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MARINE AND CONTINENTAL DEPOSITS OF STEPHANIAN AGE IN EASTERN ASTURIAS (NW. SPAIN)

E. MARTINEZ-GARCIA * & R. H. WAGNER * *

ABSTRACT

An unconformable succession of predominantly shallow marine deposits is recorded from Arenas de Cabrales (text-figs 1, 2, 4). Intercalated continental strata near the base of this succession show a flora of Stephanian A (or B) age (Pls 3-5), and subsequent marine beds yield brachiopods of Kasimovian or later (Gzhelian) age. These rocks are younger than previously studied strata at Inguanzo, of upper Cantabrian age, and there is evidence for onlap eastwards of a basin which was established near Cangas de Onís in lower Cantabrian times and which reached Inguanzo and then Arenas de Cabrales in upper Cantabrian and Stephanian A times (compare MARCOS 1967, 1968; and text-figs 1-4). Marine Stephanian strata are also recorded from Oceño, east of Cabrales (text-figs 1, 5, 6).

Sedimentary facies include silty mudstones, mudstones and limestones, often in fining upwards sequences with shallow marine fossils; channel sandstones and conglomerates, presumably non-marine; and occasional seat-earths, one of which is accompanied by coal and plant-bearing roof shales. Sedimentation took place in a coastal environment with mud flats, generally below sea level, but occasionally at sea level or above, when sand was brought in and *in situ* vegetation was temporarily established. River channels with coarse sandy and conglomeratic fills also influenced sedimentation locally, and the presence of limestone pebbles proves active erosion in the near vicinity. Pls 1-2 illustrate aspects of the local geology and sedimentary facies.

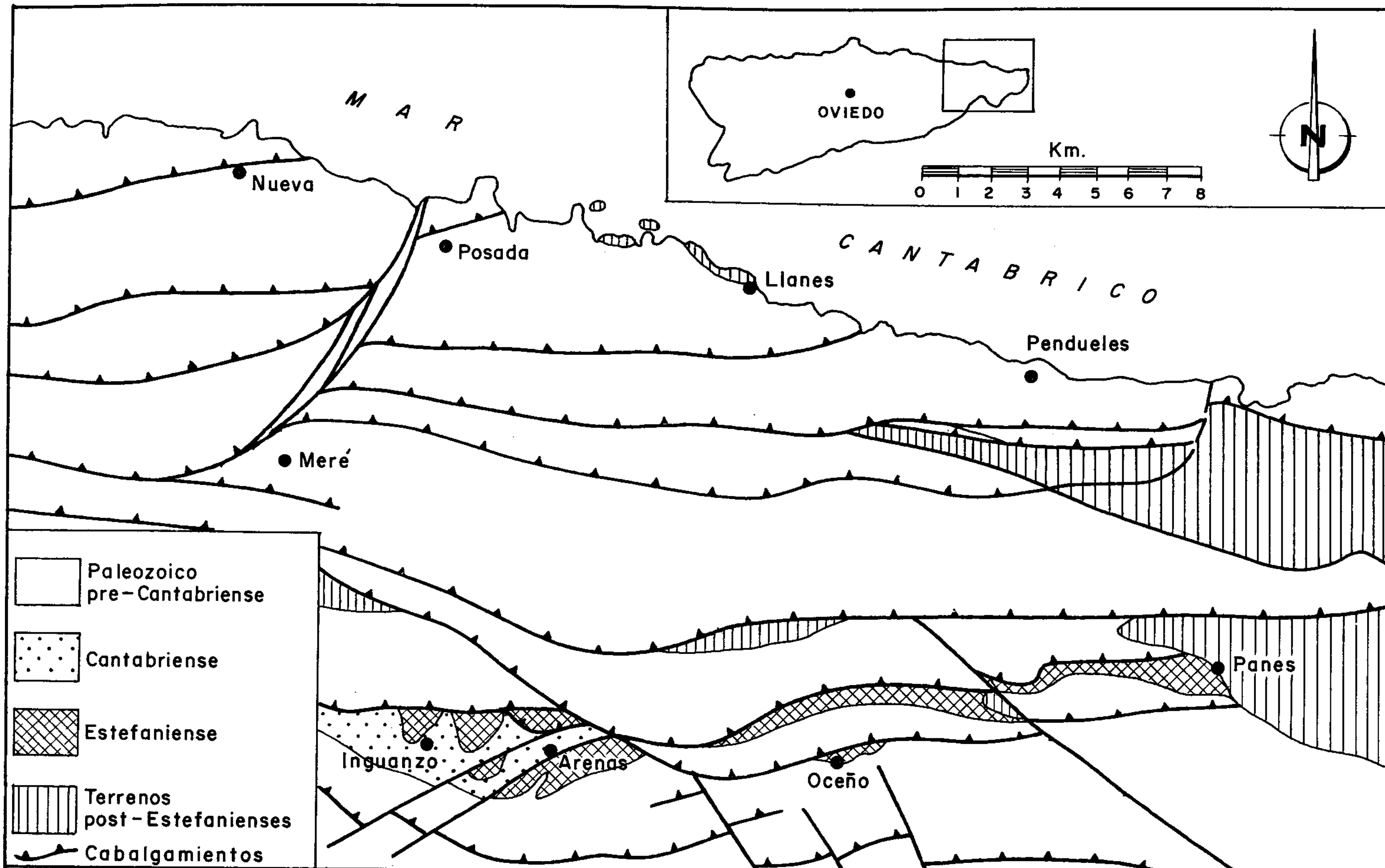
RESUMEN

Cerca de Arenas de Cabrales (Asturias Oriental) se han encontrado diversos afloramientos de estratos marinos con intercalaciones continentales, en una de las cuales se han recogido impresiones vegetales de edad Estefaniense A (o B) que figuramos (láms 3-5) y comentamos. La base de la secuencia se apoya en discordancia angular sobre calizas de edad Namuriense y posterior que afloran en las hoces del Río Cares. La misma secuencia discordante se data como Cantabriense (Estefaniense inferior *sensu lato* y más antiguo que el Estefaniense A) en los afloramientos cerca de Inguanzo y más hacia el oeste todavía, y parece ser que la cuenca estefaniense se extendió paulatinamente del oeste al este, llegando a Arenas durante el Estefaniense A. En la parte superior de la secuencia de Arenas se han encontrado braquiópodos que, según el Dr. C. F. WINKLER PRINS, apuntan una edad Kasimoviense o posterior (Gzheliense).

Se describe un corte estratigráfico detallado de la secuencia estudiada en Arenas (Fig. 4), y otros más generales de áreas cercanas (Inguanzo —Figs. 2, 3; Oceño— Figs. 5, 6), ilustrándose la geología general por el mapa de la Fig. 1.

Las facies sedimentarias son variadas e indican un régimen marino costero, generalmente lutítico, con areniscas litorales y paleocanales de areniscas y conglomerados cuarcitosos y calizos,

* Departamento de Geomorfología y Geotectónica, Facultad de Ciencias, Universidad de Oviedo, Spain.
** Department of Geology, The University, St. George's Square, Sheffield 1, England, U. K.



Text-fig. 1.—General map (Scale 1: 200,000) showing the area studied. *N. B.* For «Estefaniense» read «Estefaniense A-?B».

además de algún suelo de vegetación y hasta carbón. Aquéllos indican emergencias de vez en cuando, y los conglomerados calizos demuestran la presencia de relieves cercanos, en vías de erosión. Las láms. 1-2 dan ejemplos de las facies sedimentarias y de la geología local.

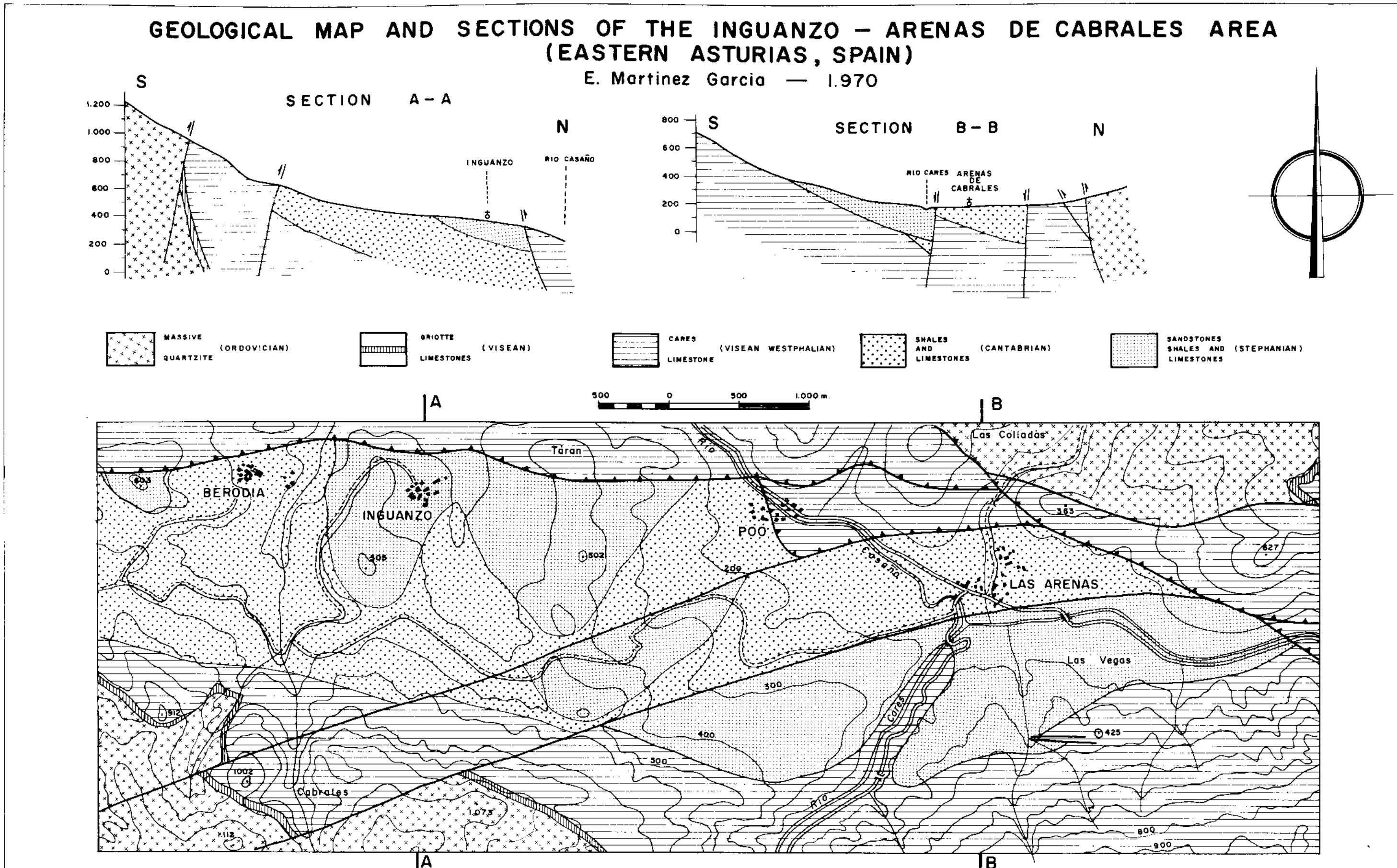
INTRODUCTION

Two papers by MARCOS (1967, 1968) provided a brief description of unconformable Carboniferous strata which crop out in a narrow, elongate strip of ground extending from *ca.* 5 km. east of Cangas de Onís to Arenas de Cabrales in eastern Asturias (text-fig. 1). The general area is situated north of the Picos de Europa, forming the highest part of the Cantabrian Cordillera, and consists of the rapidly rising ground to the south of the main road from Cangas de Onís to Panes. It is cut by a major river, the Río Cares, near Arenas de Cabrales, and this formed the eastern boundary of the area studied by MARCOS. However, the unconformable Carboniferous succesion continues east of the Río Cares, first as a direct continuation of the 20 km long strip of ground represented on MARCOS' map, and then, after strike faulting eliminated some of the outcrop, as individual outliers, e. g. at Oceño.

The rocks studied by MARCOS occur in roughly E-W striking folds with opposing dips of variable steepness. The southern limbs of the synclines are not usually affected by large scale strike faulting, but the northern limbs have been affected by thrusting which produced an anomalous contact with Moscovian limestone on the northern border of the area near Onís, Inguanzo and Arenas.

The stratigraphic succession was described in outline by MARCOS (*op. cit.*), who recorded predominantly marine mudstones with rarer conglomerates, sandstones and limestones. Although most of the succession proved to be marine, some continental intercalations including coal seams were found. These yielded identifiable plant remains which were dated by WAGNER (1967) as belonging to the Cantabrian, a chronostratigraphic unit which fills the time gap between stratotypic Westphalian D and stratotypic Stephanian A (compare WAGNER 1969). The older (lower) Cantabrian floras were found in the western part of the area studied by MARCOS, and the upper Cantabrian was dated more to the east, in the vicinity of Inguanzo. A thin succession (20 m) of rhythmically developed siltstones, mudstones and calcareous mudstones to limestones, with drifted plant macrofossils as well as spores and varied marine faunal remains, was studied in detail by WAGNER, JONES, SPINNER & WAGNER-GENTIS (1970) from an outcrop east-southeast of Inguanzo.

The present paper examines some information obtained from even more easterly exposures near Arenas de Cabrales (mapped as of Cantabrian age by MARCOS), and in the outlier of Oceño (text-fig. 1). One section, immediately south of Arenas, has been measured in detail by both authors, and more general sections were drawn for the areas of Inguanzo, Arenas and Oceño by E. M. G. who is also responsible for the preliminary maps presented here. A fossil flora discovered by E. M. G. in exposures along a canal east of the Río Cares, was subsequently collected by both authors, and identified by R. H. W. (see also the comments on this flora at the end of this paper).



Text-fig. 2.—Geological map and sections of the Inguanzo - Arenas de Cabrales area.

The authors are grateful for the identification of brachiopod faunas, as undertaken by Dr. C. F. WINKLER PRINS (Rijksmuseum van Geologie en Mineralogie, Leiden), whose provisional determinations are quoted in the text. These faunas will be the subject of a more detailed study by Dr. WINKLER PRINS at some future time. They also acknowledge with pleasure the identification of a coral specimen examined by Dr. G. E. DE GROOT (Rijksmuseum van Geologie en Mineralogie, Leiden.) The second author has had the benefit of photographic facilities in the Department of Geology, University of Sheffield, and expresses his appreciation for those photographs which were taken by Mr. B. PIGOTT of Sheffield University.

It should be emphasized that the present paper only provides a first account of more or less scattered data on an area which still requires a more systematic study. The data obtained thus far do, however, point at certain conclusions which may be of interest for a general understanding of the Carboniferous of NW Spain. It is hoped that they will stimulate further investigation in this area.

REGIONAL STRATIGRAPHY

The oldest rocks present in this area are of Upper Cambrian age (not shown on the map). They consist of sandstone/shale alternations which compare with the Oville Formation as described by COMTE 1959 (see also DE SITTER 1962). Subsequently, a thick formation of white, massively bedded quartzites is found. These have been dated, by inference, as Lower Ordovician of *pre*-Llanvirnian age (PELLO & PHILIPPOT 1967). Silurian and Devonian strata are absent below a Lower Carboniferous condensed sequence (MARCOS 1967, pp. 40-42) which lies disconformably on the Ordovician quartzites. The upper part of this sequence is composed of nodular limestones of «griotte» facies. They are followed in conformable sequence by thick, light coloured limestones which correspond only in part to the «caliza de montaña» as reported by MARTÍNEZ-GARCÍA (1971). The upper part of the limestone development is of Moscovian age, since DELÉPINE (1943) recorded Middle Moscovian fusulinids, and it seems likely that an important stratigraphic gap may be present within these limestones which LLOPIS LLADÓ (1964, p. 19) estimated as being some 1,100 metres thick (compare VAN GINKEL 1965, JULIVERT 1967). The impressive gorge of the Río Cares, south of Arenas de Cabrales, has been cut into these thick limestones.

Unconformable upper Westphalian D and Cantabrian deposits are found on top of these limestones in a comparatively narrow strip of terrain from Isongo at *ca*. 5 km east of Cangas de Onís, to Arenas de Cabrales (MARCOS 1967, geol. map.). The outcrop is continued eastwards from Arenas de Cabrales in probable Stephanian A deposits which are discussed in the present paper. The upper Westphalian D and Cantabrian strata are mainly marine in facies, with occasional non-marine intercalations (MARCOS 1968).

A.—I n g u a n z o (text-figs 2, 3).

A partially exposed succession is found along the secondary road linking the village of Inguanzo to the main road of Cangas de Onís to Panes. The base of the succession is unknown and the earliest deposits recorded are the rhythmic siltstones, mudstones and occasional limestones described by WAGNER, JONES, SPINNER & WAGNER-GENTIS (1970) from a path behind the old iron mill, just off the Inguanzo road. These rocks yielded an upper Cantabrian flora (*op. cit.*):

Neuropteris ovata HOFFMANN var. *ovata.*
Neuropteris scheuchzeri HOFFMANN.
Neuropteris planchardi ZEILLER.
Reticulopteris germari (GIEBEL) GOTHAN.
Linopteris neuropteroides (VON GUTBIER) POTONIÉ.
Callipteridium gigas (VON GUTBIER) WEISS.
Callipteridium cf. *jongmansi* (P. BERTRAND) - *striatum* WAGNER.
Pseudomariopteris ribeyroni (ZEILLER) DANZÉ-CORSIN.
Dicksonites pluckeneti (VON SCHLOTHEIM) var. *sterzeli* ZEILLER.
Sphenopteris cf. *rotundiloba* NĚMEJC.
Pecopteris acuta BRONGNIART.
Pecopteris cf. *lepidorachis* BRONGNIART.
Pecopteris (Asterotheca) truncata ROST.
Sphenophyllum oblongifolium (GERMAR & KAULFUSS) UNGER.
Annularia sphenophylloides (ZENKER) VON GUTBIER.
Cordaites sp.

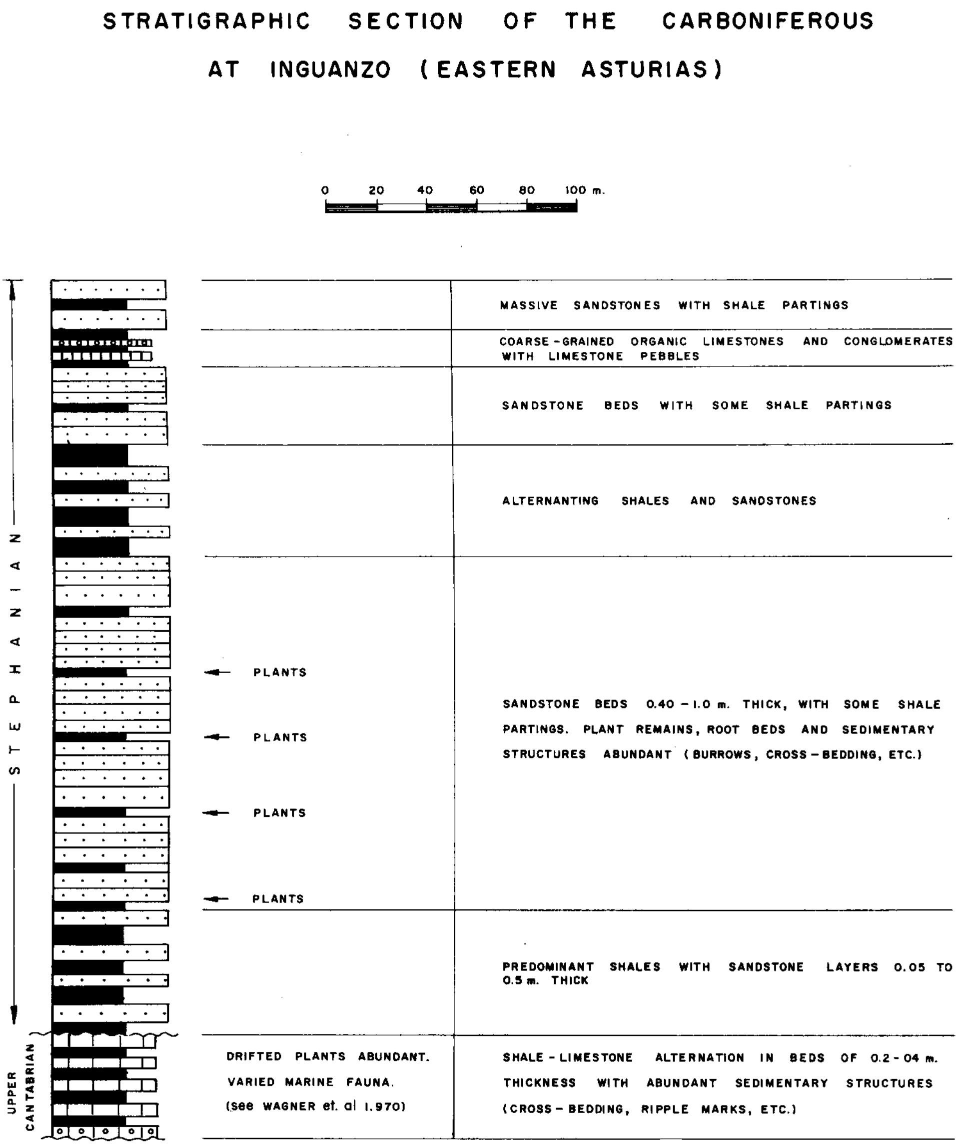
Above the mudstones a thick succession of predominant sandstones is found in a sequence which youngs northwards and which belongs to the southern flank of a syncline with only a few accessory folds. The northern flank has been eliminated by thrusting which brings the higher part of the Inguanzo succession into contact with a Westphalian limestone of an earlier sequence, unconformable with that of Inguanzo (MARCOS 1967).

The sandstones may be up to 200 m thick, and contain relatively few mudstone partings as well as some very thin limestones and conglomerates in the upper part. The facies is predominantly marine but occasional seat-earths occur as well. Burrows are frequently present. This sandstone succession (text-fig. 3) can apparently be traced eastwards to the basal part of the section of unconformable strata south of Arenas de Cabrales.

B.—A r e n a s   d e   C a b r a l e s (text-figs 2, 4).

Some 3 km east of Inguanzo, in the immediate vicinity of Arenas de Cabrales (text-fig. 1), the same sequence crops out between the rivers Cares and Casaño. However, the lower part of the succession at Inguanzo is lacking near Arenas where the sandstone unit forms the base of the unconformable sequence. The thickness of the sandstone is also strongly diminished (only some 25 metres being represented), and it thus appears that a substantial part of the Inguanzo succession has not been developed near Arenas.

A detailed section was measured along the road leading to Arenas, on the western side of the valley of the Río Cares (text-fig. 4). The local succession starts with sandstone lying unconformably on limestones of an earlier Carboniferous age which



Text-fig. 3.—Generalized stratigraphic section of upper Cantabrian and Stephanian A (?) rocks in the Inguanzo region. (MARTÍNEZ - GARCÍA 1970 *del.*).

form the gorge of the Río Cares. The lower part of the sandstone, some 15 m thick, is poorly exposed and the detailed section commences at the top of this unit, just below a thin coal (14 cm) and seat-earth (1 cm). The sandstone is coarse-grained, quartzose and yellowish in the lower part and becomes medium-grained, well washed and probably a little calcareous in the top part. At 0.55 m below the coal a layer with marine lamellibranchs was found. On the eastern side of the Río Cares, in exposures made for a small canal leading to a hydro-electric power plant, apparently the same sandstone is seen to have up to 2 m of conglomerate at the base, with small (5-10 mm diameter), well rounded and well sorted quartzite pebbles set in a limestone matrix. This basal conglomerate is followed in the canal exposure by some 4 to 5 metres of strongly burrowed calcareous sandstone. There can be little doubt that this succession represents a transgressive sequence.

Although exposure is patchy, it appears that the sandstone is thinner at the canal than it is on the western side of the river. This is in keeping with the general eastward thinning of the sandstone unit. Essentially the same succession is found in the canal exposures which also show a coal seam overlying the sandstone. However, in the canal exposures the coal is seen to be rather thicker and the presence of old tips and adits testifies to the more important development of coal in this area. In roof shales above the coal and on the old tips a large number of plant impressions were found (E. M. G. loc. A 76 — R. H. W. *det.*):

Neuropteris ovata var. *grand'euryi* WAGNER.
Alethopteris bohemica FRANKE.
Callipteridium (Eucallipteridium) gigas (VON GUTBIER) WEISS.
Callipteridium (Eucallipteridium) zeilleri WAGNER.
Dicksonites pluckeneti (VON SCHLOTHEIM) STERZEL.
Sphenopteris cf. *neuropteroides* BOULAY.
Pecopteris unita BRONGNIART.
Pecopteris melendezi WAGNER.
Pecopteris cf. *lepidorachis-candollei-densifolia* BRONGNIART / GOEPPERT.
Pecopteris paleacea ZEILLER.
Pecopteris spp.
Sphenophyllum oblongifolium (GERMAR & KAULFUSS) UNGER.
Annularia sphenophylloides (ZENKER) VON GUTBIER.
Calamostachys tuberculata STERNBERG.
Cordaites sp.

They form an assemblage which could be either Stephanian A or B in age, but which is certainly later than the upper Cantabrian flora found below the sandstone unit at Inguanzo (compare WAGNER *et al.* 1970). Comments on the flora listed above are given at the end of this paper (see also Pls. 3-5).

The gorge of the Río Cares separates the exposures examined on the western and eastern sides of the valley, and the question arises whether the succession is the same on both sides. It appears that this must be answered in the affirmative. The sequence of marine sandstone followed by seat-earth and coal is the same in both exposures, and in both cases the coal with its roof shales are followed by a marine succession containing conglomerates and limestones alternating with sandstones and mudstones. Moreover, the mapping by one of us (E. M. G.) has failed to suggest any tectonic or stratigraphic discontinuity between the successions recorded on the western and eastern sides of the valley.

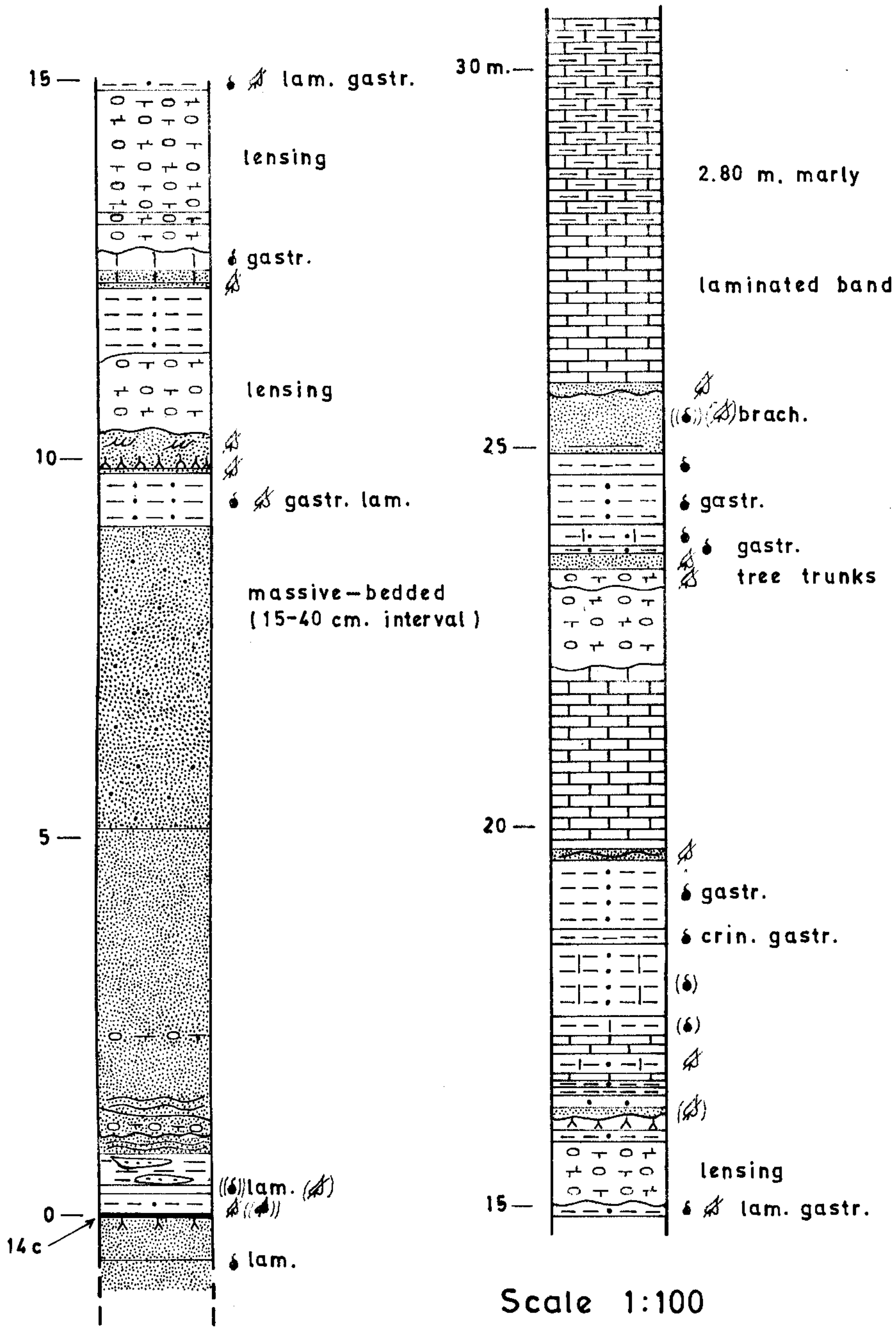
The well exposed road section west of the Río Cares (text-fig. 4) shows 0.30 m of somewhat micaceous, slightly silty shales with comminuted plant remains which are rarely identifiable (*Cordaites*, *Stigmaria*), at the roof of the thin coal. These are the lateral equivalent of the fossiliferous shales of the coal in the canal exposures, and apparently represent a deposit further from the source of the vegetation. It could well be that the thicker coal and more fossiliferous roof shales east of the Río Cares were formed near the site of a temporary basin margin, whilst the thinner coal and less fossiliferous roof shales in the road section were formed nearer the marine basin.

The proximity of the sea is proved by the find of occasional, probably marine lamellibranchs intermingled with rare, finely comminuted plants in 0.10 m of dark grey shales, which are succeeded by 0.05 m of slightly ferruginous siltstone in a lens containing abundant brachiopods, lamellibranchs and comminuted plant debris. These rocks are found immediately above the roof shales of the road section, and constitute a clear sign of transgression. Dark grey, slightly silty shales (0.15 m); grey, micaceous siltstone with comminuted plants (0.04-0.10 m); dark grey, finely laminated shales (0.04 m); slightly micaceous siltstone with finely comminuted plants (0.04 m); and dark grey shales (0.03 m) are found in quick succession before a ripplemarked and ripple cross-laminated sandstone (0.07 m) is reached. The siltstones are all lenticular and apparently erosive at the base. They appear to mark channels in the dark grey, probably marine shales. The thin sandstone above the siltstones and shales may be interpreted as a ripplemarked beach or estuarine deposit, and the same environment may be assumed for 0.18 m of siltstone with ripplemarks and ripple cross-lamination throughout, which follows in the succession. An occasional lens of quartzite conglomerate is recorded at this horizon which also shows bedding planes with comminuted plant debris.

Approximately 4 m of channel sandstone with an erosive base forms the next deposit. It contains a lens of conglomerate at the base and another higher up. Most of the pebbles consist of limestone and thus appear to indicate a torrential source. They are mixed in with a minor proportion of quartzite pebbles. The sandstone is coarse-grained, yellowish, with probably a partly calcareous matrix, since the quartz grains are quite loose in the weathered crop. It appears massively bedded (intervals of 10 to 25 cm), and ripplemarks have been found at 0.55 m from the base.

Another 4 metres (approximately) of massively bedded sandstone (15 to 40 cm intervals) follow in normal succession. This sandstone is white, quartzose with a siliceous cement. It is succeeded by 0.70 m of silty, marine shales with large gastropods, occasional lamellibranchs, and abundant comminuted plant remains. This deposit apparently marks the top of a gradually transgressive sequence, and is to be regarded as more clearly marine than the preceding sandstones which may have been

STRATIGRAPHIC SECTION OF STEPHANIAN ROCKS



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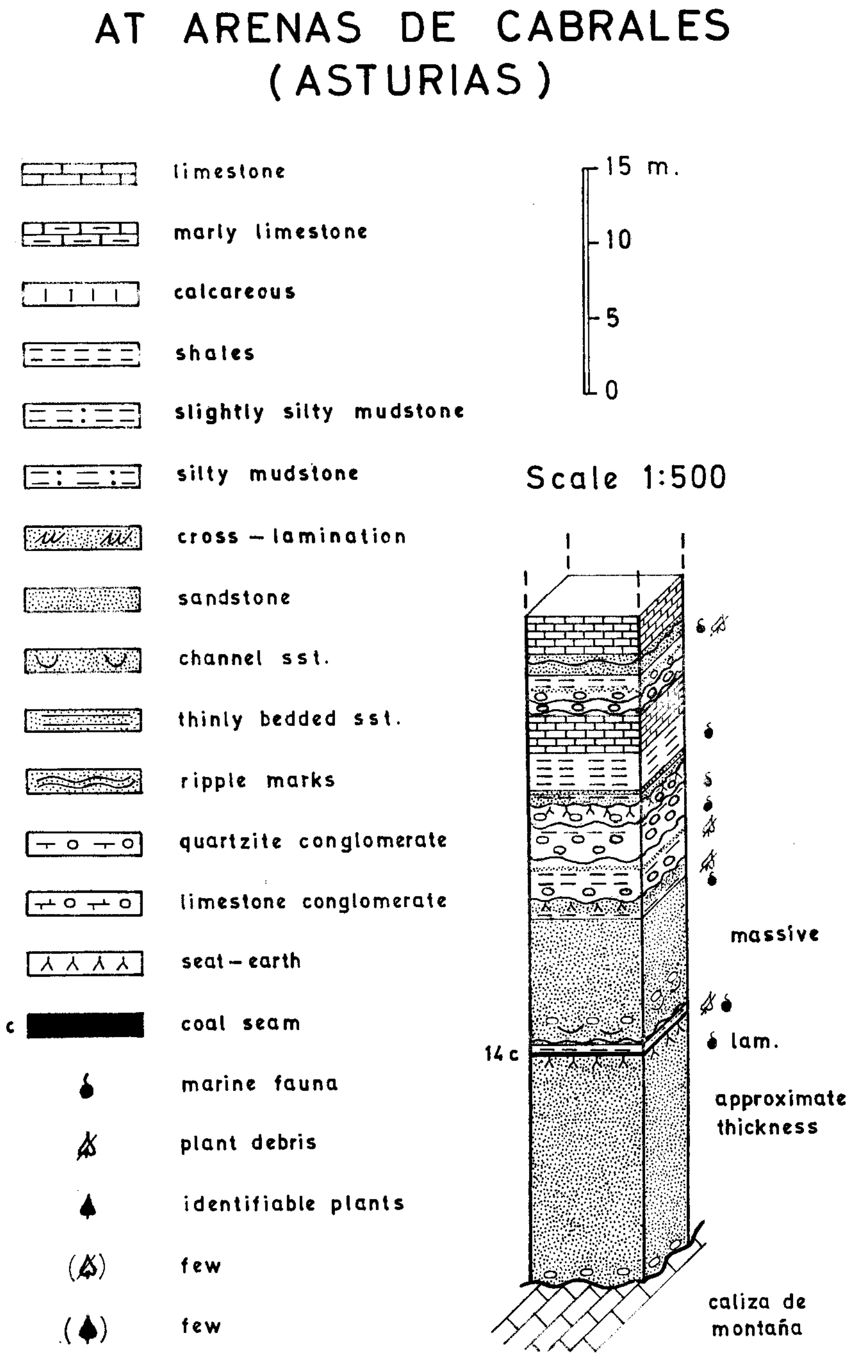


Text-fig. 4.—Stratigraphic section of Stephanian A(?) rocks at Arenas de Cabrales. The column on the left (scale 1 : 100) represents the section measured along the road west of the Río Cares. The column on the right (scale 1 : 500) gives the full succession from the base of the unconformable sequence upwards and combines the stratigraphic section on the western bank with information obtained east of the Río Cares (where a conglomerate occurs at the base of the unconformable succession).

non-marine at the base and which were certainly river-generated (as shown by the limestone pebbles in the conglomerate lenses).

Above the marine shales another regression is marked by 0.02 m of sandstone with comminuted plant debris, which is followed by 0.06 m of coarse-grained sandstone with abundant Stigmarian rootlets forming a seat-earth. Thinly bedded, well washed sandstones with some ripple cross-lamination and abundant plant debris, form the presumably non-marine roof measures (0.50 m thick). These are followed by a lenticular body of conglomerate, up to 2 m thick, with mixed quartzite and limestone pebbles, the diameter of which ranges from 2 to 40 mm. It represents a channel fill, either fluviatile or directly river-generated in an estuarine environment. The latter probability is suggested by the marine shales (0.85 m) which succeed the channel fill, and which contain abundant gastropods with a lesser proportion of lamellibranchs and brachiopods, occurring together with a few drifted plant remains (mainly comminuted but sometimes identifiable: e.g. *Annularia sphenophylloides* (ZENKER) VON GUTBIER).

A new influx of river borne material is marked by 0.05 m of medium-grained sandstone with abundant comminuted plant debris, occurring at the base of another 0.20 m of sandstone which becomes calcareous upwards and which is followed by 0.25 m of calcareous mudstone with gastropods.

Three successive lenticular bodies of conglomerate (0.35 m of quartzite and limestone pebbles in a calcareous matrix; 0.12 m of limestone and quartzite pebbles in a quartzose matrix; and 1.60 m of limestone and quartzite pebbles in a calcareous matrix) represent further channel fill deposits. They are succeeded by 0.16 m of slightly silty mudstone with lamellibranchs, a few gastropods and fairly abundant plant debris.

A further lenticular channel fill, 0.85 m thick, of limestone and quartzite pebbles (5 to 20 mm diameter) in a calcareous matrix, is followed by 0.15 m of slightly silty shale, and this is succeeded by 0.15 m of slightly silty mudstone with Stigmarian rootlets forming a seat-earth.

The *in situ* vegetation is cut off by another channel fill represented by 0.12 m of sandstone with comminuted plant debris. A transgressive fining upwards sequence is then recorded with 0.15 m of dark grey sandy shale, 0.10 m of dark grey slightly sandy shale, 0.10 m of dark grey shales, and 0.12 m of fine-grained limestone (calcilutite). This is succeeded by 0.24 m of thinly laminated, slightly silty and marly shales with finely comminuted plant debris; 0.23 m of calcilutite; 0.24 m of dark grey shales (slightly marly) with indeterminate shell remains; 0.95 m of marly, slightly silty shales with occasional crinoid debris; 0.20 m of dark grey shales with crinoids and brachiopods; and 0.90 m of grey, slightly silty mudstone with gastropods (mainly in the upper part of the unit).

Another fining upwards sequence then starts with 0.15 m of thinly bedded, fine-grained sandstone with abundant comminuted plant debris, and showing ripple cross-laminations and occasional ripplemarks. This sequence is completed by 0.10 m of marl, succeeded by 2.30 m of slightly marly, fine-grained limestone which is thinly bedded (interval 2-10 cm).

The limestone is cut off abruptly by 1.10 m of conglomerate with a strongly erosive base and constituting a channel fill. It consists of limestone pebbles (generally 4-10 mm diameter but occasionally reaching sizes of up to 50 mm) in a calcareous matrix. This conglomerate is poorly sorted. It is succeeded by 0.20 m of conglomerate with mainly quartzite and occasional limestone pebbles (2-4 mm diameter) in a quartzose matrix and containing drifted tree trunks. It seems likely that these conglomerates are fluviatile and non-marine. They are followed in a gradual transition by 0.20 m of sandstone with comminuted plant remains, 0.10 m of marly siltstone with gastropods, 0.28 m of silty mudstone (slightly marly) with abundant small shell remains, 0.65 m of slightly silty mudstone with gastropods, and 0.25 m of fossiliferous shales. This forms another fining upwards sequence which is transgressive.

A subsequent deposit of 0.80 m of medium-grained, slightly calcareous sandstone with occasional brachiopods and some comminuted plant remains, shows renewed shallowing and/or increased erosion. Very likely, the former is true because this marine sandstone is followed by 0.15 m of coarse-grained channel sandstone with plant debris, of probable fluviatile facies. This is succeeded by 2.10 m of fine-grained, slightly marly limestone which contains a laminated band, possibly of algal origin. The exposed section ends with 2.80 m of fine-grained, marly limestone.

The general picture of the succession immediately south of Arenas de Cabrales is one of transgression, with coarse-grained, near-shore deposits at the base of the unconformable sequence. Temporary stability, with the absence of terrigenous runoff and the lack of appreciable subsidence, is indicated by the coal seam of 14 cm thickness in the measured section. The latter being thicker in the canal exposures to the east, where a non-marine facies may also have been of slightly longer duration at this horizon, there is reason to assume a basin margin towards the east. Since the combined evidence of mapping and stratigraphic dating also suggests a greatly expanded sequence at the base of the unconformable succession westwards, the presence of a basin margin to the east accords well with the information at hand. After the coal horizon with its underlying seat-earth a gradual marine transgression is recorded by the strata examined. Presumably, this is due to a renewed eastward expansion of the basin. Subsequent river-generated deposits may reflect orogenic activity in the terrigenous source area, and most of the measured section seems to record intermittent orogenic movements in the source area providing occasional influxes of river-generated sandstones and conglomerates in a gradually subsiding area with fining upwards marine transgressive sequences. It is the presence of frequent limestone pebbles in the conglomerates deposited as channel fills, which suggests a tectonically active source area. Otherwise, the sandstone/conglomerate intervals might also have been interpreted as distributary channels reaching into a gradually subsiding coastal marine area, of generally transgressive tendencies, and which locally filled up to above sea level (as witnessed by the occasional seat-earths) as the river channels wandered to any particular part of the area of sedimentation.

The upper part of the measured section, with its gradually predominating limestone deposits, is also represented in the exposures SE of Arenas where a rich fauna has been collected from a sandy limestone following upon a conglomerate (1 m thick) which rests upon marine sandstones with animal tracks (Pl. 1, fig. 1). The fauna consists of brachiopods, bryozoa, gastropods, lamellibranchs, crinoids, etc. (Coll. E. M. G. loc. AC 61). Among the brachiopods Dr. C. F. WINKLER PRINS kindly identified:

Martinia sp.
Brachythyrina carnica (SCHELLWIEN 1892).
Choristites cf. *fritschi* (SCHELLWIEN 1892).
phricodothyrid (Elythidae).
marginiferid.
dictyoclostid.

An associated plant fragment has been identified as *Linopteris neuropteroides* (VON GUTBIER) POTONIÉ (R. H. W. *det.*).

Approximately 2 or 3 metres above this level a more prolific brachiopod fauna was found in limestone exposures along the road leading to the small power plant for which the canal was built. From this locality (Coll. E. M. G. loc. AC 71) Dr. C. F. WINKLER PRINS identified:

Lissochonetes? ex gr. *L.? rarus* (IVANOV & IVANOVA 1936).
Avonia (Quasiavonia) echidniformis (CHAO 1925).
Alexenia sp. ex gr. *A. reticulata* IVANOVA 1935.
Linoproductus cf. *coralineatus* IVANOV 1935.
Choristites cf. *fritschi* (SCHELLWIEN 1892).
Brachythyrina carnica (SCHELLWIEN 1892).
Plycatocyrtia zitteli (SCHELLWIEN 1892).
Martinia aff. *juresanensis* STEPANOV 1948.
Martinia cf. *karawanica* VOLGIN 1959.
Phricodothyris sp.
Kozlowskia sp.
Rhynchonellida.

According to WINKLER PRINS (pers. comm.) this assemblage may be regarded provisionally as indicating a Kasimovian or younger (Gzhelian) age. This agrees well with the Stephanian A or B age suggested by the plant fossils from the canal exposures.

A single coral collected from the brachiopod limestone was identified by Dr. G. E. DE GROOT (pers. comm.) as *Stereostylus* sp.

This fossil locality was also known to DELÉPINE (1943), who recorded the following species:

Productus semireticulatus ex gr. *P. gruenewaldti* KROTOV.
Marginifera sp.
Spirifer cf. *fritschi* SCHELLWIEN.
Spirifer strangwaysi DE VERNEUIL.

Spirifer denicostatus IVANOV.
Reticularia lineata (MARTIN).
Martinia sp.
Pugnax sp.

DELÉPINE failed to notice the unconformable position of the succession yielding this fauna, and assumed that the limestone containing the fauna belonged to the top part of the «calcaire des cañons» (= «caliza de montaña»). He therefore attributed a younger age to the «caliza de montaña» than it actually possessed. E. & F. HERNÁNDEZ PACHECO (1935, 1936) assigned a Carboniferous age to the Stephanian sandstones of Arenas de Cabrales, and extended this age to some Ordovician quartzites in nearby exposures made by the Río Cares. This was contested by P. HERNÁNDEZ SAMPELAYO (1936), who reported the find of *Cruziana* in the latter quartzites (from a locality further east in the general area), to which he assigned a general Silurian age *(sensu lato)*.

C.—O c e ñ o (text-figs 5,6).

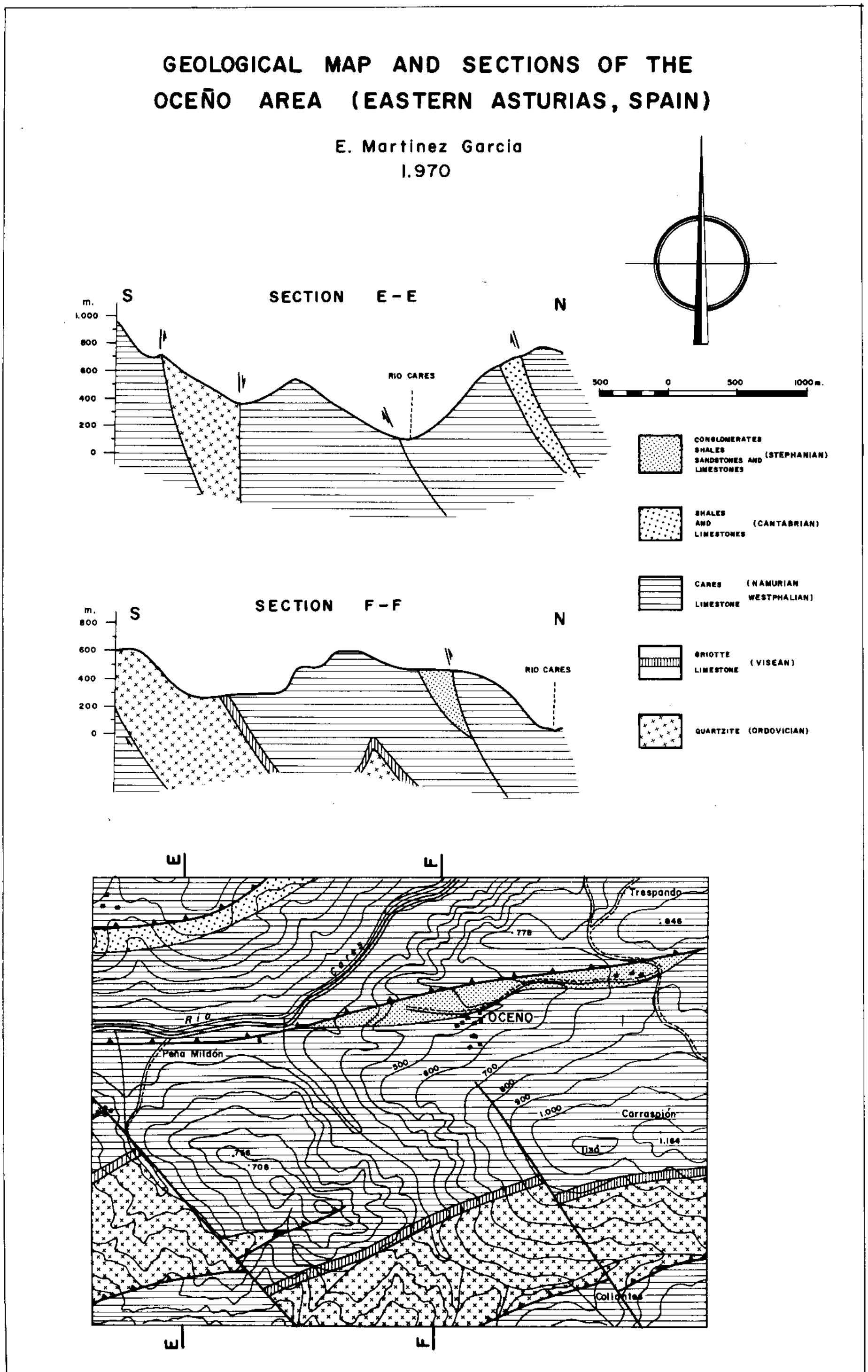
The outcrop described in the preceding section disappears to the east due to an E-W trending thrust fault (Pl. 1, fig. 2). Following this thrust, a new outcrop of reduced dimensions is found along the mountain road which links the village of Oceño with the main road of Cangas de Onís to Panes. Only a general section has been measured here, but similar facies are found to those examined near Arenas. Sandstones are less important and conglomerates are more strongly represented (Pl. 2, figs. 1, 2). Lutites in the middle of the section have yielded abundant remains of lamellibranchs and gastropods together with some drifted plants. Among the latter *Callipteridium zeilleri* WAGNER has been recognized.

OUTLINE OF THE TECTONIC STRUCTURE

The maps and sections (text-figs 1, 2, 5) show the presence of long E-W trending thrust faults which dip northwards and which accompany the strike of the beds over large distances. These thrusts are related to E-W striking folds which were formed prior to the unconformity underlying the upper Westphalian D, Cantabrian and Stephanian A succession. Subsequent folding along E-W axes occurred together with thrusting such as that which is seen to have affected the northern border of upper Cantabrian and Stephanian A rocks near Inguanzo and Arenas de Cabrales.

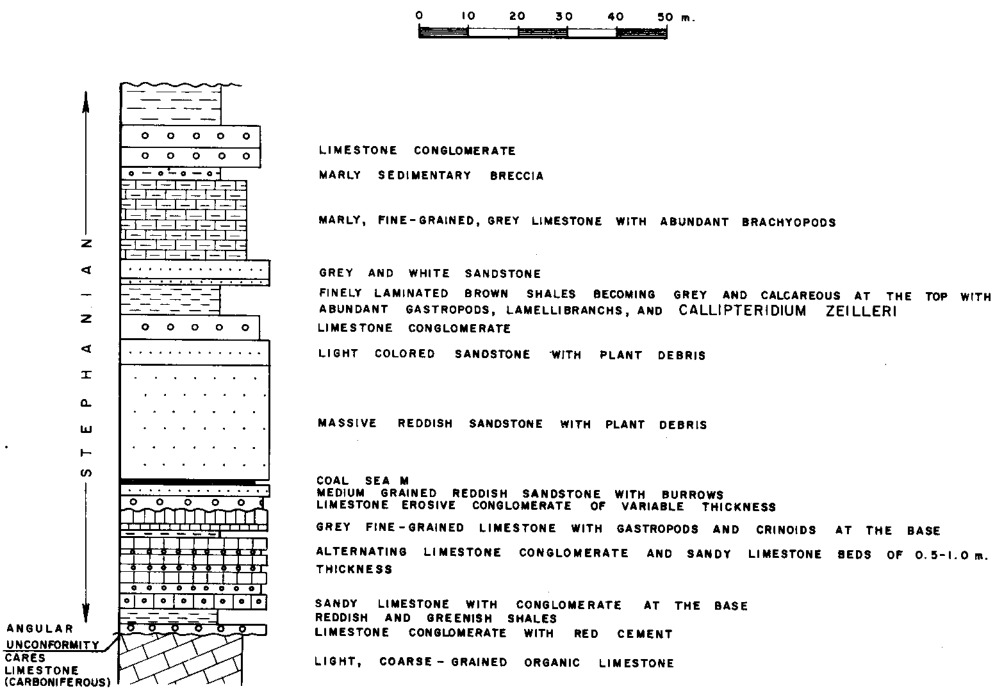
Later NW-SE trending wrench faults and NE-SW striking normal faults are also observed. Probably, these are late Upper Palaeozoic in age, either intra-Stephanian (Asturian) or Permian. Most of these faults were rejuvenated during the Alpidic Tertiary movements.

Since the present paper is primarily concerned with the stratigraphy of the unconformable Cantabrian and Stephanian A strata, a more detailed account of the tectonic structure is beyond its scope.



Text-fig. 5.—Geological map and sections of the outlier at Oceño. For Stephanian read Stephanian A-?B, i. e. rocks following onto those corresponding to basal Stephanian (=Cantabrian).

STRATIGRAPHIC SECTION OF THE CARBONIFEROUS
AT OCEÑO (EASTERN ASTURIAS)



Text-fig. 6.—Generalized stratigraphic section at Oceño (MARTÍNEZ - GARCÍA, 1970 *del.*).

CONCLUSIONS

1.—The upper Cantabrian mudstones at Inguanzo are overlain by apparently conformable sandstones which may well be the same as those found at the base of the unconformable succession immediately south of Arenas de Cabrales. This tends to suggest overlap (onlap) in eastern direction. The sandstones are also thinning in this direction, and a coal seam is found in the Arenas region where a swamp facies may have been established for a certain length of time on the margin of the marine, transgressive basin. The eastward thickening of this coal seam and the presence of plant-bearing roof shales in the eastern part of the region provide a further indication of longer lasting non-marine conditions in the face of a gradually advancing marine transgression from the west.

2.—Dating of the coal seam at Arenas de Cabrales as Stephanian A or B indicates that the upper Cantabrian marine basin, as represented in the region of Inguanzo, did not reach into the area of Arenas which was incorporated into the basin at a later time. Although the flora recovered from the coal-measures at Arenas cannot be dated more accurately than Stephanian A or B, it should probably be regarded as Stephanian A in age, if a gradual onlap is envisaged. If future, more detailed palaeontological information should indicate a Stephanian B age, it would probably be necessary to assume an unconformable relationship between the sequence at Arenas de Cabrales and that near Inguanzo. There is not, at present, any evidence for such an interpretation.

3.—A gradual onlap in eastern direction is also indicated by the stratigraphic dating of deposits in the same succession at some 10 km west of Inguanzo, where lower Cantabrian strata have been recorded near the base of the unconformable succession (MARCOS 1967, 1968; WAGNER 1967).

4.—It is to be noted that the entire succession, recorded by MARCOS (*op. cit.*) and the present writers, reflects predominantly marine facies. This invites comparison with the predominantly marine strata of the *post*-Leonian succession of upper Westphalian D, Cantabrian and Stephanian A rocks in northern Palencia (WAGNER & VARKER 1971, WAGNER & WINKLER PRINS 1970). *Post*-Asturian Stephanian B rocks of continental facies are found to lie with a strongly angular unconformity on Stephanian A in NE Palencia (*op. cit.*). The *post*-Asturian deposits are generally of non-marine facies in NW Spain.

5.—The Cantabrian and Stephanian A (?) succession in the Gamonedo-Cabrales area of eastern Asturias differs from the contemporaneous succession in northern Palencia in several respects however. Firstly, there is a marked difference in thickness. Although there is no accurate account of the thickness in the Gamonedo-Cabrales area, it appears likely that the total succession is not in excess of 1,000 metres. In northern Palencia the contemporaneous succession may be over 5,000 metres thick. The facies are correspondingly different. There is a high proportion of fine-grained lutites and calcilutites in the Inguanzo, Arenas and Oceño sections, which is not present in Palencia where the rate of sedimentation was generally higher. It has been suggested by WAGNER *et al.* (1970, p. 484) that the sequence at Inguanzo was deposited on a foundered portion of the Cantabrian Block, and this may explain the marked difference with the succession in Palencia which is clearly basinal.

COMMENTS ON THE FOSSIL FLORA AT ARENAS DE CABRALES
(R. H. WAGNER)

Ninety identifiable plant impressions were collected from the exposures near the canal of Arenas de Cabrales, and some of these are illustrated on Pls 3-5 in order to provide a documentation.

Neuropteris ovata HOFFMANN is only represented by one specimen which shows the relatively broad pinnules and closely spaced nervules of the var. *grand'euryi* WAGNER. This variety has been reported as appearing for the first time in late Cantabrian strata. It is common throughout Stephanian A and B in Northwest Spain.

Alethopteris bohemica FRANKE (Pl. 5, fig. 3) is one of the two most common elements found in the locality at Arenas de Cabrales. It shows the characteristic, slightly pointed pinnules with a prominent midvein and closely spaced, fine lateral veins. This species occurs from basal Cantabrian to late Stephanian B, but is generally found in Stephanian A and B.

Callipteridium (Eucallipteridium) gigas (VON GUTBIER) WEISS (Pl. 3, fig. 1) is represented by several specimens which show the closely packed pinnules with a distinct midvein and closely spaced, not too oblique laterals. The specimen illustrated shows the intercalated pinnules on the rachis of the penultimate order. This species is found from Stephanian A into Autunian, and has been recorded once from Cantabrian strata in the Guardo-Cervera coalfield.

Callipteridium zeilleri WAGNER (Pl. 4, fig. 1) has more triangular pinnules with a wider venation. The specimen figured does not show such a wide venation as to allow a clear separation from the comparable *Callipteridium striatum* WAGNER which is characterized by more closely spaced veinlets. The transition from *C. zeilleri* (compare WAGNER 1965) started to take place in Stephanian A time (i. e. Stephanian A as characterized by the Carboneros and Calero Members of the Barruelo Formation in northern Palencia).

Dicksonites pluckeneti (VON SCHLOTHEIM) STERZEL is only represented by a poorly preserved fragment. This species occurs from middle Westphalian D to Autunian.

The specimen figured as *Sphenopteris* cf. *neuropteroides* BOULAY (Pl. 4, fig. 1) is not well enough preserved to be identified without reservation. The sturdy limb of the pinnules showing somewhat angular lobes compares favourably with the published figures of this species which ranges from Upper Westphalian to Stephanian B (compare ALVAREZ RAMIS 1966).

A terminal fragment of a pinna of *Pecopteris melendezi* WAGNER (Pl. 4, fig. 3) shows the fused terminal, slightly confluent pinnules, and strongly marked veins which characterize this species. Only one probable bifurcation has been observed among the simple veins in this specimen which does not possess the longer pinnules likely to show a higher incidence of forked veins. *Pecopteris melendezi* has been tentatively identified from Cantabrian strata in the Guardo-Cervera coalfield (Palencia), but is more generally found in Stephanian B strata.

Pecopteris unita BRONGNIART (Pl. 4, fig. 4) is represented by a fragment of a pinna showing contiguous pinnules with a sloping midvein and single, curved laterals. This species ranges throughout the Stephanian, and is first found in middle Westphalian D rocks.

Some fragments of *Pecopteris* showing pinnules of unequal length, which are closely adpressed, and which possess a very slightly decurrent midvein and simple laterals, are probably to be identified with *Pecopteris paleacea* ZEILLER (Pl. 5, figs. 1-2).

One of these specimens shows the possible presence of a gradually fused terminal, and the rachides preserved with these pinnae of the last order are sufficiently strong to agree with the species suggested. *Pecopteris paleacea* has mainly been recorded from Stephanian B-C, but also occurs in Stephanian A. It should be noted that the material is too fragmentary to be absolutely sure of the identification.

Another *Pecopteris* (Pl. 5, fig. 4) is of the general group of *P. lepidorachis-densifolia-candollei*, all characterised by parallel-sided pinnules with rounded apices and regularly once forking veinlets. An occasional second bifurcation of the lateral veins is observed in the specimen in hand, which cannot be identified specifically due to the absence of a preserved terminal.

Some additional fragments of *Pecopteris* (e. g. Pl. 4, fig. 2 -bottom part) are likewise unidentifiable specifically.

Sphenophyllum oblongifolium (GERMAR & KAULFUSS) UNGER is represented by well characterized verticils of biconvex leaves with elongate teeth on the distal border. This species first appears in upper Cantabrian times and persists throughout the Stephanian. It is one of the most common constituents of Stephanian floras.

Annularia sphenophylloides (ZENKER) VON GUTBIER is a common Upper Westphalian and Stephanian species, and so is *Annularia stellata* (VON SCHLOTHEIM) WOOD of which the fructification is recorded as *Calamostachys tuberculata* STERNBERG.

REFERENCES

ALVAREZ-RAMIS, C. (1966).—Primera aportación al estudio de los «Sphenopteris» del Carbonífero español. a) (Estefaniense: 1.ª parte). *Estudios Geol.*, XXI (1965), pp. 1-77, figs. 1-34, láms. I-LXIII.

COMTE, P. (1959).—Recherches sur les terrains anciens de la Cordillère Cantabrique. *Mem. Inst. Geol. Min. España*, LX, pp. 1-440, carte géol. et coupes.

DELÉPINE, G. (1943).—Les faunes marines du Carbonifère des Asturies (Espagne). *Mém. Acad. Sci. Inst. France*, 66, pp. 1-122, pls I-VI.

GINKEL, A. C. VAN (1965).—Carboniferous fusulinids from the Cantabrian Mountains. *Leidse Geol. Meded.*, 34, pp. 1-225, text-figs. 1-13, pls I-LIII, maps and sections.

HERNÁNDEZ-PACHECO, E. & F. (1935).—Observaciones respecto a la estratigrafía y tectónica de la cordillera cántabro-astúrica. Corte geológico a través del extremo oriente de Asturias. *Bol. R. Soc. Esp. Hist. Nat.*, XXXV, 9, pp. 487-497.

HERNÁNDEZ-PACHECO, E. & F. (1936).—Discusión acerca de la nota de los Sres Hernández Pacheco (E. & F.). Corte geológico del extremo oriente de Asturias. *Bol. R. Soc. Esp. Hist. Nat.*, XXXVI, pp. 58-59.

HERNÁNDEZ-SAMPELAYO, P. (1936).—Sobre las Cruzianas de las Sierras Planas (Asturias). *Bol. R. Soc. Esp. Hist. Nat.*, XXXVI, pp. 14-16, láms. 1-4.

JULIVERT, M. (1967).—La ventana tectónica del río Color y la prolongación septentrional del manto del Ponga. *Trabajos de Geología, Fac. Ci. Univ. Oviedo*, 1, pp. 1-26, figs 1-3, mapa geol.

LLOPIS LLADÓ, N. (1964).—Sur la paléotectonique des Asturies et ses rapports avec la moitié occidentale de la Péninsule Ibérique. *Bol. Inst. Est. Asturianos (Supl. Ci.)*, 10, pp. 1-52, figs. 1-14.

MARCOS, A. (1967).—Estudio geológico del reborde NW de los Picos de Europa (Región de Onís-Cabrales, Cordillera Cantábrica). *Trabajos de Geología, Fac. Ci. Univ. Oviedo*, 1, pp. 39-46, fig. 1, mapa geol.

MARCOS, A. (1968).—Sobre la existencia de niveles de tránsito entre el Westfaliense D y el Estefaniense A en el oriente de Asturias. *Acta Geol. Hispánica*, III, 1, pp. 15-18, figs. 1-2.

MARTÍNEZ-GARCÍA, E. (1971).—The age of the Caliza de Montaña in the eastern Cantabrian Mountains. *Trabajos de Geología, Fac. Ci. Univ. Oviedo*, 3, pp. 267-276, text-figs. 1-2.

PELLO, J. & PHILIPPOT, A. (1967).—Sur la présence du Llanvirn au Puerto Sueve (zone orientale des Asturies, NW de l'Espagne). *C. R. somm. Soc. géol. France*, 1967-4, p. 156, 1 fig.

SITTER, L. U. DE (1962).—The structure of the southern slope of the Cantabrian Mountains. Explanation of a geological map with sections (scale 1:100,000). *Leidse Geol. Meded., 26*, pp. 255-264, geol. map and sections.

WAGNER, R. H. (1965).—Stephanian B flora from the Ciñera-Matallana coalfield (León) and neighbouring outliers. III: Callipteridium and Alethopteris. *Notas y Comuns Inst. Geol Min. España*, 75, pp. 5-61, text-figs. 4-15, pls. 20-27.

WAGNER, R. H. (1967).—Apuntes sobre las floras de la zona Gamonedo-Cabrales, en la parte oriental de Asturias. *Trabajos de Geología, Fac. Ci. Univ. Oviedo*, 1, pp. 47-58, láms I-III.

WAGNER, R. H. (1969).—Proposal for the recognition of a new «Cantabrian» Stage at the base of the Stephanian Series. *C. R. 6e Congrès Carbonifère, Sheffield 1967*, I, pp. 139-150, fig. 1.

WAGNER, R. H., JONES, D. G., SPINNER, E. & WAGNER-GENTIS, C. H. T. (1970).—The upper Cantabrian rocks near Inguanzo, eastern Asturias, Spain. *In* «Colloque sur la stratigraphie du Carbonifère», *Congrès et Colloques Univ. Liège*, 55, pp. 465-486, text-figs. 1-2, pls. 30-33.

WAGNER, R. H. & VARKER, W. J. (1971).—The distribution and development of post-Leonian strata (upper Westphalian D, Cantabrian, Stephanian A) in northern Palencia, Spain. *Trabajos de Geología, Fac. Ci. Univ. Oviedo*, 4.

WAGNER, R. H. & WINKLER PRINS, C. F. (1970).—The stratigraphic succession, flora and fauna of Cantabrian and Stephanian A rocks at Barruelo (prov. Palencia), N. W. Spain. *In* «Colloque sur la stratigraphie du Carbonifère», *Congrès et Colloques Univ. Liège*, 55, pp. 487-551, text-figs 1-4, text-pls. I-III, pls. 34-38.

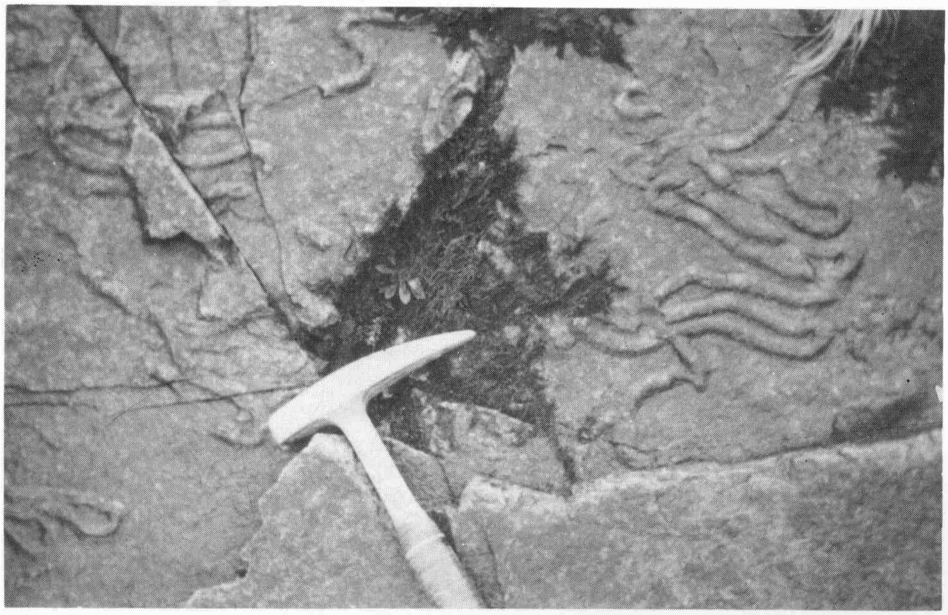


Fig. 1.—Tracks in sandstone in the upper part of the sequence at Arenas de Cabrales.

Fig. 2.—Photograph of the section near Oceño, looking eastwards at the thrust fault which forms the northern limit to the Stephanian beds (occurring in the area with grass slopes containing limestone bands).

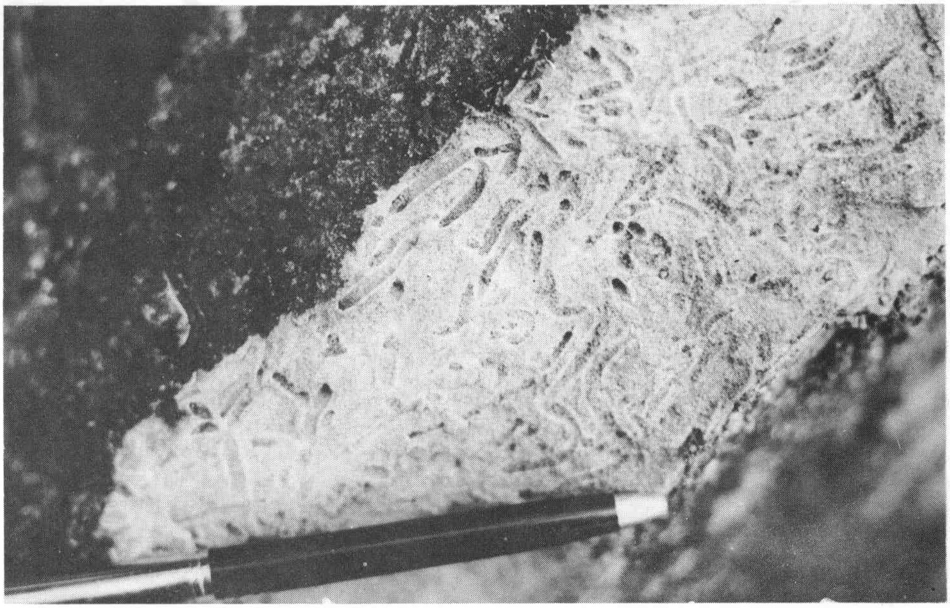


Fig. 1.— Burrows in the basal sandstones of the Stephanian sequence at Oceño.

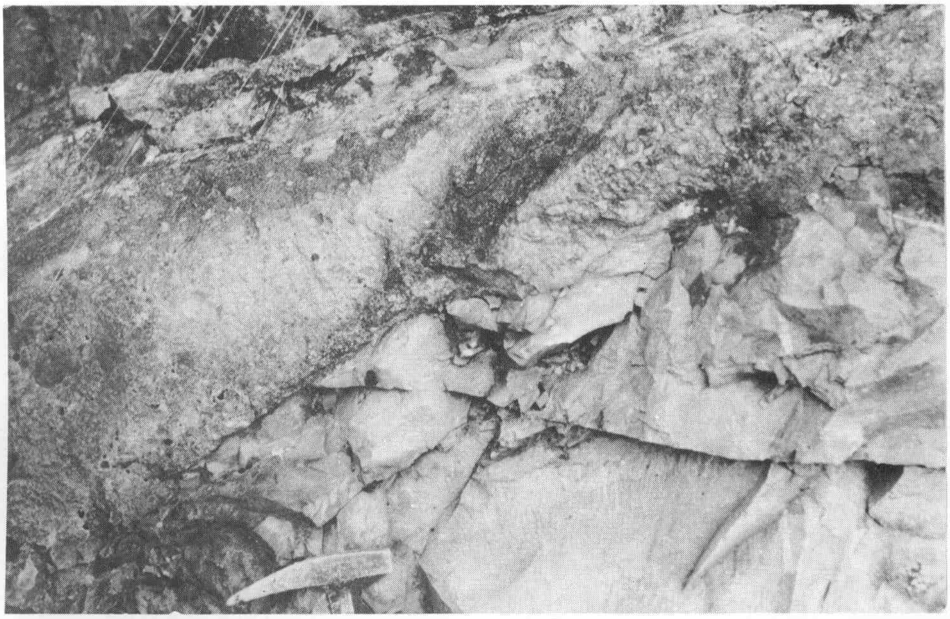


Fig. 2.—Channel fill of limestone conglomerate in the Stephanian of Oceño.

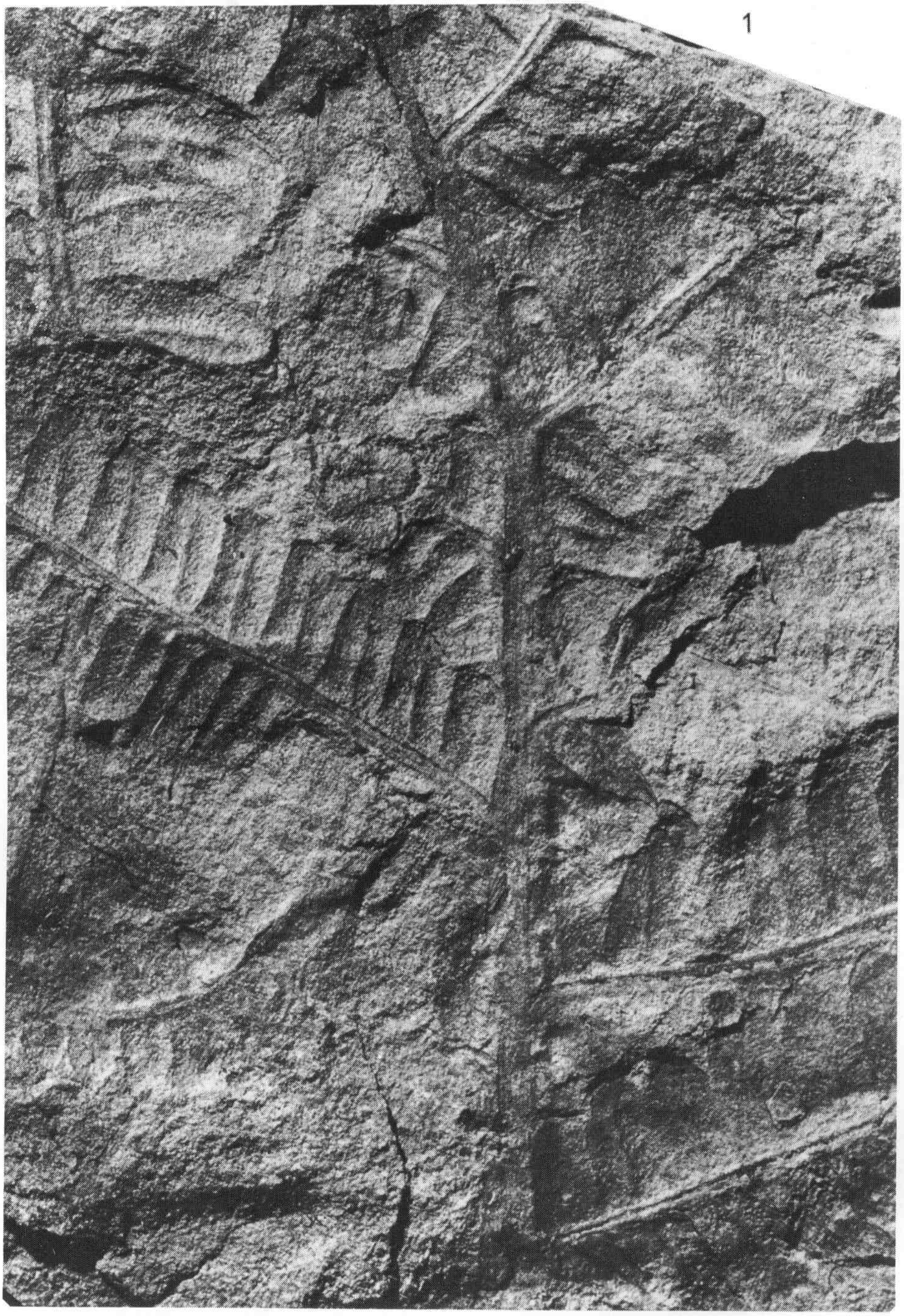


Fig. 1.—Callipteridium (Eucallipteridium) gigas (VON GUTBIER) WEISS, × 3., Loc. A 76. Arenas de Cabrales.

PLATE 4

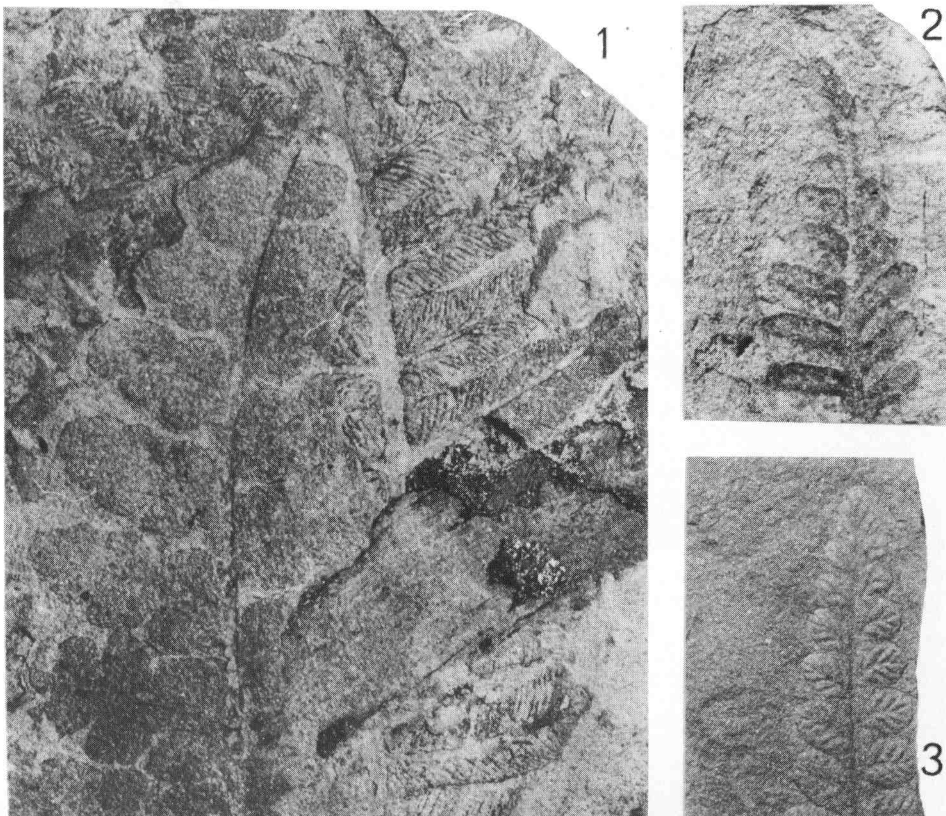
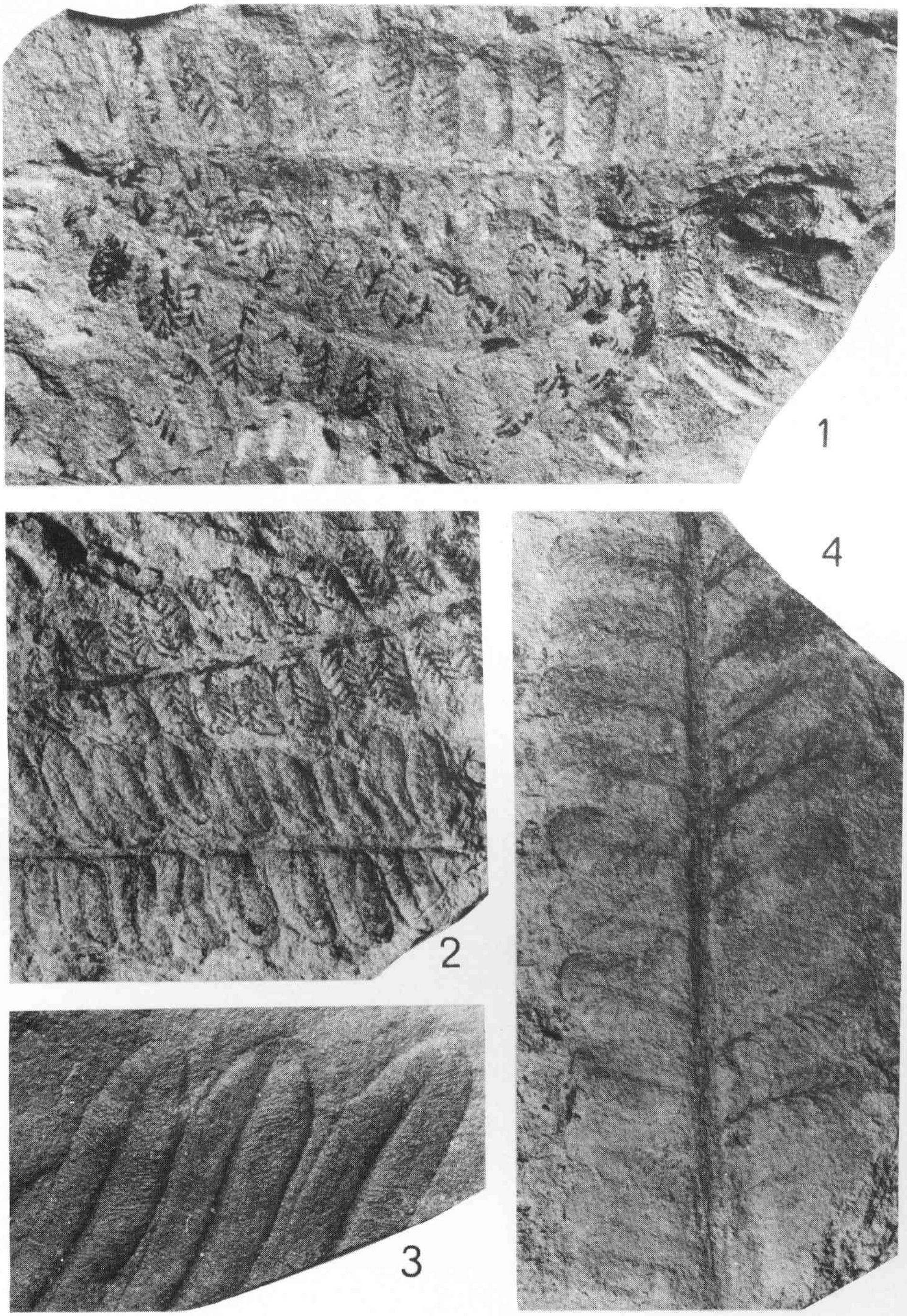


Fig. 1.—*Sphenopteris* cf. *neuropteroides* Boulay and *Callipteridium zeilleri* Wagner, × 3. Loc. A 76. Arenas de Cabrales.

Fig. 2.—*Pecopteris* sp., × 3. Loc. A 76.

Fig. 3.—*Pecopteris melendezi* Wagner, × 3. Loc. A 76.

Fig. 4.—*Pecopteris unita* Brongniart, × 3. Loc. A 76.



Figs. 1-2.— *Pecopteris paleacea* ZEILLER, × 3. Loc. A 76. Arenas de Cabrales.
Fig. 3.— *Alethopteris bohemica* FRANKE, × 3. Loc. A 76.
Fig. 4.— *Pecopteris* cf. *lepidorachis-candollei-densifolia* BRONGNIART-GOEPPERT, × 3. Loc. A 76.