GEOLOGY AND PALEONTOLOGY OF THE CHINLE FORMATION, PETRIFIED FOREST NATIONAL PARK AND VICINITY, ARIZONA AND A DISCUSSION OF VERTEBRATE FOSSILS OF THE SOUTHWESTERN UPPER TRIASSIC

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Abstract - The Chinle Formation (Upper Triassic) consists primarily of clastics deposited within a large basin in the Colorado Plateau area of the western United States. The Petrified Forest Member is the thickest unit of the Chinle Formation and may be divided into lower and upper units, separated by the petrified-log-bearing Sonsela Sandstone. In the Petrified Forest National Park area, the Petrified Forest Member is nearly 300 m thick. Vertebrate fossils have been recovered at various levels in the Petrified Forest Member and the faunal composition, stratigraphy and sedimentological features of the major localities are discussed herein. In the lower Petrified Forest Member, vertebrate fossil-bearing sites include the Placerias and Downs quarries near St. Johns and the Dying Grounds, Crocodile Hill and Jasper Forest localities in Petrified Forest National Park. Other sites discussed from within the park include Crystal Forest, where fossils are found within a fine-grained facies of the Sonsela Sandstone, and Flattops, Dinosaur Hill ("Lacey Point") and the Lungfish locality which lie within the upper Petrified Forest Member of the Chinle Formation. Numerous vertebrate fossils of Triassic age have been discovered in the southwestern United States, many of which are still undescribed. A review of southwestern Carnian and Norian-age fossils indicates the presence of a wide variety of metoposaur amphibians, phytosaurs, aetosaurs, rauisuchians and dinosaurs as well as other reptilian taxa.

ARIZONA TECTONICS

The Chinle Formation, widely exposed throughout the Colorado Plateau area (Fig. 1), was deposited in a large basin that was filled by westward and northwestward flowing streams and lacustrine sediments (Blakey and Gubitosa, 1983). According to Smiley (1985), the Mogollon highlands, situated within central and southern Arizona, provided a source of eolian and fluvial-transported volcanic sediments, lahars and sediments from the older Permian-age formations. Within southeastern Utah, the Uncompahgre ighlands are said to have provided a further source of volcaniclastic material. However, studies by Blakey and Middleton (1983) and Middleton (pers. comm., 1988, 1989) indicate that the source area for the volcaniclastics is not clearly established. At least some of the volcaniclastic material deposited by the Chinle streams was probably derived from the Cordilleran volcanic arc to the west and southwest of the Chinle basin, and other clasts in the Sonsela and Shinarump are most likely derived from Precambrian sources in central Arizona.

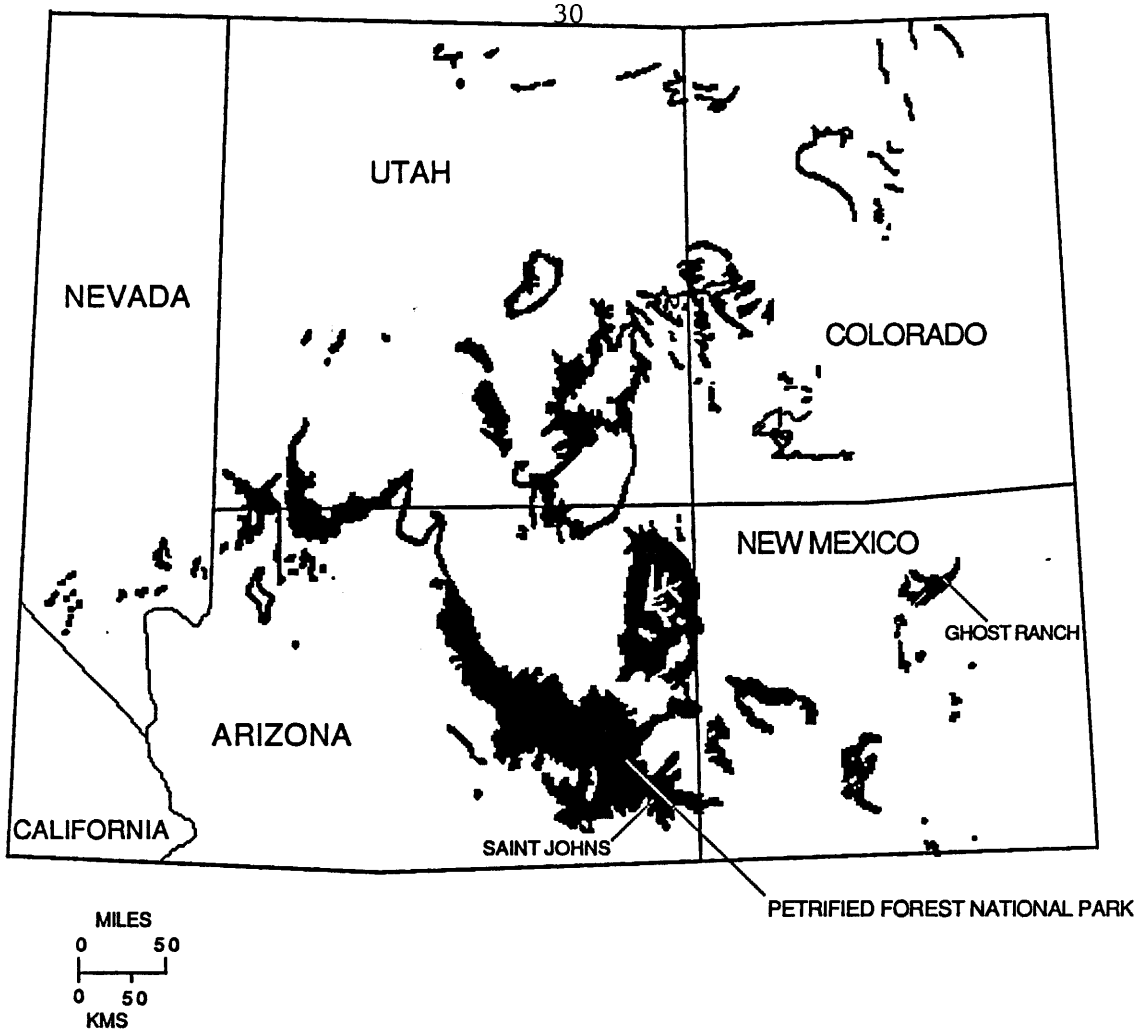

FIGURE 1. Chinle Formation exposures, southwestern United States.

The Panthalassa shoreline was situated near the western edge of Arizona, with a number of rivers draining into it from the highland areas. The dominant depositional environments for this region consisted of fluvial and lacustrine environments deposited upon the western Pangaean floodplain (Smiley, 1985).

The tectonic and depositional situation within Arizona changed within the Upper Triassic, and especially during the Triassic-Jurassic transition. Studies by Wilson and Stewart (1967) point to a decrease in volcanic bentonites, an increase in grain size and a sediment-color change that marks the Triassic-Jurassic boundary. Sedimentological changes also are apparent between the upper and lower Petrified Forest members, indicating changes in fluvial and lacustrine deposition and possibly as concerns tectonism and climate.

VERTEBRATE FOSSILS FROM THE UPPER TRIASSIC CHINLE AND DOCKUM FORMATIONS, SOUTHWESTERN UNITED STATES

Seven localities produced microvertebrate fossils within Petrified Forest National Park during a reconnaissance by field crews from Tarleton State University during May-June, 1988. The fossils studied to date from these localities are discussed in a

paper by Murry (this volume). However, numerous other vertebrate fossils have been recovered from the southwestern United States, many of which have not yet been fully described. The most abundant of these are metoposaurid amphibians, aetosaurs and phytosaurs. A brief discussion of these groups and others is included herein as a review of southwestern Triassic vertebrate paleontology.

Remains of metoposaurs have been recovered from numerous localities within both the lower and upper Petrified Forest Member in the southwestern United States. The species of metoposaur commonly reported is Metoposaurus fraasi (Colbert and Imbrie, 1956; Roy-Chowdhury, 1965). This is a large metoposaurid (skull length in excess of 600 mm) with a rather deep otic notch and well-developed tabular horns. The vertebrae are short and wide. This amphibian is very common in Carnian-age sediments throughout the Southwest where it is second only to the ubiquitous Rutiodon in abundance. Fragmentary remains possibly attributable to this species are found in Norian exposures, but they are very rare.

Another amphibian that seems abundant in the southwestern Triassic is tentatively referred to the genus Anaschisma. This is a small metoposaurid (maximum skull length about 300 mm) with a shallow otic notch and reduced tabular horns. The vertebrae are more elongate than those of Metoposaurus. This labyrinthodont is present in both Carnian- and Norian-age southwestern deposits, but it is especially common in the latter. The congenerity of this material with the genotype of Anaschisma (A. browni) has not been sufficiently established. Kalamoiketer pinkleyi Branson and Mehl (1929) may be the correct name for the southwestern specimens, but the holotype (U. Mo. 554 VP) is in need of restudy. Also, detailed comparisons need to be made with the Cumnock metoposaur, Dictyocephalus elegans (see Davidow-Henry, 1987).

Remains of tanystropheids have been reported from the lower Petrified Forest Member of the Chinle Formation (at the Placerias and Downs quarries), but this material, all of which has been referred to Tanytrachelos sp., has not been described or illustrated (Jacobs and Murry, 1980). Between 1924 and 1932, C.L. Camp collected at a site in the Blue Hills, northeast of St. Johns, Arizona, which produced a rather extensive series of small (but above the general microvertebrate size level) tetrapod fossils. Included in this interesting collection is a nearly complete cervical vertebra, probably cervical number 12, which can be attributed to Tanystropheus s.s. The recovery of a Tanystropheus specimen from a late Carnian, continental vertebrate assemblage is unexpected. This genus is usually found in European marine deposits of Anisian-Ladinian age. However, Baird has reported (Baird, pers. comm. to Long, 1983; Baird, 1986) a Tanystropheus cervical vertebra from continental Anisian or Ladinian rocks (lower Economy) of Nova Scotia, and Wild has described an incomplete Tanystropheus cervical column from Argillite di Riva di Solto (Upper Norian) of Italy (Wild, 1980). Obviously, this peculiar reptile occupied a much larger arena (geographical, stratigraphical and environmental) than we

previously thought.

A possible proterochampsid archosauromorph, informally referred to as "Acallosuchus rectori," has been recovered from the lower Petrified Forest Member of the Chinle Formation in northeastern Arizona and the Dockum Formation of Crosby County, Texas. This is a medium-sized form (skull length estimated at about 200 mm). The skull was very long and slender; it appears to be covered, as are the lower jaw elements, with very large osteoderms. The vertebrae are long and low, and the pelvic and appendicular elements are primitive, at the proterosuchian grade. Three types of body armor are present, including upstanding (?) triangular plates, low keeled plates and conical spikes.

Phytosaurs are represented in the Triassic of the southwestern United States primarily by Nicrosaurus and Rutiodon. Nicrosaurus buceros (n. comb.) is an advanced phytosaurid restricted to Norian-age exposures in Arizona, New Mexico and Texas. This genus is never found with the more primitive, Carnian-age genus Rutiodon. It is primarily the temporal region that exhibits features which distinguish these two genera. In Nicrosaurus, the postorbitosquamosal bar is very wide and prominently sculptured. The medial expansion of the bar constricts the transverse diameter of the supratemporal fenestrum. The length of the postorbitosquamosal bar is no more than six times its width. The squamosal is triangular in lateral profile, and it terminates posteriorly in a point; a distinct groove often marks its outer surface. Two quite distinct morphotypes can be demonstrated in this species (as can also be seen in the Germanic N. kapffi skulls): (1) a massive, high-snouted form, probably an adult male characteristic; and (2) a more slender-snouted form (? female). In morphotype 1, the rostral crest is never so well-developed as in the Stubensandstein species N. kapffi. Several taxonomic labels have been created for southwestern, Norian-age phytosaurs (i.e., Machaeroprosopus tenuis, M. andersoni, M. validus and Pseudopalatus pristinus), and these probably are conspecific with Cope's N. buceros.

Rutiodon sp. (or spp.) are probably restricted to Late Carnian exposures in Arizona, New Mexico and Texas. In this genus, the postorbitosquamosal bar is always narrow and usually devoid of sculpturing; its length is equal to about 9 times its width. The supratemporal fenestrum is very wide. The squamosal is usually deep posteriorly and exhibits no lateral groove. As in Nicrosaurus, two skull morphotypes can be distinguished; a delicate, slender-snouted form and a massive, heavy-snouted type. As in the more advanced genus, these morphs appear to be related to sexual dimorphism rather than taxonomic characters. It is currently unclear as to whether more than a single species of Rutiodon was present in the soutwestern Carnian. Several full-crested rutiodont skulls have been incorrectly attributed to Nicrosaurus (as "Nicrosaurus" gregorii).

According to the work of Long and Ballew (1985), it appears that aetosaurs are quite common in the southwestern Triassic and are quite useful in biostratigraphic studies. At least five genera are present. Stagonolepis wellesi n. comb. (for

Calyptosuchus wellesi Long and Ballew, 1985) is a medium-sized (3-4 m) stagonolepidid known from much of the skeleton, though only the armor has been described in detail (see Long and Ballew, 1985, for description). The postcranial elements are of more delicate build than those of Desmatosuchus. The cervical vertebrae are ventrally keeled (keels are lacking in Desmatosuchus). Dorsal, sacral and anterior caudal vertebrae have tall neural spines, and the dorsals exhibit very large transverse processes (Desmatosuchus has short neural spines and transverse processes). The ilium is high with a short blade (in Desmatosuchus, the iliac blade is long). The hind limb elements are long and slender (these are short and massive in Desmatosuchus). S. wellesi is a common species in lower Petrified Forest Member sediments in Arizona, and in Carnian-age deposits elsewhere in the Southwest; it is never found in the upper Petrified Forest Member or other Norian deposits.

A diminutive new stagonolepidid, informally designated "Acaenasuchus geoffreyi," has the maximum width of its paramedial plates equal to 40 mm (in contrast to 370 mm in Typothorax coccinarum). This species is currently known only from its dermal armor, which indicates a narrow-bodied aetosaur probably no more than 600 mm in total length. The cervical armor is elongated; the paramedian plates of the dorsal region bear anterior bars rather than thin laminae, and a lattice type of sculpturing is present. The posterodorsal edges of the paramedian plates are beveled. Eminences are present on the paramedian plates as thin, longitudinal ridges with lateral and medial "wings". The lateral plates have sharp, thorn-like horns or ridges throughout the presacral region. This tiny aetosaur is rarely encountered; it appears to be restricted to the lower Petrified Forest Member of the Chinle Formation in northeastern Arizona.

In 1985, Long and Ballew described the armor of Desmatosuchus haplocerus in some detail. After reviewing the distribution of this species they concluded that it was restricted to exposures of Carnian age. However, in that same year, Bryan Small described some excellent material of D. haplocerus from the Miller Quarry, near Post, Texas. After examination of the entire Miller Quarry collection, Long is in agreement with Chatterjee and Small on their assignment of a Norian age for this collection. Since 1985, rare isolated specimens of D. haplocerus have been discovered in Norian-age beds of Arizona and New Mexico. It is, therefore, concluded that Desmatosuchus survived into the Norian, but as an extremely rare element when contrasted to its much greater frequency in southwestern Carnian deposits.

Paratypothorax is based on the distinctiveness of its dermal armor, though a few non-integumentary specimens (i.e., at Heslach, Germany: Wild, pers. comm. to Long, 1986; the Miller quarry, Texas: Small pers. comm. to Long, 1987; and the Crystal Forest excavation, Arizona) have been associated with Paratypothorax armor since the genus was named in 1985. These unpublished specimens support Long and Ballew's referral of the armor to the Stagonolepididae rather than to the Phytosauridae.