

DEPOSITIONAL AND CLIMATIC SETTING OF THE  
UPPER TRIASSIC CHINLE FORMATION, COLORADO PLATEAU

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**Abstract** - Sedimentologic studies of the Upper Triassic Chinle Formation in the Four Corners region indicate a continental depositional system characterized by fluvial channels and overbank floodplains, paleosols, crevasse splays and crevasse deltas, lacustrine basins with lacustrine deltas and marginal mudflats, and eolian sand-sheet and eolian-dune deposits. Lithology, color, organic-carbon preservation and trace fossil assemblages indicate that water was abundant, water tables were high, and rates of clastic and volcanic deposition were high for the lower part of the Chinle. For part of the upper Chinle, lacustrine carbonate and eolian sand sheet and dune deposition predominated, water tables and sedimentation rates were lower, and drier and more oxidizing conditions prevailed. Depositional facies indicate that water was abundant in the depositional system, and the Late Triassic climate was punctuated by seasonally dry periods. Climate also fluctuated on a longer term and resulted in lithological cycles in lacustrine sequences. Both monsoonal climate and long-term climate changes from monsoonal circulation during the Late Triassic to predominately dry conditions in the Early Jurassic were the result of the northward migration of Pangaea out of the low latitudes.

#### INTRODUCTION

Sedimentary rocks of the Upper Triassic Chinle Formation are widely exposed on the Colorado Plateau (Fig. 1). Locally, the Colorado River and its tributaries have exposed the Chinle in exquisite three-dimensional detail. Steep cliffs provide sedimentologists and stratigraphers with the opportunity to contemplate the architecture of complexly interbedded continental lithofacies, and badlands are coveted by paleontologists in their exploration for new fossil discoveries. The diversity and regional distribution of Chinle exposures provide ample opportunity to pursue either discipline.

Sedimentologic and paleontologic investigations provide complementary evidence for reconstructing Late Triassic depositional environments, paleoecology and paleoclimate. Chinle strata host vertebrate and invertebrate fossils that reflect the energy and setting of the depositional environment. Chinle fossils provide constraints on the environments on the basis of degree of articulation and preserved taxonomic assemblages. Interdisciplinary studies utilizing both sedimentologic and paleontologic evidence can confirm hypotheses derived independently, and provide information not inherent in either study operating alone.

This paper summarizes the depositional setting of the Chinle

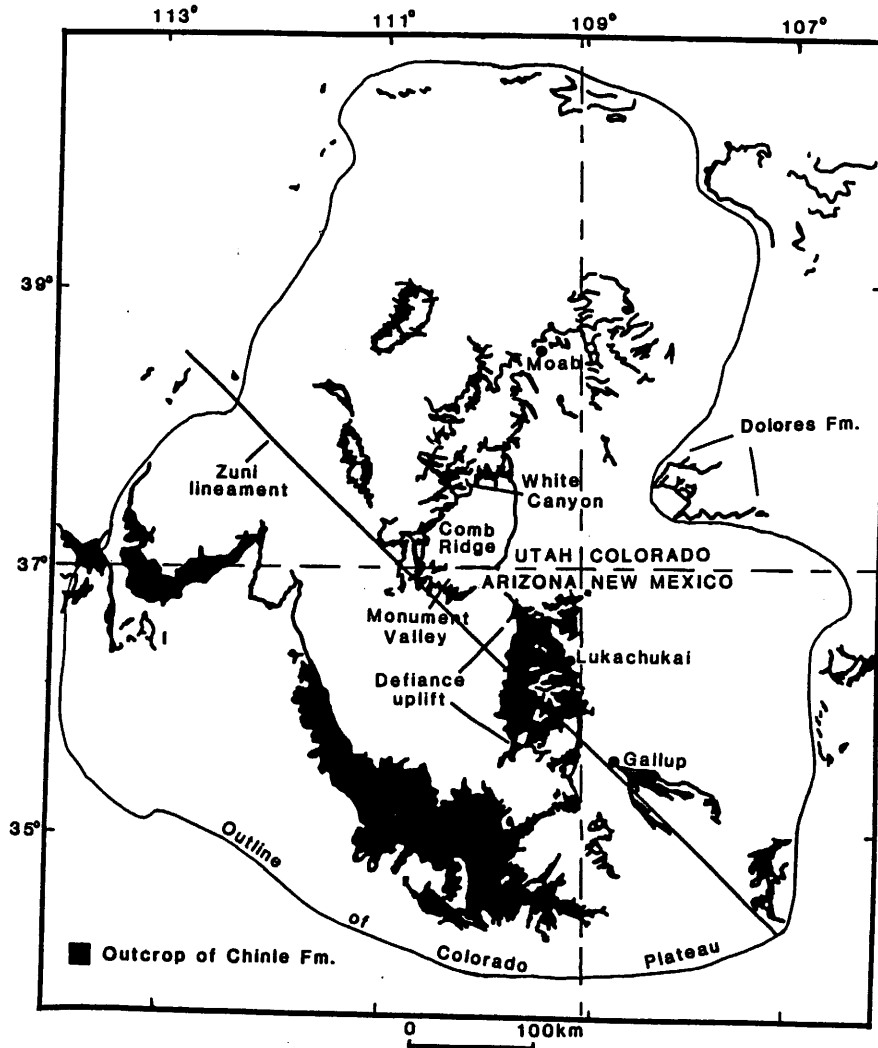


FIGURE 1. Map of the Colorado Plateau showing outcrop of the Chinle Formation and geographic features referred to in the text (derived in part from Stewart et al., 1972).

Formation in the Four Corners region of Arizona, Utah, Colorado and New Mexico on the Colorado Plateau. Depositional environments are summarized from published and ongoing sedimentologic studies by the author and from published and unpublished (theses) research by other workers. The Chinle Formation represents the record of sedimentation of a geographically widespread continental deposystem containing complexly interfingered fluvial, floodplain, lacustrine-deltaic, lacustrine and eolian facies. Comparisons of Chinle depositional environments at specific sites and within different members must be tempered with the variability represented by the Chinle, because current research is continually providing refinements and new interpretations of Chinle sedimentology. All of the environments discussed for a specific lithostratigraphic unit may not be present at every site or in every region, and facies not specifically described for certain units may be present at any

location. The range of interpretations of Chinle fluvial strata alone that are cited in the literature attests both to the variability of Chinle sedimentation and to the degree of caution that must be included in one's interpretation. Interpretations of depositional environments should be based on detailed sedimentologic and stratigraphic study, and should incorporate paleontologic, paleopedologic and petrographic data when available. Extension of interpretations to strata far beyond the study area must be considered as tenuous.

### PALEOGEOGRAPHY

The Chinle Formation was deposited in a continental back-arc basin (Fig. 2) (Dickinson, 1981). A magmatic-volcanic arc on the western and southwestern edge of the Triassic continent provided

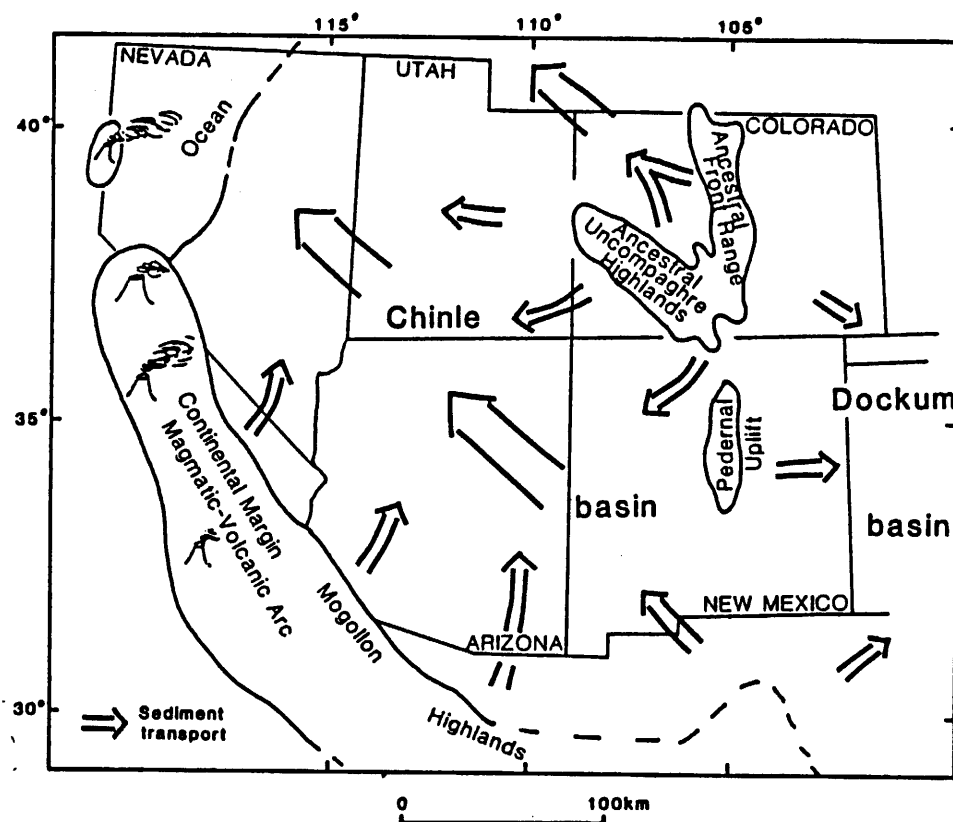


FIGURE 2. Reconstruction of Late Triassic paleogeography in the vicinity of the Colorado Plateau showing major tectonic features and paleotransport directions.

volcanic ash and clastics to the Chinle basin (Stewart et al., 1972; Blakey and Gubitosa, 1983; Busby-Spera, 1988). Detrital material was provided to the Chinle basin from the ancestral Rocky Mountains, which comprised the ancestral Front Range and the ancestral Uncompaghere highlands, and from the Mogollon highlands. Sediment was shed southward and westward from ancestral Uncompaghere highlands and the southern end of the

ancestral Front Range and northward from the Mogollon highlands. The Mogollon highlands apparently coincided with volcanic-magnetic terrane and associated uplifted sedimentary rocks of the southeastern extension of the continental arc, forming the southern rim of the Chinle basin. The Pedernal uplift extended southward from the ancestral Rockies in central New Mexico and probably acted as a divide between the Chinle drainage area to the west and the area of Dockum Group deposition to the east. The presence of Upper Triassic marine deposits and marginal-marine strata in west-central Nevada (Silberling and Wallace, 1969) indicate that the ocean lay a considerable distance to the west.

### DEPOSITIONAL ENVIRONMENTS

The Chinle Formation on the Colorado Plateau contains a bewildering array of formal and informal stratigraphic units that have evolved from numerous and disparate studies over the years. Stewart et al. (1972, fig. 1) summarize the nomenclature of the Chinle on the Colorado Plateau. For the present paper, certain lithosomes that are considered to be stratigraphic equivalents will be discussed together to facilitate description of and reference to their facies.

#### Stratigraphy

Through most of its extent, the Chinle unconformably overlies the Triassic Moenkopi Formation and locally in the Defiance uplift overlies the Permian De Chelly Sandstone. The base of the Chinle Formation is represented by either the Shinarump Member, Agua Zarca Sandstone Member, Gartra Member, sandstone member or mottled strata. In many places, mottled strata underlie other members at the base of the Chinle, but locally the mottled strata occur several tens of meters above the base of the Chinle or are present in rocks below the base of the Chinle (Stewart et al., 1972; Dubiel, 1987a). Mottled strata are considered to be the result of pedologic processes that altered Chinle sediments or underlying rocks (Stewart et al., 1972; Dubiel, 1987a,b,c; Dubiel et al., 1987). The basal members and mottled strata within the Chinle are collectively referred to as the Shinarump facies in the following discussion.

Several distinct lithostratigraphic units overlie the Shinarump facies. Rocks directly overlying this facies across most of the Colorado Plateau comprise the stratigraphically equivalent Monitor Butte Member, Mesa Redondo Member, lower red member, sandstone and mudstone member and Salitral Shale Tongue. These units consist of a uniformly heterogeneous lithosome consisting of interfingering sandstone and mudstone that is referred to as the Monitor Butte facies. In southeastern Utah, the Moss Back Member overlies the Monitor Butte Member, but locally in the White Canyon area of southeastern Utah the Moss Back interfingers with the Monitor Butte and with the overlying Petrified Forest Member (Dubiel, 1987a). The Petrified Forest Member is a heterogeneous lithosome that is one of the most geographically widespread units in the Chinle. The Petrified

Forest Member overlies the Moss Back Member in southeastern Utah and locally overlies the Monitor Butte facies or Shinarump facies (Stewart et al., 1972, fig. 1). The Petrified Forest Member is overlain by the Owl Rock Member. The Owl Rock is overlain by the Church Rock Member in most of southeastern Utah and by the Church Rock Member and the stratigraphically equivalent Rock Point Member in the southern part of Monument Valley and around the Defiance uplift. The Church Rock Member of most of southeastern Utah apparently is not stratigraphically equivalent to the type Church Rock Member along the southern part of Comb Ridge, nor to the Rock Point Member in the Defiance uplift (O'Sullivan, 1970; Dubiel, 1987a, in press-a). All the rocks that have been assigned to both the Church Rock and the Rock Point are referred to herein as the Rock Point facies.

The Chinle Formation is overlain by the Lower Jurassic Wingate Sandstone in most of the study area. Locally in the area around Gallup, New Mexico, and to the east, the Chinle is overlain by the Middle Jurassic Entrada Sandstone (O'Sullivan, 1970; Stewart et al., 1972; Pipiringos and O'Sullivan, 1978; Peterson and Pipiringos, 1979; Dubiel, in press-a).

### Sedimentology

Reconstructions of depositional environments for the Chinle Formation on the Colorado Plateau have been refined through the years, but the original interpretations of a continental setting have not been refuted. Early reports on Chinle paleontology that described pelecypods, gastropods, arthropods, amphibians, reptiles, fish and plants indicated a continental depositional setting for the Chinle on the basis of the individual fossil occurrences. Many individual reports on local geology or on uranium-vanadium deposits in the Chinle discussed local continental depositional environments. It is beyond the scope of this report to summarize all of the publications that deal with individual fossil or mineral occurrences in the Chinle. Stewart et al. (1972) incorporated paleontologic, lithologic and stratigraphic data into a comprehensive analysis of the depositional environments found within the Chinle on the Colorado Plateau. Since that time, advances in sedimentology and academic interest in the Chinle have produced sedimentologic studies on individual depositional components of the Chinle or have focused on regional reconstructions of depositional environments.

### Shinarump Facies

The Chinle Formation fills large valleys and smaller scours eroded into the underlying Moenkopi Formation and De Chelly Sandstone (Witkind and Thaden, 1963; Stewart et al., 1972; Blakey and Gubitosa, 1983; Dubiel, 1983); these paleovalleys formed in response to a lowered regional base level. A subsequent rise in base level resulted in aggradation of fluvial systems of the Shinarump facies that filled the lower reaches of the paleovalleys.

The Shinarump facies is characterized by white to gray and

reddish-orange, medium- to coarse-grained and conglomeratic sandstone. The sandstone exhibits numerous cut-and-fill structures, lenticular internal scour surfaces, and locally contains large-scale lateral accretion bedding. In many sandstone bodies, abundant planar crossbedding grades upward to large-scale trough cross-stratification. Sandstone bodies grade laterally into siltstone and mudstone units that contain organic-carbon fragments and whole, carbonized plant fossils.

Sedimentary structures, isopach maps and facies analysis indicate that the Shinarump facies was deposited by fluvial systems that trended northward and westward from the Mogollon highlands and southward and westward off of the ancestral Uncompaghre highlands in the Four Corners area (Stewart et al., 1972; Blakey and Gubitosa, 1983; Dubiel, 1983, 1987a) and northward and westward from the ancestral Rockies in western Colorado (Fig. 3) (Stewart et al., 1972; Shropshire, 1974; Dubiel

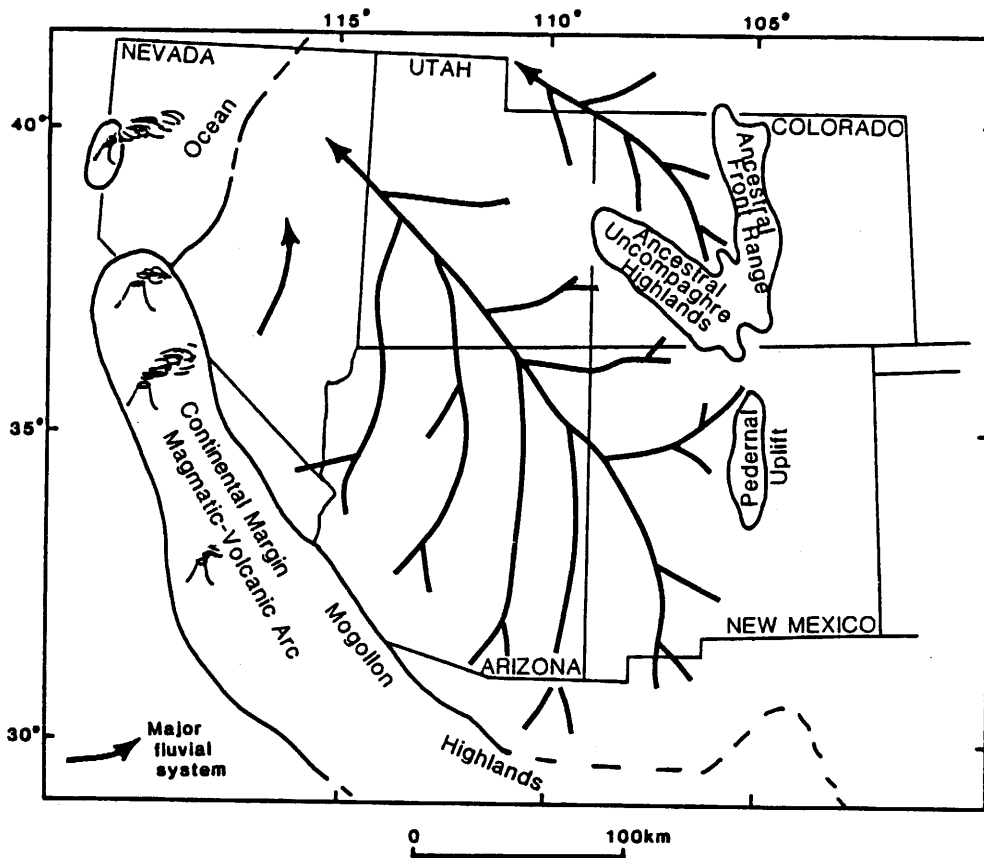


FIGURE 3. Major fluvial systems of the Shinarump facies.

and Skipp, 1989). Fluvial systems occupied or modified preexisting paleovalleys cut in underlying strata. These systems filling the paleovalleys were initially restricted in their lateral migration by the valley walls; but as aggradation continued to fill the paleovalleys, streams were able to migrate farther laterally. The upward transition from conglomeratic and