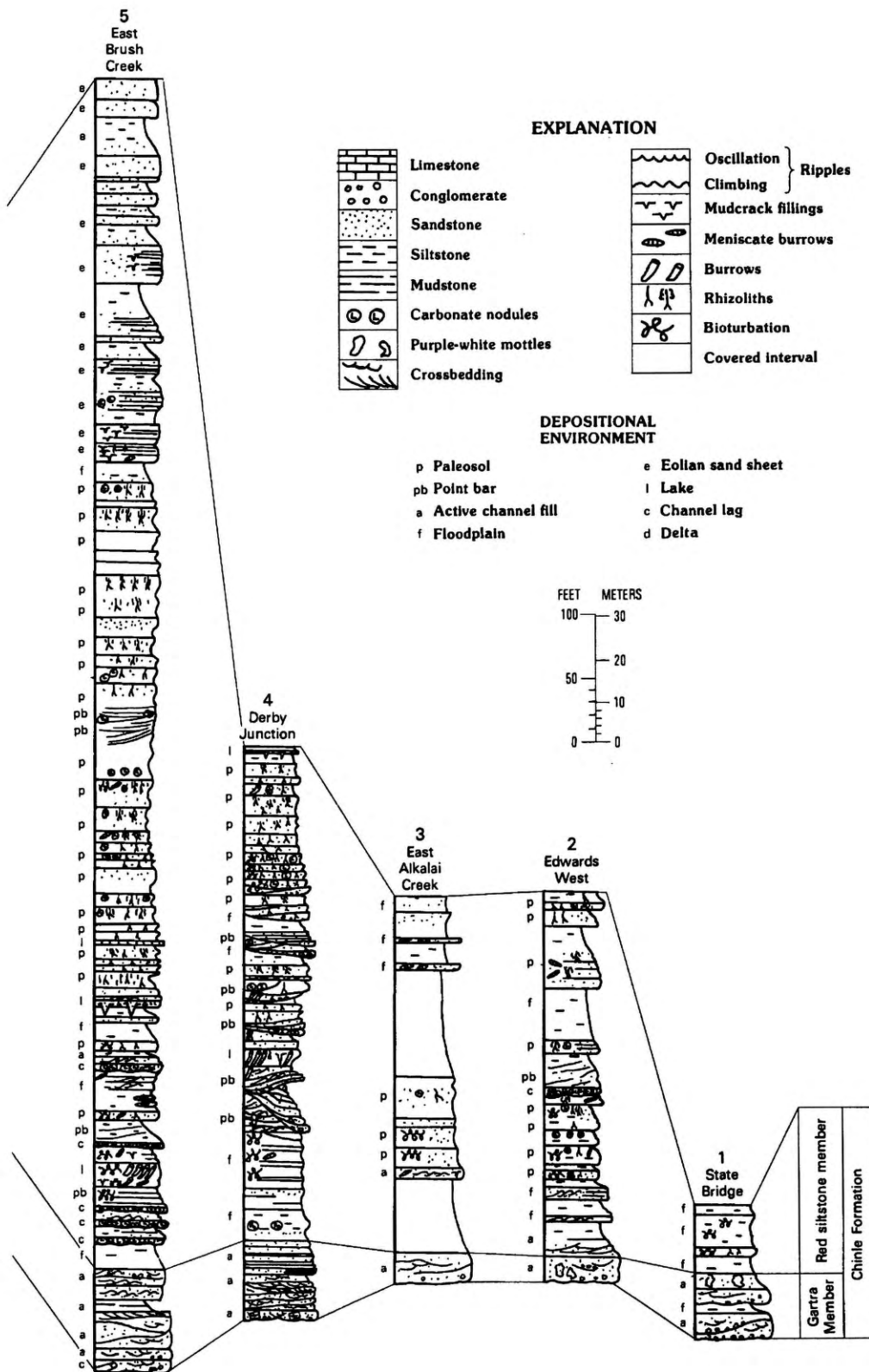


Figure 4 (above and following pages). Measured stratigraphic sections of the Upper Triassic Chinle Formation. Lines of section shown on figure 2. Sections show lithofacies, depositional environments, and stratigraphic units. A, Cross section of Chinle Formation in the Eagle basin. B, Cross section across the Uinta Mountains to the San Rafael Swell.

The red strata can be assigned to two distinct lithofacies, referred to as lateral-accretion deposits and floodplain deposits (discussed in the next section). The lateral-accretion deposits are characterized by large-scale cross-stratification, whereas the floodplain deposits are dominantly massive to horizontally bedded. The lateral-accretion deposits contain sets of large-scale, epsilon cross-

stratification (ECS) (Allen, 1963, 1965a, b) (fig. 7). Within the sets, the lithology grades upward from gray to reddish-gray, limestone- and siltstone-pebble conglomerate and quartzose sandstone at the base, through reddish-brown, interbedded sandstone, siltstone, and mudstone, to dominantly reddish-brown siltstone and mudstone at the top. Individual strata within the ECS are thin to thick



ECS units can be traced laterally into horizontally bedded strata described in the following section as overbank floodplain deposits.

The large-scale epsilon cross-stratification is interpreted as lateral-accretion stratification (LAS) (Allen, 1965b), because the trend of the small-scale sedimentary structures within the units indicates that flow was across the dip of the ECS. The interbedded sandstone, siltstone, and mudstone of the LAS are interpreted as point bars that resulted from helical channel flow in moderately to highly sinuous fluvial systems, and the finer grained deposits at the top of the sequences represent deposition by waning currents in abandoned channels and oxbow lakes (Moody-Stuart, 1966; Jackson, 1976). The predominantly fine grain size of the strata and the carbonate clasts indicate a mixed-to suspended-sediment load in the fluvial system. The limestone-pebble conglomerate at the base of the LAS represents the basal channel lags of the fluvial system. The carbonate clasts are intraformational, derived from calcic paleosols developed on floodplain deposits described in the following section. The carbonate pebbles also represent the

4A) and also have been reported from the Chinle Formation near Bedrock, Colorado. (Dubiel, Good, and Parrish, 1989), and the equivalent Dolores Formation on the western flank of the Uncompahgre Plateau (Blodgett, 1984, 1988, 1990). Low-gradient, moderate- to high-sinuosity fluvial systems developed on both sides of the ancestral Uncompahgre uplift subsequent to filling of paleovalleys by coarse-grained fluvial deposits of the Gartra Member. These meandering fluvial systems dominated Chinle deposition in the Eagle basin as proximal depositional systems that supplied sediment to depositional settings to the northwest. The point-bar deposits are virtually nonexistent in outcrops examined in the Uinta Mountains and near Dinosaur National Monument and are rare in the San Rafael Swell sections measured for this study (fig. 4B).

Floodplain Deposits

A large part of the upper Chinle Formation is composed of dark-reddish-brown to reddish-orange, massive to horizontally stratified, thin- to thick-bedded

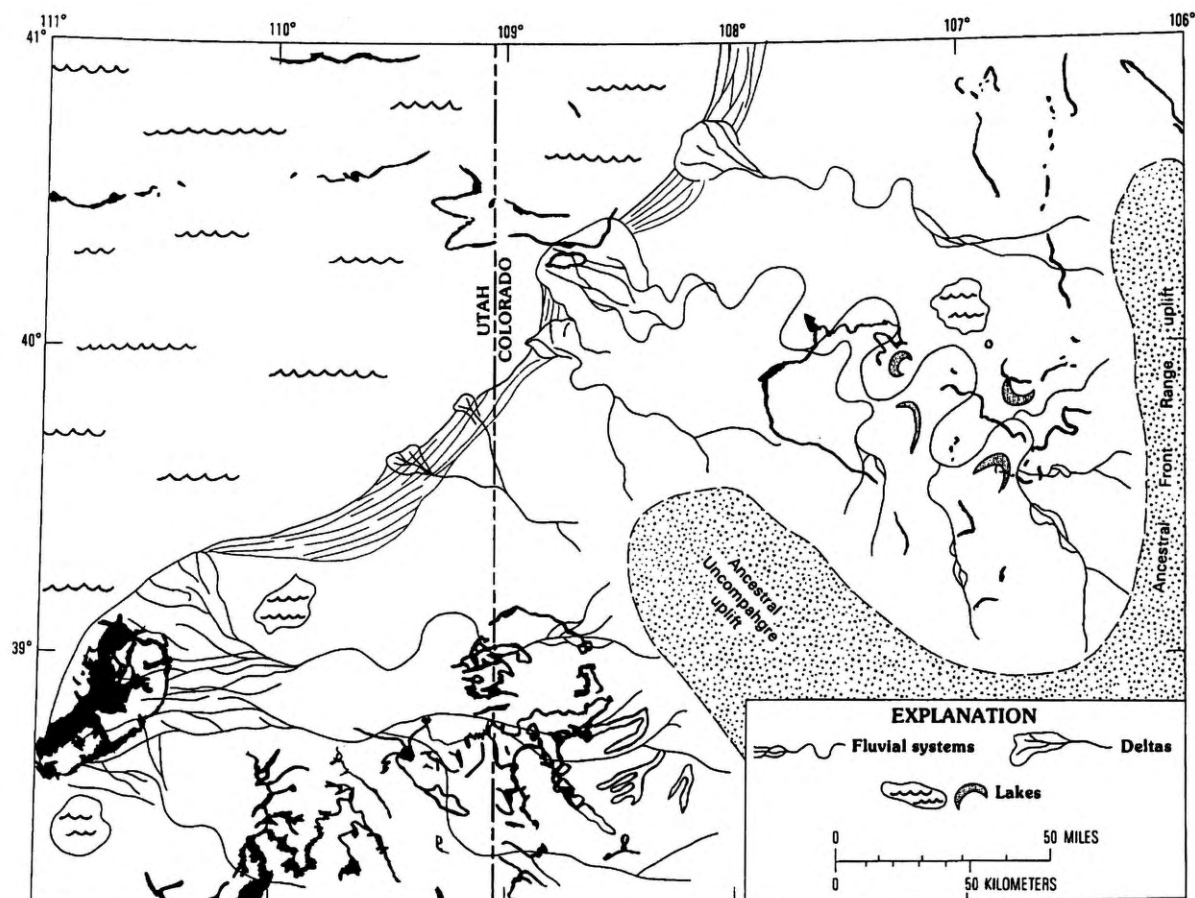


Figure 15. Schematic reconstruction of Chinle depositional systems in the Uinta, Piceance, and Eagle basins. Diagram shows paleogeography and location and trend of major fluvial, deltaic and lacustrine systems. Outcrops of Chinle Formation shown in black. Compare to figure 2 for locations of measured sections.

Stratigraphic panels of the Chinle Formation across the Uinta Mountains into northeastern Utah and northwestern Colorado near Dinosaur National Monument (fig. 4B) depict the sequence of depositional environments in this region. Conglomerates and sandstones at the base of the Chinle represent the initial development of fluvial systems. These fluvial strata contain mostly carbonate intraclasts and very few siliciclastic pebbles, a composition indicating an intrabasinal source for the pebbles. It is likely that the ancestral Rocky Mountains were reduced in elevation or even covered by Chinle deposits at this time. Fluvial systems were succeeded by a large lacustrine system. Aspects of the lacustrine facies, such as the presence of analcime, indicate not only that the lake was at times saline and alkaline, but also that it was, at least in part, contiguous with a large lake system interpreted to have existed in the Upper Triassic Popo Agie Formation farther to the north in Wyoming. The presence of limestone in the sections in the eastern part of Dinosaur National Monument attests to the lack of clastic and volcanic detritus in some

lacustrine settings. Lacustrine deltas, which provided clastic material to the lake, existed in the eastern Uinta Mountains. The deltas were fed in part by fluvial systems that flowed northwest out of the Eagle basin and northwest off of the northwestern flank of the ancestral Uncompahgre uplift.

Preliminary studies in the San Rafael Swell, Colorado National Monument, (fig. 4B) and near Bedrock, Colorado (Dubiel, Good, and Parrish, 1989), provide insight about the relationship between Chinle environments there to those in the Uinta, Piceance, and Eagle basins. The Moss Back and Church Rock Members in the sections measured in the San Rafael Swell represent fluvial and deltaic deposition that flowed northwest into a large lake. Lacustrine strata at the top of the Chinle in the San Rafael Swell probably correlate with similar strata at the top of the Chinle in the Uinta Mountains, although the distances between the outcrops are very large. The lacustrine deposits may also be correlative, but, as suggested by McCormick and Picard (1969), additional unrecognized facies changes may be present beneath the Uinta basin.