ISSN (print): 1698-6180. ISSN (online): 1886-7995
www.ucm.es/info/estratig/journal.htm

Journal of Iberian Geology 33 (1) 2007: 93-124

Journal of Iberian Geology
AN INTERNATIONAL PUBLICATION OF EARTH SCIENCES

The Early Permian of Valdeviar in Sevilla province, SW Spain: basin history and climatic/palaeogeographic implications

El Pérmico Inferior de Valdeviar (Sevilla), SW de España: geología histórica de la cuenca e implicaciones climáticas y paleogeográficas

R.H. Wagner[1], E. J. Mayoral[2]

[1]*Centro Paleobotánico, Jardín Botánico de Córdoba, Avda. de Linneo, s/n, 14004 Córdoba (Spain); cr1wagro@uco.es.*
[2]*Departamento de Geodinámica y Paleontología, Facultad de Ciencias Experimentales, Universidad de Huelva, Campus de El Carmen, Avda. de las Fuerzas Armadas, s/n, 21071 Huelva (Spain); mayoral@uhu.es*

Received: 19/12/05 / Accepted: 12/04/06

Abstract

Lower Permian sediments are described from a continental basin, which expanded gradually southwards from a local area with significant palaeotopography. It accumulated red beds, acidic volcaniclastic deposits, and basaltic lava flows with a small representation of more acidic lavas. A volcanic centre has been detected at 3-5 km distance to the NE of the Valdeviar Basin. Fluviatile conglomerates with an admixture of local screes and braided conglomeratic sandstones occur in the initial basin, but the overall facies conditions are more generally lacustrine in upward succession, with shales and siltstones containing ichnofossils, drifted plant remains, and occasional stands of small trees. Periodic drying led to soil formation with reddening. Red beds in the higher part of the succession contain lenticular sandstone and conglomerate bodies showing density flow as well as more occasional fluviatile facies corresponding to ephemeral streams. Flash flood deposits occur higher up in the succession. These higher red beds, overlying the volcaniclastic deposits, show southeasterly onlap to where they overlie directly the weathered surface of intrusive rocks constituting the local basement. Silicified conifer/cordaite logs occur in a substantial part of the higher red beds where trees standing on a topographic relief on the basin margin were uprooted and swept down into the basin by mass flow. Lingering volcanic influences will have provided the free silica which penetrated the wood cells. Caliches are found higher in these red beds. Well preserved plant assemblages collected from lacustrine deposits belong almost exclusively to sphenopsids, ferns, pteridosperms and cordaites, but sizeable lycopsid trunks also occur. About 40 taxa have been identified, altogether, and these are partially illustrated. They are characteristic of lower Rotliegend/mid Autunian. Conifer foliage has only been recorded from one locality, and peltasperms are rare to absent. Comparison is made with Guadalcanal, at about 30 km distance, where lacustrine deposits have also yielded Autunian flora. Some ichnofossils are illustrated as well. Stratigraphic sections are recorded and significant sedimentary processes are explained by description and illustration. An overlying succession of red beds with brick red colours, and containing more substantial calcareous horizons (caliches), are probably of Triassic age. These paraconformable strata, occurring in the southern part of the Valdeviar depression, are recorded but not described in the present paper. The regional tectonic and palaeogeographic conditions of the Early Permian basin are discussed.

Keywords: Permian, Triassic, Rotliegend, Autunian, Sierra Morena, Sevilla, Spain, red beds, palaeobotany, ichnofossils.

Resumen

Se describe el relleno de una cuenca continental del Pérmico Inferior, que muestra una expansión gradual hacia el SE y que comienza en su extremo NW con depósitos correspondientes a una paleotopografía fuerte. En esta cuenca se acumularon, además, capas rojas, depósitos volcanoclásticos ácidos, y coladas de basalto con una representación menor de lavas más ácidas. Un centro volcánico fue detectado a unos 3 a 5 km al NE de la cuenca de Valdeviar. Conglomerados fluviales con un fuerte elemento brechoide sugieren el cauce de un río caudaloso con aportes laterales de coluvión de un paleorelieve importante. Siguen areniscas conglomeráticas de tipo braided. Estos depósitos caracterizan al relleno inicial de la cuenca, pero las condiciones sedimentarias se cambiaron predominantemente a lacustres más adelante, con lutitas y limolitas que muestran icnofósiles, restos vegetales flotados, y agrupaciones locales de árboles pequeños. Se secaron las áreas lacustres periódicamente, dando lugar a un régimen oxidante con formación de suelos. Las capas rojas superiores, lutíticas, contienen areniscas y conglomerados lenticulares que representan canales someros, efímeros, además de coladas de arenisca fina. Depósitos de tipo "flash flood" se presentan en la parte alta de las capas rojas superiores, donde éstas muestran un solapado hacia el SSE, llegando a descansar directamente sobre la superficie meteorizada de un granito. Restos de tronco de coníferas y/o Cordaitales se encuentran en buena parte de las capas rojas superiores. Corresponden a árboles que vivían sobre un paleorelieve en el borde de la cuenca, y que fueron desarraigados por la movilización de los suelos convertidos en corrientes densas que los llevaron a la cuenca. Procesos volcánicos residuales habrán favorecido una silicificación de los troncos por el relleno de las células de madera. Hay niveles de caliche en la parte alta de las capas rojas superiores. Los elementos de flora hallados en los sedimentos lacustres pertenecen a esfenópsidas, helechos, pteridospermas, y cordaites, además de raros troncos de licópsida; es una asociación de facies húmeda. Los restos de flora, de buena preservación, representan unos 40 taxones, de los que se figuran varios. Caracterizan al "Rotliegend" inferior (Autuniense medio). Follaje de coníferas solamente se encontró en una localidad, y no hay más de un solo registro de peltaspermácea. Se compara con el Autuniense de Guadalcanal, a unos 30 km de Valdeviar. Allí se han registrado también floras de régimen lacustre. Se describen cortes estratigráficos parciales, así como los procesos sedimentarios más característicos, con los dibujos y fotos correspondientes. Se facilitan también ilustraciones de algunos icnofósiles. Una sucesión de capas rojas color ladrillo y que muestra un desarrollo fuerte de caliches, es atribuída al Triásico. Se encuentra en paraconformidad en la parte Sur de la depresión de Valdeviar. Se comentan las condiciones tectónicas y paleogeográficas de la cuenca del Pérmico inferior.

Palabras clave: Pérmico, Triásico, Rotliegend, Autuniense, Sierra Morena, Sevilla, España, capas rojas, Paleobotánica, icnofósiles.

1. Introduction

In the Sierra Norte of the province of Sevilla, Sierra Morena, Andalusia, a narrow, elongate basin (33 x 6 km), striking NW-SE, contains non-marine Lower Permian sediments in the Viar river valley. The Viar is a tributary of the Guadalquivir River, flowing into the Atlantic Ocean south of Sevilla (Fig. 1). This is the southernmost occurrence of Permian strata in western Europe, but equivalents exist in Morocco. Lower Permian deposits occur in various different parts of the Iberian Peninsula as well as in other parts of western Europe. The Lower Permian strata of Valdeviar commence with fluviatile conglomerates and sandstones in the extreme NW part of the basin where they are overlain by substantial flows of basalt filling up a palaeotopography. On the SSE side of the basin the Lower Permian red beds are overlain (together with a succession of paraconformable, probable Triassic strata) by marine Tertiary deposits of the Guadalquivir Basin (Fig. 2). The Valdeviar depression is bounded to the Northeast by mountains, a few hundred metres high, which are constituted by igneous rocks and Precambrian metamorphics followed by Palaeozoic strata, from Cambrian (poorly dated) to upper Devonian and Mississippian sediments (Sanz and Ledesma, 1975). Although the present-day topography is perhaps a little higher than that of Early Permian times, a similar palaeotopography seems to have existed. A tectonically undisturbed volcanic complex of presumed Early Permian age has been found intruded into cleaved mudstones of the Cambrian at some 3 to 5 km NE of the Valdeviar (Wagner and Mayoral, 2005).

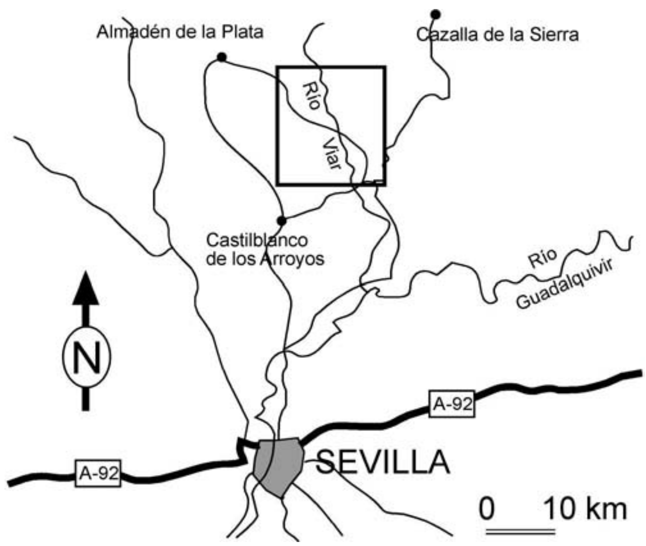

Fig. 1.- Location of Valdeviar Basin in western Andalusia.
Fig. 1.- Situación de la cuenca de Valdeviar en Andalucía occidental.

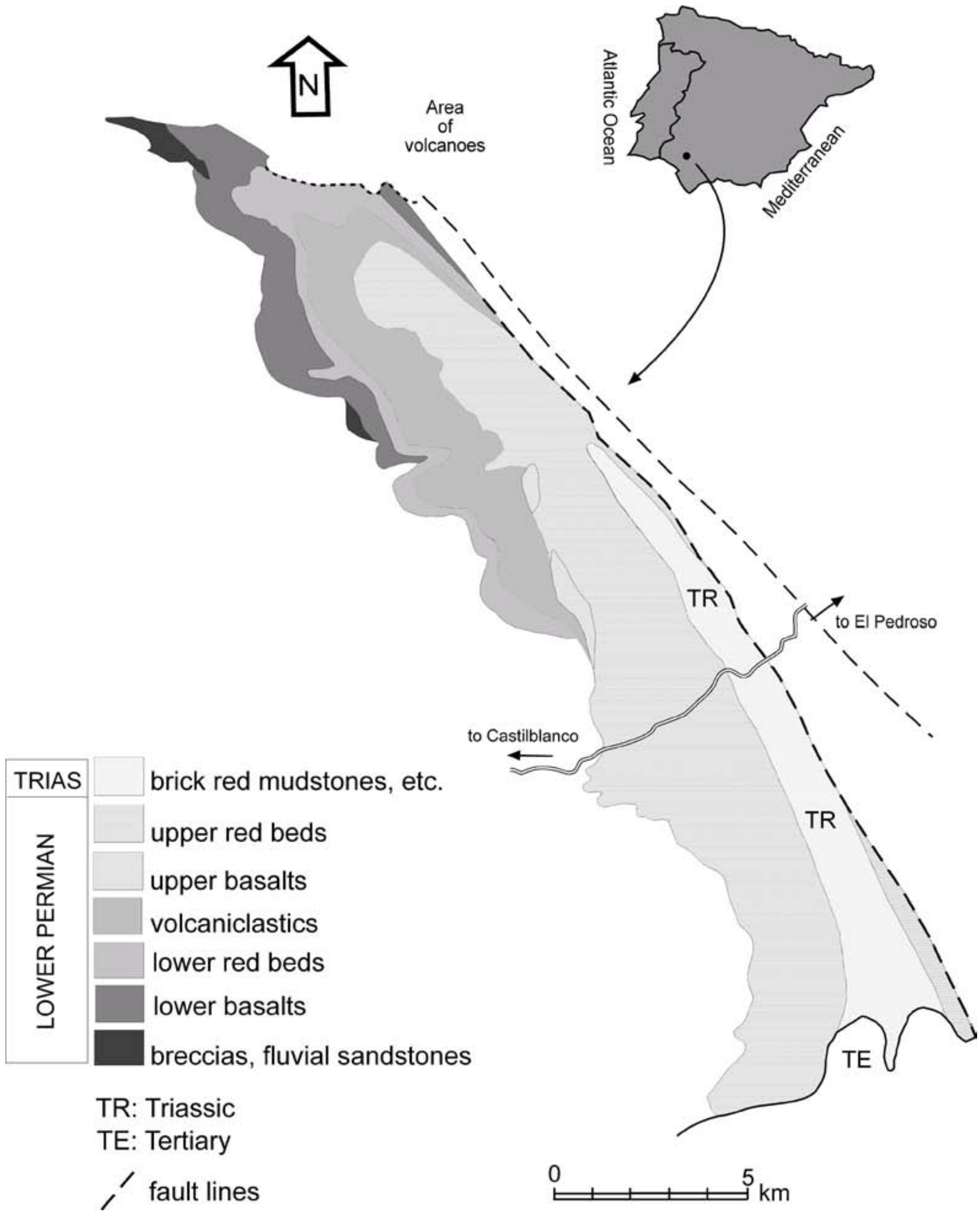

Fig. 2.- General Geological Map of Valdeviar Basin. Basement area left blank.
Fig. 2.- Mapa geológico general de la cuenca de Valdeviar. Área de basamento en blanco.

The contact between the Lower Permian deposits and Precambrian to Lower Palaeozoic (mainly Cambrian) sediments as well as poorly dated Devonian and Mississippian strata to the NE, is reputedly a steeply dipping fault, which has been interpreted as a normal fault by Gavala (1927) and as a reverse fault by Simon (1943) and later authors. However, an unconformable sedimentary contact between the Lower Permian and underlying, presumed Mississippian limestone has been observed in one locality in the north-northeastern part of Valdeviar, and it is clear that the Permian deposits are not fault-bounded everywhere on the NE side of the basin. However, the generally flat-lying Lower Permian sediments have been steepened significantly near the northeastern boundary. This must be due to post-Permian or even post-Triassic tectonic movements, possibly associated with the reactivation of important fault zones of pre-Early Permian times. The dip diminishes rapidly southwestwards to a subhorizontal position of strata which reflects the essentially unfolded condition of the Lower Permian deposits in Valdeviar. On the southwestern side the dip is only a few degrees basinwards. The general impression created is that of a strongly asymmetrical synclinal structure. On the undisturbed southwestern side of the basin an unconformable contact is observed between subhorizontal Lower Permian sediments including basalt flows lapping up against a palaeotopography on tectonically deformed Lower Palaeozoic strata with igneous intrusions. Whereas the underlying rocks on the NE side of the Valdeviar Basin are assigned to the Ossa-Morena Zone of Lotze (1945), those on the SW side have been referred to the South Portuguese Zone, apparently for reasons of structural geology (Simancas, 1983, 1985). However, a re-examination of the structural interpretation may be in order. Indeed, the rocks found on the SW side of the Valdeviar Basin, in the general area of Castilblanco, are more similar to those of Ossa-Morena than they are to those of the South Portuguese Zone. Simancas (1983) postulated that the Valdeviar Basin would correspond to subsidence on the SW side of the fault which he considered to be the Ossa-Morena/South Portuguese boundary, and ascribed a syn-sedimentary movement to this fault late in its tectonic history. Field evidence shows this to be unlikely. An important fault zone exists to the NE of the Valdeviar Basin, but it is unclear that this fault zone delimited the Early Permian Basin.

Wagner (2004) has shown that local basins of various Pennsylvanian ages in the Ossa-Morena Zone and the adjacent Lusitanian-Alcudian Zone originated alongside major strike-slip faults with hundreds to thousands of kilometres lateral displacement, and that the various segments of the Ossa-Morena Zone were different terranes that came finally together near the end of Pennsylvanian times when full assembly was achieved. The Iberian Massif did not exist as an entity before Stephanian C (= early Autunian) times*.

The tectonic and sedimentary history of the Valdeviar basin is similar to that of Early Permian basins elsewhere in the Iberian Peninsula, and this has palaeogeographic and climatic implications which need to be discussed.

2. Published data: a critical appraisal

The area covered by the Valdeviar Basin occupies parts of the Geological Survey 1:50,000 map sheets of Castilblanco de los Arroyos (Martín Escorza and Rivas Ponce, 1975), Almadén de la Plata (García Monzón *et al*., 1974), Ventas Quemadas (Sanz and Ledesma, 1975), and Lora del Río (García *et al*., 1975).

Simancas (1985) presented a general map of the Valdeviar Basin in conjunction with a stratigraphic column showing the following units, from the base upwards: red conglomerates (1) followed by basalts (2), a further interval of red beds (3), a grey unit including siliceous rocks (4), another basalt (5), and a further, more major interval of red beds (6). This succession is distributed in such a manner that the higher red beds are seen to overlap the lower stratigraphic units south-southeastwards. Simancas invoked wedging, which is partially true, but the published maps show evidence of a palaeotopography filled in by the lower units, whilst the higher red beds show onlap south-southeastwards due to a gradual expansion of the basinal area. Indeed, unit (6) rests on basement rocks in the southeastern subarea of the Valdeviar Basin, where these higher red beds overlie a weathered surface on granite. Onlap within the higher red bed succession is also apparent from facies considerations.

The map and stratigraphic column published by Simancas (1985) have served as a support for the sedimentological studies by Sierra and Moreno (1998, 2004). On the whole, the general geological map by Simancas (1985) provided a useful guide to the stratigraphic units present in the Valdeviar Basin, but he failed to recognise the volcaniclastic nature of his grey unit (4), and the onlap relationships were not taken into account. Sierra *et al*. (1999) and Sierra and Moreno (2004) described alluvial fan deposits at the base of the lower red bed succession, in the NW part of the basin. These were regarded as having been linked to upstanding relief on the NE (Ossa-Morena) side of the sedimentary basin, but this conclusion is subject to reservation in view of the local nature of the breccias (in fact, conglomerates with an admixture of angular clasts), which do not occur all along the northeastern boundary of the basin. These strata, which occur in the extreme northwestern part of the basin, are perhaps better interpreted as fluviatile valley fill deposits. The upper red beds (6) were described by these authors as representing sedimentation on a floodplain with a NW directed drainage pattern; the clastic deposits would have originated from a source area to the NE. A general evolution from braided stream deposits to a floodplain with meandering river courses was deduced by Sierra and Moreno (2004), who also recorded the presence of caliches. However, their emphasis on fluvial processes is questionable, and they recorded far too large a proportion of sand bodies in the upper red bed succession (see the stratigraphic column published by Sierra and Moreno, 1998, 2004). These red beds are predominantly silty mudstones, often thinly bedded though commonly homogenised by soil processes. The lenticular sandy and conglomeratic intercalations present a mixture of localised stream and flash flood deposits in the general context of a shallow lacustrine basin with evidence of ephemeral ponding. This differs appreciably from the interpretation by the cited authors.

After initially following the description by Simancas (1985), the grey bed interval was studied in detail by Sie-

* An analysis of floral records in the St. Étienne and Autun basins in south-central France suggests that Stephanian C of St. Étienne and lower Autunian of Autun are time-equivalent (Wagner, 1998). These two basins had an independent existence.

rra *et al*. (2000) after they were made aware by one of the present writers (RHW) that this was a volcaniclastic unit, with well preserved fossil plant remains occurring quite commonly on certain horizons where fine volcanic ash fell into a lacustrine environment. They determined the presence of dacitic-rhyolitic tuffs and tuffaceous rocks, and stated that the volcanic source would lie to the North, a conclusion which seems to have been reached on the assumption that the volcaniclastic strata would wedge southwards. It is true that the cream-coloured interval with volcaniclastic beds, up to 40 m thick according to Sierra *et al*. (2000), is found only in the northern part of the basin, but this is probably due to the infilling of a basinal depression with onlap in south-southeastern direction. The volcanic centre has recently been detected at about 3-5 km NE of the Viar Basin (Wagner and Mayoral, 2005) (Fig. 2).

Explosive volcanism is a common denominator in Lower Permian sediments of the Iberian Peninsula and elsewhere in Europe, with an early occurrence of Stephanian C (= early Autunian) age in Puertollano (Castilla-La Mancha), central Spain (Králík and Pešek, 1985). Six subunits were distinguished by Sierra *et al*. (2000, 2003) in the volcaniclastic unit, and two explosive volcanic events were recognised. However, the succession of volcaniclastic strata as published by these authors is not easily recognised in the field and the present writers distinguish a larger number of eruptions as represented by several pyroclastic intervals and ash fall deposits, followed by ash flow beds in the higher part. Lateral variation in the volcanic ash deposits suggests that the stratigraphic column published by Sierra *et al* (2000) is not generally applicable.

The presence of silicified tree trunks has been reported by Simon (1943), Broutin (1978, 1986), Vozenin-Serra *et al.* (1991), and, most recently, by Sierra and Moreno (2004). No distinction was made by these authors between standing trees and transported logs. Broutin (*op. cit.*) and Vozenin-Serra *et al.* (1991) studied silicified wood from a locality near the base of the higher red beds, presumably from transported logs, and determined the presence of (poorly preserved) cordaitaleans and/or conifers. These silicified logs are flat-lying fragments of tree trunks in mass flow deposits linked to upstanding relief on the northeastern basin margin. Gavala (1927) and Simon (1943) determined an Early Permian age on the basis of plant impressions from the higher red bed unit, and Broutin (1981, 1986) confirmed this age by a microfloral assemblage.

Basalts have been recorded both below and above the volcaniclastic unit. These are of tholeitic composition, according to Simancas and Rodríguez-Gordillo (1980). Basalt flows are involved rather than sills because weathered top surfaces have been found in a stratigraphic succession which also includes siliciclastic deposits.

Simon (1943) recorded greenish grey shale intercalations within the wine-red overlying succession. These yielded plant impression of similar age to those found most recently in the volcaniclastic unit and confirm the continuity in stratigraphic succession within the Valdeviar Basin. The lingering volcanic influences apparently disappear in upward succession, although the permineralisation of transported logs in the overlying siliciclastic succession (higher red beds) is most likely due to volcanic ash being present in the enveloping sediment. Assoumi *et al*. (1992) described dark limestones containing ostracodes and showing pedogenic characters from Gargantafría, apparently from the lower part of the volcaniclastic interval. They also described pedogenic nodules, presumably associated with rooting structures, from higher in the succession.

A final succession of brick red mudstones and sandstones, including conglomerates, and thick bands of caliche, overlies the darker red beds. These occupy the southeastern part of the Valdeviar Basin. A stratigraphic break below these highest deposits is recorded by Sierra (2004), i.e. below her “Tabla de Miradores”. She did not suggest a different age, but Sopeña *et al*. (1983, p. 54) had pointed out already that these higher red beds could well be later in age, and might correspond to Triassic. The find of dinosaur footprints (Bernáldez, 1987) provides confirmation of this assumption.

3. Stratigraphic succession

Conglomerates attributed to alluvial fans by Sierra and Moreno (2004), occur in exposures in the extreme northwestern part of the basin, not far from Almadén de la Plata. These strata, which include both rounded pebbles and angular clasts of different sizes, possess a reddish matrix. The mixture of different degrees of rounding and angularity, as well as a variety of clast sizes, suggest fluvial bed load with an admixture of angular scree elements of more local origin. The conglomerates and conglomeratic sandstones are followed in succession by coarse sandstones, partly conglomeratic, with low-angle cross bedding and shallow channel forms, suggestive of braided stream deposits (Fig. 3). Altogether, some 80-100 m are represented of these almost flat-lying strata, which appear to abut laterally onto a sizeable palaeotopography. Rather than alluvial fan, these appear to be valley fill deposits. The area occupied by these strata is surrounded by mountains representing the remnant of the ancient palaeotopography. The palaeovalley presumably deepened northwestwards, since the c. 80-100 m thick valley fill deposits thin in the opposite direction where overlying basalt flows provide a reliable datum, and where only a few tens of metres of siliciclastics are found eventually below the basalts. Both siliciclastics and basalts lap up against a palaeotopography in this southeasterly direction.

The assumption by Sierra and Moreno (2004) that alluvial fan deposits would be associated with the NE basin margin, which they regarded as a syn-sedimentary fault, is clearly untenable. The Early Permian basin commenced with a valley fill in the extreme northwestern area and most of the Valdeviar Basin as presently exposed became gradually incorporated by southeasterly onlap. This is a completely different scenario.

The sandstones with low-angle cross bedding and shallow channel forms which suggest braided stream deposits, are more laterally extensive than the underlying conglomerates. The sandstones are involved in the southeasterly onlap, and thin in this direction. Only 8 m of cross-bedded sandstone are found in the Los Canchales 1 section, corresponding to a more southerly area in the northwestern part of the basin (Wagner and Mayoral, 2005, Fig. 2). Overlying and intercalated with the conglomeratic sandstones of the braided stream deposits, wine-red silty mudstones and siltstones occur with fine-grained sandstone intercalations. In one of these sandstones, the large bilobate trace fossil *Psammichnites gigas* Torell 1870 (Fig. 4) has been found. The red beds are, on the whole, massive (homogenised) slightly silty to silty mudstones, apparently indicative of soil formation in an oxidising environment. A measured section (Los Canchales 1; Wagner and Mayoral, 2005, fig. 2) shows 11.50 m of red beds followed by 8 m of coarse-grained, conglomeratic sandstone with cross-bedding and shallow channel bases (indicative of braided stream deposits) and, subsequently, 5 m of poorly exposed red silty mudstone with fine-grained, greenish sandstone intercalations. This section, as measured on the hillside flanking the river valley of Gargantafría (Fig. 5), a tributary of the Viar river, continues with 15 m of basalts, as a massive unit (no individual flows detected) with a weathered top surface showing red mud drapes and a sedimentary breccia on top. This basalt laps up against a palaeotopography in places on the northwestern border of the Valdeviar Basin (see the geological maps of García Monzón *et al*., 1974, and Simancas, 1985). A poorly exposed red mudstone, 3 m thick, follows in succession. Subsequent deposits are 20 m of basalt with a weathered top surface overlain by red and green mudrock which incorporates balls of weathered alveolar basalt (Fig. 6). As mentioned already by Simancas (1985), these are clearly basalt flows. This implies a deep-seated fracture zone tapping material from the mantle. The greatest thickness of basalt is present in the extreme northwestern part of the Valdeviar Basin, where it overlies predominantly fluviatile deposits. On the western side of this part of the basin the basalts lap

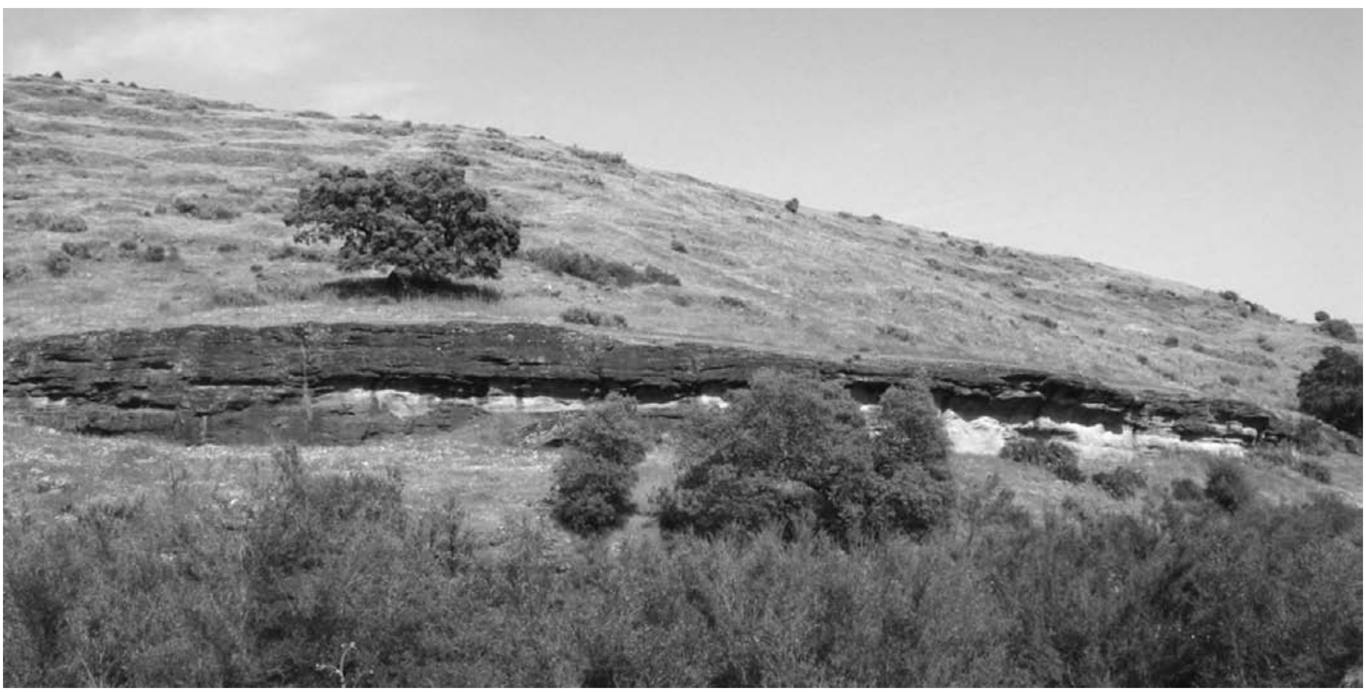

Fig. 3.- Fluviatile sandstones in valley fill deposits at the base of the succession, extreme northwestern part of the Valdeviar basin.
Fig. 3.- Areniscas fluviales en el relleno de paleovalle al comienzo de la sucesión estratigráfica de Valdeviar; extremo NW de la cuenca.

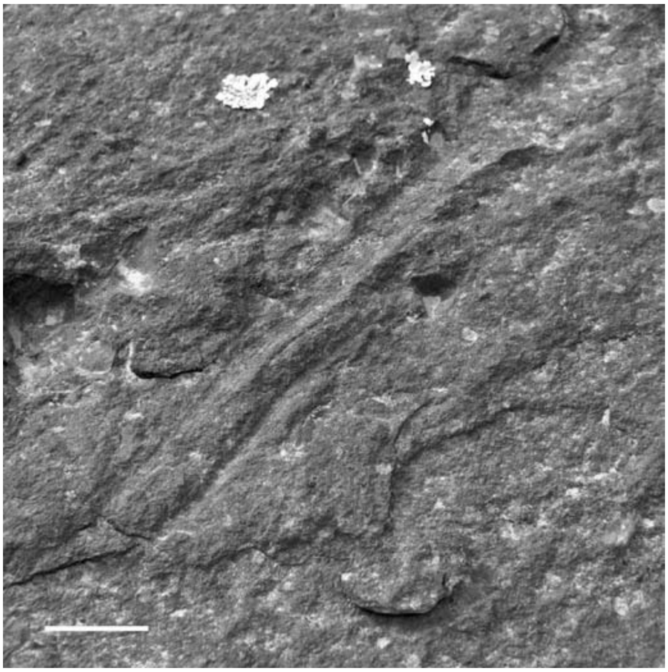

Fig. 4.- *Psammichnites gigas* Torell. Trace fossil on the bedding plane of a lacustrine siltstone a little above the lower basalts. At 2 km W of Loma de los Castillejos. Scale bar: 1 cm.

Fig. 4.- *Psammichnites gigas* Torell. Icnofósil en el plano de estratificación de una limolita lacustre a poca distancia por encima de los basaltos del tramo inferior. Localidad a 2 km al Oeste de la Loma de los Castillejos. Escala (barra): 1 cm.

up against "basement" southeastwards and fill in a shallow palaeotopography. The origin of the basalts may be related to the volcanic complex discovered by Wagner and Mayoral (2005) at 3 to 5 km NE of the Valdeviar Basin, but this is conjectural until this volcanic complex is mapped and a petrographic study has been made. The basalts wedge in southeastern direction. Only some 15 m of basalt are found near the Cerro de los Pavones, on the north-northeastern side of the basin (Fig. 12).

In the Los Canchales 1 section (Fig. 7) in the northwestern part of the basin, the basalt flows are followed by 2.50 m of red and greenish mudstones containing a small lenticular sandstone (15 cm thick), probably an ephemeral stream deposit.

At the same stratigraphic level in the northernmost part of the basin, red beds overlying the basalt flows show thinly bedded red mudrock with abundant trace fossils and the impressions of fern foliage fragments. The ichnofossils comprise the following taxa (EJM det.): *Torrowangea angulata* Gámez-Vintaned and Liñán 1993, *Cochlichnus* sp. indet., *Psammichnites gigas* Torell 1870 (Fig. 4), *Psammichnites* aff. *implexus* (Rindsberg 1994), *Skolithos linearis* Haldemann 1840, *Protovirgularia* aff. *dichotoma* Han and Pickerill 1994, *Protovirgularia* sp. indet., *Monomorphichnus lineatus* Crimes *et al*. 1977. This assemblage represents the *Scoyenia* ichnofacies,

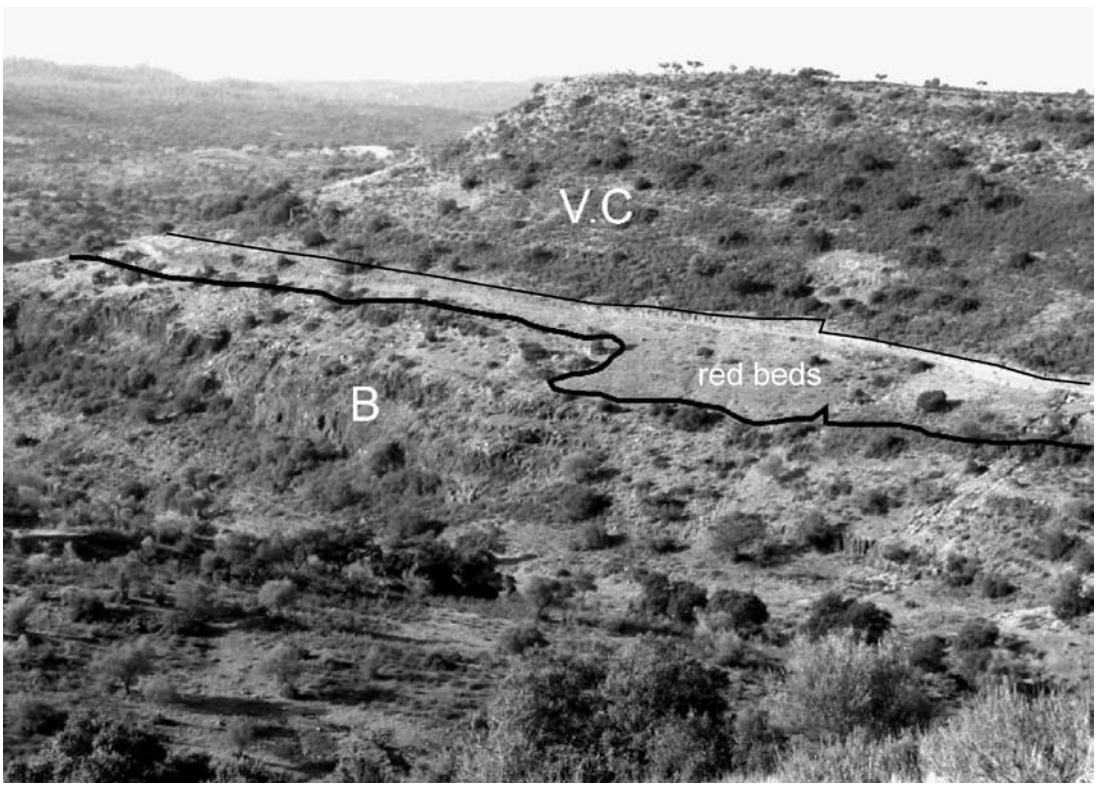

Fig. 5.- General view of Los Canchales ridge flanking the Gargantafría river valley. B: Basalts; VC: Volcaniclastics.

Fig. 5.- Vista general de la cuesta de Los Canchales en el valle de Gargantafría. B: Basaltos; VC: Volcanoclásticos.

Fig. 6.- Los Canchales 1 (compare Fig. 7): Weathered surface of the highest basalt flow preceding the volcaniclastic succession. Greenish grey mudrock fills the hollows between rounded "balls" of vesicular basalt.

Fig. 6.- Los Canchales 1 (ver Fig. 7): Superficie meteorizada de la última colada de basalto antes de dar paso al intervalo de volcanoclásticos. Lutitas verdosas rellenan las depresiones en la superficie meteorizada con "bolos" de basalto vesicular.

which corresponds to a shallow lacustrine environment with a tendency to near total water loss. A humid vegetation seems to have been established in the vicinity of the ponded areas, and this is reflected by finding relatively large pecopterid fern fragments associated as drifted remains. These cannot have floated in from afar. A similar development of strata has been recorded from a higher stratigraphic level, low in the higher red bed succession (above the volcaniclastic unit), as exposed in the Viar river valley (Fig. 17).

Returning to the Los Canchales 1 section (Fig. 7), the red beds are succeeded (after 4 m unexposed) by a little over one metre thick greyish green mudstone which is followed by 80 cm of coarse-grained, cream-coloured volcanic tuff with a faint internal lamination, and 2.50 m of alternating shales and fine-grained, silicified tuff showing internal lamination (shale/tuff ratio about 70%). These deposits initiate a substantial interval of volcaniclastic strata reaching a maximum thickness of about 40 m of tuffs and tuffaceous deposits in the northwestern part of the basin. It is difficult to determine how many volcanic events are represented, and the distribution of tuffs and tuffaceous mudstones is quite variable throughout the area. The initial eruption, as represented by the thin (80 cm) volcanic tuff bed mentioned, is followed by intermittent ash fall.

The volcanic centre presumed to be responsible for the c. 40 m of tuffs and tuffaceous deposits at Valdeviar has been detected at 3-5 km distance to the NE (in the area covered by the Geological Map sheet of Almadén de la Plata and part of the adjacent Constantina sheet). Ash flow deposits of the same characteristics as in Valdeviar, have been seen to mantle at least one of the volcanic chimneys found. Evidently, the pyroclastic surges flowed down the sides of the volcanoes, where they are preserved with the original dips of 60-70º. These may have reached the Valdeviar Basin as relatively thin horizontal deposits nearer the distal end of each flow. However, many tuffs in Valdeviar seem to represent ash fall deposits. Volcanic chimneys in the area NE of Valdeviar are seen as agglomerates with fragments of host rock (Cambrian cleaved shales) and tuff incorporated (Fig. 8). In other cases, fine-grained subvolcanic rock is present in areas representing the base of volcanoes. It obviously was quite a substantial volcanic centre with several craters. It must be emphasised that, apart from local faulting, the only movements that took place from Permian times onwards, represented uplift and relative downwarp in areas of deposition, so that the Permian situation has remained relatively unaltered. The volcanoes are found in upright position, without later

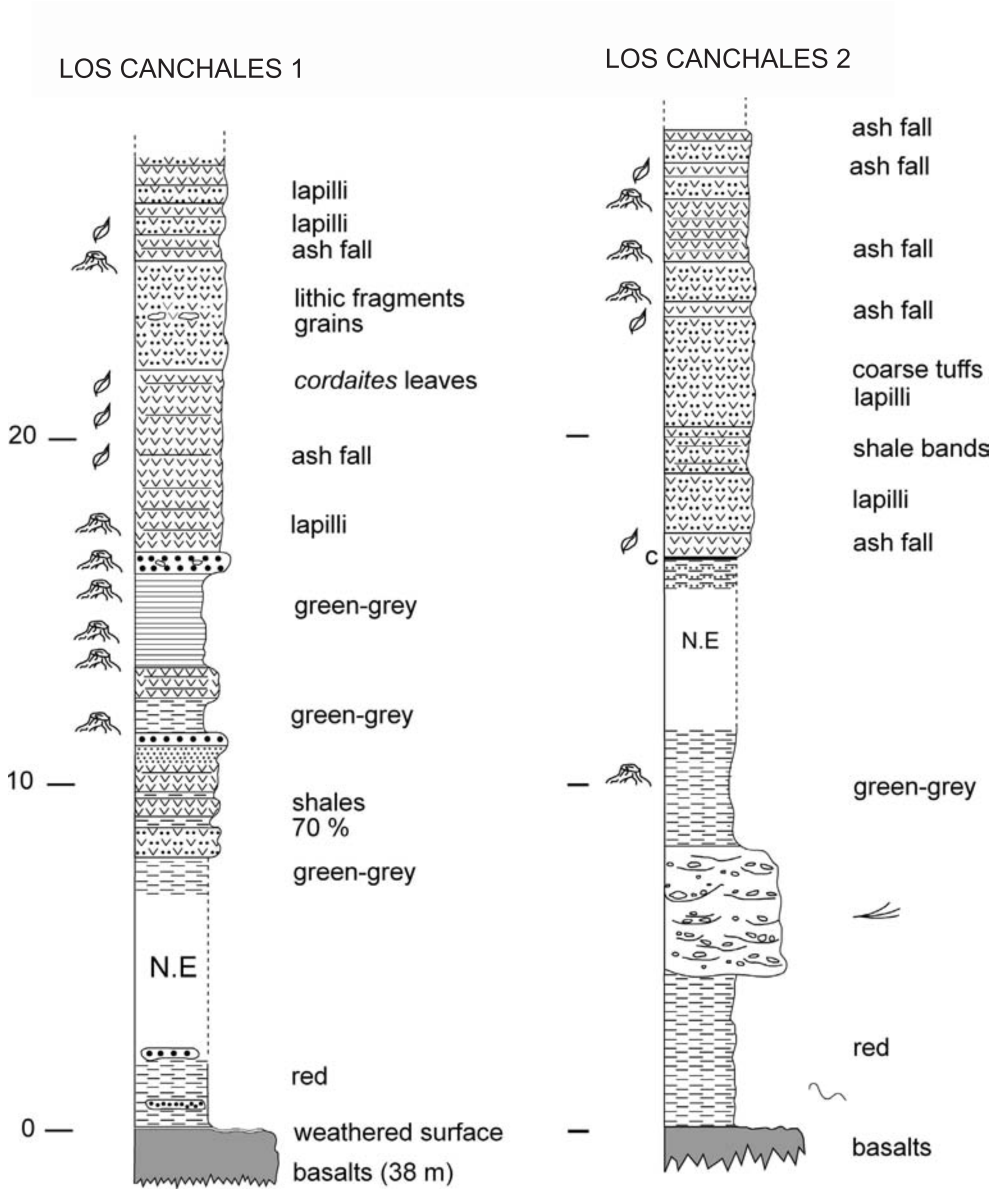

Fig. 7.- Stratigraphic columns in the northern part of the basin, on the western side: Los Canchales sections 1 and 2. Vertical scale in metres. Legend as for Fig. 11.

Fig. 7.- Columnas estratigráficas en la parte septentrional de la cuenca, al lado W: Los Canchales cortes 1 y 2. Escala vertical in metros. Leyenda como para la Fig. 11.

tectonic modification. Local erosion obviously took place to only a limited extent, thus giving rise to the suspicion that, in essence, an exhumed Permian relief is present in the near vicinity of the Valdeviar Basin. This may have been preserved by a Mesozoic cover, now removed. The extensive area with volcanic chimneys and associated cream coloured volcanic ash deposits, which has been discovered at a short distance from Valdeviar (see Fig. 2 for approximate location), still needs to be studied in detail.

The first explosive volcanic eruption, as represented by 80 cm of coarse tuff (possibly a pyroclastic bed), and subsequent ash fall deposits in the Los Canchales 1 section (Fig. 7), is succeeded by a fairly substantial interval of shales and mudstones, greenish in colour, in which a volcanic ash component is apparently present. Indeed, a parallel and cross-laminated, cream-coloured, medium-grained tuff band, 80 cm thick, occurs at 1.20 m above the base of the mudstone unit. This may represent a minor eruption, which had only a slight effect on the overall sedimentation. In this mudstone interval, 5.65 m thick, which has been found to be laterally quite extensive within the northwestern part of the basin, five horizons of standing trees of indeterminate affinity have been detected. These occur as short conical stumps, with basal diameters up to 35 cm, which are slickensided as a result of differential compaction (Fig. 9). The presence of fairly sizeable trees at several horizons suggests a mire

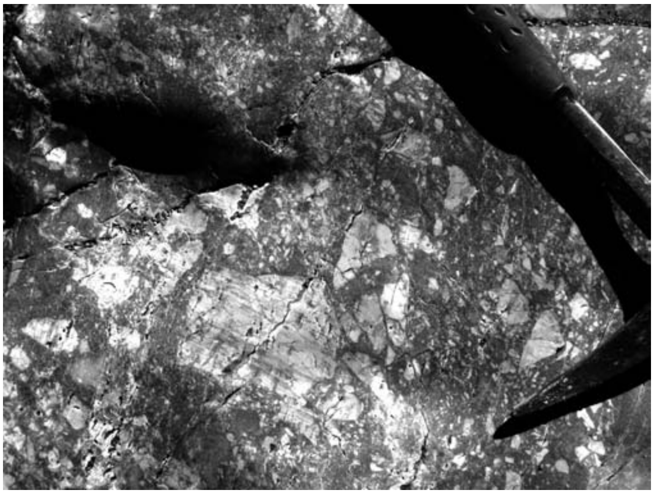

Fig. 8.- Polished section (natural polish by water) of agglomerate in volcanic chimney in the heavily intruded area of Cambrian mudrock NE of the Valdeviar Basin (outcrop in river bed – next to Loma del Gallinero).

Fig. 8.- Sección pulida (por agua en el arroyo) de aglomerado en una chimenea volcánica que se encuentra en el campo volcánico emplazado en lutitas cámbricas al NE de Valdeviar, cerca de la Loma del Gallinero.

with only a thin layer of water. The top unit, 55 cm thick, is a coarse-grained, partly conglomeratic sandstone with a large tuffaceous component. This is overlain by a 70 cm thick, fine-grained tuff which has preserved silicified trees, found loose in outcrop but not seen in standing position. The corresponding ash fall seems to belong to another explosive volcanic eruption as indicated by the presence of an overlying pyroclastic layer, 25 cm thick. A medium-grained, parallel-bedded, cream-coloured tuff, 40 cm thick, follows in succession, and this is followed by 25 cm of coarse-grained tuff with lapilli. Both layers show sharp basal contacts and may correspond to successive eruptions, following close upon one another (Fig. 7).

This (third?) episode of volcanic eruption was apparently a major one, because these coarse pyroclastic deposits are followed by 4.30 m of fine- and medium-grained tuffs with parallel and undulate bedding. Thin (1-3 cm), rather crumbly, coarse-grained tuffs are found intercalated and these may represent the ultimate parts of ash flows. However, fine-grained ash-fall deposits predominate in this interval. Many of these fine-grained tuffs show internal lamination, and ripplemarks are found on some of the top surfaces. Floated plant remains, most commonly *Cordaites* leaves and *Calamites* stem and foliage remains, are found on the bedding planes of these ash fall deposits. Fragments of the foliage of ferns and seed ferns occur as well, albeit less commonly. These fine-grained tuffs are highly siliceous and heavily jointed so as to break up into small pieces (giving rise to the term "areniscas rómbicas" as used by Gavala, 1927). A varied flora has been recovered from these beds, which clearly represent volcanic ash fall in a body of water, and thus are essentially lacustrine. The floral remains confirm a humid environment which favoured lycopsids, sphenopsids, ferns, and less common pteridosperms. One of the coarser ash bands shows graded bedding. In some of the fine-grained tuffs the plant remains are found occasionally at an angle to the bedding plane, thus suggesting minor density flow. The presence of *Skolithos* tubes indicates that the water was quite shallow, and the presence of well preserved plant remains suggests a vegetation of local origin. Local ponding and not a large lake must be envisaged (see Fig. 18 for a general interpretation of the palaeogeography).

A subsequent unit, 3.30 m thick, shows rather massive (40-70 cm) beds composed of tuffaceous material and lithic fragments. Fining upwards sequences are found as well as rarer coarsening upwards sequences. Cross-bedding is present and there is a suggestion of shallow channel forms. Some of the more massive beds are conglomeratic. It appears that a shallow fluvial facies is represented, mainly reworking volcanic material. At the top of this unit a standing tree has been observed, with a swollen base, as is common in trees living in a marshy environment (Fig. 10). This tree is rooted in coarse-grained, tuffaceous sandstone, 70 cm thick, which is overlain by a fine-grained tuff with a sharp basal contact. The latter represents volcanic ash fall and cannot be regarded as forming part of the small scale fluvial unit. Parallel and undulate lamination is observed in this tuff band which contains occasional *Cordaites* leaves. It is obviously of lacustrine facies.

A subsequent, coarse-grained, massive tuff bed, 30 cm thick, shows the presence of lapilli, and although this might be regarded as the end part of an ash flow deposit (also in view of the nearby position of the volcanic centre) it could also be the result of coarse ash fall (volcanic eruptive episode 4?). Two subsequent massive, coarse-grained tuff bands with lapilli (20 cm each) probably represent successive eruptions within the same volcanic episode. These are overlain by 50 cm of fine-grained, siliceous tuff, representing ash fall in standing water. A few floated wood fragments show that an aqueous medium was involved. The contact with the underlying presumed pyroclastic deposit is an abrupt one.

A fifth episode of volcanic eruption is indicated by the next deposit of massive coarse-grained tuff. This is the end of the measured section but not of the total thickness of volcanic tuffs present at Los Canchales. Indeed, it is estimated that another 10 to 20 metres of tuff and tuffaceous deposits remain to be examined in detail. These have been seen in part in the Gargantafría road section (Fig. 11) at the southern edge of the Los Canchales ridge, but higher volcaniclastic strata are found in more scattered outcrops beyond this road section. These beds have also been observed in gullies on the slope of the Los Canchales ridge, where they are overlain by poorly exposed red beds. Fine-grained volcanic ash fall deposits, quite often strongly silicified, are found here as minor intercalations in between coarse-grained tuff beds with convex top surfaces suggesting density flow. A similar development of the higher part of the volcaniclastic unit has been recorded in the Cerro de los Pavones, as described later (Fig. 12).

Lateral variations exist but the general facies are similar in the different stratigraphic sections examined on the northwestern side of the Valdeviar Basin (e.g. Los Canchales section 2, at only a few hundred metres SE of section 1 – Fig. 7). An overall shallow lacustrine facies is attested to by several horizons of standing trees in the lower, greenish mudstone interval, as well as in tuffaceous beds, and by the kind of trace fossils encountered. Occasional coal smuts in shale intervals in the near-basal part of the volcaniclastic unit show that plant material accumulated in some of the ponded areas. These gave rise to a serious attempt at coal exploitation in the early part of the 20th century, an attempt which was doomed to failure in view of the lenticular nature of the coaly layers and the very small thicknesses involved (only a few centimetres where coal smuts have been seen in outcrop). Gavala (1927) and Simon (1943) recorded stratigraphic sections measured in a mine shaft cut through volcaniclastic deposits (the "areniscas rómbicas" of Gavala) in the area close to where the Gargantafría joins the Viar river.

Exposures along the road leading to the dam on the Gargantafría, a tributary of the Viar river, have allowed observation of some of the higher beds in the volcaniclastic succession (Fig. 11). These include several metres thick intervals of massive, very coarse-grained tuffs (bed thicknesses of up to one metre). Grading suggests pyroclastic ash fall. Plant remains are rare and mainly restricted to more fine-grained tuff layers corresponding to a lacustrine environment. The dominant presence of calamitalean remains agrees with this environment. Attention is drawn to a fern/pteridosperm rootlet bed at 36 m above the base of the measured section (Fig. 11). This is followed by a rather coarse volcanic ash band with large fragments of the presumed pteridosperm *Alethopteris brevis* Weiss. In the upper part of this road section one finds thick beds of coarse-grained tuff which is totally devoid of plant debris. Weakly expressed channel forms suggest ash flow, not necessarily in water. Top surfaces of coarse-grained tuff in this higher part of the volcaniclastic succession often show the convexity which appears associated with density flow. The uppermost strata in this succession, as seen in more scattered outcrops beyond the Gargantafría road section, have not been studied, but a cursory examination suggests the absence of plant remains and a non-lacustrine facies.

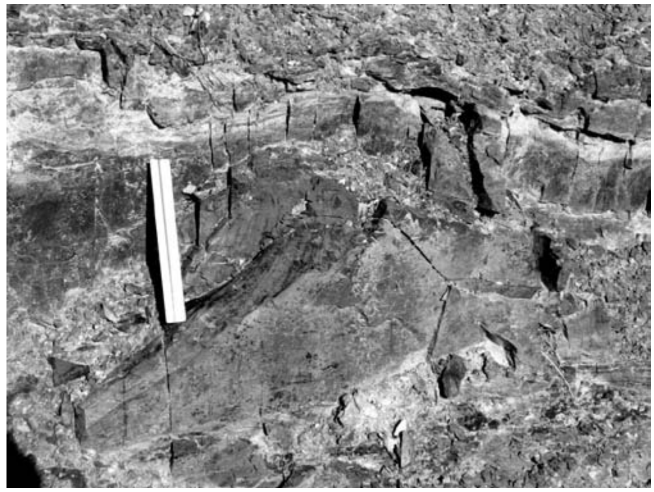

Fig. 9.- Slickensided mudstone replica of tree stump of indeterminate affinity in the lowermost part of the volcaniclastic unit in Los Canchales 1 section. Volcanic tuff layer above bulges on top of tree stump. Ruler 10 cm long.

Fig. 9.- Molde con superficie de espejos por compactación de un tocón de árbol indeterminable en la parte más inferior de la unidad volcanoclástica en Los Canchales, corte 1. Notar la presencia de una capa de toba volcánica con pequeñas elevaciones por encima del tocón, probablemente como consecuencia de la compactación diferencial. La regla tiene 10 cm de largo.

Fig. 10.- Silicified tree stump in volcanic tuff of Los Canchales 1 section; in life position.

Fig. 10.- Base de un árbol silicificado en toba volcánica (Los Canchales corte 1). Está en posición de vida.

However, this part of the volcaniclastic unit has been examined in detail in a section near the Cerro de los Pavones, in the north-northeastern part of the basin (Fig. 12). These strata, which dip between 55º and 60º SW, are

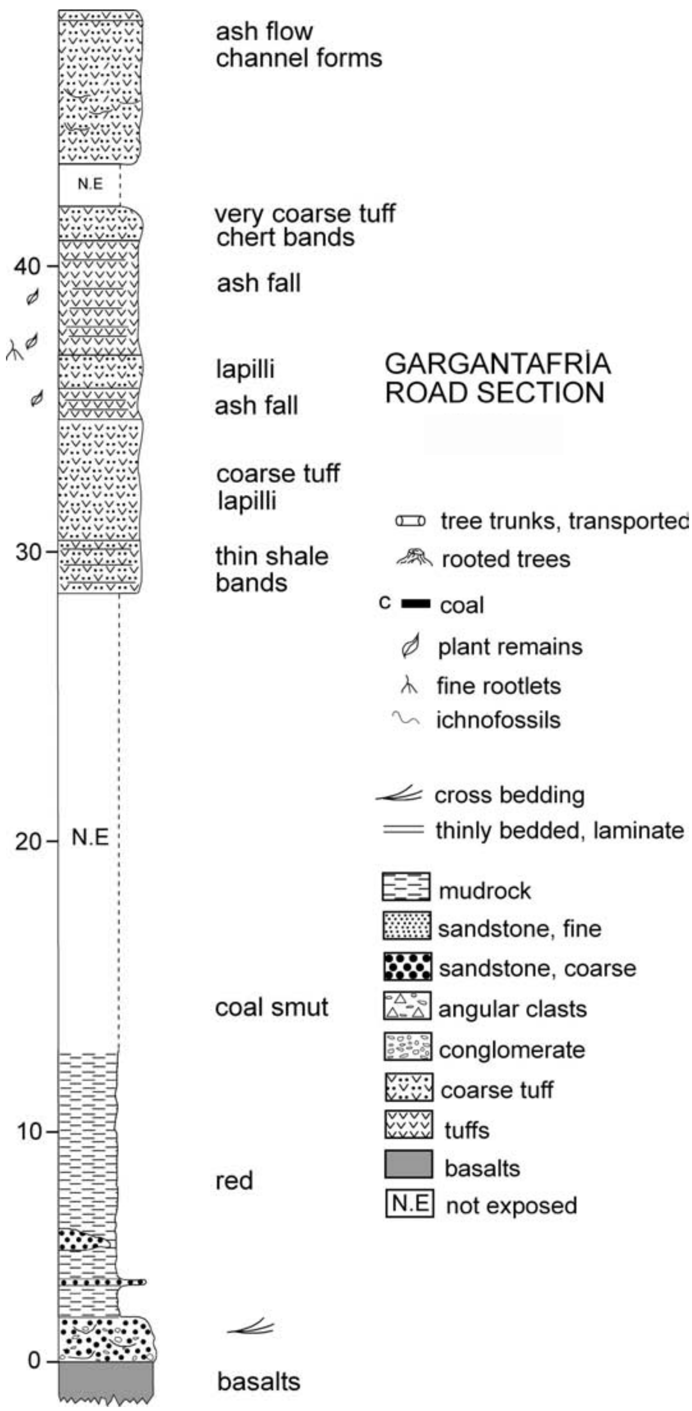

Fig. 11.- Gargantafría road section (vertical scale in metres).
Fig. 11.- Corte del camino al azud de Gargantafría (escala vertical en metros).

conformable with an underlying karstic surface on limestones of presumed Mississippian age, according to the Geological Survey map (Castilblanco sheet in transition with that of Almadén de la Plata). This karstic surface represents the Early Permian erosion surface. Consequently, there is no fault separating the Lower Permian strata from the underlying "basement". The unconformable contact is seen to cut the tectonic structures in underlying rocks obliquely. Four basalt flows are identified in the Lower Permian succession after about 5 m unexposed. It is likely that siliciclastic red beds are involved in the unexposed interval because these are seen in another section, some 500 m to the North. The top surfaces of the basalt flows are heavily weathered (about 75% of each flow), thus suggesting successive halts in sedimentation on the edge of the basin southeastwards. The total thickness of basalts exposed is only about 15 m, which is a good deal less than the c. 35 m thickness found a little to the North. The basalts probably lapped up against a SE basin margin. The c. 55º to 60º dip of the Lower Permian strata as well as that of the underlying karstic surface shows that the northeastern basin margin was steepened by later tectonic movements, probably faulting accompanied by tilting at some distance behind the unconformable contact. A major fault involving Precambrian schists (shown as Ordovician on the Geological Survey map) lies less than a hundred metres to the NE.

The Pavones (Fig. 12) section continues with about 27 m of red beds, mainly mudrock with some sandstone and conglomerate layers, including 3 m of red sandstone with shallow channel forms suggestive of braided stream deposits. Poorly exposed, rather coarse, cream coloured tuff beds, altogether c. 10 m thick, follow in succession. About 30 m of strata are unexposed. These correspond probably mainly to mudrock, in view of the lack of topographic expression, and the presence of mudrock immediately below an overlying succession of volcaniclastic deposits. These are exposed with a thickness of 13 m, including mudstone intercalations (Fig. 12). Individual beds of volcaniclastic material correspond mainly to coarse tuff, and these commonly show convex top surfaces, sometimes with coarse, pebbly material in patches on top. This suggests density flow, an impression which is reinforced by one bed appearing as the frontal part of such a mass flow deposit. Often, large orthoclase feldspars are seen in the coarse tuff beds. Only a relatively small interval, 1.25 m thick, of fine tuff with plant remains in the lower 2 centimetres, has been recorded as the result of ash fall in water (at about 80 m above the base of section – Fig. 12). The composition of the sparse floral remains encountered shows a humid environment which agrees with the laminate nature of these tuffs. These ash fall deposits overlie a very coarse-grained tuff with a standing tree stump on its top surface (see Fig. 12). Black chert bands occur in the upper part of the ash fall deposits. Casts of standing trees have been seen as well as small depressions on the top surfaces of ash flow deposits, which may correspond to the imprint of small tree bases.

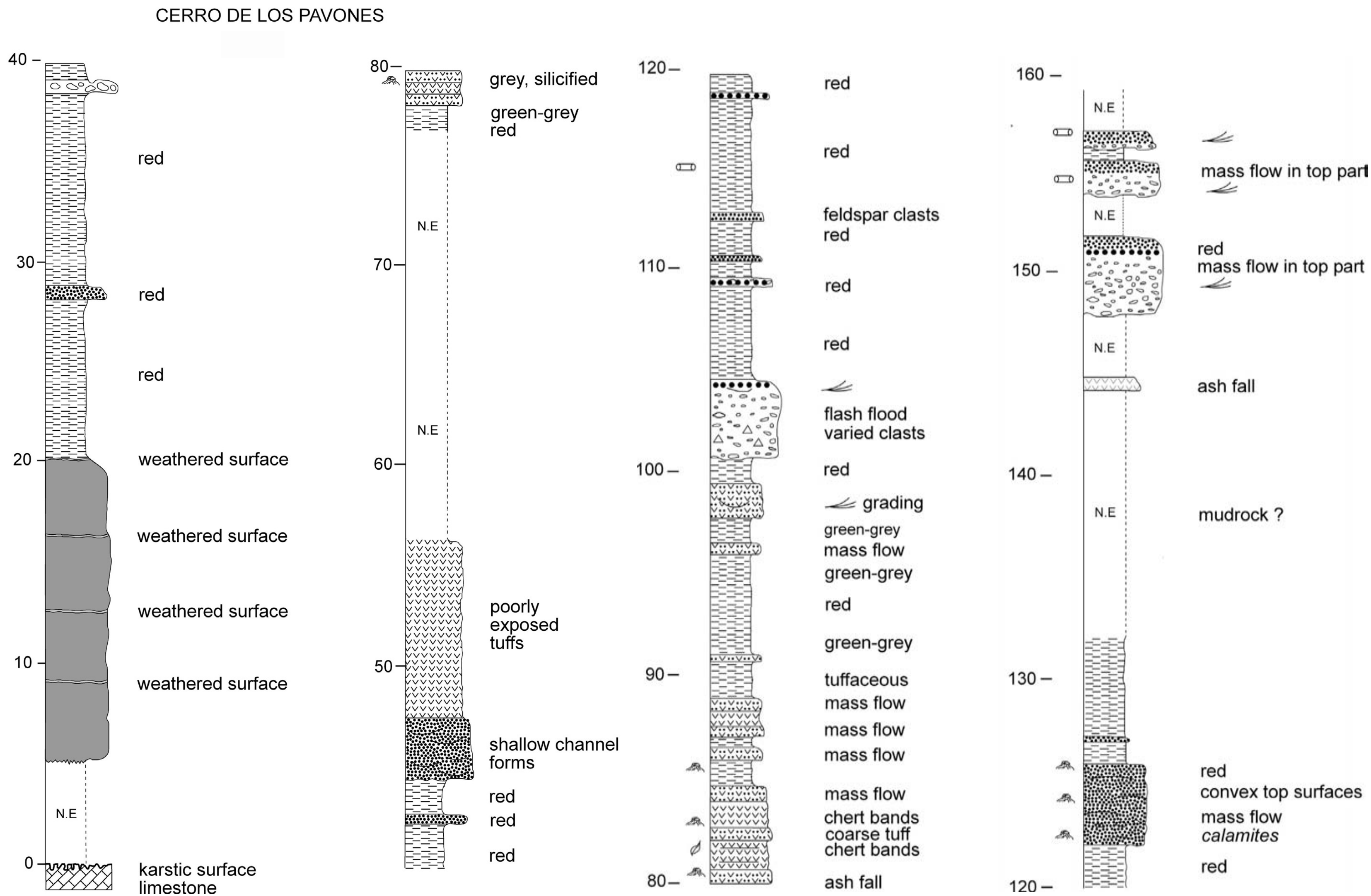

Fig. 12.- Stratigraphic section near Cerro de los Pavones in the northeastern part of Valdeviar. Legend as in Fig. 11.
Fig. 12.- Corte estratigráfico al lado del Cerro de los Pavones en la parte NE de Valdeviar. Leyenda como en la Fig. 11.

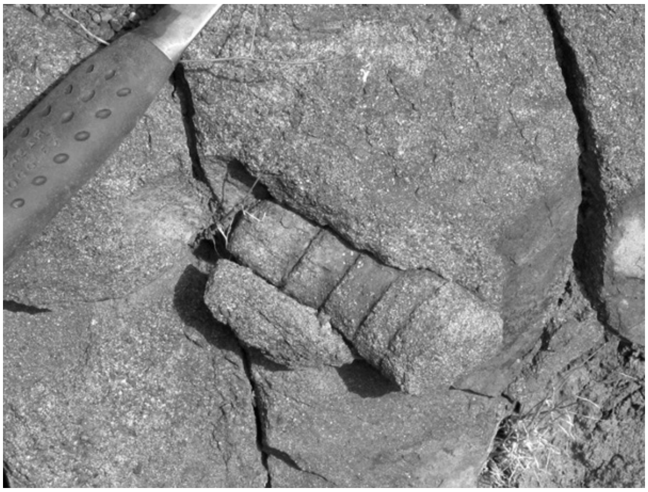

Fig. 13.- *Calamites* pith cast in life position, pushed sideways by sand flow. Pavones section (Fig. 12).

Fig. 13.- Molde interno de un *Calamites* en posición de vida y empujado por el movimiento lateral (de colada) de una arenisca fina. Corte de los Pavones (Fig. 12).

Fig. 14.- Flat-lying silicified tree trunk fragment, in conglomerate (mass flow deposit), Pavones section (compare Fig. 12). Ruler is 10 cm long.

Fig. 14.- Fragmento de tronco silicificado transportado, en posición horizontal, dentro de un conglomerado representando una colada sedimentaria. Corte al lado del Cerro de los Pavones (comparar Fig. 12). La regla mide 10 cm.

Fig. 15.- Large silicified tree trunk, 16.80 m long, flat-lying; excavated from the enveloping sediment of mixed lithology. NW of Cerro de los Pavones.

Fig. 15.- Un tronco silicificado de grandes dimensiones (16,80 m de largo), que yace en posición horizontal. Excavado del sedimento mezclado que lo envuelve. Localidad al NW del Cerro de los Pavones.

There is a gradual transition between the succession of volcaniclastic deposits and overlying red mudrock. Apart from mudstone intercalations in the volcaniclastic succession, there is a 1.70 m thick fluviatile sandstone with a large tuffaceous component, at 99 m up section. This bed seems to represent a shallow stream deposit. At 101 m up section, a conglomerate is found with varied clast sizes and composition (mainly quartz, but also quartzite, metamorphic rock and orthoclases). Higher conglomerates and coarse sandstone beds in predominant mudrock again show evidence of shallow stream deposits, probably laid down as laterally impersistent lenses. A small *Calamites* is found in growth position on top of a conglomeratic sandstone bed which appears to have been deposited by mass flow (Fig. 13). This *Calamites* stem was pushed slightly out of its upright position by the fluidised sediment.

At approximately 115 m up section, red mudstones with sandstone and conglomerate intercalations include the first mass flow deposits with flat-lying silicified tree trunks as found in some profusion in the Cerro de los Pavones. A sandstone unit at 122 m up section shows mass flow deposits with convex top surfaces. Some of these top surfaces show depressions left, most likely, by small rooting trees. A thin volcanic tuff bed still occurs as high as 145 m up section (Fig. 12). The conglomeratic mass flow deposits near the top of the section contain fragments of sizeable logs (Fig. 14), including an almost complete tree trunk (Fig. 15). The permineralisation of these wood fragments suggests lingering volcanic influences. In the general area of the Cerro de los Pavones parts of silicified tree trunks are found to occur in mass flow deposits (several different beds) in an interval of some of 40 m altogether. It seems that additional beds containing mass-transported (silicified) tree trunks occur also higher up in the red bed succession. A field in the El Chaparral property, further South in the Valdeviar Basin, shows a profusion of silicified log fragments weathered out from mudstone which is not exposed in stratigraphic section. Likewise, from an even more southerly part of the Valdeviar Basin, North of Cantillana, Simon (1943, p. 419, Abb. 20) figured weathered-out silicified log fragments scattered about in a field near an exploratory shaft sunk by the Marqués de Esquivel in the early part of the twentieth century. Fossil plant impressions recorded by Gavala (1927) and Simon (1943) from these exploratory workings and exposures in the same area, show the same Early Permian age (corresponding to lower Rotliegend) as is deduced from the finds in the volcaniclastic unit at Los Canchales and near the Cerro de los Pavones, in the northern part of the basin. This proves that the red beds following upon the volcaniclastic strata, and which onlap onto granitic basement southeastwards, are in stratigraphic continuity. The total thickness involved is difficult to establish in these flat-lying strata with onlap, but an estimate of 150 to 200 m of red beds does not seem unreasonable. Plant fossils in the Gavala Collection are in dark grey and cream coloured mudrock, so the upper red beds are not uniformly red in the higher part. Exposures examined by the present writers in the southern part of the Valdeviar also include cream coloured mudrock with plant fossils in these higher red beds.

A small succession of strata immediately overlying the volcaniclastic unit in the northwestern part of the Valdeviar has been examined in exposures along the “Canal de Viar”. Here, several bands of black chert alternating with greenish grey shales are found in a total succession which is a little over a metre thick (Fig. 16). It may be that these cherts are the result of leaching on an erosion surface on top of a pile of volcanic tuff deposits. Overlying these cherts, which appear to be local, there is a small succession of light coloured lavas which have not yet been studied, but which include orange coloured beds, probably due to a high orthoclase content. These are associated with the second interval of basalt outpourings recorded by Simancas (1985) as a strictly local occurrence. Indeed, a measured section in the Viar river bank (Fig. 17) shows a lateral contact of this basalt where it wedges into sediments in the lowermost part of the overlying red bed succession. The presence of varied lava flows, including basalt, shows that deep seated fractures still existed in the basin floor.

The exposures along the Canal de Viar include a subsequent unit of red mudrock, in which small lenses of conglomerate occur. These apparently correspond to shallow stream channels. The conglomerates grade upwards into yellowish sandstones with low-angle cross bedding. Among the varied clasts in the conglomeratic deposits one finds angular fragment of orange coloured, orthoclase feldspar rich lava which must have been locally eroded. There is an obvious comparison with the conglomeratic deposits in red mudrock overlying the volcaniclastic succession in the Cerro de los Pavones section (Fig. 12). The wine-red shales into which the stream channels were cut, retain the thin parallel bedding suggestive of lacustrine deposits.

A small section of red beds has been examined in an exposure on the Viar river bank (Fig. 17), where these beds are in lateral transition with the upper basalt as recorded by Simancas (1985). A thickness of 17.60 m of strata shows mainly wine-red silty and slightly silty mudstones, generally homogenised, although traces of thin bedding often remain. Intercalated sandstones are partly due to density flow, with convex top surfaces and unsorted, mixed

Fig. 16.- Black chert on top of volcaniclastics in exposures along the Canal del Viar. Poorly exposed lavas follow in succession.

Fig. 16.- Chert negro a techo de la unidad volcanoclástica en los afloramientos del Canal del Viar. En este lugar le siguen lavas acídicas (que afloran mal).

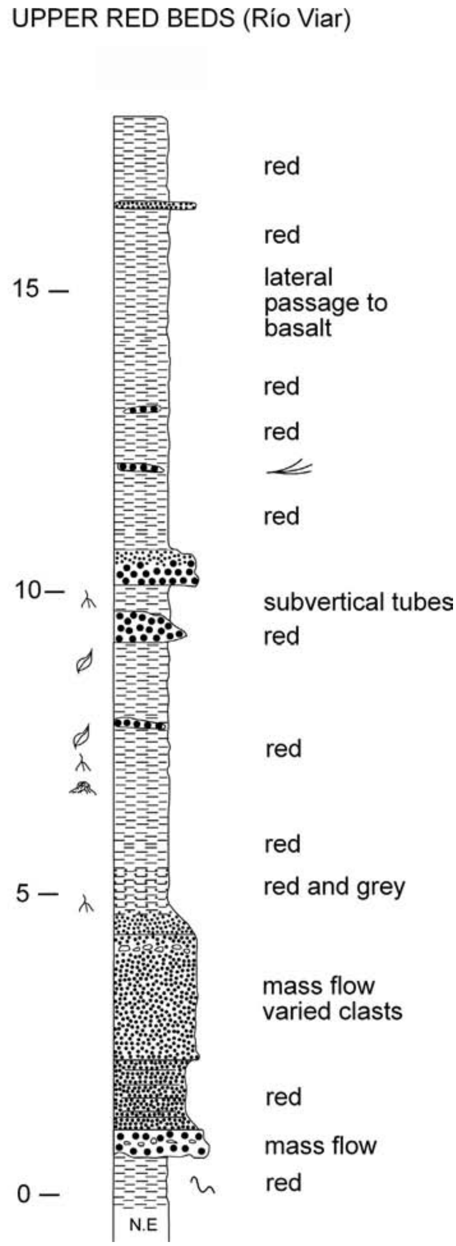

Fig. 17.- Stratigraphic section low in the higher red beds (Viar River section), where they are in lateral transition with upper basalt. Scale in metres.

Fig. 17.- Corte estratigráfico de unos estratos en la parte inferior de las Capas Rojas Superiores, en transición lateral con los basaltos superiores. A la orilla del Río Viar. Escala en metros.

clasts which originated from the basin margin (schists, quartzites, quartz and indeterminate metamorphic rocks). Two superimposed layers of mudrock with standing tree stumps have been seen, and rootlet bioturbation has been recorded in two instances. Large scale cross-bedding occurs in a coarse sandstone bed. The overall impression is gained of a very shallow lacustrine environment with sand flow bodies and minor stream deposits occurring as small, lenticular intercalations. These strata were subjected to oxidation immediately subsequent to deposition.

4. General facies considerations on the higher red beds (with onlap)

The higher red bed succession has been described as containing evidence of a fluvial facies (Sierra and Moreno, 1998). However, although some fluviatile beds occur as temporary stream deposits of a local nature, the general facies is lacustrine with evidence of drying and strong weathering with pedogenesis. Parallel bedding predominates, and trace fossils show recurrent lacustrine conditions. An occasional horizon of small standing trees of indeterminate kind completes the picture of shallow water producing marshy conditions. The sandstone and conglomerate intercalations in this succession of predominant mudrock are lenticular bodies with facies varying from mass flow to minor stream deposits. The sandstone/conglomerate component is probably not in excess of 20-30% of the total succession.

Most spectacular are mass transport deposits of mixed lithology, i.e. silty mud together with sand and small pebbles, which contain silicified wood fragments as recorded from the Pavones section (Figs 14 and 15). These are often found weathered out and lying on the present-

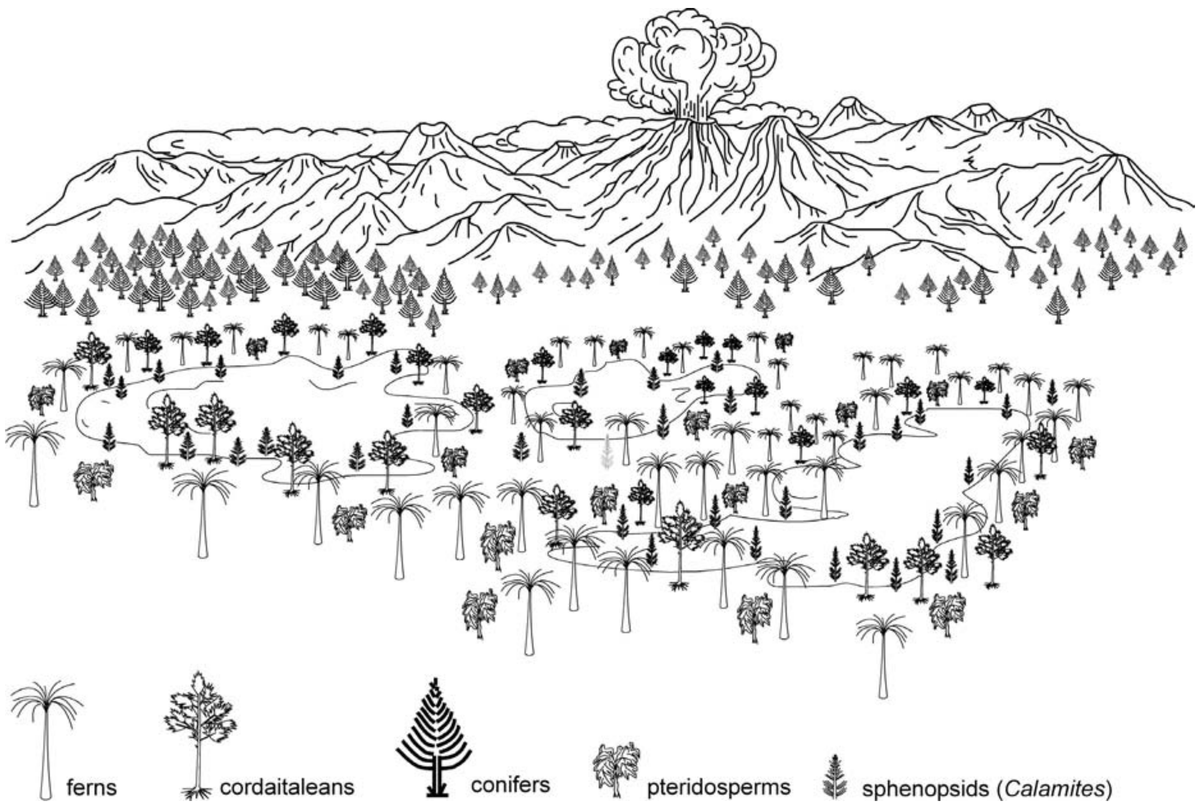

Fig. 18.- Explanatory drawing of the relative position of different floral elements. Hill slopes with conifers on basin margin; ponded areas with hygrophile elements in the basinal depression.

Fig. 18.- Dibujo explicativo de la posición relativa de los elementos diferentes de flora. Coníferas en la ladera flanqueando la cuenca; elementos higrófilos en la cuenca misma (con charcos).

day erosion surface (being the most resistant elements to erosion), but where they occur within the sediment, they prove to be flat-lying. The wood remains appear to be fragments of sizeable logs, showing diameters of up to 1 metre. The length of these log fragments is variable, generally less than a metre, but in one recorded instance, an almost complete tree trunk has been found with a basal diameter of 0.90 to 1 m and a total length of 16.8 m. The flaring base shows that the lower part of a sizeable tree is involved (Fig. 15). Apparently, the mobilised (fluidised) surface weathering material on hill slopes bordering the sedimentary basin, uprooted the woody trees growing in the area bordering the basin margin (Fig. 18), and moved the uprooted trees downhill. The density flow would dismember the trees by detaching branches and in most but not all cases breaking up the tree trunk into smaller fragments (Fig. 19).

Permineralisation would have occurred *in situ* after the flow abated. The fact that free silica was available to fill the wood cells before the cellulose of the cell walls was sufficiently degraded to obliterate the cell structure, seems to suggests that volcanic ash was a component of the soil material covering the hill slope. The continuing volcanic influence seems to confirm that stratigraphic continuity exists between the cream-coloured volcaniclastic strata below and the immediately overlying succession of red beds. Indeed, the silicified wood fragments occur in the lower part of the upper red bed succession, in several different beds produced by mass flow in an interval which is at least 50 m thick and which may span an estimated 100 to 150 m.

The topographic relief on which the uprooted trees grew, was apparently situated on the northeastern basin margin. This is deduced from finding the frontal parts of silt/sandstone flows oriented in such a way as to suggest that the flows came in from the NE. This refers to roadside exposures at 1 km SW of Collado de la Zamarrona, which show several metres of wine-red sandstone consisting of about 20 cm thick, massive beds produced by mass flow (Fig. 20). The top surfaces of each flow show the presence of small unsorted, angular and subangular pebbles which were transported on top of the sandstone slurries, probably as a result of buoyancy (Fig. 21). Such deposits may be attributed to the mobilisation of weathered sandy material with angular pebbles at periods of seasonal rainfall producing flash floods. This allows the assumption of alternating wet and drier conditions, and has clear climatic implications. These beds produced by

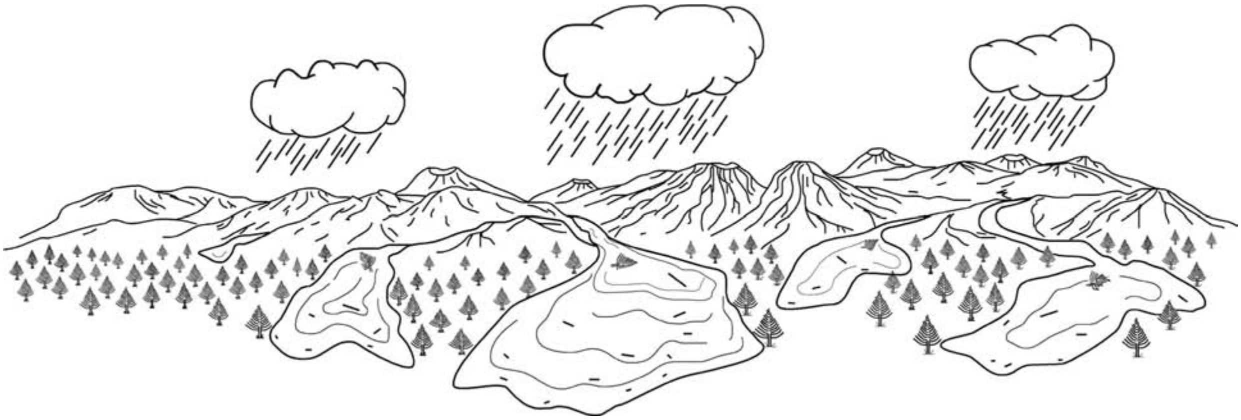

Fig. 19.- Drawing illustrating conifer trees uprooted by and broken up by mass flow.
Fig. 19.- Dibujo explicativo de las coladas de "barro" capaces de desarraigar los árboles de conífera, y descuartizarlos.

sand flow with the minimum water content allowing fluidisation, show characteristically frontal faces (Fig. 19). Where dense flow became a little more fluid, 5 to 10 cm thick sandstone beds were produced with local cross-stratification, simulating braided stream deposits. The apparent absence of channel forms shows the cross-bedding to have been produced by ephemeral streams. One such cross-bedded sandstone unit is succeeded by a massive-bedded, fine-grained sandstone showing *Skolithos* on several horizons (Fig. 22). This suggests ponding and subsequent drying out of an ephemeral small body of water (presumably freshwater in the context of a continental basin). These are all lensing deposits.

The higher red bed succession shows onlap in south-southeastern direction. The amount of onlap is difficult to establish geometrically, but facies interpretation allows a certain amount of conjecture. Onlapping red beds are seen to overlie a weathered surface on granite where the road from Castilblanco to El Pedroso crosses the Viar river (Fig. 2). The first overlying deposits show first of all a mixture of arkoses and angular clasts, mainly corresponding to red sandstone belonging, most likely, to the Lower Permian sediments deposited in the earlier, more northerly, part of the basin. These are followed by "flash flood" deposits (Fig. 23) with clasts of varied extrabasinal origin, generally angular to subangular with a patina indicative of arid conditions. Clasts are up to 40 cm in diameter, randomly disposed and represented by granite, metamorphic rocks, sandstone and rare quartz. The origin is local, from the southwestern basin margin. Matrix is a red sandstone. Higher up in the same exposures the clast size diminishes and small scale cross bedding occurs. About 25 m of flash flood deposits are exposed in this road section. Climatic conditions apparently became drier, and this agrees with the occurrence of small bands of limestone nodules (caliche) at approximately this horizon in the higher part of the upper red beds. The southeasterly onlap as a result of a gradually expanding basin, brought a higher part of the red bed succession into contact with the local "basement", and although conditions did not change dramatically, the corresponding sediments apparently reflect an increased aridity. This environmental change is better understood in terms of slightly different times, i.e. as a result of onlap (Fig. 24), rather than the southeastward wedging of (volcaniclastic) grey beds as proposed by Simancas (1985).

The predominantly wine-red coloured strata show occasional intercalations of grey beds which are thinly bedded, presumably lacustrine, a conclusion which is supported by the occasional presence of drifted plant remains. Perhaps, more permanent areas of shallow water persisted in the basin. The climate, though reasonably dry, with occasional flash floods, probably stopped short of being semi-arid. On the other hand, occasional caliches were formed, apparently as a result of the precipitation of limestone in a lacustrine setting.

5. Triassic? deposits

Sierra (2004) suggested that a major break in sequence existed below a laterally extensive conglomerate sandstone unit (her "Tabla de los Miradores") which occurs at the base of a succession of brick red deposits, which constitutes the highest part of the succession at Valdeviar, and which exist in the ESE part of the basin. These deposits are predominantly mudrock, but contain also substantial sandstone/conglomerate beds as well as major caliche horizons. Although similar, the facies is not identical to that of the wine-red deposits below. The presumed Triassic deposits, from which dinosaur footprints were recorded by Bernáldez (1987), seem to have been laid down in a depression which coincides partly with the earlier, Early Permian basin (Fig. 2). It seems likely that the pedogenic nodules, partly with cone-in-cone structure, described by

Fig. 20.- Lobate frontal parts of two successive density flow beds of fine-grained sandstone. Roadside section at 1 km SW of Collado de la Zamarrona. Vertical scale: 30 cm.

Fig. 20.- Frentes lobulados de dos coladas sucesivas de arenisca fina. Corte al lado de la carretera a 1 km al SW del Collado de la Zamarrona. Escala vertical: 30 cm.

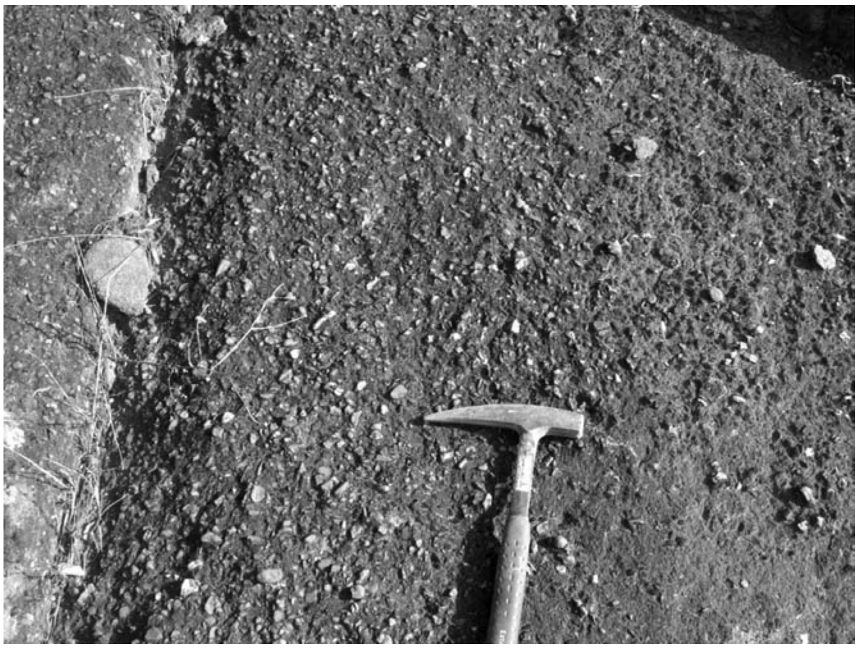

Fig. 21.- Small angular pebbles "floating" on top layer of one of the density flow beds shown in Fig. 20.

Fig. 21.- Clastos pequeños angulosos flotantes (por boyanza) en la cara superior de una de las coladas de la Fig. 20.

Aassoumi *et al.* (1992), and corresponding to their locality 1, came from these beds.

6. Stratigraphic dating

Gavala (1927) published a small list of plant fossils identified by M. Ruíz Falcó, which he regarded as indicative of Early Permian. Illustrations were provided of these remains of conifer foliage which were attributed to three different species. Two specimens are in the collections of the Museo Geominero in Madrid. These are regarded as *Otovicia hypnoides* (Brongniart) Kerp *et al.* (RHW det.). The third specimen figured by Gavala (1927, lám. VII) as *Walchia piniformis* (Schlotheim) Sternberg, is no longer available. The figuration at less than natural size does not allow a proper identification, but two unfigured specimens from the Gavala Collection suggest that *Walchia piniformis* may indeed be present. Additional plant remains belong to *Neurodontopteris auriculata* (Brongniart) Potonié, *Odontopteris* sp., *Callipteridium pteridium* (Schlotheim) Zeiller forma *gigas* (Gutbier) Weiss, *Sphenophyllum verticillatum* (Schlotheim) Zeiller, *Asterophyllites equisetiformis* (Schlotheim) Brongniart, *Cordaites* sp., "seeds". These taxa are compatible with an Autunian age. The floral remains reported by Gavala are in the Museo Geominero in Madrid, where they have been re-examined. Ruiz Falcó and Madariaga Rojo (1933, lám. IX, fig. 11) figured a specimen of *Sphenophyllum*

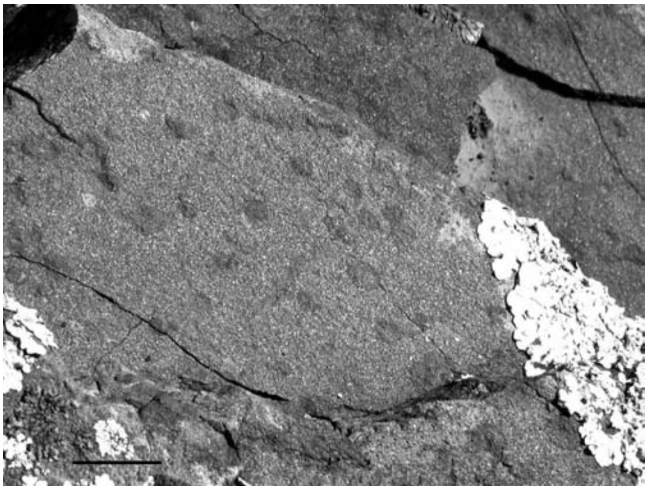

Fig.22.- *Skolithos linearis* Haldemann. In lacustrine fine-grained sandstones at c. 1 km SW of Collado de la Zamarrona.

Fig.22.- *Skolithos linearis* Haldemann en arenisca de grano fino, de facies lacustre, a 1 km aproximadamente al SW del Collado de la Zamarrona.

Fig. 23.- Varied angular clasts in "flash flood" breccia near the base of overlapping upper red beds in roadside exposure near the bridge crossing the Viar River (Castilblanco – El Pedroso road). Location of road in Fig. 2.

Fig. 23.- Clastos angulosos variados en una brecha de tipo "flash flood" cerca de la base de las Capas Rojas Superiores donde solapa en dirección SE. Afloramiento al lado de la carrretera que cruza el Río Viar en dirección a El Pedroso. Posición de la carretera señalada en la Fig. 2.

verticillatum (Schlotheim) Zeiller, which was correctly identified. The same authors (Ruiz Falcó and Madariaga Rojo, 1941) summarised the information given by Gavala (1927) and reproduced the list of plant fossils given by Ruiz Falcó in that paper. Their 1941 publication was a posthumous work, after manuscript notes, and this may well explain the mention of *Sphenophyllum alatifolium* Renault which, presumably, refers to the specimen figured as *Sphenophyllum verticillatum* in 1933.

Simon (1943) made additional collections from the same locality and an another one in the southwestern part of the Valdeviar Basin, corresponding to grey to cream-coloured intercalations in the red beds belonging to the succession overlapping the volcaniclastic unit in southward direction. These plant fossils were identified by W. Gothan, and attributed to lower Rotliegend. Additional remains were listed by Jongmans (1951), who mentioned *Odontopteris genuina* Grand'Eury (= *Lescuropteris genuina* (Grand'Eury) Remy and Remy) as a new element. This specimen remained unfigured.

Broutin (1978, 1981, 1986) and Vozenin-Serra *et al.* (1991) figured and described the anatomy of conifer and cordaite wood remains corresponding to silicified trees in red beds overlying the volcaniclastic succession of strata. Broutin also figured a very poorly preserved leaf impression from the volcaniclastic strata, which he compared with the Gondwana plant *Botrychiopsis*, probably in error. Broutin (1981, 1986) further recorded a suite of palynomorphs of Autunian age. These were partially illustrated (*op. cit.*).

New collections of plant impressions, mainly from the lower half of the volcaniclastic unit in the northern part of the Valdeviar Basin confirm an Early Permian age corresponding to mid-Autunian and lower Rotliegend. Taxa identified thus far are as follows (RHW det.): *Neuropteris cordata* Brongniart, *Mixoneura gimmii* (Remy) Wagner, *Mixoneura osmundaeformis* (Schlotheim) comb. nov., *Alethopteris brevis* Weiss, *Alethopteris schneideri* Sterzel, *Callipteridium rochei* Zeiller, *Dicksonites plueckenetii* (Schlotheim) Sterzel, *Renaultia lebachensis* (Weiss) Brousmiche, *Corynepteris angustissima* (Sternberg) Němejc, *Corynepteris erosa* (Gutbier) Kidston, *Oligocarpia leptophylla* (Bunbury) Grauvogel-Stamm, *Sphenopteris dechenii* Weiss, *Sphenopteris* sp., *Senftenbergia elaverica* (Zeiller) Wagner, *Remia pinnatifida* (Gutbier) Knight, *Nemejcopteris feminaeformis* (Schlotheim) Barthel, *Lobatopteris geinitzii* (Gutbier) Wagner, *Pecopteris densifolia* Göppert, *Pecopteris* cf. *monyi* Zeiller, *Pecopteris oreopteridia* (Schlotheim) Brongniart, *Pecopteris permica* Němejc, *Pecopteris potoniei* Němejc, *Pecopteris pseudoreopteridia* Potonié, *Pecopteris puertollanensis* Wagner, *Pecopteris* spp., *Sphenozamites rochei* Renault, *Sphenophyllum oblongifolium* (Germar and Kaulfuss) Unger, *Sphenophyllum* sp., *Parasphenophyllum* sp., *Lobatannularia* sp., *Annularia carinata* Gutbier, *Annularia pseudostellata* Potonié, *Annularia sphenophylloides* (Zenker) Gutbier, *Annularia spicata* Gutbier, *Annularia spinulosa* Sternberg, *Calamostachys tuberculata* (Sternberg) Jongmans, *Asterophyllites* sp., *Macrostachya carinata* Germar, *Calamites multiramis* Weiss, *Calamites* sp., *Cordaites* sp., *Sigillaria brardii* Brongniart, *Lepidostrobus* sp., *Syringodendron* sp., *Omphalophloios*? sp. Only one small fragment of *Autunia conferta* (Sternberg) Kerp has been collected. This specimen came from a red bed below the volcaniclastic unit, whereas most (practically) all plant remains collected most recently occurred in water-lain volcanic tuff. *Autunia conferta* is obviously very rare at Valdeviar. The assemblages found in the volcaniclastic deposits reflect a humid environment which confirms the overall lacustrine facies. A few examples are illustrated in Figs 25-29. A full description of the about 40 taxa encountered will be the subject of a special paper. The lists given in the present paper are therefore to be regarded as preliminary.

The floral elements found are identical to those encountered in other Lower Permian areas in Spain (e.g. Fombuena in Zaragoza province – Amerom *et al*., 1993; and Valdesotos in Guadalajara province – Wagner, 1999), as well as elsewhere in Europe (e.g. Saxony – Barthel, 1976). However, it is noted that only one small fragment of a callipterid (*Autunia conferta*) has been found at Valdeviar, whereas callipterids are more common in the other Lower Permian areas in the north-central part of the Iberian Peninsula. In this respect, there is a clear resemblance with the Autunian flora recorded from Guadalcanal, at only 30 km distance, where only a single species of callipterid has been recorded (Broutin, 1986). The extreme rarity of finds of callipterids and the paucity of conifer foliage at Valdeviar is of environmental/palaeoclimatic significance.

7. Palaeoclimatic interpretation

The succession of strata in the Valdeviar Basin carries a clear palaeoclimatic signature. A humid climate seems to have characterised the early part of the basin history as represented by conglomerates and overlying braided stream deposits in the extreme northwestern part of the basin. Overlying and partly intercalated red beds, generally silty mudstones homogenised by soil formation, suggest seasonally drier conditions. However, lacustrine facies are in evidence above a major interval of basalts. These include well-bedded red shales and siltstones with shallow water ichnofossils and drifted fern fragments. Overlying volcaniclastic deposits contain a laterally quite persistent interval of greenish mudstones in the lower part. A lacustrine facies is indicated by the presence of several horizons with standing trees of indeterminate origin. Higher up, but still in the lower part of the volcaniclastic succession, there is evidence of ash fall in standing water, probably representing small ponded areas rather than a large lake. The presence of a fossil flora consisting of sphenopsids, lycopsids, cordaitaleans, a varied suite of ferns (including tree fragments), and more occasional pteridosperms, is indicative of a humid environment. The find of sizeable sigillarian tree stumps (*Syringodendron*) emphasises the wet conditions. Most of the upper part of the volcaniclastic succession is less clearly lacustrine, and shows evidence of mass flow, partly with a mixture of tuff and siliciclastic elements. In the lower part of the red bed succession overlying the volcaniclastics there is still evidence of lacustrine facies with periodic drying leading to oxidising conditions. Sporadic rainfall mobilised weathering products on hill slopes on the NE basin margin. These dense flows uprooted conifer or cordaitalean "woody" trees growing on a palaeotopography just beyond the basin margin, generally tearing them apart by differential flow, and sweeping the fragments into the basin where they are preserved as flat-lying logs in thick beds of varied grain and clast sizes (Figs. 14, 15, 19).

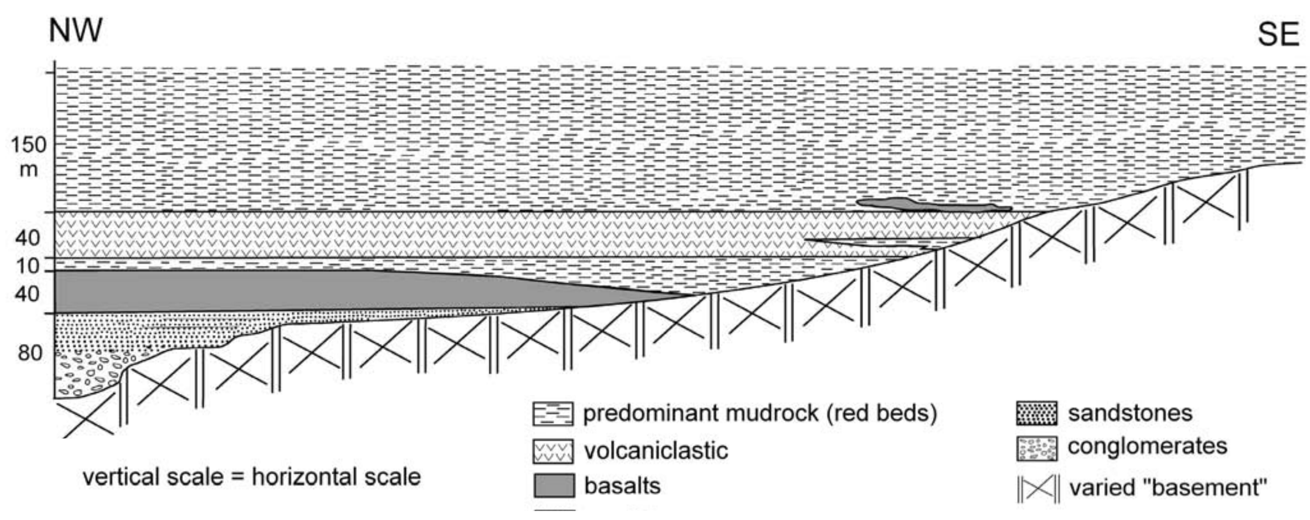

Fig. 24.- Diagram illustrating onlap relationship of different formations in southeastern direction.
Fig. 24.- Esquema mostrando el solapamiento progresivo en dirección SE de las distintas unidades estratigráficas en Valdeviar.

Fig. 25.- *Mixoneura gimmii* (Remy) Wagner, x 3. Lower part of volcaniclastic unit. Scale bar: 5 mm.
Fig. 25.- *Mixoneura gimmii* (Remy) Wagner, x 3. Parte inferior de la unidad volcanoclástica. Escala de la barra: 5 mm.

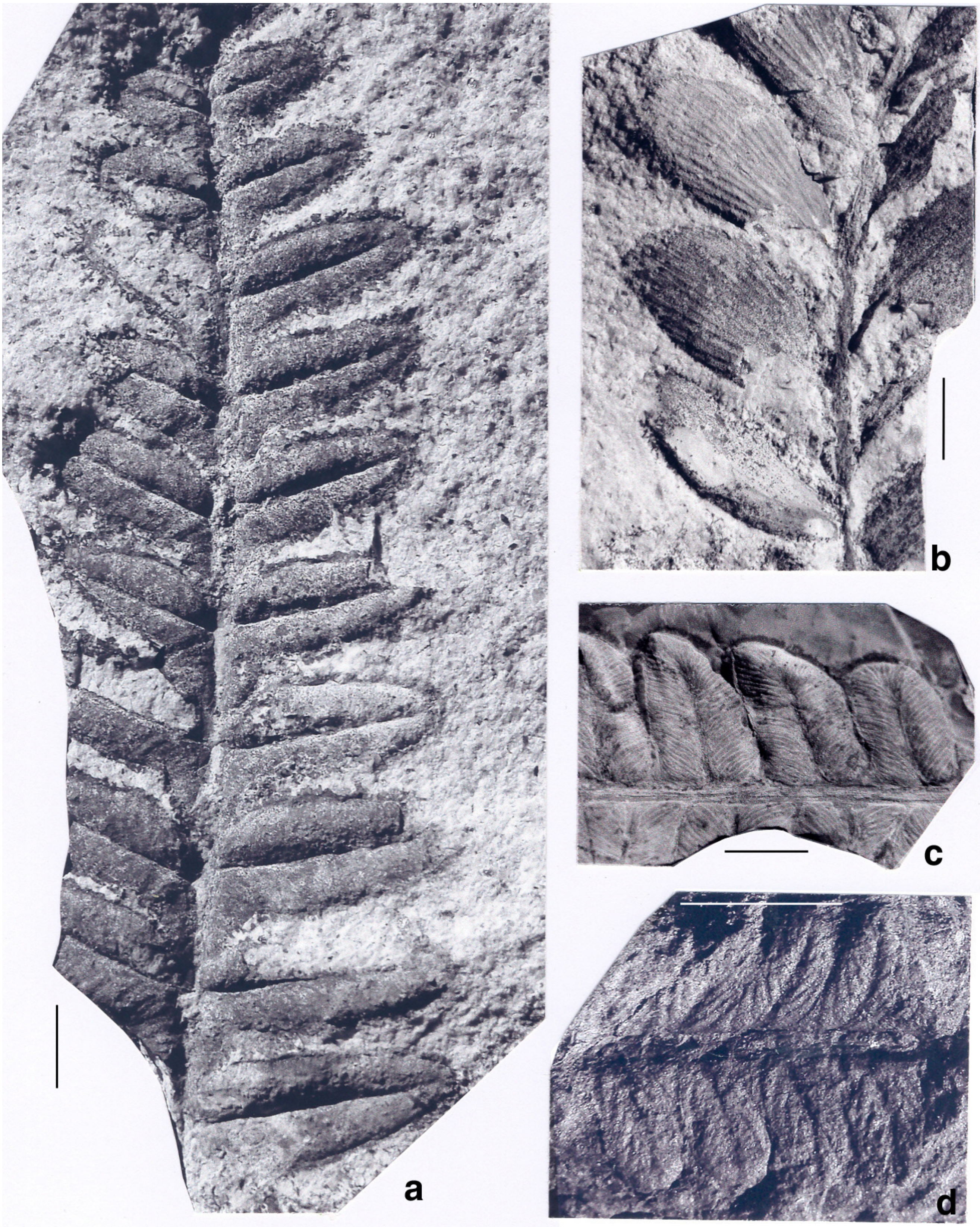

Fig. 26.- a) *Alethopteris brevis* Weiss, x 3. b) *Sphenozamites rochei* Renault, x 3. c) *Callipteridium rochei* Zeiller, x 3. d) *Autunia conferta* (Sternberg) Kerp, x 6. Lower part of volcaniclastic unit. All scale bars: 5 mm.

Fig. 26.- a) *Alethopteris brevis* Weiss, x 3. b) *Sphenozamites rochei* Renault, x 3. c) *Callipteridium rochei* Zeiller, x 3. d) *Autunia conferta* (Sternberg) Kerp, x 6. Parte inferior de la unidad volcanoclástica. Todas las escalas de barra: 5 mm.

Fig. 27.- a) *Cordaites* sp., x 3. b) *Nemejcopteris feminaeformis* (Schlotheim) Barthel, x 3. c) *Pecopteris puertollanensis* Wagner, x 3.Lower part of volcaniclastic unit. All scale bars: 5 mm.

Fig. 27.- a) *Cordaites* sp., x 3. b) *Nemejcopteris feminaeformis* (Schlotheim) Barthel, x 3. c) *Pecopteris puertollanensis* Wagner, x 3. Parte inferior de la unidad volcanoclástica. Todas las escalas de barra: 5 mm.

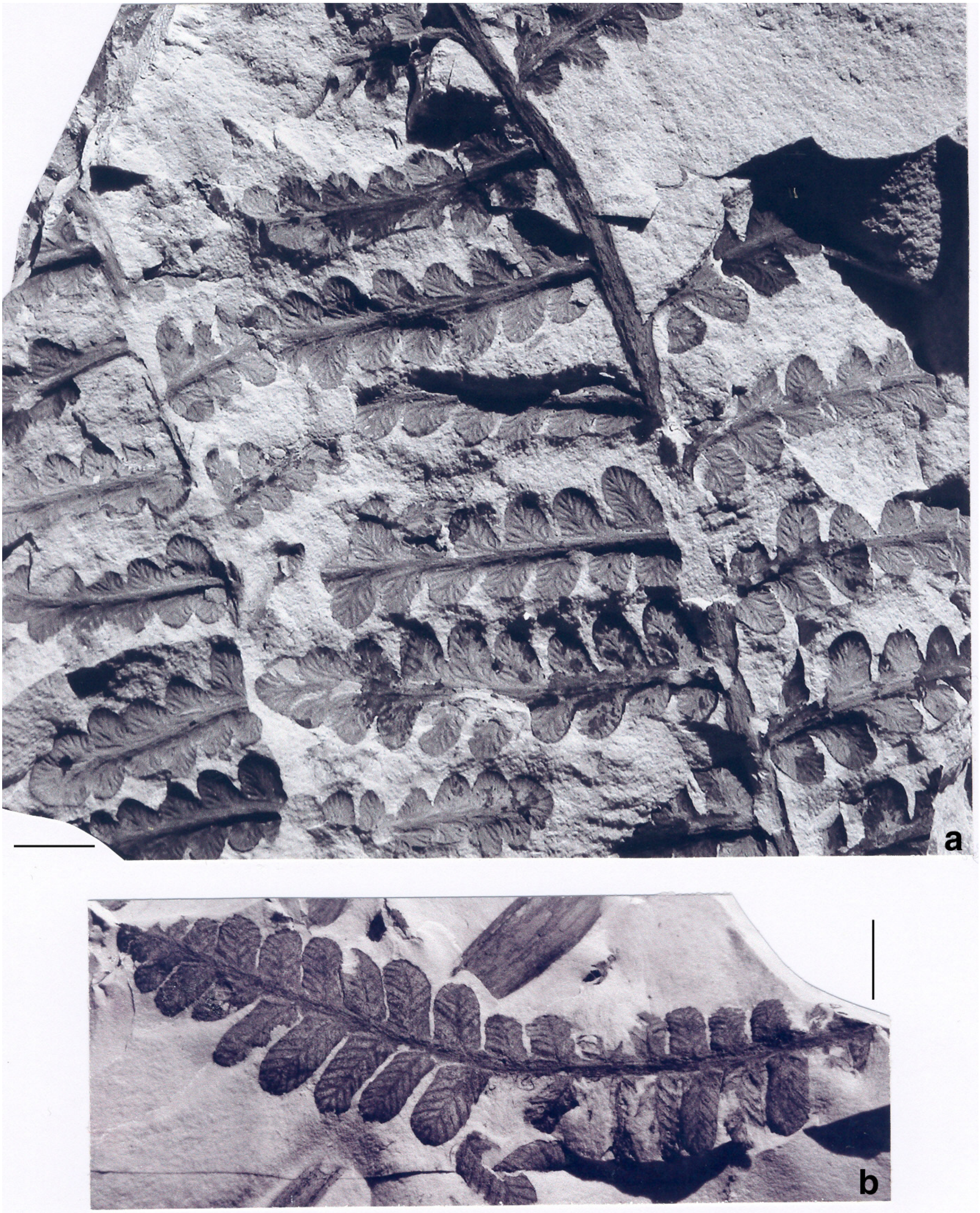

Fig. 28.- a) *Remia pinnatifida* (Gutbier) Knight, x 3. b) *Pecopteris* cf. *monyi* Zeiller, x 3. Lower part of volcaniclastic unit. All scale bars: 5 mm.

Fig. 28.- a) *Remia pinnatifida* (Gutbier) Knight, x 3. b) *Pecopteris* cf. *monyi* Zeiller, x 3. Parte inferior de la unidad volcanoclástica. Todas las escalas de barra: 5 mm.

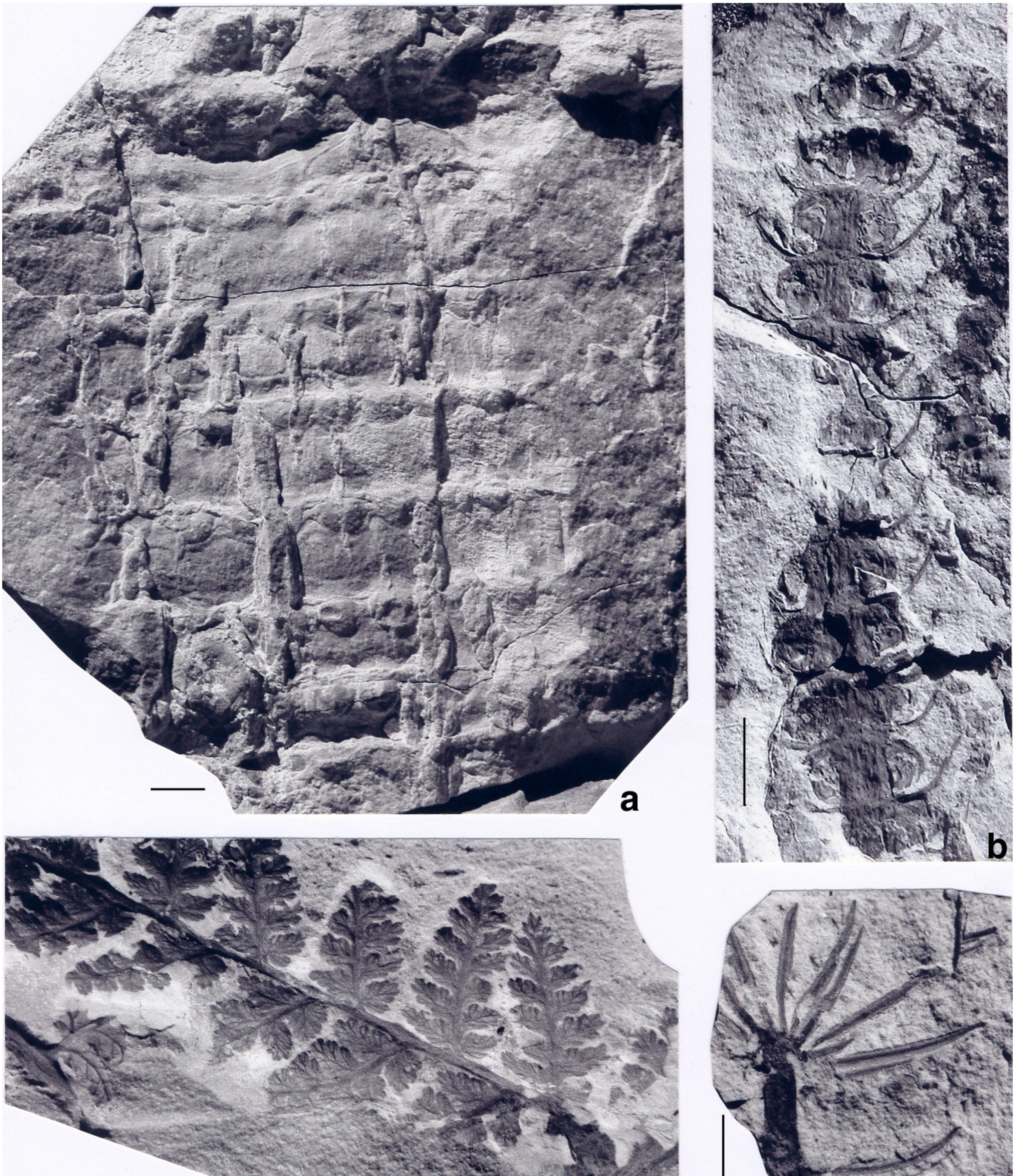

Fig. 29.- a) *Calamites multiramis* Weiss. Outer surface of stem with branch scars, x 2. b) *Calamostachys tuberculata* (Sternberg) Weiss, x3. c) *Annularia carinata* Gutbier, x 3. d) *Renaultia lebachensis* (Weiss) Brousmiche, x 3. All scale bars: 5 mm.

Fig. 29.- a) *Calamites multiramis* Weiss. Superficie externa del tallo mostrando cicatrices rameales, x 2. b) *Calamostachys tuberculata* (Sternberg) Weiss, x3. c) *Annularia carinata* Gutbier, x 3. d) *Renaultia lebachensis* (Weiss) Brousmiche, x 3. Todas las escalas de barra: 5 mm.

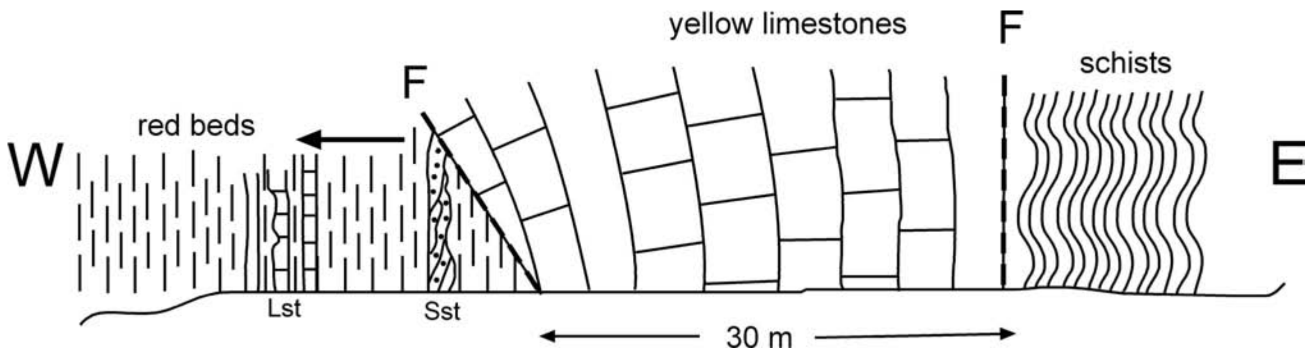

Fig. 30.- Section corresponding to an abandoned road cutting alongside the main road to El Pedroso. Red beds assumed to be Triassic are in thrust contact with presumed Mississippian cream coloured limestones. These, in turn, are in fault contact with Precambrian schists with bands of gneiss. This is the more important fault (see Fig. 2). Scale: 1:500

Fig. 30.- Corte al lado de la carretera antigua a El Pedroso. Muestra un contacto por falla entre capas rojas atribuibles, quizá, al Triásico, y calizas de color ocre posiblemente misisípicas. Estas, a su vez, se encuentran en contacto por falla con esquistos precámbricos. Esta falla es de mayor envergadura (ver Fig. 2). Escala: 1:500.

Silicification of the logs may be related to residual volcanic activity. Where an excess of water became available, shallow stream deposits were generated and shallow ponds developed which dried out subsequently. It seems possible to deduce a fairly dry climate with occasional, rather strong rainfall mobilising weathered soils on hill slopes. This climate with occasional rain fall was rather different to the everwet conditions of Pennsylvanian times at the same near-equatorial latitude.

At a higher level within the upper red beds, and corresponding with a southerly expansion of sedimentary basin by means of onlap onto a granitic basement, flash flood deposits occur. These show mass flow of coarse, pebbly material derived from the basin margins. Angular clasts are in evidence in these deposits. Some of the more sizeable clasts show a desert patina. The higher part of the upper red beds also shows the presence of caliches. A progressively drier climate may be deduced.

The sedimentary history of the Lower Permian of the Valdeviar Basin agrees to a large extent with that known from coeval deposits in the central part of Iberia and elsewhere in Europe. However, the near-absence of "callipterid" floral elements is noted as is a more consistent permanence of humid conditions up to and including the lower part of the higher red beds succession. Better drained soils seem to have been restricted to the basin margin. Still, the marshy ground was subjected to oxidising conditions producing red beds, so that permanent lakes seem to be out of the question. Occasional heavy rainfall seems to have been a factor in re-establishing marshy conditions of an ephemeral nature.

The climatic history of Valdeviar, which lay at a low palaeolatitude, may be related to the change from everwet to seasonally drier conditions which characterised the Euramerican Realm in post-Carboniferous times. Waning of the Pennsylvanian Ice Age brought a different rainfall pattern, and this is reflected in the Lower Permian succession at Valdeviar.

An overlying, brick red succession of strata in the Valdeviar depression, which seems to be of Triassic age, carries a rather different climatic signature. Here, caliches are apparently more common as well as developed in relatively thick calcareous bands. No volcanic influences have been found in these highest red beds with abundant caliches. The climatic signature is that of a relatively dry environment, although laterally extensive sandstones and conglomerates are apparently due to fluvial processes. The break with the earlier, Lower Permian succession is at the base of laterally persistent conglomerates which are generally clast-supported and which seem to be of a fluviatile origin.

8. Palaeotectonic considerations

The Valdeviar Basin shows steepening of the dip (55º to 90º) alongside the present-day northeastern basin margin. Simon (1943) attributed this to drag as a result of "basement" rocks having been thrust across the Lower Permian sediments, and Simancas (1985) ascribed this thrust fault to a reactivation of more important earlier fractures coincident with the boundary between the Ossa-Morena and South Portuguese zones, which he interpreted as a major strike-slip fault. Simancas assumed a genetic relationship between the ancient fault zone and the Early Permian basin, proposing, in effect, that syn-sedimentary faulting occurred on the northeastern basin margin. He emphasised this relationship by suggesting that the basalts would have intruded by means of this tectonic fracture. However, the basalts occur only in the northwestern part of the basin, and their distribution seems unrelated to a (supposed) northeastern boundary fault. The present writers have observed an apparently undisturbed unconformable contact between Lower Permian strata and a varied suite of "basement" rocks in the vicinity of the Cerro de los Pavones, in the northern part of the NE boundary to the Valdeviar Basin. This puts into question the hypo-thesis of syn-sedimentary faulting on the NE basin margin. Steepening of the Lower Permian strata is therefore post-sedimentary and most likely related to tilting of fault blocks beyond the present-day NE boundary which is due to outcrop conditions and not to a sedimentary basin margin. South of the hill known as Cerro de los Pavones there is another exposed section of steeply dipping Lower Permian strata along the road following the higher reaches of the Viar river. Although the actual contact with underlying basement rocks (schists with thin bands of gneiss) is not exposed in this section, the Lower Permian succession closely resembles that at Pavones, and appears to be complete. A fault contact with the unconformable basement rocks is therefore most unlikely. About 14 km to the SE along the northeastern boundary of Valdeviar, a well-exposed section of steeply dipping strata exists in the cutting of the old road leading to El Pedroso (Fig. 30). This shows red beds with substantial nodular limestone bands, possibly of Triassic age, in a near-vertical position. These are covered by what appears to be a steeply angled thrust fault which brings the red beds into contact with a cream-coloured limestone, 40 m thick, which the geological map (Ventas Quemadas sheet) attributes to the Lower Carboniferous (Mississippian). This limestone is in fault contact with schists with thin bands of gneiss, a unit which is attributable to the Precambrian (Fig. 30). A major fault zone is represented, even though the geological map fails to show it as such. Its age and general significance is unknown, but the outcrop distribution as shown on the published maps suggests that a very important geological fracture is represented. Simancas (1985) proposed that this would coincide with the Ossa-Morena/ South Portuguese zonal boundary, but this is subject to reservation. It is beyond the brief of the present paper to analyse this question in depth.

It is unclear how much of the Lower Permian succession has been suppressed at this point, or, indeed, whether the red beds involved are Triassic or should be ascribed to the higher part of the upper red beds of the (onlapping) Lower Permian succession. The present writers assume that Triassic is involved.

García-Navarro and Sierra (1998) made a detailed tectonic analysis of faults associated with the northeastern boundary of the Valdeviar Basin. Like the earlier authors, they assumed that the Lower Permian deposits would be invariably limited by a fault contact. This has now been shown to be incorrect for the northeastern boundary in the general area of the Cerro de los Pavones where the Lower Permian deposits are in (unconformable) stratigraphic contact with underlying "basement" rocks. On the other hand, a faulted contact between possibly Triassic strata and a presumed Mississippian limestone has been seen in the El Pedroso road section. The significance of this fault is not quite clear, but it is obviously of lesser importance than a fault zone which occurs a little beyond this contact. The question arises whether the tectonic data collected by García-Navarro and Sierra (1998) might relate, at least in part, to the more important fault zone mentioned above, which puts Mississippian (?) in contact with Precambrian schists with bands of gneiss.

More work is required, but it seems that faulting and tilting of the rocks underlying the Lower Permian (and Triassic) deposits may have been responsible for the steepening of Lower Permian strata along the north-eastern boundary of its outcrop. These post-Triassic (?) movements may have occurred along earlier (Carboniferous?) fault zones.

9. Early Permian regional setting

The area of Ossa-Morena, consisting of several parallel strips of different terranes, which obtained their present configuration during the Pennsylvanian (Wagner, 2004), was fully consolidated in Early Permian times. As mentioned before, this implies that the present position of the Valdeviar Basin with regard to its surroundings is not likely to be different to that in the Early Permian. This is apparently confirmed by the find of a major volcanic centre, at 3 to 5 km distance from the Valdeviar Basin (Fig. 2). This appears to be about right for the relationship with the volcaniclastic deposits in the basin.

In the more remote vicinity, at some 30 km NE of Valdeviar, there are several outcrops of Lower Permian strata in the general surroundings of San Nicolás del Puerto (Sevilla), Guadalcanal (Sevilla) and Fuente del Arco (Badajoz). Although floral remains from the Guadalcanal area also show an Autunian age (Broutin, 1986), the Lower Permian strata at Guadalcanal may be marginally older than those found at Valdeviar. This assumption may be impossible to substantiate on floral evidence, but the climate seems to have been wetter at the time when sedimentation took place in the Guadalcanal area, where there is a notable absence of red beds. Apart from thickness variations in the different outliers near Guadalcanal, the general succession in this area is limited to only a few tens of metres. The beds are flat-lying, unfolded, with evidence of a minor palaeotopography which was filled in by the Autunian sediments which are generally of lacustrine facies. The slight evidence of volcanic activity in the shape of tuffaceous "tonstein" bands within the lacustrine shales, suggests a possible genetic link with the more substantial volcaniclastic interval in the lower part of the Valdeviar succession, but this cannot be regarded as a foregone conclusion.

10. Peninsular and European context

The Lower Permian strata of the Iberian Peninsula occur in various different areas which are widely separated geographically and which belong to separate basins (see the general account by López-Gómez *et al*., 2002). On the other hand, they have a number of characteristics in common. In all cases there is a volcaniclastic component which shows that the tectonic regime had changed after NW-SE strike-slip faulting had ceased to operate near the end of Pennsylvanian times, and the Iberian Massif had come into being as a distinct entity. Volcanic activity associated with a tensional tectonic regime involved a wider European region, reaching across France and western Germany into Saxony in central Europe, and this tends to show the fundamental unity of the European area, including Iberia.

Within the Iberian Peninsula the orogenic/compressional regime of northern Spain (Cantabrian Mountains, Pyrenees) finished before Stephanian C (equals early Autunian), and this appears coincident with the full assembly of terranes in the southwestern part of the Iberian Peninsula. A tensional tectonic regime followed, together with widespread magmatic activity. The tensional regime is supposed to be related to strike-slip faults bordering the Iberian Massif (see López-Gómez *et al*., 2002, fig. 10.1), but the broader geotectonic implications are subject to discussion. It is unlikely that major rift basins existed in Early Permian times, and the authors advocating this scenario (*op. cit.*) do, in fact, describe Late Permian and Triassic conditions. Indeed, it is noted that the Early Permian fault pattern shows NW-SE and NNE-SSW components, producing local basins which do not add up to major rift structures. The geological history of the Valdeviar Basin shows that a local depression was involved without any evidence of syn-sedimentary faulting on the scale required for a rift basin. There is a clear absence of alluvial fan deposits along a basin margin, as could be expected for a fault-controlled basin.

Explosive rhyolitic-dacitic volcanism as found at Valdeviar (Sierra *et al*., 2000) is a common denominator in the Iberian Massif, from Stephanian C onwards (as at Puertollano in the province of Ciudad Real – Králik and Pešek, 1985). The widespread nature of this vulcanicity is apparent from records in the Lower Permian of Guadalajara (Ramos, 1979; Sopeña, 1979), Soria (Peña *et al*., 1977; Rey and Ramos, 1991) and Zaragoza (Amerom *et al*., 1993). These records are all quite local and difficult to fit into a broader pattern. An exhaustive summary of data relating to Early Permian explosive vulcanicity in Central Iberia has been published by Muñoz *et al*. (1985). It was clearly a widespread phenomenon related to crustal thinning with anatexis. Muñoz *et al.* (1985) noted that the explosive vulcanicity did not seem to have involved lava flows of acidic composition. A small occurrence of what appear to be acidic lavas has been observed (but not yet investigated) at Valdeviar. Muñoz *et al.* (1985) also pointed out the association with basaltic outpourings which they related to the same crustal processes. The comparison with the situation at Valdeviar is striking. Lago *et al.* (2004) also reviewed the evidence of magmatic relationships in central Spain (Iberian Chain) and described the succession of magmatic rocks, including both intrusives and volcaniclastics of Early Permian age. They record a range from basalt to rhyolite, with a predominance of andesitic rocks. The tectonic environment of the explosive vulcanism at Valdeviar and its surroundings is unclear, and the detailed geology of the major volcanic centre at some 3 to 5 km distance has not yet been investigated. The existing Geological Survey maps of the area are in urgent need of revision.

The other aspect is palaeoclimatic. Red bed sedimentation became more widespread in Europe from the Early Permian onwards. This relates to the changeover from everwet palaeoequatorial conditions during the Pennsylvanian Subperiod of the Carboniferous, to a generally less humid climate with alternating wet and drier episodes during the Early Permian. This tendency, due to the global climatic changes induced by the rapid shrinking and eventual disappearance of a large South Polar ice cap, gradually increased throughout the Permian. Soil formation shifted from gleys under reducing conditions to red beds under oxidising conditions. The composition of the fossil floral record also changed. Peltaspermales (callipterids) and conifers came to the fore when palaeoenvironmental aspects favoured the preservation of floral elements growing on better drained soils. The classical paper by Gothan and Gimm (1930) was the first to draw attention to alternating wet and drier floral associations in the Early Permian of Thuringia, Germany. Later work has confirmed and refined these pioneer investigations. In Valdeviar the callipterids have only been recorded with one small fragment of *Autunia conferta*. Their general absence may be explained by the fact that fossil collections were made predominantly from ash fall deposits in a lacustrine environment. It is noted that conifer foliage has been recorded by Gavala (1927). A similar quasi-absence of callipterids and paucity of conifers at Guadalcanal has been ascribed to palaeogeographic configurations (Broutin, 1986).

The climatic changes linked to the waning of the Pennsylvanian Ice Age, which were of global significance, are not likely to have come about at exactly the same time with the same intensity in the different parts of the palaeoequatorial belt. Within the European and Iberian context, it appears that the Iberian Massif experienced drier conditions at a somewhat later time than occurred in central Europe. Broutin (1986) found several taxa of Cathaysian complexion, i.e. elements living under ever-wet conditions, in the Guadalcanal area, and only a few conifers representative of better drained soils. Records of plants of Angaran affinity, as reported by the same author, are subject to reservation. Only grey sediments were laid down at Guadalcanal. Red beds are found in Valdeviar, thus showing evidence of oxidising conditions with soil formation where lacustrine areas dried out. The ephemeral nature of the ponded areas at Valdeviar shows drier episodes in a generally humid area. Indeed, the floral remains show a composition (sphenopsids, ferns, pteridosperms, rare lycopsids, and *Cordaites*), which is indicative of humid conditions. Callipterids are generally absent, as they are, on the whole, at Guadalcanal where the illustrations of *"Callipteris"* include *Alethopteris schneideri* Sterzel (Broutin, 1986, pl. V, figs. 1, 4, 5), leaving only a few fragments of doubtful attribution as possible remains of *Autunia conferta* (Sternberg) Kerp (Broutin, 1986, pl. V, figs. 2, 3, 6, 8). The record of conifer remains in Valdeviar is restricted to the one locality reported by Gavala (1927). A possible age difference between the Guadalcanal and Valdeviar areas is marginal and unlikely to be reflected in the composition of the fossil floras.

There is a difference with time-equivalent floras from Guadalajara province, ENE of Madrid, where well characterised remains of the callipterids *Autunia conferta* and *Gracilopteris raymondii* (Zeiller) Kerp have been found (Sopeña, 1979; Wagner, 1999). At Fombuena, in the province of Zaragoza, callipterids are rare, though undoubtedly present (Amerom *et al*., 1993). The floral composition at Fombuena is almost entirely identical to that in Valdeviar, but *Taeniopteris* leaves are recorded at Fombuena, whereas these have not yet been found in Valdeviar. This is a matter of facies. *Autunia conferta* is mentioned as a rare element at Fombuena (Amerom *et al*., 1993) just like it is at Guadalcanal (Broutin, 1986) and Valdeviar. Preservation at Fombuena is in fine, silicified tuffaceous deposits, similar to those found in the volcaniclastic interval at Valdeviar. Ichnofossils reported from the Fombuena occurrence are also the same as those found at Valdeviar. J. Broutin, J. Gisbert and E. Liñán (*in* Amerom *et al*., 1993) attributed the preservation of plant impressions at Fombuena to entombment by pyroclastic flow, but this alternative interpretation to ash fall in a lacustrine environment may have to be reconsidered.

10. Conclusions

The Valdeviar Basin represents an Early Permian intracontinental depression which commenced in what appears to have been a substantial palaeovalley in the extreme northwestern part of the basin, the full extent of which is unknown. Sedimentation gradually extended southeastwards, filling up a palaeotopography at first, and then spreading into a wider basin. There is evidence of a hilly country having existed northeast of the basin, but there is no evidence of syn-sedimentary faulting. The rectilinear contact of steeply dipping Lower Permian (and overlying Triassic?) deposits with a variety of "basement" rocks on the NE outcrop boundary is due to post-sedimentary tectonic movements at some distance beyond this boundary, probably faulting accompanied by tilting. Part of the NE boundary shows an undisturbed (unconformable) stratigraphic contact, but a steeply angled thrust of apparently minor importance occurs in another part. The area of sedimentation was basically lacustrine under climatic conditions which provoked periodic drying and soil formation under oxidising conditions. Both ichnofossils and hygrophile plant megafossils attest to the humid environment in the sedimentary basin. Basalt flows and rhyodacitic volcanic ash deposits with minor acidic lava flows attest to strong magmatic activity which has been traced to a volcanic centre in a wide area of Cambrian cleaved mudrock to the NE of the Valdeviar Basin. These volcanoes occur in tectonically undisturbed, upright position. Topographic relief on the NE basin margin carried coniferous forests which were partly uprooted by mass flow produced by occasional, strong rainfall mobilising weathering products on hill slopes. Shallow stream deposits were produced when more water was available, and shallow ponds of an ephemeral nature were created locally under the same climatic conditions. Conglomeratic flash flood deposits occur in the higher part of the Lower Permian red beds, which also contain minor bands of caliche. Overlying, paraconformable Triassic red beds, including fluvial conglomerates, show more substantial caliches.

The Valdeviar Basin shows similar characteristics to sedimentary basins of the same Early Permian (mid-Autunian) age elsewhere in the Iberian Peninsula. Floral remains are of "Rotliegend" character, but with a lesser proportion of conifers and peltasperms than is known from central Europe. This is probably due to the predominantly lacustrine facies, and should probably be interpreted in palaeoenvironmental terms rather than palaeofloristic ones. Climatically, the Valdeviar Basin is not apparently different to other Early Permian basins in western Europe, and there is no confirmation of a high mountain chain separating the SW part of the Iberian Massif from the remainder of the Iberian Peninsula, as Broutin (1986) proposed on the basis of a study of floral remains from the Guadalcanal area, at some 30 km NNE of Valdeviar.

Acknowledgements

This paper has been written as a result of the Project "Carta Paleontológica del área de afección del Pantano de Melonares (provincia de Sevilla)" of the "Consejería de Cultura" of the Junta de Andalucía, regarding the geological/palaeontological impact of the flooding of the Viar valley by the Melonares reservoir. The unfailing courtesy and helpfulness of personnel of the "Confederación Hidrográfica del Guadalquivir", Miguel Ángel Puertas and José Luis Sánchez López, in particular, is acknowledged with pleasure. Eloisa Bernáldez has made every effort to make this investigation possible. A number of fossil plant remains were made available by Ildefonso Bajo, Joaquín Cárdenas and Jaime Gil, whose early guidance in the field is gratefully acknowledged by the first author. Thanks are due to Carmen Álvarez-Vázquez for the photographs of plant fossils. Helpful comments by the referees, Ronny Rössler and Alfonso Sopeña, are gratefully acknowledged as well. Bill DiMichele and Hans Kerp identified the *Syringodendron* recorded in this paper.

References

Amerom, H.W.J. van, Broutin, J., Ferrer, J., Gámez-Vintaned, J.A., Gisbert, J., Liñán, E. (1993): Les flores du Permien basal et la paléoichnologie de la fosse de Fombuena (province de Zaragoza, Espagne). *Mededelingen Rijks Geologische Dienst*, 48: 1-63 (pls 1-16).

Aassoumi, H., Broutin, J., El Wartiti, M., Freytet, P., Koeniguer, J.-C., Quesada, C., Simancas, F., Toutin-Morin, N. (1992): Pedological nodules with cone in cone structure in the Permian of Sierra Morena (Spain) and Central Morocco. *Carbonates and Evaporites*, 7 (2), 140-149.

Barthel, M. (1976): Die Rotliegendflora Sachsens. *Abhandlungen des Staatlichen Museums für Mineralogie und Geologie, Dresden,* 24: 190 p., Tafn 1-48.

Bernáldez, E. (1987): Informe sobre la carta paleontológica de la provincia de Sevilla. *Anuario Arqueológico de Andalucía, 1985. III: Actividades de Urgencia*, 261-269.

Broutin, J. (1978): *Dadoxylon (Cordaioxylon)* sp. Grand'Eury 1877. Note préliminaire sur les bois fossiles du Permien du Rio Viar (province de Séville, Espagne). *103e Congrès national des sociétés savantes, Nancy, 1978. Sciences,* fasc. II: 47-52.

Broutin, J. (1981): *Étude paléobotanique et palynologique du passage Carbonifère-Permien dans les bassins continentaux du Sud-Est de la zone d'Ossa-Morena (environs de Guadalcanal, Espagne du Sud). Implications paléogéographiques et stratigraphiques*. Thèse de Doctorat d'Etat ès Sciences Naturelles, 234 p., pls 1-30, pls I-XXX, pls A-D (unpublished).

Broutin, J. (1986): Étude paléobotanique et palynologique du passage Carbonifère Permien dans le Sud-Ouest de la Péninsule Ibérique. *Cahiers de Paléontologie*, *Éditions du Centre National de la Recherche Scientifique*, 165 p., pls I-XXX.

Crimes, T.P., Legg, I., Marcos, A., Arboleya, M. (1977): Late Precambrian-low Lower Cambrian trace fossils from Spain. In: Trace Fossils 2 (T.P. Crimes, J.C. Harper, eds),. *Geological Journal, Special Issue*, 9: 91- 138.

Gámez-Vintaned, J.A., Liñán, E. (1993): Paléoichnologie. In: H.W.J. Amerom *et al.: Les flores du Permien basal et la paléoichnologie de la fosse de Fombuena (province de Zaragoza, Espagne)*: 19-26, pls 12-16.

García, A., Pignatelli, R., Crespo, A., Torres, T. (1975): Mapa Geológico de España E. 1: 50.000. Lora del Río (963). Memoria, 17 p. Mapa Geológico.

García-Navarro, E., Sierra, S. (1998): Evolución tectónica del borde oriental de la cuenca del Viar (Zona Sudportuguesa). *Revista Sociedad Geológica de España,* 11 (3-4): 223-232.

García Monzón, G., Jerez Mir, F., Argüelles, A., Cueto, L.A. (1974): Mapa Geológico de España E. 1:50.000. Almadén de la Plata (919). Memoria, 29 p. Mapa Geológico.

Gavala, J. (1927): Mapa Geológico de España a escala 1:50.000. Memoria correspondiente a la hoja de Cantillana. *Boletín Instituto Geológico y Minero de España,* XLIX: 79 p., Mapa Geológico y cortes.

Gothan, W., Gimm, O. (1930): Neuere Beobachtungen und Betrachtungen über die Flora des Rotliegenden von Thüringen. *Arbeiten Institut für Paläobotanik und Petrographie der Brennsteine, Preussische Geologische Landesanstalt*, 2 (1): 39-74.

Haldemann, S.S. (1840): *Supplement to Number One of "A monograph of the Limniades, or fresh-water univalve shells of North America", containing descriptions of apparently new animals in different classes, and the names and characters of the subgenera in Paludina and Anculosa*. J. Dobson, Philadelphia, 3 p.

Han, Y., Pickerill, R.K. (1994): Taxonomic reassessment of *Protovirgularia* M'Coy 1850 with new examples from the Palaeozoic of New Brunswick, eastern Canada. *Ichnos*, 3: 203-212.

Jongmans, W.J. (1951): Las floras carboníferas de España. *Estudios Geológicos*, VII, 14: 281-330.

Králík, J., Pešek, J. (1985): The Volcanic Rocks of the Puertollano Basin, Ciudad Real, Spain. In: M.J. Lemos de Sousa and R.H. Wagner (eds), Papers on the Carboniferous of the Iberian Peninsula (Sedimentology, Stratigraphy, Palaeontology, Tectonics and Geochronology), *Anais da Faculdade de Ciências, Universidade do Porto,* Supplement to volume 64 (1983): 245-267, pls 1-6.

Lago, M., Arranz, E., Pocovi, A., Galé, C., Gil-Imaz, A. (2004): Lower Permian magmatism of the Iberian Chain, Central Spain, and its relationship to extensional tectonics. In: Wilson, M., Neumann, E.-R., Davies, G.R., Timmerman, M.J., Heeremans, M., Larsen, B.T. (eds), Permo-Carboniferous Magmatism and Rifting in Europe. *Geological Society, London, Special Publications,* 223: 465-490.

López-Gómez, J., Arche, A., Pérez-López, A. (2002): Permian and Triassic. In: W. Gibbon, T. Moreno (eds), The Geology of Spain. *Geological Society, London*: 185-212.

Lotze, F. (1945): Zur Gliederung der Varisziden der Iberischen Meseta. *Geotektonische Forschungen*, 6: 78-92.

Martín Escorza, C., Rivas Ponce, A. (1975): Mapa Geológico de España E. 1: 50.000. Castilblanco de los Arroyos (940). Memoria, 25 p. Mapa Geológico.

Muñoz, M., Ancochea, E., Sagredo, J., de la Peña, J.A., Hernán, F., Brandle, J.L., Marfil, R. (1985): Vulcanismo permo-carbonífero de la Cordillera Ibérica. *Dixième Congrès International de Stratigraphie et de Géologie du Carbonifère, Madrid 1983*, Compte Rendu, 3: 27-52. Instituto Geológico y Minero de España.

Peña, J.A. de la, Fonollá, F., Ramos, J.L., Marfil, R. (1977): Identificación del Autuniense en la rama aragonesa de la Cordillera Ibérica (provincia de Soria). *Cuadernos de Geología Ibérica*, 4: 123-134.

Ramos, A. (1979): Estratigrafía y paleogeografía del Pérmico y Triásico al Oeste de Molina de Aragón (Provincia de Guadalajara). *Seminarios de Estratigrafía, Serie Monografías*, 6: 313 pp.

Rey, D., Ramos, A. (1991): Estratigrafía y sedimentología del Pérmico y Triásico del sector Deza-Castejón (Soria). *Revista Sociedad Geológica de España*, 4 (1-2): 105-125.

Rindsberg, A.K. (1994): Ichnology of the Upper Mississippian Hartselle Sandstone of Alabama, with notes on other Carboniferous formations. *Bulletin of the Geological Survey of Alabama*, 158: 1-107.

Ruiz Falcó, M., Madariaga Rojo, R. (1933): Vegetales fósiles del Carbonífero español. *Boletín del Instituto Geológico y Minero de España,* LIII: 69-89, láms VI-IX.

Ruiz Falcó, M., Madariaga Rojo, R. (1941): Aportación al estudio de los terrenos Carbonífero y Permiano en España. *Boletín del Instituto Geológico y Minero de España*, LV: 145-248.

Sanz H.-Sampelayo, D.T., Ledesma García, D.F. (1975): Mapa Geológico de España E. 1:50.000. Ventas Quemadas (941). Memoria, 30 p. Mapa Geológico.

Sierra, S. (2004): *Análisis estratigráfico de la cuenca pérmica del Viar (SO de España).* Universidad de Huelva, Facultad de Ciencias Experimentales, Departamento de Geología. Tesis doctoral (unpublished).

Sierra, S., Moreno, C. (1998): Arquitectura fluvial de la cuenca pérmica del Viar (Sevilla, SO de España). *Revista Sociedad Geológica de España*, 11 (3-4): 197-212.

Sierra, S., Moreno, C. (2004): Cuenca Pérmica del Viar. *In:* J.A. Vera (ed.), *Geología de España*: 214-215. *Instituto Geológico y Minero de España*.

Sierra, S., Moreno, C., González, F. (1999): Los abanicos aluviales de la cuenca pérmica del Viar (SO de España): Caracterización sedimentológica y petrográfica. *Geogaceta,* 25: 195-197.

Sierra, S., Moreno, C., González, F. (2000): El vulcanismo pérmico de la cuenca del Viar (SO de España): Caracterización de la Secuencia Volcanoclástica Gris. *Geogaceta,* 27: 159-162.

Sierra, S., Moreno, C., González, F. (2003): Coladas piroclásticas antiguas: un caso de estudio en la cuenca pérmica del Viar (SO de España). *Geogaceta,* 33: 83-86.

Simancas, J.F. (1983): Geología de la extremidad oriental de la Zona Sudportuguesa. *Tesis Doctoral, Universidad de Granada,* 439 p. (unpublished).

Simancas, J.F. (1985): Estudio estratigráfico de la cuenca del Viar. In: 5ª Reunión del Grupo de Ossa-Morena, Belmez (Córdoba): 7-17. *Temas Geológico Mineros*, Instituto Geológico y Minero de España.

Simancas, J.F., Rodríguez Gordillo, J.F. (1980): Magmatismo basáltico hercínico tardío en el NW de Sevilla. *Cuadernos de Geología, Universidad de Granada*, 11: 49-60.

Simon, W. (1943): Zur Geschichte der spanischen Sierra Morena. 4. Variscische Sedimente der Sierra Morena. Die Viar Schichten. *Senckenbergiana,* 26 (5): 401-426.

Sopeña, A. (1979): Estratigrafía del Pérmico y Triásico del NW. de la Provincia de Guadalajara. *Seminarios de Estratigrafía*, 5: 329 p.

Sopeña, A., Virgili, C., Arche, A., Ramos, A., Hernando, S. (1983): El Triásico. *In*: *Libro Jubilar J.M. Ríos. Geología de España,* II: 47-62. Instituto Geológico y Minero de España.

Vozenin-Serra, C., Broutin, J., Toutin-Motin, N. (1991): Bois permiens du Sud-Ouest de l'Espagne et du Sud-Est de la France. Implications pour la taxonomie des Gymnospermes paléozoïques et la phylogénie des Ginkgophytes. *Palaeontographica,* Abt. B, 221 (1-4): 1-26.

Torell, O.M. (1870): Petrificata Suecana Formationis Cambricae. *Lunds Universitet, Årsskrift*, 6: 1-14.

Wagner, R.H. (1998): Consideraciones sobre los pisos de la Serie Estefaniense. *Monografías de la Academia de Ciencias Exactas, Físicas, Químicas y Naturales de Zaragoza,* 13: 9-19.

Wagner, R.H. (1999): Macrofloras del Carbonífero/Pérmico. *In*: E. Aguirre e I. Rábano (coord.), *La huella del pasado. Fósiles de Castilla-La Mancha. Patrimonio histórico.* Junta de Comunidades de Castilla-La Mancha: 75-98.

Wagner, R.H. (2004): The Iberian Massif: a Carboniferous assembly. *Journal of Iberian Geology,* 30: 93-108.

Wagner, R.H., Mayoral, E. (2005): El Pérmico inferior de la cuenca de Valdeviar (Sevilla, SW de España). *Geo-Temas*, 8: 263-266.