Gymnospermous woods from the Upper Triassic of northern Chile

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ABSTRACT


The anatomical study of three gymnosperm fossil woods from the Upper Triassic La Coipa, La Ternera and Las Brecas formations is presented. Prototaxisoxylon intertrappeanum is a taxacean wood from India characterized by its tertiary thickenings on their secondary tracheids; Proteaxonexcyparyxylon klitzchii is a cupressaceous wood also present in the Namaqua Formation of South Africa while Protophyllocoeloeylon corticiformis is a Protopoaceae member which was already described from the Upper Triassic of Argentina. The present text is the first description of Triassic woods from Chile.

Key-words— Coniferopsida (Taxales, Coniferales), Anatomy, Upper Triassic, Northern Chile.

INTRODUCTION

THREE fossil woods are described and cited for the first time from different localities and formations, of northern Chile (Text figure 1). Fossil wood had only been reported as such and to our knowledge had never been described before from these units.

In a recent paper Herbst et al. (in press) gave a summary of the scarce former literature related to the megaflora of these formations. They all contain a typical Triassic Dicroidium flora composed of abundant Pteridophyta (mainly Marattiaceae, Osmundales, Gleicheniaceae, Dipteridaceae and the genus Neocalamites), Pteridosperms (Dicroidium, Diplasiophyllum, Lepidopteris, etc.) Ginkgoales (Ginkgoites. Sphenobaiera), Cycadales (Pseudocycas), other leaves (Taeoniophytes, Yabeicellae) and very rare Conifers (Rissikia and Heidiphyllum). The woods here described belong to the latter Class of plants.

MATERIAL AND METHOD

Sources of the material are as follows:

The material described in this paper has been collected

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from Hito La Candelaria (close to La Coipa Mine), North of C. Maricunga, Province of Copiapó, III Region, Chile. The wood samples occur in La Coipa Formation which is considered to be Lower Triassic? (Suarez & Bell, 1993).

It seems doubtful to us, as cited in Suarez & Bell (1993) that the La Coipa Formation is of Lower Triassic age as its flora, although locally somewhat distinct, is typically of the Middle-Upper Triassic associations, as are the other floras of northern Chile.

Locality—Quebrada El Carbón, area of C° La Ternera, Province of Copiapó, III Region, Chile.

Horizon—La Ternera Formation.

Age—Upper Triassic (Sepúlveda & Naranjo, 1982).

Locality—Punta del Viento, 20 km East of Vicuña, Province of Elqui, IV Region, Chile.

Horizon—Las Breas Formation.

Age—Upper Triassic (Dediós, 1967; Letelier, 1972).

The specimens are fairly well preserved, completely silicified, but only secondary wood is present in all the specimens, generally with well marked growth rings.

The acetate-peel technique was used with good results, in addition to other observations. A minimum of 15 measurements was made in all cases; the mean size is given while the maximum and minimum values are in parentheses. The terminology used is that of Greguss (1955) and standard measurements as proposed by Chatthaway (1932).

SYSTEMATICS

Class—CONIFEROPSIDA

Order—TAXALES

Family—TAXACEAE
Genus—Prototaxoxylon Kräusel & Dolianiti, 1958

Prototaxoxylon intertrappeum Prakash & Srivastava, 1961
(Pl. 1 figs 1, 2, 3, 5, 7 and Text-fig. 2)

Type species—Prototaxoxylon africanum (Walton) Kräusel & Dolianiti, 1958

Description—Decorticated wood fragment with only secondary wood preserved, with well-marked growth rings and abundant "shearing zones". Xylem tracheids are rectangular in outline in transversal section (TS) with about 24 µm (30-15 µm) in tangential x 27 µm (30-15 µm) radial diameters respectively (Pl. 1, fig. 1). In all growth rings the late wood is narrow, with 5 (9-2) rows of cells while early wood has 46 (63-32) rows of cells. Mean sensitivity (Fritts, 1972) could not be obtained as together with true, there are many false rings. In longitudinal radial (LR) section, tracheids are 53 x 900 µm wide / long. Their walls bear rounded, uniseriate araucarioid pits, contiguous and spaciate; areole aperture is circular. Pits measure 10 x 12 µm wide / high. The flattening coefficient (e=d / D) is 1 (Pl. 1, figs 2, 3, 5, 7). On the radial walls there are thickened spiral bands running clock- or counterclock-wise over the pits (Pl. 1, figs 2, 3, 5, 7, Text. fig. 2). Cross fields have biseriate, scattered, bordered pits with circular pore apertures; mean number of pits per field is 4 (8-2) (Text-fig 2). The radial system is homogeneous, rays are uniseriate, low, with oval cells in tangential longitudinal (TL) section. Mean height of rays is of 3 cells (7-2). On these walls the uniseriate pits are smaller than those of radial walls. In TS the rays are separated by about 7 (16-2) tracheids (Pl. 1, fig. 1). On TL walls the uniseriate pits are smaller than those of the LR walls.

Material—CTES-PB Nº 10252, Sgo-PB Nº 1595; CTES-PMP Nº 2036-2037 (sections).

Locality—Hito La Candelaria, Mina La Coipa, Chile (see above).

Horizon—La Coipa Formation.

Age—Upper Triassic.

Discussion—The described specimen can be assigned undoubtedly to the genus Prototaxoxylon Kräusel & Dolianiti (1958), mainly because of the arrangement of the spiral thickening bands on the tracheidal walls (characteristic of all the Taxales), the bordered pits and the field-crossings.

There are some other Gondwana woods with the same type of secondary wood, viz., Taxopytis Kräusel, Taxoxylon Unger and Taxaceoxylon Kräusel & Jain. But these are different in their abietinoid pits on tracheidal walls while in Prototaxoxylon they are mid-way between araucarioid and cordaitoid. Incidentally, it seems that this and some other morphological characters in homologous structures of seeds and cones, are the reasons why Bliss (1918), Sahni (1920) and Florin (1948) suggested that the Taxales evolved from some ancestral type of Cordaitales.

Prototaxoxylon has an extensive biochron, from Permian to Tertiary; five species are known from the Gondwana realm: P. indicum (Mehta) Prakash & Srivastava, P. andrewsii Agashe & Chitnis, both from the Permian of India; P. brasilianum Kräusel & Dolianiti from the Permian of Brazil, P. africanum (Walton) Kräusel & Dolianiti from the Late Mesozoic or Lower Tertiary of South Africa, and finally P. intertrappeum Prakash & Srivastava from the Lower Tertiary of India. P. ferizianense Fahkr and Marguerier (in Fahkr, 1977) is known from the

Text-figure 2—Prototaxoxylon intertrappeum Prakash & Srivastava. Aspects of the cross-field scheme of the spiral thickening bands running clock and counter clock-wise on tracheidal walls. Scale bar: 35 µm.

Text-figures 3, 4—Protaphylloclea raywoodii klotzschii Giraud. Transverse section of secondary woods, ch: secretory canal. Scale bar: 100 µm.

3. Protaphylloclea cordatiradiata Menéndez. Tracheids with mixed and uniseriate pits and phyllocladoid cross-field in secondary xylem; to the right short tracheids without pits. Scale bar: 38 µm.
PLATE 1

1, 2, 3, 5, 7 *Protosoxylon intertrappeum* Prakash and Srivastava.

1. transversal section: tracheids of secondary xylem, scale bar: 70 μm. 2, 5: longitudinal radial sections: spiral thickening bands running clock or counterclockwise over the tracheidal walls of the secondary xylem and uniseriate pits, scale bars. 3, 7 represent 35 μm; 2 = 70 μm; 5 = 15 μm.
Jurassic of Iran, i.e., outside the classical Gondwana realm.

Comparisons with all these species showed that the Chilean specimen could be assigned to *P. intertrappeum*, with which it shares most characters, mainly the thickness and arrangement of the spiral thickenings, the cross-fields, the predominance of uniseriate bordered pits, smaller tangential than radial pits and the presence of false growth rings.

A few unimportant characters have not been seen in our specimen: Sanio-bars in some tracheids, the number of pits in the cross-fields (1-10 in the Indian specimen and 2-7 in ours) and a small amount of biseriate radial pits. Maheshwari (1972) also found some variations in this latter character which.

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**PLATE 2**

1. 2. *Protochamaecyparis* *klitzschii* Giraud. Tangential longitudinal section: frequency and height of secondary xylem rays, scale bar represents 80 µm and 100 µm for figs. 1 and 2 respectively.

3-6. *Protophylocladus* *cordiceritaensis* Menéndez. 4. Transverse section: tracheids of secondary xylem, scale bar represents 100 µm.

3. 6. Longitudinal radial section: 3. mixed pits on the tracheidal wall, 6. araucarioid biseriate pits on tracheids, scale bar represents 50 µm.

5. Longitudinal tangential section: uniseriate and low rays, scale bar: 80 µm.
<table>
<thead>
<tr>
<th>Name of the Wood</th>
<th>Growth Rings</th>
<th>Bordered Pitting (Radial Wall)</th>
<th>Bordered Pitting (Tangential Wall)</th>
<th>Spiral Bands</th>
<th>Medullary Rays</th>
<th>Field Pitting</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. <em>Prototaxoxylon africanum</em> (Walton) Kräusel &amp; Dolianiti (1958)</td>
<td>Distinct</td>
<td>Uniseriate and contiguous, occasionally biseriate</td>
<td>Not seen</td>
<td>1-2 seriate, confined to the wall between the pits</td>
<td>Almost uniseriate 1-18 cells high</td>
<td>2-8, border not visible</td>
</tr>
<tr>
<td>2. <em>Prototaxoxylon indicum</em> Prakash &amp; Srivastava (1961)</td>
<td>Well marked</td>
<td>Uniseriate or irregularly biseriate (then alternate or opposite), contiguous, circular or horizontally elliptical in shape</td>
<td>Absent</td>
<td>1-2 seriate, passing in between the pits or across the borders of contiguous pits</td>
<td>Uniseriate(?), one (or more ?) cell deep; ray cells fairly thick-walled</td>
<td>6-7, border elliptical</td>
</tr>
<tr>
<td>3. <em>P. brasiliense</em>, Kräusel &amp; Dolianiti (1958)</td>
<td>Absent</td>
<td>Single series occasionally 2-seriate and alternate</td>
<td>Absent</td>
<td>Close, narrow and nearly horizontal, bands across the pits, look like scalari-form pitting</td>
<td>1-6 (1-2) cell high, uniseriate</td>
<td>1-4, broadly oval, slit like oblique opening</td>
</tr>
<tr>
<td>4. <em>P. intertrappeum</em>, Prakash &amp; Srivastava. (1961)</td>
<td>Distinct</td>
<td>Normally uniseriate and contiguous, sometimes biseriate, circular or vertically compressed in shape</td>
<td>Scarce, normally uniseriate &amp; separate.</td>
<td>2-seriate. Close both left and right-handed, pass usually across the borders of contiguous pits or through the space between the separate pits</td>
<td>1-seriate, 2-7 cells high, ray cells usually oval</td>
<td>2 (4-8) biseriate, scattered, bordered pits, pore circular</td>
</tr>
<tr>
<td>5. <em>P. andrewsii</em>, Agashe &amp; Chitnis, (1971)</td>
<td>Very distinct</td>
<td>1-3 seriate circular slightly horizontally compressed bordered pits</td>
<td>Absent</td>
<td>Single or double, closely spaced clockwise or anti-clock wise</td>
<td>1-2 seriate. 1-8 cells high</td>
<td>Cupressoid, ovoid 2-6 per field central pore circular to oblique</td>
</tr>
<tr>
<td>6. <em>P. ferizelle</em>, Fahkr &amp; Marguerier</td>
<td>Poorly marked</td>
<td>1-2 seriate and mixed, circular and contiguous or spicate</td>
<td>Absent</td>
<td>Horizontal or oblique</td>
<td>Uniseriate, 1-13 cells high</td>
<td>Oculipore, elliptical</td>
</tr>
</tbody>
</table>

(*) Partially adapted from Prakash and Srivastava 1961
according to him, depends on how far from the pith are observations of xylem made.

Differences with the other species of Prototaxoxylon are shown in Table 1.

*P. interruppeum* was originally described from Lower Tertiary sediments of India, but Prakash and Srivastava (1961) already admitted a close resemblance to more “primitive” Permian species. The present finding in Triassic rocks fills this gap.

**Family—CONIFERALES**

**Genus—PROTOCHAMAECYPARIXYLOX**

*Protochamaecyparoxylon klitzchii* Giraud 1985

**Description**—Decorticated wood fragment, 30 cm in diameter x 35 cm long. Only pinoxylic xylem with weakly marked growth rings is preserved. Tracheids are rectangular in transversal outline, 33 μm (44-23 μm) radially x 37 μm (43-15 μm) tangentially respectively. Transition from early to late wood is gradual, but some distortion due to shearing zones is observed. In TS traumatic secretory channels are seen, with a mean of 66 μm in radial x 74 μm in tangential diameters; traumatic parenchyma cells of mean 37 x 42 μm radially / tangentially can also be seen (Pl. 1, fig. 4, Text-figure 3).

In LR section, araucarioid, mainly uniseriate (few biseriate), contiguous, bordered pits are seen on radial walls (Pl. 1, fig. 6).

Cross-fields show 1-2 cupressoid oculipore-type (elliptical, oblique lumen) pits. No pits have been observed on tangential walls. Radial system is homogeneous, with uniseriate rays; cells are rounded, low, only 4 (8-3) cells high; in TS rays are separated by a mean of 11 (18-5) tracheids (Pl. 2, figs 1, 2).

**Material**—CTES-PB No 10253, Sgo PB No 1596; CTES-PMP No 2038-2039 (sections).

**Locality**—Punta del Viento (see above).

**Horizon**—Las Breas Formation.

**Age**—Upper Triassic.

**Discussion**—The presence of diagnostic characters like isolated vertical parenchyma, traumatic secretory channels, radial pits mainly uniseriate and cupressoid cross-fields, shows great affinities with the Cupressaceae and specially with the genus *Protochamaecyparoxylon* Giraud. This is a monotypic genus (*P. klitzchii*) from the Nandanga Formation (Upper Triassic of the Karroo Series) from Tanzania.

Our specimen can confidently be identified with this species as all characters coincide, except the number of pits in cross-fields which in present specimen are 1 to 2, while in the African specimens their number is 2 to 4. But this seems to be a very minor difference.

**Family—PROTOPINACEAE**

**Genus—PROTOPHYLLOCLADOXYLON** Kräusel, 1959

*Protophyllocladoxylon cortaderiaensis* Menéndez, 1956

**Type species**—*P. leuchstii* Kräusel, 1939.

**Description**—Trunk of about 1 m diameter, with well-marked growth rings. Tracheids have a rectangular outline, approximately 57 μm (64-37 μm) radially x 55 μm (58-23 μm) tangentially (Pl. 2, fig. 4). Transition from early to late wood is gradual. On radial walls tracheids bear rounded, contiguous, uniseriate araucarioid pits, with circular pore aperture and biseriate contiguous, rounded to a few polygonal (hexagonal) pits as well as mixed pits (Kräusel, 1939) (Pl. 2, figs 3, 6; Text-figure 4). Cross-fields have only one pit without areoles. Radial system is homogeneous. Rays are homocellular, uniseriate (a few biseriate), low. Mean cell height is 2 with a maximum of 4 (Pl. 2, fig. 5).

**Material**—CTES-PB No 10254, Sgo PB- No 1597; CTES-PMP No 2040-2042 (sections).

**Locality**—Quebrada El Carbón — Chile (see above).

**Horizon**—La Ternera Formation.

**Age**—Upper Triassic.

**Discussion**—The presence of mixed pits on the radial tracheidal walls is the main character of the Family Protopinaceae.

All the anatomical characters here described are coincident with *Protophyllocladoxylon* Kräusel, which has a large biochron from the Upper Carboniferous to the Cretaceous, and is known from Germany, Russia, Africa, Brazil and Argentina. Specifically, our material is undoubtedly assignable to *P. cortaderiaensis* Menéndez from the Upper Triassic Brear Formation of Argentina. With this species it shares the simple punctuation of the cross-fields, the un-, bi- and mixed pits on the radial tracheid walls.

**CONCLUDING REMARKS**

It is interesting to remark that in spite of the rare Conifers (*sensu lato*) impressions in the megafloras (only *Rissikia* and *Heidiphyllum* have been recorded) these woods belong to Gymnosperms.

The specimens are evidently allochthonous and surely represent, at least partially, the upland flora which surrounded the cultivable areas into which they have been drifted. This xyloflora is composed of already known genera and species, in some cases with extra-gondwanic distribution (like *Prototaxoxylon* and *Protophyllocladoxylon*); this is in sharp
contrast with the "endemism" shown by the leaf-impression megafloras which presumably represent the "typical" floras of each site or locality in our case different lowland associations of Dicroidium-flora. This fact shows once more that there was stronger uniformity in upland forests, with a much wider than usually accepted distribution of tree taxa. This seems to be the case in many Triassic and Permian floras. Recently two of us (Crisafulli & Lutz, in press) have described a Permian xyloflora from Uruguay where also several taxa of upland trees of rather wide distribution are present, which are not represented by the leaf-impression flora (Herbst et al., 1992).

Other Permian flora from Brazil and India show the same differential distribution between leaves and woods.

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