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THE LOWER CARBONIFEROUS AND NAMURIAN ROCKS NORTH OF LA ROBLA (LEON)

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ABSTRACT

North of La Robla and east of the Río Bernesga a condensed sequence of Viséan limestones is followed by a thick succession of mudstones, siltstones and sandstones with a gradually increasing turbidite content, and thinly bedded limestones alternating with sandy deposits. These Namurian rocks represent the terrigenous basin facies, up to Namurian B in age, which replaces the carbonate facies of «caliza de montaña» present to the north. These rocks are preceded by a full succession of Devonian strata interrupted only by a disconformity below late Famennian to early Tournaisian deposits which are disconformable in turn with the Lower Viséan limestone.

The Namurian rocks are folded into a near-isoclinal syncline, the Alba Syncline, which shows several accessory folds, particularly in its northern flank. The outcrops in the Alba Synclinorium are represented on the map of text-fig. 1, and a detailed section through the main syncline is given by text-fig. 5. A more complete section through the Alba Synclinorium is continued northwards into the Ciñera-Matallana coalfield by text-fig. 6. Stratigraphic columns through the Lower Carboniferous and Namurian strata north of La Robla are provided by text-figs. 2-4.

RESUMEN

Al norte de La Robla y al este del Río Bernesga existe una sucesión condensada de calizas viseenses, yacente sobre areniscas y calizas de edad probablemente fameniense superior/tournaisiense inferior, con un contacto por disconformidad. A las calizas viseenses siguen concordantemente calizas y lutitas, limolitas/areniscas/lutitas, con una facies turbidítica cada vez más acusada, y calizas laminadas alternando con areniscas. Estos estratos namurienses representan la facies terrígena, relleno de cuenca, que reemplaza la «caliza de montaña» (hasta el Namuriense B inclusive) de los afloramientos más septentrionales de la provincia de León.

Los estratos namurienses al norte de La Robla están plegados en forma sinclinal, casi isoclinal y pertenecen al Sinclinorio de Alba que muestra varios pliegues relativamente pequeños en ambos flancos, aunque sobre todo en el flanco norte. Los afloramientos de rocas formando parte de este sinclinorio están señalados en el mapa de la Fig. 1, y un corte detallado del sinclinal principal lo da la Fig. 5. Por la Fig. 6 se representa un corte más completo, mostrando un Devónico casi completo en la rama norte, plegada, del sinclinorio, y llegando al Estefaniense B discordante de la cuenca hullera de Ciñera-Matallana. Las Figuras 2 a 4 representan cortes estratigráficos del Carbonífero inferior y Namuriense terrígeno en la zona al norte de La Robla.

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INTRODUCTION AND ACKNOWLEDGEMENTS

Geological mapping on behalf of the S. A. Hullera Vasco-Leonesa forms the basis of the information recorded in the present paper, and the writers are pleased to acknowledge their corresponding debt of gratitude. Some additional stratigraphic information was obtained privately by the first author. The writers are indebted to Mrs C. H. T. WAGNER-GENTIS for the initial mapping of the area between La Robla and the Ciñera-Matallana coalfield, but they accept full responsibility for the final results of the mapping which are based mainly on fieldwork by the second author. The stratigraphic sections of Carboniferous rocks were obtained by the first writer, who also supervised fieldwork and who accepts responsibility for the general form and presentation of this paper. The authors gratefully acknowledge information on goniatites and conodont samples supplied by Mrs C. H. T. WAGNER-GENTIS and Drs. J. GANDL (Universität Würzburg) and A. C. HIGGINS (University of Sheffield).

The region studied forms part of the southernmost exposures of Palaeozoic rocks in the Cantabrian Cordillera. These are, in fact, the first to be seen from the main road leading from León into the mountains which rise steeply from the Meseta with its late Tertiary and Quaternary blanketing deposits. A thin strip of steeply dipping Cretaceous accompanies the Palaeozoic rocks which were moved over the Cretaceous by means of a steeply angled reverse fault (ALMELA 1949, PASTOR 1963, EVERS 1967).

Previous work in the area north of La Robla includes the geological maps and stratigraphic information given by ALMELA (1949), COMTE (1959), DE SITTER (1962), and PASTOR (1963). The work published by EVERS (1967) is also relevant though not dealing directly with this region. The geological information relating to the Ciñera-Matallana coalfield is derived from WAGNER & ARTIEDA (1970) and WAGNER (1971[a]). Reference is made to the stratigraphic units discussed by BOSCHMA & VAN STAALDUINEN (1968) and WAGNER, WINKLER PRINS & RIDING (1971). The area north of La Robla figures incidentally in some of the oldest geological literature on the Cordillera Cantábrica, e. g. DE VERNEUIL (1850, p. 158-footnote) and BARROIS (1882, pp. 576-577).

On the map published by COMTE (1959) a large expanse of Carboniferous rocks, mainly attributed to the Westphalian *(sensu lato)*, is shown in the area north of La Robla and south of the Devonian strata which occur on the southern border of the Ciñera-Matallana coalfield, containing strongly unconformable Stephanian B deposits. These rocks were mentioned in passing by WAGNER (1957, p. 233 - footnote) as the terrigenous lateral equivalent of the Namurian carbonate deposits of «caliza de montaña» further north. He referred to them as lagoonal in the sense of having been trapped between a hinterland source area to the south and a barrier reef complex off the coast, a concept which has not been confirmed by later work (WAGNER, WINKLER PRINS & RIDING 1971). In fact, the terrigenous Namurian rocks north of La Robla proved to be the time equivalent of thinly bedded non-reef carbonate deposits linked to a submerged massif to the north. They may be interpreted as basinal deposits derived from a southern hinterland and interfingering with the bedded limestones of the massif *(op. cit.)*.

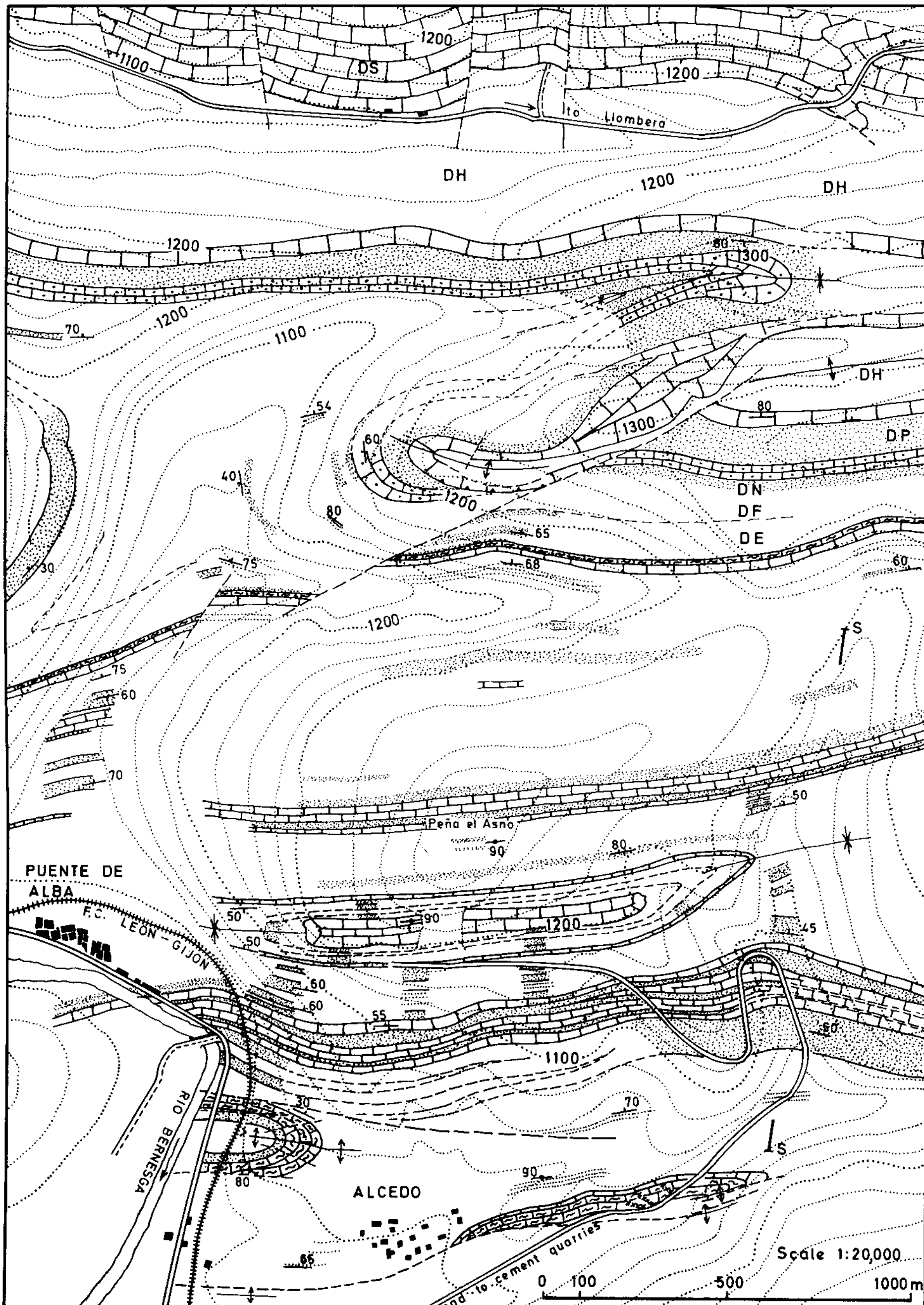
The general synclinal or synclinorial structure of the Palaeozoic north of La Robla is most clearly expressed on the maps published by DE SITTER (1962) and PASTOR (1963). It appears as the Alba Syncline on one of the sections published by DE SITTER (1962) and this name is maintained in the present paper. The general outline of this structure is most clearly marked by a characteristic horizon, the Viséan nodular limestone of the Genicera Formation which forms an easily recognizable band of *ca.* 20 m thickness at the base of the thick terrigenous deposits of Namurian age in the central part of the syncline.

STRATIGRAPHIC SUCCESSION

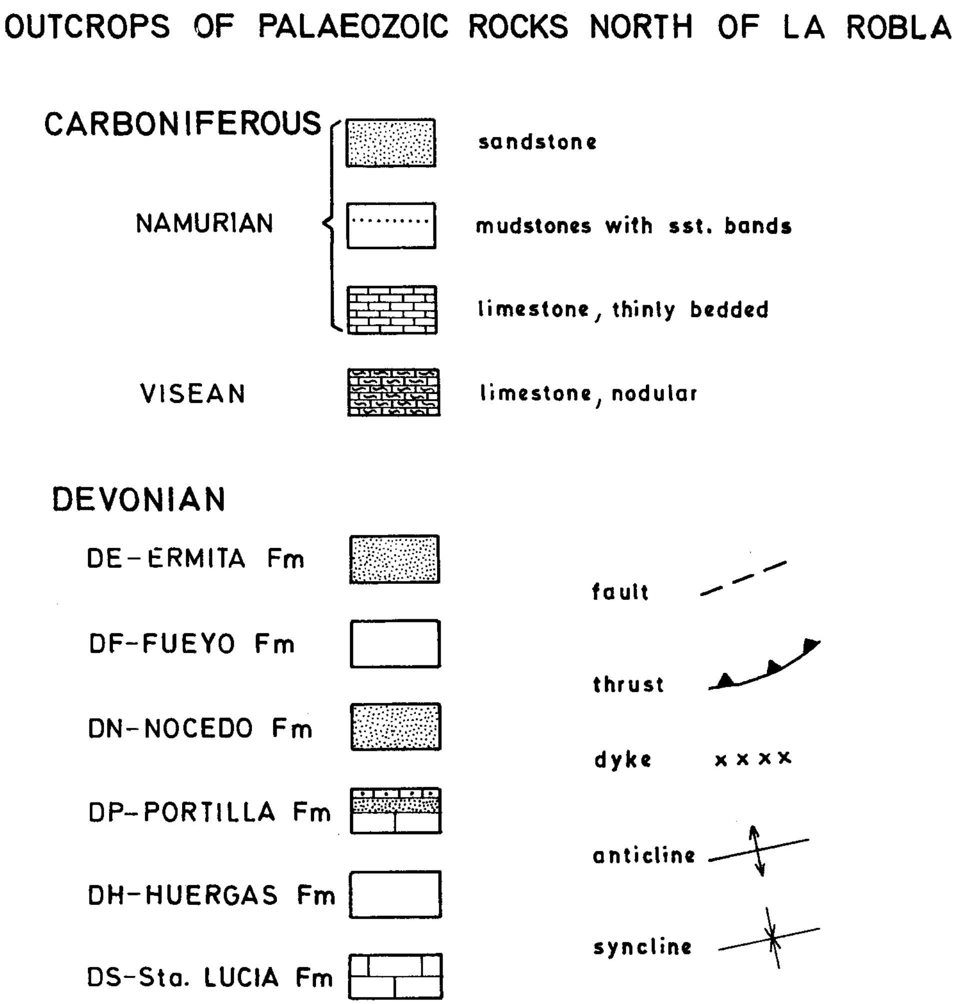
The sequence of Cambrian, Ordovician, Silurian and Devonian rocks in this part of northern León has been described by COMTE (1959), who made a detailed description of the exposures along the Bernesga river. Only the Devonian is represented with the Carboniferous in this area, and the following formations are found here: La Vid Formation (Siegenian-Emsian), Santa Lucía Formation (Emsian-Eifelian), Huergas Formation (Eifelian-Givetian), Portilla Formation (Givetian), Nocedo Formation (Frasnian), Fueyo Formation (Famennian), Ermita Formation (late Famennian?-early Tournaisian). These form an almost complete representation of Devonian rocks, interrupted only at the top by uplift and subsequent transgression in late Famennian times (COMTE 1938, 1959). Isopachites published by VILAS (1970) for several formations in the Lower and Middle Palaeozoic of northern León show a general thinning northwards, related to an area of lesser sedimentation which may be identified with the Cantabrian Block of RADIG (1962), in the central part of the present mountain chain. The Cantabrian Block moved in late Famennian times and produced a dôme from which all strata down to Ordovician were eroded. COMTE *(op. cit.)* even recorded erosion down to the level of Cambrian rocks, but since he occasionally included Ordovician quartzites with overlying, disconformable, late Famennian to early Tournaisian sandstones (compare EVERS 1967), there is reason to doubt this. Silurian and Lower Devonian strata are found on the flanks of the dôme formed in late Famennian times, and a gradually more complete Devonian succession occurs in the areas which were situated further from the arched central part of the Cantabrian Block. The area north of La Robla, showing an almost complete representation of Middle and Upper Devonian strata, was apparently situated at some distance from the central dôme. Only a minimal uplift was experienced in this area.

Railway cutting south-east of Puente de Alba.

The post-epeirogenetic transgressive deposits of the Ermita Formation, characterized by calcareous and ferruginous sandstones, are well developed in the area north of La Robla. There is a certain amount of variation in the lithological sequence recorded for the Ermita Formation in different parts of northern León (see the discussion on this formation *in* WAGNER, WINKLER PRINS & RIDING 1971), and the detailed



Text-fig. 1.—Geological map showing the outcrops of Palaeozoic rocks north of La Robla, and corresponding to the Alba Syncline only. Block symbol for limestones, dots for sandstone, dots and block symbol combined for calcareous sandstone, blank for lutites. Line of section (text-fig. 5) marked S—S.



Legend to text-fig. 1

stratigraphy of this disconformable unit is still poorly understood. An interesting section of the Ermita Formation is found in the core of a small anticline which occurs as a subsidiary structure in the southern flank of the Alba Syncline north of La Robla. This formation and the overlying, disconformable, nodular limestones of Viséan age (Genicera Formation) are well exposed in the railway cutting in the area between the villages of Puente de Alba and Alcedo (see text-fig. 1). From this locality DE VERNEUIL (1850, p. 158) first recorded the presence of «Griotte» limestone in Northwest Spain, comparing it with the «Griotte» of the Pyrenees. This locality was also visited by BARROIS (1882, p. 577) and several other workers who all reported on the nodular limestone. Despite the interest evinced by the various investigators, and the introduction of an Alba Formation on the basis of the section of Viséan nodular limestone present in this railway cutting (VAN GINKEL 1965, p. 184), no measured section was published. A general section of the rocks in the southern flank of the small, subsidiary anticline south of Puente de Alba is now given in text-fig. 2. A more detailed log of the various formations is as follows (formations according to WAGNER, WINKLER PRINS & RIDING 1971):

Olleros Formation (Namurian).

— Shales with thin sandstone bands (not examined in detail). Conformable and apparently undisturbed contact with:

Olaja Beds.

—2.00 m red and grey shales. Tectonic contact by small strike fault which probably eliminated a small thickness of strata in an otherwise conformable succession:

Genicera Formation (Viséan).

— 12.00 m pink and grey, wavy-bedded limestone.
— 0.60 m red shales with red nodular limestones.
— 7.20 m red nodular limestone.
— 0.75 m grey to cream coloured nodular limestone. Disconformable contact with:

Ermita Formation (late Famennian?-lower Tournaisian).

— 0.30 m current bedded, coarse-grained, grey limestone. Irregular contact with:
— 0.24-0.28 m fine-grained, yellowish weathering sandstone. Irregular contact with:
— 0.36 m coarse-grained, grey limestone. Irregular contact with:
— 0.25 m fine-grained, yellowish weathering sandstone. Irregular contact with:
— 0.25 m coarse-grained, grey limestone. Irregular contact with:
— 0.15 m fine-grained, yellowish weathering sandstone. Irregular contact with:
— 0.12 m coarse-grained, grey limestone. Irregular contact with:
— 0.60 m fine-grained, yellowish weathering sandstone. Irregular contact with:
— 0.25-0.35 m coarse-grained, grey limestone. Irregular contact with:
— 0.70-0.80 m fine-grained, yellowish weathering sandstone. Irregular contact with:
— 0.31 m coarse-grained, grey limestone. Irregular contact with:
— 1.45 m fine-grained, yellowish weathering sandstone. Irregular contact with:
— 0.85 m coarse-grained, grey limestone. Irregular contact with:
— 0.85 m calcareous sandstone.
— 0.12 m coarse-grained, sandy limestone.
— 0.08 m calcareous sandstone. Irregular contact with:
— 0.20-0.25 m coarse-grained, grey limestone. Irregular contact with:
— 1.75 m calcareous sandstone, well bedded (15 to 30 cm interval).
— 0.08 m sandy limestone.
— 0.50 m calcareous sandstone.

— 0.08-0.11 m sandy limestone.
— 14.70 m well bedded sandstone (beds 10 to 20 cm thick), fine-grained, grey, slightly calcareous in places and showing occasional channelling. Probably disconformable contact with:

N o c e d o F o r m a t i o n ??

— silty mudstones and shales (not examined in detail).
— sandstones (not examined in detail).

This succession, commencing with sandstones and shales which are tentatively regarded as belonging to the Nocedo Formation of COMTE (1936, 1959), shows a total of 23.30 m of sandstones and limestones of the Ermita Formation, overlain disconformably by 20.55 m of nodular and wavy-bedded limestones of the Genicera Formation. The contact between the silty mudstones and shales attributed to the Nocedo Formation and the sandstones of the Ermita Formation is fairly abrupt, and it is here that the widespread disconformity associated with the Ermita transgression is placed. In the absence of stratigraphic dating, however, this interpretation is tentative and subject to confirmation. That part of the succession which belongs undoubtedly to the Ermita Formation, is characterized by calcareous sandstones and coarse-grained limestones which become increasingly more common in the top part of the formation. These limestones are composed of well cemented debris of highly fragmented shells with a relatively high proportion of brachiopod remains. They also contain rather large, well rounded quartz grains (generally 0.5 to 2 mm in diameter) which are sufficiently abundant to justify the term sandy limestone. More or less obvious current bedding is usually present in these sandy, detrital limestones which may have been deposited in very shallow water. Common brachiopods have been observed in at least one of these limestones, and it may well be from this band that COMTE (1959, p. 195) recorded *Dalmanella interlineata* SOWERBY, *Cleiothyris royssii* LEVEILLÉ and *Camarotoechia letiensis* GOSSELET. It is noted that the alternating sandstones and limestones show irregular contacts. These may be interpreted as scours produced whenever the composition of detrital material changed. Altogether, the impression is created that these deposits are generally of a littoral facies.

The limestone bands in the Ermita Formation were sampled for conodonts. After treatment, Dr. A. C. HIGGINS (personal communication) reports that abundant quartz grains are found in the residues which also contain some glauconite and extremely rare, badly fragmented conodonts. The quartz grains were found to be rounded and no freshly broken grains were encountered. The few conodonts recovered from the residues proved difficult to identify (as the result of breakage) and were certainly insufficient for a stratigraphic age determination. The general aspect of the residues is consistent with a littoral environment.

A comparison with the Olleros de Alba and Santiago de las Villas sections through the Ermita Formation in the southern flank of the Alba Syncline (HIGGINS *et al.* 1964, pp. 212, 214; HIGGINS 1971) also shows the presence of *ca.* 20 m of sandstone leading into limestone at the top of the formation. However, the facies of these rocks appears to be different. The top limestone of the Ermita Formation at Olleros and Santiago de las Villas is fine-grained and contains abundant conodonts which have been dated by HIGGINS as belonging to the early Tournaisian *kockeli-dentilineata* Zone. In the absence of more exact palaeontological information (the brachiopods mentioned by COMTE being generally characteristic of Famennian and Strunian), the relative position of the strata of the Ermita Formation in the railway section south-east of Puente de Alba remains to be established. They could be a little different in age to the highest beds of the Ermita Formation at Olleros de Alba and near Santiago de las Villas, which show a different facies.

This assumption is strengthened by the absence, in the anticline south of Puente de Alba, of a black shale unit (Vegamián Formation) which follows disconformably on the Ermita Sandstone Formation at Olleros de Alba and Santiago de las Villas, and which also appears in an exposure of Lower Carboniferous strata at only some 300 metres south of the subsidiary anticline in the railway cutting near Puente de Alba. This exposure coincides with an abandoned limekiln immediately north of the strike fault shown on the map of text-fig. 1, and corresponds to the anticlinal structure near Alcedo. It has been noted by HIGGINS *et al.* (1964) that the absence of the Vegamián Formation is linked to an east-west trending area which may represent a submarine ridge with the corresponding abrasion and removal of the black shale formation. In some exposures within this area a coarsely crystalline limestone, consisting essentially of fragmented crinoid debris, occupies the same approximate time span as the Vegamián Formation of black shales, i. e. the Upper Tournaisian. This Baleas Formation (WAGNER *et al.* 1971, HIGGINS 1971) also seems to be absent in the railway exposure south of Puente de Alba, but a more accurate dating of the limestones in the upper part of the Ermita Formation south-east of Puente de Alba must be awaited before palaeogeographic conclusions can be drawn.

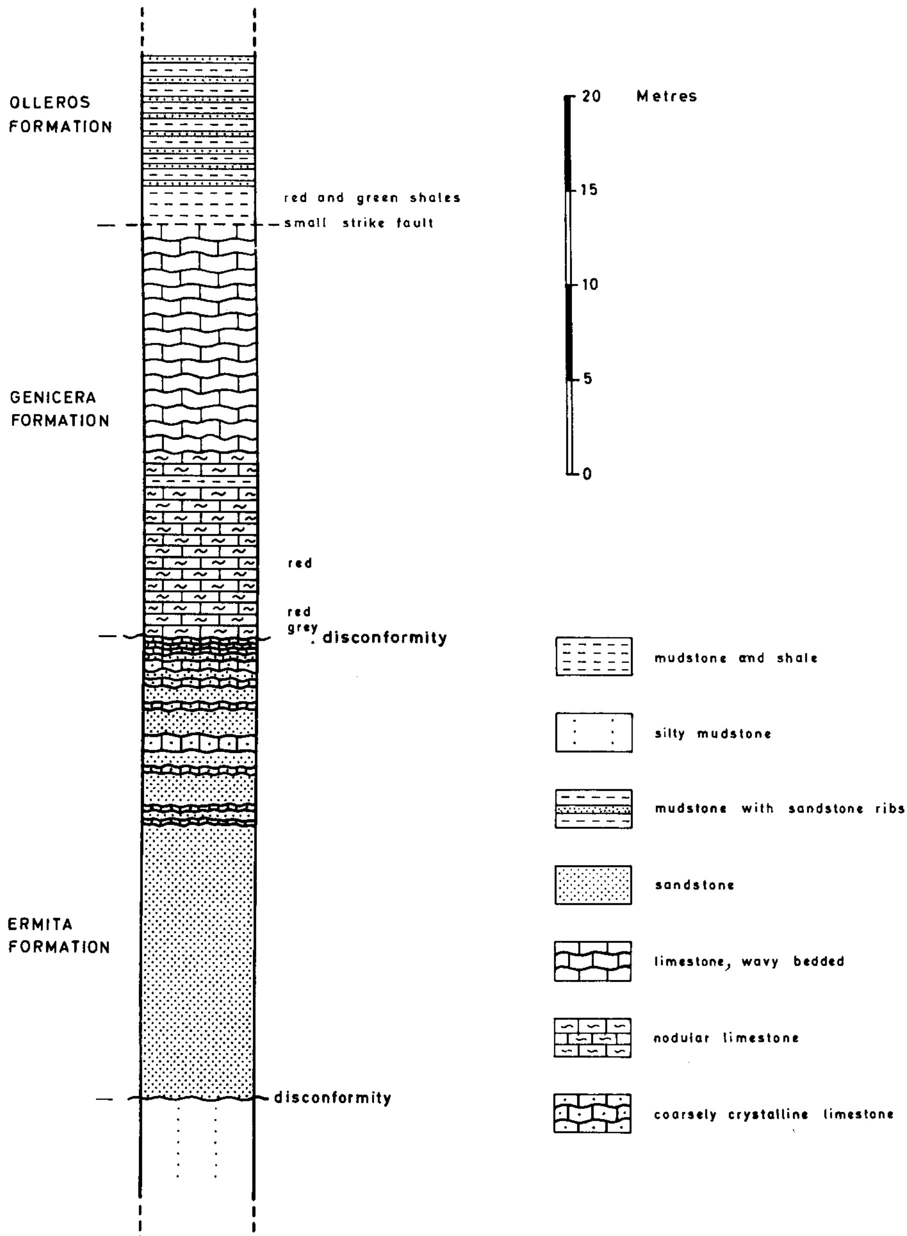
The disconformable limestones of the Genicera Formation, as found in the railway cutting near Puente de Alba, present a clearly different environment to that of the littoral strata of the Ermita Formation. They are fine-grained nodular limestones, characterized by a goniatite fauna, and the abrupt contact between these limestones and the underlying current bedded detrital limestone at the top of the Ermita Formation constitutes a marked break in sequence. This break apparently occurs everywhere at the same time throughout the Cantabrian Cordillera, i. e. below the top *anchoralis* Zone (conodonts) and the cu II ß-γ Zone (goniatites) (compare HIGGINS *et al.* 1964, HIGGINS 1971, WAGNER *et al.* 1971), and this locality south-east of Puente de Alba is no exception to the rule.

Following the steeply dipping beds in the railway section along the strike, a fossiliferous band with goniatites was found by Dr. J. GANDL at 0.60 m above the base of the first unit of grey to cream coloured limestones of the Genicera Formation,

Text-fig. 2.—Stratigraphic section of late Famennian/early Tournaisian Ermita Formation, Viséan Genicera Formation, and Namurian Olleros Formation in the subsidiary anticline in the southern flank of the Alba Syncline, as exposed along the León-Gijón railway south-east of Puente de Alba. The red and green shales above the Genicera Formation are assigned to the Olaja Beds.

LOWER CARBONIFEROUS AND ADJOINING ROCKS IN RAILWAY SECTION NEAR PUENTE DE ALBA (PROV. LEON, NW. SPAIN)

Scale 1: 400



the exact locality being situated near the periclinal termination of the anticline. These goniatites were kindly made available to Mrs. C. H. T. WAGNER-GENTIS, who identified *Ammonellipsites kayseri* (SCHMIDT) GORDON and *Nautellipsites hispanicus* (FOORD & CRICK) WAGNER-GENTIS. These are Lower Viséan species. Most significant, perhaps, is *Ammonellipsites («Pericyclus») kayseri* which has also been found in northern Palencia, within 2 m from the base of the nodular limestone formation (compare WAGNER 1971[b]). *Nautellipsites hispanicus* was also found by Dr. GANDL in red nodular limestone at 4 to 6 metres above the base of the Genicera Formation in the railway section south-east of Puente de Alba. This species ranges more extensively in the Lower Viséan than *Ammonellipsites kayseri* (personal communication by C. H. T. WAGNER-GENTIS).

Goniatites from the red nodular limestone near Puente de Alba were first recorded by BARROIS (1882, pp. 577, 292-295, pl. XIV). A general collection from this locality (i. e. including the abandoned quarries in red nodular limestone on the western side of the Río Bernesga) was also made by WAGNER-GENTIS (1960, p. 47), who moreover revised BARROIS' material: *Merocanites subhenslowi* WAGNER-GENTIS (recorded as *Merocanites henslowi), Merocanites applanatus* var. *bicarinatus* PAREYN, *Nautellipsites hispanicus* (FOORD & CRICK), *Beyrichoceras malladae* (BARROIS) WAGNER-GENTIS, *Goniatites striatus* SOWERBY, *Goniatites crenistria* PHILLIPS, *Goniatites falcatus* ROEMER. These species represent assemblages of Lower and Upper Viséan ages corresponding to the B and P Zones of BISAT and the cu II γ to cu IIIβ zones of SCHMIDT. Using partly different names, a selection of the same species was recorded by KULLMANN (1963, p. 172), who was apparently unaware of some of the previous work. From red nodular limestone in a small accessory fold in a quarry west of the Bernesga river (loc. 1199) a specimen of *Stenopronorites* was obtained by C. H. T. WAGNER-GENTIS (pers. comm.). This suggests that the Genicera Formation north of La Robla may reach an horizon in the Lower Namurian.

The goniatite-bearing nodular limestone near Puente de Alba has been referred to by COMTE (1959, p. 330) as «Griotte de Puente de Alba» and was quoted by COMTE as being representative of the «Marbre Griotte» as meant by BARROIS (1882). This locality, which has the distinction of being the one noted by DE VERNEUIL (1850, p. 158), has been named by VAN GINKEL (1965, p. 184) as the type locality of his Alba Formation. No description of the stratotype was provided however, and reasons have been given by WAGNER, WINKLER PRINS & RIDING (1971) for suppressing the Alba Formation of VAN GINKEL in favour of a Genicera Formation, based on exposures near Genicera which provide a more characteristic and fuller development of strata. The Genicera Formation near Puente de Alba shows an almost continuous development of nodular and wavy-bedded («griotte») limestone. This is characteristic of the development of the Genicera Formation in the most southerly exposures of the Cantabrian Chain. In its typical development south-west of Genicera a chert horizon is intercalated in the lower part of this formation. In the southerly exposures it is also customary to find the top part of the limestone to be replaced by red and green mudstones of the Olaja Beds (WAGNER *et al.* 1971), from which WAGNER-GENTIS *(in* WAGNER *et al.* 1971) has described a Lower Namurian goniatite fauna of the E_2 Zone.

The same Olaja Beds are found above the Genicera Formation in the railway cutting south-east of Puente de Alba. The contact between the limestone and the mudstone is disturbed by a small strike fault (compare text-figs. 1, 2) which apparently eliminates a small part of the local succession. Above the Olaja Beds a conformable succession of mudstones with thin sandstone bands is found.

Exposures along to road to the cement quarries.

The subsequent succession is more completely developed some 1,300 metres east of the railway exposures discussed above. It is likely that a strike fault immediately north of the Lower Carboniferous strata in the railway cutting does not continue in this area (compare text-fig. 1) and that a continuous succession is found along the new road leading to the limestone quarries of «Cementos La Robla». This road section, cutting through the southern flank of the Alba Syncline (compare text-fig. 5), commences with nodular and wavy-bedded limestones of the Genicera Formation which have been folded into a steeply plunging anticline, faulted on its southern side. Within this anticlinal structure four intrusive dykes are found to be cutting through the limestones and some associated mudstones (text-fig. 1—east of Alcedo). These dykes are heavily weathered and have not been examined in detail by the present writers. However, the most westerly of these dykes has been studied by PASTOR (1963, p. 41), who recorded it as a «sill» of basic composition. Despite the presence of much alteration, PASTOR established its composition as being that of an olivine basalt. It should be noted that doleritic dykes have also been described from the nearby area of the Ciñera-Matallana coalfield (GONZÁLEZ PRADO, *in* WAGNER & ARTIEDA 1970), where they were emplaced during a folding phase of probable Permian age.

The red and pink limestones of the Genicera Formation are followed in the section of the «Cementos» road by a small thickness (*ca.* 10 m) of grey, thinly bedded limestone which is identical in facies and stratigraphic position to the basal part of the Barcaliente Limestone (lower part of the «caliza de montaña») in exposures further north in the same general area of northern León (compare WAGNER, WINKLER PRINS & RIDING 1971). It probably represents a tongue of this formation which wedges southwards. A subsequent development of approximately 120 metres of grey mudstone with thin sandstone bands and beds of sideritic ironstone, is patchily exposed. The sandstone bands are sometimes slightly calcareous. They show ripplemarks as well as thin mica flakes on the bedding planes. This mudstone sequence above the thin tongue of Barcaliente Limestone (see text-fig. 3) corresponds to the lower part of the Olleros Formation as described by WAGNER *et al.* (1971). It represents a terrigenous facies of Namurian age which follows upon and laterally replaces the more condensed carbonate sequence, and this may be interpreted as the first basinal deposits building up towards a gradually increased rate of sedimentation.

A more rapid sedimentation is shown in fact by the subsequent deposits as described below.

The first sandy deposits after the poorly exposed mudstone sequence consist of two sandstone bands with intervening lutitic beds, 2.85 m thick altogether.

This horizon is indicated by a single line of dots in text-fig. 3. The lower sandstone is 1.15 m thick and consists of fine-grained, massively bedded, grey sandstone (bedding interval 10 to 25 cm), with an abrupt basal contact marked by load casting, and a smooth top. There is evidence of graded bedding. The lutitic interval, 1.50 m thick, consists of slightly calcareous, slightly sandy mudstone showing spheroidal weathering, and thin bands of fine-grained, cross-laminated and ripplemarked sandstone (2 to 6 cm bands). It also contains sideritic ironstone nodules. The top sandstone bed is also characterized by graded bedding, an abrupt lower contact with possible prod marks, and a more gradual passage upwards into slightly silty mudstones. Possible ball and pillow structures are found within this bed which is only 0.30 m thick. The graded bedding and sole markings indicate a steepening basin slope and the beginning of turbidite deposition.

There follow 6.50 m of compact, slightly silty mudstones which are also slightly calcareous and which contain thin bands of sideritic ironstone (1 to 2 cm thick), and light grey sandstone beds (3 to 8 cm thick) showing sole markings at the base and ripple cross-laminations within each bed.

Subsequently, an important interval of sandstone deposits is found. The first 4.20 m of this interval consist of medium-grained sandstone beds, 5 to 25 cm thick, which show load casting where they rest on lutitic passages. They contain finely comminuted plant debris (text-fig. 3). Then follow 11.50 m of massively bedded, medium-grained sandstones (bedding interval 0.20 to 1 m), which show signs of wedging. These sandstones are poorly sorted and appear to be rather mixed in composition. They show rounded bases where they are in contact with thin lutitic intervals, and there is evidence of scouring which agrees with the presence of occasional directional sole markings.

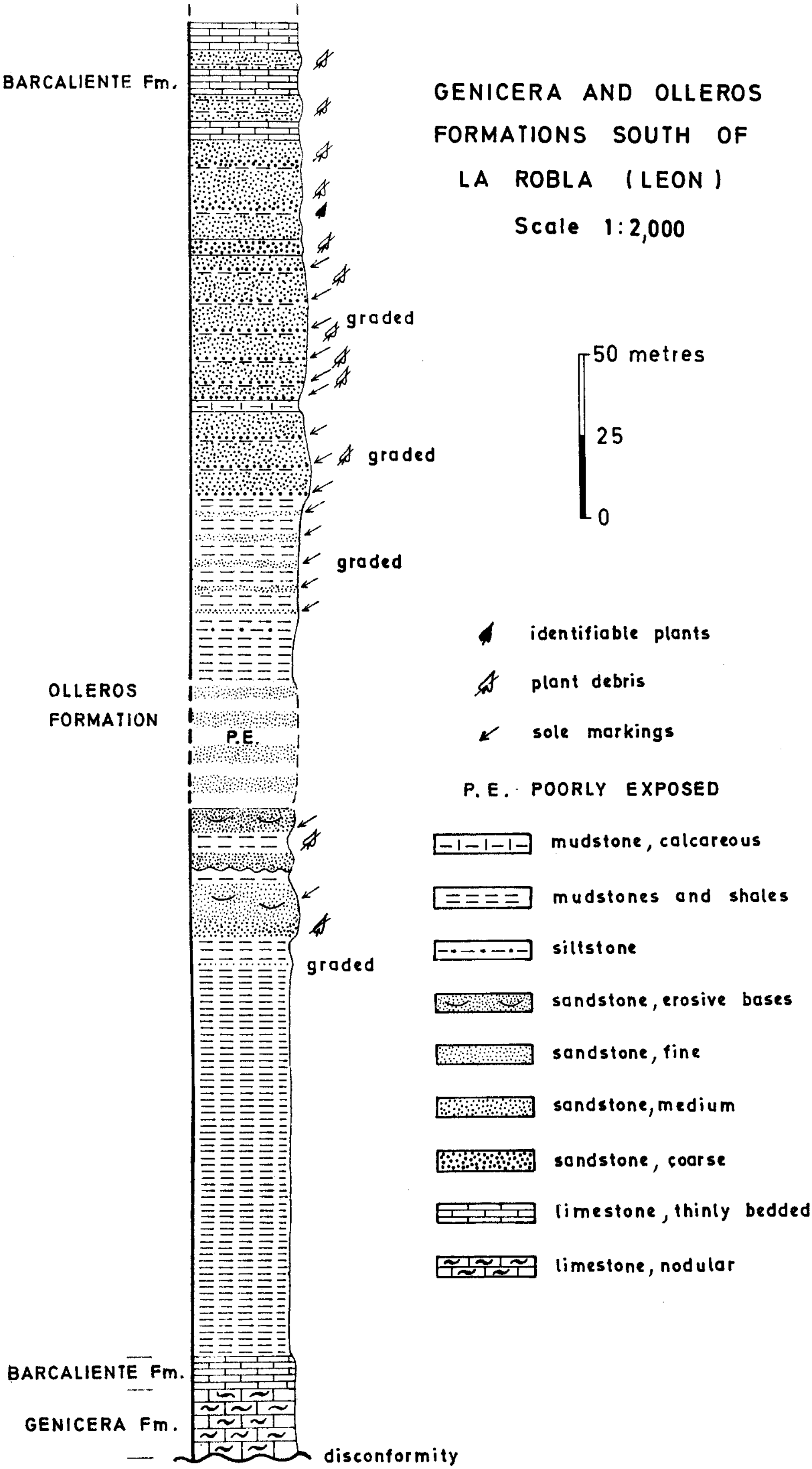
A unit of 3 metres of compact, slightly silty mudstone, bluish grey in colour, contains bands of silty mudstone which show graded bedding, and ripplemarks with ripple cross-laminations in the upper part. These bands of silty mudstone are often slightly sideritic. They show abrupt contacts at the base which may also show directional sole markings (in the top part of the entire unit).

There follow 6 m of massive sandstone beds, up to 2 m thick, which show erosional contacts with thin lutitic intervals. Bottom structures are present, and the lutitic intervals contain finely comminuted plant debris.

Another lutitic unit of grey, compact, slightly silty and slightly calcareous mudstone with fine-grained, yellowish, probably somewhat ferruginous sandstone beds, occupies the next 6.80 metres. These sandstone beds are thin (5 to 12 cm) and towards the top of the unit they are seen to contain comminuted plant debris and ripple cross-laminations.

A further unit of massive sandstones, 7 m thick altogether and consisting of beds up to 1.50 m thick, shows sole markings at the base of the lowermost bed and load casting with signs of erosion at the base of the highest bed.

Text-fig. 3.—Generalized stratigraphic section of Viséan and Namurian rocks exposed along the road to the limestone quarries of «Cementos La Robla S. A.». The strongly condensed sequence of Viséan rocks is represented by the nodular limestones of the Genicera Formation.


GENICERA AND OLLEROS FORMATIONS SOUTH OF LA ROBLA (LEON)
Scale 1:2,000
50 metres
25
0
BARCALIENTE Fm.
graded
graded
graded
OLLEROS FORMATION
P.E.
graded
BARCALIENTE Fm.
GENICERA Fm.
disconformity
identifiable plants
plant debris
sole markings
P. E. · POORLY EXPOSED
mudstone, calcareous
mudstones and shales
siltstone
sandstone, erosive bases
sandstone, fine
sandstone, medium
sandstone, coarse
limestone, thinly bedded
limestone, nodular

In the subsequent 40 odd metres there is little outcrop, but the few available exposures indicate that this interval is mainly sandy. This is the sequence marked as poorly exposed in the column of text-fig. 3. A further unit of some 10 metres of bluish grey lutitic rocks is also poorly exposed.

Complete exposure is restored with 10 m of bluish grey, slightly silty lutites which contain thin siltstone bands (1 to 6 cm each) with abrupt basal contacts and gradual passages upwards into mudstones. These siltstone bands show occasional sole markings and more frequent ripple cross-lamination throughout most of the thickness of each band.

There follows a variable thickness (0.50 to 1.30 m) of fine-grained sandstone with ripple cross-laminations near the base and ripplemarks in the upper part. This is succeeded by 0.15 m of fine-grained, grey sandstone with sole markings at the base and ripplemarks at the top.

In approximately 35 metres, bluish grey, slightly silty mudstones are found alternating with fine-grained, grey sandstones which are characterized by directional sole markings, and ripplemarks at the top. These sandstone bands are generally 5 to 10 cm thick, and they show clear graded bedding. The turbidite facies, already present occasionally below this unit, here apparently became established more generally. It is the predominant facies of the subsequent deposits (text-figs 3, 4).

These deposits commence with 26.50 m of massive sandstone beds (0.20 to 1.20 m on the average) with thin lutitic intervals occupying approximately one sixth of the total sequence. The sandstone beds show an abrupt and erosive contact with the underlying lutites, and possess bottom structures in the shape of load casts or directional sole markings. They also possess graded bedding, commencing with coarse quartz sand or microconglomerate at the base and developing gradually upwards into coarse to medium-grained sandstone with ripplemarks in the highest part where the sandstone grades into slightly silty, bluish grey shales alternating occasionally with siltstones showing ripple cross-laminations. Comminuted plant remains occur without orientation in some of the sandstone beds. These are typical turbidite deposits, which appear to be rather mixed in composition (on field evidence) and which grade upwards into a more autochthonous shallow marine deposit. The predominance of turbiditic sandstone beds provides evidence of a rapid sedimentation at rather short intervals of time.

The subsequent 50.50 metres of turbiditic sandstone deposits have been measured in detail (text-fig. 4) and the following log is presented (from top to bottom):

— 0.50 m medium-grained sandstone.
— 0.10 m slightly silty lutite.
— 0.45 m sandstone.
— 0.50 m medium-grained sandstone with load casting at the base.
— 0.20 m sandstone with load casting at the base.
— 0.20 m medium-grained sandstone with directional sole markings and graded bedding.
— 0.50 m medium-grained sandstone with load casting at the base.
— 0.24 m medium-grained sandstone with directional sole markings.
— 0.14 m silty lutite.
— 0.13 m medium-grained sandstone.

— 0.01 m slightly silty lutite.
— 0.10 m medium-grained sandstone.
— 0.05 m slightly silty lutite.
— 0.30 m sandstone.
— 0.04 m slightly silty lutite.
— 0.20 m medium-grained sandstone.
— 0,01 m lutite.
— 0.30 m medium-grained sandstone, erosive at the base.
— 0.25 m medium-grained sandstone with load casting at the base.
— 0.95 m coarse-grained sandstone with graded bedding.
— 0.55 m sandstone with directional sole markings at the base and ripplemarks at the top.
— 0.50 m medium-grained sandstone with load casting at the base.
— 0.01 m slightly silty, micaceous lutite.
— 0.12 m medium-grained sandstone with graded bedding and load casting at the base.
— 0.10 m slightly silty, micaceous lutite.
— 0.55 m medium-grained, wedging sandstone with an erosional base and ripplemarks at the top.
— 0.20 m medium-grained, wedging sandstone with a strongly erosive base.
— 0.01 m lutite.
— 0.40 m medium-grained sandstone with directional sole markings at the base and ripplemarks at the top.
— 0.01 m lutite.
— 1.05 m coarse to fine-grained sandstone with microconglomerate at the base, graded bedding throughout, and ripplemarks at the top.
— 0.10 m medium-grained sandstone with microconglomerate at the base; also some load casting and ripplemarks at the top.
— 0.05 m silty lutite with abundant comminuted plant debris and mica flakes.
— 0.16 m medium-grained sandstone with directional sole markings.
— 0.12 m lutite with abundant comminuted plant debris.
— 0.35 m medium to fine-grained sandstone with graded bedding, and directional sole markings at the base.
— 0.01 m slightly silty lutite.
— 0.40 m medium-grained sandstone with graded bedding, directional sole markings at the base and ripplemarks at the top.
— 0.01 m lutite.
— 0.25 m medium-grained sandstone with directional sole markings at the base and ripplemarks at the top.
— 0.01 m lutite.
— 0.45 m medium-grained sandstone with directional sole markings.
— 0.65 m medium-grained sandstone with load casting at the base and ripplemarks at the top.
— 0.10 m silty lutite with abundant comminuted plant debris.
— 0.12 m medium-grained sandstone with load casting and directional sole markings.
— 0.06 m silty lutite which is carbonaceous as the result of very abundant comminuted plant debris.
— 0.30 m sandstone.
— 0.80 m medium-grained sandstone with directional sole markings.
— 0.35 m silty lutite with abundant comminuted plant debris.
— 0.30 m sandstone with graded bedding and directional sole markings.
— 0.40 m coarse-grained sandstone with graded bedding.
— 0.30 m coarse-grained, microconglomeratic sandstone with comminuted plant remains; probably felspathic; directional sole markings at the base.
— 1.10 m coarse-grained, microconglomeratic sandstone.
— 0.01 m lutite.
— 0.40 m coarse-grained sandstone with load casting at the base.
— 0.01 m slightly silty lutite, micaceous.
— 0.23 m sandstone with graded bedding and load casting at the base.
— 0.01 m lutite.
— 1.00 m medium-grained sandstone with some comminuted plant debris at the base and ripplemarks at the top.
— 0.25 m slightly silty, micaceous lutite with comminuted plant debris.
— 0.25 m sandstone with graded bedding.
— 0.06 m lutite.
— 0.25 m sandstone with graded bedding and load casting at the base.
— 0.20 m sandstone with graded bedding and load casting at the base.

— 0.12 m sandstone with graded bedding and load casting at the base.
— 0.15 m sandstone with graded bedding and load casting at the base.
— 0.03 m slightly silty lutite with abundant comminuted plant debris.
— 0.18 m sandstone with graded bedding and load casting at the base.
— 0.25 m sandstone with graded bedding and load casting at the base.
— 0.45 m sandstone with graded bedding and load casting at the base.
— 0.50 m sandstone with graded bedding and load casting at the base.
— 0.25 m coarse-grained sandstone with graded bedding.
— 0.07 m silty lutite.
— 0.45 m sandstone.
— 0.40 m massive sandstone with load casting at the base.
— 0.30 m sandstone with ripplemarks.
— 1.10 m sandstone with directional sole markings.
— 0.10 m silty lutite, carbonaceous, with abundant comminuted plant debris.
— 0.65 m sandstone.
— 0.40 m silty lutite.
— 0.10 m well bedded siltstone.
— 0.30 m sandstone with graded bedding, and passing gradually into the overlying siltstone.
— 0.50 m coarse-grained, well bedded sandstone (2 cm beds), with comminuted plant debris.
— 1.50 m coarse-grained, massive sandstone.
— 0.06 m silty lutite with comminuted plant debris and mica flakes.
— 1.20 m sandstone with graded bedding and directional sole markings at the base.
— 0.03 m silty lutite.
— 0.20 m sandstone with graded bedding and directional sole markings.
— 0.20 m silty lutite with abundant comminuted plant debris.
— 0.22 m sandstone with graded bedding and load casting at the base.
— 0.02 m silty lutite.
— 0.30 m sandstone with graded bedding and load casting at the base.
— 0.02 m slightly silty lutite.
— 0.25 m sandstone with graded bedding.
— 0.05 m slightly silty lutite.
— 0.45 m sandstone with graded bedding.
— 0.08 m silty lutite with finely comminuted plant debris and mica flakes.
— 0.45 m sandstone with graded bedding, directional sole markings at the base and ripplemarks at the top.
— 0.10 m slightly silty lutite.
— 0.15 m sandstone with graded bedding, directional sole markings at the base and ripplemarks at the top.
— 0.20 m silty lutite passing into slightly silty lutite with comminuted plant debris.
— 0.27 m sandstone with graded bedding, comminuted plant debris, and ripplemarks at the top.
— 0.18 m silty lutite passing into slightly silty lutite with comminuted plant debris.
— 0.20 m sandstone with ripplemarks.
— 0.05 m slightly silty lutite, micaceous.
— 1.30 m sandstone with ripplemarks in the top 6 cm.
— 0.05 m silty lutite, carbonaceous because of abundant comminuted plant debris.
— 0.65 m sandstone with load casting at the base and ripplemarks at the top.
— 1.65 m sandstone, well bedded, and containing frequent ripplemarks in the top 12 cm.
— 0.01 m lutite.
— 0.60 m sandstone with graded bedding, some load casting at the base and ripplemarks at the top.
— 0.04 m strongly carbonaceous lutite, almost a coal.
— 0.04 m silty lutite with abundant comminuted plant debris.
— 0.25 m coarse-grained sandstone with graded bedding.
— 0.07 m sandstone with comminuted plant debris and mica flakes.
— 0.15 m sandstone with graded bedding and load casting at the base, passing gradually into the overlying sandstone.
— 0.06 m silty lutite.
— 0.06 m sandstone.
— 0.02 m silty lutite with mica and comminuted plant debris.
— 0.40 m coarse-grained sandstone with graded bedding and comminuted plant debris near the top.
— 0.04 m silty lutite, micaceous, with abundant comminuted plant debris.
— 0.90 m coarse-grained sandstone with graded bedding, load casting at the base and ripplemarks at the top; some driftwood.

— 0.01 m slightly silty lutite, micaceous, with abundant comminuted plant remains.
— 0.30 m coarse-grained sandstone with graded bedding and ripplemarks.
— 0.25 m sandstone with drifted plant stems.
— 0.03 m slightly silty lutite, carbonaceous.
— 1.60 m sandstone with graded bedding and ball and pillow structures at 40 cm above the base; ripplemarks at the top.
— 0.03 m lutite.
— 0.15 m sandstone with graded bedding and ripplemarks with ripple cross-laminations at the top.
— 0.10 m slightly silty lutite.
— 1.40 m coarse-grained sandstone, completely massive, with ripplemarks at the top.
— 0.03 m carbonaceous lutite.
— 0.50 m very coarse-grained sandstone with abundant drifted plant stems; also graded bedding.
— 0,95 m coarse-grained sandstone with microconglomerate at the base, graded bedding throughout, and ripplemarks at the top.
— 0.02 m lutite.
— 2.80 m coarse-grained sandstone with abundant driftwood, seed casts and shale pellets forming a microconglomerate at the base of a graded, turbiditic sandstone of varied composition; although quartz is predominant, some felspar may be present in the very coarse, basal part of this sandstone; a few ripplemarks are observed at the very top.
— 2.45 m slightly calcareous, slightly silty lutite with beds of siltstone and silty, calcareous mudstone showing ripple cross-lamination and some drifted, comminuted plant debris.
— 0.35 m sandstone with directional sole markings at the base, graded bedding throughout and ripplemarks at the top.
— 1.20 m slightly calcareous and slightly silty lutites with ripplemarks and ripple cross-laminations as well as some cross bedding; comminuted plant debris present.

The detailed log reproduced above (see also text-fig. 4) forms a record of turbidites which conform to the general pattern of massive, graded sandstones with bottom structures and mainly rather coarse deposits at the base, showing an abrupt and generally irregular contact with the preceding bed, and ripplemarks near the top where a gradual passage into more shaly deposits is seen. The latter, quite commonly, show the presence of comminuted plant debris which is occasionally so abundant as to form dirty coal layers. These shaly and carbonaceous deposits, representing the background sedimentation, form only a very small proportion of this succession which is dominated by turbiditic sandstones. It is likely that an extreme instability of the basin, with a continual rejuvenation of the basin slope, is reflected by these rapidly succeeding flows of turbiditic sandstone.

After this sequence measured in detail, a further succession of sandstones shows a somewhat less clearly turbiditic aspect. They are still alternating with lutitic intervals representing the background sedimentation in the basin. The following units have been recorded (top right hand column of text-fig. 4).

Five metres of yellowish weathering, rather well sorted, coarse to medium-grained sandstones with a 20 to 30 cm bedding interval, are found alternating with thin lutitic beds which contain comminuted plant debris. Also the sandstones contain occasional floated stem and branch remains. Load casting occurs at the base of some of these sandstones.

They are followed by 7.50 metres of massively bedded sandstones (bedding interval 30 to 100 cm) which are grey, relatively well sorted, medium-grained and quartzose with some additional, unidentified minerals. These sandstone beds show erosional bases which may be due to submarine channelling.

A lutitic interval of 0.40 m shows a basal unit of 0.10 m of very sandy lutite with abundant floated plant debris, and a more compact bed of 0.30 m with floated plant debris including occasional small leaf fragments which are identifiable (loc. 2163): *Pecopteris aspera* BRONGNIART, *Sphenopteris crispa* STOCKMANS & WILLIÈRE, *Sphenopteris* sp. *Pecopteris aspera* is a well known Middle to Upper Namurian species which appears already in Namurian A (STOCKMANS & WILLIÈRE 1954, Tableau 2). *Sphenopteris crispa* has been described from the Lower Namurian of Belgium. It should be noted that the specimens found in locality 2163 are all very fragmentary and that the identifications, though reasonably certain, are therefore to some extent tentative. With regard to *Sphenopteris crispa*, it should also be noted that the type specimen from Belgium is also rather fragmentary and that an absolute identification is consequently even more difficult. It is not considered worth-while to figure any of the small fragments collected from loc. 2163.

Beyond loc. 2163 only a general section has been recorded of the rocks in the southern flank of the Alba Syncline (text-fig. 3). Above the lutitic interval with plant fragments some 13 metres of yellowish weathering sandstones occur. These show beds of 10 to 100 cm thickness, with lutitic intervals constituting approximately 10 % of the total thickness of this unit. The sandstones are apparently well sorted and well washed, possibly slightly calcareous, with occasional shale pellets and drifted plant stems. They are generally coarse-grained, but some medium-grained, grey sandstones occur in the upper part.

An interval of 0.25 metres of very sandy shales with abundant drifted plant debris separates this unit from a further 9 metres of sandstones similar to those described above.

They are followed by 5 m of fetid, micritic limestone which is thinly bedded (beds varying in thickness from 0.5 to 5 cm, and averaging 1-2 cm). The limestone beds alternate with marls or slightly silty calcareous mudstones. There are occasional nodules of pyrite in the limestones which also show the presence of horizontal tracks. The entire limestone/marl unit is crumpled into small folds formed as the result of incompetent layers being folded within a sequence of mainly competent strata, and the thickness of this unit within the flanks of the isoclinal Alba Syncline is therefore quite variable. This limestone unit is interpreted as a southern tongue of the Barcaliente Limestone Formation, which is a single limestone unit, several hundred metres thick, in a thrust slice only a few kilometres north of the area discussed here. The facies of this limestone formation is that of a quiet marine deposit, formed rather slowly below wave base. It is a platform deposit, linked to the Cantabrian Block in the centre of the Cantabric-Asturian orogen, and the presence of tongues of Barcaliente Limestone in the basinal sequence north of La Robla indicates a position near the margin of this block.

Alternating sandstones and lutites, with a combined thickness of 8.14 metres, form an interval of more rapid sedimentation before the next tongue of Barcaliente

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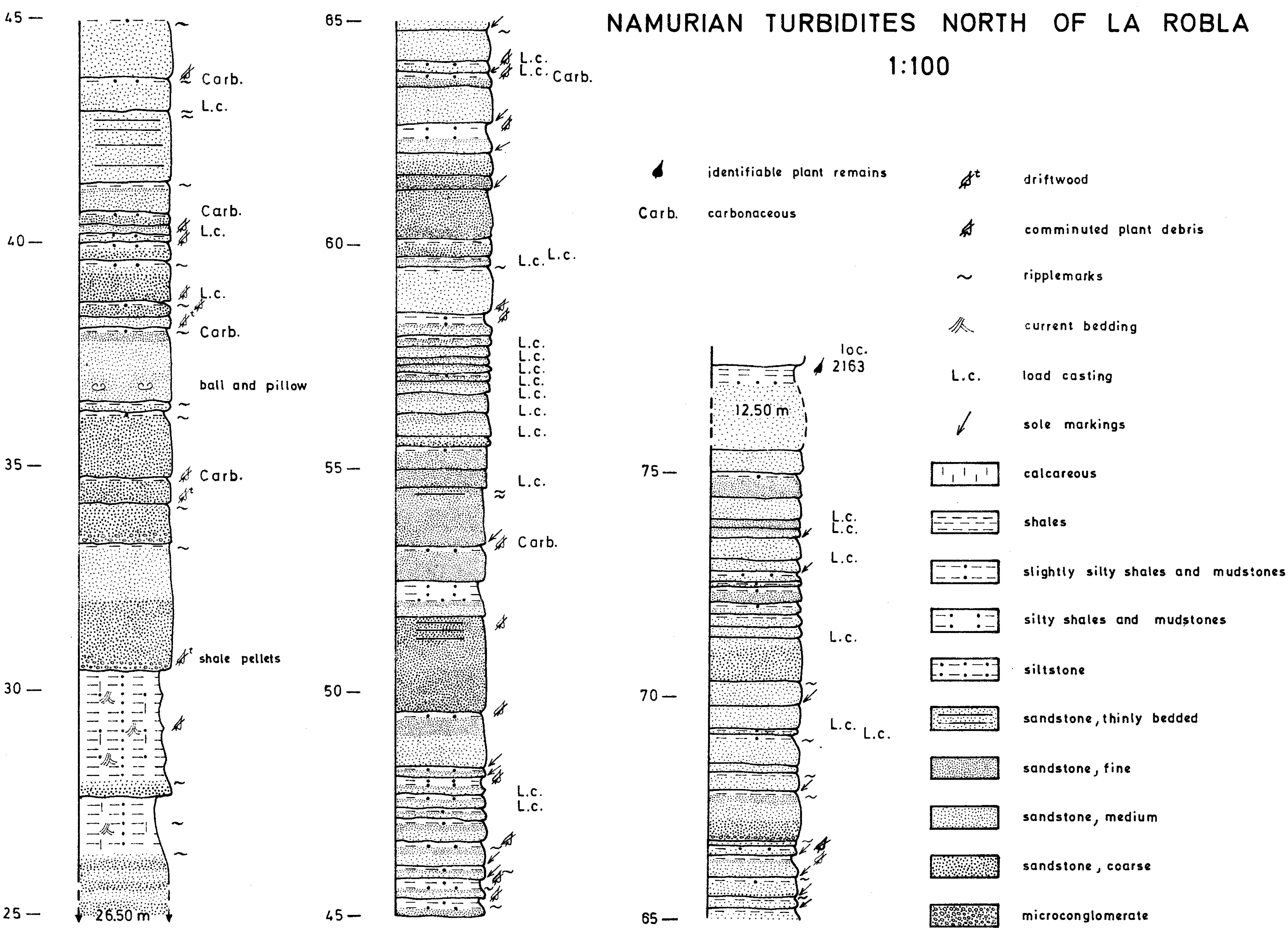
Text-fig. 4.—Detailed stratigraphic section of the main turbidite sequence in the Namurian rocks exposed along the road to the limestone quarries of «Cementos La Robla S. A. ».


NAMURIAN TURBIDITES NORTH OF LA ROBLA
1:100
identifiable plant remains
Carb. carbonaceous
driftwood
comminuted plant debris
ripplemarks
current bedding
L.c. load casting
sole markings
calcareous
shales
slightly silty shales and mudstones
silty shales and mudstones
siltstone
sandstone, thinly bedded
sandstone, fine
sandstone, medium
sandstone, coarse
microconglomerate
Carb.
L.c.
ball and pillow
shale pellets
26.50 m
12.50 m
loc. 2163
45
40
35
30
25
65
60
55
50
75
70

Limestone is reached (text-fig. 3). The following beds are recorded from this interval (from top to bottom):

— 0.30 m sandstone.
— 0.15 m sandy lutite with comminuted plant debris.
— 1.15 m sandstone with ripplemarks at the top.
— 0.02 m silty lutite with abundant comminuted plant debris.
— 0.48 m sandstone with ripplemarks at the base.
— 0.08 m silty lutite with abundant comminuted plant debris.
— 0.20 m sandstone.
— 0.10 m silty lutite with comminuted plant debris.
— 0.16 m sandstone with sole markings at the base.
— 0.02 m silty lutite with abundant comminuted plant debris.
— 0.06 m sandstone.
— 0.06 m silty lutite with abundant comminuted plant debris.
— 0.25 m sandstone.
— 0.08 m silty lutite with abundant comminuted plant debris.
— 0.20 m sandstone.
— 0.04 m silty lutite with abundant comminuted plant debris.
— 0.15 m sandstone.
— 0.04 m silty lutite with comminuted plant debris.
— 1.50 m sandstone in beds of 30 to 60 cm thickness and showing erosional bases.
— 0.01 m silty lutite with comminuted plant debris.
— 0.10 m sandstone.
— 0.10 m silty lutite with comminuted plant debris.
— 0.20 m sandstone.
— 0.40 m silty lutite with abundant comminuted plant debris.
— 0.75 m sandstone in beds of 10 to 20 cm thickness.
— 0.25 m silty lutite with abundant comminuted plant debris.
— 0.50 m sandstone with comminuted plant debris.
— 0.15 m silty lutite with abundant comminuted plant debris.
— 0.08 m sandstone with abundant comminuted plant debris.
— 0.10 m very silty lutite with comminuted plant debris.
— 0.25 m sandstone.
— 0.10 m fine-grained shales.
— 0.20 m medium-grained sandstone.
— 0.10 m silty lutite with abundant comminuted plant debris producing a carbonaceous deposit.

The next unit consists of 8 metres thinly bedded, micritic, fetid limestones alternating with marls. These are succeeded by sandstones with sole markings, which alternate with silty lutites showing the presence of comminuted plant debris. The following beds are recorded in this unit (from top to bottom):

— 0.20 m silty lutite with abundant comminuted plant debris.
— 0.16 m sandstone with sole markings.
— 0.20 m sandstone with sole markings, and showing a gradual passage upwards into silty lutite.
— 0.10 m silty lutite with abundant plant debris.
— 0.17 m sandstone with sole markings.
— 0.10 m silty lutite with comminuted plant debris.
— 0.04 m sandstone with sole markings.
— 0.15 m silty lutite with abundant comminuted plant debris and mica flakes.
— 0.17 m sandstone with sole markings.
— 0.05 m silty lutite with comminuted plant debris.
— 0.30 m medium - to fine-grained sandstone with sole markings.

The 0.20 m of lutite at the top of the measured sequence are followed by over 4 metres of massive sandstones (30 to 100 cm thick individually) which are medium-grained, well sorted, with some load casting and showing the presence of silty lutite bands with abundant plant debris in the upper part.

Then follow 0.25 metres of thinly bedded, fetid, micritic limestone, representing another tongue of the Barcaliente Limestone Formation, and 0.10 to 0.15 metres of sandstone which is clearly graded, massive, yellowish weathering, and ripplemarked (with ripple cross-lamination) at the top. A further unit of 0.40 m thinly bedded, marly, yellowish grey limestone is followed by 0.10 m sandstone with sole markings, graded bedding, and ripplemarks at the top. The measured section is closed by approximately 8 metres of thinly bedded limestone which is marly in the upper 2 metres. Parallel lamination is observed in this limestone which is intensely folded within the southern flank of the Alba Syncline.

The succession is continued beyond the measured section of text-fig. 3 by approximately 200 metres of sandstones alternating with lutitic intervals of a facies similar to those mentioned. Another thin band of fetid limestone is found subsequently, and this is followed by some more sandstones and lutites which are succeeded by the limestone band of the southern part of Peña El Asno, constituting the highest horizon of Namurian strata found in the Alba Syncline north of La Robla.

Altogether, *ca.* 740 metres of strata are recorded in the Alba Syncline above the horizon of the nodular limestone (Genicera Formation) of Viséan age. The Namurian age of these deposits is confirmed by the sparse floral remains encountered in loc. 2163, at 380 metres from the Viséan limestone. WAGNER, WINKLER PRINS & RIDING (1971) discussed the probable age of the terrigenous Namurian deposits in the Alba Syncline and in the tectonic units immediately to the north (i. e. at Pola de Gordón and east of this village). They cited evidence for a Lower Namurian age for the condensed mudstones of the Olaja Beds (compare WAGNER-GENTIS *in* WAGNER *et al.* 1971) and for a Namurian B age of the Barcaliente Limestone tongue at a few hundred metres above the base of the terrigenous sequence. A Namurian B age would therefore be most likely for the plant locality 2163, discussed in the present paper. It is also noted that the Barcaliente Limestone Formation in the more northerly tectonic units (corresponding to a position on the Cantabrian Block) appears to reach into the upper Namurian B (compare MOORE, NEVES, WAGNER & WAGNER-GENTIS 1971). This may point to a Namurian B age for even the highest strata in the Alba Syncline, which are still characterized by tongues of Barcaliente Limestone.

The Namurian succession north of La Robla is apparently not as complete as that in the western part of the Alba Syncline, north and northwest of Olleros de Alba, where PASTOR (1963) recorded a conglomerate within a sequence containing limestone tongues of the Barcaliente Formation.

Summary of the stratigraphic succession.

The general succession of Lower Carboniferous and Namurian rocks north of La Robla, as discussed in the present paper, consists of a highly condensed carbonate unit of Viséan age (Genicera Formation), a condensed terrigenous unit of probable Lower Namurian age (Olaja Beds), still rather slowly deposited mudstones of probably early Namurian B age (lower part of Olleros Formation) and a much more rapidly deposited succession of turbiditic sandstone deposits of later Namurian B age (upper part of Olleros Formation). Tongues of the Namurian A-B Barcaliente Limestone Formation are found at different levels of the terrigenous succession, and these represent the southern limit of this formation, wedging into the basinal terrigenous pile of sediments.

TECTONIC STRUCTURE

The general map published by COMTE (1959) shows a large area of Upper Carboniferous rocks (marked as Westphalian —*sensu lato)* in the region north of La Robla, and a synclinorial structure is represented by the corresponding cross section. DE SITTER (1962, map) shows these rocks as Culm, and also reproduces the structure as synclinorial (see, particularly, his Section 1, drawn a little to the west of the area discussed in the present paper). PASTOR (1963) gives some more structural detail and represents these strata, correctly, as Namurian of flysch facies. He also shows the southern boundary as a faulted contact with Cretaceous rocks (in agreement with ALMELA 1949).

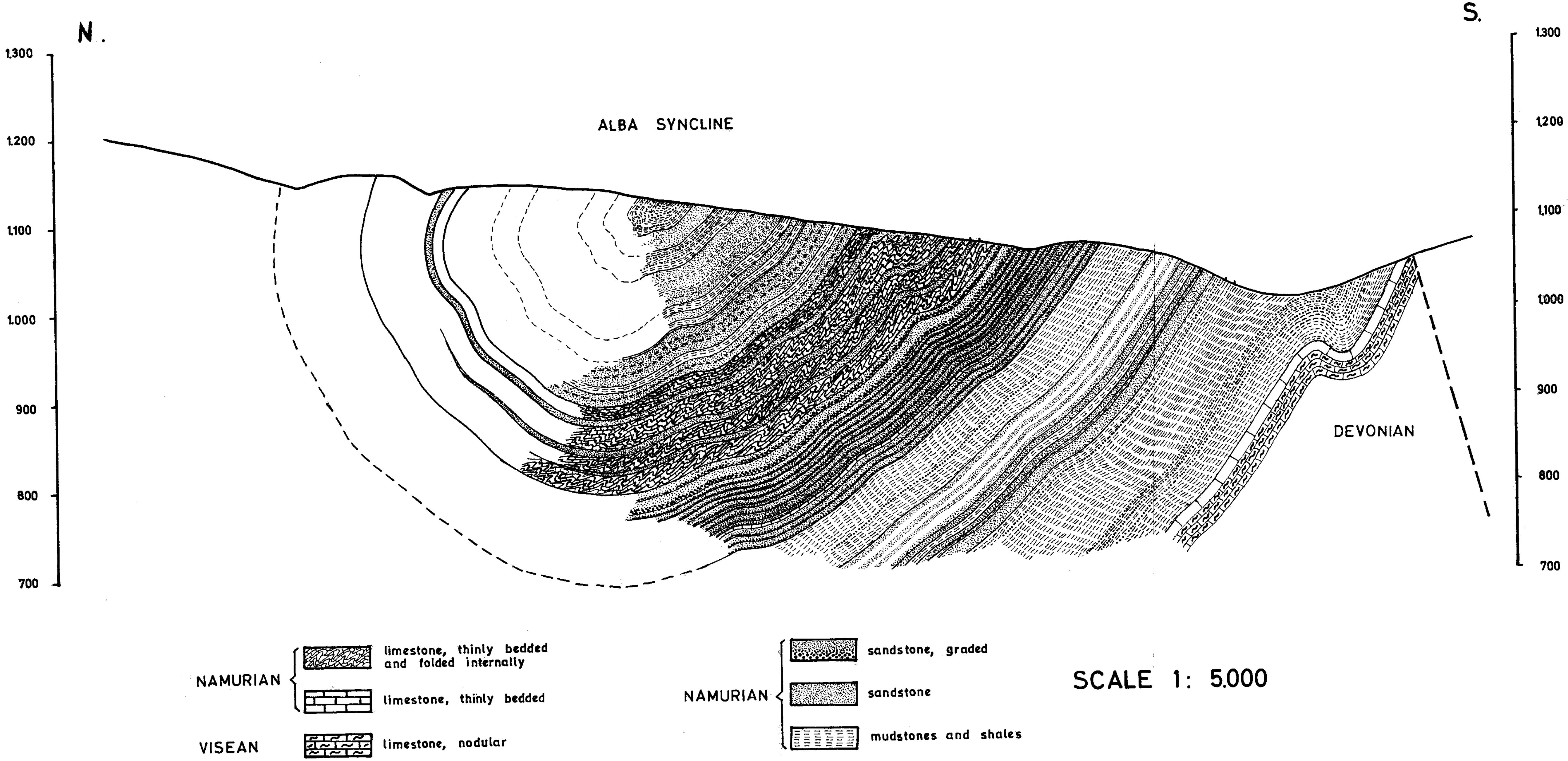
The synclinorial structure north of La Robla has been mapped in some detail by the present writers, in connection with the project for a tunnel which will eventually connect the coal mines of the S. A. Hullera Vasco-Leonesa, at Santa Lucía, with the consumer plants at La Robla. Text-fig. 1 shows the outcrops mapped in this area, with a minimum of interpretation. The accuracy of the mapping has been improved by using surveyed stakes in the southern part of the area. A cross section through the Namurian strata (text-fig. 5) shows the Alba Syncline in a well exposed area coinciding partly with the road to the cement quarries (intersection shown as raised lines on the section profile). This section, to the scale of 1:5,000, follows the line marked S-S on the map. Text-fig. 6 shows the more comprehensive section constructed from a point west of Alcedo to the coal-bearing sequence of the Ciñera-Matallana coalfield, and which follows the proposed line of tunnelling. This section is slightly oblique to the strike and runs approximately SSW-NNE.

The geological map (text-fig. 1) commences in its southern part with a faulted anticlinal structure in Viséan nodular limestone of the Genicera Formation which, together with a thin band of Namurian Barcaliente Limestone, plunges underneath Namurian terrigenous rocks at Alcedo. West-southwest of Alcedo this faulted anticline again brings up Viséan limestone which is accompanied here by Upper Tournaisian black shales of the Vegamián Formation. These heavily crumpled strata at the site of an abandoned limekiln just east of the León-Gijón railway, are not represented on the map which does, however, show the position of the faulted anticline at this point.

The section of text-fig. 5 has been drawn from the fault which accompanies the plunging anticline east of the road to the cement quarries on the southern slope of Peña El Asno. A poorly exposed lutitic sequence probably coincides with a weakly expressed anticlinal fold in the southern flank of the main Alba Syncline, and thus shows a wider outcrop than is warranted by its stratigraphic thickness. The small accessory anticline, which is weakly expressed on the line of section of text-fig. 5, is regarded as the continuation of the more clearly developed subsidiary anticline in Upper Devonian and Lower Carboniferous strata along the railway line east of the Bernesga river (text-figs 1, 6). Most of the southern flank of the Alba Syncline in the line of section of text-fig. 5 shows a continuous succession of relatively undisturbed northward dipping strata in which several bands of thinly bedded limestone are prominently represented and thickened out of proportion to their stratigraphic importance as a result of internal crumpling. These thinly bedded, easily deformed strata alternate with more competent, generally sandy units which retain their stratigraphic thickness. In the line of section the core of the Alba Syncline is situated in a sandstone/shale sequence, but a little westwards some additional bands of Barcaliente Limestone are developed at a slightly higher stratigraphic level. The highest of these limestone bands forms the synclinal core which is exposed in the mountain called Peña El Asno (compare text-fig. 1 and Pl. 1). It shows the structure to be isoclinal, with the axial plane dipping northwards.

The more comprehensive section of text-fig. 6 passes through the small accessory anticline south-east of Puente de Alba, which is well exposed along the railway line (text-fig. 1). This anticline shows a small strike fault in its southern limb and is more seriously affected by faulting in its northern flank where the lower, lutitic part of the terrigenous Namurian succession is to a large extent suppressed. The higher, more sandy part of this succession, which also shows the presence of several limestone bands, is apparently developed continuously up to the limestone which forms the core of the Alba Syncline in the southern part of Peña El Asno (Pl. 1).

The section of text-fig. 6 continues through the less fully exposed northern flank of the Alba Syncline which appears to be folded, and which shows an exaggerated width of outcrop for the turbiditic sandstone/shale succession below the main bands of Barcaliente Limestone in this region north of La Robla. A normal succession is recorded for the lutitic lower part of the terrigenous Namurian (Olleros Formation) which is here exposed in the hollow occupied by the arroyo leading to Puente de Alba (compare text-fig. 1). On the higher ground forming the southern slope of Canto Raso a limestone ridge is found to correspond to Viséan nodular limestone (Genicera Formation) followed by a thin band of thinly bedded Namurian limestone (Barcaliente Formation). Below the Viséan limestone an Upper and Middle Devonian succession is developed in a normal sequence of formations which range from Eifelian/Givetian Huergas Shales to upper Famennian/lowermost Tournaisian Ermita Sandstone Formation (see map). The Huergas Shales are in the core of a small anticline which is affected by a vertical fault striking approximately SW-NE. This fault hinges at the anticline and produces downthrow on the north-western side. The section of text-fig. 6 cuts through this fault which here results in the elimination of some part of the Upper Devonian succession. Just before the anticlinal crest is reached on the downthrown side of the oblique vertical fault, a small thrust effects some further shortening which produces a contact with Huergas Shales and Portilla Limestone of the Givetian. After a subsequent small syncline, apparently undisturbed by faulting, the sequence is continued downwards into Huergas Shales and Santa Lucía Limestone, the latter showing a small anticlinal structure which widens its outcrop just



Text-fig. 5.—Section through the southern flank of the Alba Syncline along the line marked S-S in text-fig. 1 (map). The raised lines on the section profile indicate intersections with the road to the cement quarries north of La Robla.

Text-fig. 6.—Section from the northern border of the Ciñera-Matallana coalfield (Stephanian B) to the subsidiary anticline in the southern flank of the Alba Syncline north of La Robla.

north of the Llombera road. The Lower Devonian La Vid Formation then appears below the Santa Lucía Limestone (Emsian/Eifelian) and forms an anticline which is the last small structure in the northern flank of the Alba Syncline.

A possible thrust fault separates this anticline in the La Vid Formation (limestones and shales) from an outcrop of massive limestone within the Santa Lucía Formation at Vega Fonda, and this shows a faulted contact with Stephanian B coal-measures of the Bienvenidas and San José formations (compare WAGNER 1971[a], text-figs. 1, 24). This small outcrop of Santa Lucía Limestone, which is caught up between two faults, probably connects with the larger mass of limestone of the same formation in the mountain called Cueto de San Mateo, where the Santa Lucía Limestone shows an anticlinal and a synclinal fold within a probably minor thrust sheet lying on Namurian strata.

These Namurian strata, belonging to the lower part of the Olleros Formation (with *Reticuloceras* of Namurian B age), are found with a considerable width of outcrop in the core of an anticline in Stephanian B rocks of the Ciñera-Matallana coalfield. They are mainly lutites with thin sandstone beds and intercalations of Barcaliente Limestone, which show an inverted thrust contact with the steeply dipping northern limb of an isoclinal syncline in Devonian and Carboniferous strata underlying the Matallana Syncline in strongly unconformable Stephanian B coal-measures. It is noted that the Barcaliente Limestone Formation of the Namurian A-B is well developed in this isocline which there marks an important facies change from the contemporaneous Olleros Formation on the southern side of the inverted thrust. The latter thus represents an important shortening which is also noticeable in the absence of most of the Upper Devonian deposits (Fueyo Formation and at least part of the Nocedo Formation) below the disconformable Ermita Formation.

Two additional inverted thrust faults are found below the Stephanian B coal-measures of the Vegacervera Syncline, the northern flank of which rests on a repetition of Middle Devonian strata forming another overturned sequence. The structure of the southern flank of the Vegacervera Syncline has been investigated in more detail since text-fig. 6 was drawn, and it proves to be more steeply folded than has been indicated in the section. The apparently southward dipping fault in the Esperanza Valley region is a transcurrent one.

Text-fig. 6 shows clearly that the entire region represented on the map of text-fig. 1 belongs to the Alba Syncline which is centred on the Namurian rocks of Peña El Asno, and which contains a number of small subsidiary folds, particularly in its northern flank, which thus shows a considerably widened outcrop. It contains a full succession of exposed Middle and Upper Devonian strata (with some Lower Devonian at the base), extending from Vega Fonda in the north to beyond Canto Raso in the south. The succession then continues with the disconformable late Famennian to early Tournaisian Ermita Sandstone Formation which is succeeded in turn, also disconformably, by Viséan nodular limestone of the Genicera Formation. The central part of the Alba Syncline shows a thick succession of terrigenous Namurian rocks (mainly Namurian B) which are partly developed in a turbidite facies. North of the folded northern limb of the isoclinal Alba Syncline, the overturned northern flanks of several isoclinal synclines are found as thrust slices which generally also show some part of the synclinal cores. These underlie the strongly unconformable Stephanian B strata of the Çiñera-Matallana coalfield which, in the line of section (text-fig. 6) show three main synclines with two intervening anticlines (compare WAGNER & ARTIEDA 1970 and WAGNER 1971[a]).

CONCLUSIONS

The region north of La Robla, containing the southernmost exposures of Palaeozoic rocks in this part of northern León, is somewhat unusual both palaeogeographically and tectonically. Apart from the rather full record of Upper Devonian strata, already reported by COMTE (1959), it contains a terrigenous Namurian succession which corresponds to the northern edge of a flysch basin with a transition to the platform area of the Cantabrian Block being marked by the presence of tongues of Barcaliente Limestone (lower «caliza de montaña»). This basin should be more fully developed under the Late Mesozoic and Tertiary deposits of the Leonese Meseta. Tectonically, the region north of La Robla shows a synclinorial structure which does not appear to have suffered the same degree of shortening as the thrust slices further north, but which is essentially similar in that isoclinal folds with northward dipping axial planes are generally recorded.

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A view of the isoclinal core of the Alba Syncline at Peña El Asno, taken from the west. Thinly bedded Barcaliente Limestone in the core of the isoclinal syncline follows upon a succession of lutites, sandstones and occasional limestone bands.