

A Nonmarine Standard for Part of Late Triassic Time

By Spencer G. Lucas

A local sequence of layered rocks (strata) and the geologic events it documents as well as the fossils it contains can represent an interval of geologic time: this concept is an old one in the science of geology. Indeed, well exposed and fossil laden rock sequences provide standards by which geologists order and interpret the major events of Earth history. Most such standards are in rocks that were deposited originally in the sea, since these rocks readily document geological and biological events that can be traced across the broad expanses of ocean basins and their shallow embayments and supra-continental seaways.

However, during the Triassic Period, 250 to 208 million years ago, all Earth's continents existed as one supercontinent (Pangaea) surrounded by a single "superocean" (Panthalassa). On that world map, not just rock sequences deposited in the ocean but also those deposited on land (nonmarine rock sequences) have a high potential for recording widespread events.

One such high potential nonmarine sequence of rocks is exposed in the badlands of the Petrified Forest National Park in Arizona. Here, an approximately 382 m (1,164 ft) thick sequence of Upper Triassic rocks is exposed over most the 37,864 ha (93,492 acres) of the park (Billingsley 1985). These rocks (Fig. 1) were deposited by rivers – in their channels and on their floodplains – and by lakes. Geologists term them the Chinle Group (or Formation), a sequence of nonmarine strata of Late Triassic age that was deposited in a vast basin extending from at least Wyoming to Texas, north-south, and from western Oklahoma to southeastern Nevada, east-west – an area of about 2.3 million km² (0.9 million square miles) (Lucas 1992).

Geological Events

The approximately 382 m (1,164 ft) of Upper Triassic strata exposed in Petrified Forest NP record a complex history of changing environments over a period of about 9 million years. Although the broad outlines of this history are understood, much detail remains to be elucidated.

Sediments accumulated in this area under a monsoonal climate of marked wet-dry seasonality at a latitude of about 5 degrees north of the equator (Dubiel et al. 1991). The oldest sediments exposed in the park, those of the Blue Mesa Member of the Petrified Forest Formation, are river-floodplain sediments riddled with ancient soil profiles. A break in the sedimentary record (unconformity) separates the Blue Mesa Member from the overlying Sonsela Member.

Sonsela river channels were larger and carried heavier bedloads than either earlier or later Late Triassic river channels preserved in the park. The Sonsela Member rivers flowed to the north and the northeast during a time of increased stream gradients in highlands well to the south of the park. This also was a time of lower gradients in the park and that facilitated the deposition of a laterally extensive sheet of sandstone and conglomerate that is about 9 to 13 m (30-40 ft) thick (Deacon 1990).

Overlying sediments of the Painted Desert Member represent river floodplain, channel and pond

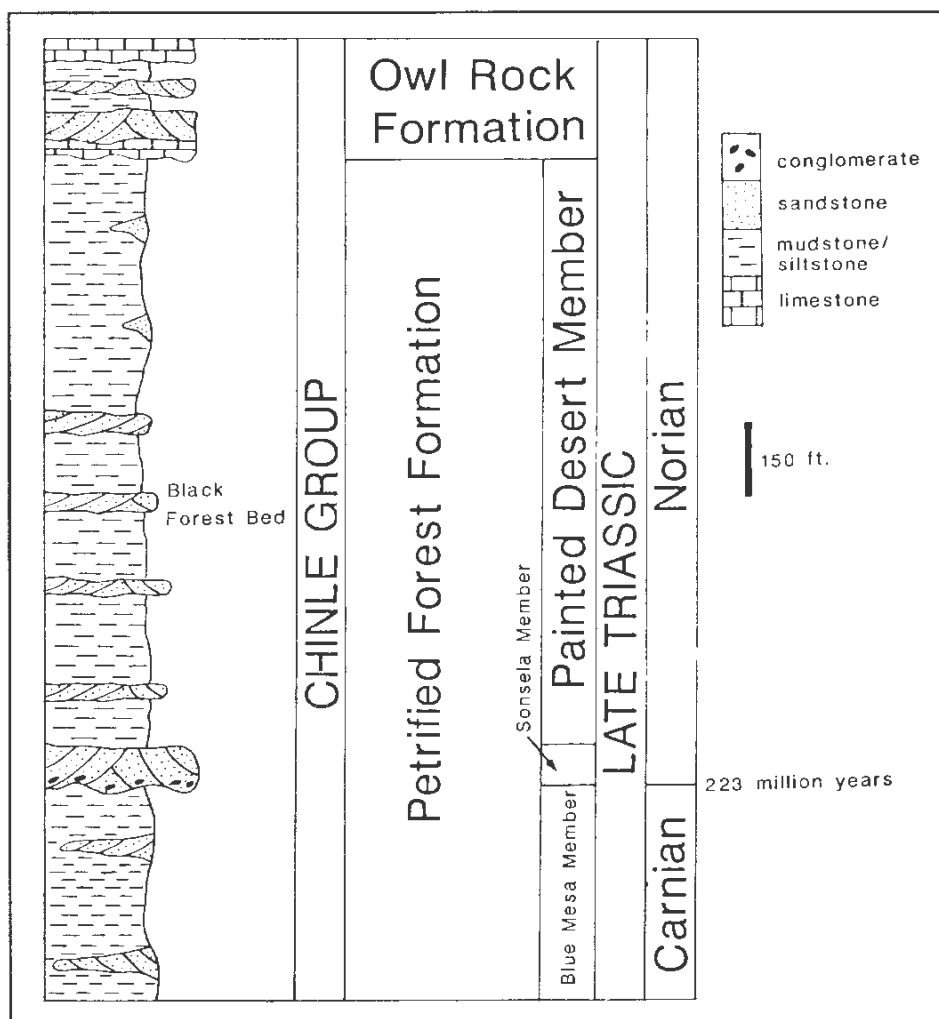


Figure 1. Upper Triassic rock types, stratigraphic units and their age in the Petrified Forest National Park.

deposits. One highly distinctive river-channel complex – the Black Forest Bed – consists of reworked volcanic ash much older than the sediments that encase it. The source of this ash still is uncertain (Ash 1992). Large channel and sheetflood sandstones of the Painted Desert Member imply lower subsidence rates than during deposition of the Blue Mesa Member.

The youngest Upper Triassic strata exposed in the park is the Owl Rock Formation. Its limestones have been interpreted as lacustrine, but many are actually pedogenic calcretes (soil caliches). The Owl Rock Formation reflects a period of greater landscape stability and lower sedimentation rates than prevailed during deposition of the underlying Upper Triassic strata exposed in the park.

Biological Events

Fossils found in Petrified Forest NP are of plants and of invertebrate and vertebrate animals. The most famous plant fossils are *Araucarioxylon*, a type of fossil conifer wood, the state fossil of Arizona. It and the wood of two other extinct conifers, *Woodworthia* and *Schilderia*, form the extensive fields of petrified logs and stumps from which the

park takes its name. Fossil leaves found in the park are principally of ferns, conifers, and cycadeoids. They indicate moist, humid climates in the vicinity of the river channels and the pond margins where most of these fossils were preserved. Fossil pollen and spores (palynomorphs) are common in Upper Triassic strata in the park and are an important means by which their age is established (Litwin et al. 1991).

The most common invertebrate fossils in the park are of freshwater clams, the unionids, a group still extant. Their shells form extensive beds, some of which are well preserved, others of which are fragmented, having been transported prior to burial, and still others of which are oncholithic (algal encrusted). Growth bands preserved in the unionids' shells and in the shells of associated freshwater gastropods support the idea of a markedly seasonal climate. Other invertebrate fossils include ostracodes (seed shrimp) and charophytes (calcareous egg cases of algae) in some layers in the Upper Triassic rock sequence that were deposited by permanent lakes 6 to 8 m (18-24 ft) deep. Still other Late Triassic

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invertebrates preserved in the park – conchostracans (clam shrimp), insects, and crayfish – either are not common enough or not well enough studied to permit many conclusions at present.

The most extensive fossil record from the park is of vertebrates. The fishes are mostly lungfishes, best known from their isolated toothplates, but small freshwater sharks and primitive bony fishes also are well represented as fossils.

The park's commonest vertebrate fossils are of phytosaurs, aetosaurs, and metoposaurs. The metoposaurs were a Late Triassic group of large (up to 2 m long) amphibians. The Blue Mesa Member metoposaurs are mostly large (*Beuttneria*), whereas the Painted Desert metoposaurs are mostly small (*Apachesaurus*). The phytosaurs, a group of crocodile-like reptiles of the Late Triassic, show a similar disjunct distribution, with phytosaurs below the Sonsela Member (*Rutiodon*) different from those above it (*Pseudopalatus*). Aetosaurs, large armored plant-eating reptiles, show a similar distribution – *Stagonolepis* and *Desmatosuchus* the dominant aetosaurs below the Sonsela, *Typhorax* the dominant aetosaur above it (Hunt and Lucas 1990). Other vertebrates known from fossils found in or just outside the park include the cow-sized mammal-like reptile *Placerias*, lizard-like trilophosaurs, and the raiusuchians, which include the ferocious meat-eater, *Postosuchus*. Some of North America's oldest dinosaurs are found in the park; they are only a million or so years younger than the oldest North American dinosaurs, which are from the Chinle Group near St. Johns, Arizona and near Big Springs in West Texas (Lucas et al. 1992).

The fossil vertebrates found in the park can be segregated into two "faunas," a lower fauna in the Blue Mesa Member and an upper fauna in the Painted Desert Member (Lucas 1990, 1992; Murry 1990). The fact that few vertebrates cross from one fauna to the other represents a reorganization (evolutionary turnover) of the vertebrates that suggests some time is missing between the two faunas, but causes of the reorganization remain unknown.

A Nonmarine Standard

For Late Triassic nonmarine environments, the 100 percent rock exposure over a large area, the extent and duration of collecting and research, and the prolific fossil record of the Petrified Forest NP are unparalleled. Therefore, as a key to ordering and interpreting an interval of Late Triassic geologi-

cal and biological events on land, the sequence in the park should provide a global standard for geologists and paleontologists. This standard, for example, documents a complex evolutionary turnover of terrestrial vertebrates about 223 million years ago, at about the junction of the Carnian and Norian stages of the geologic timescale. This turnover is not the mass extinction identified by some authors (e.g. Benton 1991) but a more subtle replacement that took place over the course of millions of years.

We are fortunate that so excellent a standard for part of Late Triassic time is preserved in one of our national parks. Management of the park's rocks and fossils has not only conserved these resources but for many years has provided vigorous support, both logistically and materially, to the scientific study of park geology and paleontology. This management and the scientific study it promotes have established the Petrified Forest NP as a vital geological and paleontological standard that for years to come will continue to enhance understanding of the Late Triassic world.

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