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FOSSIL TREE RINGS AND PALEOCLIMATE FROM THE TRIASSIC OF ANTARCTICA

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ABSTRACT: Fossil tree rings are described from fossil wood collected in the Lower- Middle Triassic Fremouw Formation, central Transantarctic Mountains, Antarctica. The wood consists of isolated logs within a paleostream channel, stems and roots within permineralized peat, and a standing fossil forest. The tree rings provide an accurate measure of abiotic factors important in understanding Triassic paleoclimatic in the southern hemisphere.

INTRODUCTION

Tree ring data are an important tool in interpreting climates of the past. For the most part, tree rings have been employed to study more recent climate changes and have been especially useful in the dating of archaeological sites. Within the past ten years, however, the techniques used to analyze Recent woodhave been extended to older fossil material, especially Cretaceous and Tertiarywoods (e.g., Creber and Chaloner, 1984; Parrish and Spicer 1988; Taylor, 1989;Spicer and Parrish, 1990). Based on the changes in radial cell diameter withinthe rings and the variation in ring width, it is possible to extrapolate climateinformation that is especially useful when coupled with data from megafloras, microfloras and the sedimentology of the site. This integrated approach has been used successfully by Spicer and Parrish (1990a) in their work on Late Cretaceous™early Tertiary floras from high northern latitudes.

Although fossil wood (Francis, 1986) and fossil forests (Jefferson, 1982) have been reported from the Antarctic peninsula region, there have been relatively few reports of fossil wood as a paleoclimate indicator from the continent of Antarctica (but see Jefferson and Taylor, 1983; Taylor, 1989; Taylor et al., 1992). The material presented in this paper consists of dispersed fossil wood and in situ trunks from Triassic deposits in the Beardmore Glacier region of Antarctica (Queen Maud Range, central Transantarctic Mountains). Wood was collected from a paleostream channel deposit at Fremouw Peak and from a standing forest nearby in the Gordon Valley. The channel deposit includes large logs and trunks as well as blocks of permineralized peat that contain woody axes (Taylor et al., 1989). The fossil forest site is represented by trunks in growth position that occur near the eastern end of Gordon Valley and is regarded as part of a levee deposit. Both sites occur within the upper member of the Lower Middle Triassic Fremouw Formation (Barrett et al., 1986). Based on palynomorphs, the peat/log deposit at Fremouw Peak is considered to be early Middle Triassic (Anisian) (Farabee et al., 1990). The Gordon Valley forest is slightly lower stratigraphically.

All specimens are permineralized in silica and were studied by means of cellulose acetate peels prepared after etching in hydrofluoric acid. Tree rings were examined and measured for changes in mean ring width, changes in radial cell diameter across rings, annual sensitivities, mean sensitivities and earlywood/latewood boundaries. Mean and annual sensitivities represent a measure of the variability of a particular environment, while the type and location of earlywood/latewood boundaries has been useful in relating particular anatomical features to certain climatic regimes (Creber and Chaloner, 1984). When coupled with information from associated floras, ring data from these fossil woods can provide important information on paleoclimate in Antarctica during the Triassic.

FOSSIL TREE RINGS

All wood specimens consist of dense, pycnoxylic (conifer-like) wood with conspicuous growth rings, consisting of extensive earlywood and little latewood (1-2 cell layers) (Fig. 1-1). Tree ring boundaries are not particularly distinct; this structural type compares favorably with woods described from other high latitude sites (e.g., the North Slope of Alaska and Alexander Island off the Antarctic peninsula) (Jefferson, 1982; Parrish and Spicer, 1988; Spicer and Parrish, 1990b). There is little change in cell diameter from earlywood to latewood with earlywood cells consistent in their size and shape across each ring (Fig. 1-2). This indicates an equable climate and continuous growth during the growing season.

The Gordon Valley forest consists of 99 silicified trunks. They range from 20 to 60 cm in diameter, with the largest trunk 0.5 m tall. The maximum number of growth rings in a single specimen is 86. Ring width ranges from 0.23 to 7.11 mm; mean width is 1.52 mm. Density of trees within the standis calculated to have been 257.6 trees ha^{-1}. The trunks with the narrowest rings also have the largest number of rings, a feature that is typical of most living trees. Although the wood is only moderately well-preserved, there appears to be no evidence of frost rings or false rings (=intrannual bands). The only associated flora with the *in situ* trunks consists of *Dicroidium* leaves, which are preserved as impression/compressions in the shale at the base of the trunks. *Dicroidium* is a common foliage type in the Triassic of the southern hemisphere and is generally considered to belong to the seed fern group Corystospermales. The fronds cover 92% of the bedding plane and no doubt represent the foliage type that was borne by the trunks. Based on the number of rings, the density of the forest, and the overall size of the trunks, we interpret the Gordon Valley deposit as a mature forest.

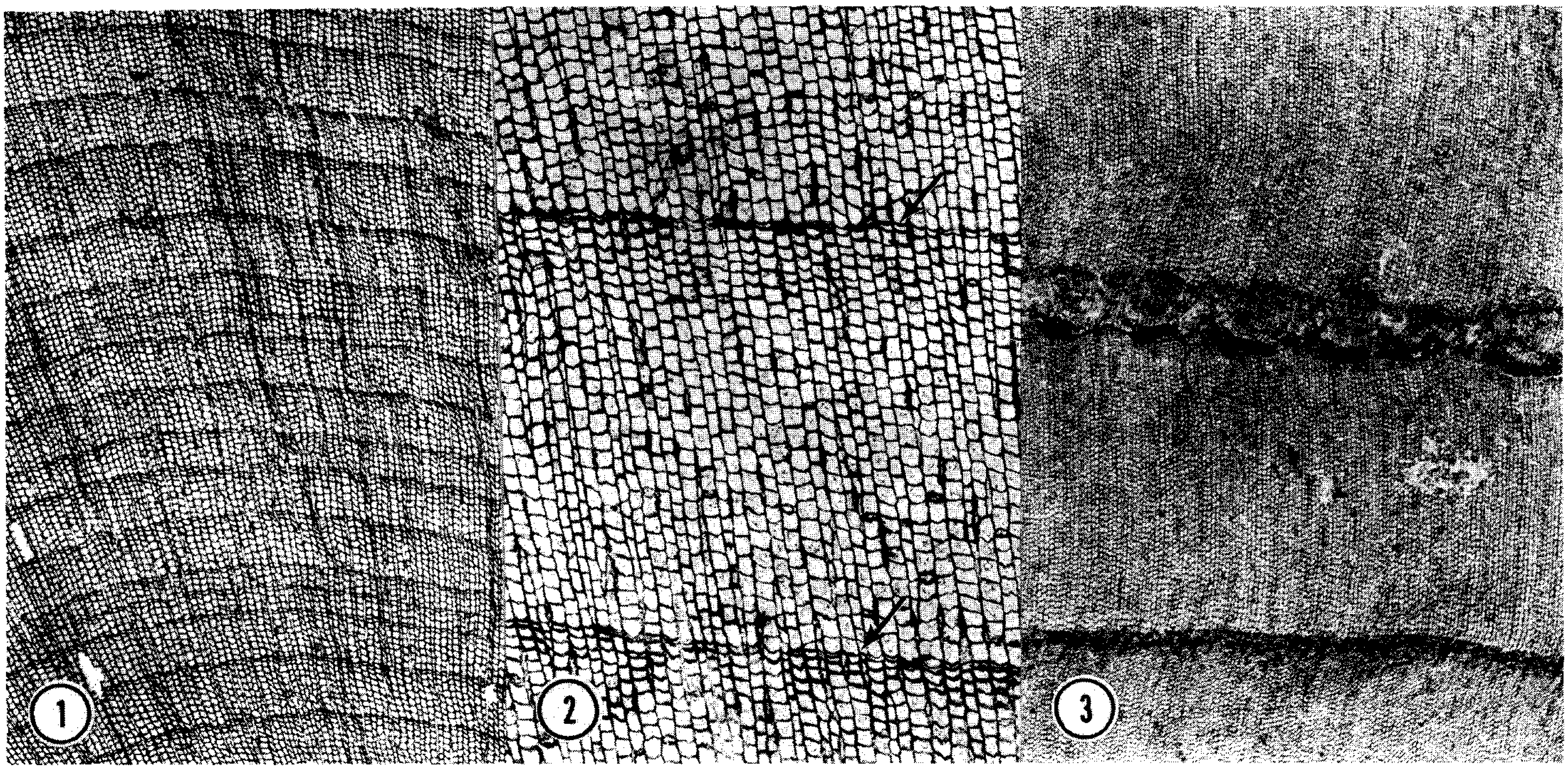

FIGURE 1. (1) Transverse section of growth rings in permineralized peat (1) showing variability. (10,116 A3) X 15;
(2) Transverse section of growth rings showing regular production ofearlywood and small amount of latewood (arrows) (572 D top) X 42;
(3) Transverse section of cambial disruption near ring boundary similar to modern frost rings. Normal ring boundary below. (11,475 A #1) X 12.

The wood specimens contained in the peat and logs preserved at the Fremouw Peak site are more varied, consisting of both stems and roots. The roots exhibit smaller ring widths than the stems (mean ring width ≈ 0.50 mm for roots; 1.34 mm for stems). In general, the stream bed specimens tend to be larger than those in the peat. The largest stem in the paleochannel exhibits 85 rings, while that in the peat contains 55 rings. The largest preserved root also occurs in the stream bed (215 rings). Anatomically the specimens from the peat and the stream bed are similar with one exception. The largest stem in the channel exhibits disruptions in the radial rows of wood cells in several different growth rings (Fig. 1-3). These disruptions appear identical to frost rings that form in modern woods in response to a freeze, either late in the spring after the cambium has begun active growth, or early in the fall before the cambium has entered dormancy. These disruptions thus suggest that there were occasional hard freezes during the growing season (frost rings do not provide information about conditions during dormant winter months). No wood specimens in the peat contain frost rings, and the flora present in this deposit does not agree well with the presence of unseasonable frosts (see below). Therefore, a reasonable explanation for multiple frost rings in this particular trunk may be that this tree was growing at a higher altitude than the peat deposit and therefore experienced more unseasonable cold spells during the growing season. Although the wood in this specimen is moderately well preserved, it could have been transported some distance to the site of deposition.

Although the Gordon Valley flora contains only *Dicroidium* leaves, the peat flora associated with the wood at Fremouw Peak is more extensive. At this time, the following plants have been described from this deposit (Taylor and Taylor, 1990; Taylor et al., 1993): a cycad stem *(Antarcticycas)*, a sphenophyte stem (*Spaciinodum*) and associated cones, four types of filicalean fern stems and petioles, an osmundaceous fern (*Millerocaulis*), seed fern stems belonging to *Dicroidium* foliage (Meyer-Berthaud et al., 1993), foliage of *Dicroidium*, and numerous fungi, representing 3-4 major groups. Cycads today are restricted to warm, generally moist climates. Although it is possible that this plant exhibited a climatic tolerance unlike that of modern cycads, the anatomy of the stem would suggest otherwise it contains no specialized strengthening tissue and no evidence of thick leaf base armor or cuticle that would normally be associated with a more inhospitable climate. In fact, the anatomy of *Antarcticycas* is remarkably similar to living *Bowenia*, which is today endemic to Australia, consisting of delicate, parenchymatous tissue throughout the stem with manoxylic wood (i.e., containing a large proportion of thin-walled parenchyma tissue) (Smoot et al., 1985). The presence of so many different types of fungi would also seem to suggest a warm, moist climate. Support for a relatively warm climate in Antarctica during the Triassic is also provided by the variety of vertebrate fossils, including a diverse array of reptiles and amphibians, found at a site in nearby Gordon Valley (Hammer et al., 1990). These remains are considered to be late Early to early Middle Triassic and occur stratigraphically below the permineralized peat deposit.

Due to the high paleolatitude of these fossil sites, there must have been a winter season of reduced light and winter darkness. The presence of mats of *Dicroidium* leaves in the shale surrounding the fossil forest would suggest that these plants partially adapted to winter conditions by dropping their leaves. Several authors (e.g., Wolfe, 1987; Spicer and Chapman, 1990) have suggested that high latitude deciduous floras can be correlated with times of warm polar climates. The method of winter adaptation in the diverse types of plants that occur within the permineralized peat, however, is still uncertain. Due to the number and kinds of organisms present in the Gordon Valley fauna, migration cannot be used as an explanation for their presence at such high latitudes. Both the plant and the animal evidence, and especially the data from in situ tree rings, would argue for a warmer climate than has been predicted by climate modelers for this time (e.g., Kutzbach and Gallimore, 1989).

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