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The palynology of the Sonsela member (Late Triassic, Norian) at Petrified Forest National Park, Arizona, USA

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ABSTRACT

Recent paleontological investigations and lithostratigraphic revisions reveal a marked biotic turnover zone within the continental deposits of the Sonsela member of the Chinle Formation (Late Triassic, Norian) at Petrified Forest National Park, USA.

Within the Sonsela member we found three pollen assemblage biozones: Zone II (90.5–94 m above the Mesa Redondo member) contains a relatively diverse palynological assemblage, with a mix of pteridosperms, voltzialean and some Mesozoic conifers. Following a 2.3 m hiatus, Zone IIIa (96–97.5 m) is characterized by a decrease in pteridosperms and Mesozoic conifers and a drop in voltzialean conifer diversity. The alleged voltzialean conifer pollen *Klausipollenites gouldii* was dominant in this part of the assemblage and a significant rise in spores and cycad pollen was also evident. In Zone IIIb (97.5–98.5 m) diversity increases and several taxa, which were absent in Zone IIIa reappear, although *K. gouldii* remained the most abundant taxon. The transition between the palynological assemblages Zones II and IIIa coincide approximately (within a ~2.5 m interval) with a documented faunal turnover.

The floristic assemblages suggest that the climate of the south-western United States during the Norian was most likely semi-arid and highly seasonal, despite being located at tropical latitudes, with aridification occurring towards the end-Triassic as the continent drifted northwards and global volcanism increased. The gymnosperm-dominated palynofloral assemblage as opposed to the fern- and horsetail-dominated macrofossil record of the Sonsela member of the Chinle Formation, conforms to a semi-arid upland environment alternated by riparian, swampy lowland.

1. Introduction

The Chinle Formation in the southwestern USA was deposited in the Late Triassic, probably during the early Norian to Rhaetian (Irmis et al., 2011; Olsen et al., 2011; Ramezani et al., 2011). The formation is entirely continental in origin and was deposited in a lowland basin largely influenced by outflow from surrounding mountainous areas (Dubiel et al., 1991). The Chinle Formation unconformably overlies the Early to Middle Triassic Moenkopi Formation and is overlain by strata of the Glen Canyon Group, the lowermost part of which is probably also Late Triassic in age and contains the Triassic/Jurassic boundary (Donohoo-Hurley et al., 2010). The tetrapod faunas and biostratigraphy of the Chinle Formation have been researched extensively (Long and Murry, 1995; Irmis, 2005; Parker and Martz, 2011). The Chinle Formation has also been studied extensively for plant macrofossils (e.g. Daugherty, 1941; Ash, 1972, 2001) and to a lesser extent palynology (e.g. Fisher and Dunay, 1984; Litwin et al., 1991).

Recently an extensive review of the exposures of the Chinle Formation at Petrified Forest National Park (PEFO) yielded a stratigraphic succession that clarified many of the problems associated with the Chinle Formation stratigraphy (Martz and Parker, 2010). Moreover, the new stratigraphic revisions of the Chinle Formation helped to elucidate the local tetrapod biostratigraphy. The Adamanian–Revueltian transition, two North American Triassic tetrapod biozones, occurs in the Sonsela member (e.g. Hunt and Lucas, 1993; Lucas and Heckert, 1996) and has been constrained to a discrete 3 m thick horizon within this unit (Parker and Martz, 2011). This faunal change also occurs in an interval where a palynozonal transition has been documented (Litwin et al., 1991). However, the palynozonal transition was not as well constrained stratigraphically as the faunal change (Parker and Martz, 2011).

Here we present a new palynological study of the Sonsela member at Petrified Forest National Park (PEFO) that aims to constrain the

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palynozonal transition found by Litwin et al. (1991) and to correlate it with the faunal transition documented by Parker and Martz (2011). We will discuss paleo-environmental circumstances prevailing in the Norian of southwestern North America as hypothesized in earlier studies as well as the paleobotanical affinities of important pollen and spore types found in the Late Triassic of PEFO.

2. Materials and methods

2.1. Study site, geological setting and age

Petrified Forest National Park (PEFO) is located in northeast Arizona, USA (35.06°N, 109.78°W — Fig. 1) and in the park, Chinle Formation exposures are approximately 350 m thick and have been dated at 225–205 Ma with U–Pb radiometric isotopes (Parker and Martz, 2011). Based on recent recalibrations of the Triassic timescales this places them in the earliest Norian to middle Rhaetian (Riggs et al., 2003; Furin et al., 2006; Irmis et al., 2011; Ramezani et al., 2011). The Chinle Formation also outcrops in several adjacent southwestern states: Arizona, western New Mexico, Utah, Colorado and Nevada (Dubiel, 1994). Outcrops of similar age in eastern New Mexico, Texas and Oklahoma are usually assigned to the Dockum Group and outcrops in southwestern Colorado to the Dolores Formation (Fig. 1), because of lithological and traditional nomenclatural differences (Stewart et al., 1972; Dubiel, 1994; but see Lucas, 1993).

The lithological members comprising the Chinle Formation are not all continuous and have been given a range of regional names. The members exposed within the Petrified Forest National Park region are, from lowest to uppermost: the Shinarump/Mesa Redondo, Blue Mesa, Sonsela, Petrified Forest and Owl Rock members (sensu Parker, 2006; Woody, 2006; Martz and Parker, 2010; Irmis et al., 2011). Late Triassic strata at PEFO are capped by Neogene sedimentary and volcanic deposits.

The exposed outcrops of the Chinle Formation at PEFO consist of a variety of gray to white sandstones and variegated mudstones. The petrified logs for which the park is best known are localized within various semi-continuous sandstone bodies in at least nine different stratigraphic levels throughout the park (W.G. Parker, unpublished data). The logs are either replaced by silica, or permineralized in the original structure. The park is also rich in vertebrate fossils (Long and Murry, 1995; Irmis, 2005; Parker and Martz, 2011).

The Mesa Redondo and Blue Mesa members are mostly comprised of mudstones and occasionally interbedded with sandstones (Martz and Parker, 2010). The Sonsela member was originally recognized as a single, laterally contiguous, multi-story sandstone body within the Petrified Forest member (e.g. Murry, 1990), but was greatly expanded by Heckert and Lucas (2002) and Woody (2006) to include several semi-continuous sandstone deposits interbedded with mudstones that had previously been assigned to the upper and lower portions of the Petrified Forest member (Stewart et al., 1972; Billingsley, 1985). The overlying Petrified Forest member (previously the upper Petrified Forest Member or Painted Desert member) is also rich in sandstone bodies (e.g. Billingsley, 1985), even though it has a much higher mudstone content than the Sonsela member (Woody, 2006). The uppermost member exposed at PEFO (Owl Rock) is composed almost entirely of mudstones, but with thick lenses of carbonate (Dubiel, 1993) (Fig. 2).

The proposed Adamanian–Revueltian faunal turnover occurs within the Sonsela member (Lucas and Heckert, 1996; Parker and Martz, 2011) and the revised lithostratigraphic framework of PEFO (Martz and Parker, 2010) allows for a detailed view of the succession of strata within the Sonsela member, even though the outcrops of these strata are discontinuous throughout PEFO. The mostly informal bed-level units within the Sonsela member at PEFO are from bottom to top: the Camp Butte, Lot's Wife, Jasper Forest, Jim Camp Wash and Martha's Butte (Fig. 2). The Rainbow Forest bed/Jasper Forest bed (Heckert and Lucas, 2002; Raucci et al., 2006) is a re-occurring sandstone body throughout the park (Martz and Parker, 2010) and contains one of the largest accumulations of petrified wood in the region. The other beds are rich in sandstone lenses that can be traced over some distance, but are not as continuous as the Jasper Forest Bed. These beds also contain various white to gray mudstone deposits and localized coalified beds rich in plant material.

2.2. Sampling strategy

Samples were collected from continuous mudstone sections, coalified plant beds and other beds that were associated with fossil plant material. Several other outcrops were also sampled to create a

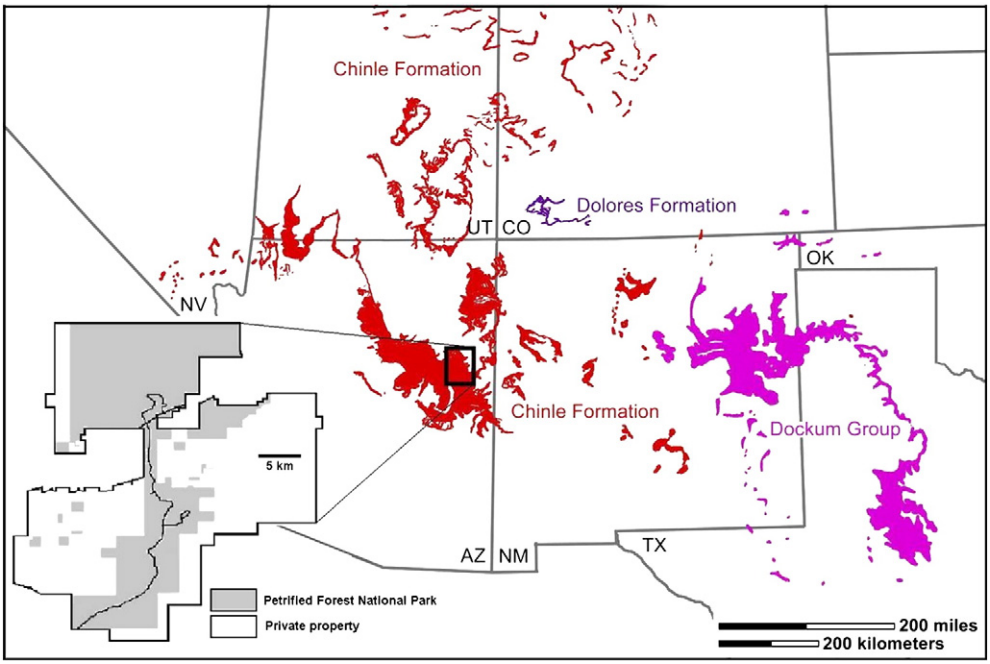

Fig. 1. Late Triassic outcrops of Southwestern USA and location of Petrified Forest National Park in respect to these outcrops. NV = Nevada, UT = Utah, CO = Colorado, AZ = Arizona, NM = New Mexico, OK = Oklahoma, TX = Texas. Edited from J.W. Martz in Martz and Parker (2010).