Palaeobotanist 48 (1999) 31-38
0031-0174/99/31-38 $2.00

Gymnospermous woods from the Upper Triassic of northern Chile

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(Received 11 November 1997; revised version accepted 04 August 1999)

ABSTRACT

Lutz AI, Crisafulli A & Herbst R 1999. Gymnospermous woods from the Upper Triassic of northern Chile. Palaeobotanist 48(1) : 31-38.

The anatomical study of three gymnosperm fossil woods from the Upper Triassic La Coipa, La Ternera and Las Breas formations is presented. *Prototaxoxylon intertrappeum* is a taxacean wood from India characterized by its tertiary thickenings on their secondary tracheids; *Protochamaecyparixylon klitzschii* is a cupressaceous wood also present in the Nandanga Formation of South Africa while *Protophyllocladoxylon cortaderitaensis* is a Protopinaceae 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.

सारांश

उत्तरी चिली से प्राप्त उपरिट्रायसिकयुगीन अनावृतबीजी काष्ठ

एलीशिया आई. लुत्ज़, एलेक्ज़ेन्ड्रा, क्रिसाफुल्ली एवं रेफ़ील हब्र्स्ट

ला कोयपा, ला टर्नेरा तथा लास ब्रीस नामक तीन शैल समूहों से प्राप्त उपरिट्रायसिकयुगीन तीन अनावृतबीजी अश्मित काष्ठों का शारीर वैज्ञानिक अध्ययन इस शोध पत्र में प्रस्तुत किया गया है। *प्रोटोटैक्सोज़ाइलॉन इन्टरट्रेपियम* भारत की एक टैक्सेशियन काष्ठ है, जिसे इनके द्वितीयक वाहिनियों पर स्थित इसकी तृतीयक स्थूलता से अभिलक्षणित किया गया है। *प्रोटोकैमीसाइपेरीज़ाइलॉन क्लित्ज़शाइ* एक क्यूप्रेससमय काष्ठ है, जो दक्षिण अफ्रीका के नानडांगा शैलसमूह में भी उपस्थित है, जबकि *प्रोटोफ़िल्लोक्लैडोज़ाइलॉन कार्टेडेराइटीन्सिस* प्रोटोपिनेसी कुल का एक सदस्य है, जिसे उपरिट्रायसिकयुगीन अर्जेन्टीना से पहले से ही अंकित किया जा चुका है। प्रस्तुत शोधपत्र चिली से प्राप्त ट्रायसिकयुगीन अश्मित काष्ठ का प्रथम वर्णन प्रस्तुत करता हैं।

INTRODUCTION

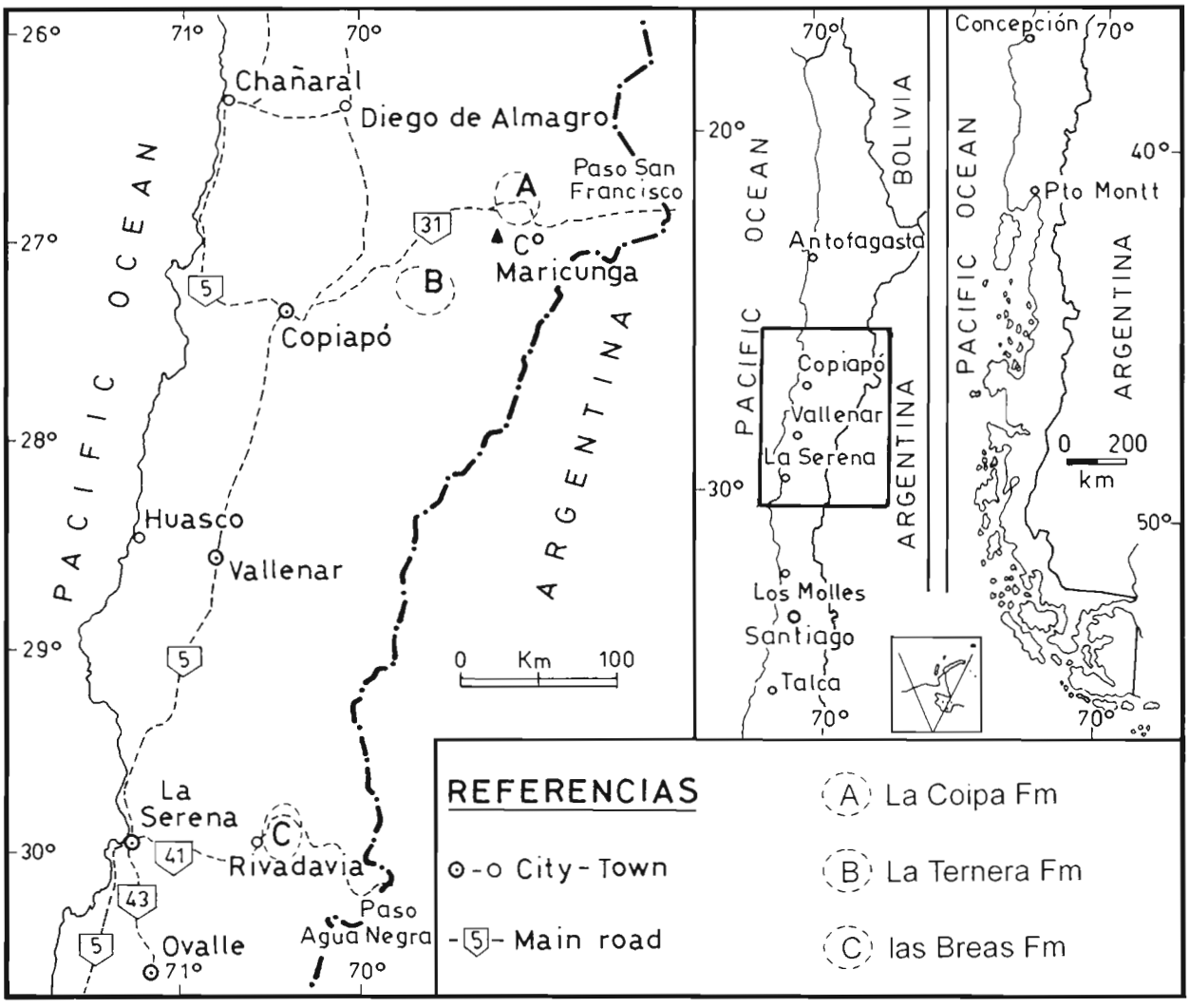
THREE fossil woods are described and cited for the first time from different localities and formations, of northern Chile (Text figure 1). Fossil wood had only been reported as such and to our knowledge had never been described before from these units.

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 Marattiales, Osmundales, Gleicheniaceae, Dipteridaceae and the genus *Neocalamites*), Pteridosperms (*Dicroidium, Diplasiophyllum, Lepidopteris*, etc.) Ginkgoales (*Ginkgoites, Sphenobaiera*), Cycadales (*Pseudoctenis*), other leaves (*Taeniopteris, Yabeiella*) 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



Text-figure 1—Location map, showing the areas of the formations with fossil woods.

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 minimun of 15 measurements was made in all cases: the mean size is given while the maximun and minimun 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 araucariod 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 N° 10252, Sgo- PB N° 1595; CTES-PMP N° 2036-2037 (sections).

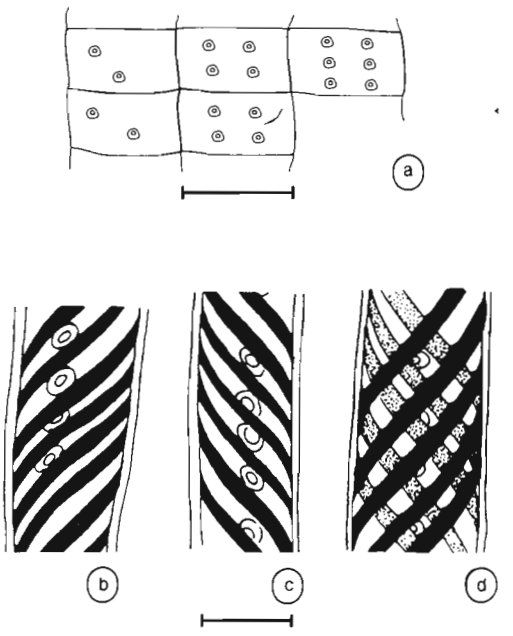
Locality—Hito La Candelaria, Mina La Coipa, Chile (see above).

Horizon—La Coipa Formation.

Age—Upper Triassic.

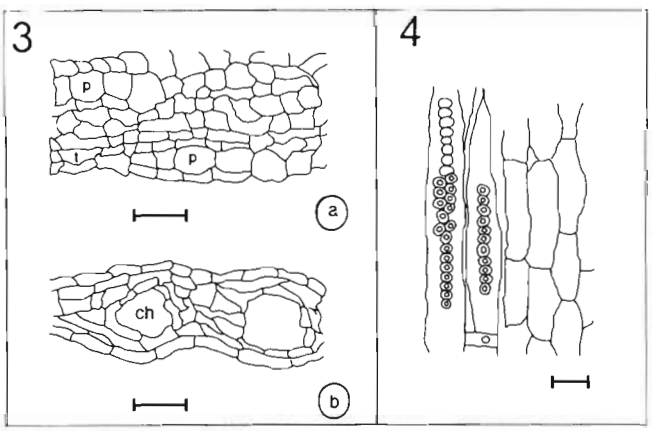
Discussion—The described specimen can be assigned undoubtely to the genus *Prototaxoxylon* Kräusel & Dolianiti (1958), mainly because of the arrangement of the spiral thickening bands on the tracheidal walls (characteristic of all the Taxales), the bordered pits and the field-crossings.

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.



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

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. feriziense* Fahkr and Marguerier (in Fahkr,1977) is known from the



Text-figures 3, 4—*Protochamaecyparixylon klitzchi* Giraud. Transverse section of secondary woods, ch: secretory canal. Scale bar: 100 µm. **4.** *Protophyllocladoxylon cortaderitaensis* Menéndez. Tracheids with mixed and uniscriate pits and phyllocladoid cross-field in secondary xylem; to the right short tracheids without pits. Scale bar: 38 µm.

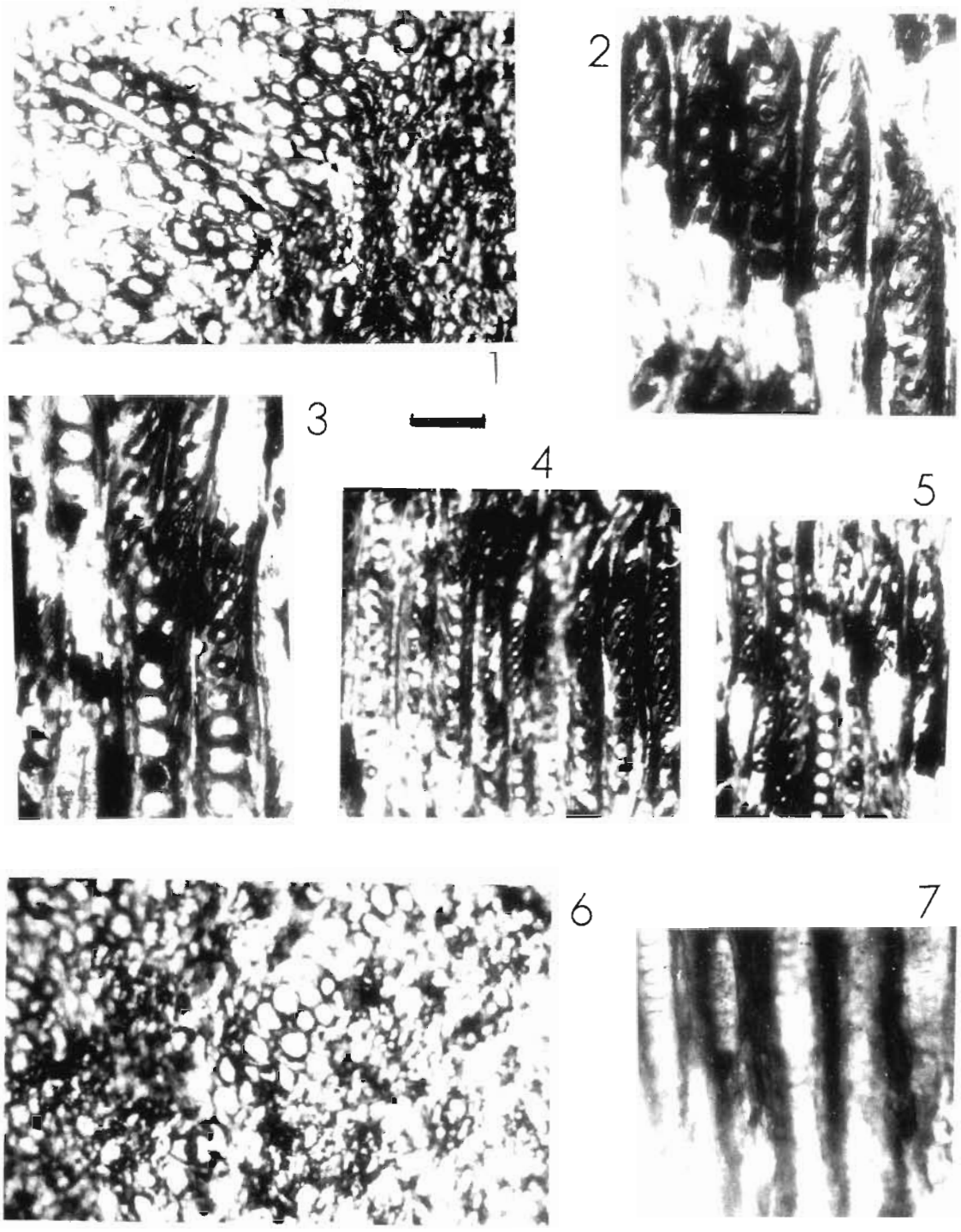


PLATE 1

1, 2, 3, 5, 7 *Prototaxoxylon 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 counterclock- wise over the tracheidal walls of the secondary xylem and uniseriate pits. scale bars. **3, 7** represents 35 µm; **2**= 70 µm; **5**=15 µm.

4, 6. *Protochamaecyparixylon klitschii* Giraud. **4**. transversal section: tracheids of secondary xylem, partial parenchimatic ring and growth ring, scale bar represents: 80 µm. **6**. longitudinal radial section: uniseriate pits on the tracheidal walls of secondary xylem, scale bar represents 70 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,

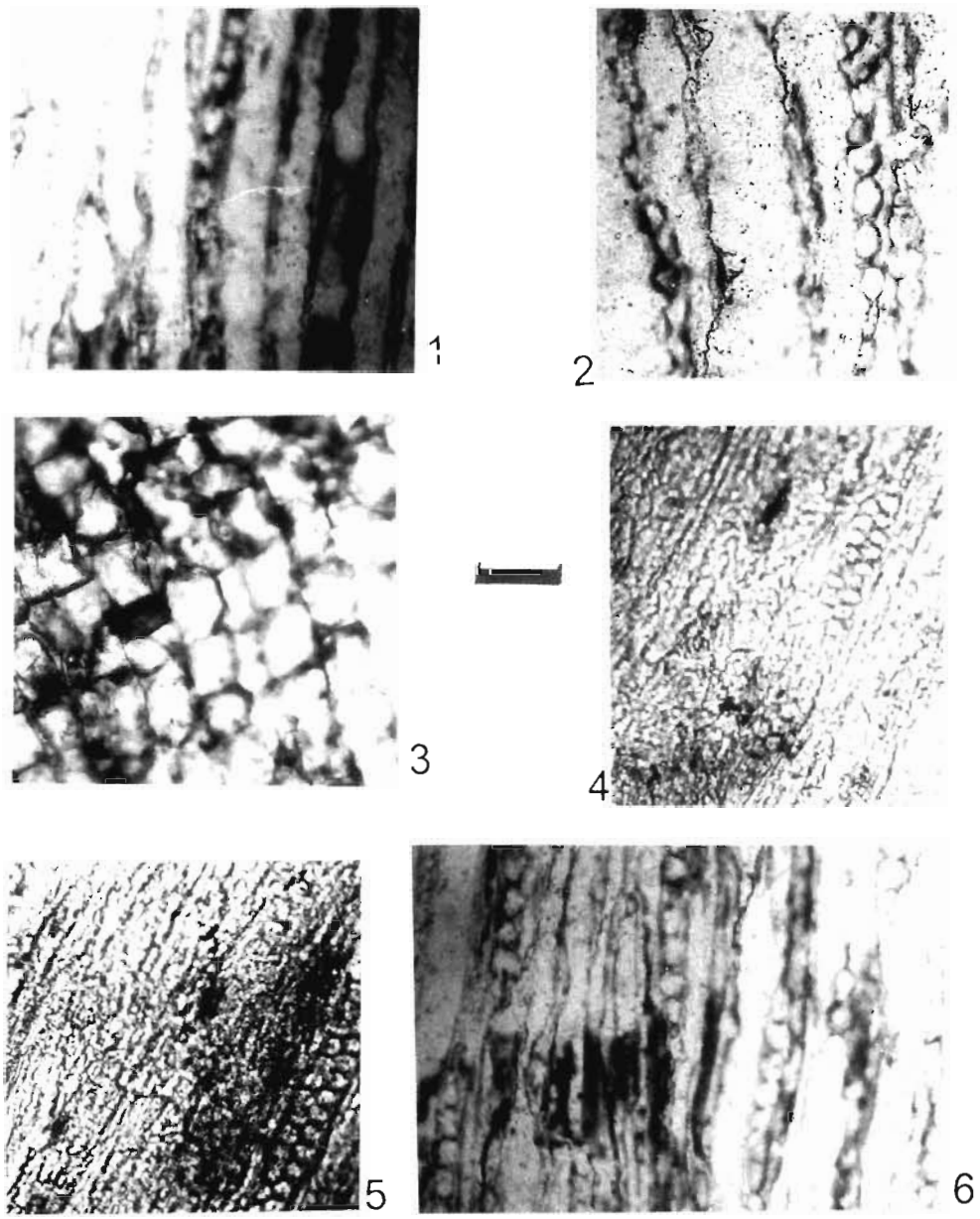


PLATE 2

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

3-6. *Protophyllocladoxylon cortaderitaensis*. Menéndez. 4. Transversal 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 I - Showing the characteristics of the species of *Prototaxoxylon*(*)

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

(*) 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. intertrappeum 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.

Order—CONIFERALES

Family—CUPRESSACEAE

Genus—PROTOCHAMAECYPARIXYLON Giraud 1985

Protochamaecyparixylon klitzchii Giraud
Pl. 1, figs 4, 6; Pl. 2, figs 1, 2; Text-fig. 3

Type species—*P. klitzchii* Giraud, (in Giraud & Hankel) 1985

Description—Decorticated wood fragment, 30 cm in diameter x 35 cm long. Only picnoxylic 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 disttorion 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, araucariod, 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 N° 10253, Sgo- PB N°1596; CTES-PMP N° 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 *Protochamaecyparixylon* 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, 1939

Protophyllocladoxylon cortaderitaensis Menéndez, 1956
Pl. 2, figs 3-6; Text-fig. 4

Type species—*P. leuchsii* 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 N° 10254, Sgo PB- N° 1597 ; CTES-PMP N° 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. cortaderitaensis* Menéndez from the Upper Triassic Barreal Formation of Argentina. With this species it shares the simple punctuation of the cross-fields, the uni-, 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 fluviatile 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.

Acknowledgement—*The research work reported in this paper is supported by FONDECYT Grant No. 1950065. We gratefully acknowledge Eva Acevedo, Claudia Lovera and Orlando Bertoni for their assistance in the preparation of the material. The authors A. Lutz and R. Herbst, together with A. Troncoso (Chile) have collected the specimens.*

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