FAUNAL REVIEW OF THE UPPER TRIASSIC CHINLE FORMATION OF ARIZONA

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ABSTRACT

The Chinle Formation of Arizona is a highly fossiliferous terrestrial unit from the Late Triassic Period. Fossil vertebrate collections from the Chinle Formation date back to the late 1890s and document a diverse fauna that is correlative with other Late Triassic faunas worldwide. No fewer than 18 holotype specimens including metoposaurids, phytosaurs, aetosaurs, crocodylomorphs, dinosauromorphs, and other archosaurs have been described from Chinle exposures in Arizona. A faunal overview of the most important localities and a review of the vertebrates is provided.

INTRODUCTION

CHINLE FORMATION exposures in Arizona document a diverse vertebrate fauna from the Carnian and Norian stages of the Late Triassic Period. These exposures stretch southeast from the Shinarump Cliffs on the Arizona-Utah border to the Arizona-New Mexico border east of St. Johns, covering much of the northeastern corner of the state (Figure 1). Since paleobotanist Lester Ward discovered the first vertebrate remains east of Cameron, numerous vertebrate collections have been made by collectors such as Barnum Brown, Maurice Mehl, Charles Camp, Edwin Colbert; and in recent years by crews from the Museum of Northern Arizona, the University of California at Berkeley, the New Mexico Museum of Natural History, Southern Methodist University, and Petrified Forest National Park. These collections include numerous holotypes and are a cornerstone in our understanding of the Late Triassic Period of North America.

Institutional abbreviations- FMNH, Field Museum of Natural History, Chicago**;** GR, Ruth Hall Museum of Paleontology, Ghost Ranch, New Mexico**;** MNA, Museum of Northern Arizona, Flagstaff; PEFO, Petrified Forest National Park; PFV, Petrified Forest Vertebrate Locality; SMU, Southern Methodist University; TTUP, The Museum at Texas Tech University, Lubbock; UCMP, University of California Museum of Paleontology, Berkeley; USNM, United States National Museum, Washington, D. C.

STRATIGRAPHY AND AGE

The Chinle Formation in Arizona consists almost entirely of fluvial and lacustrine sediments with mudstone, siltstone, and sandstone being the major constituents. These sediments are highly variegated and provide much of the color for what is known as the "Painted Desert". In Arizona, the Chinle Formation is currently divided into nine formal members (Figure 2). To the west near Cameron, seven of these are present, named from oldest to youngest the Shinarump, Cameron, Blue Mesa, Sonsela, Petrified Forest, Owl Rock, and Rock Point members (Stewart et al., 1972; Kirby, 1991; Lucas, 1993). To the east, in the vicinity of PEFO, six are present, the Shinarump, Mesa Redondo, Blue Mesa, Sonsela, Petrified Forest, and Owl Rock (Figure 2). According to Heckert and Lucas (2003) the Mesa Redondo Member (Cooley, 1958) is equivalent to the Bluewater Creek Member (Lucas and Hayden, 1989), however contrary to those authors, if they do represent the same strata, the name Mesa Redondo has priority since it has been recognized as valid by numerous authors other than Stewart et al. (1972) (e. g., Gottesfeld, 1972; Gillette et al., 1986; Murry, 1990; Demko et al., 1998; Dubiel et al., 1999; Polycyn et al., 2002). The Cameron Formation (Lucas, 1993) is the formal name for the "sandstone and mudstone member" of the Chinle Formation (Stewart et al., 1972) and may extend eastward as far as Holbrook where it grades laterally into the Mesa Redondo Member (Kirby, 1994).

Traditional Sonsela Sandstone Bed (Akers et al, 1958) outcrops in Arizona are restricted to the areas around PEFO and St. Johns and northward over the Defiance Uplift, however the expanded Sonsela Member (Heckert and Lucas, 2002a; Woody, 2003) can be identified westward around Cameron (Lucas, 1993) and to the north around Lee's Ferry (R. Irmis, personal commun., 2004). Regionally, the basal Chinle (Shinarump) rests unconformably on the Middle Triassic Moenkopi Formation, while in the St. Johns area an informal unit, the "mottled strata", separates the two (Stewart et al., 1972). Recently,

Heckert and Lucas (2003) provided the formal name Zuni Mountains Formation for this unit, however the mappability of this unit in Arizona has not yet been demonstrated.

Fossil vertebrates and palynomorphs suggest a Late Triassic age (Carnian and Norian) for the Chinle Formation in Arizona (Colbert, 1972; Litwin et al., 1991; Lucas, 1998). This is also supported by paleomagnetism (Steiner and Lucas, 2000). An isotopic date of 209 ma for the Black Forest Bed of the Petrified Forest Member is the only published date for this formation in Arizona (Riggs et al., 2003) providing a Norian age (Muttoni et al., 2004).

The vertebrate fauna of the Chinle is extremely cosmopolitan with identical faunas being known from Chinle exposures in Utah and New Mexico, as well as the Popo Agie Formation of Wyoming and the Dockum Group of New Mexico and Texas (Long and Murry, 1995). Furthermore, similar faunas can be found in strata of generally the same age worldwide (Lucas, 1998).

HISTORY OF VERTEBRATE COLLECTIONS

The first collection of vertebrate material from the Chinle Formation in Arizona was made by Lester Ward east of Cameron in 1899 in what became known as the "Ward Bone Bed", just north of Tanners Crossing of the Little Colorado River (Figure 1). Collected material includes phytosaur bones, osteoderms of the aetosaur *Stagonolepis*, and a "cranial plate" of a large metoposaur (Lucas, 1904). In 1901, Ward returned to the site with Barnum Brown where Brown collected more phytosaur, aetosaur and metoposaur material including the holotype interclavicle of the metoposaur *Metoposaurus fraasi* (USNM 2152) and the holotype humerus of the dicynodont *Placerias hesternus* (Lucas, 1904; Welles, 1972).

In 1906, John Muir made a small collection of vertebrates (UCMP 26693) from the Crystal and Black Forests at Petrified Forest National Park (Long and Murry, 1995). This material contains the first collected material of the aetosaur *Typothorax coccinarum* from Arizona. In 1913, S. W. Williston collected an ilium (FMNH 1252) of an indeterminate phytosaur from near Holbrook (Long and Murry, 1995). Maurice Mehl, then with the University of Wisconsin, collected the holotype skull of the phytosaur *Machaeroprosopus validus* from the Petrified Forest Member near Cameron above the Ward Bone Bed in 1914 (Camp and Welles, 1956). Unfortunately this specimen has been lost, but the description suggests that it represents a pseudopalatine-grade phytosaur (Mehl et al., 1916). In 1922, Mehl collected the holotype skull of the phytosaur *Pseudopalatus pristinus* from the northern part of what is now Petrified Forest National Park (Mehl, 1928).

Based on an initial reconnaissance by Berkeley researcher Ynez Mexia in 1919, Annie Montague Alexander and her field companion, Louise Kellogg, discovered numerous fossils in 1921 in exposures that were then north of Petrified Forest National Park, including the holotypes of "*Machaeoroprosopus*" *lithodendrorum* and "*M.*" *adamanensis* (Camp, 1930). Charles L. Camp aided the two women with the excavations that summer and proceeded to spend much of the two decades in Arizona excavating fossils not only in the vicinity of PEFO but also near St. Johns and to the north in the Defiance Uplift. It was in Chinle exposures near St. Johns that Camp discovered the *Placerias* Quarry, which produced numerous specimens of the dicynodont *Placerias*, phytosaurs, aetosaurs, poposaurs, rauisuchians and the first Triassic dinosaur material (*Camposaurus arizonensis* Hunt et al., 1998) recovered in Arizona. In the nearby "Blue Hills" Camp discovered several other localities, which produced a partial carapace of the aetosaur *Stagonolepis*, the holotype of the aetosaur *Acaenasuchus geoffreyi* (Long and Murry, 1995), as well as material of the pseudosuchian *Revueltosaurus hunti* (Heckert, 2002; Parker et al., 2005).

At the same time that Charles Camp was working at the Blue Hills and *Placerias* Quarry, Barnum Brown, now with the American Museum of Natural History, recovered more material from the area of the Ward Bone Bed. In 1929 and 1930, Brown, Llewellyn Price, and William Hayden collected a partial reptile skeleton and associated material, which Colbert (1952) later described as the holotype of the crocodylomorph *Hesperosuchus agilis*. In 1936, Brown and Roland Bird collected a magnificent phytosaur skeleton (AMNH 3060) that Colbert (1947) referred to "*Machaeroprosopus*" *gregorii*. This skeleton complemented other phytosaur material (AMNH 3000-3004) collected from the region by Brown in his earlier trip in 1930 (Colbert, 1947). Meanwhile, to the east Charles Gilmore and George Sternberg collected several phytosaur skulls from the area around PEFO and St. Johns for the U. S. National Museum.

In 1945, Charles Camp accompanied Edwin Colbert of the American Museum of Natural History to northeastern Arizona to show him his Triassic localities. Colbert worked in the Petrified Forest in 1946, collecting several phytosaur skulls as well as metoposaur material, none of which has ever been described. Colbert also collected material from the Davis Ranch near St. Johns. Although Colbert planned on returning to the area in 1947, the enroute

FIGURE 1. Map showing Chinle Formation exposures in Arizona. Letters refer to localities referred to in the text; A, *Placerias*/Downs quarries; B, Blue Hills; C, Stinking Springs; D, Petrified Forest National Park; E, Joseph City/Marcou Mesa; F, Nazlini; G, Many Farms/Round Rock; H, St. Michaels/Allentown/Lupton; I, Ward Bone Bed; and J, Ward Terrace.

discovery of the major dinosaur quarry at Ghost Ranch, New Mexico derailed these plans and Colbert never again conducted major paleontological research in the Chinle of Arizona. Also around this time, G. E. Hazen of the U. S. Geological Survey collected vertebrates from near St. Johns. Hazen's most important discovery was an isolated tooth from an unknown tetrapod, which represents a new taxon (Irmis and Parker, 2005).

The 1950s and 1960s saw generally little new collecting of Chinle vertebrates, however in Petrified Forest National Park, park naturalist Phillip Vancleave collected the holotype of the enigmatic archosauromorph *Vancleavea campi* (Long and Murry, 1995). Brady (1954, 1958) described the first occurrences of the aetosaur *Desmatosuchus haplocerus* from Arizona based on armor plates collected near Lupton and Allentown. In addition, just to the west of PEFO MNA geologist Bill Breed collected a lateral osteoderm of *Desmatosuchus* (MNA 697) from above the Sonsela Member. This find represents the only occurrence of *Desmatosuchus* in the upper Chinle and is referable to a new species also known from Texas, *D. smalli* (Parker, 2005).

In the 1970s the Museum of Northern Arizona embarked on an aggressive research program which included intense prospecting of the Owl Rock Member at Ward Terrace (Kirby, 1989, 1991), the reopening of the *Placerias* Quarry and the discovery of the adjacent Downs Quarry (Jacobs and Murry, 1980), as well as the first paleontological inventory of Petrified Forest National Park (Cifelli et al., 1979). These projects were the first to sample the microvertebrate fauna of the Chinle and resulted in nearly doubling the known Chinle taxa (Jacobs and Murry, 1980). In 1989 and 1990, the *Placerias* and Downs quarries were again reopened by crews from the University of California (Berkeley) resulting in the collection of hundreds more specimens (Kaye and Padian, 1994), while Kirby (1989) made additional collections from the Owl Rock Member and provided the first description of this fauna.

In the 1980s the UCMP began a decade of research in the Chinle Formation with the majority of the work being centered in Petrified Forest National Park (Long and Padian, 1986; Murry and Long, 1989; Long and Murry, 1995). Through this research the first unambiguous dinosaur material from the park was recovered (Padian, 1986), the taxonomic

utility of aetosaur armor was established (Long and Ballew, 1985), while additional discoveries were made including the holotypes of the phytosaur *Pseudopalatus mccauleyi* (Ballew, 1989) and the basal saurischian *Chindesaurus bryansmalli* (Long and Murry, 1995; Langer, 2004). In the late 1990s Phillip Murry of Tarleton State University studied the microfauna of PEFO and the St. Johns area (Murry, 1989) and erected a new species of *Trilophosaurus*, *T. jacobsi*. Contrary to Sues and Olsen (1993) *T. jacobsi* is a valid species of *Trilophosaurus* (Heckert et al., 2003; Heckert, 2004).

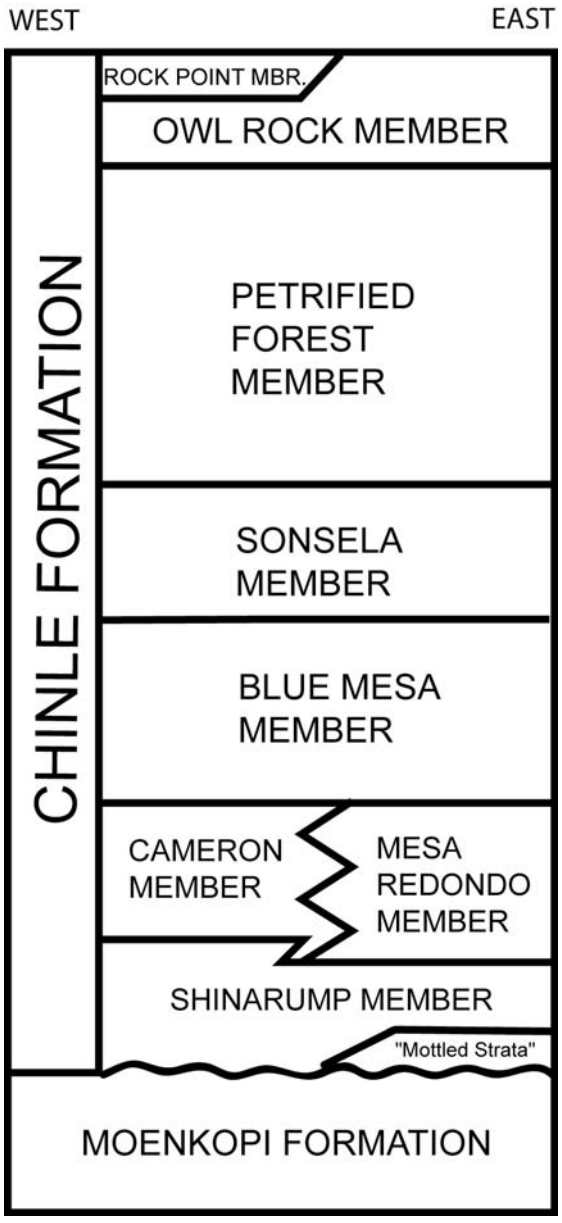

FIGURE 2. Relation of individual members of the Chinle Formation of Arizona from West to East.

In 1996, Adrian Hunt, then with the Mesalands Dinosaur Museum in Tucumcari, New Mexico, initiated his "Dawn of the Dinosaurs" project in PEFO. To date only preliminary results have been published (e. g., Hunt and Wright, 1999), however this project resulted in the collection of potentially important aetosaur and other pseudosuchian material.

In the early 1990s, New Mexico Museum of Natural History research associate Stan Krzyzanowski discovered a new vertebrate locality in the Blue Hills near St. Johns. This site has been collected repeatedly since then, providing important microvertebrate information (Heckert, 2004). Andy Heckert of the University of New Mexico collected microvertebrates from the Blue Forest in PEFO in the late 1990s (Heckert, 2004). Also around this time, crews from Southern Methodist University collected several sites near Stinking Springs Mountain, between PEFO and St. Johns (Polcyn et al., 2002). In 2001, staff from the Petrified Forest National Park initiated an ongoing paleontological inventory of the park, which resulted in the collection of numerous important vertebrate fossils (Parker and Clements, 2004; Stocker et al., 2004; Parker et al., 2005; Parker and Irmis, 2005).

VERTEBRATE LOCALITIES AND FAUNAS

A) *Placerias*/Downs quarries, St. Johns, Arizona (Figure 1)

The *Placerias* quarry (UCMP A269) represents one of the most taxonomically diverse quarries in the Chinle Formation (Heckert and Lucas, 2003). Since initial excavations by the UCMP in the 1930s, thousands of macro- and microvertebrates have been recovered representing over 80 taxa and constituting one of the best collections of Late Triassic vertebrates in the world (Fiorillo et al., 2000). Most prominent in this collection is the remains of approximately 40 individuals of the therapsid dicynodont *Placerias hesternus* (Camp and Welles, 1956).

Key References: Camp and Welles, 1956; Jacobs and Murry, 1980; Kaye and Padian, 1994; Long and Murry, 1995; Heckert and Lucas, 2003.

Stratigraphy: Since the outcrops in the area are poorly developed direct stratigraphic positioning of the quarry is problematic. Early workers placed the quarry low in the Blue Mesa Member (e. g., Camp and Welles, 1956; Jacobs and Murry, 1980), whereas Lucas et al. (1997) place it in the Mesa Redondo (=Bluewater Creek) Member. The lithology of the beds and the local presence of the Shinarump Member suggest that the quarry is situated stratigraphically low in the Chinle as advocated by Lucas et al. (1997). The Downs quarry (MNA 207N)

is located 30 meters east of the *Placerias* quarry at approximately the same stratigraphic horizon (Lucas et al., 1997).

Faunal List:

Chondrichthyes:	"*Xenacanthus*" *moorei*
	Lonchidion (=*Lissodus*) *humblei*
	Acrodus sp.
	Phoebodus sp.
Osteichthyes:	Osteichthyes indet.
	Redfieldiidae indet.
	Colobodontidae indet.
	Semionotidae indet.
	Palaeoniscidae indet.
	Arganodus sp.
	cf. *Australosomus* sp.
	Coelocanthidae indet.
Amphibia:	*Buettneria perfecta*
	Apachesaurus gregorii
Parareptilia:	Procolophonidae indet.
Eureptilia:	cf. *Uatchitodon* sp.
Lepidosauria:	Sphenodontidae indet.
Archosauromorpha:	*Trilophosaurus jacobsi* (holotype)
	Trilophosaurus sp.
Prolacertaformes:	*Tanytrachelos* sp.
Archosauria:	*Tecovasaurus murryi*
Phytosauridae:	*Paleorhinus* sp.
	Leptosuchus sp.
Stagonolepididae:	*Stagonolepis wellesi*
	Desmatosuchus haplocerus
	Acaenasuchus geoffreyi
	Paratypothorax-like form
Rauisuchidae:	*Postosuchus kirkpatricki*
Poposauridae:	*Poposaurus gracilis*
	Chatterjeea elegans
Crocodylomorpha:	*Hesperosuchus agilis*
	Parrishia mccreai (holotype)
Dinosauromorpha:	Indeterminate form
Dinosauria:	*Camposaurus arizonensis* (holotype)
Synapsida:	*Placerias hesternus* (holotype of *P. gigas*)
	?Cynodontia indet.

Discussion: The fauna of the *Placerias* and Downs quarries has been well documented including the dicynodonts (Camp and Welles, 1956), the microfauna (Kaye and Padian, 1994), the pseudosuchians (Long and Murry, 1995), and the dinosaurs (Hunt et al., 1998). Camp and Welles (1956) described the *Placerias* quarry dicynodont as a new species *Placerias gigas*, distinct from *P. hesternus*, which had been described by Lucas (1904) on the basis of an isolated humerus from the Ward bonebed near Cameron. Camp and Welles diagnosed *D. gigas* as possessing a humerus that is more massive and with broader distal condyles than that of *P. hesternus*. However, these same authors (p. 289) admit that the latter difference could be caused by crushing in the holotype humerus. Therefore, the only difference between *P. gigas* and *P. hesternus* is the robustness of the humerus, which probably does not warrant specific differentiation (Long and Murry, 1995).

The *Placerias* quarry is also unique in regards to the presence of numerous cranial elements of suchian archosaurs, especially basicrania. Elsewhere in the Chinle Formation, these elements are rarely recovered. This presents a taphonomic quandary for Chinle workers since cranial material of the same taxa are routinely recovered in the correlative Dockum Group in Texas.

Although Camp and Welles (1956) and Fiorillo et al. (2000) state that association of material from the quarry is extremely rare this has not been conclusively demonstrated. A quick purview of the *Placerias* quarry collection by the author has suggested that more associated material may be present than previously believed. For example, the *Poposaurus* pelvic material figured by Long and Murry (1995) includes left and right ilia, ischia, pubes, and a series of sacral vertebrae with ribs that can be demonstrated to belong to the same animal. Whereas all of these specimens have different catalog numbers, original field numbers on the bones show that they originated from the same 12 square meter area in the quarry. In addition, the specimens are of the same size, preservation, and fit together precisely.

The quarry contains the highest stratigraphic and only occurrence of the phytosaur *Paleorhinus* in Arizona (Long and Murry, 1995). Although consisting solely of a rostral fragment, this specimen clearly possesses external nares that are far anterior of the antorbital fenestra, an autopomorphy of that genus (Ballew, 1989). This supposedly high occurrence of *Paleorhinus* was challenged by Padian (1994), who suggested that this specimen may represent an ontogenetic growth stage in a more derived phytosaur, however Lucas et al. (1997) countered that based on size and characteristics of the nares the specimen does not represent a juvenile. Despite the fact that *Paleorhinus* and *Leptosuchus* are considered index taxa of two distinct biochrons (Otischalkian and Adamanian) by Lucas et al. (1997), these authors argue that the presence of *Paleorhinus* in the base of the Adamanian, simply demonstrates that the *Placerias* quarry represents earliest Adamanian time. However, the recent discovery of *Paleorhinus* in the Norian Bull Canyon Formation (Revueltian) of Texas (Lehman and Chatterjee, 2005) negates the utility of *Paleorhinus* as an index taxon

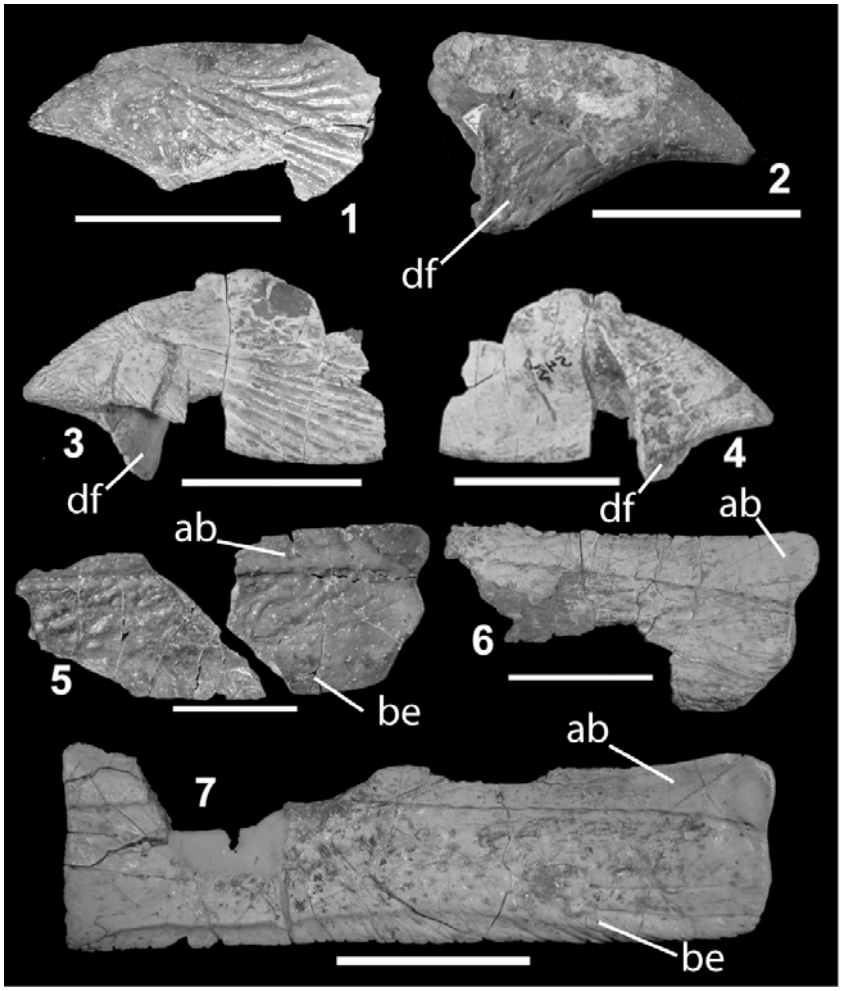

FIGURE 3. 1-7, lateral and paramedian plates of an undescribed *Paratypothorax*-like aetosaur from Arizona and Texas. 1, MNA V3202, right lateral plate in ventral view. 2, MNA V3202, right lateral plate in dorsal view. 3, TTUP 545, left lateral plate in dorsal view (reversed for comparison). 4, TTUP 545, left lateral plate in ventral view (reversed for comparison). 5, MNA V3202, partial right paramedian plate in dorsal view. 6, TTUP 545, partial right paramedian plate in dorsal view. 7, TTUP 545, right paramedian plate in dorsal view. Scale bars = 5 cm. Abbreviations: ab - anterior bar; be - beveled edge; df - dorsal flange.

for the Otischalkian and renders further explanations of this overlap unnecessary.

The *Placerias* quarry contains the highest concentration of aetosaur remains from the Chinle Formation including at least 14 individuals of *Desmatosuchus haplocerus*, a taxon that is rare elsewhere in the Chinle (Long and Ballew, 1985; Parker, 2003). The quarry also contains a large amount of armor of the aetosaur *Stagonolepis wellesi*. Long and Ballew differentiated "*Calyptosuchus*" (= *Stagonolepis*) *wellesi* from the type species *S. robertsoni* by several characters, most prominently the presence of small "spikes" on the lateral cervical osteoderms (plates). These authors (p. 47) specifically refer a specimen from the Downs quarry (MNA V3202) as representing "a series of paramedian and lateral plates from the cervical and anterior dorsal region of a single individual". However, investigation of MNA V3202 (Figure 3) reveals that the specimen consists of mostly fragmentary plates with a single paramedian fragment assignable to *Desmatosuchus* and the rest of the material assignable to an aetosaur that is unlike *Desmatosuchus* or *Stagonolepis*. The lateral plates (Figures 3.1-3.2) are very similar to those of *Paratypothorax* (Hunt and Lucas, 1992), and TTUP 545 (Figures 3.3-3.4) while a partial paramedian plate (Figure 3.5) appears to possess a high width to length ratio, another character of *Paratypothorax*. However, the strongly beveled posterior margin of the plate differ from *Paratypothorax*, while closely resembling TTUP 545 (Figures 3.6-3.7), which is currently being described as a new taxon by Martz and Small (in press). This new taxon is a sister taxon to *Paratypothorax* (Parker, 2003) and possesses lateral

plates identical to those of MNA V3202. Thus, *S. wellesi* did not possess spikes on the cervical lateral plates (Heckert and Lucas, 1999; *contra* Long and Murry, 1995**).**

The presence of at least a third aetosaur taxon in the *Placerias* quarry calls into question the taxonomic assignments made by Long and Murry (1995) regarding the aetosaur cranial and postcranial from the quarry. As mentioned previously the association of material in the quarry has not been fully determined and the criteria used by Long and Murry (1995) to assign much of the material to either *Desmatosuchus* or *Stagonolepis* are unknown. Inspection of the collection demonstrates discrepancies in material assigned to specific genera (e. g., *Desmatosuchus* braincases) and therefore the assignments provided by these authors should be considered tenuous. Unfortunately, these specimens are often used for comparative studies (e. g., Small, 2002; Heckert et al, 2003) and the degree of confusion currently being introduced into the literature is presently unknown. Nonetheless, a reinvestigation of the quarry excavation such as the one conducted by Martz (2002) for the Late Triassic Canjilon quarry may provide more resolution in associating non-diagnostic crania and postcrania with diagnostic osteoderms. The promise of this method has already been demonstrated by the example of the *Poposaurus* pelvis discussed earlier.

Long and Murry (1995) assigned a series of "sphenosuchian" vertebrae from the *Placerias* quarry to a new taxon, "*Parrishia mccrea",* which they differentiated from *Hesperosuchus* by the presence of cervical centra with no ventrodorsal offset of the articular faces. New material similar to this taxon from Petrified Forest National Park demonstrates that the anteriormost cervical vertebrae did possess this offset. Thus, no characters currently exist to discriminate "*Parrishia*" from *Hesperosuchus* and therefore specimens assigned to "*Parrishia"* most likely only represent larger specimens of *Hesperosuchus*.

Long and Murry (1995) list the putative herrerasaurid *Chindesaurus bryansmalli* as being present in the *Placerias* quarry based on isolated vertebrae, however Hunt et al. (1998) argued that although these vertebrae are "herrerasaurid" they are not referable to *Chindesaurus*. All of these authors note the presence of a coelophysoid dinosaur material, which Hunt et al. (1998) designated as the holotype of "*Camposaurus arizonensis*". Right and left astragali, each fused with the respective calcaneum, tibia, and fibula do appear to be dinosaurian in nature; however the single autapomorphy used to diagnose this genus is equivocal, falling within the range of variation in *Coelophysis* (Downs, 2000) and the material simply represents the non-diagnostic remains of a primitive dinosaur. Therefore, "*Camposaurus arizonensis*" is a *nomen dubium* as advocated by Heckert (2001). Isolated teeth referred to as "fabrosaurid" and "anchisaurid" by Long and Murry (1995) most likely belong to pseudosuchian archosaurs akin to *Revueltosaurus callenderi* (Kaye and Padian, 1994; Parker et al., 2005). The occurrence of a pterosaur (Long and Murry, 1995) from the quarry has never been substantiated.

B) Blue Hills/St. Johns (Figure 1)

Numerous collections have been made in Chinle Formation exposures around the town of St. Johns, initially by Camp in the 1930s and most recently by the New Mexico Museum of Natural History and Science. All localities from the Blue Mesa Member (*sensu* Woody, 2003; = lower Petrified Forest Member) near St. Johns will be included here.

Key References: Camp, 1930; Long and Murry, 1995; Heckert, 2004.

Stratigraphy: In the area of St. Johns, the Blue Mesa Member is never more than 30 meters in thickness and conformably overlies the Mesa Redondo Member (Heckert et al, 2003). The Sonsela Member is present north of St. Johns with the contact between it and the underlying Blue Mesa Member being erosional (Heckert et al., 2003; Heckert, 2004). According to these authors the majority of the Blue Mesa Member localities are near the base of the unit, including the Krzyzanowski bonebed (NMMNH locality 3764).

Faunal List:

Osteichthyes:	Actinopterygii indet.
	Arganodus sp.
Amphibia:	*Buettneria perfecta*
Archosauromorpha:	Indeterminate forms
Archosauriformes:	Indeterminate forms
Pseudosuchia:	*Revueltosaurus hunti*
Stagonolepididae:	*Stagonolepis wellesi*
	Desmatosuchus haplocerus
	Acaenasuchus geoffreyi (holotype)
Phytosauridae:	*Leptosuchus adamanensis*
	(*M. zunii* holotype)
Rauisuchidae:	*Postosuchus kirkpatricki*
Poposauridae:	*Poposaurus gracilis*
Crocodylomorpha:	*"Parrishia mccreai"*
Dinosauria:	Indeterminate forms?
Synapsida:	*Placerias hesternus*

Discussion: Camp (1930) described a partial phytosaur skull and skeleton (UCMP 27036) from UCMP locality 7307 in the "Blue Hills" northeast of St. Johns, as a new species "*Machaeoroprosopus*" *zunii*. Long and Murry (1995) later synonymized this taxon with *Leptosuchus adamanensis*. This locality (UCMP 7307) provided a wealth of material

including much of the first microvertebrate material noted from the Chinle Formation. Included in this sample are diminutive aetosaur plates, which Long and Murry (1995) described as the holotype of the aetosaur *Acaenasuchus geoffreyi*; isolated "ornithischian" teeth, which Heckert (2002) referred to *Revueltosaurus hunti*; and many more elements that have not been studied in detail.

Heckert and Lucas (1999; 2002b) argued that *Acaenasuchus geoffreyi* is not a valid taxon and instead represents a juvenile form of *Desmatosuchus haplocerus*. Comparison of the type material of *Acaenasuchus* shows characters that are not present in *D. haplocerus* such as a well-developed anterior bar and a radial patterning of the pits on the dorsal paramedians. While the plates of *Acaenasuchus* bear superficial resemblances to those of *Desmatosuchus* (i.e., they have "spikes" on the lateral plates), direct comparisons of material from these two taxa show differences that cannot be resolved simply by ontogenetic change given our currently poor understanding of this process in aetosaurs. Until more complete material is recovered it is best to consider *Acaenasuchus* as a valid taxon. Histological work is currently in progress in an attempt to determine the ontogenetic stage of material referred to *Acaenasuchus* (R. Irmis, personal commun., 2004).

Heckert and Lucas (2002c) assigned other "aetosaur" plates from UCMP 7307 as juvenile specimens of *Stagonolepis wellesi*. These plates do appear aetosaur-like in their overall morphology, however the recent discovery of the postcrania of the pseudosuchian *Revueltosaurus callenderi* in PEFO has shown that this taxon possesses plates identical to those Heckert and Lucas attribute to *Stagonolepis* (Parker et al., 2005). Isolated teeth referred to *R. callenderi* from the same locality by Long and Murry (1995) have been demonstrated by Heckert (2002) to belong instead to another species, *R. hunti*. Recent investigation of the collection from UCMP 7307 has turned up a characteristic squamosal of *Revueltosaurus*. Thus, it appears these osteoderms belong to *Revueltosaurus* rather than an aetosaur and that *Revueltosaurus* is present in the Blue Mesa Member as well as the Petrified Forest Member. At this time *Revueltosaurus hunti* is tentatively considered to be a valid species based on the description of the teeth provided by Heckert (2002) even though the osteoderms and squamosal are identical to that of *R. callenderi.*

At a second site (UCMP 7308) approximately at the same horizon as 7307, Charles Camp collected a partial skeleton of the aetosaur *Stagonolepis wellesi*. Although incomplete, this specimen possesses plates that are extremely similar to the holotype skeleton from Texas. In addition, cervical centra are present that are keeled ventrally as in *S. robertsoni*, and a partial dentary is present representing the only known skull material of *S. wellesi*. Camp directly compared this specimen with the holotype of *S. robertsoni* during a visit to Scotland in 1936 (Camp, unpublished notes), noting the strong similarities.

A third site in the area (NMMNH locality 3764), the Krzyzanowski bonebed was discovered by NMMNH associate Stan Krzyzanowski in the early 1990s, providing a diverse microfauna (Heckert, 2004). This site is of significance as it provides what Krzyzanowski et al. (2004) call the "Rosetta Stone" for Chinle microvertebrate studies. Tooth types that are usually found isolated, occur at this site in whole or partial jaws providing more precise taxonomic and morphological information (Krzyzanowski et al., 2004).

Heckert (2004) describes, but does not figure, from this locality, a proximal tibia that bears a cnemial crest, assigning it to the Dinosauria based on this character. However basal ornithodirans such as *Silesaurus* also possess this character (Dzik, 2003). Heckert (2004) assigns hollow centra from the same site to indeterminate saurischian dinosaurs, however hollow centra with a gross morphology identical to those of theropod dinosaurs also occur in the poposaurids *Poposaurus* and *Chatterjeea* (Long and Murry, 1995). Thus, these specimens cannot be unequivocally assigned to the Dinosauria and instead represent indeterminate archosaurs.

From a fourth locality (NMMNH 3763), Heckert et al. (2002) assign a fragmentary "rauisuchian" maxilla to the South American genus *Saurosuchus* based on the ornamentation of the lateral surface of the bone. This would provide the first North American occurrence of *Saurosuchus* and strengthen hypothesized "Chinle-Ischigualasto correlations based on the shared presence" of specific taxa. However, a recent redescription of the North American genus *Postosuchus* (Weimbaum, 2004) shows that this character is also present in that taxon. Differences between this specimen and the holotype of *Saurosuchus* have also been pointed out by Langer (2005). Therefore, the maxillary fragment cannot be assigned with certainty to *Saurosuchus* and could equally pertain to *Postosuchus* or the unknown skull of *Poposaurus*.

C) Stinking Springs (Figure 1)

Chinle Formation exposures north of North Stinking Springs Mountain in Apache County were first examined by Charles Camp in 1924 who noted indeterminate phytosaur remains being present (Long and Murry, 1995; Polcyn et al., 2002). In the 1990s a crew from Southern Methodist University conducted a more intensive study of the area (Polcyn et al., 2002). These workers not only recovered phytosaur

remains but discovered a microvertebrate quarry (SMU locality 252) comparable to the *Placerias*/Downs quarries in diversity.

Key References: Polcyn et al. (2002)

Stratigraphy: From the description given by Polcyn et al. (2002) it appears that the Mesa Redondo, Blue Mesa, Sonsela, and Petrified Forest Members are present in the area of North Stinking Springs Mountain. The "Richey Tank" facies of these authors (p. 43) consists of "predominantly fluvial channel deposits and sandy mudstones" and effectively divide the Blue Mesa and Petrified Forest Members as does the Sonsela Member in Petrified Forest National Park and therefore most likely represents a coeval unit. SMU locality 252 is in the Blue Mesa Member approximately 10-20 meters above the contact with the underlying Mesa Redondo Member (Polcyn et al., 2002). The Richey Tank Site (SMU locality 254) produced a partial skull of *Pseudopalatus* sp. (SMU 74776) and several other unidentified fragmentary skulls (Polcyn et al., 2002). Since this locality is in the stratigraphically higher Sonsela Member, these fossils will not be included in the following faunal list, which will contain only taxa from the Blue Mesa Member (SMU localities 251-253, 255).

Faunal List:

Chondrichthyes:	"*Xenacanthus*" *moorei*
	Lonchidion (=*Lissodus*) *humblei*
Osteichthyes:	Redfieldiidae indet.
	Colobodontidae indet.
	Semionotidae indet.
	cf. *Turseodus* sp.
	Arganodus sp.
	cf. *Chinlea* sp.
Amphibia:	*Buettneria* sp.
	Apachesaurus sp.
	Indeterminate forms
Parareptilia:	Procolophonidae indet.
Lepidosauria:	Sphenodontidae indet.
Archosauromorpha:	*Trilophosaurus jacobsi*
	Vancleavea sp.
Archosauria:	*Revueltosaurus* sp.
	Indeterminate forms
Phytosauridae:	"*Smilosuchus*" sp.
	Leptosuchus sp.
Stagonolepididae:	*Stagonolepis wellesi*
	Acaenasuchus geoffreyi
Crocodylomorpha:	*Hesperosuchus agilis*
	cf. "*Parrishia mccreai*"
Dinosauromorpha:	Indeterminate form
Dinosauria:	?*Coelophysis* sp.
Synapsida:	?Cynodontia indet.

Discussion: This site is of importance due to its taxonomic diversity. Of interest are the osteoderms and other material of *Vancleavea* sp. (*sensu* Hunt et al., 2002), which has now been demonstrated to occur in numerous stratigraphic units and horizons across the southwestern U. S. suggesting these animals were a major part of most Late Triassic faunas. The same can be said for the teeth of the pseudosuchian *Revueltosaurus*. Polcyn et al. (2002) have tentatively assigned laterally compressed serrated teeth and isolated vertebrae to theropod dinosaurs but obviously these may also belong to poposaurids as admitted by these workers. Still, these authors note that several jaw fragments with teeth may actually pertain to coelophysoids. If these are truly referable to dinosaurs these would represent some of the earliest occurrence of saurischian dinosaurs in the Chinle Formation outside of the *Placerias* quarry. Polycyn et al. (2002) also note that tricuspid teeth, preliminarily referred to therapsid cynodonts, may actually pertain to pterosaurs. This would pertain to similar material from the *Placerias* quarry as well and would represent the first evidence of pterosaurs from the Chinle of Arizona. However, similar tricuspid teeth are known from basal archosauromorphs (Renesto and Dalla Vecchia, 2000).

D) Petrified Forest National Park (Figure 1)

The Chinle Formation is well exposed in Petrified Forest National Park and consists of five members, Mesa Redondo, Blue Mesa, Sonsela, Petrified Forest, and Owl Rock. Due to the accessibility of these exposures because of their inclusion in a National Park, they have almost been continuously prospected since 1905. Only the faunas for the Blue Mesa, Sonsela, and Petrified Forest Members will be listed as no fossils have ever been found in the limited outcrops of Mesa Redondo Member and no vertebrates have been recovered from Owl Rock exposures in the park.

Key References: Camp, 1930; Murry and Long, 1989; Murry, 1989; Long and Murry, 1995; Heckert, 2004; Parker and Irmis, 2005.

Stratigraphy: The Chinle Formation in Petrified Forest National Park is approximately 300 meters thick and consists mainly of what traditionally was called the upper and lower Petrified Forest Members, divided by the Sonsela Sandstone Bed (Stewart et al., 1972). Heckert and Lucas (2002a) and Woody (2003) independently determined that the lithological change that characterized the depositional event culminating in the deposit of the unit traditionally known as the Sonsela Sandstone Bed (Akers et al., 1969) forms a distinct unit. Furthermore, it was demonstrated that beds from both the upper and lower Petrified Forest Members were actually correlative. As a result the Petrified Forest Member

was restricted to only the upper beds (=Painted Desert Member of Lucas, 1993), the unit containing the traditional Sonsela Sandstone Bed is designated the Sonsela Member and the lower beds form a second new member, the Blue Mesa Member. Currently only the Petrified Forest and Blue Mesa Members can be easily identified outside of the park (e. g., Heckert et al., 2003), and future studies are needed to determine the extent of the Sonsela Member, particularly where it does not consist solely of the upper sandstone unit (the traditional Sonsela Sandstone Bed).

All three members contain laterally continuous sandstone marker beds that are extremely useful for correlation (Billingsley, 1985). Most of these informal units were given formal names by Heckert and Lucas (2002a) however since many of these beds do not extend beyond the park boundaries the use of formal names for these units is not favored as advocated by Woody (2003).

Faunal Lists:

Blue Mesa Member:

Chondrichthyes:	"*Xenacanthus*" *moorei*
	Lonchidion (=*Lissodus*) *humblei*
	Acrodus sp.
Osteichthyes:	Osteichthyes indet.
	Redfieldiidae indet.
	Colobodontidae indet.
	Semionotidae indet.
	cf. *Turseodus* sp.
	cf. *Lasalichthyes* sp.
	Arganodus sp.
	cf. *Chinlea* sp.
Amphibia:	*Buettneria perfecta*
	Apachesaurus gregorii
Eureptilia:	*Acallosuchus rectori* (holotype)
Archosauromorpha:	*Trilophosaurus buettneri*
	Vancleavea campi (holotype)
Archosauria:	*Crosbysaurus harrisae*
	Indeterminate forms
Phytosauridae:	*Leptosuchus adamanensis* (holotype)
Stagonolepididae:	*Stagonolepis wellesi*
	Desmatosuchus haplocerus
	Acaenasuchus geoffreyi
Rauisuchidae:	*Postosuchus kirkpatricki*
Crocodylomorpha:	cf. "*Parrishia mccreai"*
Dinosauria:	?Saurischia indet.
Synapsida:	*Placerias hesternus*

Discussion: The Blue Mesa fauna from Petrified Forest National Park is mostly known from the area of the Blue Forest, and from two quarries, PFV 122 (Dying Grounds) and PFV 124 (Crocodile Hill). The productive horizon for these sites, as well as the type locality of *L. adamanesis* is a highly fossiliferous greenish mudstone unit that is widely exposed in this area of the park. The "Dying Grounds" locality (Parker, 2002) is a small basin where the ground surface is literally covered with bone fragments, teeth, and coprolites. The microvertebrates of this locality have been documented by Murry and Long (1989) and Heckert (2004).

Crocodile Hill is the type locality of *Acallosuchus rectori*, an enigmatic "reptile" known only from skull fragments, with a fragmentary lower jaw that is covered with osteoderms (Long and Murry, 1995). When this specimen was originally collected by Charles Camp, he provisionally identified it as a "dinosaur" or "pterosaur" and provided a sketch in his field notes. Unfortunately, the specimen was damaged during collection and subsequent storage (Long and Murry, 1995) and does not resemble this sketch in its current condition.

PFV 124 may also be the type locality of *Vancleavea campi* (Long and Murry, 1995). This partial skeleton (PEFO 2427) consists entirely of postcranial fragments including vertebrae, limb fragments, and partial osteoderms. The material superficially resembles elements collected from the Petrified Forest Member of the park, as well as two articulated skeletons (GR 138) of an armored archosauromorph from the Whittaker Quarry at Ghost Ranch, New Mexico (Small and Downs, 2002). Hunt et al (2002) have assigned all of this material to *Vancleavea*, however if the new Petrified Forest Member material and the stratigraphically higher specimens from the Whittaker Quarry demonstrate morphological and therefore taxonomic differences, the holotype specimen from the Blue Mesa Member may prove to be a non-diagnostic member of this distinct archosauromorph group and *Vancleavea* would therefore be a nomen dubium.

Hunt et al. (1996) and Hunt and Wright (1999) state the presence of indeterminate theropod dinosaurs from PFV 122 and from PFV 211 (Dinosaur Ridge), which is stratigraphically located several meters above PFV 122. Purported theropod material includes vertebrae, limb and jaw fragments, however none of this material has ever been figured or described and its dinosaurian affinities cannot presently be substantiated given the numerous morphological similarities between basal dinosaurs and pseudosuchians such as *Chatterjeea* and *Revueltosaurus*.

Heckert (2004) assigns isolated teeth from the Dying Grounds to the ornithischian taxon *Crosbysaurus harrisae*, however whereas isolated teeth can diagnose taxa, these taxa cannot be referred to the Ornithischia with certainty (Parker et al., 2005). Therefore, *Crosbysaurus* represents an indeterminate archosaur.

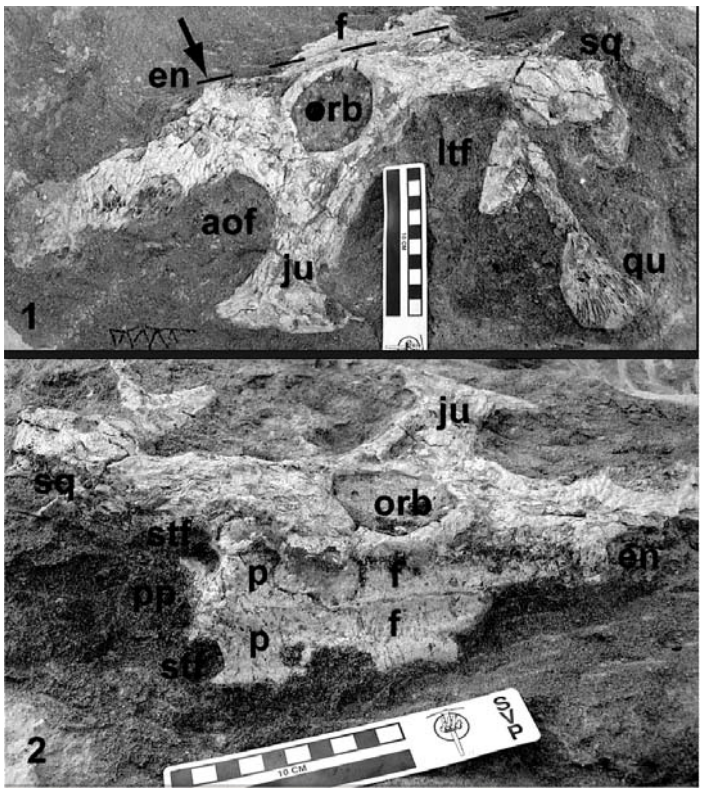

FIGURE 4. 1-2, *Pseudopalatus* sp. skull in situ. 1, skull in lateral view showing level of skull roof (dashed line) and dorsal projection of the nares (arrow). 2, skull in dorsal view. Scale bars are in centimeters. Abbreviations: aof – antorbital fenestra; en – external nares; f – frontal; ju – jugal; ltf – lower temporal fenestra; orb – orbit; p – parietal; pp – parietal process; sq – squamosal; stf – supratemporal fenestra.

Sonsela Member:

Chondrichthyes:	*Reticulodus synergus*
Osteichthyes:	Redfieldiidae indet.
	cf. *Turseodus* sp.
	Arganodus sp.
Amphibia:	*Buettneria perfecta*
Archosauromorpha:	*Trilophosaurus* sp.
	Vancleavea sp.
Phytosauridae:	*Leptosuchus adamanensis*
	Leptosuchus lithodendrorum (holotype)
	cf. *Leptosuchus* (=*Smilosuchus*) *gregorii*
	Pseudopalatus pristinus
	Pseudopalatus mccauleyi (holotype)
	Pseudopalatus sp.
Stagonolepididae:	*Stagonolepis wellesi*
	Stagonolepis sp.
	Desmatosuchus haplocerus
	Paratypothorax sp.
	Paratypothorax-like form
	Typothorax coccinarum
Rauisuchidae:	*Postosuchus kirkpatricki*

Discussion: The fauna of the Sonsela Member is newly recognized and includes taxa from localities that had previously been considered to be in either the Petrified Forest or Blue Mesa Members by Long and Murry (1995). The only body fossil documented from the traditional Sonsela Sandstone Bed in the park is a partial phytosaur skull described by Hunt et al (2002). This skull was discovered in 1993 by former park ranger Marten Schmitz in the bluffs above the Rainbow Forest. Encased in a large block of sandstone, the skull was then considered to be too difficult to extract and was studied in-situ. Hunt et al. (2002) differed significantly in their taxonomic assessment of this skull, with the senior author (Hunt) considering it to represent the first North American occurrence of *Nicrosaurus*, whereas the two junior authors (Andrew Heckert and Spencer Lucas) assigned to skull to *Pseudopalatus*. Subsequent in-situ preparation of the skull roof and later collection of the skull (PEFO 31218) by park staff, strongly suggests referral to *Pseudopalatus* (i. e., slit-like supratemporal fenestra; external nares craterlike and situated above the level of skull roof (Ballew, 1989)) although the squamosals and occiput are not yet

exposed to allow for a determination of species (Figures 4.1-4.2).

Reassignment of other strata to the expanded Sonsela Member (Heckert and Lucas, 2002; Woody, 2003) has greatly expanded our faunal knowledge of this unit and demonstrates that the fauna is transitional in nature between the underlying Blue Mesa Member and the overlying Petrified Forest Member (Woody and Parker, 2004). Therefore, the large hiatus and extinction event at the base of the traditional Sonsela Sandstone Bed advocated by Lucas (1993) and Heckert and Lucas (1996) cannot be substantiated lithologically or biochronologically. This lack of a substantial stratigraphic break is also supported by paleomagnetism (Steiner and Lucas, 2000:25803).

Lucas and Hunt (1993) designated formal biochronological units for the Late Triassic based on tetrapods, particularly aetosaurs and phytosaurs with *Stagonolepis* and *Leptosuchus* (=*Rutiodon*) being index taxa for the Adamanian (latest Carnian) and *Typothorax* and *Pseudopalatus* being index taxa for the Revueltian (early-middle Norian). Currently, the highest occurrence of *Stagonolepis* is at PFV 304 (Milkshake Quarry), which is situated approximately 4 or 5 meters above the Rainbow Forest Bed along old Highway 180. The lowest occurrence of *Typothorax* is from the Rainbow Forest Bed at PFV 121, just below Blue Mesa.

The highest occurrence of *Leptosuchus* is from the Rainbow Forest Bed at localities PFV 169 (*L. adamanensis*) and an upper tongue of the Rainbow Forest Bed at PFV 99 (cf. *L. gregorii*) in the Devils Playground. The holotype of *L.* "*lithodendrorum*" (= *L. crosbiensis*) is from PFV 97, 8 meters beneath PFV 99 in a lower tongue of the Rainbow Forest Bed. The lowest occurrence of *Pseudopalatus* is from PFV 295, a couple of meters above the Rainbow Forest Bed, near Mountain Lion Mesa.

Figure 5 provides stratigraphic ranges in PEFO of taxa mentioned in this section. These occurrences demonstrate that *Stagonolepis* and *Typothorax* overlap as do possibly *Pseudopalatus* and *Leptosuchus*. Although this overlap consists of only several meters, the use of these forms as index taxa for the Late Triassic needs to be reevaluated, especially in light of new findings from Texas (Lehman and Chatterjee, 2005; Langer, 2005).

It is important to note that all occurrences of *Paratypothorax* in the Chinle Formation of Arizona, for which locality information is available, occur in the Sonsela Member (*contra* Long and Murry, 1995) and therefore could represent an index taxon for this unit (Figure 5). A partial *Paratypothorax*-like plate figured by Heckert (1997:Fig. 3f) from the Mesa Redondo (=Bluewater Creek) Member in New Mexico probably pertains to the new taxon being described by Jeff Martz

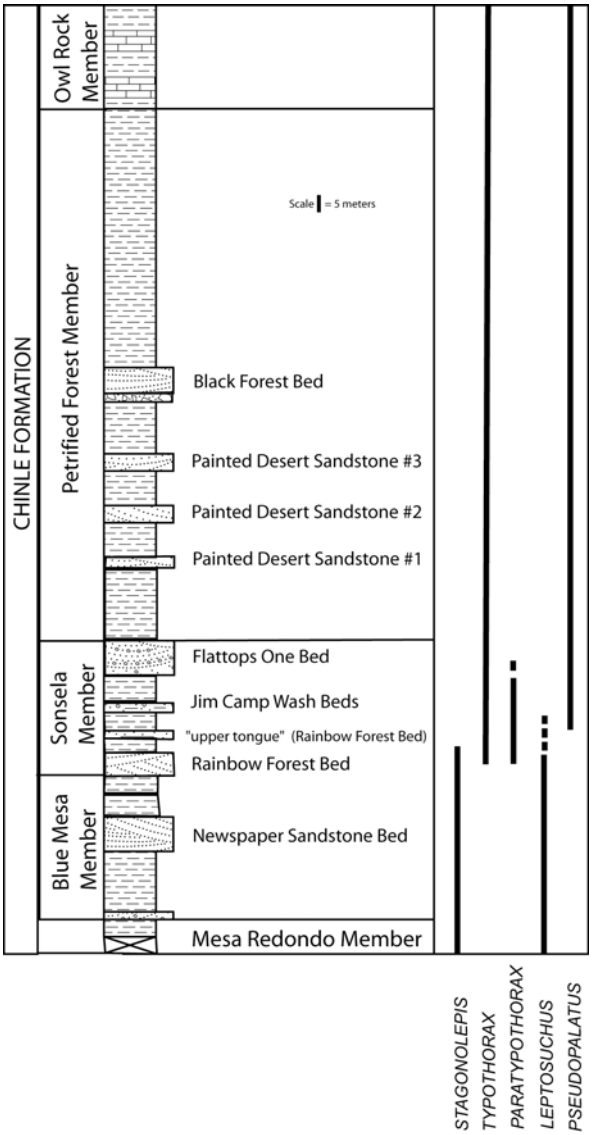

FIGURE 5. Composite stratigraphic section from Petrified Forest National Park showing ranges for taxa proposed as biostratigraphic index taxa. Modified from Lucas (1993).

and Bryan Small (see previous discussion for the *Placerias* Quarry) as it cannot be differentiated from TTUP 545.

Several pieces of jaw of *Trilophosaurus* sp. from locality PFV 191 (Flag Canyon) represent a new taxon being described by Bill Mueller from Texas Tech University. Numerous plates of a *Paratypothorax*-like aetosaur from various localities in the Sonsela Member represent a new taxon being described by the author and Randall Irmis. Reexamination of the holotype of *Pseudopalatus mccauleyi* along with the assignment of new material demonstrates that this is a valid species (Parker and Irmis, 2004; *contra* Long and Murry, 1995; Zeigler et

al, 2003). The *Stagonolepis* sp. specimen from the Milkshake Quarry (PFV 304) is represented by numerous plates with an interesting morphology that could differentiate it from known species of the genus.

Petrified Forest Member:

Chondrichthyes:	*Reticulodus synergus*
Osteichthyes:	Redfieldiidae indet.
	Colobodontidae indet.
	cf. *Lasalichthyes* sp.
	Arganodus sp.
	cf. *Chinlea* sp.
Tetrapoda:	*Kraterokheirodon colberti* (holotype)
Amphibia:	*Buettneria perfecta*
	Apachesaurus gregorii
Lepidosauria:	Sphenodontidae indet.
Archosauromorpha:	*Vancleavea* sp.
Pseudosuchia	*Revueltosaurus callenderi*
Phytosauridae:	*Leptosuchus adamanensis*
	Pseudopalatus pristinus
	Pseudopalatus mccauleyi
Stagonolepididae:	*Typothorax coccinarum*
	Desmatosuchus smalli
	"*Desmatosuchus*" *chamaensis*
Rauisuchidae:	*Postosuchus kirkpatricki*
Poposauridae:	*Chatterjeea elegans*
Crocodylomorpha:	*Hesperosuchus agilis*
Dinosauromorpha:	*Chindesaurus bryansmalli* (holotype)
Dinosauria:	*Coelophysis* sp.

Discussion: The fauna of the Petrified Forest Member is very similar to that of the Sonsela Member, with some "holdovers" from the Blue Mesa Member (*Buettneria perfecta*, *Apachesaurus gregorii*, *Hesperosuchus agilis*, and *Postosuchus kirkpatricki*). Future detailed studies of these taxa may prove specific separation, however these taxa are currently considered to simply possess long stratigraphic ranges. New additions to the fauna include the pseudosuchian *Revueltosaurus callenderi* (Hunt, 1989), which was previously thought to represent an ornithischian dinosaur (Parker et al., 2005); and *Chatterjeea elegans* (Long and Murry, 1995), a derived suchian with numerous character convergences with basal dinosaurs. This fauna also contains the first unequivocal dinosaur material from PEFO. Padian (1986) described a partial skeleton of a theropod dinosaur from the Dinosaur Hill locality (PFV 40). Padian tentatively assigned this specimen (UCMP 129618) to *Coelophysis bauri* and was the first to point out the undiagnostic properties of the holotype of *Coelophysis*. Besides several undescribed specimens noted by Hunt and Wright (1999), no further theropod material was collected from the park until 2004, when material from two partial skeletons was recovered from PFV 231 (The Giving Site). This material is still mostly unprepared although preliminary analysis shows that it is identical to UCMP 129618 (Parker and Irmis, 2005). PFV 231 represents one of the richest sites uncovered in the park to date providing new material of the following taxa; *Arganodus* sp., *Apachesaurus gregorii*, *Typothorax coccinarum*, *Chatterjeea* sp., *Chindesaurus bryansmalli*, *Coelophysis* sp., *Revueltosaurus callenderi*, *Vancleavea* sp., and a crocodylomorph (Stocker et al., 2004).

The holotype of *Chindesaurus bryansmalli* was collected from the Dinosaur Hollow locality (PFV 20) in 1985. Long and Murry (1995) referred an isolated pelvis from the Tecovas Formation of Texas to *C. bryansmalli* (followed by Langer (2004)). The iliac fragments from the holotype of *C. bryansmalli* bear only a superficial resemblance to the Tecovas ilium. Hunt et al. (1998) demonstrated important differences between the holotype and the referred ilium and erected a new taxon, *Caseosaurus crosbiensis* for the Tecovas ilium. Long and Murry (1995) tentatively refer *C. bryansmalli* to the Herrerasauridae, however the holotype again possesses only superficial resemblances to *Herrerasaurus* and until better pelvic and cranial material is recovered it is best to consider *Chindesaurus* a non-herrerasaurid basal saurischian (Langer, 2004).

In 1984, Lynette Gillette discovered a large isolated tooth from just northeast of the Dinosaur Hill quarry. This tooth is identical to one collected from the lower Chinle Formation near St. Johns in the late 1940s. Murry and Long (1989) and Long and Murry (1995) assigned these teeth to a traversodontid cynodont, however Irmis and Parker (2005) demonstrated that these similarities were superficial in nature and that these teeth belong to an unrecognized group of tetrapods and erected a new taxon, *Kraterokheirodon colberti*, for this material.

In 1962, Bill Breed collected MNA V697, a lateral plate of the aetosaur *Desmatosuchus*, from the Delaney Tank NE locality (PFV 294). This locality represents the highest occurrence of *Desmatosuchus* and the only co-occurrence of *Desmatosuchus* and *Typothorax* in Arizona. Long and Ballew (1985) figured and identified this plate as belonging to the cervical series, however closer examination has shown that this plate is broken, missing its lateral flange. Parker (2003) interpreted this plate as a dorsal lateral plate and demonstrated that it is identical to *Desmatosuchus* material from the Norian age Post quarry in Texas, in possessing an elongate dorsal eminence that is slightly recurved ventrally. This differs significantly from the lateral armor of *Desmatosuchus haplocerus* and both the Delaney Tank plate and the Post quarry material represent a new species of *Desmatosuchus* (Parker, 2005).

In 2003, an aetosaur plate with an elongate spine-like dorsal eminence was collected from PFV 75. This plate is referable to "*Desmatosuchus*" *chamaensis*, previously known only from the Petrified Forest Member of the Chama Basin in New Mexico (Zeigler et al., 2002). Parker (2003) demonstrated that "*D.*" *chamaensis* possesses few synapomorphies with *Desmatosuchus*, and instead represents a sister taxon of *Paratypothorax* and represents a distinct genus.

E) Joseph City/Winslow (Figure 1)

Extensive badlands of the Chinle Formation outcrop north and east of Winslow, including the "Little Petrified Forest" State Park and along the flanks of Marcou Mesa. Historically these exposures have been rarely prospected.

Key Reference: Long and Murry (1995)

Stratigraphy: The Shinarump and Cameron Members of the Chinle Formation are widely exposed around Winslow and north of Interstate 40. Farther north of the freeway, stratigraphically higher exposures are encountered including the Blue Mesa, Sonsela and Petrified Forest Members. To date, fossils have only been recovered from the Blue Mesa and Sonsela Members.

Faunal List:

Osteichthyes:	Osteichthyes indet.
	Arganodus sp.
Amphibia:	*Buettneria perfecta*
Archosauria:	indeterminant form
Phytosauridae:	*Leptosuchus* sp.
Stagonolepididae:	*Desmatosuchus haplocerus*
	Acaenasuchus geoffreyi
	Paratypothorax-like form

Discussion: In 1983 the UCMP briefly collected in the area of Rincon Basin, northeast of Winslow. Long and Murry (1995) list the presence of *Buettneria perfecta*, *Leptosuchus* sp., *Desmatosuchus haplocerus*, and *Acaenasuchus geoffreyi* but provide no specimen data. The occurrence of "fabrosaurid" teeth probably references an archosaur similar to *Revueltosaurus callenderi*. In 2003, Sterling Nesbitt recovered a small cervical paramedian plate of a *Paratypothorax*-like aetosaur from Sonsela Member outcrops north of Joseph City (S. Nesbitt, personal commun. 2003). The plate morphology is similar to that of a new taxon from Petrified Forest National Park.

A brief reconnaissance of a locality discovered by private individuals in exposures along Marcou Mesa by staff from the Museum of Northern Arizona, including the author, in 2002, revealed a vertebrate microsite that contained *Arganodus* sp. toothplates and numerous scales and teeth of indeterminate osteichthyans. None of this material was collected pending the determination of land ownership (private).

F) Nazlini (Figure 1)

The Chinle Formation is extensively exposed in the Defiance Uplift on the Arizona-New Mexico border (Figure 1). Exposures of the Blue Mesa Member near Nazlini on the Navajo Reservation were collected by Charles Camp and Samuel Welles of the UCMP in 1932 and 1956 (Long and Murry, 1995).

Key Reference: Long and Murry (1995); Camp (1932)

Stratigraphy: U. S. Route 191 climbs onto outcrops of the Owl Rock Formation before dropping down into the Chinle Valley. The Chinle Valley is broadly exposed to the east and a small road switches back down through exposures of the Owl Rock and Petrified Forest Members continuing onwards towards Nazlini. Vast exposures of the Sonsela and Blue Mesa Members are present in the valley.

Faunal List:

Amphibia:	*Buettneria perfecta*
Phytosauridae:	*Leptosuchus* sp.
	Leptosuchus gregorii
Stagonolepididae:	*Stagonolepis wellesi*

Discussion: Charles Camp, Samuel Welles, and a crew from the UCMP spent July 8-14, 1932 collecting vertebrate and plant material from the Chinle Formation in the Beautiful (Chinle) Valley near the Nazlini Trading Post (Camp, 1932). Material collected during this expedition includes UCMP 35738 and UCMP 36656, several plates of the aetosaur *Stagonolepis wellesi*, as well as two phytosaur skulls. UCMP 35740 is a partial skull of *Leptosuchus* sp., whereas UCMP 63921 is a large skull of *Leptosuchus gregorii*. Although Camp (1932) noted the presence of numerous other specimens in the field, most were apparently too badly weathered to collect.

G) Many Farms/Round Rock (Figure 1)

Exposures east of the town of Many Farms and south of a prominent geological feature known as Round Rock were prospected by the UCMP in 1927, 1932, 1938, and 1942 and by the MNA in the late 1990s (Long and Murry, 1995; Parker, 2003).

Key References: Camp, 1930; Long and Murry, 1995; Parker, 2003.

Stratigraphy: Chinle Formation exposures east of Many Farms and south of Round Rock are mainly those of the Blue Mesa Member capped in places by resistant sandstones of the Sonsela Member (Deacon, 1990). Farther to the north, the Petrified

Forest and Owl Rock Members are prominent; however no collections have been made from those units. At MNA locality 1476 (*Desmatosuchus* quarry) the Blue Mesa Member is approximately 35 meters thick and the overlying Sonsela Member has a thickness of 15 meters (Parker, 2003). The Sonsela Member in this area consists mainly of a ten meter thick trough cross-bedded sandstone with minor cobbles and petrified logs.

Faunal List:

Amphibia:	*Buettneria perfecta*
Phytosauridae:	*Leptosuchus adamanensis*
	Leptosuchus gregorii (holotype)
Stagonolepididae:	*Desmatosuchus haplocerus*

Discussion: In 1927, Charles Camp collected the holotype specimen of "*Machaeroprosopus*" (=*Leptosuchus*) *gregorii* approximately 10 miles southwest of the Round Rock Trading Post (Camp, 1930). In 1997, staff from the Museum of Northern Arizona collected a mostly complete skeleton of the aetosaur *Desmatosuchus haplocerus* a few kilometers to the west of Camp's 1927 locality. This specimen is the most complete *Desmatosuchus* specimen from the Chinle Formation and has provided important information regarding the dermal armor, vertebrae, and pelvis of this taxon (Parker, 2001; 2003). A few years previously, the MNA collected a skull of *Buettneria perfecta* from this area; however this specimen has never been fully prepared or described.

H) St. Michaels/Allentown/Lupton (Figure 1)

Although Charles Camp briefly visited this area in 1924, the majority of the collections from this area are located at the MNA (Long and Murry, 1995).

Key References: Long and Murry, 1995; Brady, 1954; Brady, 1958.

Stratigraphy: All of the collections in this area are probably from the Blue Mesa Member of the Chinle Formation; however it is possible that they derive from a lower member such as the Mesa Redondo.

Faunal List:

Amphibia:	*Buettneria perfecta*
Phytosauridae:	*Leptosuchus* sp.
Stagonolepididae:	*Stagonolepis wellesi*
	Desmatosuchus haplocerus
Poposauridae	*Poposaurus gracilis*

Discussion: In 1954, Lionel (Major) Brady of the Museum of Northern Arizona described a cervical spike from the aetosaur *Desmatosuchus* that had been collected from near Lupton providing the first documentation of this taxon in the Chinle Formation (Brady, 1954). Four years later, Brady (1958) described more cervical armor of *Desmatosuchus* from St. Michaels. The University of Arizona collections contains a paramedian plate of the aetosaur *Stagonolepis wellesi* and a proximal ischium of *Poposaurus gracilis*, collected approximately 3 kilometers south of St. Michaels in 1952 (Long and Murry, 1995).

I) Cameron/Ward Bone Bed

In 1899, paleobotanist Lester Ward made the first collections of vertebrate material from the Chinle Formation just east of Cameron. This site, known as the Ward Bone Bed, was excavated several times, most prominently by the American Museum of Natural History in 1929, 1930, and 1936; as well as the UCMP in 1933, 1941, and 1981.

Key References: Lucas, 1904; Camp and Welles, 1956; Colbert, 1947; Colbert, 1952; Welles, 1972; Long and Murry, 1995.

Stratigraphy: Camp and Welles (1956) provided a stratigraphic schematic for the Ward Bone Bed. They placed the main locality in a gray shale approximately 22 meters above the top of the Shinarump Member. Furthermore, these authors estimated that the type of *Placerias hesternus* came from a bed approximately 15 meters above the main locality. Although Lucas (1993) provides a section for this area, he does not measure from the top of the Moenkopi Formation therefore it is difficult to correlate his section with that of Camp and Welles (1956). Nonetheless, the combined data of Lucas (1993) and Camp and Welles (1956) suggest that the Ward Bone Bed is either in the upper portion of the Cameron Member or the lower portion of the Blue Mesa Member. Kirby (1989) considered the "Shinarump Conglomerate" of Camp and Welles (1956) to contain both the Shinarump and Cameron Members. Thus, according to Kirby (1989) the main bone bed is in the Blue Mesa Member approximately 12 meters above its base.

Camp and Welles (1956) were not able to accurately place the type locality of *Machaeroprosopus validus* (Mehl, 1922) in their section; however they felt that it probably was situated approximately 130 meters above the top of the Moenkopi Formation. This would place it in the Petrified Forest Member.

Faunal List:

Amphibia:	*Buettneria perfecta* (holotype of "*Metoposaurus fraasi"*)
	Apachesaurus gregorii
Phytosauridae:	"*Smilosuchus" gregorii*
	Machaeroprosopus validus (Holotype- from 70 m above main locality)

Stagonolepididae:	*Stagonolepis wellesi*
	Desmatosuchus haplocerus
Rauisuchidae	*Postosuchus kirkpatricki*
Crocodylomorpha	*Hesperosuchus agilis* (Holotype)
Synapsida	*Placerias hesternus* (Holotype)

Discussion: The Ward Bone Bed is a significant site in the Chinle Formation because out of nine taxa noted from this area, four are holotype specimens. Obviously, this is a result of the site being one of the first discovered in the Chinle; however this does not diminish the locality's importance. In 1936 Barnum Brown and Roland Bird excavated the skull and partial skeleton of a large phytosaur. This specimen (AMNH 3060) was assigned by Colbert (1947) to "*Machaeroprosopus*" (=*Leptosuchus*) *gregorii* and represents one of the finest and most complete phytosaur specimens recovered from the Chinle. The holotype of ***M. validus*** is unfortunately lost, but Mehl's (1922) description strongly suggests that is represents a pseudopalatine-grade phytosaur.

UCMP 36718 is the pelvis and several vertebrae of the "rauisuchian" *Postosuchus*. This represents the westernmost occurrence of this taxon (Long and Murry, 1995).

J) Ward Terrace (Figure 1)

Outcrops of the Owl Rock Member at Ward Terrace, east of Cameron were collected by staff from the MNA in the 1970s and late 1980s. Much of the information regarding these collections is from unpublished and published work of Randy Kirby (1989; 1991).

Key References: Kirby, 1989; Kirby, 1991; Long and Murry, 1995; Murry and Kirby, 2002.

Stratigraphy: According to Kirby (1991) all but one of the MNA Owl Rock Member localities at Ward Terrace occur in the upper 24 meters of the member between what Kirby terms the "third and fourth ledges" and within 4 to 22 meters of the overlying Rock Point Member. One locality (MNA 526 – Badger Wash) is tentively placed several meters lower at the level of the "second ledge". The boundary between the Petrified Forest and Owl Rock Members is placed at the "first ledge" (i. e., the first prominent limestone horizon).

Faunal List:

Chondrichthyes:	*Reticulodus synergus* (Holotype)
Osteichtheyes:	Redfieldiidae indet.
	Colobodontidae indet.
	Turseodus cf. *dolorensis*
	Semionotus sp.
	Chinlea ?*sorensoni*
Amphibia:	cf. *Buettneria* sp.
	Apachesaurus gregorii
Lepidosauria:	Sphenodontidae indet.
Archosauromorpha:	*Trilophosaurus* cf. *buettneri*
Archosauria:	Indeterminate forms
Phytosauridae:	*Pseudopalatus pristinus*
	Pseudopalatus buceros
Stagonolepididae:	*Typothorax coccinarum*
Rauisuchidae:	*Postosuchus kirkpatricki*
Poposauridae:	*Chatterjeea elegans*

Discussion: Long and Murry (1995) list the presence of *Paratypothorax* sp. from the Owl Rock Member based on fragmentary dorsal eminences from paramedian plates. Since many aetosaurs possess such eminences, including posterior dorsal and caudal paramedian plates of *Typothorax*, the presence of *Paratypothorax* in the Owl Rock Member cannot be substantiated.

SUMMARY

With the exception of collections made from the Petrified Forest Member in Petrified Forest National Park and the Owl Rock Member at Ward Terrace, the majority of collected material from the Chinle Formation of Arizona is from the lower Chinle (Sonsela, Blue Mesa, and Mesa Redondo Members). These collections from the lower Chinle sample several facies from semi-aquatic (Crocodile Hill, Dying Grounds, Blue Hills) to terrestrial (*Placerias* Quarry). Predominant forms in the semi-aquatic facies include metoposaurs and phytosaurs, while the more terrestrial faunas include a higher proportion of aetosaurs, crocodylomorphs, synapsids, and the earliest dinosaurs. Microvertebrates are well represented from numerous sites including the *Placerias* Quarry, Stinking Springs, and the Dying Grounds. Crocodile-line archosaurs are predominant in all of the faunas from the Chinle Formation. Curiously, only four sites in Arizona (*Placerias* Quarry, Dinosaur Hill (PFV 40), Jeremiah' Perch (PFV 278), Giving Site (PFV 231)) contain unambiguous dinosaur material (*contra* Hunt and Wright, 1999). Although undescribed material mentioned by Hunt and Wright (1999) from at least two other sites in PEFO may possibly pertain to dinosaurs, dinosaurs are not as diverse in the park as postulated by these authors.

FUTURE STUDIES

Obviously our knowledge of the faunal content of the Chinle Formation of Arizona would greatly benefit by increased fieldwork. Currently only the areas near St. Johns, Petrified Forest National Park, and Cameron are being routinely surveyed for fossils. The future expansion of Petrified Forest National Park will allow for better access to numerous Chinle

Formation exposures that have been off-limits to researchers. Historic and preliminary work in the Defiance Uplift and north of Joseph City near Marcou Mesa demonstrates a high potential for good fossils in these areas.

The faunas from the upper units of the Chinle, the Petrified Forest Member and the Owl Rock are badly underrepresented with the Owl Rock fauna being described only in a very preliminary paper and an unpublished thesis (Kirby, 1989; 1991). Investigation of Chinle outcrops north of the Little Colorado River between Winslow and Cameron is badly needed.

ACKNOWLEDGMENTS

Thanks to Bob McCord and the staff of the Mesa Southwest Museum for extending the invitation to contribute to this volume. Thanks to the staff of Petrified Forest National Park, especially Karen Dorn, Lee Baiza, and Scott Williams for support and assistance of the paleontology program in the park. Fossil collection and site inventories have been conducted by Randall Irmis, Daniel Woody, Sue Clements, Michelle Stocker, Sterling Nesbitt, Jeff Martz, Lori Browne, Trent Hall, Jeff Shuman, Pete Reser, Andy Heckert, Barry Albright, Yasemin Tulu, Katie Brakora, Bronson Barton, and Scott Rogers. Suggestions by Randall Irmis and two anonymous reviewers improved the manuscript. Summer interns receive financial support from the Petrified Forest Museum Association and the GSA GeoCorps America program. This project is funded by the Recreation Fee Demo Program of the National Park Service. This is PEFO Paleontological Contribution number 7.

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