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PALYNOLOGICAL INVESTIGATIONS OF PALEOZOIC AND LOWER MESOZOIC SEDIMENTARY ROCKS OF CENTRAL CHILE

por

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ABSTRACT

Paleozoic and lower Mesozoic marine, transitional and non marine sedimentary rocks from central Chile were sampled for palynological study. Rare poorly-preserved spores and pollen in one sample from Llafquentué suggest a Late Triassic age. The other ninety-two samples contain palynomorphs too thermally altered to identify or are barren of palynomorphs. The palynomorph remnants indicate the Paleozoic - lower Mesozoic sedimentary sequences throughout central Chile have undergone considerable burial metamorphism, with some local contact metamorphism from adjacent igneous bodies. In most areas metamorphism equivalent to anthracite - meta - anthracite coal rank, or beyond is indicated. Upper Triassic rocks at La Huerta, Hualañé, at Buenuraqui - Gomero, Concepción, and at Llafquentué are slightly less metamorphosed.

RESUMEN

Con el propósito de efectuar investigaciones palinológicas se colectaron muestras de formaciones sedimentarias, marinas, transiciona - les y no marinas de Chile Central. Escasos granos de polen y esporas mal conservados de una muestra de Llafquentué sugieren una edad triásica superior. Las otras noventa y dos muestras contienen palinomorfos demasiado alterados térmicamente para ser identificados o son estériles. Los remanentes de palinomorfos indican que las secuencias sedimentarias del Paleozoico y Mesozoico inferior a lo largo de Chile Central han estado sometidas a un considerable metamorfismo de carga y localmente a metamor -

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fismo de contacto producido por cuerpos ígneos adyacentes, Para la mayoría de las áreas se señalan los equivalentes del metamorfismo en relación con el rango de carbonización (antracita- metantracita o menor). Las rocas triásicas de La Huerta y Hualañé, de Buenuraqui - Gomero y Concepción y de Llafquentué están levemente menos metamorfizadas que las de las demás regiones.

INTRODUCTION

Ninety three (93) samples of fine-grained sedimentary rocks were collected for palynological study in three principal regions of central Chile in November 1978. The samples were from well-dated to poorly- dated Paleozoic and lower Mesozoic marine, transitional and non-marine sequences.

The purpose of the study was, in part, to recover datable palynomorphs from otherwise unfossiliferous or poorly-dated rocks. Another aim was to compare the recovered fossil palynomorph assemblages with those of similar age from other areas of Gondwanaland to determine any regional differences or similarities in the floras. An important objective was to recover palynomorphs from rocks with well-dated marine faunas, particularly from the Middle Triassic - Lower Jurassic succession, in order to correlate the essentially continental Gondwana palynostratigraphy with the standard marine stages.

The sampled areas include the Huentelauquén - Los Vilos- Los Molles area, along the coast northwest of Santiago; the Huelañé = Curepto-Gualleco area, in the coastal ranges southwest of Santiago; and the Concepción area, in the lower River Bío-Bío valley. A few additional samples from Pocillas, Llafquentué and Panguipulli were also provided.(Fig. 1).

Sample lithology included mainly carbonaceous (light grey to black) mudstone and siltstone, with some very fine and fine sandstone , and limestone. Samples were prepared using standard palynological techniques.

Sample collection and palynological work was carried out by R.A. Askin. Stratigraphic and structural interpretation was provided by R. Charrier, F. Hervé, R. Thiele, J. Frutos and others, as noted below.

SAMPLE DATA AND RESULTS

Huentelauquén - Los Vilos - Los Molles area

Forty seven (47) samples were collected (with R. Charrier) from

coastal outcrops at Huentelauquén, Los Vilos, El Puquén, and south of Los Molles (Fig. 1). Sample data (in note form) is as follows:

Mal Paso, north of Huentelauquén (Strata of Quebrada Mal Paso, described by MUNDACA et al., 1979). Permian mudstone with *Productus boliviensis* d' Orbigny. Sample N°G4-38-76 provided by R. Charrier: barren

Punta Tomás, 8 km north of Huentelauquén. Lower and upper breccias . The first including large packets of contorted stratified sediments, and sandy lenses. They probably represent slumped carboniferous? sediments and slope debris accumulated during Early Triassic transgression, respectively, (CHARRIER 1977; MUNDACA et al., 1979) 11 samples: all barren of palynomorphs.

Punta Crucita. Fine sandstone outcrop, marine, relations unknown, possibly older than Puerto Manso breccias (MUNDACA et al., 1979). 1 sample: barren.
Dark shale outcrop, marine, probably equivalent to Huentelauquén Formation. 1 sample: barren.

Huentelauquén, Arrayán Cove (locality A of CHARRIER, 1977). Devonian Arrayán Formation. 1 sample: barren.

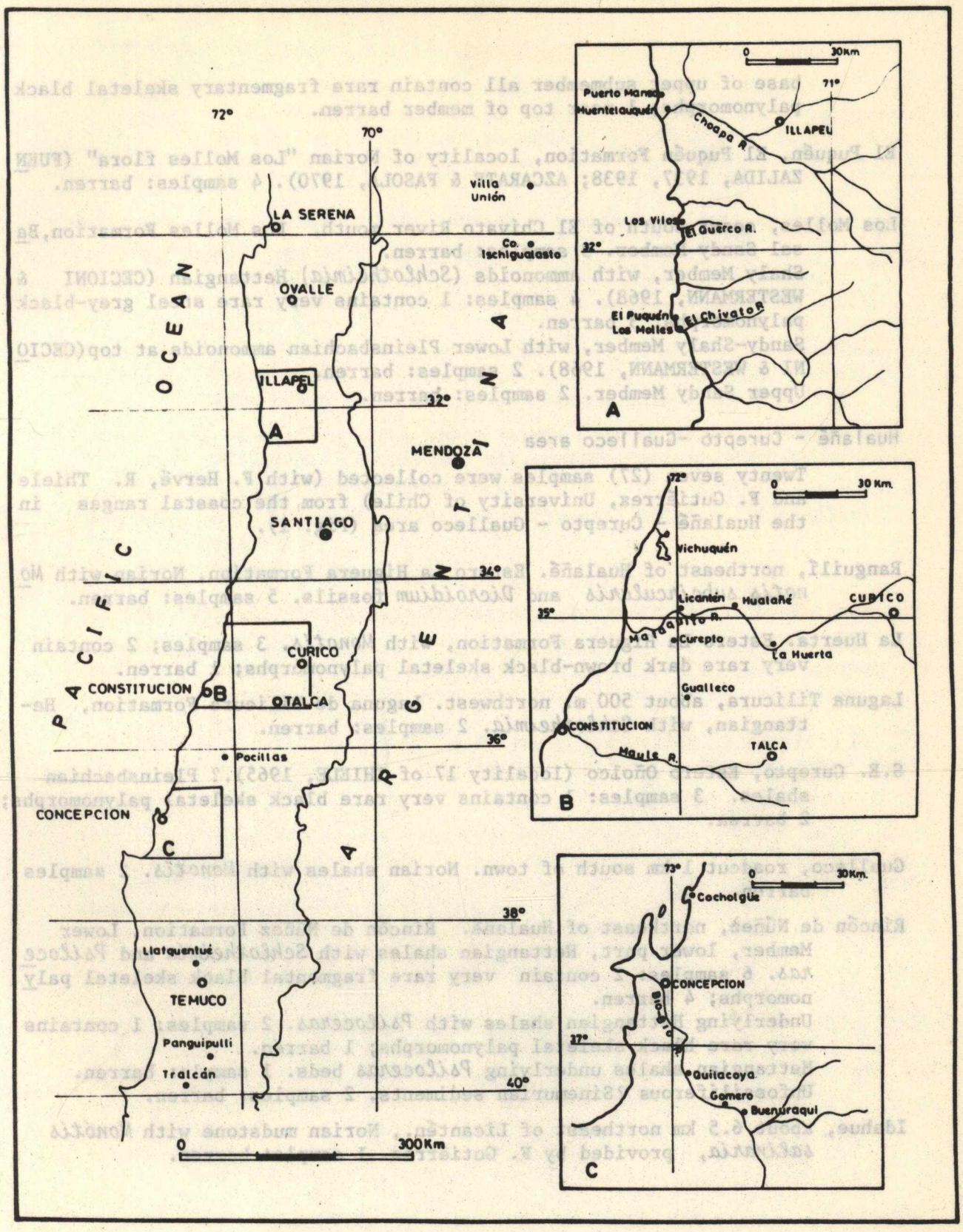
Huentelauquén, Choapa River mouth (locality C of CHARRIER, 1977). Desembocadura Beds of Huentelauquén Formation, black shales with limestone intercalations, with? Carboniferous - Permian marine invertebrates (MINATO and TAZAWA, 1977). 3 samples: barren.

Huentelauquén, Millahue Creek (locality D, CHARRIER, 1977), ? Mesozoic shales. 2 samples: barren.

Los Vilos, Los Cerrillos, Los Vilos Formation (below the unconformity with the El Quereo Formation, see CECIONI & WESTERMANN, 1968) ? Carboniferous sandstone. 2 samples: barren.

Los Vilos, El Quereo River mouth. El Quereo Formation (section described by CECIONI & WESTERMANN, 1968), Graywackes Member, deltaic sediments. 4 samples: 1 sample near base contains very rare black (steel grey) fragmentary spores and bisaccate pollen; 1 barren; 2 samples near top of member at El Quereo River mouth contain rare black skeletal grains barely recognisable as spores and bisaccate pollen.

Shales with Keratophyres Member, with upper Anisian marine invertebrates in lower part (CECIONI & WESTERMANN, 1968). 6 samples: 1 near base of member barren; 2 samples from lower submember, 1 from middle submember (from limestone), and 1 from


72°
70°
LA SERENA
Villa Unión
Co. Ischigualasto
OVALLE
ILLAPEL
A
32°
MENDOZA
SANTIAGO
34°
CURICO
CONSTITUCION
B
TALCA
36°
Pocillas
CONCEPCION
C
38°
Llatquentué
TEMUCO
Panguipulli
Tralcán
40°
0
300Km
PACIFIC OCEAN
ARGENTINA
0
30Km
71°
Puerto Manso
Huentelauquén
Choapa R.
ILLAPEL
Los Vilos
El Quereo R.
32°
El Puquén
Los Molles
El Chivato R.
A
72°
0
30 Km.
Vichuquén
Licantén
Hualañé
CURICO
35°
Mataquito R.
Curepto
La Huerta
Gualleco
CONSTITUCION
TALCA
Maule R.
B
73°
0
30Km.
Cochalgüe
CONCEPCION
Biobío R.
37°
Quitacoya
Gomero
Buenuraqui
C

base of upper submember all contain rare fragmentary skeletal black palynomorphs; 1 near top of member barren.

El Puquén, El Puquén Formation, locality of Norian "Los Molles flora" (FUENZALIDA, 1937, 1938; AZCARATE & FASOLA, 1970). 4 samples: barren.

Los Molles, coast south of El Chivato River mouth. Los Molles Formation, Basal Sandy Member. 3 samples: barren.
Shaly Member, with ammonoids (*Schlotheimia*) Hettangian (CECIONI & WESTERMANN, 1968). 4 samples: 1 contains very rare steel grey-black palynomorphs; 3 barren.
Sandy-Shaly Member, with Lower Pleinsbachian ammonoids at top (CECIONI & WESTERMANN, 1968). 2 samples: barren.
Upper Sandy Member. 2 samples: barren.

Hualañé - Curepto -Gualleco area

Twenty seven (27) samples were collected (with F. Hervé, R. Thiele and F. Gutiérrez, University of Chile) from the coastal ranges in the Hualañé - Curepto - Gualleco area (Fig. 1).

Ranguilí, northeast of Hualañé. Estero La Higuera Formation, Norian with *Monotis subcircularis* and *Dicroidium* fossils. 5 samples: barren.

La Huerta. Estero La Higuera Formation, with *Monotis*. 3 samples; 2 contain very rare dark brown-black skeletal palynomorphs; 1 barren.

Laguna Tilicura, about 500 m. northwest. Laguna de Tilicura Formation, Hettangian, with *Schlotheimia*. 2 samples: barren.

S.E. Curepto, Estero Oñolco (locality 17 of THIELE, 1965).? Pleinsbachian shales. 3 samples: 1 contains very rare black skeletal palynomorphs; 2 barren.

Gualleco, roadcut 1 km south of town. Norian shales with *Monotis*. 2 samples barren.

Rincón de Núñez, northeast of Hualañé. Rincón de Núñez Formation, Lower Member, lower part, Hettangian shales with *Schlotheimia* and *Psiloceras*. 6 samples: 2 contain very rare fragmental black skeletal palynomorphs; 4 barren.
Underlying Hettangian shales with *Psiloceras*. 2 samples: 1 contains very rare black skeletal palynomorphs; 1 barren.
Hettangian shales underlying *Psiloceras* beds. 1 sample: barren.
Unfossiliferous ?Sinemurian sediments. 2 samples: barren.

Idahue, about 6.5 km northeast of Licantén., Norian mudstone with *Monotis salinaria*, provided by F. Gutiérrez. 1 sample: barren.

Concepción área

Fifteen (15) samples were collected (with J. Frutos, L. Díaz, M. E. Cisternas and A. Cecioni, University of Concepción) from the Quilacoya and Buenuraqui - Gomero area in the lower River Bío-Bío valley, and at Cocholgüe north of Concepción (Fig. 1).

Quilacoya, Upper Triassic beds, Member 3 (marine). 1 sample: barren

Cerro Calquinhue, Upper Triassic Member 2 (continental), at coal mine near locality 2 of Tavera, 1960). 3 samples: barren. Same member, in roadcut south of mine. 2 samples: barren.

Buenuraqui, west of station along railway line. ? Member 4 (transitional), Upper Triassic, with *Dicroidium*, etc. 4 samples: 3 contain dark brown-black spores and bisaccate pollen; 1 barren

Gomero, east of station along same railway line as above. ? Member 4 (transitional). 3 samples: all contain corroded dark brown-black spores and bisaccate pollen.

Cocholgüe, on coast north of village, Paleozoic mudstone. 2 samples: barren.

Additional samples provided by F. Hervé

Pocillas. Triassic La Patagua Formation. 1 sample, Pocillas 0-14:barren.

Llafquentué, north of Temuco. Llafquentué-Huimpil Formation, member 2 of PARADA & MORENO (1980). Triassic shale with coaly laminae . 1 sample: contains very rare dark brown spores and pollen.

Panguipulli, north of Tralcán, ? Triassic sediments. 2 samples, Pm 767: barren; Pm 768: contains very rare black fragmental palynomorphs.

Only the sample from Llafquentué contains identifiable palynomorphs. Many other samples contain palynomorphs but they are all skeletal grains unidentifiable even to genus level. Occasionally, as noted above, the original form of a bisaccate pollen grain or a spore can be discerned. These samples are effectively barren.

THERMAL METAMORPHISM

Organic matter, including palynomorphs, is heated after burial and progressively altered with increasing heat at increasing depth of burial. This effect is dependent on the local geothermal gradient and the length of time at raised temperatures.

Thermal alteration of palynomorph wall material manifests itself as a change of color and opacity, from pale yellow is newly produced spores and pollen, through deeper yellow to amber to brown to brown-black, to opaque black which apperars steel grey in thin areas. Palynomorphs at this late stage of thermal alteration are often preserved as skeletal remnants of their former shapes, and are barely recognisable as palynomorphs. This late stage of alteration is equivalent to anthracite - meta-anthracite coal rank.

Besides heating due to increased depth of burial, organic matter is also affected by heating from igneous bodies. Degree of alteration depends on the type of igneous body (its amount of heat), depth of burial (affects cooling rates), distance from the igneous body, and indirectly on factors affecting heat transfer such as water content, porosity and permeability of the intruded sediments.

The lack of palynomorphs in many of the samples from central Chile may be the result of an original absence of palynomorphs caused by, for example, unsuitable paleoenvironments or depositional facies. Palynomorph absence may also be the result of a high grade of metamorphism causing the complete destruction of any palynomorphs present in the rock, which is thought to be the case in many areas. For some, for example, Cocholgüe, probable thermal destruction of palynomorphs is supported by the high metamorphic grade of the rocks themselves. Other organic matter in the barren samples is almost all opaque black - steel gray, and where palynomorphs are observed in adjacent sediments they are highly altered skeletal grains.

It is apparent from the results of this study that the Paleozoic lower Mesozoic sedimentary sequences throughout the sampled areas of central Chile have been subjected to considerable heating. Tectonic history of central Chile during evolution of the southern Andes is extremely complex, as illustrated by AGUIRRE et al., (1974), who presented evidence for many cycles of orogeny and volcanism, with associated granitoid emplacement, in the 30°- 35° S area from the Late Triassic to the Miocene. Evidence for several metamorphic episodes in this Andean region was given by LEVI (1970). The palynomorphs have been thermally metamorphosed and almost or totally destroyed during periods of deep burial. Sediments inmediately adjacent to igneous bodies have probably been further affected by contact metamorphism. Because of the complex nature of the geologic history, no actual temperatures can be suggested from the palynomorph color, as such temperature scales assume continual metamorphism with constant heat flow through time which is almost certainly not the case in central Chile.

Relative thermal alteration of palynomorphs in each of the sampled areas is discussed below. To give an indication of the degree of alteration, palynomorph color is correlated with the coal rank (ASTM standard) scale, based on STAPLIN (1977, Text-fig. 10).

Huentelauquén - Los Vilos - Los Molles área

All sample throughout the Huentelauquén area are barren of palynomorphs. Seven of ten samples of the EL Quereo Formation near Los Vilos contain skeletal palynomorphs at a late stage of thermal alteration, that is, they have been heated to the equivalent of the anthracite-meta-anthracite coal-rank boundary. This formation includes submarine keratophyre flows in one member , is overlain by keratophyres and tuffs (Pichidangui Formation), and is intruded by diabase dikes (CECIONI & WESTERMANN, 1968). One sample of eleven from the Los Molles Formation contains very rare palynomorphs of steel grey - black color equivalent to anthracite- meta -anthracite. The sampled sedimentary units cropping out along the coast are bounded to the east by huge Mesozoic batholithic masses. This activity may account for at least part of the thermal metamorphism in this area.

Hualañé - Curepto - Gualleco area

One sample from the Upper Triassic Estero La Higuera Formation at La Huerta contains skeletal palynomorphs of dark brown - black color. These are slightly less metamorphosed than those from the Los Vilos- Los Molles area, and indicate a thermal alteration state equivalent to anthracite.

The few recognisable palynomorphs in Lower Jurassic shales at Estero Oñolco and Rincón de Núñez, however, are altered to anthracite- meta- anthracite.

Concepción area

Six samples from the Buenuraqui - Gomero section contain rare corroded palynomorphs which are sometimes recognisable as trilete spores and bisaccate pollen. Their dark brown-black color indicates they have been altered to the equivalent of semi anthracite.

Panguipulli

Palynomorphs in one sample from Panguipulli have been altered to the equivalent of anthracite - meta - anthracite.

Llafquentué

Palynomorphs in the sample from Llafquentué are dark brown in color. They are the least metamorphosed of all those mentioned above, corresponding to low volatile bituminous coal rank, and are the only palynomorphs in this study which are assignable to genus and species level.

PALYNOLOGY OF LLAFQUENTUE SAMPLE

The sample from Llafquentué is a dark grey mudstone with coaly

laminae collected in member 2 of Llafquentué-Huimpil Formation (PARADA and MORENO, 1980) on the south east side of Llafquentué valley. The organic fraction of this sample (laboratory preparation number 1659 and repository numbers CUM -95-R to CUM -100-R) consists primarily of woody material and inertinite, with very rare dark brown spores and pollen.

The assemblage is of very low diversity and includes the forms listed below. Most specimens are too poorly preserved to warrant detailed taxonomic treatment, instead an informal listing and brief description is given. Porcentages are based on a count of 200 specimens. Sizes of specimens are given as follows: minimum (average) maximum (number of specimens measured). Number of specimens used for dimensions does not relate to relative abundance number.

A large proportion(29%) of the assemblage is made up of various smooth, granulate and apiculate spores, most of them too poorly preserved to identify. Among them some specimens of *Stereisporites antiquasporites* (WILSON & WEBSTER) DETTMANN 1963 (1%), *Osmundacidites wellmanii* COUPER 1953 (1,5%), plus rare specimens of *Acanthotriletes* sp., *Apiculatisporis* spp., and *?Neoraistrickia taylorii* PLAYFORD & DETTMANN 1965, can be recognised.

Calamospora tener (Leschik) de Jersey 1962. Thin-walled trilete spore, usually distorted and folded; short laesurae; exine smooth; diameter 39 - 53µm (5 specimens); 3,5 % (Pl.1, Fig.1).

Dictyophyllidites mortoni (de Jersey) PLAYFORD & DETTMANN 1965. Subtriangular trilete spores; laesurae about 3/4 radius, usually with narrow elevated lips; exine about 1 µm thick, smooth, with proximal arcuate thickenings 2 - 4 µm wide adjacent to laesurae, may exhibit prominent arcuate folds; diameter 26(37) 46 µm (20 specimens); 18% (Pl. 1, figs 2,3).

Dictyophyllidites harrisii COUPER 1958. Similar to *D. mortoni* but larger and with less prominent proximal thickenings and folds;47 (51) 56 µm (10 specimens); 4,5 %.

Annulispora folliculosa (Rogalska) de Jersey 1959. Subcircular trilete spores; laesurae up to 3/4 radius, usually with slightly thickened lips; exine smooth, cingulate, cingulum 2 -3 µm wide; with distal annular thickening 2 - 4 µm wide, external diameter 14- 19 µm, outer margin lobate. The species is broadly interpreted here and also includes forms with thicker lips in polar area than was originally described for the species. Diameter 23 (29) 35 µm (10 specimens); 2.5 % (Pl. 1, figs.4,5).

Bisaccate pollen, 16.5%, most too poorly preserved for identification , although many appear to be assignable to the genus *Alisporites*, as broadly interpreted by de JERSEY (1962). Some specimens of *Alisporites australis* de JERSEY 1962 (Pl.1, Fig. 7) are recognised, plus one specimen of *Sulcosaccispora alaticonformis* (Malyakina) de Jersey 1968. Only one possible taeniate bisaccate specimen was observed; this was a very poorly preserved torn diploxylonoid grain.

Equisetosporites cacheutensis JAIN 1968. Polyplicate pollen, rounded to elongate oval; exine with 7 - 10 longitudinal ridges 2-4 µm wide, coalesce at ends, separated by furrows 1 -2 µm wide; inner layer or intexine usually distinctly and widely separated from ends of grain; length 55 (62) 73 µm, width 24 (34) 48 µm (7 specimens); 3,5% (Pl. 1, Figs. 6, 10).

Cycadopites spp., 20%. Monocolpate pollen which includes generally smooth forms included in *Cycadopites nitidus* (Balme) de JERSEY 1964, 21 (43) 52 µm x 13 (23) 30 µm (20 specimens), 10% (Pl.1, Fig. 8); and smooth forms with thickened margins along the colpus included in *C. crassimarginis* (de Jersey) de JERSEY 1964, 31 (43) 52 µm x 16 (24) 32 µm (10 specimens), 4% (Pl. 1, Fig. 9).

Age

The Llafquentué palynomorph assemblage is believed to be of Late Triassic age, based partly on the ocurrence of relatively common *Annulispora folliculosa*. The first appearance of *A. folliculosa* helps define the base of the *Crateristporites rotundus* Zone of southeastern Queensland, Australia (de JERSEY, 1975), and the base of subzone C of the *Alisporites* zone in the Transantarctic Mountains (KYLE, 1977; KYLE & SCHOPF in press). The *Crateristporites rotundus* Zone (Ipswich Coal Measures) was suggested to be of Late Triassic age, probably Karnian (de JERSEY, 1971a, 1975), although this conclusion was based on somewhat indirect methods, as no marine invertebrate age control is available. The species has a similar Upper Triassic distribution in Tasmania (PLAYFORD, 1965) and the Carnarvon Basin, Western Australia (DOLBY & BALME, 1976). *A. folliculosa* also occurs in Rhaetian marine beds in southwest Auckland, New Zealand (DICKSON, 1972); in Liassic rocks in Queensland (eg. REISER & WILLIAMS, 1969, de JERSEY, 1971b), and was first described from Liassic rocks in Poland (ROGALSKA,1954). To one author's (R.A.A.) knowledge this is the first record of *Annulispora* in South America.

The only other species in the Llafquentué assemblage of stratigraphic significance is *Equisetosporites cacheutensis*. This polyplicate pollen species was described by JAIN (1968) from the Cacheuta Forma

tion at Minas de Petróleo (32 km southwest of Mendoza), Argentina. The plant megafossil assemblage from Minas de Petróleo (Potrerillos Beds, Cacheuta Formation) was originally believed to be Middle Triassic (JAIN & DELEVORYAS, 1967), based mainly on comparison with the Queensland Ipswich flora, then believed to be of Middle Triassic age. Recent comparisons of the plant microfossils (DOLBY & BALME, 1976) and megafossils (RETALLACK, 1977) still equate the Minas de Petróleo flora with the Ipswich, now generally accepted as Late Triassic. The presence of the apparently restricted species *E. cacheutensis* suggests correlation of the Llafquentué beds with the Upper Triassic Cacheuta Formation. Other species such as *O. wellmanii* (= *O cacheutensis* Jain), plus bisaccate and monocolpate species, appear to be in common with the Minas de Petróleo assemblage, although a more conservative taxonomic approach is used for the Llafquentué palynomorphs, due in part to their poor preservation. These other species are, however, of wide distribution through time and are thus of little stratigraphic value.

The Late Triassic age indicated by the palynomorphs agrees with the previous conclusions of FRITZCHE (1921) and HERNANDEZ (in HAUSER, 1970) based on plant megafossil collections.

Regional considerations

The Llafquentué assemblage is very restricted in composition, and is unusual when compared with other southern Late Triassic palynofloras in that it includes a relatively small percentage (16,5%) of bisaccate pollen. Southern (or Gondwana) Late Triassic assemblages are usually dominated by bisaccates. Even the similar-aged Minas de Petróleo assemblage, which contains an unusually high proportion of monocolpate (24%) and alete (23%) forms, includes 46.5% "non-striate saccate pollen grains" (JAIN, 1968).

The Llafquentué assemblage contains a high proportion (20%) of monocolpate pollen, a feature in common with other Argentinian Triassic floras, for example, Minas de Petróleo (JAIN, 1968) and Ischigualasto - Villa Unión (HERBST, 1965, 1970). It is however, dominated by simple trilete spores (55%), including smooth and apiculate forms, *D. mortoni* being the predominant species. HERBST (1972) pointed out a curious similarity in Argentinian Triassic palynofloras which distinguishes them from other Gondwana floras, namely the very low percentage (1-3%)of trilete spores, the great majority of which are of relatively simple morphology. The Llafquentué trilete spores are also mainly simple morphotypes, as noted above, but they are far more abundant than in the Argentinian assemblages of similar age to the northeast.

In terms of DOLBY & BALME's (1976) Gondwana microfloristic provinces, the Llafquentué flora is most similar to the "Ipswich Microflo-

ra", a widespread high-latitude Middle -Late Triassic plant association. Although the poor preservation and restricted nature of this microfossil assemblage precludes a certain assignment, the central Chilean plant megafossils support correlation with the Ipswich plant association. This conclusion is also consistent with its paleolatitude on a Triassic Gondwanaland reconstruction (Fig. 8 of DOLBY & BALME, 1976, after SMITH et al., 1973).

The sample probably represents sediments accumulated in a restricted environment such as a swampy backwater, and includes mostly the spores and monocolpate pollen of plants growing in and inmediately around the site of deposition. PARADA and MORENO (1980) arrived at similar conclusions for the depositional environment.

CONCLUDING REMARKS

One sample from central Chile, from Llafquentué, contains palynomorphs identifiable to genus and species level. The Llafquentué assemblage is poorly preserved due to thermal alteration, and of very low diversity. We believe it represents an assemblage of spores and pollen produced mainly by plants growing in and inmediately around a restricted site of deposition, probably a swampy backwater. The palynomorph assemblage suggests a Late Triassic age for the Llafquentué beds, consistent with previous plant megafossil evidence.

Ninety two (92) other samples collected from Paleozoic and lower Mesozoic sedimentary rocks of central Chile are barren of palynomorphs or effectively barren, that is they contain rare palynomorphs too poorly preserved to identify. These effectively barren samples do, however, provide an indication, from the color of the few remaining palynomorphs, of the degree of thermal metamorphism the rocks have undergone. They show that the sampled Paleozoic and lower Mesozoic sedimentary rocks in central Chile have been subjected to considerable heating during deep burial. Most have been thermally metamorphosed to at least the equivalent of anthracite - meta -anthracite coal, and many probably beyond that. The Upper Triassic Estero La Higuera Formation at La Huerta, Hualañé area, and the Upper Triassic sediments at Buenuraqui - Gomero, Concepción area, are slightly less metamorphosed. The Llafquentué beds are the least metamorphosed of all those examined in this study. There the dark brown palynomorph color indicates a degree of alteration equivalent to low volatile bitominous coal.

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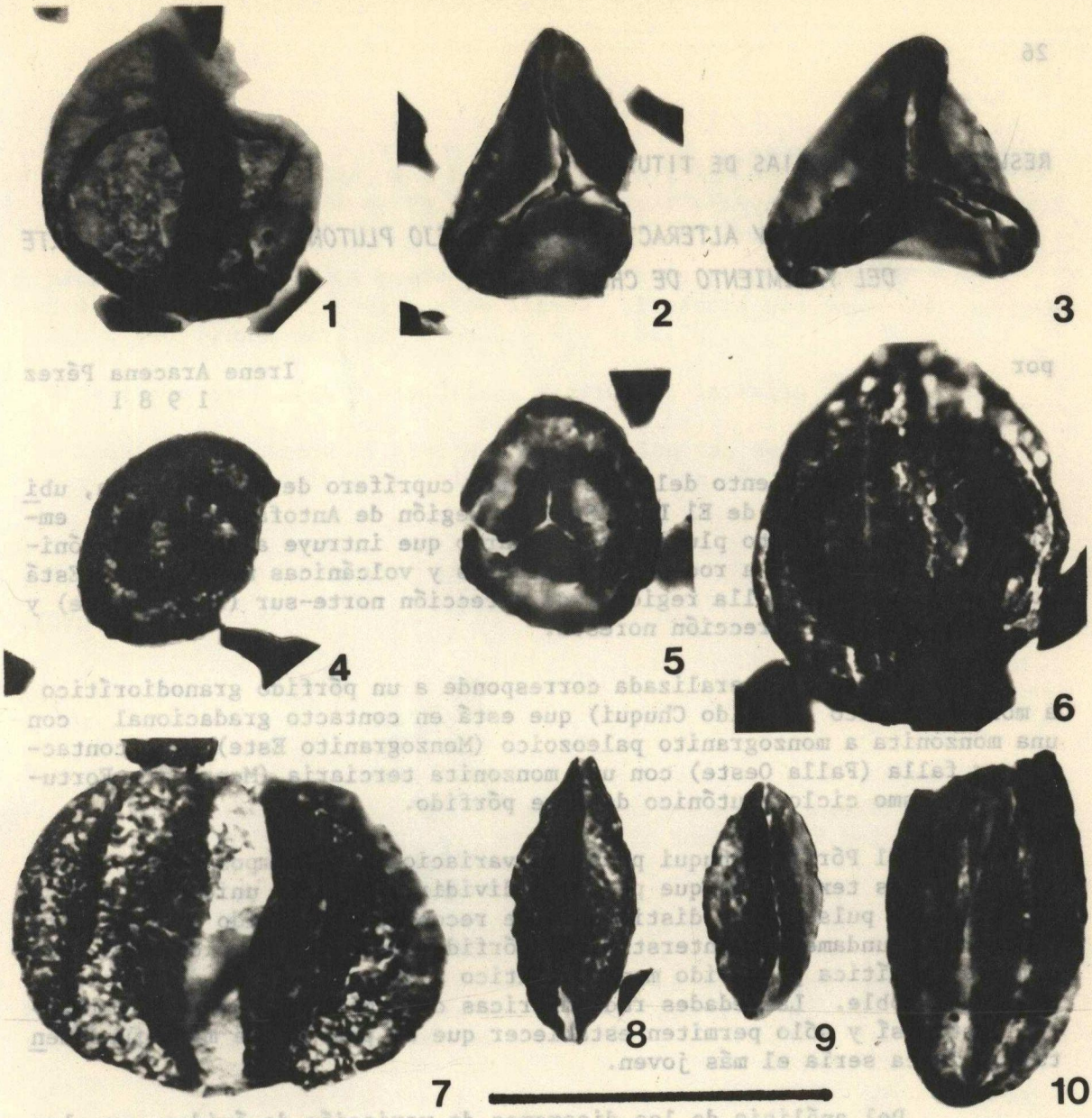

PLATE 1 Photomicrographs of plant microfossils from member 2, Llafquentué-Huimpil Formation, Llafquentué, Chile. Magnification x 1000 (bar is equivalent to 50 microns). Figured specimens area stored on circled microslides in the Reference Collection at the Centro Universitario de Micropaleontología (CUM), División de Geología, Departamento de Geología y Geofísica, Universidad de Chile, Santiago. 1. *Calamospora tener* (Leschik) de Jersey. (1659/1; CUM-95-R). 2,3 *Dictyophyllidites mortoni* (de Jersey) Playford & Dettmann. 3 shows prominent arcuate folds. (2. 1659/10; CUM-98 R. 3.1659/11; CUM-99 R). 4,5 *Annulispora folliculosa* (Rogalska) de Jersey. (4. 1659/13; CUM-100-R. 5. 1659/8; CUM-96-R. 6,10. *Equisetosporites cacheutensis* Jain. (6.1659/13; CUM-100-R. 10. 1659/11; CUM-98-R). 7. *Alisporites australis* de Jersey. (1659/1; CUM - 95-R). 8. *Cycadopites nitidus* (Balme) de Jersey. (1659/8; CUM -96-R). 9. *Cycadopites crassimarginis* (de Jersey) de Jersey. (1659/9; CUM-97-R).