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THE STRATIGRAPHY AND STRUCTURE OF THE CIÑERA-MATALLANA COALFIELD (PROV. LEON, N. W. SPAIN)

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ABSTRACT

An unconformable succession of up to 1,500 metres of strata in the Ciñera-Matallana coalfield can be divided into 7 formations (text-figs. 1-2). The San Francisco Formation contains valley fills and also gradually wedges westwards where a basin margin to the north-west can be demonstrated. The Pastora Formation contains a thick seam (up to 20 metres) which is worked in the western part of the coalfield and which probably represents sedimentation in swamps bordering a N.W.-S.E. oriented lake (text-fig. 11). The centre of the lake is marked by a shale lens. East-northeastwards the Pastora coal splits and thins in a mixed fluviatile and swamp facies area which is generally non-workable. The Cascajo Formation is a lacustrine unit with two *Leaia* bands at the base. These form reliable marker bands found everywhere in the Ciñera-Matallana coalfield as well as in several outliers beyond the coalfield. The Roguera Formation contains thin, generally non-workable coals, the facies being a mixed fluviatile, lacustrine and swamp facies. The San José Formation, with five numbered coals, has been extensively worked in the southern part of the coalfield, but is unproductive in the most northerly area. It contains several immature sandstones, fluviatile in origin. The top coal (San José 1) has a plant-bearing roof with characteristic flora (e. g. *Alethopteris leonensis)*, recognized practically all over the coalfield. The Bienvenidas Formation is more nondescript, with fluviatile sandstones prominently developed locally, and rather short lived intervals of swamp facies alternating with fluviatile and lacustrine deposits. The Matallana Formation is characterized by thick, fluviatile sandstones (often with large floated tree trunks) alternating with fluviatile and lacustrine deposits. The Matallana Formation is characterized by thick, fluviatile sandstones (often with large floated tree trunks) alternating with coal-measures and rather common lacustrine shales.

Lacustrine horizons with *Anthraconauta/Carbonita* bands are found throughout the succession in the Ciñera-Matallana coalfield, but are impersistent and of no use as marker bands, except for very local correlation. Floras collected throughout the totally non-marine succession have been dated as Stephanian B (Table I).

The general distribution of formations, the main coal seams and some of the more prominent sandstone bands in the Ciñera-Matallana coalfield are marked in text-fig. 2, which also shows the marker bands used as formational boundaries.

The unconformable Stephanian B rocks were folded into synclines and anticlines with accessory folds on the flanks of the major structures. The latter constitute a synclinorium in the central part of the coalfield (text-fig.20). Normal faults along the E-W trend of the major fold structures accompany earlier thrust faults associated with the folding, and small oblique faults cut the folds, thrusts and normal faults.

A basic intrusive rock forms dykes and sills which badly affect the Pastora coal east of the shale lens interpreted as the central part of the depositional lake. This shale lens probably acted as a barrier to the intrusion. The distribution of facies during the formation of the thick Pastora coal

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(text-figs. 10 and 11) controls the limits of the workable areas of this seam which accounts for practically all the coal produced nowadays in the Ciñera-Matallana region.

A general geological map to the 1 : 50,000 scale (text-fig. 1) summarizes the information obtained by mapping at the 1 : 5,000 and 1 : 10,000 scales. The 1 : 2,000 scale sections of individual formations (text-figs 4, 7, 13-16) reflect information obtained at the 1 : 100 scale, and the cross-sections of text-figs 20, 21, 22, 23 and 24 are the result of seam by seam correlation combined with mapping.

Two stratigraphic sections published at the 1 : 200 scale (text-figs 17 and 18) show the detailed succession of strata in the Pastora, Roguera and San José formations in certain parts of the coalfield.

RESUMEN

La cuenca minera Ciñera-Matallana contiene una secuencia de hasta 1.500 metros de estratos continentales, repartidos entre 7 formaciones (Figs. 1-2). La Formación San Francisco empieza con rellenos de valle (Fig. 3) y, además, se acuña paulatinamente hacia el Noroeste, donde se ha podido demostrar un borde de cuenca. La Formación Pastora contiene en su parte superior una capa ancha de carbón, de hasta 20 m espesor, que está en explotación en la parte occidental de la cuenca minera. Esta capa se formó en zonas pantanosas bordeando un lago de orientación NW - SE (Fig. 11), cuyo cauce recibió lodos que hoy día aparecen como un lentejón de lutitas lajadas. Hacia el ENE la Capa Pastora se divide en venas al mismo tiempo que disminuye su potencia de carbón y que aumentan los estériles, pasando la facies a un régimen más fluvial. La Formación Cascajo es de facies lacustre, iniciándose esta formación por un nivel de lutitas con abundantes valvas de *Leaia* que sirve de nivel guía sobre todo el área investigada. La Formación Roguera muestra una facies mixta, fluvial, lacustre y pantanosa, con algunos carbones delgados. La Formación San José tiene 5 capas delgadas de carbón explotado en la parte sur de la cuenca minera. Arman en estratos fluviales, lacustres y pantanosos con areniscas de poca madurez. El techo de la formación lo dá la Capa 1.ª de San José (ó Capa Estrecha de San José) con una flora asociada muy característica que se mantiene en la mayor parte de la cuenca minera. La Formación Bienvenidas muestra la presencia de algunas areniscas fuertes de facies fluvial que se acuñan rápidamente, y tiene características generalmente variables dentro de las facies fluvial, pantanosa y lacustre. El límite con la Formación Matallana es arbitrario y coincide con la Capa Alvaro que se muestra constante sobre el área investigada. La Formación Matallana está caracterizada por un desarrollo fuerte de areniscas fluviales, con troncos arrastrados, que alternan con facies pantanosas y lacustres en intervalos hulleros.

Niveles lacustres con *Anthraconauta* y *Carbonita* abundan en toda la cuenca, pero tienen poca continuidad lateral. Por otra parte, varios niveles lacustres con *Leaia baentschiana* Beyrich han podido ser utilizados como niveles guía. La flora fósil es abundante y variada (Cuadro I) y se data como Estefaniense B. Algunos niveles de flora se mantienen con una composición característica sobre gran parte de la cuenca y han podido ser utilizados como niveles guía.

La distribución general de las formaciones, las capas de carbón más importantes para la estratigrafía, y algunas de las areniscas principales figuran en la Fig. 2 que muestra igualmente los niveles guía usados como límites de formación.

La secuencia estefaniense B fue plegada en un sinclinorio (Fig. 20), cuyos elementos sinclinales y anticlinales se independizaron en la parte occidental de la cuenca minera (Figs. 21, 23). Los flancos de las estructuras mayores se arrugaron y fallaron posteriormente, originándose pequeñas escamizaciones sobre pliegues accesorios que tienen su importancia en las labores mineras (Fig. 22). Fallas directas acompañan a los pliegues y corresponden, muy probablemente, a una etapa de descompresión al final de la fase tectónica. Algunas fallas oblicuas, transcurrentes, de poca importancia, cortan a los pliegues, las pequeñas cobijaduras y a las fallas directas de rumbo E-W.

Una roca intrusiva básica (diabasa) se manifiesta como diques y un sill que afecta a la Capa Pastora al este del lentejón de lutita lajada que representa al cauce del lago de sedimentación. Es probable que este lentejón lutítico actuase como una barrera a la intrusión que raramente lo penetró. La distribución de facies durante la época de formación de la Capa Pastora (Fig. 11) influye directamente sobre los límites de explotabilidad de esta capa que da actualmente el 90 % de la producción hullera de toda la cuenca minera (Fig. 10).

Un mapa geológico a escala 1 : 50.000 (Fig. 1) recoge los resultados principales de una cartografía hecha a escala 1 : 5.000 y otra, más antigua, a escala 1 : 10.000. Los cortes estratigráficos a escala 1: 2.000 (Figs. 4, 7, 13-16) presentan una imagen simplificada de los mismos cortes medidos a escala 1: 100. Dos de aquéllos se han representado a escala 1: 200 (Figs. 17, 18) y sirven de ilustración al método empleado.

Los cortes geológicos de las Figs 20 a 24 representan la estructura geológica obtenida por la cartografía ayudada por una correlación fina de las capas de carbón por mediación de niveles guía.

INTRODUCTION

The Ciñera-Matallana coalfield in northern León is one of a series of sinclinoria and synclines in strongly unconformable post-Asturian strata which follow the arcuate strike of the Cantabric-Asturian tectogen of Late Palaeozoic age in the Cordillera Cantábrica. Its sequence of strata was deposited on steeply folded and thrust rocks of Cambrian to Namurian ages (see Map: text-fig. 1), which showed a mountainous relief at the time when the first unconformable strata were formed. These strata were dated entirely as Stephanian B in the Ciñera-Matallana coalfield (WAGNER 1962, 1963[a], 1966; WAGNER & ARTIEDA 1970), and sedimentation commenced probably a little later here than it did in the Sabero coalfield, some 25 km to the east, where the first post-Asturian deposits have been dated as late Stephanian A (KNIGHT 1971). Towards the NW the basal strata of the post-Asturian succession were formed in progressively later times, and those of Cangas del Narcea and Tineo (western Asturias) date as early Stephanian C.

The stratigraphy and structure of the Ciñera-Matallana coalfield have been described recently by the present writer *in* WAGNER & ARTIEDA (1970), as the result of investigations carried out on behalf of the mining company S. A. Hullera Vasco-Leonesa at Santa Lucía de Gordón (León). Only a general summary is presented here, together with a few additions and corrections, and a more detailed description is provided of two stratigraphic sections which were visited on 23rd September 1970 by participants in the field meeting organized by the I.U.G.S. Subcommission on Carboniferous Stratigraphy and the Comisión Nacional de Geología.

Previous work has been commented on in WAGNER & ARTIEDA (1970). Prior to the publication of the geological map in the cited paper (and which is reproduced here as text-fig.1), more general maps were published by ALMELA (1949), WAGNER (1963[a]), and EVERS (1967). None of those represented more than a general outline of the coalfield and an impression of its general structure which was accompanied, in the case of EVERS' map, by some isolated data on the outcrop of otherwise unidentified coal seams.

In the present paper, a brief description is provided of the most salient characteristics of the seven formations recognized in the Ciñera-Matallana coalfield. The distribution of coal seams and other beds of stratigraphic importance has been indicated in the diagrammatic columns of text-fig. 2. The detail of the stratigraphic succession has been established after a programme of surface trenching, and supplementary information was obtained from cross-cuts in coal mines. A substantial part of this information is due to the efforts of Mr. F. J. VILLEGAS, whose collaboration is acknowledged with pleasure. It should also be noted that this investigation could not have been undertaken without the active support of the S. A. Hullera Vasco-Leonesa. The assistance of the Surveyor's Department of this company has been particularly helpful. The many discussions with mining engineers and deputy engineers of the S. A. Hullera Vasco-Leonesa have not only provided information but, above all, the necessary incentive for trying to solve the many problems that a tectonically disturbed coalfield poses to the geologist as well as to the mining engineer in charge of working rather heavily folded and faulted seams which are also subject to changes in the sedimentary facies. This aspect of a direct and often immediate application of geological information to the working of a coalfield has been particularly interesting and stimulating.

The Ciñera-Matallana coalfield originally produced from a large number of seams distributed throughout the succession of up to 1,500 metres thickness. However, a gradual concentration of the workings has taken place at the same time as the general output of the coalfield increased. Nowadays, the working of thin seams has virtually ceased, and the production of coal is obtained almost entirely from a single seam, up to 20 m thick (though more usually reaching a thickness of 5 to 12 metres), which occurs in the western part of the coalfield. This seam splits into a number of generally non-workable coals in the eastern part of the coalfield where only a few small mines exist in thin seams of various stratigraphic positions (and belonging to different formations). The Ciñera-Matallana coalfield produced 666,092 metric tonnes of semi-bituminous coal in 1969, and this constituted 34.41 % of the non-anthracitic coal produced by the province of León. Planning for the nineteen seventies is geared to an eventual production of 1,400,000 tonnes (ARTIEDA *in* WAGNER & ARTIEDA 1970).

It will be clear from the foregoing that the geological investigation of the Ciñera-Matallana coalfield, after establishing the total stratigraphic succession and the general tectonic structure of the area, has tended to delimit the useful occurrence of the one major coal seam mentioned above (i.e. the Pastora Seam). However, the thin seams worked in different parts of the coalfield had to be examined in their stratigraphic

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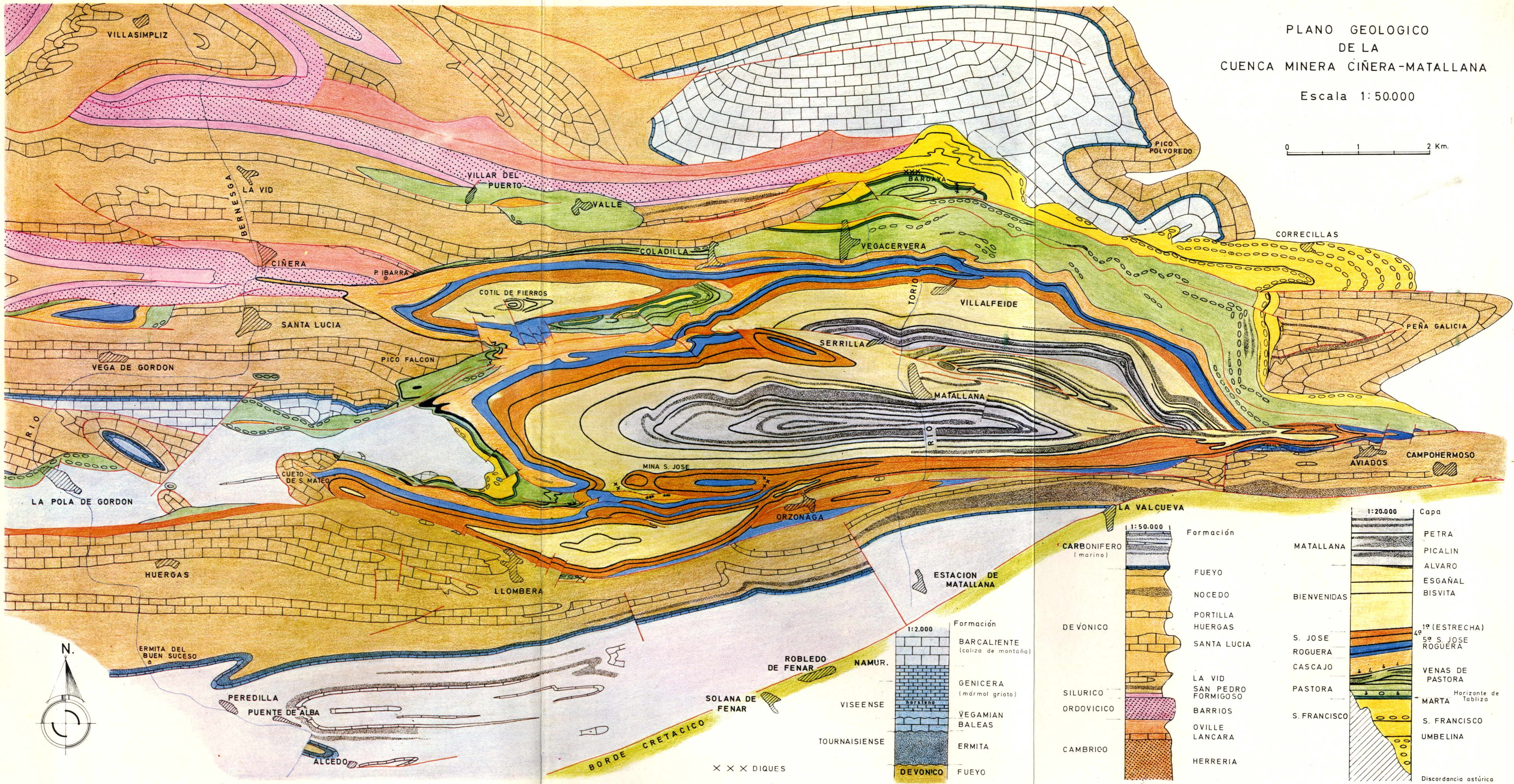
Text-fig.1.—Geological Map of the Ciñera-Matallana coalfield (Scale 1 : 50,000). This map, originally published in WAGNER & ARTIEDA 1970, shows the structure of the coalfield in more detail than that of the surrounding, mainly pre-Stephanian B strata. The information on the coalfield and its outliers is based on an unpublished 1 : 5,000 map which is generally more accurate for the western and central parts of the coalfield than it is for the south-eastern part, particularly, where some of the interpretation still needs to be checked. The stratigraphic column on the right represents the formations recognized in the unconformable Stephanian B succession (formational names on the left side of the column) and of the most important coal seams (names on the right). The central column gives a generalized succession of Cambrian to Namurian strata, with formational names and general lithology after COMTE 1959. The marine Carboniferous succession depicted in the central column is based on the mainly terrigenous succession of Namurian rocks present in the area near Pola de Gordón and extending eastwards, and in the more southerly exposures from Peredilla to Estación de Matallana (compare WAGNER & FERNÁNDEZ-GARCÍA 1971, and WAGNER, WINKLER PRINS & RIDING 1971). The column on the left provides the more detailed succession of formations of Tournaisian, Viséan and Namurian ages, as described by WAGNER, WINKLER PRINS & RIDING 1971, and depicts the carbonate development of Namurian rocks («caliza de montaña») occurring in the northern part of the area. The reverse fault separating the Palaeozoic from basically unconformable Cretaceous strata is after EVERS 1967.

The lithological symbols used are: block symbol for limestones, dots for sandstones, ovals for conglomerates, heavy black lines for coal seams, and red lines for faults. *Errata:* The Ordovician Barrios Formation E. of Villasimpliz is limited by a thrust fault from the independent structures further east. The thin limestone forming an anticline east of Alcedo should have the greenish blue colour corresponding to the Genicera Formation, which is mainly of Viséan age.

Apologies are extended for the imperfect rendering of some colours which have been inadequately reproduced by the printing process.


PLANO GEOLOGICO
DE LA
CUENCA MINERA CIÑERA-MATALLANA
Escala 1: 50.000
0
1
2 Km.
VILLASIMPLIZ
PICO POLVOREDO
VILLAR DEL PUERTO
VALLE
BARDAYA
LA VID
BERNESGA
CORRECILLAS
VEGACERVERA
COLADILLA
CIÑERA
P. IBARRA
COTIL DE FIERROS
TORIO
VILLALFEIDE
SANTA LUCIA
SERRILLA
PEÑA GALICIA
VEGA DE GORDON
PICO FALCON
MATALLANA
RIO
RIO
CAMPOHERMOSO
AVIADOS
MINA S. JOSE
CUETO DE S. MATEO
LA POLA DE GORDON
LA VALCUEVA
ORZONAGA
HUERGAS
LLOMBERA
ESTACION DE MATALLANA
N.
ERMITA DEL BUEN SUCESO
ROBLEDO DE FENAR
NAMUR.
PEREDILLA
PUENTE DE ALBA
SOLANA DE FENAR
BORDE CRETACICO
ALCEDO
× × × DIQUES
1:2.000
Formación
BARCALIENTE (caliza de montaña)
GENICERA (mármol griota)
VEGAMIAN
BALEAS
ERMITA
FUEYO
VISEENSE
TOURNAISIENSE
DEVONICO
1:50.000
Formación
CARBONIFERO (marino)
FUEYO
NOCEDO
PORTILLA
HUERGAS
SANTA LUCIA
LA VID
SAN PEDRO FORMIGOSO
BARRIOS
OVILLE
LANCARA
HERRERIA
DEVONICO
SILURICO
ORDOVICICO
CAMBRICO
1:20.000
Capa
MATALLANA
BIENVENIDAS
S. JOSE
ROGUERA
CASCAJO
PASTORA
S. FRANCISCO
PETRA
PICALIN
ALVARO
ESGAÑAL
BISVITA
1ª (ESTRECHA)
5ª S. JOSE
ROGUERA
VENAS DE PASTORA
Horizonte de Tabliza
MARTA
S. FRANCISCO
UMBELINA
Discordancia astúrica

context, prior to their abandonment, and coverage has therefore been fairly even. Nevertheless, certain parts of the coalfield have been investigated in more detail than others, particularly where a programme of trenching and drilling was executed.

Illustrations to the present paper were mainly published also in WAGNER & ARTIEDA 1970.

STRATIGRAPHY OF THE COALFIELD

The stratigraphic succession of the Ciñera-Matallana coalfield can be studied at outcrop, and since the structure consists of rather steeply dipping synclines and anticlines, it is possible to obtain sections of considerable stratigraphic thickness by trenching. Since 1962 various sections were measured and drawn to the scale of 1 : 100. The presence of certain marker bands could be established, and a general impression was obtained of the stratigraphic development of the 1,500 metres of strata studied. The succession is entirely non-marine and marker bands vary from lacustrine shales with a specialised fauna to certain persistent coal seams with characteristic floral assemblages in roof shales. The most useful marker bands were two relatively thin horizons (10 to 20 cm thick) of dark grey shales with abundant *Leaia baentschiana* BEYRICH, which occur throughout the coalfield at the base of a larger development of lacustrine deposits, up to 90-100 m thick (Cascajo Formation). The latter form a prominent, usually well exposed formation of thinly bedded, somewhat silty shales with siltstone partings and sandstones in the upper part. This formation is a good mappable unit, the identification of which is assured by finding the associated *Leaia* bands. Another *Leaia* band, this time with common *Leaia* and *Carbonita*, is found at the base of a much thinner lacustrine horizon lower down in the succession. This is the Tabliza Horizon, which can be confused with the Cascajo Formation, of similar facies, in tectonically disturbed sections. The Tabliza Horizon was deposited at a time when the basin margin was situated within the area of the Ciñera-Matallana coalfield. It is therefore not found in the north-western and westernmost parts of the coalfield. Two further *Leaia* bands, showing *Leaia* in association with *Anthraconauta* and *Carbonita*, occur in the roof shales of coal smuts developed in the interval between seams 5 and 4 of the San José Formation (see text-fig.14). These two bands are only developed in the southern part of the coalfield.

A large number of *Anthraconauta*/*Carbonita* bands are found throughout the succession in different parts of the coalfield. Most of these show very limited lateral continuity, sometimes no farther than a few hundred metres, and have proved generally unreliable as marker bands. An exception is made for the lacustrine roof shales of the Picalín coal seam in the Matallana Formation, which are locally persistent in the central part of the coalfield.

Certain coals could be traced extensively throughout the coalfield and proved useful as formational boundaries. One of these persistent coal beds, viz. seam 5 of the San José Formation, is usually accompanied by a thin (1-5 cm) band of dark lacustrine shale showing comminuted plant debris associated with rare *Leaia*, «*Estheria*», and somewhat more common *Anthraconauta*. Another persistent coal, seam 1 (Estrecha) of the San José Formation, has a well preserved and characteristic fossil flora in its roof shales. The most common among the characteristic plants in this assemblage is *Alethopteris leonensis* WAGNER which occurs next to *Callipteridium zeilleri* WAGNER, *Mixoneura matallanae* WAGNER, *Neuropteris* cf. *praedentata* GOTHAN, *Sphenopteris rossica* ZALESSKY, etc. It should be noted that there is no single floral element which can be regarded as restricted to any particular bed or formation in the Ciñera-Matallana coalfield, and it is the assemblage which characterizes the flora of the roof shales of seam 1 of the San José Formation. The third coal used as a formational boundary is the Alvaro Seam which has been traced by workings in the central part of the coalfield. It shows no outstanding characteristic apart from a commonly developed mudstone parting dividing this seam into two veins.

In one case a marked change in facies has been used to delimit formations. The Cascajo Formation of lacustrine facies is succeeded by the Roguera Formation of swamp, fluviatile and limited lacustrine facies. The formational boundary is placed at the first seat-earth occurring above the lacustrine formation.

In the Ciñera-Matallana coalfield the stratigraphic evolution of the succession has therefore been used in combination with certain marker bands for a subdivision into formations. These formations are as follows, from top to bottom (text-fig. 2):

7) Matallana Formation (up to 275 m thick, eroded at the top): an extensively worked succession of thin seams (Alvaro, Picalín, Petra) in coal-measure intervals between thick fluviatile sandstones.

6) Bienvenidas Formation (350-380 m thick): a variable coal-measure sequence with some locally developed thick fluviatile sandstones and rarely workable coal seams with the exception of the Bienvenidas seams at Cotil de Fierros and the Esgañal and Bisvita seams.

5) San José Formation (75-90 m thick): a regular sequence of thin seams (San José 5, 4, 3, 2 and 1 in ascending order) in a usually rather sandy succession; these coals wedge and disappear northwards.

4) Roguera Formation (60-70 m thick): swamp, fluviatile and lacustrine deposits of variable characteristics and containing one coal seam (Roguera or Nieves seam) which has been worked at intervals.

3) Cascajo Formation (90-105 m thickness generally, and wedging eastwards): mainly lacustrine shales with more important sandstone intervals in the top part.

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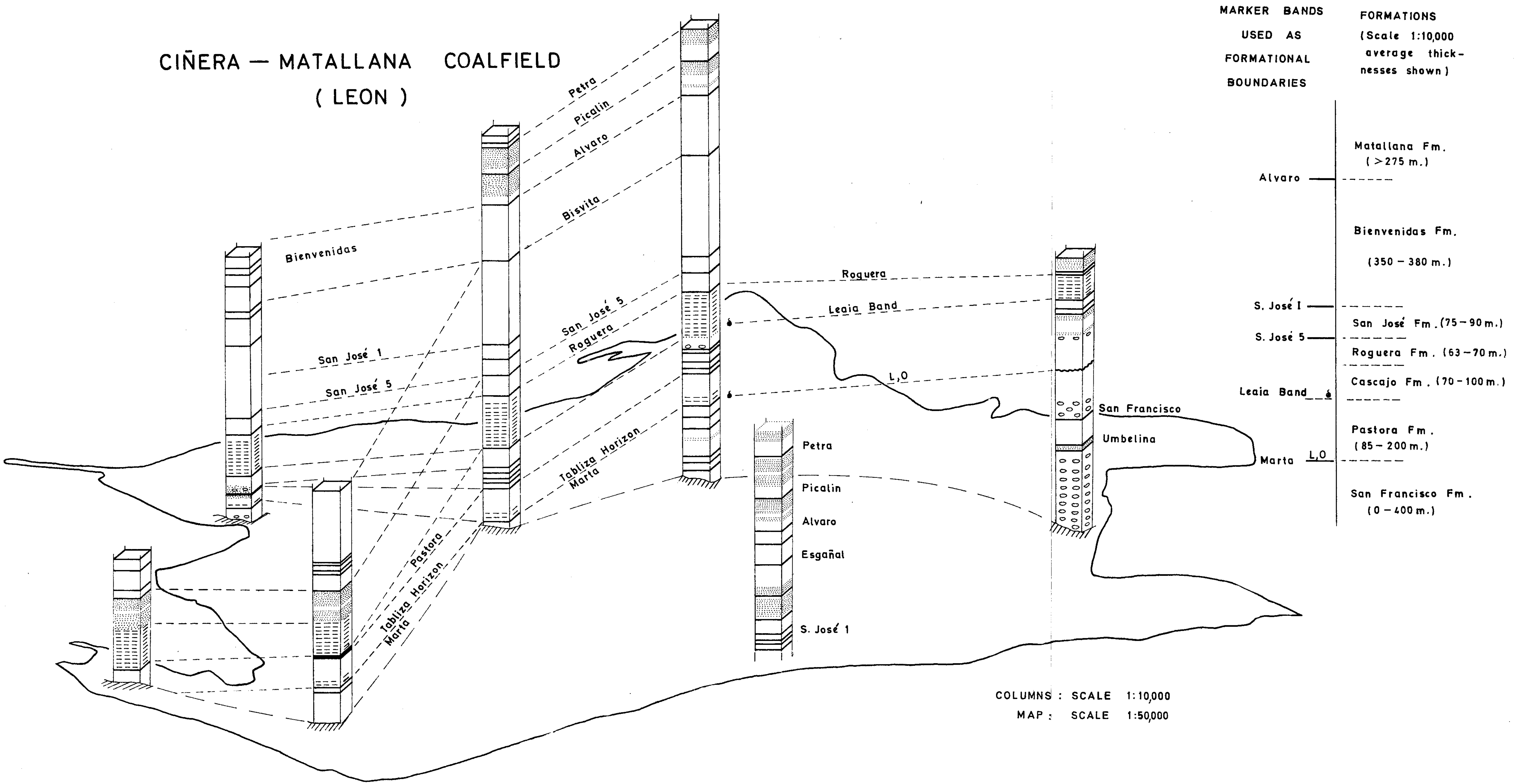
Text-fig. 2.—Local correlation diagram with generalized stratigraphic columns, at scale 1 : 10,000, of the succession in the Ciñera-Matallana coalfield. The outline of the coalfield, drawn at scale 1 : 50,000, gives the position of the sections represented. Correlation lines link marker horizons and certain coal seams which are persistent throughout a large part of the coalfield. Note the decreasing thickness of the San Francisco Formation (below Tabliza Horizon) in a western and north-western direction, where a basin margin has been demonstrated. Note also the different development of the Pastora coal in the various sections in the western part of the coalfield. Symbols used are: heavy black lines for coal seams, ovals for conglomerates, dots for sandstones, and dashes for the predominantly shaley lacustrine deposits of the Tabliza Horizon and the Cascajo Formation. L stands for *Leaia*, and O for ostracodes *(Carbonita)*.


CIÑERA — MATALLANA COALFIELD
(LEON)
Petra
Picalin
Alvaro
Bisvita
Bienvenidas
San José 5
Roguera
San José 1
San José 5
Tabliza Horizon
Marta
Pastora
Tabliza Horizon
Marta
Roguera
Leaia Band
L,O
San Francisco
Umbelina
Petra
Picalin
Alvaro
Esgañal
S. José 1
MARKER BANDS USED AS FORMATIONAL BOUNDARIES
FORMATIONS (Scale 1:10,000 average thicknesses shown)
Matallana Fm. (>275 m.)
Alvaro
Bienvenidas Fm. (350 – 380 m.)
S. José I
San José Fm. (75 – 90 m.)
S. José 5
Roguera Fm. (63 – 70 m.)
Cascajo Fm. (70 – 100 m.)
Leaia Band
Pastora Fm. (85 – 200 m.)
Marta
L,O
San Francisco Fm. (0 – 400 m.)
COLUMNS : SCALE 1:10,000
MAP : SCALE 1:50,000

2) Pastora Formation (85-200 m): a coal-measure sequence following upon lacustrine shales; coal-measures consisting mainly of one thick coal (Pastora seam) in the western part of the coalfield, whereas thin, generally non-workable coals characterize the eastern part.

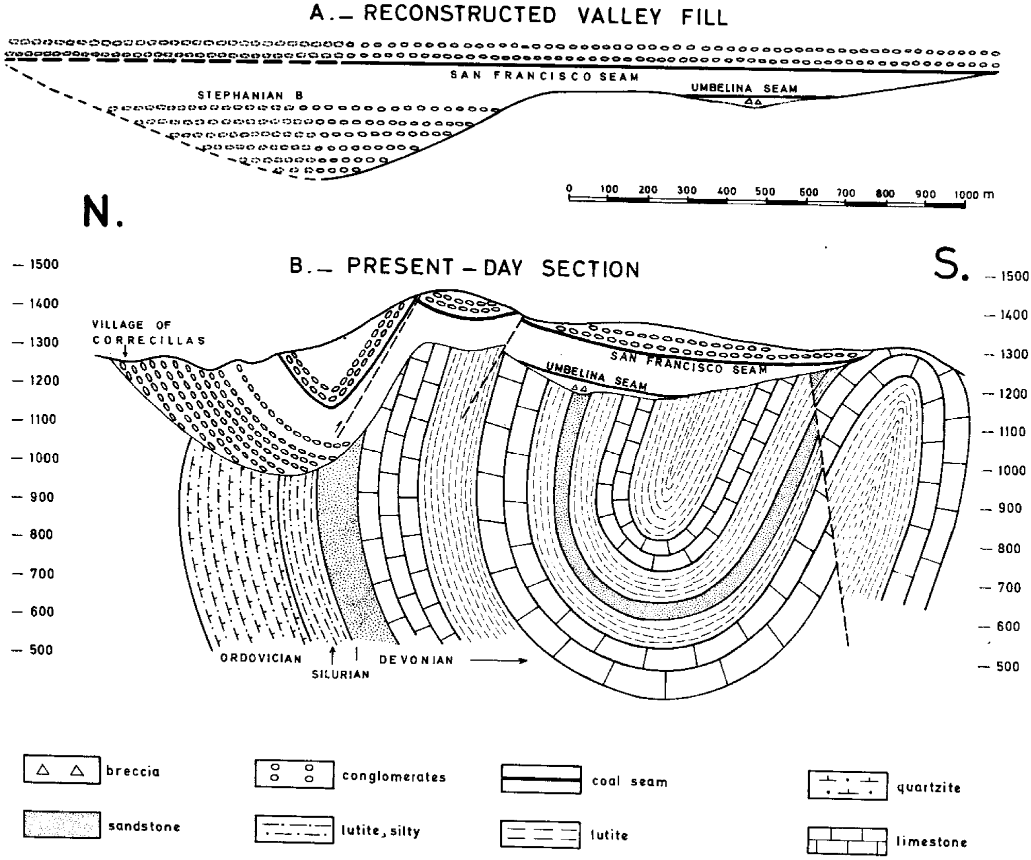
1) San Francisco Formation (0-400 m thick): mainly valley fill deposits with locally workable coals; formation expanding eastwards and wedging north-westwards against the basin margin.

These formations were introduced and described briefly in WAGNER 1963b, with the exception of the San Francisco and Pastora formations which were recorded as the Lower Coal-Bearing Formation, and the Cascajo Formation which was referred to informally as «Hard Beds». A full description with type sections was given in WAGNER & ARTIEDA 1970.

San Francisco Formation

The type section of this formation is situated south of Correcillas where its maximum development is recorded in a valley fill (text-fig.3) showing the presence of *ca.* 200 metres of torrential conglomerates with limestone and quartzite boulders. The San Francisco Seam in the upper part of this valley fill has been traced southwards into the Valley of San Pedro where the slightly older Umbelina Seam was worked. In the area of the Umbelina workings, immediately west of the Peña Galicia Syncline in Devonian limestones (see Map: text-fig.1), the torrential conglomerates at the base of the valley fill are not developed (compare text-fig. 4, right hand column) and it seems likely that this seam was formed on a shelving margin of the ancient valley. The Umbelina Seam does, in fact, only occur locally. A reconstruction of the main valley indicates that it was probably oriented in an E-W direction, with a general slope eastwards.

Another valley fill with an important development of strata of the San Francisco Formation occurs on the northern edge of the coalfield, in the mining group of Bardaya (see Map: text-fig. 1) where coal from this formation was worked until recently. The thickness of rocks representing this formation at Bardaya is a good deal less than that recorded in the valley fill at Correcillas (text-fig.3), and it may be that a gradual elevation of the basin margin westwards plays a rôle here. Only 3 km south-southwestwards, at Coladilla, the San Francisco Formation is seen to wedge entirely, due to a progressive onlap which can be shown to have been directed to the NW. At Bardaya the top of the San Francisco Formation is clearly delimited by a few thin coals with a lacustrine shale forming the roof of the highest seam. It contains fairly common *Leaia* in association with *Carbonita* and *Anthraconauta*. This band occurs at the base of some 15 to 25 metres of silty and very silty shales which are micaceous and which contain comminuted plant fragments. They represent an apparently lacustrine horizon which, in combination with the *Leaia/Carbonita/Anthraconauta* Band above the coal, forms a marker throughout that part of the coalfield where the San Francisco Formation is developed; i.e. everywhere except for the extreme north-western part where a rising basin margin prevented this formation from being deposited. This horizon is well



Text-fig. 3.—Geological section of the area south of Correcillas which shows a valley fill at the base of the San Francisco Formation. A reconstruction of the valley fill is provided by straightening out the folded San Francisco Seam and by projecting the northern flank of the ancient valley, as mapped in the area west of Correcillas. The scale of the section and that of the reconstructed valley is 1 : 20,000 (vertical=horizontal scale).

exposed near the col known as Alto de Tabliza, *ca.* 4 km SE of Santa Lucía and due north of Llombera (see Map: text-fig.1). It has been named the Tabliza Horizon. The thin coal(s) below the lacustrine horizon can also be traced extensively and serves as a marker band. It has been named the Marta Seam, even though it is not workable. In the easternmost section of the Ciñera-Matallana coalfield, south of Correcillas, in the San Pedro Valley (text-fig.4), the horizon of the Marta Seam is probably represented by a complex of seat-earths with a carbonaceous shale. The latter is overlain by a thin

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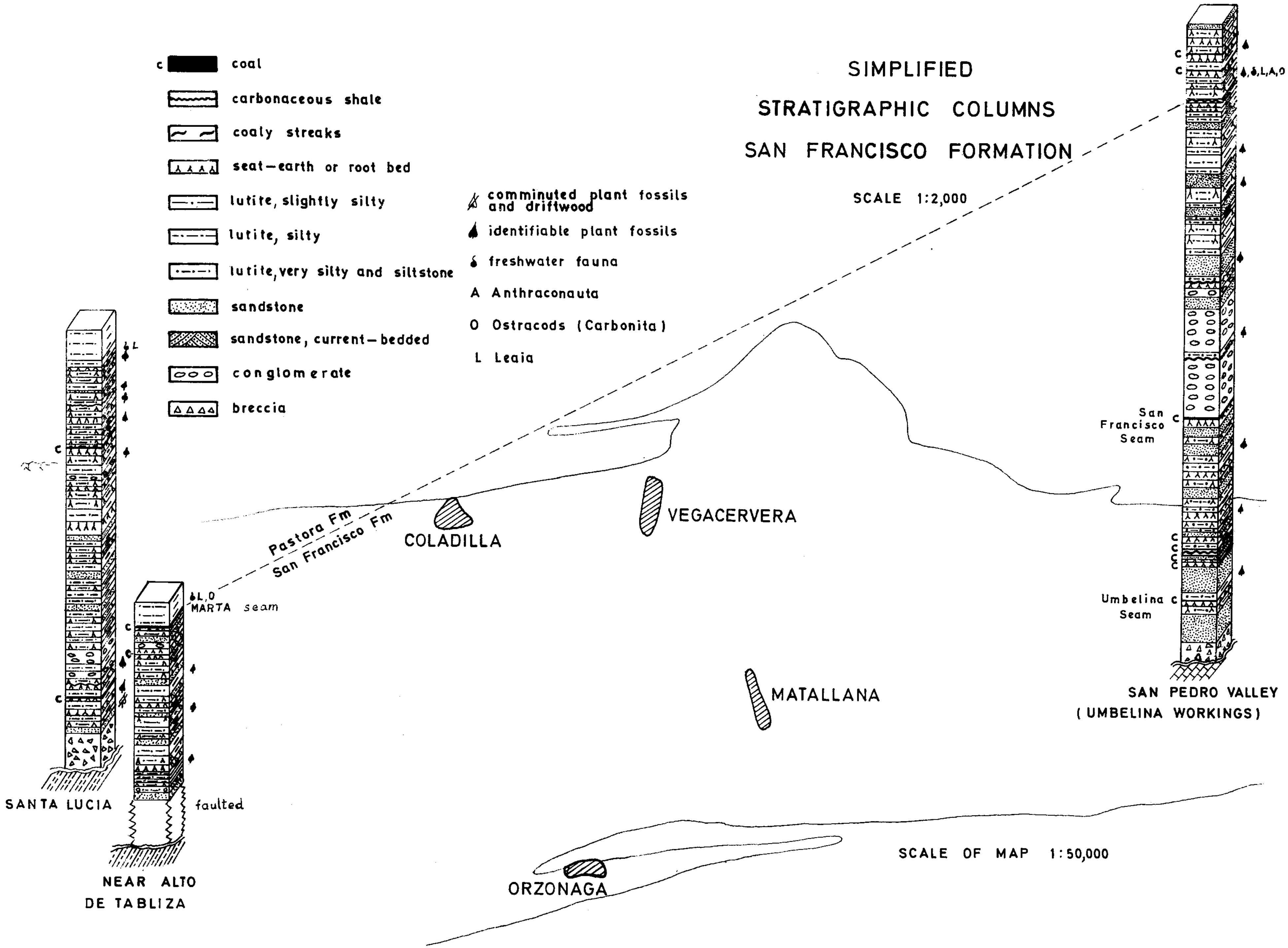
Text-fig. 4.—Simplified stratigraphic columns at scale 1 : 2,000 for the San Francisco Formation in different parts of the coalfield. The San Francisco stratotype is in the area south of Correcillas, which is represented (incompletely — see text-fig. 3) by the stratigraphic section measured in the San Pedro Valley (containing the Umbelina Seam) at 1 km south of Correcillas.


SIMPLIFIED
STRATIGRAPHIC COLUMNS
SAN FRANCISCO FORMATION
SCALE 1:2,000
c coal
carbonaceous shale
coaly streaks
seat-earth or root bed
lutite, slightly silty
lutite, silty
lutite, very silty and siltstone
sandstone
sandstone, current-bedded
conglomerate
breccia
comminuted plant fossils and driftwood
identifiable plant fossils
freshwater fauna
A Anthraconauta
O Ostracods (Carbonita)
L Leaia
SANTA LUCIA
NEAR ALTO DE TABLIZA
faulted
L,O MARTA seam
Pastora Fm
San Francisco Fm
COLADILLA
VEGACERVERA
MATALLANA
ORZONAGA
SCALE OF MAP 1:50,000
San Francisco Seam
Umbelina Seam
L,A,O
SAN PEDRO VALLEY
(UMBELINA WORKINGS)

shale band with *Leaia, Carbonita* and *Anthraconauta.* The Tabliza Horizon is uncharacteristic in this section and consists here of thinly bedded shales with drifted comminuted plants and occasional rootlets.

Pastora Formation

This formation, which has its stratotype at *ca.* 600 m E of the mine shaft, Pozo Balanza, of the Santa Lucía mining group, is characteristically developed in the western part of the Ciñera-Matallana coalfield. Its lower limit lies at the *Leaia/Carbonita/Anthraconauta* Band overlying the Marta coal seam, and the lacustrine interval represented by this band and the subsequent Tabliza Horizon forms the lower part of the Pastora Formation. This interval is not developed everywhere in the western part of the coalfield, for the San Francisco Formation and the lower part of the Pastora Formation are progressively eliminated by onlap in a north-western direction. The onlap is clearly demonstrated by exposures on the northern edge of the main coalfield (i.e. excluding the outlier at Valle and Villar — see Map). In the village of Coladilla the Tabliza Horizon is found in conjunction with a thin wedge of strata belonging to the highest part of the San Francisco Formation.* At *ca.* 80 metres west of the village the Tabliza Horizon lies immediately on top of a Devonian limestone (Santa Lucía Formation) which forms part of the substrate of the unconformable Stephanian B deposits, and 2.5 to 3 km further westwards a succession of coals in the upper part of the Pastora Formation are in contact with the Devonian. This contact is tectonically undisturbed. The recorded onlap is also clearly apparent in the reconstructed sections of text-fig.5, which are based on stratigraphic sections measured in different parts of the western end of the coalfield (compare text-fig.6). They show a basin slope of *ca.* 5°, a figure which probably represents the cumulative effect of differential subsidence at the basin margin rather than the actual slope at any particular time during sedimentation. Superimposed on the basin slope in text-fig. 5 (top), a valley fill occurs as a local interruption in the gradually sloping basin margin. This valley does not appear to have followed an E-W direction like the large valley filled in with conglomerates of the San Francisco Formation in the vicinity of Correcillas (compare text-fig. 3).

Above the very silty, micaceous shales in the top part of the Tabliza Horizon a widespread development of less silty shales with frequent ostracodes *(Carbonita)* and less common phyllopods *(Leaia baentschiana* BEYRICH and *«Estheria» tenella* GOLDENBERG) is found. These lacustrine rocks also contain occasional thin bands of limestone (text-fig. 6). They pass upwards into gradually more sandy deposits with comminuted plant debris, and a well developed sandstone horizon is usually encountered before a facies of seat-earths and coals is reached in the upper part of the Pastora Formation.

The development of coals in the upper part of the Pastora Formation is quite variable in different parts of the Ciñera-Matallana coalfield (text-fig.2). In the eastern

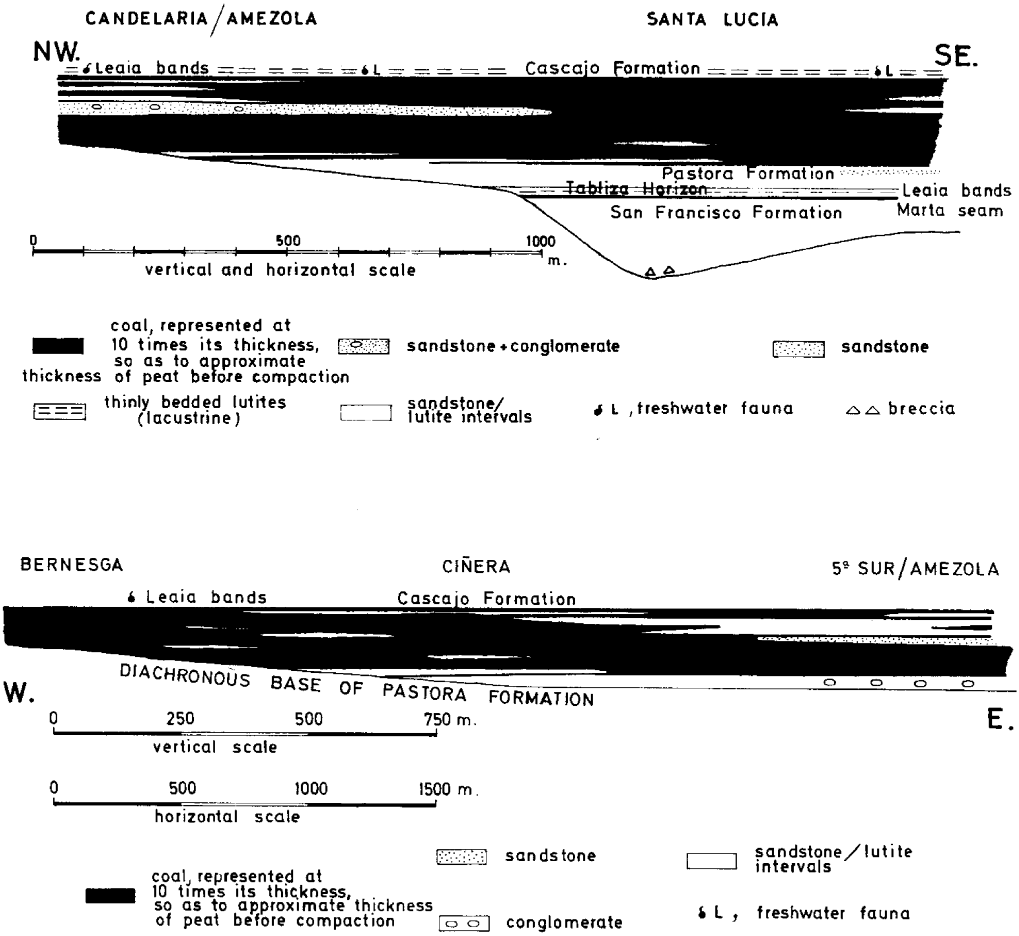
* Information obtained after the map of text-fig. 1 had been printed.

part of the coalfield only a minimal development of thin, non-workable coals occurs in the top part of the formation. The number of coal smuts increases in the central part of the coalfield, and westwards these coals increase in thickness until, south-west of Coladilla, the first workable seams are found. Northwards, in the Bardaya area, there is also one workable seam (i.e. seam 5) in the Pastora Formation (text-fig.7). In the Coladilla area (text-figs 7, 8 and 17) the main concentration of seams occurs in the lower half of the upper part of the Pastora Formation, and it is this complex of coals which fuses into a major seam called the «Anchà de Pastora» (= thick seam of Pastora) in the mining areas of Amézola and Candelaria (text-figs 6, 9). This seam can be up to 7 metres thick. It is succeeded in these mining areas by a coarse quartz sandstone which often contains large limestone pebbles, forming a limestone conglomerate. This sandy interval is massive to massively bedded and is irregular in thickness. Its lithological characteristics and its limited distribution make a fluvial origin (channel fill) most likely. Where this sandstone/conglomerate does not occur, viz. in the mining areas of Santa Lucía, Competidora and Ciñera (Pozo Ibarra) (see text-fig.9), a coal facies occurs throughout the upper part of the Pastora Formation, and a very thick coal seam may be developed with only a few partings of an irregular nature. This is the Pastora Seam (also called Competidora, Emilia, Bernesga, Tabliza, Cuarta Sur, Cuarta Norte, Quinta, etc. in the various mining areas of the western part of the coalfield), which may be up to 20 metres thick. The local nomenclature of the thick coal in the upper part of the Pastora Formation is complicated further by the successive numbering of the same seam (i.e. the «Ancha de Pastora») in a number of small thrust slices which produce repetitions in cross-cuts driven through these structures in the area of Amézola. A more stable nomenclature is being established.

The Pastora Seam is not generally developed as one single coal and thin splits are a fairly common occurrence. In the area of Amézola there is a fairly regular complex of thin coals in a coal-bearing interval above the sandstone-conglomerate which forms the roof of the «Ancha de Pastora» and which apparently represents the infilling of a river channel cutting down into the peat. These rider seams (called «Venas de Techo» or roof veins) are usually non-workable, with the exception of the highest «Vena de Techo» which has been occasionally worked for its pure coal. In the Santa Lucía, Ciñera and Competidora mining areas small seams are found to be splitting off both at the top and at the bottom of the main coal development, and «dirt» partings are relatively common throughout.

The different development of rocks in the Pastora Formation in the western part of the coalfield is illustrated by the stratigraphic columns drawn in text-figs 2, 6 and 7.

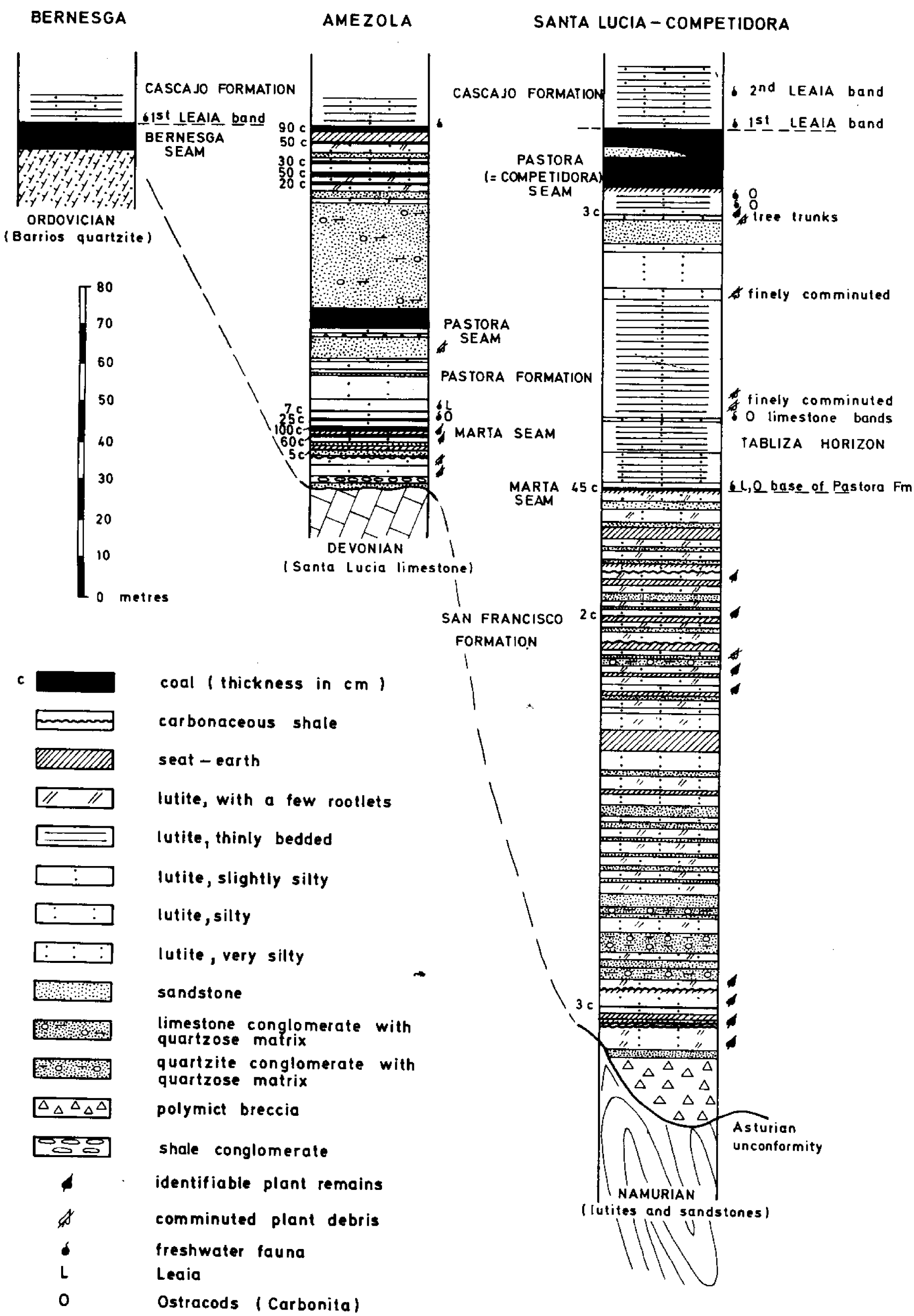
The presence of a thick sandstone/conglomerate horizon above the «Ancha de Pastora» in the Amézola area (text-fig. 6) produces a marked increase in thickness of the coal-bearing sequence which is most probably linked to compaction, since this horizon is the apparent equivalent of coal in the Santa Lucía-Competidora area (text-fig. 6). In view of the fact that coals are highly compacted sediments, the partial replacement by virtually uncompacted sandstone/conglomerate should result in a important difference in the ultimate thickness of the compacted sequence. In order to test this assumption, two general sections, corresponding to different mining areas in the western part of the coalfield, were drawn in text-fig. 5, with the thickness of coals exaggerated ten times with respect to the lutite, sandstone and conglomerate intervals in the coal-bearing sequence. Although the total compaction of coal may well be in excess of the × 10 factor chosen, it is likely that some of the initial compaction during sedimentation may have been compensated for already at the time of formation. The lutites, shown as uncompacted intervals, will also



Text-fig. 5.—Reconstructed sections of the Pastora and San Francisco formations in the western part of the coalfield where the thick coal of the Pastora Seam is developed. The original distribution of sediment has been reconstructed by exaggerating the present-day thickness of coal ten times (thus allowing for differential compaction). The reconstructions suggest a fairly even subsidence with similar thicknesses of sediment being deposited, and this agrees with the kind of facies represented (compare text-fig. 11). The sections also indicate a basin margin to the NW, with a slope of *ca.* 5°, the latter representing probably a cumulative effect. Superimposed on the basin slope in the top figure a valley fill in the San Francisco Formation is noted.

THE DIFFERENT POSITIONS OF THE BASE OF THE POST–ASTURIAN SEQUENCE IN THE WESTERN PART OF THE CIÑERA–MATALLANA COALFIELD

Scale 1:2,000



have been reduced a little in thickness. It is therefore the differential compaction factor which is important for a reconstruction. After applying the × 10 compaction coefficient for the coal, an even distribution of stratigraphic thickness is obtained throughout the area, and this suggests that the basin subsided gradually and rather evenly (with the exception of the basin margin — as shown by text-fig. 5). It also indicates that the sandstone/conglomerate lens above the «Ancha de Pastora» in the mining area of Amézola represents only a relatively short interval during which coal continued to be formed in the adjacent area. The same differential compaction factor has been applied to several sections measured in almost 3 km distance from Amézola eastwards to the region south of Coladilla, and which are combined in one general section (text-fig. 8). The latter shows that there was no apparent change in the thickness of sediments despite the gradual thinning of coals and the concomitant increase in terrigenous clastics in an eastern direction.

The splitting and thinning of coal eastwards, as shown by text-fig. 8 (see also text-fig.7), is due to a gradual change in facies, from a predominant swamp environment in the western region to a mixed fluviatile and swamp facies in the eastern area. An increase in lenticular channel fill sandstones is noted (compare text-fig. 17), and these locally convert into torrential conglomerates in sections measured several kilometres to the east. The transition from swamp to mixed fluviatile/swamp facies has been found by mapping and trenching in two different localities in the area W and SW of Coladilla, and it appears to follow a NW-SE striking line which ought to be proved again west of Orzonaga (text-fig.10). Unfortunately, the Pastora Formation is not found at outcrop in the Orzonaga region, and confirmation will have to be sought by mining and, possibly, by drilling. A similar line of transition between a swamp facies represented by thick coal and a mixed fluviatile/swamp facies without workable coals is present on the south-western side of the area of workable coal in the Santa Lucía region. A clear transition has been observed SE of Santa Lucía (see text-fig.10) where

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Text-fig.6.—Three stratigraphic sections from the western part of the coalfield, showing the development of the San Francisco and Pastora formations. The section corresponding to the mining groups of Santa Lucía and Competidora, in the south-eastern part of the area considered, has a fairly important development of rocks in the San Francisco Formation, with breccia at the base (compare WAGNER & ARTIEDA 1970, Fig. 8). This sequence can be shown to commence with a valley fill (compare text-fig. 5—top figure). The base of the Pastora Formation, immediately above the Marta Seam, is found in both the Santa Lucía - Competidora and Amézola areas. In the latter there is only a thin development of the San Francisco Formation, this time with sandstone and a shale conglomerate at the base. The San Francisco Formation is absent in the Bernesga mining area, which represents the far north-western part of the coalfield. Even the lower part of the Pastora Formation has not been developed in the Bernesga area, where the Pastora coal lies immediately on Ordovician quartzites. It marks the basin margin, which was situated to the NW or WNW. Progressive onlap took place in this direction. The development of the Pastora coal seam varies in the three areas represented. In the Santa Lucía - Competidora area, there is generally one thick coal seam, some 12 to 20 m thick. This seam is split into a thick coal («Ancha de Pastora») and a few thin riders in the Amézola area, where a thick sandstone/conglomerate horizon is developed in between. In the Bernesga area there is only one coal which is relatively thinner because the sedimentation did not apparently extend to this area before the coal formation had already started in the other areas of the Ciñera-Matallana coalfield.

the Competidora (= Pastora) coal seam becomes increasingly dirty and non-workable westwards. Also the Bernesga (= Pastora) coal seam immediately NE of Santa Lucía is represented by a non-workable fluviatile/swamp facies in the outlier west of Santa Lucía and north of Vega de Gordón. This transition is apparently quite independent from the gradual elevation of the basin margin north-westwards, which brings the Bernesga (= Pastora) coal seam in immediate contact with the unconformable substrate (see text-figs 1 and 6).

The gradual facies changes discussed above delimit the area of workable coal in the western part of the Ciñera-Matallana coalfield (text-fig. 10) and are of immediate importance to the rational extraction of coal in this region. A further, more abrupt change of thick coal into shales with thin stringers has been observed within the workable area in several localities which are also aligned in a NW-SE direction. This facies change is from swamp to lacustrine, for the shales are thinly bedded to laminate and the coals within the shales do not show the presence of seat-earths. The lateral passage is extremely rapid, and has been seen to operate within a few metres distance. Differential compaction has accentuated the abruptness of this passage which is sometimes marked by dips of the order of 70° to 75°, off the less compacted shales. Evidence of mining and detailed surface investigations, which are still being carried out at the time of writing, indicate the presence of a shale lens, several tens of metres to a few hundred metres wide and probably quite variable in width, which due to differential compaction along two bordering lines of rapid facies change, forms an elongate dôme or a string of dômes of non-workable material in the central part of the area of thick coal.

The total picture of facies distribution at the horizon of the Pastora coal seam seems to indicate a NW-SE striking lake, with the thinly bedded shale lens marking the central lake bed. Along the margins a swamp facies seems to have been established, with coal formed as the result of *in situ* vegetation and drifted plant remains. This marginal swamp facies seems to have passed laterally into a mixed fluviatile and swamp facies. One of the river channels appears to have meandered temporarily into the marginal swamp area north-east of the central furrow of the lake, and to have left a channel fill in the shape of a coarse sandstone, locally developed as a limestone conglomerate. An impression of the facies distribution as described above, is given by the reconstruction of text-fig.11.

The thick coal of the Pastora Seam has been heavily intruded by several dykes in the area west of Orzonaga where natural coke is found in mine workings which followed a dyke in 500 metres distance. Drilling and mining information combine with

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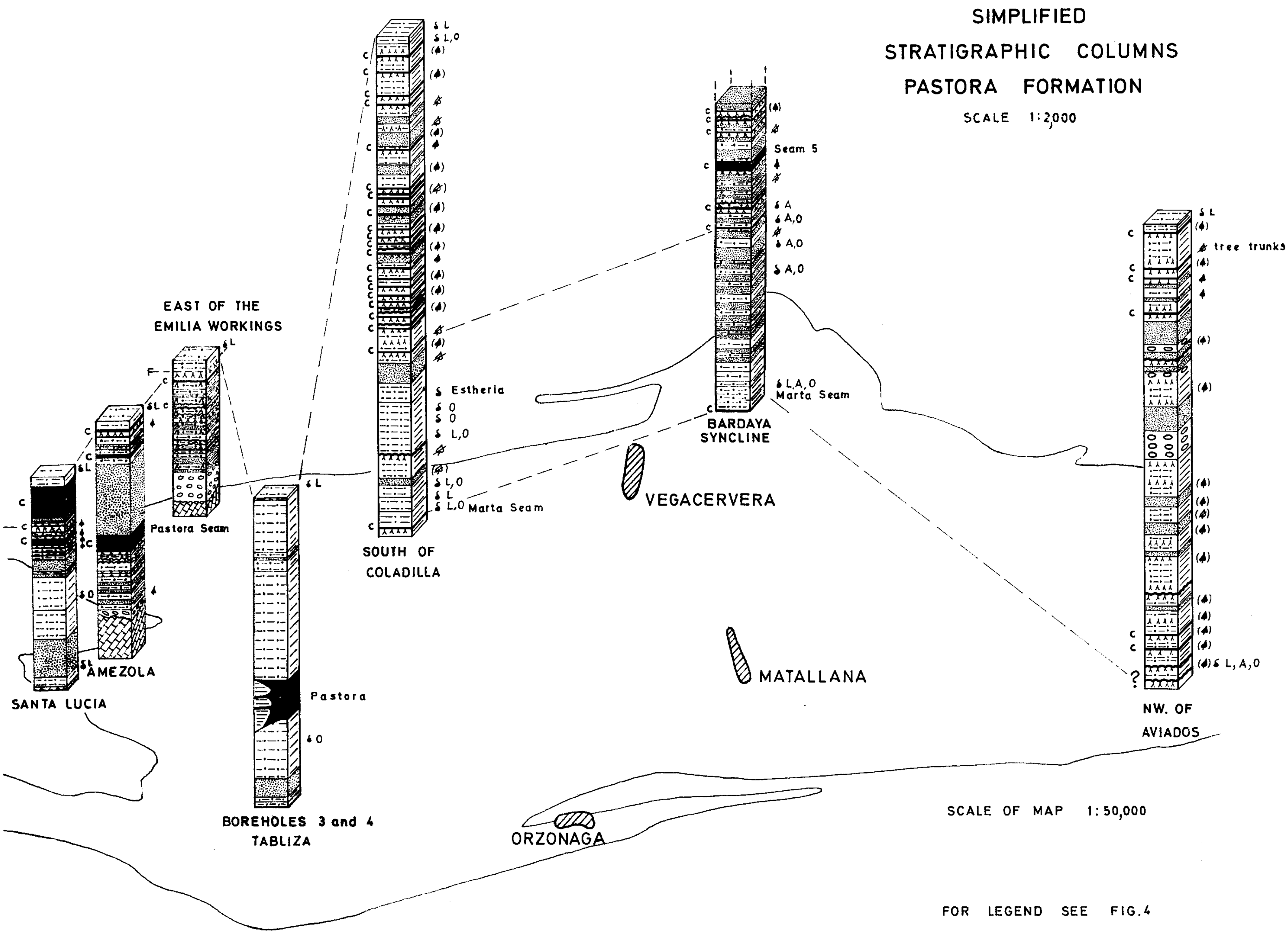
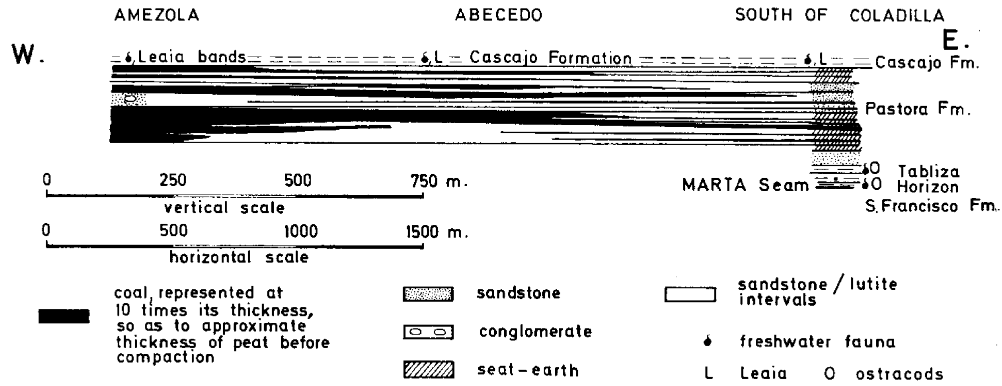
Text-fig. 7.—The simplified stratigraphic columns of the Pastora Formation show the different development of the Pastora coal in different parts of the coalfield. The thick coal of the Santa Lucía mining area splits into a thick «Ancha de Pastora» and thin «Venas de Techo» in Amézola. North-eastwards (east of Emilia workings and south of Coladilla) the entire Pastora coal has split into numerous thin, non-workable seams and the facies has become more fluviatile (compare text-figs 8 and 11). The boreholes 3 and 4 of the Tabliza mining area show the rapid passage from thick coal to a shale lens with thin, allochthonous coal streaks, which probably represent deposits in the centre of the lake depicted in text-fig. 11. In the eastern part of the coalfield the Pastora Formation is often quite conglomeratic and contains very little coal.



SIMPLIFIED
STRATIGRAPHIC COLUMNS
PASTORA FORMATION
SCALE 1:2,000
SANTA LUCIA
AMEZOLA
Pastora Seam
EAST OF THE
EMILIA WORKINGS
BOREHOLES 3 and 4
TABLIZA
Pastora
SOUTH OF
COLADILLA
Estheria
Marta Seam
BARDAYA
SYNCLINE
Seam 5
Marta Seam
VEGACERVERA
MATALLANA
ORZONAGA
NW. OF
AVIADOS
tree trunks
SCALE OF MAP 1:50,000
FOR LEGEND SEE FIG.4

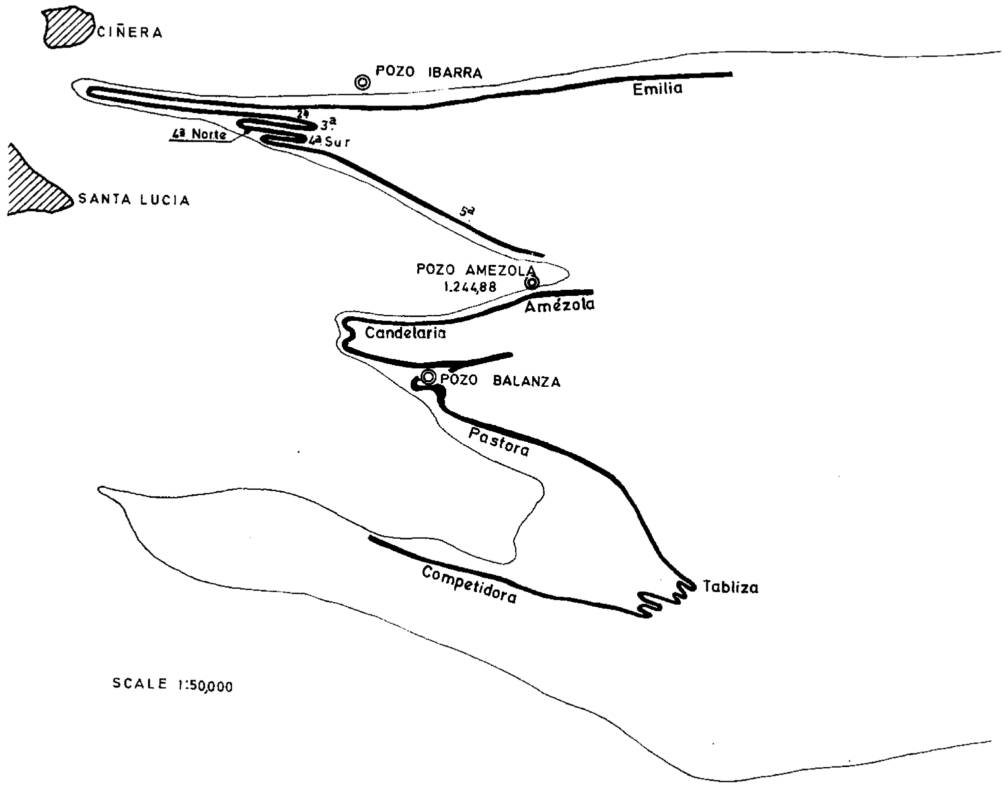


Text-fig. 8.—Diagram showing the gradual passage eastwards of the thick coal of Pastora («Ancha de Pastora») into a complex of thin, non-workable coals alternating with river overbank, swamp and fluviatile deposits. The coal has been represented at ten times its present-day thickness in order to allow for differential compaction.

evidence on the surface to indicate that the intrusion in the form of dykes was halted by the shale lens which marks the lacustrine facies within the area of the thick coal development. Only a limited amount of intrusive rock has been found thus far on the south-western side of the shale lens, and it seems as if the area of coal affected by the main sill is restricted to the region west of Orzonaga (text-fig. 10). Further exploration will be necessary to delimit exactly the total area of the intrusion.

Cascajo Formation

The swamp area forming the margins of a small lake at the time of formation of the Pastora coal seam became inundated by a larger lake which laid down its deposits on top of the coal and which also extended onto the adjoining mixed swamp and fluviatile area. The first widespread lake deposits are represented by a thin (*ca.* 20 cm) band of dark grey shales with abundant valves of the phyllopod *Leaia baentschiana* BEYRICH, less common drifted plant remains (often identifiable) and rare fish scales. This lacustrine band, which is similar but not identical to that found above the thin Marta Seam at the base of the Pastora Formation, serves as a reliable marker band throughout the coalfield and extending into its outliers at Villar del Puerto, Valle de Faya (south of Santa Lucía) and north of Vega de Gordón. It marks the base of a *ca.* 90 m thick lacustrine formation, called the Cascajo Formation after the Cascajo Mountain in the north-eastern part of the coalfield. This formation consists mainly of thinly bedded shales and silty shales with occasional siltstones which increase in importance upwards where sandstones are also found to be coming in. The more silty shale bands usually show ripple cross lamination and ripplemarks which are particularly well developed in the siltstones. The sandstones in the upper part of the Cascajo Formation show planar cross bedding, and it appears that there is a general coarsening upwards with the progressive infilling of the lake. *In situ* vegetation then becomes



Text-fig. 9.—Diagram showing the general outcrop of the Pastora coal seam as found in the mining areas in the western part of the coalfield. The name of the seam varies with the different mining areas (Competidora, Tabliza, Pastora, Candelaria, Amézola, 5ª, 4ª Sur, 4ª Norte, 3ª, 2ª, Emilia and Bernesga — the latter near Ciñera and not shown on the diagram). The three vertical shafts (Pozo Balanza, Pozo Amézola and Pozo Ibarra) for ventilation and transport of material are also shown. The coal leaves the mines via a general transport gallery («Socavón») which leads to the washery plant at Santa Lucía. All the workings are in mountainous country above the level of the valley at Santa Lucía.

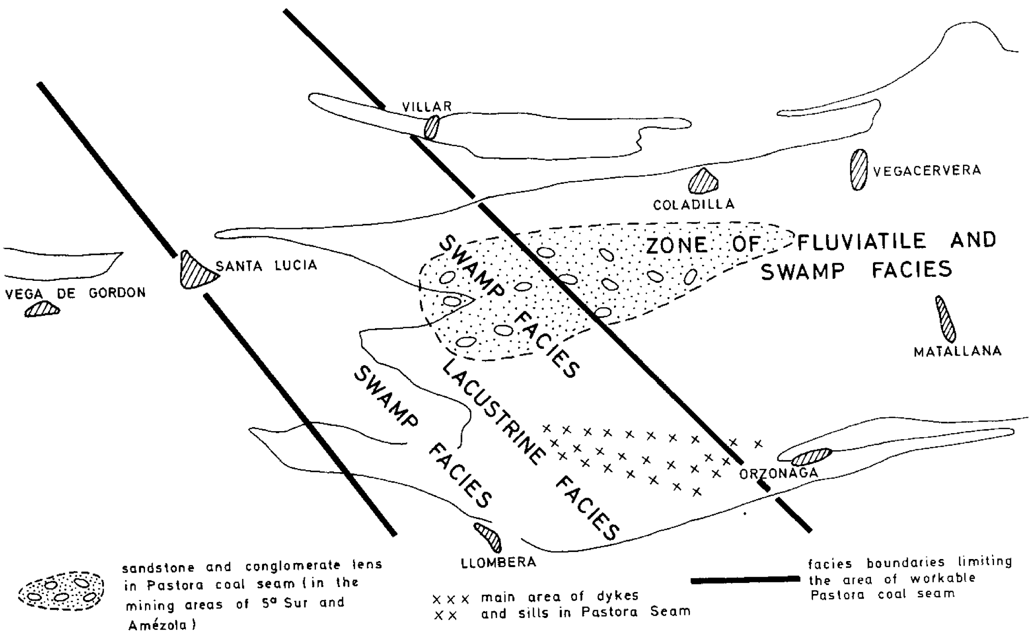
eventually established, and this marks the end of lacustrine sedimentation, thus providing a suitable upper limit to the Cascajo Formation.

This formation is generally poor in fossils, except for certain bands with lacustrine shells. At some 10 m above the first *Leaia* Band at the base of the Cascajo Formation a second *Leaia* Band is found throughout the coalfield, thus forming an additional marker band. The latter differs slightly from the first *Leaia* Band in showing usually associated *Anthraconauta* and *Carbonita* with the predominant remains of *Leaia baentschiana*. Throughout the Cascajo Formation sparse remains of *Anthraconauta* and *Anthraconaia* are found at infrequent intervals, and in the top part of the formation it is not unusual to find well developed *Anthraconauta*/*Carbonita* bands. However, the latter do not constitute marker bands since they are impersistent and strictly local in occurrence. Drifted, comminuted plant remains do occur in the Cascajo Formation, but they are exceedingly rare.

The stratotype of the Cascajo Formation is situated at *ca.* 700 m S of Coladilla, where a detailed section has been measured (text-fig.17). The formation is represented throughout the Ciñera-Matallana coalfield and also occurs in various outliers (see Map: text-fig.1). It forms an easily mappable unit, with little or no vegetation, and the occurrence of two *Leaia* bands in the basal part of the unit further enhances its usefulness. Apparently, the Cascajo Formation thins slightly in an eastern direction (text-fig.2, right hand column).

Roguera Formation

As mentioned above, the base of this formation is drawn at the facies change marked by the incoming of the first *in situ* vegetation (seat-earth) above the lacustrine Cascajo Formation. This facies change is a constant datum throughout the coalfield, with the exception of the most southerly area, N of Llombera, where there is no clear distinction between the sandy upper part of the Cascajo Formation and the equally sandy lower part of the Roguera Formation. In this part of the coalfield there is no seat-earth or complex of seat-earths to mark off the basal part of the Roguera Formation, and



Text-fig. 10.—The limits of the area of workable coal in the Pastora Formation, as determined by the distribution of different facies (compare text-fig. 11). An important lens of channel sandstone and conglomerate within the Pastora coal seam of the Amézola area probably represents a river course linked to the more fluviatile area to the east. A sill within the Pastora Seam of the area of the San José Mine (west of Orzonaga) appears to have been halted by the lacustrine shale lens which occupies the central part of the workable region, and which is interpreted as representing the deeper, central part of the lake bordered by the areas of swamp facies which produced the workable coal.

the only apparent difference with regard to the highest Cascajo Formation is found in the relative increase in the occasional drifted, comminuted plant remains at a level which is likely to correspond to the basal Roguera Formation.

The stratotype of the Roguera Formation lies in a section measured across the southern flank of the Vegacervera Syncline E of Santa Lucía, near the Esperanza Valley and on the slope leading towards the mountain called Cotil de Fierros (Map: text-fig.1). This section (text-fig.13) shows predominantly a shaly development of the Roguera Formation, with a number of seat-earths and coal smuts in the lower part, followed by the Roguera coal seam and more widely spaced coal and seat-earth horizons, until the basal coal of the San José Formation (i.e. San José seam 5) is reached. The interval between the Roguera and San José 5 seams contains several *Anthraconauta/Carbonita* bands, with some *Leaia* in the two highest bands recorded. Below the San José 5 seam, in the top part of the Roguera Formation, a silty shale horizon with drifted plant remains forms a prominent unit traceable in the field.

The characteristic facies of shales with coal smuts and several *Anthraconauta/Carbonita* bands in the Roguera stratotype is modified almost immediately south and east of the type section, and the presence of sandstones, often current bedded, is a more common feature of the Roguera Formation in different parts of the coalfield (text-figs 2, 13). The Roguera Seam, which was worked in the area of the type section (Esperanza Valley area), thins rapidly eastwards and disappears in some 500 metres along

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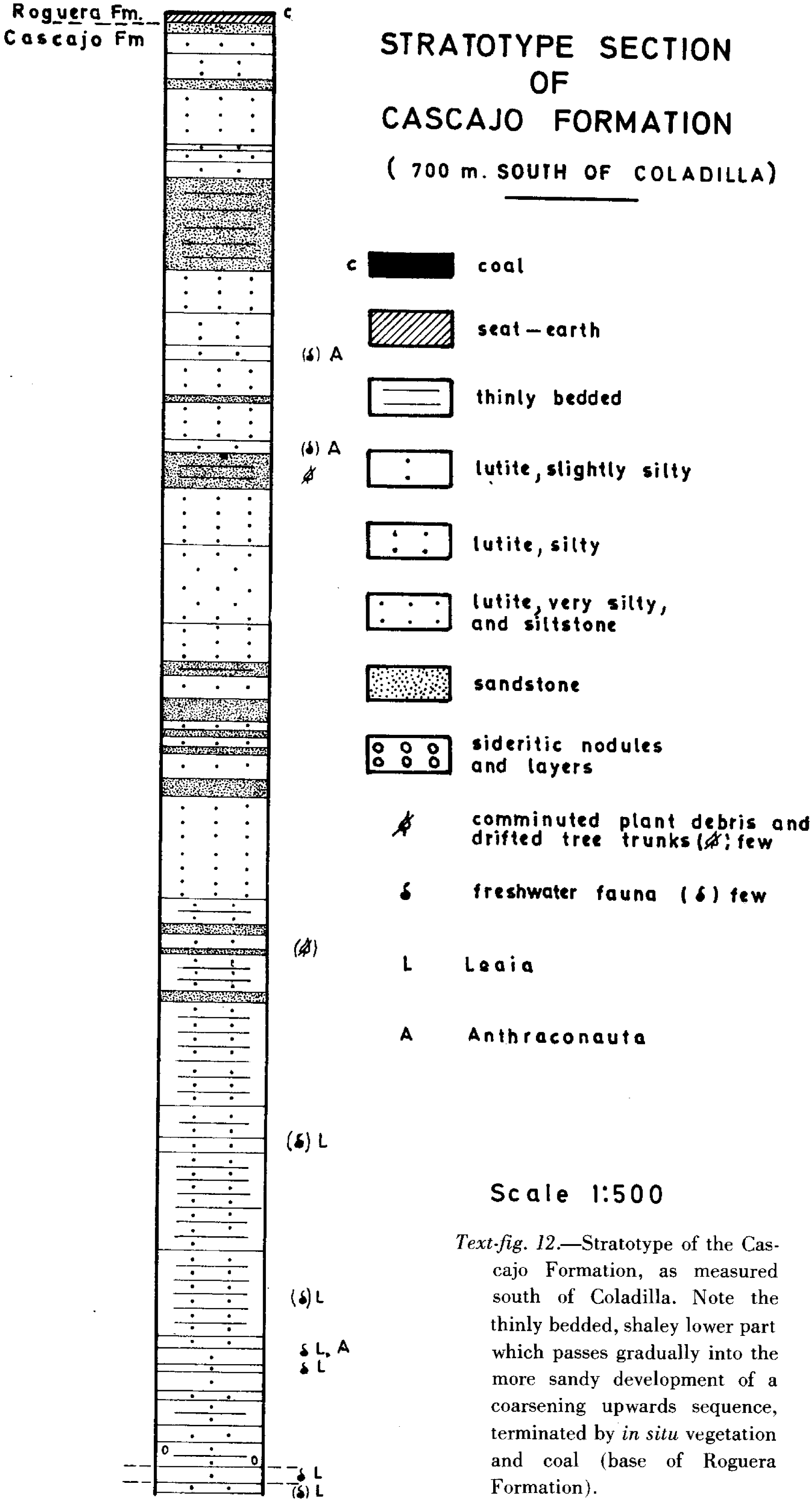
Text-fig. 11.—Reconstruction of the landscape during the formation of the Pastora coal seam. In the background are the mountains which were lying beyond the basin margin to the NW, and which provided the basin with terrigenous run-off. Since some of this run-off consisted of coarse sand with limestone pebbles, the mountains were probably quite close to the area of sedimentation. Within the latter, river courses must have channelled and filled up, as meanders were abandoned. One such meander has been depicted as channelling into a swamp area which bordered a NW-SE oriented lake; thus representing the sandstone/conglomerate lens which separates the thick «Ancha de Pastora» from its rider seams in the area of Amézola (compare text-figs. 5, 6 and 10). The lake may have been fed by small, subsidiary water courses which carried only a little, fine sediment. The corresponding muds accumulated mainly in the central and deepest part of the lake, where thinly bedded, fine-grained shales are found with thin allochthonous coals without seat-earths. Along the borders of the lake swamp areas were established with little terrigenous sedimentation and a long-lasting accumulation of vegetable matter. The corresponding thick coal has not been examined petrographically, but it should be a mixture of drifted and *in situ* vegetable material with occasional partings of seat-earth. The swamp area passes gradually east-northeastwards into a mixed fluviatile and swamp area in which only a few thin coals were formed. The reconstruction is based on the areal distribution of facies as depicted in text-fig. 10, and on the stratigraphic sections which have been partially reproduced in the two panels of the drawing. The panel on the left shows the changes of facies associated with the lacustrine shale lens in the centre and the coal with occasional partings to the SW and NE. The coal has been represented before compaction. The panel on the right shows the gradual splitting of the coal into several thin seams which are wedging north-eastwards, at the same time as in-river channel sandstones and conglomerates are becoming more frequent. The thin continuous seam below the main development of coal (Pastora Seam) is the non-workable Marta Seam, which is a reliable marker in conjunction with the immediately overlying lacustrine Tabliza Horizon. Below the Marta Seam a variable thickness of San Francisco Formation was deposited, and this includes valley fills as depicted on the right hand panel. The entire sequence of Stephanian B strata is unconformable on previously folded strata, which are represented in the reconstruction by Devonian limestones. The reconstruction was drawn by Mr. M. Jiménez Murguía at Santa Lucía de Gordón.



Text-fig. 12.—Stratotype of the Cascajo Formation, as measured south of Coladilla. Note the thinly bedded, shaley lower part which passes gradually into the more sandy development of a coarsening upwards sequence, terminated by *in situ* vegetation and coal (base of Roguera Formation).

the strike. However, to the NE, in the vicinity of Coladilla, it apparently reappears as the Nieves Seam which was extensively worked despite its very thin development of coal (*ca.* 20 cm). The same seam has been the subject of exploratory workings near Villalfeide, and was also explored some 2 km NW of Aviados, in the eastern part of the Ciñera-Matallana coalfield.

San José Formation

The stratotype of this formation lies in the southern flank of the Matallana Syncline, in the area occupied by the abandoned coal mine «La Gamonera », slightly over 1 km NNE of Llombera. The San José Formation is characteristically developed with five coal seams, numbered from 5 to 1, and two or three coal smuts («carboneros») between seams 5 and 4. These seams, which are all quite thin, have been worked extensively in the southern and central parts of the coalfield, from west of Mina San José to Aviados (see Map: text-fig.1). Towards the north they all thin and eventually disappear (text-fig.14), with Seam 5 being the last to remain as a recognizable coal (e.g. in the Esperanza Valley section).

San José 5 is usually developed as two veins, with the upper leaf commonly showing lacustrine roof shales, dark grey in colour, with *Anthraconauta, Carbonita,* and rare *Leaia* and *«Estheria»*. Two of the «carboneros» above Seam 5 also possess lacustrine roof shales with *Leaia, Anthraconauta* and *Carbonita.* They are usually accompanied by thinly bedded, probably lacustrine shales, weathering a brownish grey, of variable thickness and of limited lateral continuity.

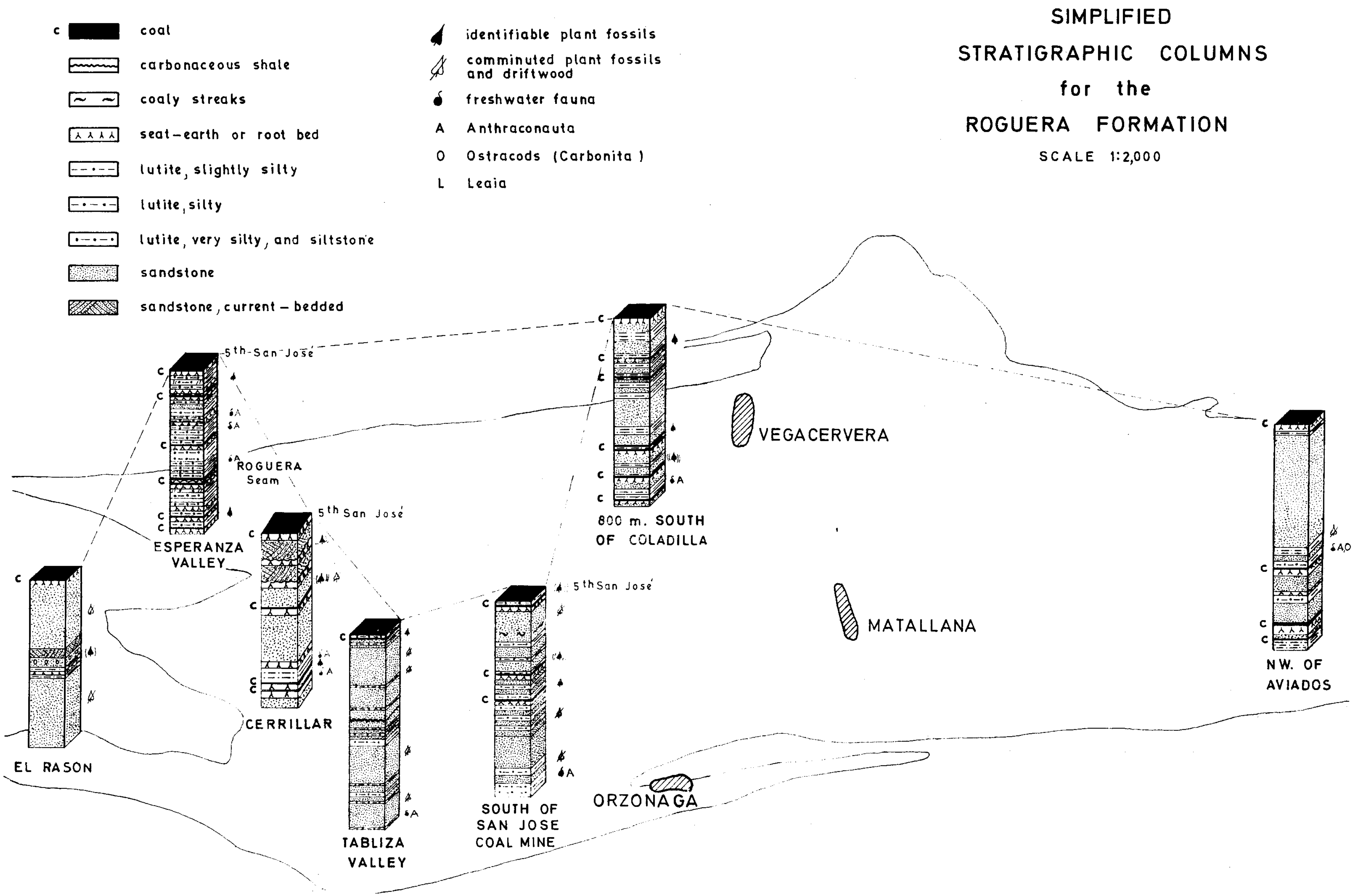
San José 4 is generally the thickest of the coal seams in this formation, though rarely exceeding 80 cm. It is also the dirtiest seam.

San José 3, 2 and 1 are extremely thin seams. Only seams 2 and 1 have been worked fairly extensively, seam 1 because of its high quality coal and in spite of its thickness (20-30 cm on average). Both seams contain plant fossils in roof shales. Seam 2 is mainly characterized by *Peçopteris arborescens* (VON SCHLOTHEIM), and Seam 1 shows a highly diversified and characteristic floral assemblage which has been found in the same band in different parts of the coalfield, and which has proved useful as a marker. The most characteristic element of this assemblage is *Alethopteris leonensis* WAGNER (see further on page 422).

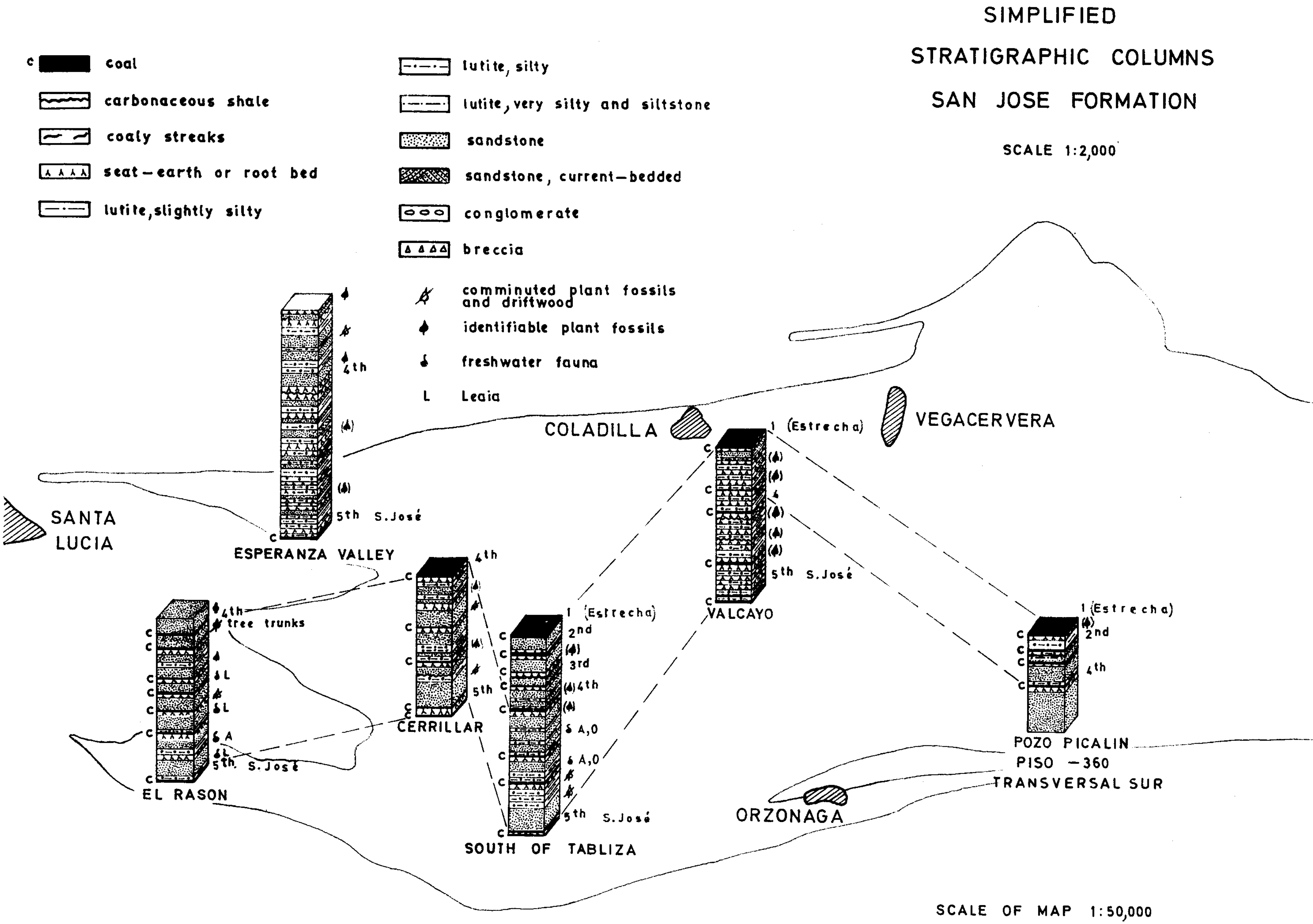
The San José Formation contains numerous sandstone bands, generally of immature aspect, which are irregularly distributed (text-fig.14).

Bienvenidas Formation

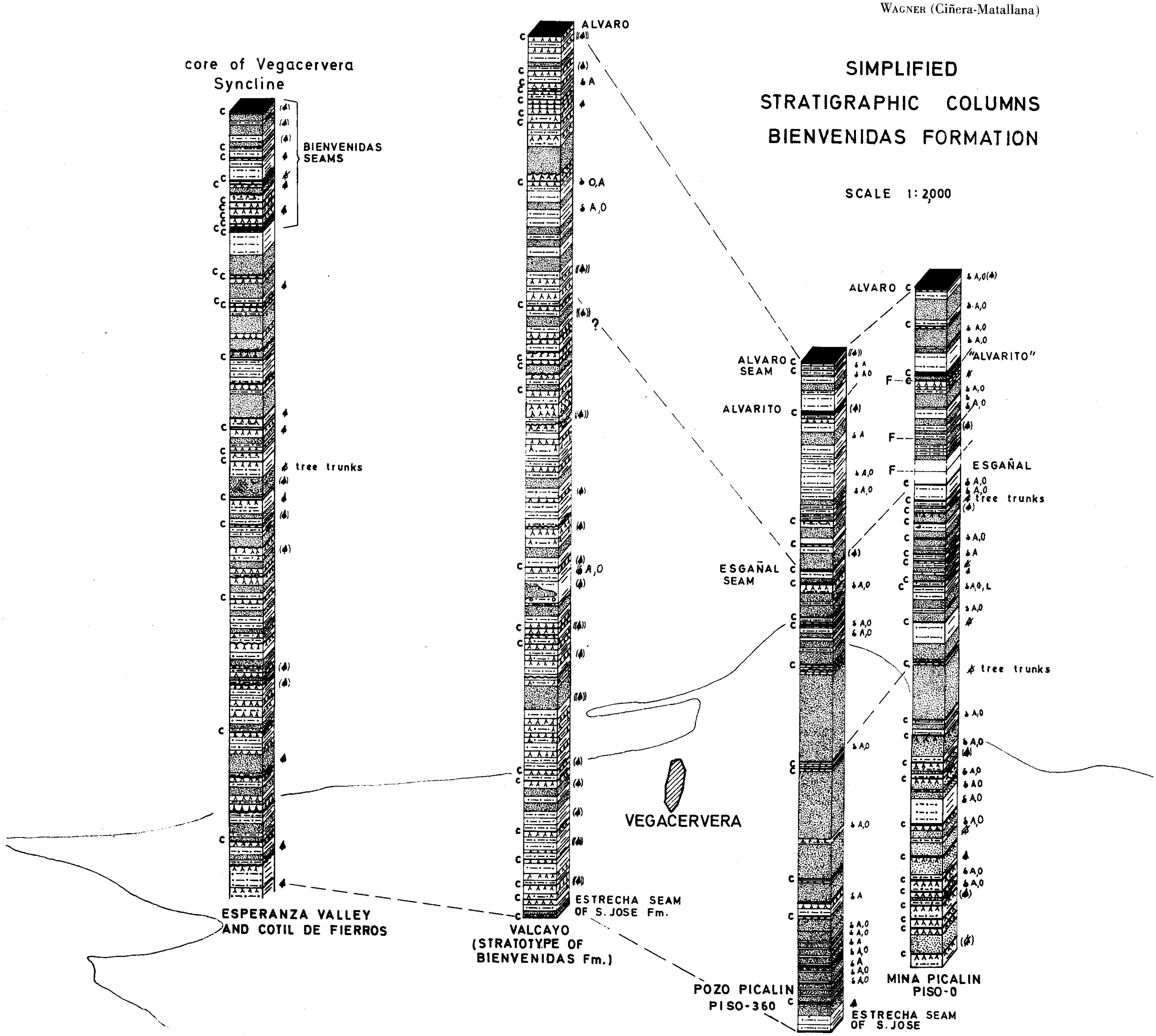
The name of this formation is derived from the Bienvenidas seams which constitute a dense sequence of workable coals at Cotil de Fierros (see Map: text-fig.1), in the core of the Vegacervera Syncline. However, its stratotype is in a section NW of Orzonaga, in the valley known as Valcayo (text-fig.15), where a continuous succession



Text-fig. 13.—Simplified stratigraphic columns of the Roguera Formation. The stratotype of this formation is in the Esperanza Valley section which shows a more shaley, more lacustrine development than the other sections.



Text-fig. 14.—Simplified stratigraphic columns of the San José Formation. The stratotype is not shown but the Cerrillar and Tabliza sections (compare text-fig.18) are near to it, and closely comparable. The San José coals have been worked in the southern and central parts of the coalfield, but mainly thin and disappear in the northern part (compare the Esperanza Valley section).



Text-fig. 15.—Simplified stratigraphic columns of the Bienvenidas Formation. The stratotype is in the Valcayo section and not in that of Cotil de Fierros, where the Bienvenidas Seams are found, and where the formation is incomplete. The Bienvenidas Seams probably correlate with the Esgañal to Alvarito Seams in the Matallana Syncline. There is a notable increase in the number of *Anthraconauta/Carbonita* Bands eastwards. No such lacustrine horizons were found in the Esperanza Valley/Cotil de Fierros section, only four *Anthraconauta* Bands occurred in the Valcayo section (stratotype), and numerous *Anthraconauta/Carbonita* Bands characterized the Bienvenidas Formation in the now abandoned Picalín Mine (Pozo San Román) east of Matallana. Rapidly wedging fluviatile sandstones of considerable thickness characterize the Bienvenidas Formation in certain parts of the coalfield, and herald the advent of even more prominent sandstones with drifted tree trunks in the following Matallana Formation. The symbols used are the same as for the other columns at the 1 : 2,000 scale (compare text-fig. 4).

is found from the San José Formation upwards into the Matallana Formation. The lower limit of the Bienvenidas Formation is placed at the horizon of the San José 1 Seam with its characteristic flora. This horizon serves as a marker band, but does not signify a change in facies. In fact, the Bienvenidas Formation continues the fluviatile and swamp facies with occasional lacustrine deposits which are also found in the preceding San José Formation. It does however show the introduction of irregularly developed, thick fluviatile sandstones, often marking clear channel fills, and which are sometimes conglomeratic. In the eastern part of the coalfield, in the area of Matallana, the Bienvenidas Formation contains a large number of *Anthraconauta/Carbonita* bands, whereas the stratotype at Valcayo shows only four bands in 380 metres. These lacustrine horizons are clearly of limited lateral extent.

The first workable seam of the Bienvenidas Formation, continuously developed throughout the coalfield, is the Bisvita Seam (*ca.* 190 m above the base of the formation) which has been worked under this name south of Villalfeide and which was also exploited in the synclinal core east-northeast of Llombera (see Map: text-fig. 1). The roof shales of this seam yield well preserved floral remains in considerable abundance and variety, and a number of these have been figured in WAGNER & ARTIEDA 1970 (loc. 1733).

Workable seams are also found in the highest part of the Bienvenidas Formation where the Esgañal-Marte complex of seams in the Matallana region corresponds to the Bienvenidas seams of Cotil de Fierros in the north-western part of the coalfield. Further upwards a thin seam, Alvarito, is found at a short distance below the Alvaro Seam which has been selected as the boundary with the overlying Matallana Formation.

Non-workable coal smuts are found throughout the Bienvenidas Formation.

Matallana Formation

The stratotype of this formation is in the Picalín Valley, ESE of Matallana de Torío. It is characterized by alternating thick, fluviatile sandstone horizons and coal-measures containing thin seams of considerable lateral continuity (text-fig.16). The sandstones are massively bedded and contain frequent horizons with large drifted tree trunks. Channel bases are common. The coal-measure intervals show lacustrine as well as swamp and river overbank facies. *Anthraconauta/Carbonita* bands are frequently present. A section in the Matallana Formation east of Serrilla has been discussed with regard to sedimentary facies by READING (1970, pp. 14, 19) who recorded coarsening upwards and fining upwards sequences with seat-earths and coals developed at the top of the latter.

The three main intervals of coal-measures contain the Alvaro, Picalín and Petra seams, respectively. The first two seams mentioned have been worked extensively in the area near Matallana, and also south of Villalfeide (where they were known as the Hulano and Miñón seams). The Picalín (Miñón) Seam is characterized by lacustrine roof shales with abundant *Anthraconauta* and *Carbonita.* This is one of the few fossil bands of this kind which show a good lateral continuity.

Detailed sections

The knowledge of stratigraphic development in the Ciñera-Matallana coalfield has been built up everywhere by measuring detailed sections to the scale of 1 : 100. Two of these sections, covering the interval from the base of the Pastora Formation to the top of the San José Formation, have been represented at scale 1 : 200 in text-figs 17 and 18. Both sections were measured by Mr. F. J. VILLEGAS.

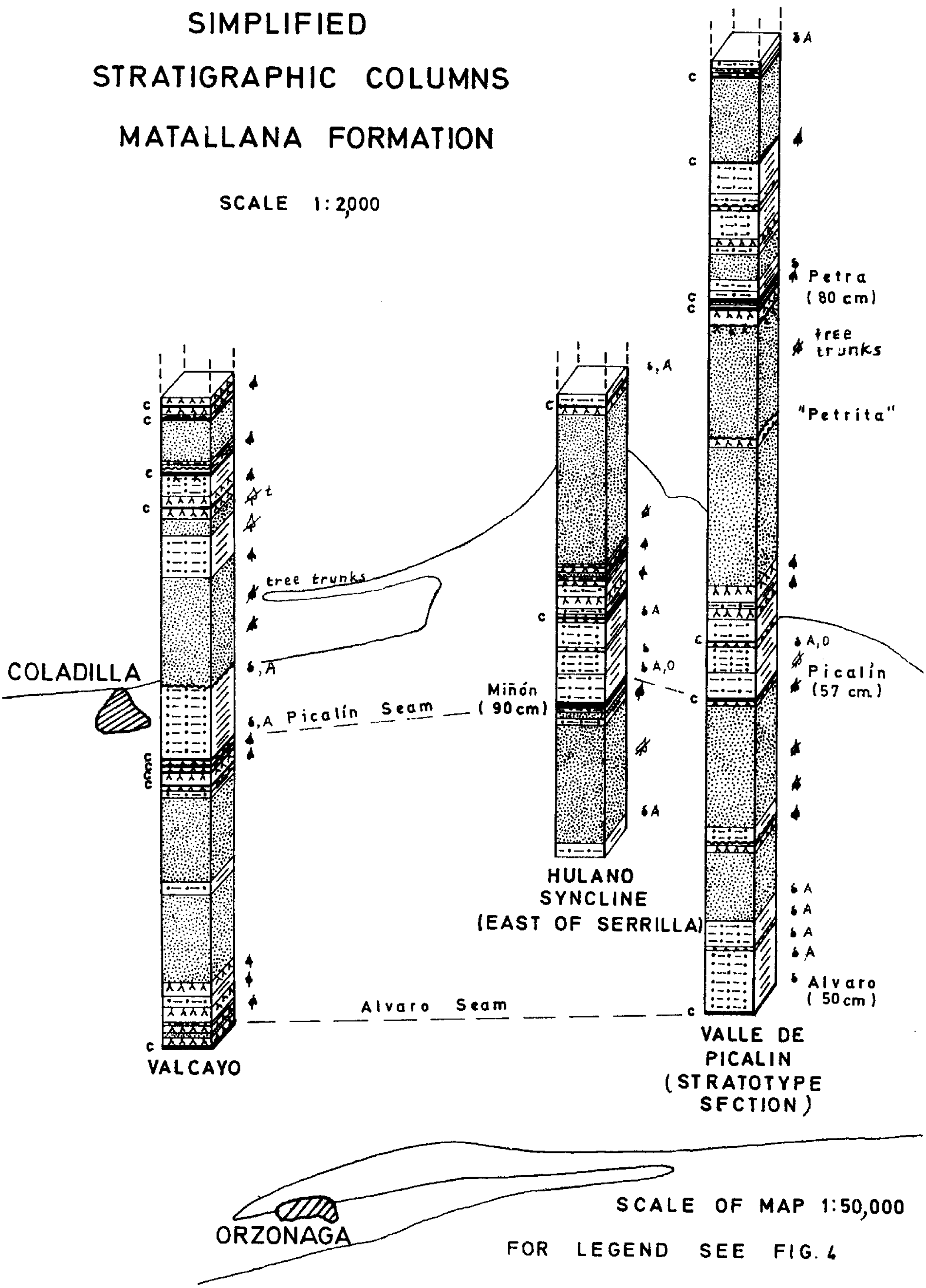
Section south of Coladilla.

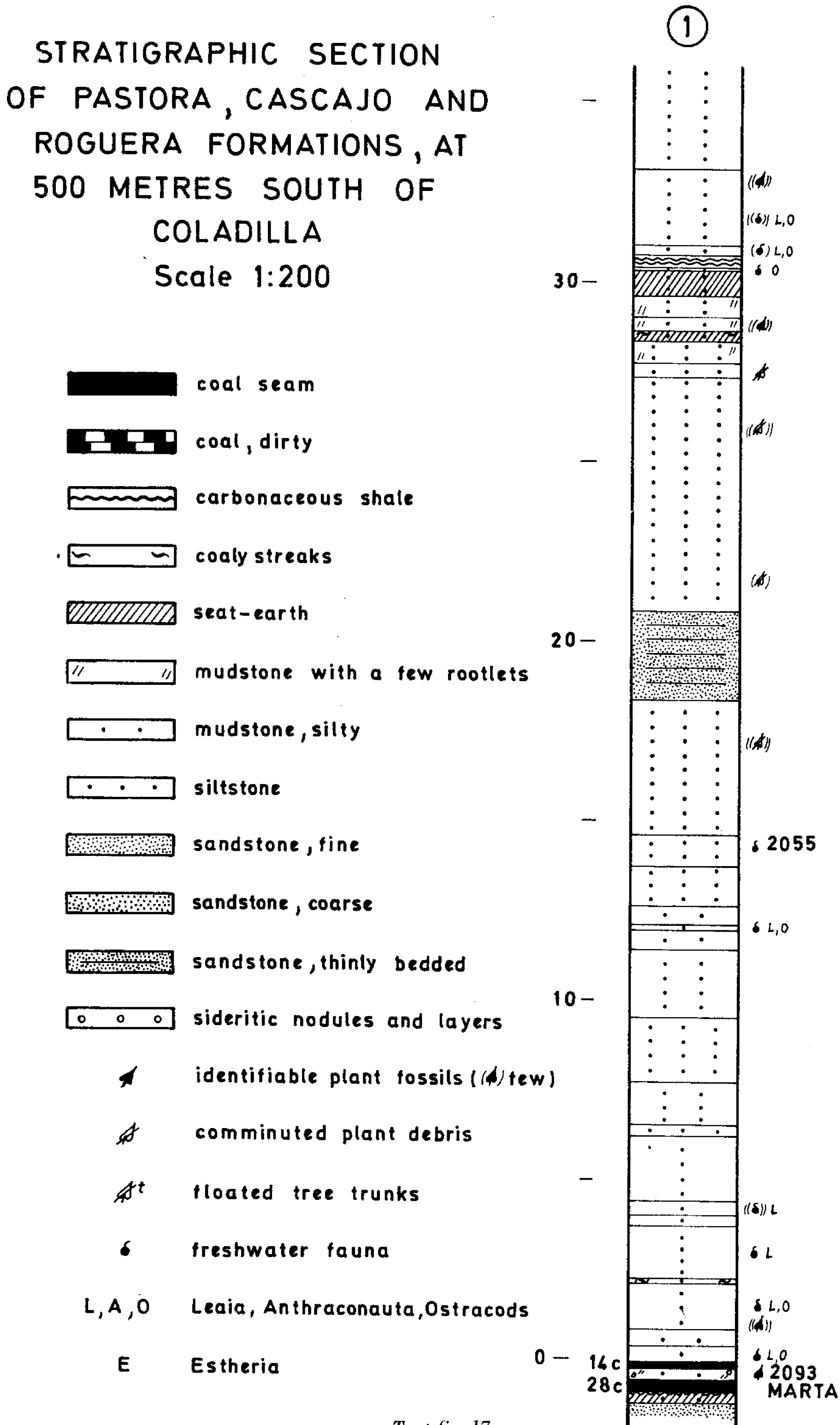
The Pastora, Cascajo and Roguera formations are illustrated by text-fig.17, representing a long section (390 m) measured south of Coladilla, in the north-western part of the Hulano Syncline (compare text-figs. 1, 19). The section commences with the top part of the San Francisco Formation, outcropping in the core of the Pico Falcón Anticline at approximately 400 m south of the village. The first strata represented are a sandstone followed by seat-earth and two thin veins of coal, together forming the Marta Seam. In between the two coal veins a few plant fossils were collected (loc. 2093): *Sphenopteris* sp., *Sphenophyllum oblongifolium* (GERMAR & KAULFUSS).

The base of the Pastora Formation is taken at the roof of the Marta Seam (point «O» of the section), where a band with *Leaia baentschiana* BEYRICH and ostracodes (*Carbonita*) forms a reliable marker throughout the coalfield. This lacustrine horizon is continued upwards by 6 m of thinly bedded shales with *Leaia* and *Carbonita* at intervals, and shows a marked change in facies from the coal-measures of the San Francisco Formation underneath. Occasional drifted plant remains, identified as *Neuropteris ovata* HOFFMANN, have been found in the lacustrine shales. A coarsening upwards sequence is observed from 6 m onwards, with only a brief return to slightly silty shales with *Leaia* and *Carbonita* at 12 m. The facies generally remains lacustrine, and non-marine shells are found up to loc. 2055, containing *Anthraconaia*. Occasional drifted pinnules of *Linopteris neuropteroides* (VON GUTBIER) are also found, and a specimen of *Pecopteris* cf. *paleacea* ZEILLER is recorded from loc.2056. Higher in the succession comminuted plant debris is found in a more sandy development of strata which may represent the progressive infilling of the lake. At 28 m the first rootlets are encountered of an interval with *in situ* vegetation marking the terminal phase of the lake fill. The whole lacustrine unit, including the sandy strata at the top, is known as the Tabliza Horizon which has been recognized throughout the coalfield, although perhaps a little less clearly in the easternmost part. Its thickness in the section south of Coladilla is probably a little in excess of that normally found.

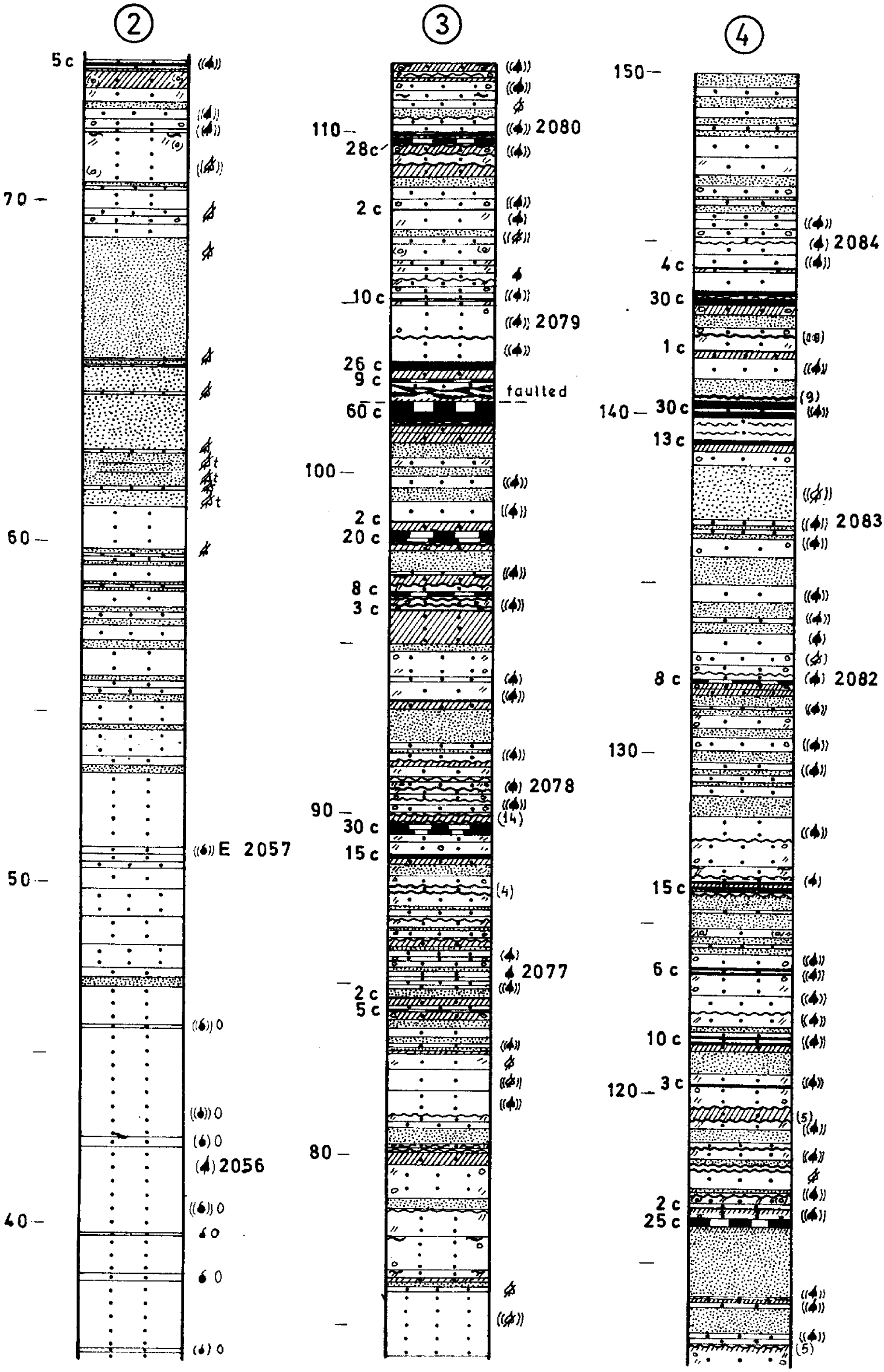
A thin band of lacustrine shales with ostracodes separates the highest seat-earth at 30 m from overlying carbonaceous shales, and renewed flooding is indicated by ostracode-bearing shales (with occasional *Leaia*) and intervening mudstones in another

Text-fig. 16.—Simplified stratigraphic columns of the Matallana Formation. The stratotype is in the Picalín Valley east of Matallana, where a full succession is present. This formation is characterized by its thick sandstone horizons alternating with coal-measures of considerable lateral continuity.

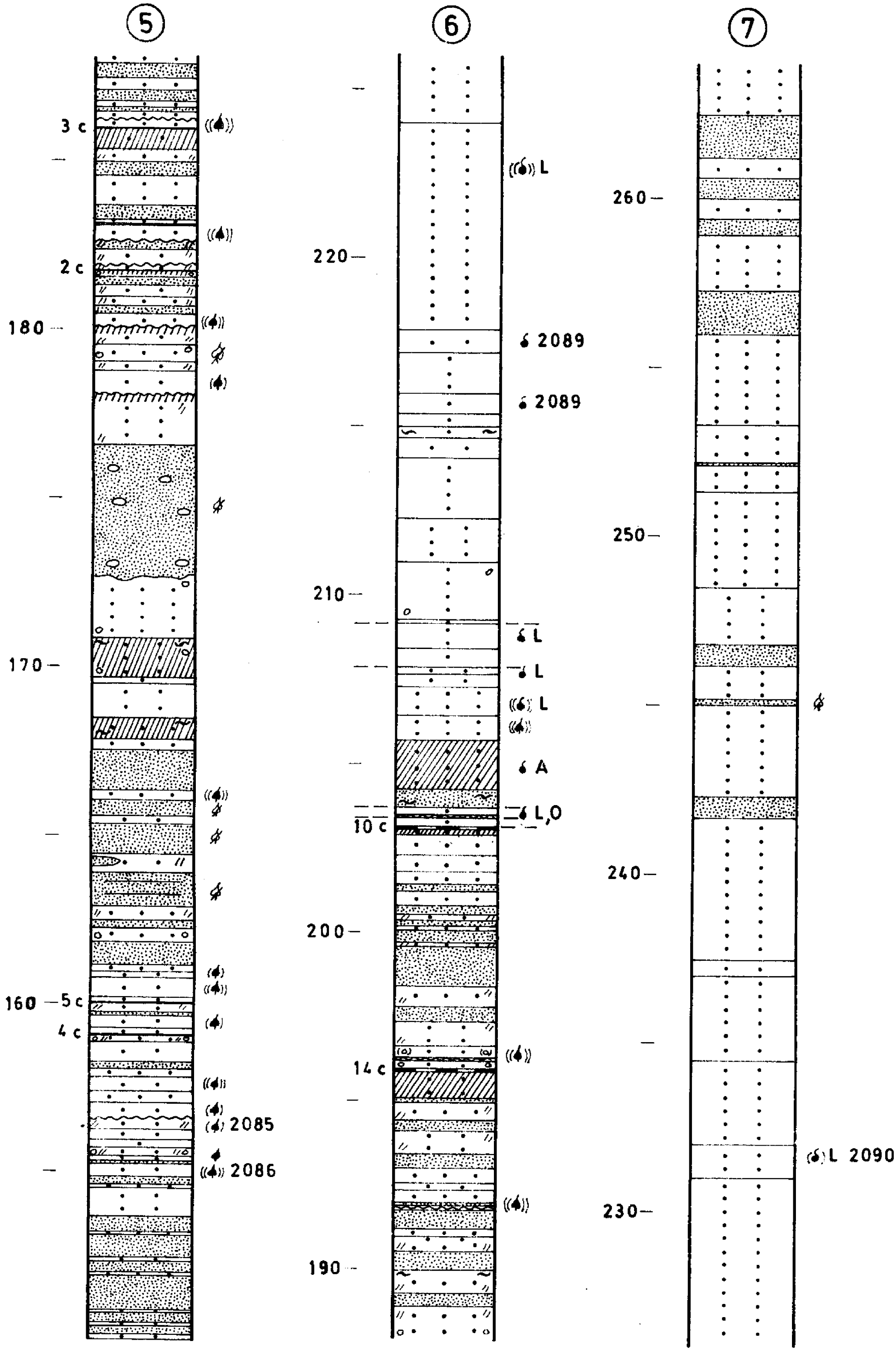

SIMPLIFIED
STRATIGRAPHIC COLUMNS
MATALLANA FORMATION
SCALE 1:2,000
COLADILLA
tree trunks
Picalín Seam
Miñón
(90 cm)
Alvaro Seam
VALCAYO
HULANO SYNCLINE (EAST OF SERRILLA)
Petra (80 cm)
tree trunks
"Petrita"
Picalín (57 cm)
Alvaro (50 cm)
VALLE DE PICALIN (STRATOTYPE SECTION)
ORZONAGA
SCALE OF MAP 1:50,000
FOR LEGEND SEE FIG. 4


STRATIGRAPHIC SECTION OF PASTORA, CASCAJO AND ROGUERA FORMATIONS, AT 500 METRES SOUTH OF COLADILLA
Scale 1:200
coal seam
coal, dirty
carbonaceous shale
coaly streaks
seat-earth
mudstone with a few rootlets
mudstone, silty
siltstone
sandstone, fine
sandstone, coarse
sandstone, thinly bedded
sideritic nodules and layers
identifiable plant fossils (few)
comminuted plant debris
floated tree trunks
freshwater fauna
L, A, O Leaia, Anthraconauta, Ostracods
E Estheria
1
30
20
10
0
14c
28c
L,O
0
2055
L
2093
MARTA

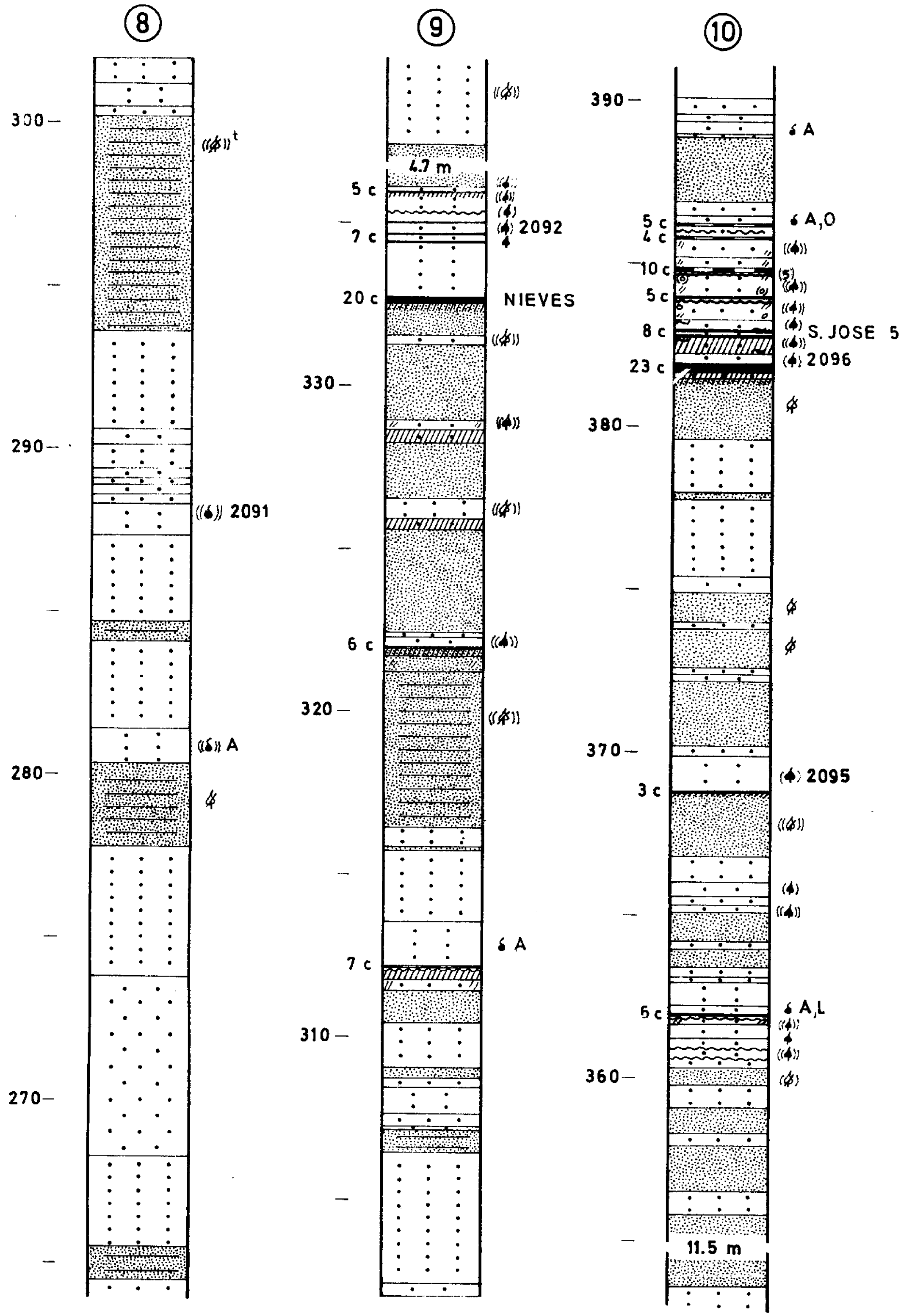
Text-fig. 17



2
3
4
5 c
70
60
50
40
E 2057
2056
110
28c
2 c
10 c
26 c
9 c
60 c
faulted
2080
2079
100
2 c
20 c
8 c
3 c
90
30 c
15 c
2078
2077
2 c
5 c
80
150
4 c
30 c
1 c
140
30c
13 c
2084
2083
8 c
2082
130
15 c
6 c
10 c
120
3 c
2 c
25 c



5
6
7
3 c
2 c
180
170
160
5 c
4 c
2085
2086
220
2089
2089
210
L
L
L
A
L,O
10 c
200
14 c
190
260
250
240
L 2090
230


8
9
10
300
290
280
270
2091
A
4.7 m
5 c
7 c
2092
20 c
NIEVES
330
6 c
320
A
7 c
310
390
A
5 c
A,O
4 c
10 c
5 c
8 c
S. JOSE 5
23 c
2096
380
370
3 c
2095
6 c
A,L
360
11.5 m

coarsening upwards sequence. Also this lacustrine interval is widely distributed, and has been recorded everywhere in the western part of the coalfield. In the eastern half of the Ciñera-Matallana coalfield it may be absent.

An apparent change in facies is found at 61 m where drifted tree trunks occur in coarse sandstone. The latter is the first in a succession of fluviatile sandstones which are rather commonly represented in the higher part of the Pastora Formation east of the thick seam worked in the westernmost area of the coalfield. This particular sandstone occurs at the base of a sandy unit, 8 m thick, which forms a constant horizon in the western part of the coalfield, where it follows invariably upon ostracode-bearing shales. Comminuted plant debris is found at various levels of this sandstone horizon.

Above the sandstone, a succession of mudstones alternating with seat-earths, carbonaceous shales and thin coals marks river overbank and swamp facies which are cut occasionally by lenticular channel sandstones of massive or massively bedded appearance. Some of those sandstones are locally conglomeratic, with limestone boulders indicating a torrential origin. This part of the succession, up to 170 m in the section, is equivalent to the «Ancha de Pastora» (thick seam of Pastora) of the mining area of Amézola, and represents the more fluviatile lateral facies of this important coal development in the more westerly part of the Ciñera-Matallana coalfield.

Identifiable plant fossils are common in this interval of thin coals produced by the splitting of the thick coal of Amézola. Most abundantly represented is *Alethopteris zeilleri* RAGOT, which also characterizes the same interval at Amézola. Further remains include *Callipteridium (Eucallipteridium) striatum* WAGNER, *Dicksonites pluckeneti* (VON SCHLOTHEIM), *Polymorphopteris polymorpha* (BRONGNIART), *Pecopteris arborescens* (VON SCHLOTHEIM), *P. ameromi* STOCKMANS & WILLIÈRE, *P.* sp. (cf. *lepidorachis* BRONGNIART), *P.* sp. div., *Sphenophyllum oblongifolium* (GERMAR & KAULFUSS), *S. costei* STERZEL, *Annularia stellata* (VON SCHLOTHEIM), *A. sphenophylloides* (ZENKER), etc. (loc.2077, 2078, 2079, 2080, 2082, 2083, 2084, 2085, 2086).

Above the seat-earth at 170 m a sandy sucession is found with a several metres thick unit of coarse sandstone with limestone pebbles and boulders. This unit is interpreted as the lateral equivalent of the sandstone/conglomerate horizon above the thick coal of Amézola, and probably marks the stratigraphic level of the river as represented in the reconstruction of text-fig. 11. A generally interfluvial facies with seat-earths and carbonaceous shales or thin coals returns after this relatively important interval of in-river deposit, and represents the local equivalent of the «Venas de Techo de Pastora» (Pastora rider seams). The thin seams present up to the level of 203 m may be the same as the rider seams of the Amézola area, but they are markedly thinner; thus conforming to the general pattern of diminishing coal formation eastwards away from the productive western part of the Ciñera-Matallana coalfield.

At 207.30 m above the base of the Pastora Formation south of Coladilla the formation ends with very silty mudstone (almost a dirty sandstone) with occasional plant remains. It forms the roof of a seat-earth which represents the top rider seam of the Pastora coal in the western part of the coalfield. Some *Anthraconaia* was found in the seat-earth.

The base of the succeeding Cascajo Formation is marked by the presence of *Leaia baentschiana* BEYRICH in a band which forms a reliable marker throughout the Ciñera-Matallana coalfield and its erosional outliers, and which indicates widespread flooding by a freshwater lake. The basal part of this *Leaia* Band in the section south of Coladilla is very sandy and probably represents the reworking of the preceding deposit of very silty mudstone. The most characteristic part of this band is formed by thinly bedded, dark grey shales with abundant valves of *Leaia* and occasional drifted plant remains (e.g. *Neuropteris* cf. *auriculata* BRONGNIART). This lacustrine shale deposit forms the base of a coarsening upwards sequence, over a hundred metres thick (Cascajo Formation), which broadly resembles the Tabliza Horizon lower down the succession. In the earlier part of the formation, up to 249 m in the section, silty shales predominate. *Leaia* and *Anthraconauta* are found at a level 6 m above the first *Leaia* Band, and rare *Leaia* is encountered again at some 222 m above the base of the section, a find which is repeated at 231 m. Very thin, rippled and ripple cross-laminated siltstone layers are found intercalated with the silty shales. Higher up in the succession, siltstones and sandstones are predominant. They are often ripplemarked and ripple cross-laminated and the sandstones may show planar cross bedding. Occasional silty shales with rare shell remains (mainly *Anthraconauta* but sometimes *Anthraconaia*) show the persistence of lacustrine conditions, even though the lake was progressively filled in by coarser deposits, presumably from a fluviatile source. The final infilling is marked by rootlets leading up to the seat-earth of carbonaceous shales at 312 m, which is regarded as the basal deposit of the Roguera Formation. Although the infilling of the lake may have reached its final stage at slightly different times in different parts of the general area, the general pattern of infilling and the level at which *in situ* vegetation was first established appear to have been similar throughout the area. The establishment of *in situ* vegetation on the former site of the Cascajo lake can therefore be used as a marker horizon separating different formations.

Lacustrine conditions did not permanently cease with the first *in situ* vegetation however, and a recurrence of lacustrine facies is noted with the roof shales of the carbonaceous shale band at 312 m, which contain *Anthraconauta*. These shales are at the base of a coarsening upwards sequence, through siltstone and sandstone to a seat-earth with 6 cm of dirty coal. Plant-bearing roof shales above this coal smut form the basal deposit of another coarsening upwards sequence, which is succeeded by three additional ones before the Nieves coal seam (20 cm thick) is reached.

The roof shales of the Nieves Seam and those above small rider coals contain a floral assemblage characterized by *Alethopteris bohemica* FRANKE and *Neuropteris ovata* var. *grand'euryi* WAGNER (loc.2092). Well preserved examples of fossil flora are commonly found in the vicinity of the Nieves (or Roguera) Seam, and *Alethopteris bohemica* is almost invariably present. For the additional flora see page 422.

A sandstone with drifted tree trunks occurs above the coal horizon of the Nieves Seam. Very silty mudstones alternate with thick sandstones in a succession which terminates at 362 m with 6 cm of dirty coal. The latter is overlain by shales with *Anthraconauta* and some *Leaia* at the base of coarsening upwards sequences culminating in seat-earth and coal (3 cm) at the top of a sandstone. Roof-shales with *Annularia stellata* (VON SCHLOTHEIM) (loc.2095) mark the base of another succession of coarsening upwards sequences leading into a complex of thin coals which represent Seam No.5 of the San José Formation. The first coal in this complex (23 cm thick) shows plant-bearing roof shales with *Neuropteris ovata* var. *grand'euryi* WAGNER, *Callipteridium striatum* WAGNER, «*Validopteris*» sp. (*sensu* STOCKMANS & MATHIEU), *Pecopteris* sp. and *Lepidophyllum triangulare* ZEILLER (loc.2096). The shales immediately above the whole complex of thin coals show the usual, lacustrine facies of the roof shales of San José Seam 5, and yield abundant ostracodes *(Carbonita)* and lamellibranchs *(Anthraconauta)*. This seam is found throughout the Ciñera-Matallana coalfield, even when the higher seams of the San José Formation are missing (the latter are wedging northwards and cannot always be recognized). It thus forms a suitable marker which has been used as a formational boundary.

Section on the eastern slope of Tabliza Valley.

A representative section through the San José Formation has been measured in the northern flank of the Llombera Syncline, on the eastern slope of the Tabliza Valley, at 900 m NE of the village of Llombera. In this section (text-fig. 18) a «standard» development of this formation is recorded for the southern part of the Ciñera-Matallana coalfield. The stable reference in this section is formed by the roof shales with characteristic flora of San José Seam No. 1, which has been taken as the starting point «O» for the thickness in metres, measured downwards.

No clear separation is observed between the Cascajo and Roguera formations in this section. The latter shows an almost complete absence of coal or carbonaceous shale with associated seat-earths, and no clear change in facies from lacustrine to *in situ* vegetation is recorded. However, it is likely that the lacustrine shale with *Anthraconauta* at the base of the figured section represents a high part of the Cascajo Formation, and that the transition from lacustrine to a more fluviatile environment is formed by the sandstones with drifted plant remains at *ca.*150 m in the section. Mainly fluviatile sandstones, belonging to the Roguera Formation, are recorded up to 110 m, where the first signs of seat-earth with a little carbonaceous shale are found. Occasional rootlets with another layer of carbonaceous shale are found at *ca.*105 m below San José 1. Near these two layers of carbonaceous shales a horizon of *Calamites* in growth position occurs (WAGNER *in* WAGNER & ARTIEDA 1970, Fig.22-A), and at this level also a trunk of *Sigillaria* has been encountered in upright position (*op.cit.*, Fig.22-B).

Fluviatile sandstones predominate in the remainder of the Roguera Formation which is terminated at the horizon of the seat-earth of Seam 5 of the San José coals. Seam 5 is commonly developed with a parting between two veins in this part of the coalfield. In this section it is overlain by a fluviatile sandstone with drifted tree trunks which have sometimes left traces of coal. The long interval between seams 5 and 4 contains three coal smuts, two of which show the presence of *Anthraconauta* and *Carbonita* in roof shales. Eastwards along the strike, in the same general area, *Leaia* has also been found associated. The presence of thin coals with lacustrine roof shales in the interval between San José seams 5 and 4 is a constant feature throughout most of the southern and central parts of the Ciñera-Matallana coalfield, and these horizons have been used as local marker bands. There is some indication of coarsening upwards sequences in the interval containing the thin coals, even though these sequences are not as clearly developed here as in the Roguera Formation south of Coladilla (text-fig.17).

San José Seam No.4 is usually the thickest seam among the thin coals of the San José Formation. From its plant-bearing roof shales the following species were obtained (loc.1964): *Sphenopteris (Oligocarpia) grigorievi* (ZALESSKY & TCHIRKOVA), *Sphenopteris* sp.

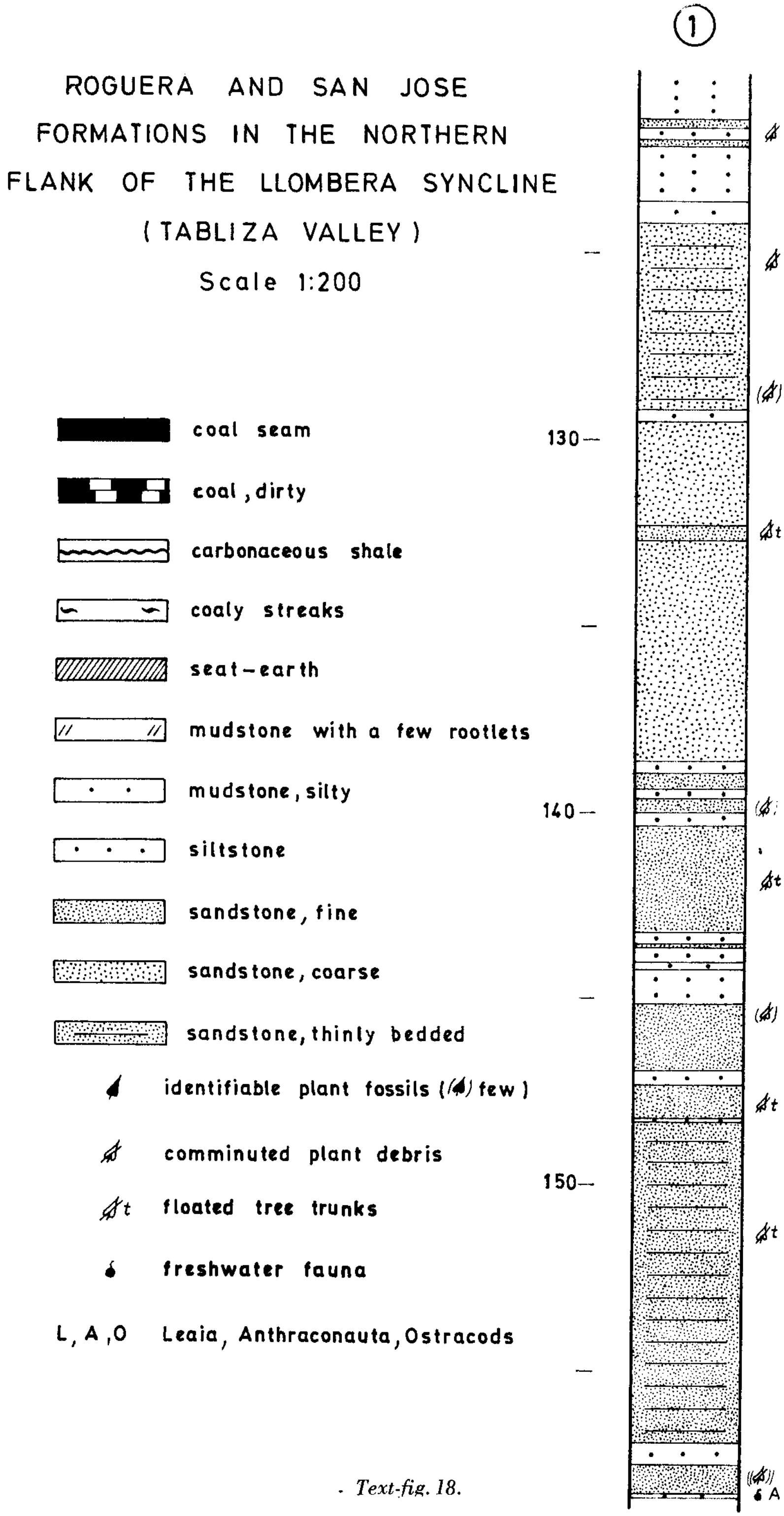
Alternating sandstones, silty and very silty mudstones, and coals with seat-earths constitute the succession incorporating seams 3, 2 and 1. They all possess plant-bearing roof shales. The floral assemblage above Seam 1 is particularly characteristic and can be recognized throughout most of the coalfield. In the section of text-fig.18 the following species were recorded (loc.1958): *Alethopteris leonensis* WAGNER, *Pecopteris* sp., *Sphenophyllum oblongifolium* (GERMAR & KAULFUSS), *Annularia stellata* (VON SCHLOTHEIM). Thin coals continue to be found above San José Seam 1, but the floral assemblage of the latter forms a reliable marker which has been used as a formational boundary.

DISTRIBUTION OF FOSSIL FLORA

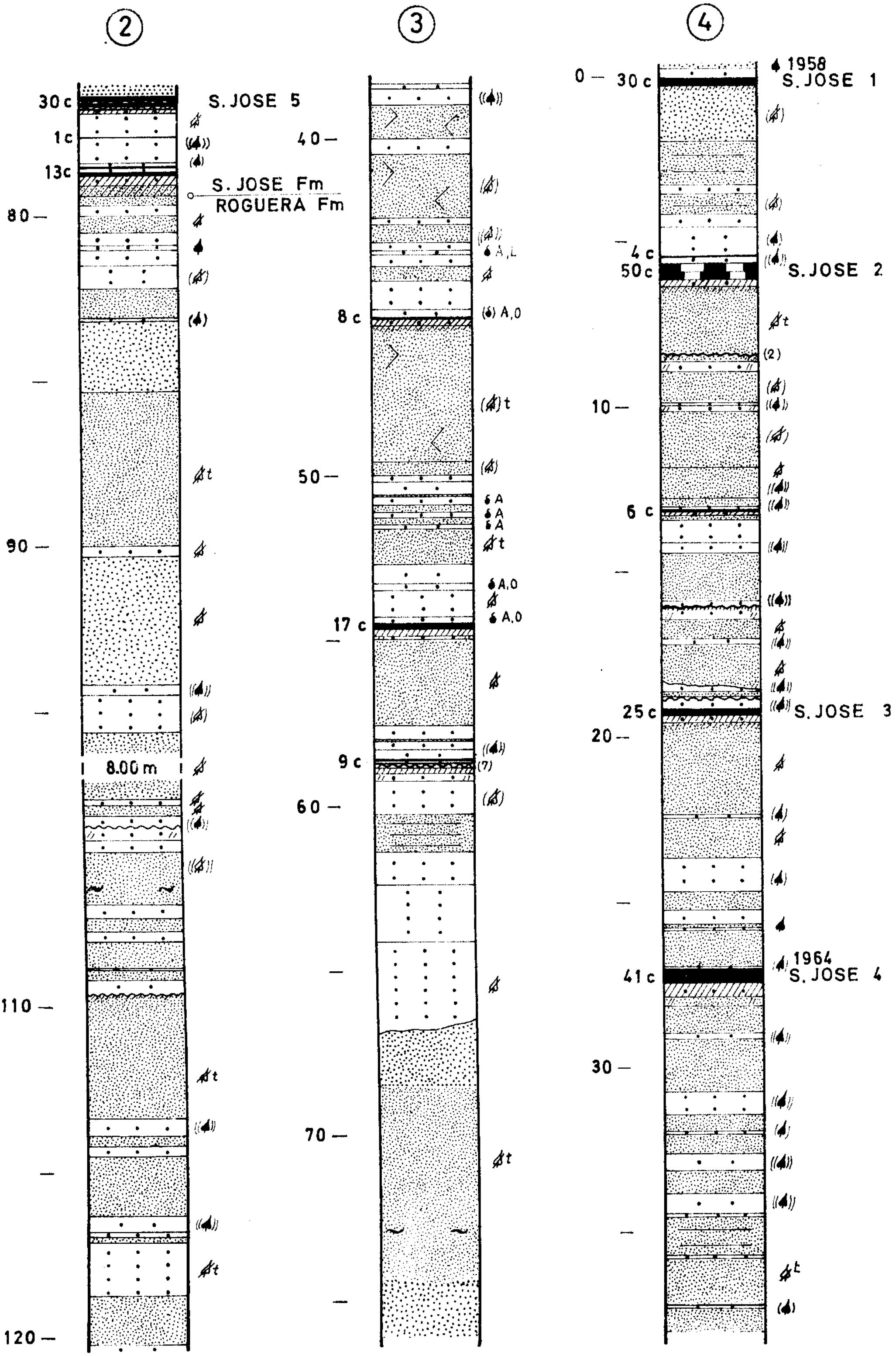
Although plant fossils abound in the Ciñera-Matallana coalfield, only one specimen (representing *Asterophyllites equisetiformis* (VON SCHLOTHEIM) — RUIZ FALCÓ & MADARIAGA 1932, lám. VI, fig. 1) was figured prior to the illustrations provided by GÓMEZ DE LLARENA (1950, láms XVII-XXI). A systematic description of the fossil flora was initiated by the writer in 1963, and continued in 1964[a] and 1965. Further illustrations appeared in WAGNER (1964[b], 1966), STOCKMANS & WILLIÈRE (1966), VAN AMEROM (1967), and WAGNER & ARTIEDA (1970).

There is little difference in age between the floras sampled in the lower and upper parts of the succession in the Ciñera-Matallana coalfield which, apparently, belongs entirely to the Stephanian B. Indications for late Stephanian B appear with the sporadic occurrence of *Sphenophyllum thoni* var. *minor* STERZEL in the San José, Bienvenidas and Matallana formations, and *Pecopteris integra* ANDRAE in the Matallana Formation. Probably, a substantial part of Stephanian B is represented, with only the basal and top parts of this stage (or substage) missing.

The composition of the Stephanian B flora in the Ciñera-Matallana coalfield is somewhat different from that in the classic Stephanian B areas of central France, even though a large number of species are identical. A recent paper by DOUBINGER & VETTER (1969) lists 98 species from the Stephanian B of Decazeville (zone d'Aubin),


ROGUERA AND SAN JOSE FORMATIONS IN THE NORTHERN FLANK OF THE LLOMBERA SYNCLINE (TABLIZA VALLEY)
Scale 1:200
coal seam
coal, dirty
carbonaceous shale
coaly streaks
seat-earth
mudstone with a few rootlets
mudstone, silty
siltstone
sandstone, fine
sandstone, coarse
sandstone, thinly bedded
identifiable plant fossils (few)
comminuted plant debris
floated tree trunks
freshwater fauna
L, A, O Leaia, Anthraconauta, Ostracods
1
130
140
150
t
A

Text-fig. 18.


2
3
4
S. JOSE 5
S. JOSE Fm
ROGUERA Fm
30 c
1 c
13c
80
90
8.00 m
110
120
40
50
60
70
8 c
17 c
9 c
A, L
A, O
A
t
(7)
0
10
20
30
4 c
50 c
6 c
25 c
41 c
1958
S. JOSE 1
S. JOSE 2
S. JOSE 3
1964
S. JOSE 4
(2)

and 44 species from that of Carmaux (zone floristique de Tronquié), with a combined total of 108 species. This represents a range covering all of Stephanian B and is therefore more complete than that represented in the Ciñera-Matallana coalfield where the earliest and latest Stephanian B may be missing. Even so, 100 species are listed for Ciñera-Matallana in Table I, and this fails to include an estimated 20 species of *Pecopteris* and *Sphenopteris* which have not yet been identified and which probably represent in part new species. It may well be that the Stephanian B flora of NW Spain is richer in species than that of central France; an impression which is forcibly strengthened by taking into account additional Stephanian B floras from different coalfields in NW Spain (compare WAGNER 1964 [b], Tables IV and V).

The exhaustively sampled floras of Decazeville and Carmaux represent a collection of some 15,000 to 20,000 specimens, whereas the collection from Ciñera-Matallana is probably not in excess of 8,000 specimens. Although both collections are large enough to provide an adequate representation of the fossil flora, there is a possibility that the size of the Decazeville/Carmaux collection has allowed a larger number of extremely rare species to be recorded. Within this category fall two bryophytes found in the zone d'Aubin of Decazeville, and a number of lycophytes.

The general distribution of floral elements in Decazeville and Carmaux is as follows: bryophytes 3, lycophytes 15, sphenophytes 17, ferns 36, seed ferns 29, other gymnospermic plants 8. This will be compared with the floral composition in Ciñera-Matallana: lycophytes 8, sphenophytes 15, ferns 51 (with probably at least another 20 species unidentified), seed ferns 23, other gymnosperms 3. It follows that the ferns (*Pecopteris* s.l., *Sphenopteris* s.l.) are more varied in Ciñera-Matallana, whilst the seed ferns comprise relatively more species in Decazeville and Carmaux. The sphenophytes are almost equally varied in both areas and, in fact, virtually the same species occur in Ciñera-Matallana and in Decazeville/Carmaux (a correspondence which is found to be even closer than that suggested by the lists published, after the probable effects of synonymy have been taken into account). The lycophytes and gymnosperms appear to be more varied in species in Decazeville and Carmaux. However, most of the lycophyte species are extremely rare and thus likely to be represented more readily in the larger collections (i.e. in Decazeville/Carmaux). Apart from *Sigillaria brardi* BRONGNIART, which is reasonably common in both areas, it may be that the number of lycophyte individuals is greater in Ciñera-Matallana than it is in Decazeville/Carmaux. Whereas lycophytes are generally rare in Decazeville/Carmaux, a certain species of *Lepidodendron* is fairly common in Ciñera-Matallana (i.e. *L.* cf. *scutatum* LESQUEREUX). With regard to the gymnosperms, it should be noted that the various species of *Cordaites* have been identified in Decazeville, whereas no such effort was made in Ciñera-Matallana. Even so, this group may be a little more varied and common in the Decazeville/Carmaux area.

The most striking difference is that which involves the ferns and seed ferns. The flora of Ciñera-Matallana contains a number of ferns (e.g. *Oligocarpia grigorievi* (ZALESSKY & TCHIRKOVA) and *Sphenopteris rossica* ZALESSKY) which have not been recorded in central France and which have been described from paralic basins like the Donbass in Russia. The pecopterid ferns also show links with areas further afield than central France, and it seems likely that the migration routes for these elements were more generally open in the area of NW Spain. On the other hand, a number of species of seed ferns appear to be better represented in central France, both with regard to species and to the relative number of specimens. Important differences stand out. In Ciñera-Matallana the species *Neuropteris ovata* HOFFMANN (var. *grand'euryi* WAGNER) is ubiquitous and probably the most common element of fossil flora. The *N. ovata* group is only represented by *Mixoneura neuropteroides* GOEPPERT in Decazeville, and this is a rare species. Most of the other neuropterids, generally not too uncommon in Decazeville, are found only sporadically in Ciñera-Matallana, and some species only occur in one of the two areas. Among the closely allied odontopterids, the well known species, *O. subcrenulata* (ROST), does not occur in NW Spain where, on the other hand, the local species *Mixoneura matallanae* WAGNER is found.

The stated differences between the Stephanian B floras of central France and those of NW Spain (as exemplified by that of Ciñera-Matallana) are probably due to palaeogeographic considerations. It is likely that the Stephanian B deposits in NW Spain were formed in a large basin at the foot of a mountainous area and near the coast, whereas the Stephanian B of central France originated mainly in local intramontane basins. The latter would therefore show a larger proportion of floral elements of the drier hill slope habitat (*Cordaites*, certain seed ferns, etc.), whereas the coastal basin in NW Spain would show a preponderance of lowland ferns and certain, different, seed ferns (such as *Neuropteris ovata*). The hill slope habitat is represented in the Stephanian B flora of Ciñera-Matallana (e.g.*Taeniopteris jejunata* GRAND'EURY, *Neuropteris auriculata* BRONGNIART, *Neuropteris gallica* ZEILLER, *Reticulopteris germari* (GIEBEL), *Odontopteris genuina* GRAND'EURY, etc.), but it appears to be relatively unimportant, and certainly less important than it is in the coalfields of central France. The great variety of ferns in the Stephanian B of NW Spain should eventually aid in comparing with the contemporaneous floras of North America and of the Donbass in Russia. Such a comparison might well be more difficult, if it centered on the Stephanian B flora of central France, where endemic species may have existed, and where a number of elements may not have penetrated due to its palaeogeographically more isolated position.

It has already been noted that the Stephanian B flora of Ciñera-Matallana does not show much change from the San Francisco Formation at the base of the succession to the Matallana Formation at the top. However, certain species and assemblages appear to characterize particular horizons and beds in the succession. Throughout the Pastora Formation, and particularly at the horizon of the «Ancha de Pastora» Seam, the presence of *Alethopteris zeilleri* RAGOT is so common as to constitute a marker which is not absolute, but a good indication. This species is commonly associated with *Odontopteris brardi* BRONGNIART, *Callipteridium (Eucallipteridium) striatum* WAGNER and *Dicksonites pluckeneti* (VON SCHLOTHEIM). None of these species is restricted to this horizon, but facies conditions were probably such as to favour the development of this assemblage which may therefore be used locally as an aid in stratigraphic correlation.

Another important horizon floristically is that of the Nieves (Roguera) Seam. Only a few metres below this seam, near the base of the Roguera Formation, the first

Table I.—Stratigraphic distribution of fossil plant species in the Ciñera-Matallana coalfield (successive formations are stated with the exception of the Cascajo Formation which is virtually devoid of plant fossils).

	FORMATIONS					
	S. Fran.	Past.	Rog.	S. José	Bienv.	Mat.
Neuropteris auriculata BRONGNIART		x		x		
Neuropteris cf. *eveni* LESQUEREUX					x	
Neuropteris gallica ZEILLER	x	x		x	x	
Neuropteris ovata var. *grand'euryi* WAGNER	x	x	x	x	x	x
Neuropteris cf. *praedentata* GOTHAN	x			x	x	
Neuropteris sp. (cf. *zeilleri* DE LIMA)		x				
Mixoneura matallanae WAGNER				x	x	
Mixoneura raymondi (ZEILLER)	x					
Mixoneura sp.nov.		x				
Reticulopteris germari (GIEBEL)				x		
Linopteris neuropteroides (VON GUTBIER)	x	x	x	x	x	
L. neuropteroides var. *latenervosa* TEIXEIRA			x	x		
Odontopteris brardi BRONGNIART	x	x		x	x	
Odontopteris genuina GRAND'EURY					x	
Callipteridium gigas (VON GUTBIER)	x	x		x	x	
Callipteridium cf. *pseudogigas* WAGNER		x				
Callipteridium striatum WAGNER	x	x	x	x	x	
Callipteridium zeilleri WAGNER		x		x		x
Alethopteris bohemica FRANKE	x	x	x	x	x	x
Alethopteris leonensis WAGNER	x			x	x	x
Alethopteris zeilleri RAGOT	x	x			x	
Pseudomariopteris ribeyroni (ZEILLER)	x	x		x	x	
Dicksonites pluckeneti (VON SCHLOTHEIM)	x	x		x	x	
Alloiopteris sp.	x				x	
Sphenopteris beyschlagi H. POTONIÉ		x			x	
Sphenopteris cremeriana H. POTONIÉ	x					
Sphenopteris decorpsi ZEILLER					x	
Sphenopteris dimorpha (LESQUEREUX)			x			
Sphenopteris elaverica (ZEILLER)		x				
Sphenopteris fayoli ZEILLER					x	
Sphenopteris cf. *fossorum* ZEILLER	x					
Sphenopteris goniopteroides LESQUEREUX	x			x		
Sphenopteris matheti ZEILLER				x	x	
Sphenopteris cf. *neuropteroides* (BOULAY)		x				
Sphenopteris cf. *pisana* DE STEFANI				x		
Sphenopteris rossica ZALESSKY				x		
Sphenopteris rotundiloba NĚMEJC	x		x	x		
Sphenopteris rutaefolia VON GUTBIER				x		
Sphenopteris spp.		x		x	x	
Oligocarpia grigorievi (ZALESSKY & TCHIRKOVA)		?	x	x	x	x
Lobatopteris corsini WAGNER				x	x	
Lobatopteris serpentigera WAGNER				x		
Lobatopteris viannae (TEIXEIRA)		x		x	x	
Polymorphopteris cf. *cistii* (BRONGNIART)				x		
Polymorphopteris multifurcata WAGNER		x				
Polymorphopteris oblongifolia (FONTAINE & WHITE)	x					

	FORMATIONS					
	S. Fran.	Past.	Rog.	S.José	Bienv.	Mat.
Polymorphopteris polymorpha (BRONGNIART)	x	x	x	x	x	x
Polymorphopteris pseudobucklandi (ANDRAE)				x		
Polymorphopteris subelegans (H. POTONIÉ)				x		
Polymorphopteris villablinensis WAGNER	x					
Pecopteris ameromi STOCKMANS & WILLIÈRE	x	x	x	x	x	
Pecopteris arborescens (VON SCHLOTHEIM)				x	x	
Pecopteris bredovi GERMAR	x		x			
Pecopteris cantabrica STOCKMANS & WILLIÈRE	x					
Pecopteris daubreei ZEILLER	x	x		x	x	
Pecopteris dentata BRONGNIART		x				
Pecopteris (Nemejcopteris) feminaeformis (VON SCHLOTHEIM)	x	x	x	x	x	x
Pecopteris hemitelioides BRONGNIART				x		
Pecopteris integra ANDRAE						x
Pecopteris jongmansi WAGNER	x		x		x	x
Pecopteris sp. nov. (cf. *lepidorachis* BRONGNIART).		x			x	
Pecopteris limai TEIXEIRA		x				
Pecopteris longiphylla CORSIN						x
Pecopteris major DOUBINGER					x	
Pecopteris melendezi WAGNER		x				
Pecopteris monyi ZEILLER	x				x	
Pecopteris paleacea ZEILLER		x		x		
Pecopteris permica NĚMEJC		x				
Pecopteris (Weissites) pinnatifida (VON GUTBIER)			x			
Pecopteris pseudointegra STOCKMANS & WILLIÈRE	x					
Pecopteris robustissima WAGNER					x	
Pecopteris unita BRONGNIART		x	x	x		
«*Validopteris*» sp. (*sensu* STOCKMANS & MATHIEU).				x	x	
Zygopteris cornuta ZEILLER			x			
Taeniopteris jejunata GRAND'EURY			x	x		x
Sphenophyllum alatifolium RENAULT		x				
Sphenophyllum costae STERZEL	x	x			x	x
Sphenophyllum incisum WAGNER	x	x			x	x
Sphenophyllum longifolium GERMAR			x	x	x	
Sphenophyllum oblongifolium (GERMAR & KAULFUSS)	x	x	x	x	x	x
Sphenophyllum thoni var. *minor* STERZEL				x	x	x
Sphenophyllum verticillatum (VON SCHLOTHEIM)			x			
Annularia sphenophylloides (ZENKER)	x	x	x	x	x	x
Annularia stellata (VON SCHLOTHEIM)	x	x	x	x	x	x
Asterophyllites dumasi ZEILLER						x
Asterophyllites equisetiformis (VON SCHLOTHEIM).	x	x	x	x		
Calamostachys tuberculata (STERNBERG)	x					
Macrostachya infundibuliformis (BRONGNIART)				x		
Calamites suckowi BRONGNIART				x		
Calamites sp.	x	x	x	x	x	x
Lepidodendron cf. *scutatum* LESQUEREUX		x	x	x		
Lepidostrobus sp.	x		x	x		
Lepidophyllum triangulare ZEILLER		x	x	x		
Lepidophloios dessorti ZEILLER					x	

	FORMATIONS					
	S. Fran.	Past.	Rog.	S. José.	Bienv.	Mat.
Bothrodendron ? sp.				x		
Sigillaria brardi BRONGNIART		x	x	x	x	
Sigillaria ovata SAUVEUR		x				
Sigillariostrobus sp.				x		
Poacordaites sp.		x	x		x	
Cordaites sp.			x	x	x	
Semina	x	x	x	x	x	x

occurrence of *Taeniopteris jejunata* GRAND'EURY and *Sphenopteris (Oligocarpia) grigorievi* (ZALESSKY & TCHIRKOVA) is recorded. Probably the stratigraphic importance of this event should not be exaggerated. *Taeniopteris jejunata* may be a hill slope element with strong facies connotations (see comments in WAGNER & WINKLER PRINS 1970, p.505), and *Oligocarpia grigorievi* may have been encountered sporadically in earlier formations of the Ciñera-Matallana coalfield. However, from the Roguera Formation upwards, it becomes a relatively common element of the flora. In the vicinity of the Nieves Seam it is usual to find specimens of *Alethopteris bohemica* FRANKE, which is particularly common at this horizon. The full stratigraphic range of this species is from basal Stephanian (Cantabrian) to late Stephanian B, and its characteristic occurrence near the Nieves Seam is probably to be explained again by considerations of habitat. The fossil flora near the Nieves Seam is generally very rich and varied, with abundant *Neuropteris ovata* HOFFMANN, *Alethopteris bohemica* and *Oligocarpia grigorievi* being accompanied by less common *Sphenopteris rotundiloba* NĚMEJC, *Sphenopteris dimorpha* (LESQUEREUX), varied pecopterids, *Sphenophyllum oblongifolium* (GERMAR & KAULFUSS), *Annularia stellata* (VON SCHLOTHEIM), etc.

A very characteristic floral assemblage has been found in the roof of San José No.1 Seam (or «Estrecha de San José»). It can be recognized throughout the southern and central parts of the Ciñera-Matallana coalfield, and it has proved its worth as a marker band which has been used successfully as a formational boundary. Evidently, the same floral habitat was developed at this horizon throughout most of the coalfield, and the fossil assemblage reflects this habitat. The total assemblage is quite varied, but the following species characterize the horizon in the roof of San José 1: *Neuropteris ovata* var. *grand'euryi* WAGNER, *Neuropteris* cf. *praedentata* GOTHAN, *Mixoneura matallanae* WAGNER, *Callipteridium (Eucallipteridium) zeilleri* WAGNER, *Alethopteris leonensis* WAGNER, *Sphenopteris rossica* ZALESSKY, *Oligocarpia grigorievi* (ZALESSKY & TCHIRKOVA), *Polymorphopteris polymorpha* (BRONGNIART), *Pecopteris ameromi* STOCKMANS & WILLIÈRE, «*Validopteris*» sp. (*sensu* STOCKMANS & MATHIEU, *non* P. BERTRAND), *Sphenophyllum oblongifolium* (GERMAR & KAULFUSS). The constant presence of *Alethopteris leonensis* at this horizon is particularly noteworthy, for this species is rarely found elsewhere in the Ciñera-Matallana coalfield.

In the higher part of the succession only the Bisvita Seam in the Bienvenidas Formation shows consistently a well preserved flora in its roof shales. Again, there is a rich and varied assemblage at this horizon (the many specimens figured from loc.1733 —WAGNER & ARTIEDA 1970, Atlas Paleontológico— came from the Bisvita Seam), but the presence of *Sphenophyllum thoni* var. *minor* STERZEL may be regarded as characteristic. A full list of species from the Bisvita Seam in loc.1733 includes: *Neuropteris* cf. *praedentata* GOTHAN, *N.* cf. *eveni* LESQUEREUX, *Mixoneura matallanae* WAGNER, *Odontopteris brardi* BRONGNIART, *O.genuina* GRAND'EURY, *Alethopteris leonensis* WAGNER, *Pseudomariopteris ribeyroni* (ZEILLER), *Dicksonites pluckeneti* (VON SCHLOTHEIM), *Alloiopteris* sp., *Sphenopteris decorpsi* ZEILLER, *S. fayoli* ZEILLER, *S. matheti* ZEILLER, *S.* sp., Aphlebiae, *Lobatopteris viannae* (TEIXEIRA), *Polymorphopteris polymorpha* (BRONGNIART), *Pecopteris arborescens* (VON SCHLOTHEIM), *P. daubreei* ZEILLER, *P. (Nemejcopteris) feminaeformis* (VON SCHLOTHEIM), *P. jongmansi* WAGNER, *P. major* DOUBINGER, *P. monyi* ZEILLER, *P. robustissima* WAGNER, *P. unita* BRONGNIART, «*Validopteris*» sp. (*sensu* STOCKMANS & MATHIEU), *Sphenophyllum oblongifolium* (GERMAR & KAULFUSS), *S. thoni* var. *minor* STERZEL, *Annularia stellata* (VON SCHLOTHEIM), *A. sphenophylloides* (ZENKER), *Calamites* sp., etc. A number of species, particularly of the *Pecopteris* group, are still unidentified.

The use of floral facies assemblages at certain horizons in the Ciñera-Matallana coalfield has been fairly successful, and it is to be expected that further horizons with distinctive floral assemblages may be found in the course of the investigation which is still in progress. A number of species are still to be identified, and additional stratigraphic sections to be examined.

Table II.—Stratigraphic distribution of fauna in the Ciñera-Matallana coalfield.

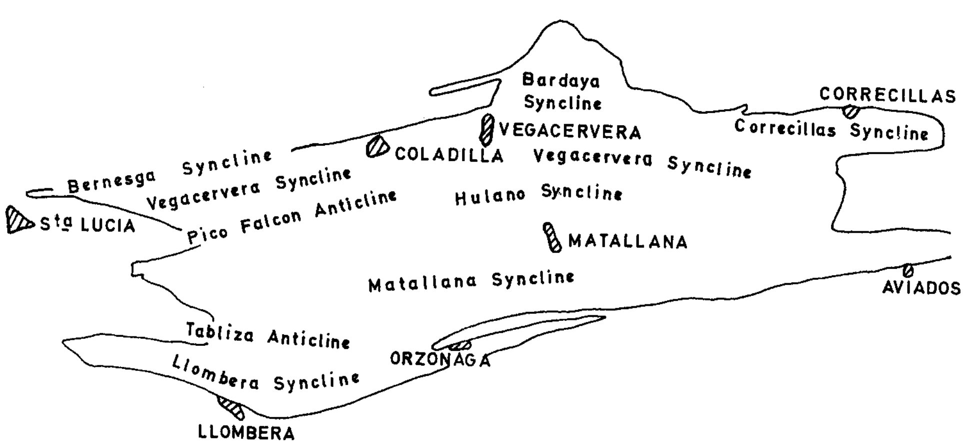
	FORMATIONS						
	S. Fran.	Past.	Casc.	Rog.	S. José	Bienv.	Mat.
Leaia baentschiana BEYRICH		x	x	x	x		
«*Estheria*» *tenella* GOLDENBERG		x	x		x		
Arthropleura sp.					x		
Euphoberia llarenae MELÉNDEZ	near Llombera (after GÓMEZ DE LLARENA 1950)						
Carbonita sp.	x	x	x	x	x	x	x
Anthraconauta phillipsii (WILLIAMSON)				x			x
Anthraconauta cf. *wrighti* DIX & TRUEMAN			x				x
Anthraconauta cf. *tenuis* DAVIES & TRUEMAN			x		x		x
Anthraconauta sp.	x	x	x		x	x	
Anthraconaia prolifera (WATERLOT) s. l.			x				
Anthraconaia aff. *puella* (WATERLOT)		x					
Anthraconaia aff. *pruvosti* (TCHERNYCHEV)				x			
Anthraconaia spp.		x		x			

N. B.—Lamellibranch identifications after EAGAR & WEIR 1971.

The borders of the Ciñera-Matallana coalfield are determined by its tectonic structure which consists of E-W striking synclines and anticlines, together forming a synclinorium in the central part of the coalfield (see text-figs 1, 20). In the western part of the area a greater degree of independence of the individual synclines and anticlines is observed (text-figs 1, 21). Several outliers north and west of the coalfield represent depressions of the synclinal axes of folds occurring also in the main area of Ciñera-Matallana. Plunges are usually of the order of 15° to 25°, if not less. The steeply dipping axial planes are usually inclined a little to the south, and the main folding pressure seems to have come from that direction.

In the flanks of the major folds small accessory synclines and anticlines are usually developed. These minor folds are mapped as slight inflexions of the strike which, subsequently, develop into small accessory synclines and anticlines with small thrusts developing near the anticlinal crests. These thrusts decrease in importance downwards and are clearly related to the folding which is much tighter in the higher parts of the tectonic structure. The style of folding and thrusting is obviously superficial and the already folded and faulted «basement rocks» (i.e the Cambrian to Namurian strata formed before the Asturian folding phase) are not affected to the same extent as the Stephanian B rocks.

A basic intrusive rock (diabase according to J. González Prado, *in* Wagner & Artieda 1970, pp.76-79) has been found as dykes cutting through the Stephanian B strata in different parts of the coalfield. The intrusive activity is therefore to be regarded as later than the formation of the main tectonic structure. On the other hand, one small dyke (locally showing up as a sill) has been seen to participate in an anticlinal



Text-fig. 19.—Nomenclature of the principal fold structures in the Ciñera-Matallana coalfield.

fold NW of Orzonaga, which is an accessory fold on the southern limb of the Matallana Syncline. This suggests that the intrusion took place *during* the folding phase responsible for the tectonic structure of the Ciñera-Matallana coalfield, and before the tectonic movements had ceased.

The E-W striking folds and thrust faults are accompanied by probably rather late tectonic normal faults, also striking E-W, which invariably depressed the synclines with regard to the main anticlines. These normal faults are interpreted as being due, at least partly, to a relaxation of the folding pressure. One of the galleries of the San José coal mine, in preparation for working the Pastora Seam, cut through the normal fault on the northern limb of the Tabliza Anticline (text-fig.24) and found it to be gaping. This seems to confirm its tensional origin. There is an important concentration of normal faults in the southern part of the Ciñera Matallana coalfield (see Geological Map: text-fig.1). One of the most important of these faults runs along the southern border of the coalfield, where it often coincides or nearly coincides with a fairly important E-W striking thrust fault. The extremely tight folding along the southern border is probably associated with both thrusting and normal faulting within a fairly restricted area. More detailed mapping along this belt of highly disturbed strata will probably result in the same sequence of events being found as in the less strongly affected remainder of the Ciñera-Matallana coalfield.

Folds, thrusts and normal faults are all cut by relatively unimportant, mainly NNW-SSE striking transcurrent faults, with vertical and horizontal components. An increasing number of these faults has been found with the more detailed investigation of smaller areas.

Text-fig.19 shows the nomenclature of the principal fold structures in the Ciñera-Matallana coalfield.

A section through the central part of the coalfield, drawn immediately east of the Torío river (text-fig.20), shows a synclinorial structure centred on the Matallana Syncline which contains the most complete succession of strata. The northern part of this syncline has been folded into a number of accessory folds which developed westwards into more independent synclines and anticlines (text-figs 21, 22, 23 and 24). The anticlines in these accessory folds are generally eliminated, or partly eliminated by small thrust faults which decrease in importance downwards in the tectonic structure. The southern flank of the Matallana Syncline is affected by several normal faults, one of which appears to be fairly important, and which depressed the core of the syncline with respect to an anticline to the south where Devonian rocks of the pre-Asturian «basement» are found in contact with the San José Formation. Another normal fault limits this anticline southwards, where it effects a contact with probable Roguera? and San José strata. The southern boundary of the coalfield in the Matallana area (text-figs 1, 20) is delineated by a thrust fault which is particularly well developed further east, north of La Valcueva and in the vicinity of Aviados (see Map).

The sections of text-figs 21 and 23 show the greater degree of individualization of synclines and anticlines adjoining the Matallana Syncline in the western part of the coalfield. On both flanks of the Matallana Syncline small, accessory folds occur, and these are commonly affected by minor thrusting which, on the small scale, repeats parts of the stratigraphic succession (see text-fig.22). Normal faults, with only a limited amount of throw, occur associated with both the Tabliza and Pico Falcón anticlines (text-figs 22, 24). These faults tend to depress the synclines with regard to the anticlines which are assumed to have remained in their original position.

Minor structural complications are found in the area where the thick Pastora coal seam is developed. In the lower central part of the Matallana Syncline southeast of Santa Lucía a small asymmetric anticline developed within the thick coal which formed a disharmonic structure with regard to the upper part of the syncline. In fact, a complex of two synclines with an intervening anticline in the Pastora coal corresponds here to the more simply folded synclinal core of the Matallana Syncline in rocks of the Cascajo, Roguera and San José formations. The local accumulation of coal in the core of the accessory anticline is considerable and has given rise to a useful thickness for mining of up to 100 m coal. On a smaller scale the Pastora Seam is often less intensely folded at its base than it is at its roof which, due to the incompetence of the thick coal, quite commonly shows sharp folds, sometimes nearly isoclinal, with minor thrusts developed in the anticlinal crests for which the local miners employ the graphic term «cresta de gallo» (=cock's comb).

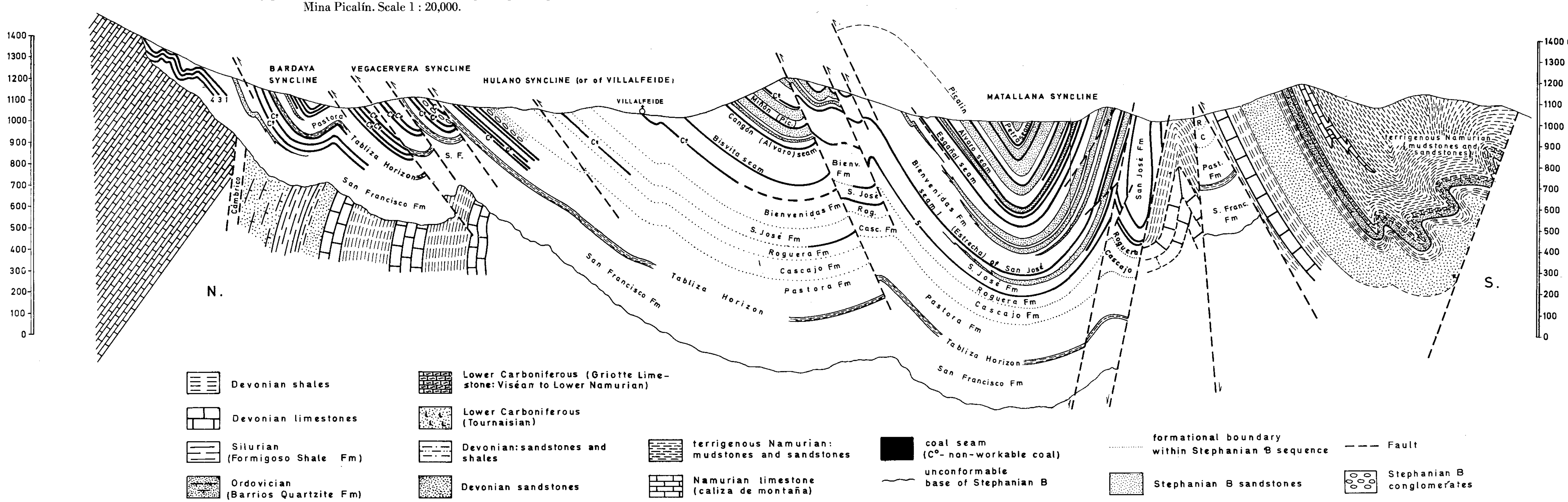
Differential compaction at the contact between the shale lens and the surrounding coal of the Pastora Seam (compare page 398) has locally produced an elongate dôme (or a string of elongate dômes) in the western part of the coalfield. The orientation of this compaction fold is NW-SE, thus forming an angle with the later tectonic fold structure trending E-W. The resultant small scale cross folding has not yet been mapped completely.

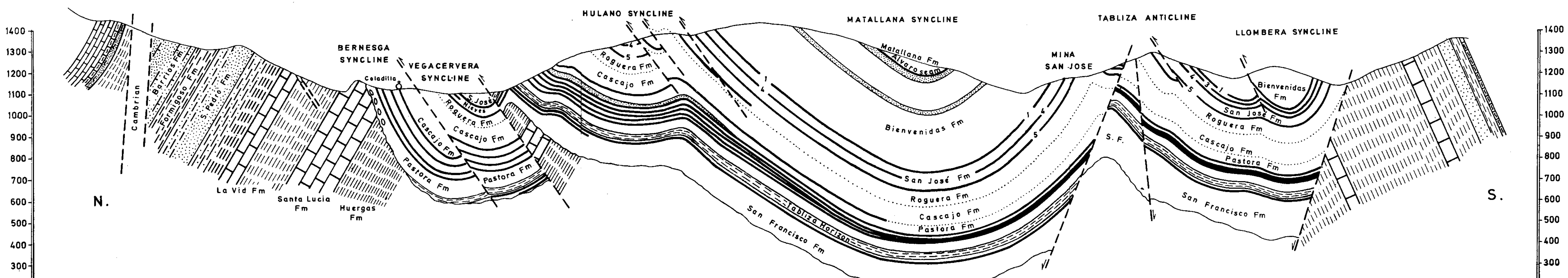
CONCLUSIONS

1. The seven formations recognized in the entirely non-marine succession of Stephanian B strata in the Ciñera-Matallana coalfield show the development of a sedimentary sequence which can be identified throughout the area investigated. Marker bands of various description have been found to aid local correlations, and these prove the widespread occurrence of certain facies at certain times in the coalfield. Valley fills at the base of the total succession show the presence of a marked topographic relief, with local differences of up to several hundred metres, at the time of formation of the initial deposits. The presence of a basin margin in the north-western part of the area could also be proved, and it seems likely that the basin of sedimentation gradually expanded north-westwards in the course of Stephanian B times.

2. Although thin coals are present in all the formations, with the exception of the lacustrine Cascajo Formation, it is only the thick coal of the Pastora Formation which is capable of sustaining a major mining operation (at the moment 90 % of the

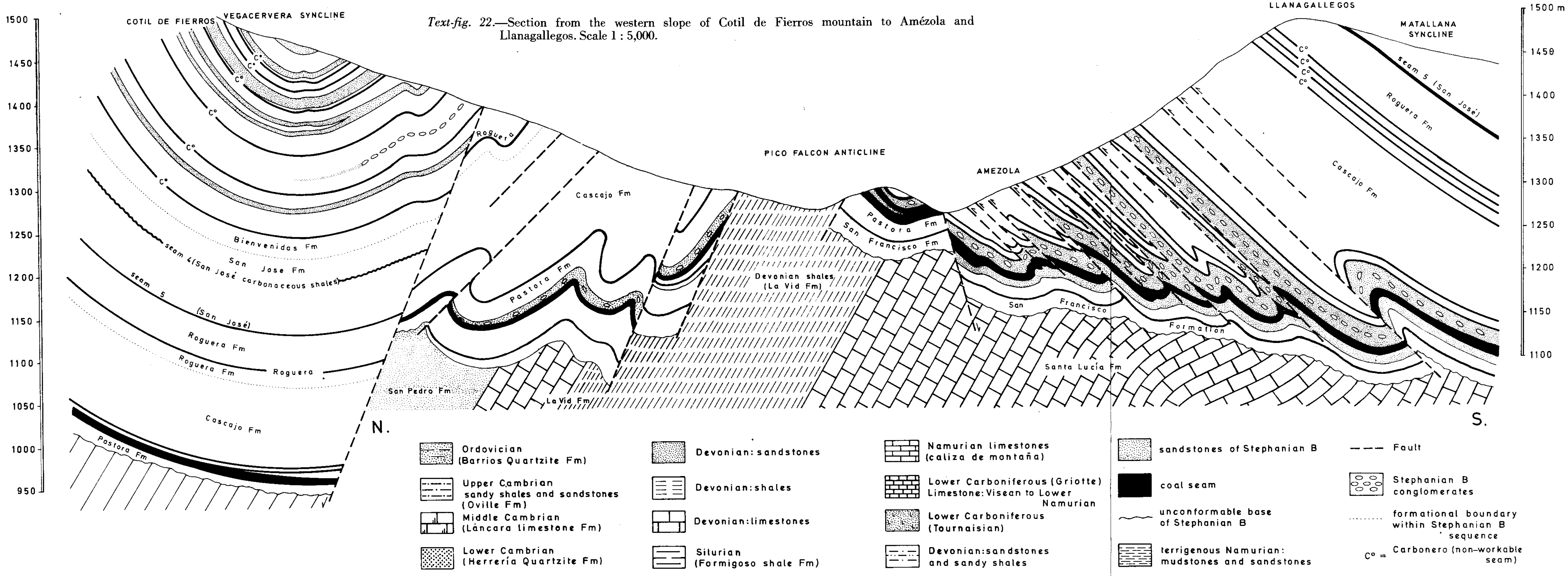
Text-fig. 20.—Section east of the Río Torío passing through Mina Bardaya and Pozo San Román of Mina Picalín. Scale 1 : 20,000.

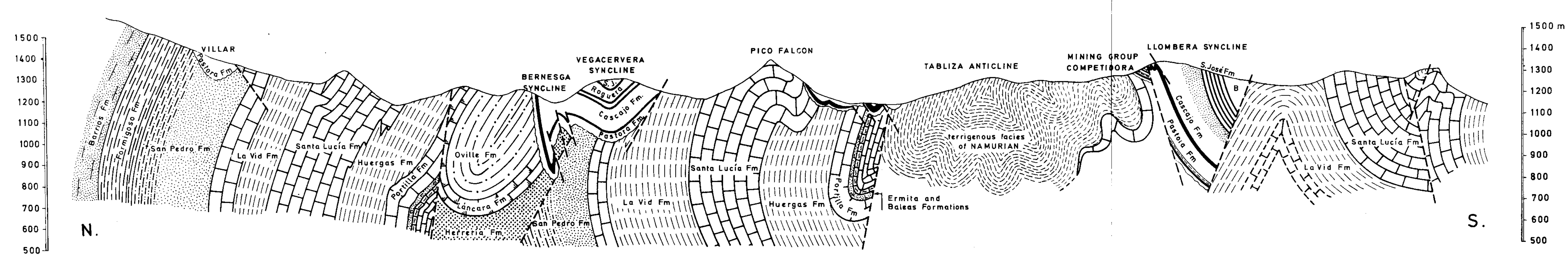




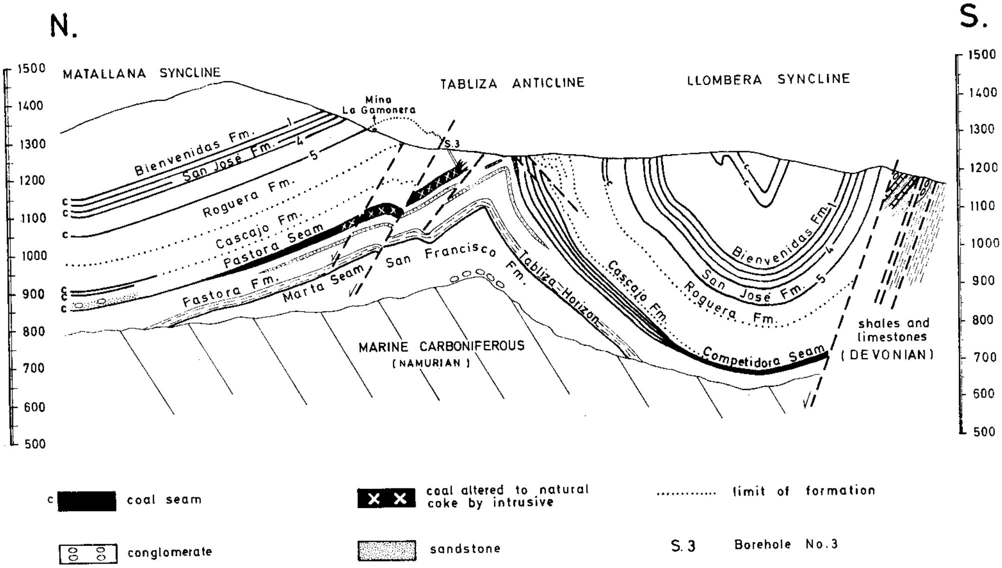
Text-fig. 21.—Section through Coladilla and Mina San José. Scale 1 : 20,000.

Text-fig. 22.—Section from the western slope of Cotil de Fierros mountain to Amézola and Llanagallegos. Scale 1 : 5,000.





Text-fig. 23.—Section passing through Pico Falcón and Competidora mining group. Scale 1 : 20,000.



Text-fig. 24.—Section through the valley of Tabliza. Scale 1 : 20.000.

production of the Ciñera-Matallana coalfield comes from this seam). A detailed stratigraphic investigation of the Pastora Formation has shown that special facies considerations control the occurrence of the thick coal of Pastora (text-figs 10, 11), thus limiting the area of working. Part of this area is eliminated by the presence of basic intrusive rock, cokefying and penetrating the coal. The main intrusion (sill) seems to have been halted by the shale lens forming a barrier between the two areas of productive coal, but further investigations will be necessary to establish whether this barrier has been effective at a greater depth of tectonic structure (i.e in the core of the Matallana Syncline).

3. The Stephanian B strata of the Ciñera-Matallana coalfield, up to about 1,500 m thick, have been folded into a synclinorium which splits into three major synclines in the western part of the coalfield (text-figs 1, 19). These folds are independent from the earlier folded «basement» consisting of fossiliferous Cambrian to Namurian strata in steeply dipping thrust slices and isoclinal folds which are totally unconformable with the overlying Stephanian B. The latter were folded in probably one folding phase with the following sequence of events: —(1) formation of E-W striking folds with an increasingly tight compression of the higher parts of the structure, and the axial planes dipping very steeply towards the south;—(2) intrusion of basic magmatic rock forming dykes and sills;—(3) formation of small accessory folds in the flanks of the major synclines and anticlines;—(4) small thrusts developing in the anticlinal crests and projecting downwards with increasing compression;—(5) relaxation of folding pressure and formation of E-W striking normal faults flanking the major anticlines;—(6) formation of NNW-SSE striking transcurrent faults with a limited amount of throw.

4. The evidence for a basin margin to the NW and the recognition of NW-SE facies belts in the Pastora Formation show that the E-W trending tectonic structure is independent from the sedimentary basin. The present-day limits of the Ciñera-Matallana coalfield are due to the tectonic structure and do not reflect the shape of the original basin. It is likely that the latter opened south-eastwards, and a link with the neighbouring Sabero coalfield, *ca.* 25 km to the east, may be expected (compare KNIGHT 1971).

5. An analysis of the varied fossil flora (see Table I) shows significant differences with the Stephanian B flora of central France, even though a large number of species are identical. The difference is mainly one of composition, a proportionately larger number of ferns being present in the Ciñera-Matallana region. Probably, the hill slope habitat is not quite as commonly represented in the Ciñera-Matallana flora as in that of central France. Also the comparatively richer flora of Ciñera-Matallana may have had easier access for migration than the Stephanian flora of central France. It is likely that the Stephanian B flora of Ciñera-Matallana lived in a coastal basin, whereas that of central France was in a more closely restricted intramontane environment.

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