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THE SEQUENCE AND STRATIGRAPHY OF THE EASTERN END OF THE SABERO COALFIELD (LEON, N. W. SPAIN)

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ABSTRACT

The Sabero coalfield (León) overlies the Asturian unconformity and has itself been folded and thrust into an asymmetrical syncline with a greatly thrust southern limb. The northern limb provides an undisturbed succession across which, to the north of the village of Saelices, a standard section, 1200 m thick, has been measured. This section has been subdivided into 13 units for the purposes of description, and the section is included here at a reduced scale (text-fig. 2). At the base of the succession are torrential conglomerates which, only in the north-east of the coalfield, overlie another coal bearing sequence. This comprises the Alejico beds which occur only in this area and which are considered both sedimentologically and from the flora to be part of the main succession. These beds, conformably overlain by the conglomerates, yet with deformed lower beds, indicate syn-sedimentary sagging, representing the earliest basin subsidence. This occurred before the final uplift of the Asturian phase which resulted in the conglomerates.

The coalfield succession thickens eastwards to the area of greatest subsidence. The sequence as seen in the measured section commences, above the conglomerates, with a marginally marine incursion, the only one known above the Asturian unconformity. It is succeeded by fluviatile sandstones with interbedded back-swamp, flood plain and lacustrine deposits with some workable coals. At the base of the one protracted lacustrine episode a *Leaia* marker band occurs which has been traced over a wide area and which has aided mapping of the thrust area south of Sabero. Andesitic dykes occur in units 7, 9, 10 and 12 in the measured section and a particularly thick, altered, olivine dolerite dyke occurs near the base of the section, immediately above the conglomerates. The section includes a stand of *Calamites* pith casts in position of growth and a distribution diagram (text-fig. 4) and discussion are included. The fossil flora shows little variation throughout the section and the indicated age is the Stephanian A-B transition. An occurrence chart (Table 1) and range diagram (Table 2) of selected species are included, together with 6 plates of some specimens. A geological map of the area around Sabero (text-fig. 3) is also included, as is a generalised column of the stratigraphic succession (text-fig. 5).

RESUMEN

El terreno hullero de Sabero (León) se depositó después de la fase astúrica, como una secuencia discordante que se plegó, a su vez, en forma de sinclinal asimétrico, con el flanco sur parcialmente cobijado. El flanco norte muestra una sucesión ininterrumpida, con 1.200 mts de potencia, que ha sido medida en un corte estratigráfico aflorando al norte del pueblo de Saelices (Fig. 2). Para facilitar la descripción del corte, se ha dividido en 13 unidades estratigráficas informales que representan episodios en el desarrollo de la sucesión de estratos. El corte fue medido a escala 1: 100, presentándose aquí una simplificación a escala: 1: 1.000. Empieza el corte con con-

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glomerados torrenciales, discordantes sobre rocas plegadas del Paleozoico inferior en el borde septentrional de la cuenca minera, pero concordantes sobre una secuencia hullera desarrollada localmente al oeste del pueblo de Alejico (Fig. 3). Los estratos de Alejico fueron deformados inicialmente durante su formación, y representan, muy probablemente, la primera cuenca subsidente post-astúrica en la zona de Sabero, que se estableció cuando los últimos movimientos tectónicos aún no habían cesado totalmente. Esto se deduce de las características sedimentológicas y paleontológicas de estos estratos, que se ciñen estrechamente a las que muestra la secuencia hullera sobreyacente.

Aquélla interesó una zona más amplia, sobre la que se extendieron los conglomerados en la base del corte medido. Se formaron, probablemente, como consecuencia de los últimos levantamientos de la fase astúrica en esta zona. Siguen a los conglomerados torrenciales unos 30 mts de estratos marinos y costeros, con fauna marina limitada y tirando a salobre, que representan al único nivel marino reconocido encima de la discordancia astúrica. A continuación vienen areniscas fluviales con alternancias de estratos pantanosos y lacustres, entre los que se encuentran unas pocas capas de carbón explotable. En la base de una formación lacustre de cierta importancia (130 mts) se encuentra un nivel guía con *Leaia* que permite la correlación entre el corte al norte de Saelices y la zona trastornada al sur de Sabero. El corte medido incluye los restos de un bosque de *Calamites*, mostrando los moldes internos de troncos en posición de vida (Fig. 4). Existen diques en varias unidades y, sobre todo, en la unidad 1, cerca de la base. La parte superior del corte incluye el Paquete Norte, término minero que se aplica a las capas Sucesiva y Estrecha, y que precede al Paquete Central que no ha sido estudiado todavía con detalle. La Fig. 1 recoge las zonas con paquetes hulleros explotables, y la Fig. 5 presenta la columna estratigráfica generalizada hasta el Paquete Central inclusive.

La flora fósil muestra poca variación desde los estratos de Alejico hasta la parte más alta del corte medido y sus correlativos al sur de Sabero. Se identifica como transicional entre Estefaniense A y B, sin que se pueda fijar el límite entre ambos pisos. Se presentan 6 láminas de los fósiles vegetales más interesantes, así como dos cuadros mostrando la distribución estratigráfica de las especies y de su repartición por las unidades descritas.

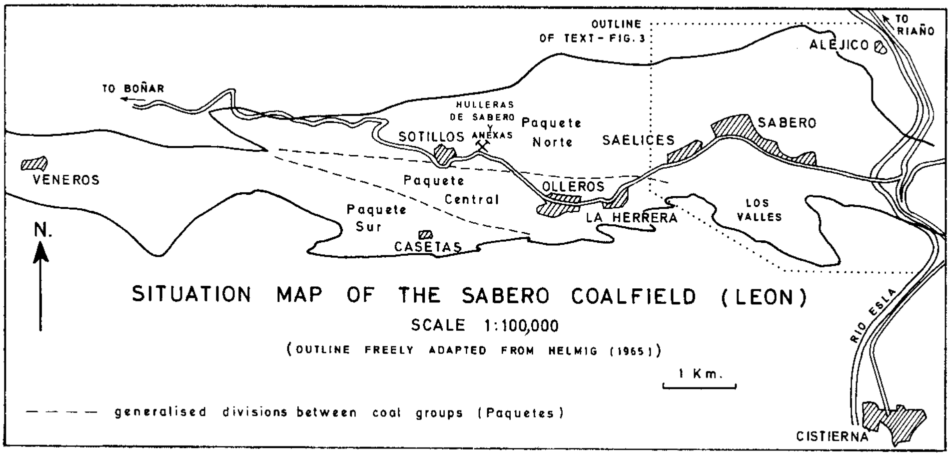
INTRODUCTION

Regional setting.

The Sabero coalfield is in the north-east of the province of León, on the southern flank of the Cantabrian Mountains, and lies 7 km north-west of Cistierna. Sabero was the site of one of the earliest iron foundries of Spain, which was supplied by local iron ore and coal. Large scale exploitation of coal resources began in the decade from 1840, and was centred around the township of Sabero, the area described in this paper. This area is now exhausted and the main centre of coal exploitation has gradually moved westwards along the Sabero valley. This movement is marked by the line of abandoned mines westwards from Sabero, the main mining centre being at present at Sotillos, 4 km west of Sabero. The principal seams now worked are in a higher part of the succession than that described here. They are generally thicker and, in Paquete Central, highly folded. Two seams of the lower mining succession, Paquete Norte, a section of which is described here, are still worked from Sotillos. All seams worked south of Paquete Central are put in Paquete Sur (text-fig. 1).

Previous work.

Early geological work on the area has been done by EZQUERRA DEL BAYO (1844), MALLADA (1898, 1903), URRUTIA (1922), and PATAC (1927). More recent geological consideration of the area begins with OLAVARRÍA (1945) who gave a summary



Text-fig. 1

of mining activity and more clearly established the relationships of the groups of seams. JONGMANS (1951) reinterpreted the floral lists and identifications of MALLADA. WAGNER (1957), while mapping to the east of the area, gave a list of plant identifications from the tip of the then working mine, Pozo Herrera 1, at Olleros, 2 km west of Sabero. This mine was working the three main groups of coal seams and the representative list indicated a Stephanian B age. The first recent mapping of the area was that of HENKES (1961). HELMIG (1965) described the Sabero coalfield in a work on some coal basins on the southern flank of the Cantabrian Mountains, also making a general map and listing plant fossils from the separate mining successions. From the flora, identified by STOCKMANS, a Stephanian A age is claimed, with possibly some Stephanian B represented in the uppermost beds. HELMIG refers the whole sequence to the Cea formation following usage of the Leiden school. The conglomeratic lower part of the sequence is referred to the Carrión member, the coal bearing upper part to the Prado member. This assumes correlation with the Valderrueda coalfield to the east, which appears older (WAGNER, VILLEGAS & FONOLLÁ 1969).

In STOCKMANS & WILLIÈRE (1966), further identifications and a floral list from the general tip at Sotillos were published, a Stephanian A age being claimed. WAGNER (1966a) gave lists of plant identifications from specific localities within the coalfield and also from the general tip of Pozo Herrera 1. On the basis of this flora he suggested a Stephanian B age. ALVAREZ-RAMIS (1966) described some Sphenopterids from this coalfield and BLESS (1966) has described an ostracod species from the area.

Mining terms.

Miners have named «paquetes» consisting of the various groups of coal seams. OLAVARRÍA (1945) quotes three main paquetes, Norte, Central and Oceja. These terms are still used, although the «Paquete de Oceja» is now commonly called Paquete Sur. With the exception of Paquete Norte, these paquetes are poorly defined and are separated by dislocations, and they are best considered as geographical areas (text-fig. 1).

Paquete Norte, the oldest group of seams, comprises two main seams, Capa Sucesiva and Capa Estrecha, and is contained in the section described here. Its relation to the other paquetes, which are apparently younger, is not yet clear. It also overlies a sequence, the paquete Alejito of HENKES, which is poorly exposed in the north-east corner of the area near the village of Alejico. OLAVARRÍA indicates that Paquete Central is a distinct and younger sequence than paquete Norte, contrary to earlier geological opinion.

Apart from paquetes Central, Oceja and Alejito, HENKES (1961) quotes three other paquetes, viz. Sucesiva, Encarnación and Blanca. These three names do not appear to be in general use and the delimitation of these paquetes is so vague as to be difficult to apply. The paquete Sucesiva contains the coals referred to as Paquete Norte; paquetes Encarnación and Blanca being sequences of beds below Paquete Norte. HENKES considered the seams of his paquete Sucesiva, exposed on the northern flank of the synclinal structure forming the coalfield, to be the equivalent of the seams of the «Paquete de Oceja», exposed on the southern side of the coalfield.

HELMIG (1965) uses the terms paquetes Norte, Central and Sur. He believes Paquete Sur to be the youngest sequence of beds, overlying Paquete Central, the latter being considered younger than Paquete Norte. HELMIG presents a diagrammatic section relating worked seams to the appropriate paquete.

Paquete Central generally represents the highly contorted seams in the centre of the coalfield. The relation to the more southerly seams of Paquete Sur is not clear. Main coal production at the present time is from the paquetes Central and Sur.

Scope of work.

The scope of the present work is to describe a fairly well exposed and continuous section of the lower part of the succession of the Sabero coalfield, as exposed on the northern flank of the Sabero Syncline which, around Sabero, plunges westwards at about 25°. The southern flank of the syncline has been faulted out or partially eliminated by thrusting so that the structure appears asymmetrical. On account of the thrusting from the south, the only undisturbed section of the lowermost rocks is seen on the northern flank. A well exposed and undisturbed succession, 1.5 km north of Saelices, a village 1 km west of Sabero, was chosen as a standard section. The only disturbances on this N-S section were two inconsiderable faults running NE-SW. The base of the section is at the strongly angular Asturian unconformity. The section runs north of Saelices and is about 1.5 km long with an approximate dip of 60° S.

To the east, the Alejico beds occur below the basal conglomerate of the measured section. They consist of a conglomeratic sequence which is too poorly exposed to permit the measuring of a section. However, both sedimentologically and from the flora, it is considered part of the Sabero succession and is described as such.

The age of the succession is determined by the floras. Some disagreement exists between dating the lower part of the succession as middle Stephanian A, by STOCKMANS, or as lower Stephanian B, by WAGNER. The present study indicates the age is probably on the Stephanian A-B boundary. This succession is, then, by comparison with other areas, the oldest recorded above this unconformity, and is of interest in interpreting the Asturian folding phase.

DESCRIPTION OF MEASURED SECTION

For the purposes of description, it has been found useful to divide the section into a number of units. These are based principally upon the type of sedimentation, but are occasionally necessitated by breaks in exposure, the measured section being continued further along the outcrop. As has already been discussed, the paquetes used by HENKES to describe the section cannot be accurately applied and are therefore disregarded. The units used here are for convenience and are not used in any formal sense or proposed as formations. Until the whole Sabero succession is more fully studied it is thought to be unwise to erect formations and so proliferate terms which may not be usefully applicable. The units are represented in text-fig. 2.

The section begins in the valley of the stream, the Arroyo de la Mina. The basal member is a lensing conglomerate from 50-100 m in thickness, lying unconformably on rocks of ages from Cambrian to Upper Devonian. On this section the underlying rocks are a slice of allochthonous Luna Group (RUPKE 1965). These are sandstones and shales of the Oville Formation of which about 20 m are exposed. These overlie a small thickness, 20 m, of the Láncara griotte and limestone which is in contact with the Devonian Portilla limestone which lies on the north side of the now vertical thrust plane of the Esla Nappe (DE SITTER 1959, RUPKE 1965).

Unit 1.

The first unit, being of variable thickness and not well exposed, contains all the rocks up to the first marker horizon. In the section there are approximately 100 m of largely limestone conglomerates. The actual contact is not seen, but nowhere along the outcrop is there evidence of a tectonic junction below the conglomerate. As noted by HENKES, the constituent pebbles of the conglomerate at any one locality are predominantly of the underlying rock. The basal part of the conglomerate consists of large rounded sandstone pebbles with a few small limestone pebbles. Gradually the proportion of limestone pebbles increases, as does their size, until by the centre, it is a limestone conglomerate with occasional large sandstone pebbles. Throughout, there are local sandy and grit lenses.

The local derivation of the pebbles of the conglomerate, the lenticular nature, poor sorting and large size, indicate torrential conglomerates, as formed in areas of high relief. This type of conglomerate, often representing «valley fills», is typical of the basal members of the coal basins of the Cantabrian Mountains.

The conglomerate is succeeded by a coarse quartzitic sandstone. However, in the section this is cut out by a large E-W dyke which follows the upper surface of the conglomerate for a considerable distance. The dyke is generally concordant with the bedding and the thickness varies somewhat, but appears to be 20 - 25 m. Considerable alteration has taken place along the dyke and this accounts for the variable appearance. At the top of the hillside, on the west side of the stream, the dyke rock is well preserved and dark green, and is an olivine basalt. A cursory microscopic investigation has shown that the felspar content is rather more sodic than would be expected, it being in the andesine range. Some slight replacement of both olivine and plagioclase felspar to calcite has taken place. Lower, in the valley, considerable variation is seen from a very white rock to a greenish rock. The latter is a very altered olivine basalt, in which there is a large amount of secondary calcite. The very white rock, however, is found to be a very fine interlocking mesh of quartz grains with muscovite, with also a considerable growth of secondary calcite. A gradation between these rock types is seen, and this is a greatly altered rock of apparently andesitic composition with small patches of the quartzitic rock. The white rock represents a raft of the country rock, the coarse sandstone cut out by the dyke, the inclusion of which has altered the local composition of the dyke. Secondary growth of calcite is locally variable.

The dyke contact, although not exposed, is closely succeeded by a massive weathering silty sandstone. There follows a succession of massive yellowish siltstones with some thin lutitic bands. The siltstones contain some sparse drifted plant debris with *Neuropteris ovata* HOFFMANN and local concentrations of decalcified lamellibranchs representing a marine fauna (loc. 68). Dr. R. M. C. EAGAR (*in litt.* 15. xii. 69) has kindly identified several elements, including *Myalina* and *Curvirimula* (confirmed by Dr. J. WEIR). EAGAR & WEIR (1971) further state that the occurrence together of *Curvirimula* and *Myalina* in an assemblage of small shells indicates an unfavourable, restricted marine environment of low salinity. *Curvirimula* is a near marine form and with *Myalina*, also marginally marine, marginal, restricted conditions are implied. This marine horizon, the first recorded above the Asturian unconformity *sensu stricto*, represents a shallow incursion with the marginal conditions indicating its maximum extent as being in this area. At the top of this unit, non-marine *Anthraconaia* sp. are present.

Lying closely above the conglomerate horizon, the incursion occurred at the end of the filling in of the sharper relief. The lower rocks at the base of the measured section are of variable thickness and the marine horizon is likely to be the first stable reference horizon. Marine conditions are represented by 10 m of strata, the end of marine conditions being taken as the top of the first unit.

Unit 2.

The end of marine influence is marked by a thin seat earth and coal (2 cm). Above this horizon a succession of massive sandstones is interbedded with thinner, sparsely plant bearing, lutitic bands. The sandstones are mixed, generally fining upwards, and of variable grain size from coarse to silty. Irregularly, grit bands and well washed quartzitic bands are developed. In the thinner bedded sandstones, apparently non-directional ripple marks and cross laminations occur. After 15 m, siltier conditions accompany the formation of rootlet beds which are followed by thin dirty coals and carbonaceous shales. The section measured on each side of the valley shows a different thickness between these thin coals, related to lenticular coarse sandstones found on the east side of the valley and not on the other.

A fairly complete flora from this unit is represented by localities 65 and 74, on the west and east sides of the valley, respectively.

A composite list is:

Neuropteris ovata HOFFMANN.
Cyclopteris fimbriata LESQUEREUX.
Linopteris florini TEIXEIRA (Pl. 1, figs. 2, 3; Pl. 2, figs. 1, 2; Pl. 3, fig. 5).
Linopteris sp.
Potoniea sp.
Callipteridium striatum WAGNER
Alethopteris cf. *magna* GRAND'EURY.
Alethopteris bohemica FRANKE
Sphenopteris cf. *matheti* ZEILLER.
Polymorphopteris polymorpha (BRONGNIART) WAGNER.
Pecopteris bredovi GERMAR.
Pecopteris cf. *melendezi* WAGNER.
Pecopteris cf. *tenuinervosa* CORSIN.
Pecopteris spp.
Pecopteris (Nemejcopteris) feminaeformis (VON SCHLOTHEIM) BARTHEL.
Sphenophyllum oblongifolium (GERMAR & KAULFUSS) UNGER.
Annularia sphenophylloides (ZENKER) VON GUTBIER.
Annularia stellata (VON SCHLOTHEIM) WOOD.
Asterophyllites equisetiformis (VON SCHLOTHEIM) BRONGNIART.

Unit 3.

Above the last coal, 157 m above the base of the section, thinner silty lutite bands are interbedded with mixed sandstones. Upwards, the lutitic intercalations become silty sandstones and the sandstones become conglomerates and grits. The thicker conglomerates contain both limestone and quartzite pebbles, thinner quartzite conglomerates appearing to fill lenticular channels. Above this conglomerate bank, silty lutite horizons are bedded between fairly coarse sandstones and grits. Rootlets are sporadically developed and plant debris, generally comminuted, is common throughout. The unit is interrupted at 34 m above its base by a thick (15-20 m) bank of sandstone with quartzite conglomerate and grit horizons. Between coarse massive layers the bank is ripple marked and shows some cross laminations and washouts. A limited flora contains only the most common elements of the previous list.

Unit 4.

After these sandstones, the following group of rocks show a fairly regular alternation of mixed, medium grain sandstones, generally massive, with bluish massive siltstones or silty lutites. The siltstones generally show a few rootlets but coal forming conditions resulted only in some very thin dirty coals at about 220 m above the section base and also at about 270 m. These conditions culminate in the first considerable coal of the section, 27 cm thick, 300 m above the base of the section. Near the base of the unit rusty ironstone nodules were common in the lutites, becoming more common nearer the top.

The flora of this alternating succession is reasonably rich and a composite list, including locality 67, is as follows.

Neuropteris ovata var. *grand'euryi* WAGNER.
Neuropteris gallica ZEILLER.
Mixoneura sp. nov.
Linopteris sp.
Callipteridium striatum WAGNER.
Alethopteris bohemica FRANKE.
Alethopteris zeilleri RAGOT.
Alethopteris sp.
Pseudomariopteris corsini (TEIXEIRA) WAGNER.
Dicksonites pluckeneti (VON SCHLOTHEIM) STERZEL.
Pecopteris spp.
Pecopteris (Nemejcopteris) feminaeformis (VON SCHLOTHEIM) BARTHEL.
Sphenophyllum oblongifolium (GERMAR & KAULFUSS) UNGER.
Annularia sphenophylloides (ZENKER) VON GUTBIER.
Sigillaria brardi BRONGNIART.

Unit 5.

From the 27 cm coal seam, the alternations of sandstone with silty lutite continue, and some small cycles are apparent, up to 1 m thick, but these have not been traced laterally for any distance. Bases are well washed sandstones which gradually grade to siltstones and then silty lutites with rootlets, occasionally forming carbonaceous shale and dirty coal. In the sandstones cross bedding and ripple marks are found with some channelling. At a point 320 m above the base of the section, a bank of conglomerates and massive sandstones interrupts the succession. The conglomerate is sandy and of pebble grade, the sandstones being fairly well washed. These appear to represent a channel and the horizon can be followed for some distance, up to 500 metres. Beyond this channel the section can no longer be followed easily on the east side of the Arroyo de la Mina, but by tracing the channel bed and correlating the succession on either side, the section can be continued on the west side, on the crest of the hill. The flora of this unit is represented by locality 67a.

Mixoneura sp. nov. (same species as in loc. 67).
Linopteris neuropteroides (VON GUTBIER) POTONIÉ.
Odontopteris cf. *brardi* BRONGNIART.
Callipteridium striatum WAGNER.

Alethopteris bohemica Franke.
Mariopteris sp.
Polymorphopteris polymorpha (Brongniart) Wagner.
Pecopteris sp.
Sphenophyllum oblongifolium (Germar & Kaulfuss) Unger.

Unit 6.

The section continues with a sequence of sandstone beds between which are thinner siltstones. The sandstones show channelling and cross bedding. A group of thin coals, generally dirty, are found in a less sandy horizon. The alternations are ended by a 15 m thick group of cross bedded sandstones which become coarser upwards in a complex of channels. Drifted plant debris is fairly common throughout.

Unit 7.

Above this channel complex a far more lutitic succession is developed. This consists of sandstone units up to 1 m thick, with interbedded siltstones and silty lutites. The latter are normally rootlet beds supporting a complex of thin and often dirty coals and carbonaceous shales, the thickest coal being 22 cm thick. The sandstones are generally mixed and silty with occasional gritty horizons. Locally, coarser sands show cross bedding. Within this group of beds, significant coal formation ends within half the thickness. Also in this unit, the first of the small dykes which sporadically occur in the rest of the succession are encountered. These are generally much altered with secondary calcite, but appear to be of andesitic composition.

The flora associated with the coals is represented by locality 77.

Neuropteris ovata var. *grand'euryi* Wagner.
Linopteris neuropteroides (von Gutbier) Potonié.
Odontopteris genuina Grand'Eury.
Callipteridium striatum Wagner.
Alethopteris zeilleri Ragot.
Dicksonites pluckeneti (von Schlotheim) Sterzel.
Pecopteris cf. *longipinnata* Teixeira.
Pecopteris cf. *melendezi* Wagner.
Acitheca sp.
Pecopteris (Nemejcopteris) feminaeformis (von Schlotheim) Barthel.
Sphenophyllum oblongifolium (Germar & Kaulfuss) Unger.
Annularia sphenophylloides (Zenker) von Gutbier.
Annularia stellata (von Schlotheim) Wood.
Lepidophyllum triangulare Zeiller.

This unit continues up to an horizon with *Anthraconauta*.

Unit 8.

Very soon above the last rootlet bed of the previous unit the sandstones become thinner and the silty lutites darker. In the latter, *Anthraconauta* sp. are locally common, especially in the finer beds, and indicate a lacustrine environment. The sandstones show grit bands, channels and ripple marks, and are generally mixed. Between these are silty units with rootlet beds and some thin coals and carbonaceous shales. Plant remains are generally drifted and poorly identifiable.

Unit 9.

This succession of rocks forms the bulk of the section along the valley of the Arroyo de la Mina. At its base there are fairly regular, broad alternations between silty lutites and medium grain sandstones which frequently show channelling. Rootlet beds are sporadically developed and support thin coals with an associated flora as represented by locality 77a.

Odontopteris genuina GRAND'EURY (Pl. 2, fig. 3).
Sphenopteris cf. *pseudocristata* STERZEL.
Pecopteris bredovi GERMAR.
Pecopteris monyi ZEILLER (Pl. 5, fig. 1).
Sphenophyllum oblongifolium (GERMAR & KAULFUSS) UNGER.
Annularia sphenophylloides (ZENKER) VON GUTBIER.

This part of the succession eventually forms a fairly thick band of coals and carbonaceous shales before reverting to alternations of sandstone and siltstones with rootlets.

Above this lies a thick succession of silty lutites with many rootlet beds, supporting a group of closely spaced but fairly thin coals up to 17 cm thick. From the section this group of coals yielded the following flora, locality 79.

Neuropteris ovata var. *grand'euryi* WAGNER.
Linopteris neuropteroides (VON GUTBIER) POTONIÉ.
Odontopteris genuina GRAND'EURY.
Callipteridium gigas (VON GUTBIER) WEISS.
Callipteridium striatum WAGNER.
Alethopteris bohemica FRANKE.
Alethopteris zeilleri RAGOT.
Pseudomariopteris ribeyroni (ZEILLER) DANZÉ-CORSIN.
Sphenopteris sp.
Dicksonites pluckeneti (VON SCHLOTHEIM) STERZEL.
Pecopteris sp. nov.? cf. *pseudovestita* D. WHITE.
Pecopteris cf. *paleacea* ZEILLER.
Pecopteris spp.
Annularia sphenophylloides (ZENKER) VON GUTBIER.

These coals are separated from an upper group of thin coals by thicker sandstone beds, mixed and silty, or quartzose and channelling. The upper group of coals comprises thin, dirty coals and carbonaceous shales, as well as some thicker coals up to 30 cm thick. Where close together, as along the section, these have been sporadically worked.

This group of coals was worked further east in Sabero village, from the Mina Encarnación, and near the old church of San Blas, and sporadically westwards from there, up to the line of the section. HENKES (1961) quotes the old mining terminology for this coal group, and those below it, as the paquete Encarnación. To avoid confusion this particular group of coal seams is here referred to as the San Blas seams. These coals thicken eastwards.

Above the coal group the succession becomes sandier with better washed, more quartzose sandstones, and also grits and a pebble grade limestone conglomerate. The sandstones show some cross bedding and the finer layers ripple marks. This bank is succeeded by a brief return to lutitic rootlet beds supporting a thin carbonaceous shale, before a sudden transition to lacustrine shales. This sharp boundary is exploited, on the line of the section, by the intrusion of an andesite dyke. A number of these thin dykes occur throughout the unit.

The flora of the San Blas coals is sparse at this locality, 79a, on the line of the section. The tip of the old mine, Mina Encarnación, locality 71, also represents this group. The following species are additional to those already mentioned from this unit.

Pseudomariopteris corsini (TEIXEIRA) WAGNER (Pl. 5, fig. 2).
Sphenopteris spp.
Pecopteris spp.
Sphenophyllum sp.
Asterophyllites equisetiformis (VON SCHLOTHEIM) BRONGNIART.

Unit 10.

This consists of a 105 m thick, characteristic sequence of lacustrine shales. The basal beds are grey blue, fine, fissile shales, becoming rather tough a few metres above the base. It is at this horizon that the phyllopod *Leaia baentschiana* BEYRICH is encountered. The carapaces are not well preserved and are often found only as three pronged impressions. The horizon and the *Leaia* band can be followed for a considerable distance, at least 2 km, along the northern flank of the Sabero Syncline and is also found in the more disturbed Los Valles area to the south of Sabero. About 40 m above the shale base the unit becomes siltier, becoming a hard siltstone band with which two andesite dykes are associated. Immediately beyond these dykes the shales revert to being fine, tough, blue and fissile, with occasional *Anthraconauta* shells. They gradually become siltier upwards and the gradual transition from blue siltstone to a silty sandstone marks the end of this unit.

Occasional drifted plant fragments, especially of *Pecopteris (Nemejcopteris) feminaeformis* and *Linopteris* sp. are found as the shales become siltier, and *Anthraconauta* fragments become correspondingly less common.

Unit 11.

The sandstone development begins as thin sandstone ribs in siltstone. These become more common and thicker, showing some fine cross lamination and ripple marks. The sandstone becomes massive and is generally silty and mixed with a large amount of drifted plant material; and as the sandstone becomes more massive cross bedding becomes very common. After 30 m the sandstones change fairly sharply to siltstones and silty lutites, the latter being grey and generally massive looking with some spheroidal weathering. There is a great deal of floated plant debris and in the finer parts occasional lamellibranch fragments are found. A massive sandstone band interrupts the silty lutites, above which the succeeding silty lutite develops a massive rootlet bed, marking a return to swampy conditions.

Unit 12

The massive rootlet bed is at the base of Capa Sucesiva, the main workable seam of the mining succession «Paquete Norte». The rootlet bed, locality 82a, contains occasional horizons of abundant *Sphenophyllum oblongifolium* (GERMAR & KAULFUSS), and also some *Neuropteris ovata* HOFFMANN and cf. *Pseudomariopteris corsini* (TEIXEIRA).

Capa Sucesiva is not seen at the surface but is represented by an «hundimiento» (collapsed working). Thickness here, on the section, was apparently above 1.50 m. The seam is succeeded by silty lutites which contain only a comminuted flora. These are succeeded by cross bedded silty sandstones and more lutites, more or less silty, with some channel sandstones. Thin carbonaceous shale bands with associated rootlet beds occur, but the next fairly thick coal seam lies about 45 m above the Sucesiva seam. Within the more lutitic horizons *Anthraconauta* is fairly common, showing the persistent recurrence of lacustrine conditions. A single *Leaia baentschiana* has also been found in one of these horizons. Plant remains are locally common and are represented at localities 82 and 83, giving the following flora.

Neuropteris ovata var. *grand'euryi* WAGNER.
Linopteris sp.
Odontopteris brardi BRONGNIART (incl. *O. minor-zeilleri* POTONIÉ).
Callipteridium striatum WAGNER.
Alethopteris zeilleri RAGOT.
cf. *Pseudomariopteris corsini* (TEIXEIRA) WAGNER.
Oligocarpia gutbieri GOEPPERT.
Dicksonites pluckeneti (VON SCHLOTHEIM) STERZEL.
Polymorphopteris polymorpha (BRONGNIART) WAGNER.
Pecopteris spp.
Sphenophyllum oblongifolium (GERMAR & KAULFUSS) UNGER.
Annularia sphenophylloides (ZENKER) VON GUTBIER.
Annularia stellata (VON SCHLOTHEIM) WOOD.

Asterophyllites equisetiformis (VON SCHLOTHEIM) BRONGNIART.
Sigillaria brardi BRONGNIART.

Rootlets are only found in a fairly thick silty bed immediately below the next coal. This pattern is seen in the succeeding coals. Between the coals *Anthraconauta* is found well distributed. Three coals exist above Capa Sucesiva and they show a broad apparent cyclicity: sandstone, siltstone, rootlet bed, coal, lacustrine shale, sandstone. These coals are 30-35 cm thick and occur close together.

To the west of the section a fairly persistent seam, Capa Estrecha, has been mined and is still worked at Sotillos. This seam is marked by extensive «hundimientos», but in the immediate area of the section the seam has split into a number of thinner seams which have not been worked. Near Sotillos a further seam, Capa H, lying between Capa Estrecha and Capa Sucesiva, is also worked but this seam is not consistently developed. The two seams Capa H and Capa Estrecha are represented on the section by three seams lying close together, about 50 m above Capa Sucesiva. Capa Estrecha also thickens east of the section and was worked extensively near Sabero.

Above the upper of the three coals lies a sequence of silty lutites, sandstone bands and some rootlet beds. Sandstones are generally well washed and channelling, with occasional ripple marks. Some thin coals and carbonaceous shales are developed, but the succession is generally one of alternating sandstones and lutites. A further group of thin dirty coals is found 110 m above Capa Sucesiva and this is succeeded by more channel sandstone.

Above the channel sandstone lie two further thin seams. On the opposite, west, side of the valley a small mine entrance, the Mina de los Gallegos, shows a thin coal seam. This seam has apparently split across the valley and is correlated to the two seams seen on the section. In the mine entrance, locality 84, the roof of the seam yielded a fairly rich flora. On the opposite side of the valley a rich flora was collected from an horizon close above the equivalent of this seam, locality 85, and a composite list is given below.

Neuropteris ovata var. *grand'euryi* WAGNER.
Neuropteris gallica ZEILLER (Pl. 1, figs. 4, 5).
Neuropteris cf. *praedentata* GOTHAN.
Linopteris neuropteroides (VON GUTBIER) POTONIÉ.
Callipteridium striatum WAGNER.
Alethopteris bohemica FRANKE.
Alethopteris zeilleri RAGOT.
Sphenopteris sp.
Renaultia chaerophylloides BRONGNIART.
Dicksonites pluckeneti (VON SCHLOTHEIM) STERZEL.
Polymorphopteris polymorpha (BRONGNIART) WAGNER.
Acitheca sp.
Pecopteris arborescens (VON SCHLOTHEIM) (Pl. 3, fig. 2).
Pecopteris cf. *dentata* BRONGNIART (Pl. 5, fig. 6).
Pecopteris sp. nov.

Pecopteris spp.
Sphenophyllum oblongifolium (GERMAR & KAULFUSS) UNGER.
Annularia sphenophylloides (ZENKER) VON GUTBIER.
Annularia stellata (VON SCHLOTHEIM) WOOD.

Above the two thin coal seams, a siltstone/sandstone alternation recurs, interrupted only by one thin coal. The succession, however, becomes gradually sandier, the sandstone being rather mixed but with coarser grit bands. The top of the sandstone is marked by another dyke, the last one seen on the northern flank of the Sabero Syncline. This dyke, like the previous ones, is deeply weathered and apparently andesitic. It had intruded along a coal which cokified.

The succession continues with a thin horizon of lutite with rootlets and coaly streaks which is succeeded by a micaceous silty sandstone, containing layers crowded with *Annularia stellata*. On the bedding surface a number of *Calamites* stems appear in position of growth (see page 221). This surface is sharply cut off by a channelling, well washed sandstone, marking the beginning of a different type of sequence. The previous bed, locality 86, contains a sparse flora:

Mariopteris sp.
Polymorphopteris polymorpha (BRONGNIART) WAGNER.
Pecopteris cf. *dentata* BRONGNIART.
Pecopteris spp.
Annularia stellata (VON SCHLOTHEIM) WOOD.

This unit represents the group of seams known to the miners as «Paquete Norte». The lower half of this unit is equivalent to the sequence which is well exposed between Sabero and Saelices, due to the widening of the mine road from Sotillos to Vegamediana (localities 54, 56, 56a, 57, 58, 59, 59a, 61, 62a, 64). A rich flora has been collected from there and additional species for this unit are as follows.

Linopteris florini TEIXEIRA.
Reticulopteris germari (GIEBEL) GOTHAN.
Cyclopteris fimbriata LESQUEREUX.
Odontopteris brardi BRONGNIART (Pl. 3, fig. 3).
Callipteridium gigas (VON GUTBIER) WEISS (Pl. 3, fig. 4).
Alethopteris barruelensis WAGNER (Pl. 4, fig. 3).
Pseudomariopteris ribeyroni (ZEILLER) DANZÉ-CORSIN.
Sphenopteris neuropteroides BOULAY (Pl. 6, figs. 2, 3).
Sphenopteris sp.
Lobatopteris viannae (TEIXEIRA) WAGNER.
Sphenophyllum cf. *alatifolium* RENAULT.
Macrostachya infundibuliformis BRONGNIART.
Lepidodendron aff. *dissitum* SAUVEUR.

Unit 13.

The well washed channel sands which cut off the *Calamites* forest bed become coarser and locally conglomeratic, and subsequently cross bedded. After a lutitic break, with a very few rootlets, laminate and somewhat silty sandstones occur. These fine upwards and grade into bluish shales. There follows a thick (130 m) shale sequence, periodically interrupted by thin channel sandstones, the lutites showing local variations in siltiness. Only in the lutite above the massive sandstone are a very few rootlets observed, these being the last ones found in the section. The succeeding shales are lacustrine with occasional *Anthraconauta*. Floral remains are only drifted *Neuropteris ovata* HOFFMANN and *Linopteris neuropteroides* (VON GUTBIER). In locality 87, approximately 110 m above the base of this unit, one identifiable fragment of *Lobatopteris lamuriana* (HEER) (Pl. 5, fig. 5) was found. After about 150 m, the shale succession becomes generally siltier and ripple marked sandstone bands develop. Thinner lutitic horizons continue with *Anthraconauta*. The section ends with a small thrust from the south which repeats further shaly horizons in an area of poor exposure.

INTERPRETATION OF THE SECTION

The conglomerates at the base of this section, lying above the Asturian unconformity, are apparently torrential conglomerates. The poor sorting, generally large size and local derivation of the pebbles, and the marked lensing indicate formation in an area of high relief. There is an absence of silty material, although there are some stratified sandstone lenses, and this, in combination with the marked rounding of the pebbles, is indicative of fluviatile deposition, as in a braided stream.

The silty, marginal marine conditions follow very closely upon the conglomerates and indicate a considerable lowering of the adjacent relief. To account for this rapid marine incursion a downwarping of the basin is suggested, which was fairly rapid, instigating basin subsidence. The incursion was brief and conditions were shallow and near shore as indicated by the fauna of a restricted marine environment. The direction of marine incursion and regression is not yet known, but their presence at this stage indicates that during the ensuing period the sea was probably never at any great distance, sedimentation taking place perhaps on a coastal plain.

The succeeding continental deposits are the mixed sandstones and siltstones of unit 2. The sandstones form a great thickness in the succeeding units and show occasional, apparently non-directional ripple marks. Limestone conglomerate banks indicate local derivation from probably a steep relief, but apart from two horizons, conglomerates are thin and quartzitic and appear to represent channels. The sandstones appear fluviatile with some braided courses. Intervening siltstones generally show rootlets but coals are uncommon and thin, and these deposits probably represent interdistributary areas which were swampy.

The sequence thus far indicates a fairly rapid sedimentation of rather coarse material, the rootlet beds throughout showing sedimentation to have been keeping pace with basin subsidence. Shallow conditions are indicated continuously by channels, ripple marks and rootlets. These shallow fluviatile and swampy conditions continue to the base of unit 5, where a thicker coal, 27 cm, indicates a longer period of stability.

Overall, the general pattern of sedimentation is maintained to the base of unit 10. Cross bedded, ripple marked and channelling sandstones of units 5, 6 and 7 appear to be point-bar deposits indicating fluviatile deposition. The siltstones are generally homogeneous, with many rootlets, and are often quite carbonaceous with some coal seams. These indicate generally swampy conditions across which a river system meandered.

The *Anthraconauta* bearing horizons of unit 8 indicate lacustrine conditions. At the top and base of this unit there are true lacustrine shales which are interrupted in the middle by a return to fluviatile sandstones and swamp conditions in which only *Anthraconauta* shell fragments were preserved.

Within the succeeding unit, a continuation of fluvial/swamp conditions, the thickness of carbonaceous shale, the thick rootlet beds and the less sandy succession indicate a slackening in the rate of subsidence. This is also indicated by the concentration of coal seams around the San Blas coals. Near the top of this unit, unit 9, a limestone conglomerate and cross bedded sandstones represent a point-bar deposit and more rapid derivation and deposition. This, however, is a brief interlude succeeded by rootlet beds and a thin carbonaceous shale.

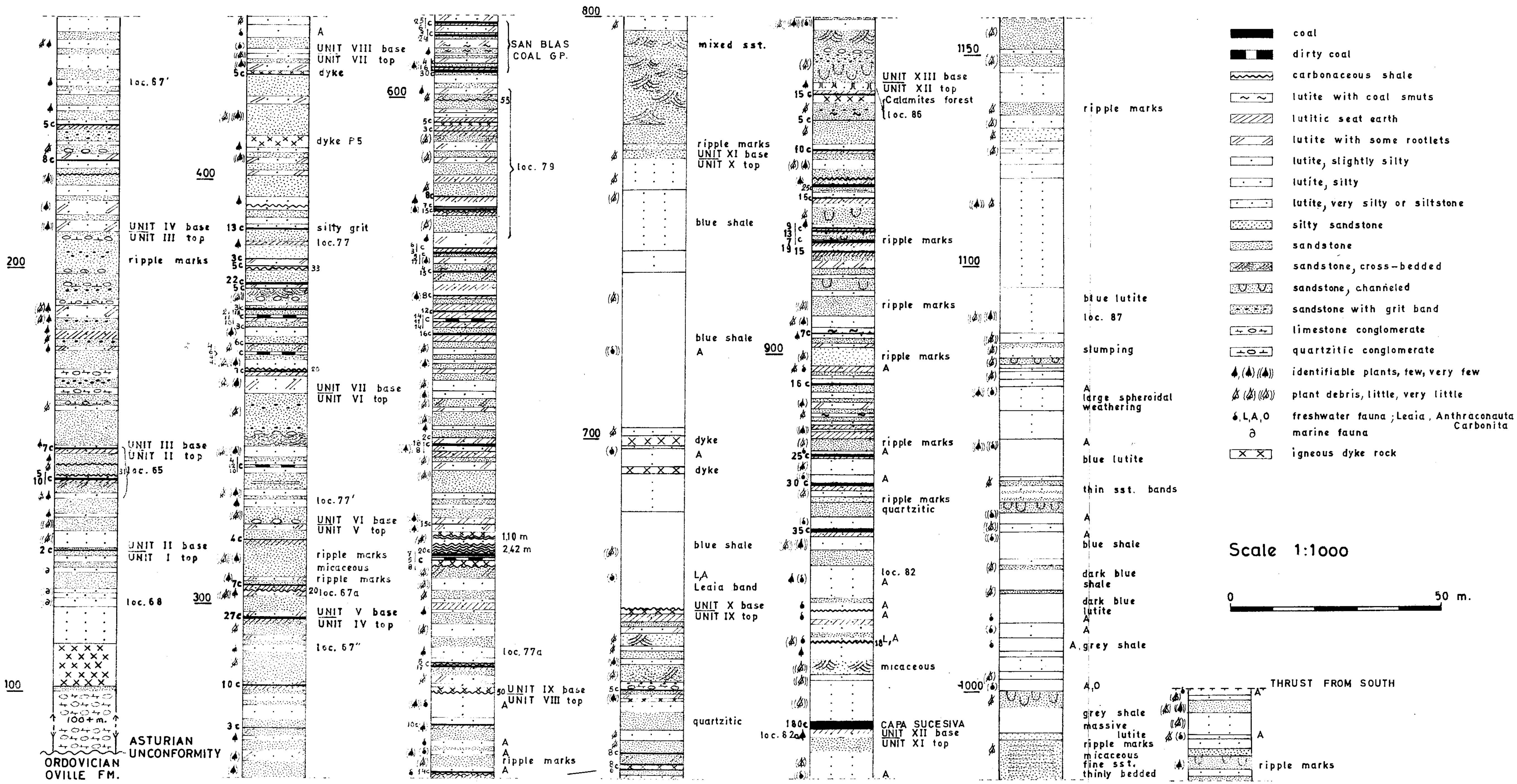
Even though the succession from unit 2 to the top of unit 9 is sandy, there is a noticeable decrease in sandiness from base to top, which is accompanied by increasingly common coals and seat-earths. The steadily subsiding basin appears to have gradually subsided more slowly and the sediments appear correspondingly more mature.

An interruption in the depositional history is marked by the blue lacustrine shales of unit 10. These lie abruptly adjacent to the final carbonaceous shale of unit 9. The fine blue shales indicate slow sedimentation some distance from source and this sudden lacustrine incursion may possibly indicate a general submergence. From the thickness of the shales, these conditions persisted for a considerable time. They grade into siltstones at the top of unit 10, and then sandstones first appear as thin sheets. This type of sedimentation appears to indicate the silting up of the lake, perhaps due to redirection of river courses.

The succeeding sandstone, cross bedded and ripple marked, probably represents a point-bar deposit. A brief return to lacustrine conditions is shown by silty lutites with *Anthraconauta*, but these are succeeded by fluviatile sandstones and then the massive lutitic rootlet bed at the base of unit 12. This represents a return to swampy conditions and underlies the seam Capa Sucesiva, which in the sequence up to this point represents the longest period of coal forming stability.

The coal group «Paquete Norte» is generally much less sandy than the preceding sequence and shows much less variation of lithology, indicating greater stability. The sandstones are fluviatile and relatively thin, ripple marked and channelled, with occasional cross bedding and common drifted stems. The intervening rocks, silty lutites with frequent *Anthraconauta*, contain many rootlet beds and relatively thick coal seams, indicating very slow subsidence. BLESS (1966), from a study of the ostracods in the roof of the seam Capa «H», in the mine at Sotillos, concluded that

COMPOSITE SECTION OF THE ROCKS OF THE NORTH FLANK OF THE SABERO SYNCLINE



Text-fig. 2

a typical shallow freshwater facies is represented. This is in agreement with the type of sediment in this section, which indicates swampy and lacustrine conditions interrupted by river channels. This sequence is brought to an end at the level of the *Calamites* forest bed.

The preservation of a forest bed indicates rapid deposition, and this, from the silty nature of the rock, indicates a probable flood plain deposit. This surface is overlain by a very well washed quartzose sandstone, extensively channelling and rapidly becoming pebbly. The sandstones above it are cross bedded and this sandstone bank is interpreted as a point-bar deposit. The conglomerate bands are fairly well sorted and mostly quartzitic. The succeeding deposits show fining of the sands and are laminate, ripple marked sandstones which gradually become silty. These rapidly grade to blue lacustrine shales with *Anthraconauta* sp. and comminuted plant debris. Throughout these shales there are occasional channel sandstones and this probably indicates the lake was relatively shallow at this point. Possible slumping is seen at one horizon. A return to slightly shallower or more near-shore conditions is seen, as sandstones become more common and mixed near the top of the section.

The sequence shows a general decrease in grain size upwards from the base. Two main lacustrine intervals interrupt the succession with finer sediments. The first interval was sufficiently sudden to suggest a movement other than steady subsidence. The sediments throughout indicate fluviatile deposition of sandstones by rivers meandering through swamp areas. This type of environment is postulated as existing upon a flood plain of sufficiently low level to support fairly extensive lakes and swamps between the main river systems. The lowermost beds, the conglomerates, indicate fairly high relief in the area, but fairly low lying relief, perhaps in broad valleys, must have existed soon after to allow the shallow marine incursion. After the withdrawal of the sea no further evidence of marine influence is seen in the section, although it is probable that the sea was never very far away. It is surprising that during probable periods of general submergence, such as during the lacustrine period of unit 10, no marine influence is detected. By this time the coastal plain was probably extensive.

THE ALEJICO BEDS

The conglomerate unit at the base of the measured section thickens eastwards and overlies a sandy coal bearing group of rocks. These beds constitute the «paquete Alejito» of Henkes and are exposed near, and to the south-west of, the small village of Alejico. The exact relationship of this sequence with the overlying conglomerate is subject to further investigation. The Alejico beds form an apparently uninterrupted succession which is very sandy and conglomeratic, with some thin coals which have been sporadically worked. The beds are poorly exposed and no detailed section could be measured, but about 200 m of strata are believed to be represented at the greatest thickness.

The base of the succession is a quartzite conglomerate with well rounded pebbles, locally derived from the Barrios quartzite (Ordovician) which underlies the western end of the outcrop. These conglomerates can be seen to overlie the Lower Palaeozoic rocks with a marked angular unconformity. The sequence above is very sandy with discontinuous limestone- and quartzite conglomerate bands. Coals are developed soon above the conglomerate and although relatively thin, up to 80 cm, their outcrops are marked by «hundimientos» (collapsed workings). The most important seams, i. e. the lowermost ones, occur at the western end of the outcrop and were worked by the Mina Mariate. The tip of this mine, locality 47, contains a sparse flora from which was collected *Alethopteris bohemica* FRANKE. From the same tip the following more important fossils were recorded, *Sphenophyllum emarginatum* BRONGNIART and *Sphenophyllum oblongifolium* (GERMAR & KAULFUSS) by STOCKMANS (*in* HELMIG 1965, p. 115), and *Lobatopteris* cf. *lamuriana* (HEER) by WAGNER (1966a, p. 42). The workings can be followed westwards for 400 m until the seams merge and thin. Eastwards these seams also apparently thin but are also cut off by a fault. The seams are not detected on the other side of this fault, where there is also a lack of exposure, but the fault may have had some control on sedimentation.

South of Alejico the beds abut onto the valley of the Esla river, and here very old mine tips show workings from thin seams some 50 m above the lowermost conglomerate. The upper one of these seams, with a characteristic conglomerate roof, can be correlated with the highest Alejico seam, up to 1 m thick, which can be traced at the base of limestone conglomerates equivalent to those at the base of the measured section further west. The tips of this seam have yielded a flora at three localities, 73, 106, 106a.

Callipteridium striatum / jongmansi WAGNER / P. BERTRAND.
Alethopteris bohemica FRANKE.
Alethopteris zeilleri RAGOT.
Pecopteris spp.
Macrostachya sp.
Annularia stellata (VON SCHLOTHEIM) WOOD.
Asterophyllites equisetiformis (VON SCHLOTHEIM) BRONGNIART.

This seam, followed westwards, wedges out very rapidly below the overlying conglomerates and, since it extends only over the area of Alejico beds, it is considered the top of these beds.

No unconformity is seen between the limestone conglomerates of unit 1 (measured section, Arroyo de la Mina) and the top Alejico beds, but from the field relations it is apparent that the lower part of the Alejico beds has suffered a considerable deformation. This is most apparent at the western end of the outcrop, in the area of the main workable seams, which is where the succession appears thickest. The concentration of seams occurs in a depression coinciding with the soft weathering Formigoso shales of Silurian age, which lie between the hard weathering Barrios quartzite (Ordovician) and San Pedro sandstones (upper Silurian to lower Devonian).

The Alejico beds probably commenced to be formed as a valley fill deposit, occurring in a valley of little relief, in a depression corresponding to the softer rocks of the underlying sequence. They show lateral thinning and the sediments are immature and of local derivation. The beds converge and merge westwards and thin eastwards. The difference in thickness in the conglomerate at the base, between the centre and edge of the proposed valley, indicates that the gradient of the valley side was small. By comparison with other valley fills described from North-West Spain (WAGNER 1957, 1966a), this was a very small valley. The considerable deformation of the lowermost beds in this small valley clearly cannot be attributed to compaction of underlying beds (compare Wagner 1966a, p. 27), yet the deformation of these beds does not affect the uppermost horizon and there is no evidence of any break in this succession. The sequence appears progressively less deformed upwards from the base. This deformation is therefore attributed to syn-sedimentary sagging, along the line of the valley, which was probably fault controlled. This subsidence was apparently locally confined but was the precursor of the later and wider subsidence of the coalfield area (compare further on, p. 212).

From the listed flora, the age of these deposits could either be upper Stephanian A or lower B. This is in agreement with the conclusions of WAGNER (1966a) from a collection on the tip of the Mina Mariate, although STOCKMANS (*in* HELMIG 1965) concluded to a Stephanian A age from a collection in the same locality. The commonness of well developed *Alethopteris zeilleri* at the top of the sequence is more indicative of Stephanian B age than Stephanian A age. On the other hand, STOCKMANS' record of *Sphenophyllum emarginatum* BRONGNIART is more indicative of Stephanian A. The flora of the Alejico beds on the whole shows a close association with that of the succeeding Sabero sequence, as measured in the Arroyo de la Mina, and the association is further emphasised by the type of sediments deposited. Such coarse sediments are more typical of the base of a post-folding succession than for sediments at the top of such a succession, i. e. they are unlikely to represent the youngest rocks of the pre-Asturian sequence.

HELMIG suggests that the Alejico beds represent his Carrión member which would have a diachronous base from upper Westphalian D, at Ocejo de la Peña, to upper Stephanian A age at Alejico, only 4 km to the south-west. The gradual expansion of the basin westwards neccessarily would require very slow onlap over a very long period of time (equivalent to the duration of the lower Stephanian *sensu lato*, i. e. including the «Cantabrian» of WAGNER 1969) and this is unlikely from the nature of the sediments which indicate rapid deposition. Furthermore, there is no evidence of a marked palaeogeographical feature which would have impeded progressive onlap for a long period. If the Alejico beds are accepted as forming the lower part of the Sabero succession, they are in a sequence quite separate from that at Ocejo de la Peña which is at the base of the long upper Westphalian D and «Cantabrian» succession described from nearby Tejerina by WAGNER, VILLEGAS & FONOLLÁ (1969). There is only a general similarity in lithology between the Ocejo sequence and that at Alejico which is due to each sequence being post-orogenic after the Leonian and Asturian fold phases respectively. The floras of each sequence are completely different in composition and age, and no intermediate assemblages are recorded from the intervening area (compare WAGNER *et al.* 1969, p. 116).

It would appear that the earliest deposition of the Sabero succession took place in shallow valleys in the Alejico area at the end of the Asturian folding, conditions being such as to allow limited formation of coal swamps. The end of the folding phase was probably associated with a relaxation which resulted in local syn-sedimentary sagging. Subsequent tectonic instability interrupted the deposition of the Alejico beds by apparently causing nearby uplift, initiating deposition of the widespread limestone conglomerates at the base of unit 1 (Arroyo de la Mina section).

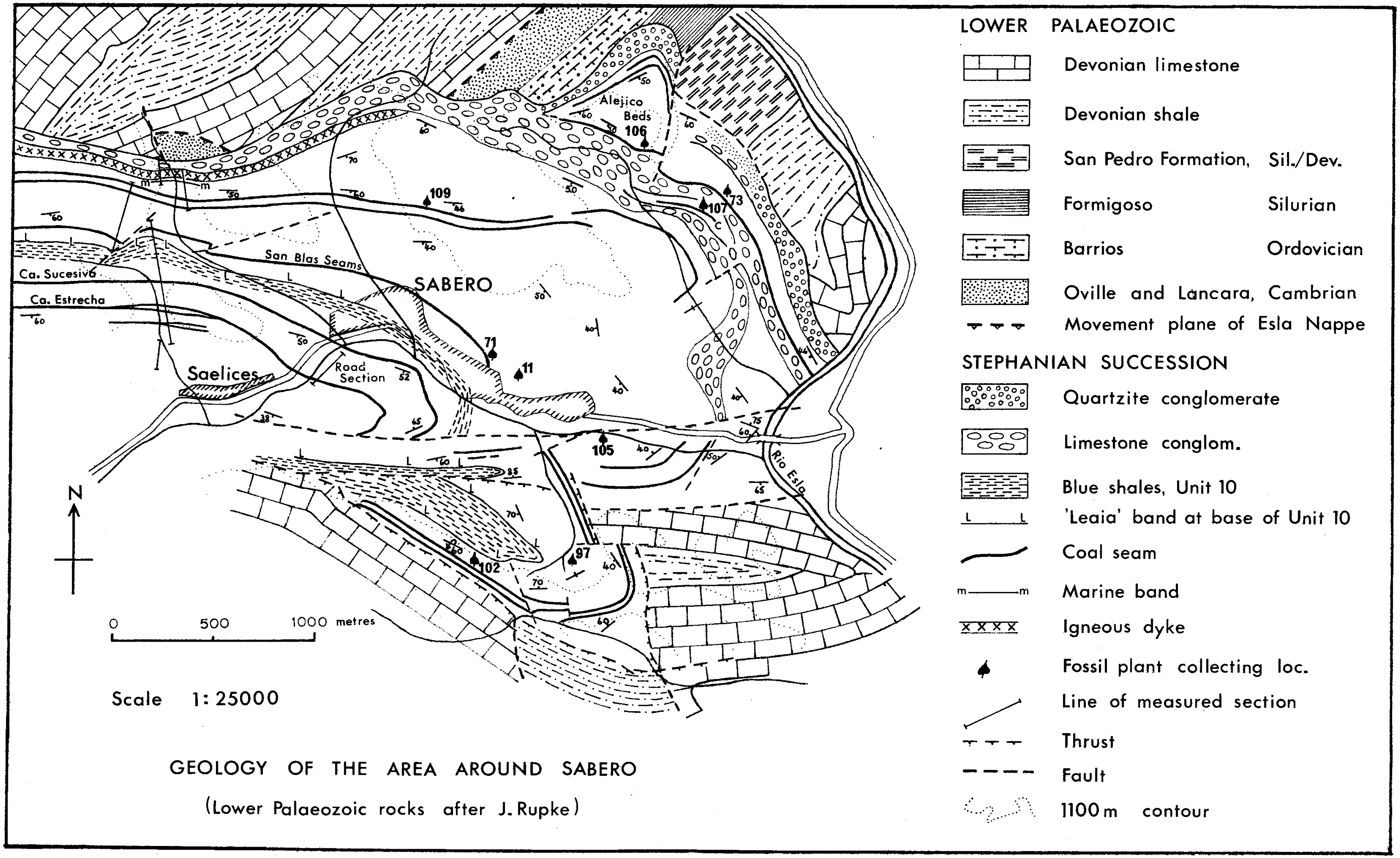
GENERAL GEOLOGY OF THE AREA

General field data.

Within the described rocks there appears a general east-west variation in thickness. This is seen from the general outcrop pattern and is especially true where the conglomerates of unit 1, of the measured section, thicken above the Alejico beds. A marked thickening of the beds between the limestone conglomerate and the coals above them is seen north of Sabero. This thickening is not a valley fill as there is no evidence above of a marked relief from outcrop pattern or from the sediments, yet the lowermost beds, the conglomerates, show a deformation, albeit slight, not seen in the coal seams above. This would appear to be syn-sedimentary sagging as seen in the Alejico beds below. The general subsidence of the area was probably preceded by local subsidences of increasingly wide extent, this one representing a wider subsidence in the area of first subsidence as seen in the Alejico beds.

Apparent thickening in the area east of Sabero is partly attributable to small E-W folds but there is also clear evidence of a true eastward thickening. Mine information is that the worked coal seams of the northern flank thickened eastwards, a general thickening being found for all seams. Thin seams, of no significance in the measured section, can be seen farther eastwards to have supported fairly extensive mining. The thickening of seams in units 7, 8 and 9 (measured section, Arroyo de la Mina) supported a number of small workings north of Sabero. Of particular interest is the thickening of the San Blas seams at the top of unit 9. The last workings to the west in these seams are seen along the measured section. Followed eastwards these workings became more extensive and, in Sabero village, supported until 1954 the fairly large Mina Encarnación, which worked these seams that had there thickened considerably.

These seams, so close below the marker band of *Leaia baentschiana*, can be identified south of Sabero in the Los Valles area. This area is considerably disturbed and no direct continuation of seams occurs. However, below the *Leaia* band, in this region there are seams of up to 1.20 m in thickness which represent the thin San Blas coals of the measured section. The extension in depth of these seams in the Los Valles area was apparently small and the mines in the area were long ago exhausted. In the same region a thin seam (20 cm), just below the *Leaia* band is equivalent to the thin carbonaceous shale adjacent to the band in the measured section. The correlation between the rocks of the Los Valles area and the corresponding part of the section in the


LOWER PALAEOZOIC
Devonian limestone
Devonian shale
San Pedro Formation, Sil./Dev.
Formigoso Silurian
Barrios Ordovician
Oville and Lancara, Cambrian
Movement plane of Esla Nappe
STEPHANIAN SUCCESSION
Quartzite conglomerate
Limestone conglom.
Blue shales, Unit 10
'Leaia' band at base of Unit 10
Coal seam
Marine band
Igneous dyke
Fossil plant collecting loc.
Line of measured section
Thrust
Fault
1100 m contour
Alejico Beds
San Blas Seams
SABERO
Ca. Sucesiva
Ca. Estrecha
Saelices
Road Section
Rio Esla
N
0 500 1000 metres
Scale 1: 25000
GEOLOGY OF THE AREA AROUND SABERO
(Lower Palaeozoic rocks after J. Rupke)

Text-fig. 3

Arroyo de la Mina is also generally indicated by the flora, collected from several localities in the area, localities 97, 99, 101, 104.

Neuropteris ovata var. *grand'euryi* WAGNER.
Callipteridium sp.
Alethopteris bohemica FRANKE.
Alethopteris zeilleri RAGOT.
Dicksonites pluckeneti (VON SCHLOTHEIM) STERZEL.
?Dicksonites sp.
Lobatopteris lamuriana (HEER) WAGNER (Pl. 5, figs. 3, 4).
Polymorphopteris polymorpha (BRONGNIART) WAGNER.
Pecopteris unita BRONGNIART.
Pecopteris spp.
Sphenophyllum oblongifolium (GERMAR & KAULFUSS) UNGER.
Annularia stellata (VON SCHLOTHEIM) WOOD.
Annularia sphenophylloides (ZENKER) VON GUTBIER.

This list shows the presence of a typical Stephanian B association of *Alethopteris zeilleri* and *A. bohemica*, together with the Stephanian A index, *Lobatopteris lamuriana*. These beds are correlated to below the level of unit 10 of the measured section, well below the occurrence of *Lobatopteris lamuriana* in the section (unit 13).

The conglomerates at the base of the main coalfield succession, as seen on the northern margin and also overlying the Alejico beds were certainly fluviatile in origin. The presence of a sandy lens containing a thin but workable coal indicates that inter-distributary swamp areas were possible between the main braided river courses. This sandy lens, lying above the area of the Alejico beds yielded a small flora, locality 107.

Neuropteris ovata HOFFMANN.
Cyclopteris sp.
Reticulopteris germari (GIEBEL) GOTHAN.
Linopteris neuropteroides (VON GUTBIER) POTONIÉ.
Dicksonites pluckeneti (VON SCHLOTHEIM) STERZEL.
Pecopteris sp.

A small flora has also been collected from the thin seams, worked sporadically, which lie close to the conglomerates in the area north of Sabero. From these are collected (loc. 109).

Neuropteris ovata var. *grand'euryi* WAGNER.
Callipteridium striatum WAGNER .
Alethopteris zeilleri RAGOT.
Sphenopteris cristata (BRONGNIART) PRESL (Pl. 6, fig. 1).
Polymorphopteris polymorpha (BRONGNIART) WAGNER.
Pecopteris (Nemejcopteris) feminaeformis (VON SCHLOTHEIM) BARTHEL.
Pecopteris sp.
Annularia sphenophylloides (ZENKER) VON GUTBIER.

This locality is believed to be equivalent to the beds of unit 4 of the measured section.

Further collections have been made in the area of the map. Locality 11, near the new school in Sabero, is notable. This locality is believed to be in an equivalent of unit 7, and contains:

Neuropteris ovata var. *grand'euryi* WAGNER.
Reticulopteris germari (GIEBEL) GOTHAN (Pl. 1, fig. 1).
Cyclopteris sp.
Sphenopteris ovalis VON GUTBIER.
Polymorphopteris polymorpha (BRONGNIART) STERZEL.
Pecopteris cf. *dentata* BRONGNIART.
Pecopteris (Nemejcopteris) feminaeformis (VON SCHLOTHEIM) BARTHEL.

An area of poor exposure, and apparently fault bounded, forms the southern and most easterly area of the coalfield west of the Esla river. Within this area some coal seams existed which were worked long ago. Tips of these seams have been cut by the widening of the mine road to Vegamediana and from this tip, locality 105, were collected:

Alethopteris zeilleri RAGOT.
Sphenopteris matheti ZEILLER.
Sphenopteris (Discopteris) cf. *wagneri* ALVAREZ-RAMIS.
Pecopteris unita BRONGNIART.
Pecopteris sp.
Sphenophyllum oblongifolium (GERMAR & KAULFUSS) UNGER.

This flora, whilst certainly Stephanian B in age, on the basis of well developed *Alethopteris zeilleri*, is insufficient for immediate correlation to the measured section.

Local palaeogeography.

Previous geological workers in the Sabero coalfield (HENKES 1961, HELMIG 1965) claimed thinning of sediments from north to south, at least for the lowermost beds. The evidence for these conclusions is not clear. This thinning was first proposed by HENKES (1961, p. 52) on account of the apparent absence in the southern exposures of the characteristic limestone conglomerates of the northern margin of the coalfield. This absence can now be seen to be due, at least in part, to thrusting of the entire southern margin. HENKES (*loc. cit.*) also claims the absence in the southern area of the shales of his paquete Encarnación. This paquete, although not defined, apparently contained the unit 10 of the section of the present author. The shales of this unit are, in fact, present in the Los Valles area, and are associated with the *Leaia* marker band.

HELMIG (1965, p. 114) points out a marked asymmetry in the sediments of the coalfield, but gives no examples. He suggests (p. 119) a southward thickening of the seams of the northern area of the coalfield, but also proposes (p. 115) a predominant derivation of conglomerates from the north, from the basin margin. This would mean that the coal seams thickened into the basin of subsidence, which is at variance with common experience in coal basins. In fact, a general thickening of coal seams eastwards has been noted, as indicated by mine data and field observations. The thickening of seams in the Los Valles area may also suggest a thickening of coal seams to the south-east. As observed by HENKES (1961), there is a westward thinning of the whole sequence of the northern flank. This is clearly seen in HENKES' map of the whole coalfield and is also apparent from the thickness of strata between the seams Capa Estrecha and Capa Sucesiva. In the mine at Sotillos the thickness between the seams is 53 m, whereas in Sabero, 4 km to the east, in a section in the mine road, this thickness is well over 100 m. A south-easterly thickening of the sequence in the Los Valles area is not clear, due to tectonic disturbance, but does not appear to be significant.

The overall picture of sedimentation, from the limited data, is ot thickening of coal seams east and south-eastwards with a thicker sequence of intervening rocks becoming developed eastwards. This implies the principal area of subsidence to have been in the east or, perhaps, north-east. If this general picture is correct it is perhaps significant that greatest subsidence remained in the same general area in which the earliest effects of subsidence and sagging are believed to have taken place, as indicated by the Alejico beds.

In the sections published by HENKES and HELMIG, the limestone conglomerates, thickly developed on the northern margin, are shown as being derived from the north and thinning southwards, towards the centre of the present day coalfield which they consider to have been the area of greatest subsidence. Whilst this assertion cannot be disproved, due to lack of exposure, it is felt to be unlikely. Further field evidence, such as a study of the extent of the marine incursion, is necessary to reach more detailed conclusions on the palaeogeography.

General relationship to neighbouring coalfields.

As has already been discussed, it is most improbable that the eastern extension of the Sabero coalfield succession is represented at Ocejo de la Peña. Whilst the Sabero coalfield certainly extends for some distance to the east of the Esla river (compare WAGNER, VILLEGAS & FONOLLÁ 1969, text-fig. 1), its basal deposits represent at the earliest a late Stephanian A age which is quite different from the adjacent Westphalian D and «Cantabrian» succession of Ocejo, Prado de la Guzpeña and Valderrueda to the east (compare WAGNER *et al.* 1969).

The next coalfield to the west is that of Ciñera-Matallana, 20 km west of Sabero. Its lower beds contain a flora of closely comparable but slightly younger age than that at Sabero (WAGNER 1966a). The successions are somewhat similar at the base, the Ciñera-Matallana coalfield being almost immediately post-Asturian folding (*sensu stricto*), but the lowermost rocks appear younger than any of the basal Sabero sequence as measured in the section of the Arroyo de la Mina. No physical connection of the two coalfields can be proved (ALMELA 1949), but that they represent the same continuous area of Carboniferous deposition is probable in view of the fact that the same eastward expansion of a basal formation exists in that coalfield (WAGNER & ARTIEDA 1970). EVERS (1967) suggests a progressively onlapping base encroaching north-westwards from Sabero, after the folding phase represented by the unconformity at the base of the Sabero coalfield succession and WAGNER (*loc. cit.*) has confirmed this. (Note: EVERS does not differentiate between the Leonian and Asturian folding phases *sensu* WAGNER 1966a).

EVERS introduces the term «Sabero Formation» in relation to the sequence of the Ciñera-Matallana coalfield. His introduction of this term is apparently with no definition and is based upon the usage by COMTE (1959) of the term «schistes houillers de Sabero». COMTE used his terminology completely informally to represent generally the Stephanian coal bearing sequences. He produced no type section and defined neither base or top of the sequence. EVERS includes within this formation the section of the Prado Member of HELMIG (1965), as described by the latter from Sabero. The Prado Member constitutes the upper part of the Cea Formation as used by HELMIG, the relation of which to the Sabero Formation is not mentioned by EVERS. In effect, the Sabero Formation has no defined meaning nor known relationship with previous terminology, and is, for use in the Sabero coalfield, disregarded.

To the east, the nearest formation of post-Asturian age is that of Peña Cildá, in N. E. Palencia. This formation, resting unconformably upon Stephanian A (Calero beds), has a middle to upper Stephanian B age (WAGNER 1966a). Intervening coalfields between Sabero and Peña Cildá are of demonstrably older age than that of Sabero, being Westphalian D to Stephanian A in age.

Structure of the coalfield.

The age of folding of the Stephanian sediments is attributed to the Saalian folding phase of Permian age by DE SITTER & ZWART (1959). HELMIG (1965) points out that the relationship of the Stephanian rocks to the overlying Cretaceous indicates that considerable deformation also occurred in mid-Tertiary times. The main structure in the Sabero area is the east-west trending syncline along the Sabero valley (text-fig. 3). This plunges westwards at about 25°. Immediately east of Sabero there are some minor and not clearly defined east-west folds which may be related to faulting. The southern flank of the main syncline nowhere shows the base of the succession and is highly disturbed with thrusts coming from the south. In the Los Valles area, south of Sabero, two subsidiary synclines are found separated by steeply dipping strike faults, which are interpreted as steepened thrusts coming from the south. This southern area is separated from the relatively undisturbed northern flank and synclinal core by a fault running along the length of the Sabero valley. From mine information this fault is vertical or reverse and further data are needed to interpret this structure which forms a major division in the coalfield. HELMIG (1965) considers this fault an extension of the La Llama Fault, as seen farther to the west, and extrapolates it to the fault scarp above Vegamediana, which was described by RUPKE (1965) as a normal fault. Mapping of the line of this fault suggests that it has no direct continuation to Vegamediana and its continuation is more likely found in the line of disturbance occurring just north of the bridge over the Esla river. Steepening of thrusts, as suggested for the reverse faults seen in the Los Valles area, could be explained by a Tertiary folding phase on the scale postulated by HELMIG (1965).

As yet there is no evidence of syn-sedimentary deformation due to E-W faults as suggested by HELMIG (1965), on the basis of «abrupt local uplifts», inferred from the limestone conglomerate bands in units 9 and 3. Syn-sedimentary sagging is considered to have occurred in the north-east of the area but this shows no E-W axis, the area of greatest subsidence appearing to have been to the east or north-east of Sabero and not along the centre of the present coalfield as suggested by HENKES and HELMIG. The limestone conglomerates, occurring intermittently in the succession, above the base, can frequently be demonstrated to be braided channels and laterally often become sandstones. With the continuous proximity of erodable relief, presumably of Devonian limestone, the lenticular limestone conglomerates are probably no more than channels in between-river sediments and need not imply uplift of any significance.

THE FLORA

Within the measured section no, or little, significant change appeared upwards in the age of the floras. The local occurrence of species in comparison with that in nearby areas comparable in age appears in Table 1 and the known stratigraphic ranges of more important elements are shown in Table 2.

The suggested age for this sequence is transitional from possibly uppermost Stephanian A to lower B. These rocks are thus the oldest yet recorded above the Asturian unconformity *sensu* WAGNER (1966a). This invites comparison with the floras of the Calero Member of the Barruelo Formation of Stephanian A age (WAGNER & WINKLER PRINS 1970), and those of the basal beds of the Ciñera-Matallana coalfield of Stephanian B age. The Calero Member, in the Barruelo-Orbó coalfield (Palencia), contains the youngest flora known below the Asturian unconformity. The Ciñera-Matallana coalfield is the next coalfield west of Sabero (20 km) and is immediately post-Asturian phase.

The flora of the lower half of the succession, units 7 and 9 especially, contains elements that normally indicate a somewhat younger age than that suggested. These include *Neuropteris gallica* ZEILLER, *Odontopteris genuina* GRAND'EURY, *Odontopteris brardi* BRONGNIART, *Reticulopteris germari* (GIEBEL), *Sphenopteris matheti* ZEILLER, and *Pecopteris melendezi* WAGNER. It is noticeable that these species are, with the exception of *O. brardi*, «flözfernes», i. e. not associated with coal seams. This, and their relation to the sandy part of the sequence with floated debris from a nearby probably juvenile landscape, suggests that they are part of a hill-slope flora which was not widely seen in the classical Stephanian area of central France until middle Stephanian B times. Because of this their stratigraphic value is sometimes not well established. For instance, *Neuropteris gallica* and *Reticulopteris germari* have long been considered elements of at least Stephanian B age. However, both these species have been found in the Calero beds of Stephanian A age and *R. germari* does in fact appear even earlier, in upper Cantabrian strata (WAGNER & WINKLER PRINS 1970).

Besides these species, there is the occurrence of *Lobatopteris lamuriana* (HEER) near the top of the succession. The occurrence of this species with *Pecopteris arborescens* (VON SCHLOTHEIM) has been claimed as typical of Stephanian A age (BERTRAND 1937, CORSIN 1952). The former species is normally confined to Stephanian A. There is a record of *Lobatopteris* cf. *lamuriana* from the Alejico beds (WAGNER 1966a). This species is also represented in the Los Valles area, close below the *Leaia* Band, i. e. probably equivalent to unit 9. The presence of *Lobatopteris lamuriana* in the lower

TABLE 1

	1	2	3	4	5	7	9	10	12	13	A	C	CM
Neuropteris ovata	x		x						x				
N. ovata var. *grand'euryi*				x		x	x		x	x		x	x
N. gallica				x					x			x	
N. cf. *praedentata*									x				
Cyclopteris fimbriata		x							x				x
Mixoneura sp. nov.				x	x				x				
Linopteris neuropteroides			x		x	x	x		x	x		x	x
L. florini		x							x				
L. sp.		x		x				x	x				
Potoniea sp.		x											
Reticulopteris germari			x				x		x			x	
Odontopteris genuina						x	x						
O. brardi (=*O. minor-zeilleri*)					cf.				x			x	x
Callipteridium striatum		x		x	x	x	x		x			x	x
C. striatum/jongmansi											x		
C. gigas							x						x
Alethopteris barruelensis									x			x	
A. bohemica		x		x	x		x		x		x	x	x
A. leonensis									x				x
A. zeilleri				x		x	x		x		x	x	x
A. cf. *magna*		x										x	
Pseudomariopteris corsini				x			x		x			x	
P. ribeyroni							x		x			x	x
Mariopteris sp.					x				x				
Renaultia chaerophylloides									x				
Oligocarpia gutbieri									x				
Discopteris cf. *?wagneri*							?						
Sphenopteris cristata				x									
S. matheti		x					?						
S. neuropteroides									x				
S. ovalis							x						
S. cf. *pseudocristata*							x						
S. sp.							x		x				
Dicksonites pluckeneti			x	x		x			x			x	x
Polymorphopteris polymorpha		x		x	x		x		x			x	x
Acitheca sp.						x			x				
Lobatopteris lamuriana							x		cf.	x		x	
L. viannae									x			x	x
L. sp. nov. cf. *pseudovestita*							x		x				
Pecopteris arborescens									x			x	x
P. bredovi		x					x					x	
P. cf. *dentata*							x		x				
P. sp. aff. *limai*									x				
P. cf. *longipinnata*						x							
P. cf. *melendezi*		x				x			x				x
P. monyi							x					x	x
P. paleacea							cf.					x	

	1	2	3	4	5	7	9	10	12	13	A	C	CM
P. cf. *tenuinervosa*		x											
P. sp. nov.									x				
P. spp.		x		x	x	x	x		x		x		
P. (*Nemejcopteris*) *feminaeformis*		x		x		x		x				x	x
Sphenophyllum oblongifolium		x		x	x	x	x		x			x	x
S. alatifolium									cf.			x	x
Annularia sphenophylloides		x		x		x	x		x			x	x
A. stellata		x				x			x		x	x	x
Asterophyllites equisetiformis		x					x		x		x	x	x
Lepidodendron aff. *dissitum*									x			x	x
Sigillaria brardi				x					x			x	
Lepidophyllum triangulare							x						
Macrostachya sp.									x		x		

Table 1.—Occurrence of plant species in the units of the measured section (N. from Saelices) in the northern part of the Sabero coalfield, and also their occurrence in the coalfields most closely comparable in age in the Cantabrian area.
Numerals — numbers of some units of the measured section.
A.—Alejico Beds.
C.—Calero Beds (Stephanian A) of the Barruelo coalfield, after WAGNER 1969.
CM.—The Lower Coal Bearing Formation (= San Francisco and Pastora formations, lower Stephanian B) of the Ciñera-Matallana coalfield after WAGNER 1966a.

part of the Carmaux coalfield in France and its sharp extinction at the Stephanian A-B boundary (DOUBINGER & VETTER 1969) indicate that there it is a definitive zonal indicator. However, in contrast to the limnic coal basins of France, it is felt that in the sequence of N. W. Spain its range is probably not so well defined and in this region may well extend into lower Stephanian B, as indicated by the associated flora.

Also present in the mine road section at Sabero, equivalent to unit 12, is *Alethopteris barruelensis* WAGNER, also recorded from the general tip of the old mine La Herrera by WAGNER (1957, 1966a). This occurrence is the highest recorded for this species which is more characteristic of upper «Cantabrian» and Stephanian A ages. The floral list shows a marked similarity to that published from the Calero Member. However, it is the common presence of species of Stephanian B aspect that leads to the assigment of these beds of the Sabero sequence to the A-B transition.

Species of clear Stephanian B aspect are *Neuropteris* cf. *praedentata* GOTHAN, *Odontopteris genuina* GRAND'EURY, *Alethopteris leonensis* WAGNER, and *Pecopteris melendezi* WAGNER. The one specimen of *Alethopteris leonensis* (Pl. 3, fig. 1) was collected from the roof of the coal seam Capa Estrecha in the mine at Sotillos (Loc. 23), equivalent to unit 12. The common simultaneous occurrence of *Alethopteris bohemica* and *Alethopteris zeilleri* is typical of lower Stephanian B age. The *Neuropteris ovata* of the Sabero sequence are commonly good examples of the variety *grand'euryi* WAGNER which develops in upper «Cantabrian» times, and the succession contains many elements which make their first appearance in Stephanian A and continue throughout B.

In comparison with the lowest beds of the Ciñera-Matallana coalfield, the San Francisco and Pastora formations (WAGNER & ARTIEDA 1970 = Lower Coal Bearing Formation of WAGNER 1964b), there is a comparable flora to that described here. However, some of the species of «B» flora seen in the Sabero sequence are not

TABLE 2.

Table 2.—Chart indicating the stratigraphic ranges of some of the more important plant species occurring in the Sabero coalfield. (Ranges mainly from WAGNER 1966a, 1969).

seen in the lower beds of Ciñera-Matallana, where coal forming conditions became more quickly established above the conglomerates so that hill-slope elements were suppressed. As has already been discussed, the exact ranges of some of these species are incompletely known. Amongst those species described by WAGNER as typical of Stephanian B were *Pecopteris melendezi* and *Alethopteris leonensis* which are also found at Sabero. The other more typical «B» species of Ciñera-Matallana are not represented at Sabero. Although closely comparable, the lowermost formation of Ciñera-Matallana appears younger than that at Sabero on the basis of those elements of «A» aspect present in the latter.

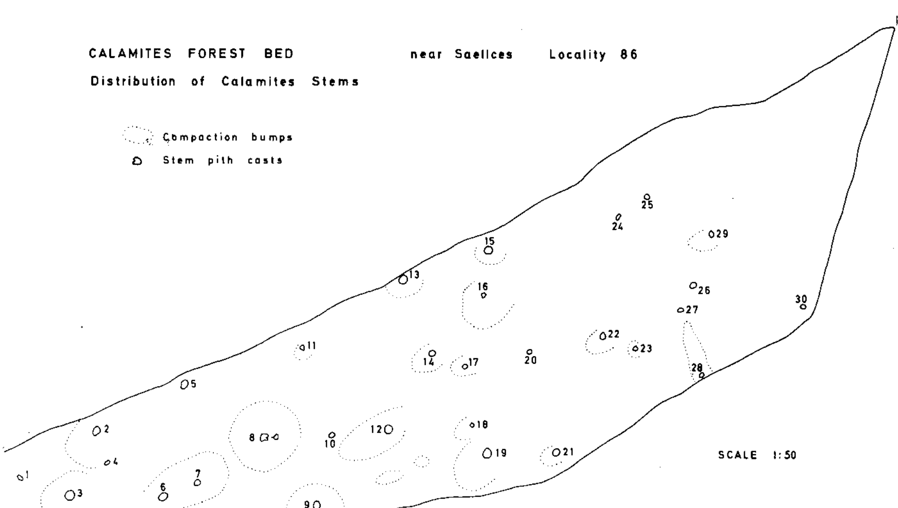
Previous identifications of flora include those of WAGNER (1957), who collected from the general colliery tip at La Herrera, representing all the mined area of the coalfield. This list gives an unmistakable Stephanian B age. STOCKMANS & WILLIÈRE (1966) give a Stephanian A age on the basis of a list from the general tip of Sotillos. This is surprising as there are no specific «A» elements and all the species quoted are also recorded from Stephanian B. HELMIG (1965) quotes STOCKMANS & WILLIÈRE's identifications from the different coal groups, deciding upon a Stephanian A age for the majority of the beds, suggesting a «B» age only for the uppermost beds. WAGNER (1966a) records the flora and localities in greater detail, but most of these localities are from higher horizons not described here. The age of these is certainly Stephanian B.

The flora of the Alejico beds is insufficiently known to place the age closer than upper Stephanian A or lower B.

CALAMITES FOREST BED

This bed is the top bed of unit 12. The *Calamites* stems are preserved in position of growth in a fine silty sandstone about 1.80 m thick, the upper half of which is generally massive. The top surface is exposed due to quarrying of the overlying bed, a well washed, quartzose, medium grain, channelling sandstone. The silty sandstone preserving the forest, lies upon the typical sequence of unit 12, relatively thinly bedded, dirty, mixed sandstones, siltstones and silty lutites. The sharp cutting off of this bed represents a sharp change in the depositional conditions.

The *Calamites* stems are preserved as internal casts and appear regularly spaced on the exposed face (text-fig. 4). Around the majority of these stems there are pronounced bumps on the surface which can be interpreted as due to compaction around stems. This is supported by the fact that many of the bumps are asymmetrical and elongated in the direction of insertion of stems which are exposed near the basal



Text-fig. 4

curve of the stem and appear obliquely emergent (see stem n.º 28, text-fig. 4). In stems perpendicularly emergent the bumps are circular.

The majority of cross-sections of the pith casts are circular but a number are markedly irregular. In number 8, two stems are found very close together with a sharp protrusion in one corresponding to a deep sulcus in the other. This is the only evidence of branching in this stand of *Calamites*. From the absence of branches at each node and from the fact that an apparent branch was alone on a whorl, it is probable that these specimens belong to the sub-genus *Stylocalamites* WEISS, which group branches irregularly. The flora of this horizon, locality 86, was very limited, with the exception of a great profusion in some layers of *Annularia stellata*. This was presumably the foliage of the species of *Calamites* forming the stand. This stand could be followed along the strike for 15 m.

The distribution of *Calamites* in position of growth excited considerable discussion in the last century, Some of the best developed and first described sections were those described by DAWSON (1854) from the South Joggins, Nova Scotia. Describing specimens comparable to *Calamites suckowi* BRONGNIART (of the sub-genus *Stylocalamites)*, DAWSON noted the tendency to grow in dense stands and interpreted the habitat as upon inundated mud flats. They were supported by adventitious roots from the lower nodes which aided sediment accumulation and rapid burial. One of these stands could be traced laterally for over ½ mile (almost 1 km). GRAND'EURY (1877) describes some remarkable vertical successions of *Calamites* stands in the St. Etienne coalfield of France. The rhizomatous nature of these *Calamites* (of the group of *C. suckowi)* was apparent, the main stem arising vertically, at times fairly dense stands arising from one rhizome. Due to repeated branching and probable continued upward growth of older deeper rooted stems, the rhizome would have little effect on the horizontal distribution of stems. Consequently. the well spaced pattern of stems seen on the described rock face is assumed to indicate control of distribution due to the shade of branch vegetation inhibiting growth of other stems. The closest together two stems are found (stems 26 and 27) is 20 cm apart. Stem 8 represents two branches in a single bump. In considering the spacing, one should take into account that the original stems had a diameter of at least twice that of the internal casts as seen on this face. The largest stem-cast seen has a diameter of 7 cm and is 48 cm long.

REMARKS ON SOME FIGURED SPECIMENS

All specimens are figured at normal size or are three times enlarged, as indicated.

The top limit of the range of *Alethopteris barruelensis* WAGNER (Pl. 4, fig. 3) occurs in the Sabero coalfield, where it occurs together with *Alethopteris zeilleri* RAGOT (Pl. 4, fig. 2) to which it is closely similar in appearance. Both specimens are figured 3 × enlarged. *A. zeilleri* is distinguished by means of the wider (30-35 vein endings per cm) and somewhat more perpendicular venation, as opposed to the denser (50 vein endings per cm approx.) and more oblique and arching veins of *A. barruelensis*.

A. zeilleri possesses more parallel sided and more rounded pinnules in comparison to the rather more tapering pinnules of *A. barruelensis*. The other commonly occurring species of *Alethopteris*, *A. bohemica* FRANKE (Pl. 4, fig. 1) presents no problems of identification due to its close venation (50 vein endings per cm) and characteristic biconvex pinnules which are closely packed and hardly decurrent.

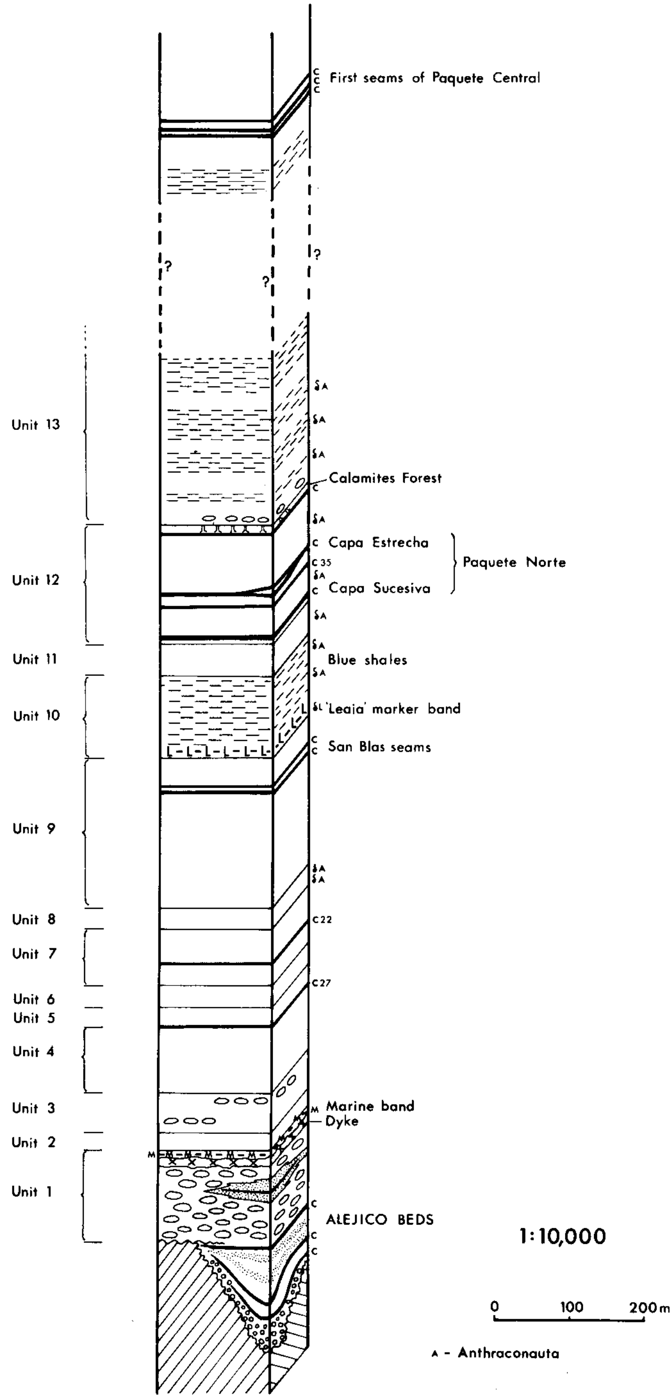
An interesting addition to the Sabero flora is *Linopteris florini* TEIXEIRA of which three specimens are figured (Pl. 1, figs. 2, 3, Pl. 2, figs. 1, 2, Pl. 3, fig. 5). These specimens show the large size, over 5 cm in length, and wide venation, up to 1 mm apart, which characterise the species. Specimens figured from Ervedosa, Portugal, by TEIXEIRA (1944) are tectonically deformed but show that the midvein is somewhat variable in length, extending up to 1/3 of the pinnule length, as is seen in specimens from Sabero. Pinnule endings are generally tapering although some specimens are more bluntly acuminate. The vein meshes are rather variable in dimensions, being relatively more broad near the base; however they do not become protractedly elongate. Comparable species are *L. gangamopteroides* (DE STEFANI) which has a very close venation, and *L. elongata* ZEILLER which is smaller with relatively more elongate vein meshes.

CONCLUSIONS

This investigation of the Sabero coalfield indicates that the age of the lowest beds is probably on the Stephanian A-B transition. Unfortunately, the oldest beds, the Alejico beds, have yielded only a poor flora. The dating indicates that the coalfield contains the oldest beds observed above the Asturian unconformity. The flora recorded is very closely comparable to that of the Calero beds (Stephanian A) in the Barruelo coalfield (Palencia), the youngest beds below the unconformity. Probably because in Sabero these beds are the oldest above the unconformity, there is the presence of a marginal marine band near the base of the sequence, not seen in other, later post-Asturian successions. This reflects the early age of deposition in this area after the folding phase causing the unconformity. A standard section of about 1200 m thickness measured upwards from the base showed no appreciable change in floral content, indicating that deposition was relatively rapid.

From the relationship of the Alejico beds to the overlying succession, it appears that basin subsidence began as local syn-sedimentary sagging in the north-east of the coalfield area and progressively occurred over a wider area. Thickening of the whole sequence towards the east indicates that the main basin of subsidence was in that direction. This is somewhat contradicted by the fact that the coal seams also thicken eastwards.

The presence of a *Leaia* marker band in the measured section (north of Saelices), which was also found in the Los Valles area, allowed interpretation of the thrust area to the south of Sabero. The southern flank of the coalfield is difficult to correlate with the generally undisturbed northern part on account of the considerable thrusting from the south which it has suffered.



Text-figure 5.—Generalised succession, showing relationships of the units of the measured section (north from Saelices) to the Alejico beds, and also the approximate position of Paquete Central. Main coal seams and other well defined horizons are indicated.

The area here considered, i. e. that around Sabero, is small compared to the total coalfield area and the rocks represent only a small part of the total coalfield succession (text-fig. 5). It is in the more contorted beds in the core of the synclinal structure of the coalfield that the major stratigraphic problems and also the youngest beds occur. From an interpretation of a simpler area, it is hoped, by means of closely measured sections, to extend the present work to a greater part of the coalfield.

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LOCALITY LIST, SABERO COALFIELD.

Mine road section.

Section of new road (old railway) from Sotillos to Vegamediana, measured between Sabero and Saelices. Section begins 150 m distant from and at a point almost south (165°) from Mina Sucesiva tower, and is measured south-west to the «hundimiento» of Capa Estrecha.

Locality	24,	—	70 m	below	Capa	Estrecha.
	41,	—	56 m	»	»	»
	56,	—	45.5 m		»	»
	56a,	—	44 m	»	»	»
	57,	—	42 m	»	»	»
	58,	—	37 m	»	»	»
	59,	—	34 m	»	»	»
	54,	—	28-23.5 m		»	»
	61,	—	20 m		»	»
	62,	—	16.5-15 m		»	»
	62a,	—	11 m	»	»	»
	64,	—	7-3.5 m		»	»

M e a s u r e d s e c t i o n.

The standard section is measured along the valleys of the Arroyo de Saelices and the Arroyo de la Mina, in a line due north from Saelices (see text-fig. 3). A well defined path passes through the valleys. The base of the section is 1.5 km north of Saelices at the base of the Carboniferous succession, very close to a small water supply building. See section (text-fig. 2) for position of localities, 65, 67, 68, 77, 79, in the valley of the Arroyo de la Mina, and 82, 82a, 86, 87, in the valley of the Arroyo de Saelices. In addition, in the valley of the Arroyo de Saelices, in the line of the measured section, on the eastern bank, there are localities,

83, — 33 m above Capa Sucesiva.
85, — 127.5 m » »

and on the western bank,

locality 84, — The roof of the small seam exposed in the mouth of the old Mina de los Gallegos.

L o s V a l l e s a r e a.

This is the hilly area to the south of Sabero (Barrio de Abajo). Compass bearings are given from the confluence of a small stream with the main stream in the Sabero valley, by the group of houses, Los Valles, at the side of the new mine road.

Locality 97, — Col below the Castillo de San Martino, 850 m from, and at 160° from stream confluence in Los Valles.
99, — Tip of the now disused Mina de Los Valles.
101, — «Hundimiento» at altitude 1020 m, bearing 170° from the stream confluence and 150° from the base of the old mine incline in Los Valles.
102, — «Hundimiento» 26 m due south of the ventilator of the Mina de Los Valles. Altitude 1160 m, bearing 170° from Sabero church.
104, — 850 m from and due south from the houses of Los Valles. Altitude 1100 m.

A d d i t i o n a l l o c a l i t i e s.

11, — On spur of hillside due east of, and 275 m from Sabero church (also just east of new secondary school).
71, — Tip of old Mina Encarnación in Sabero village.
73, — Tip of small seam below the conglomerates, on west side of path from Alejico to Sabero. Altitude 1040 m (south-west and 500 m from Alejico church).
105, — Old tips cut by new mine road, due south of most easterly houses of Sabero, south side of road.
106, 106a, — Small tips of seam below the conglomerates. Altitude 1060 m. North bank of the Arroyo de Alejico, due west from Alejico church.

107, — Small working in sandy lens in conglomerates, exposed in north bank of the Arroyo de Alejico. South-west from Alejico church, altitude 1020 m.

108, — Tip of small working on the south bank of the Arroyo de Alejico. Altitude 1000 m.

109, — Tip of small, old working. Due north of and 450 m from the Mina Encarnación.

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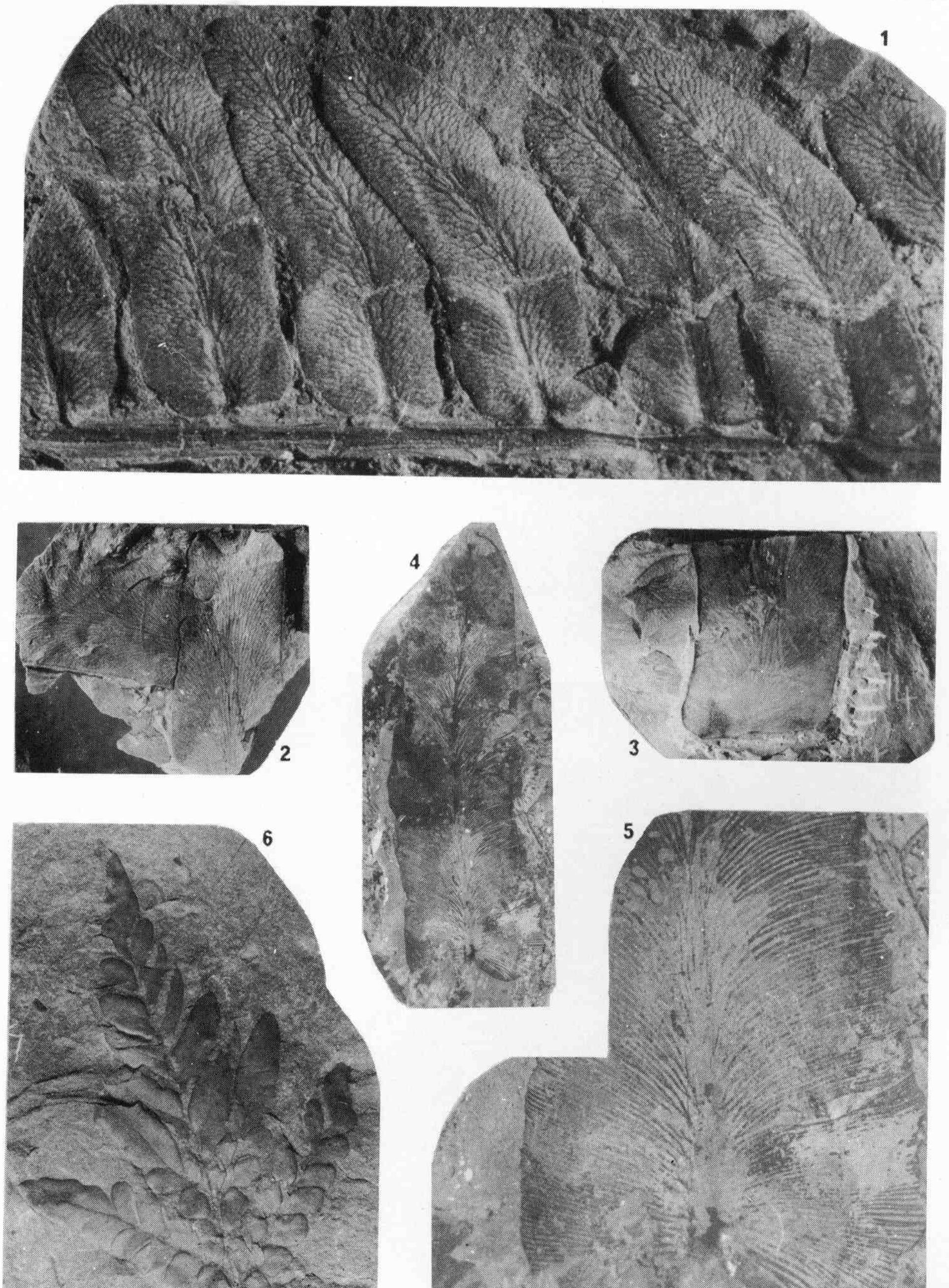
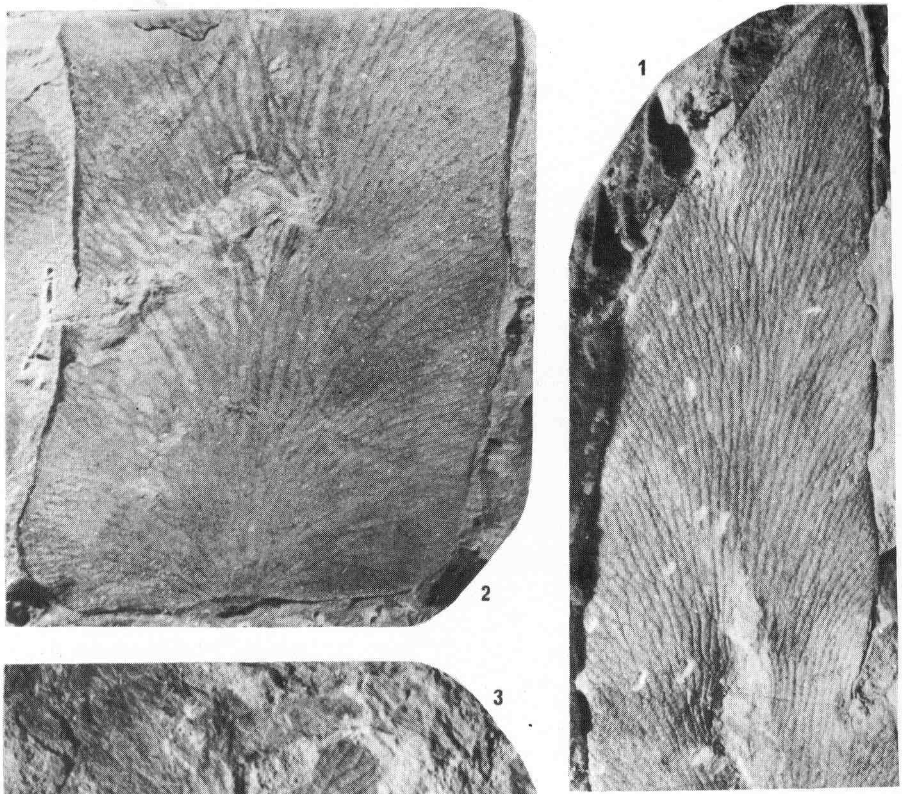
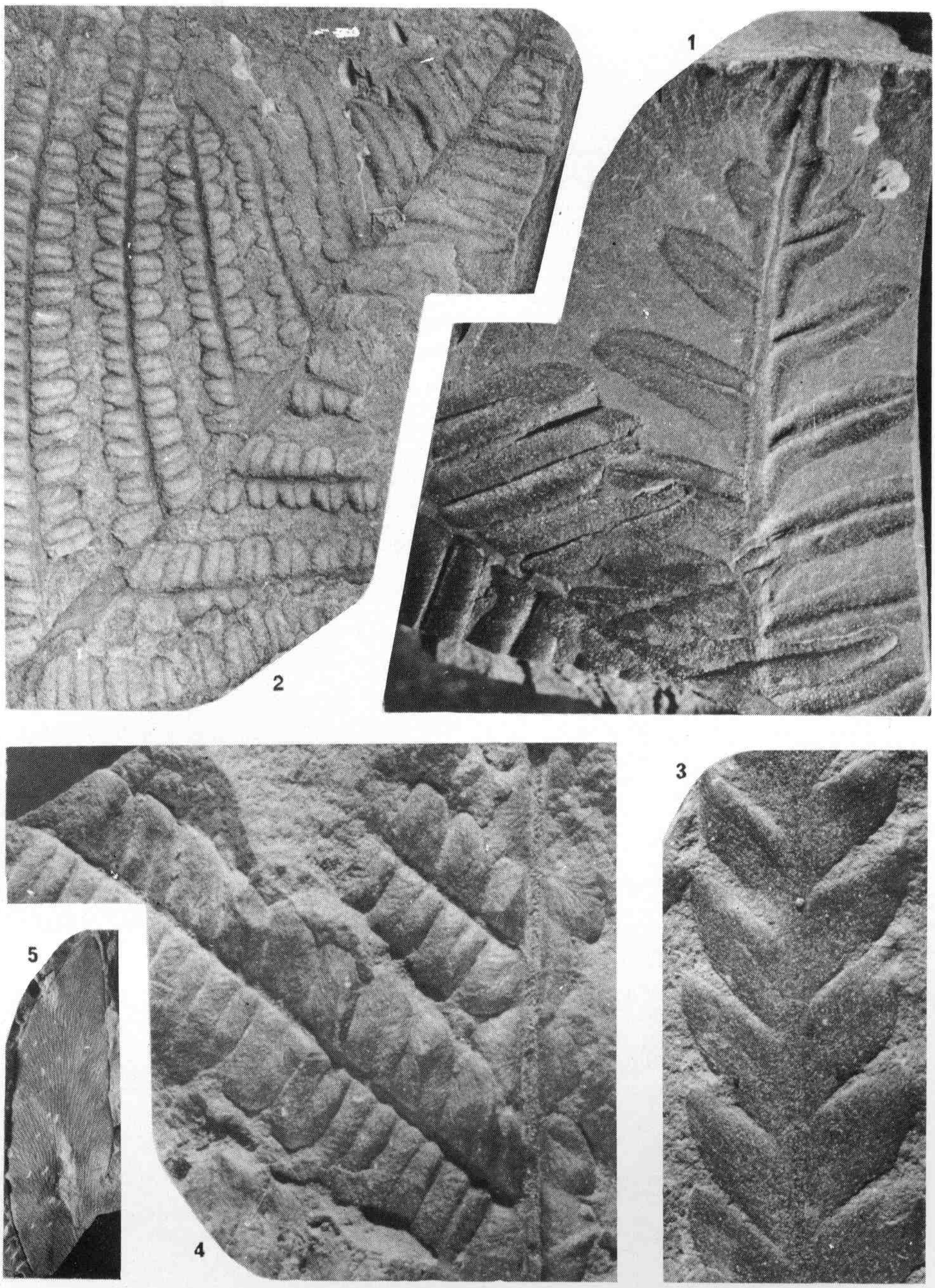


1. *Reticulopteris germari* (GIEBEL), − 3. Loc. 11 (probably unit 7).
2, 3. *Linopteris florini* TEIXEIRA, × 1. Loc. 74, unit 2.
4. *Neuropteris gallica* ZEILLER, × 1. Loc. 85, unit 12.
5. *Neuropteris gallica* ZEILLER, × 3. The same specimen enlarged to show hairs on mid-vein.
6. *Neuropteris ovata* var. *grand'euryi* WAGNER, × 1. Loc. 57, unit 12.

PLATE 2

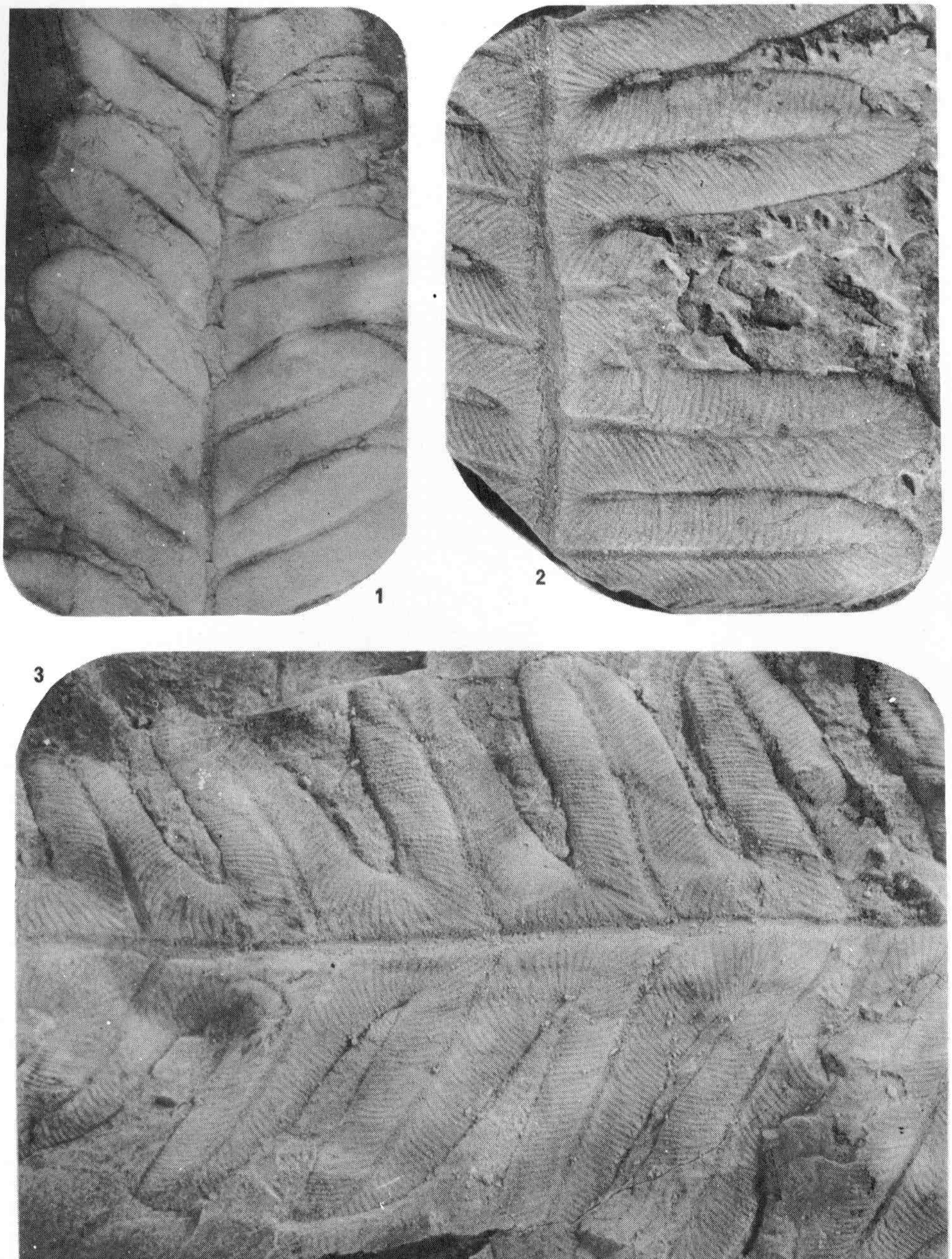


1. *Linopteris florini* TEIXEIRA, × 3. Loc. 74, unit 2.
2. *Linopteris florini* TEIXEIRA, × 3. Loc. 74, unit 2. The same specimen as on Pl. 1, fig. 3.
3. *Odontopteris genuina* GRAND'EURY, × 3. Loc. 77a, unit 9.

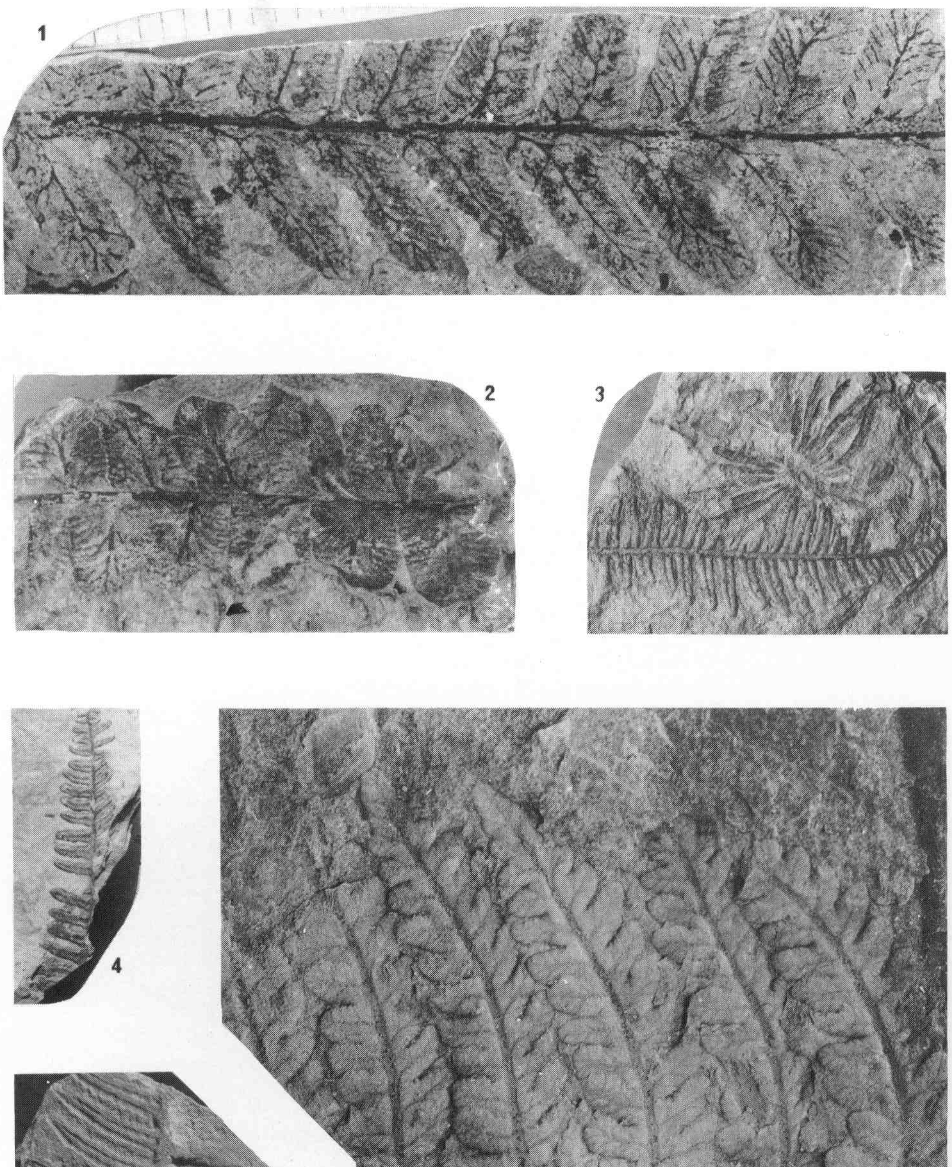


1. *Alethopteris leonensis* WAGNER, × 3. Loc. 23, unit 12.
2. *Pecopteris arborescens* (VON SCHLOTHEIM), × 3. Loc. 84, unit 12.
3. *Odontopteris brardi* BRONGNIART, × 3. Loc. 59a, unit 12.
4. *Callipteridium gigas* (VON GUTBIER), × 3. Loc. 54, unit 12.
5. *Linopteris florini* TEIXEIRA, × 1. Loc. 74, unit 2. The same specimen as on Pl. 2, fig. 1.

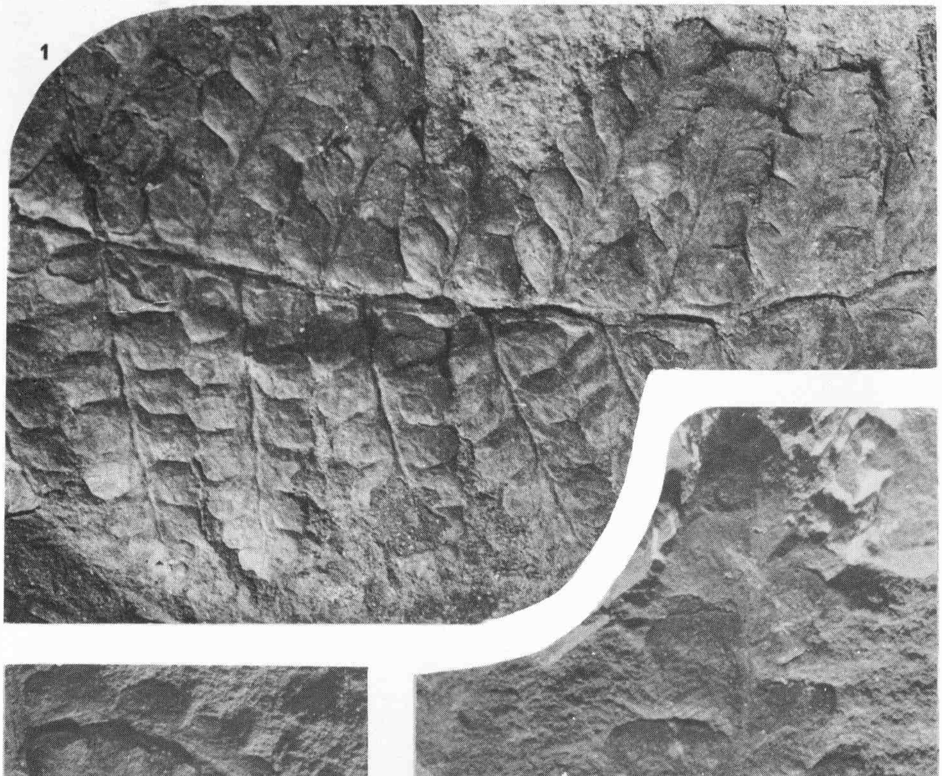
PLATE 4



1. *Alethopteris bohemica* Franke, × 3. Loc. 71, unit 9.
2. *Alethopteris zeilleri* Ragot, × 3. Loc. 59a, unit 12.
3. *Alethopteris barruelensis* Wagner, × 3. Loc. 64, unit 12.



1. *Pecopteris monyi* ZEILLER, × 3. Loc 77a, unit 9.
2. *Pseudomariopteris corsini* (TEIXEIRA), × 3. Loc. 71, unit 9.
3, 4. *Lobatopteris lamuriana* (HEER), × 1. Loc. 102, probably unit 9.
5. *Lobatopteris lamuriana* (HEER), × 1. Loc. 87, unit 13.
6. *Pecopteris* cf. *dentata* BRONGNIART, × 3. Loc. 84, unit 12.



1. *Sphenopteris cristata* (Brongniart), × 3. Loc. 109, probably unit 4.
2,3. *Sphenopteris neuropteroides* Boulay, × 3. Loc. 57, unit 12.