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THE GEOLOGY OF THE REGION TO THE SOUTHEAST OF LUGO (N.W. SPAIN)

BY

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ABSTRACT

The area described comprises the SE plunging extension of the anticlinorium of Mondoñedo-Lugo-Sarria and several structural units to the NE of it. The stratigraphy compares with that of neighbouring areas. Certain new observations have been made regarding the west flank of the East Galician-West Asturian miogeosyncline at the end of the Precambrium and during the Early Palaeozoic. Stromatolites or algae played an important part in the formation of carbonate deposits during late Precambrian (Cándana limestone) and Lower Cambrian time (Vegadeo limestone). An imprint, possibly attributable to a specimen belonging to the Precambrian Ediacara fauna, was found in the Cándana Schist Formation. A shallow or relatively high zone existed during that time in the region around Incio. The same general area formed a high again at the end of the Ordovician, causing erosion and a marked disconformity of the Silurian.

The Hercynian structures can be explained by assuming roughly WSW-ENE compression and shortening. In the NW of the area this is expressed in the first place by the recumbent folds of the Lugo-Sarria anticlinorium, and in the SE by the narrowness of the steep folds and their slightly changed direction in the general area of Seoane and El Cebrero. Normal crossfaults are related to the folding and the compression. They show locally a deviation in accordance with the direction of shear stress. Horizontal displacement along such faults in an EW direction was probably of little importance. Finally a few observations are given on the occurrence of Pb-Zn ores at the mine of Rubiales.

CONTENTS

1. INTRODUCTION

The present paper deals with an area on the eastern flank of the central Galician-Castillian zone of the Hesperides. It is a part of a belt essentially formed of Lower Palaeozoic rocks, situated between two areas where for a number of years geological investigations were carried out by the Department of Geology and Geophysics, University of Leiden: the Galician basement in the west, and the Palaeozoic Cantabrian zone in the east. The results reported here were obtained during geological mapping excercises carried out by students of the Mining Faculty of the Technological University of Delft (Netherlands) between 1971 and 1978. A more detailed report will be published by the Instituto Geológico y Minero in Madrid (Dozy 1983). The area studied is located on the W.flank of a late Precambrian and early Palaeozoic miogeosyncline of the Hesperian Massif described by J.R. Parga (1970) (figure 1). A part of the area, where results only confirmed previous work, notably that of P. Matte (1968), is not covered by the present paper, which deals with the northeastern part where new information has been collected. The geological map

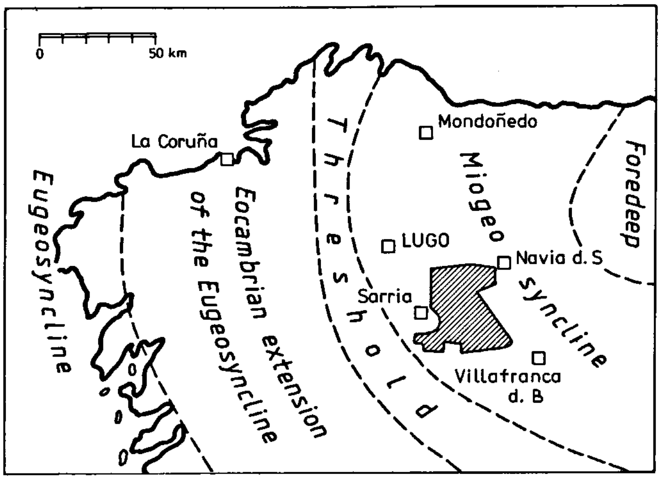

Fig. 1. Palaeogeography of Galicia during late Precambrian and early Palaeozoic time, according to Lotze (1961) and Parga (1969), and the location of the area under discussion.

of it is given as figure 2. Participants whose work has been used in the present paper are W.J. Adolfs, R. van Brakel, C.J. Dijkstra, J. Flink, P.L.M. Gilissen, C.A.M. van Hengstum, E.K. Kips, E.H.M. Maitimo, M. van Rees, H. den Rooyen, J.P.M. Ruysenaars, P.J. Sitter, B. Waardenburg and J. de Witte. Thanks are due to Compañía Exploración Minera Internacional (España) SA (EXMINESA), which made additional work possible for Mr. Gilissen, and the Molengraaff Foundation which financed voluntary work by Messrs. van Brakel en den Rooyen. As to supervision and coordination of the fieldwork assistance by Dr. F. Heybroek (who passed away in 1978), Dr. L. Dorsman and Dr. F. Koster must be gratefully acknowledged. Thanks are due to the Comisión Nacional de Geología in Madrid, who granted permission to carry out this survey, to A. Huerga Rodriguez of the Servicio Geológico y Minero in Madrid and to Dr. I. Parga Pondal in La Coruña for their support and encouragement.

Draughting and reproduction work have been carried out by Messrs. Swanink and Faessen, who are thanked for their valuable assistance.

2. STRATIGRAPHY

GENERAL

One of the difficulties experienced in the field was the similarity of the many detrital formations and the lack of fossils. The stratigraphy had to be established or confirmed while unravelling tectonic relations at the same time. This situation led to the application of local rock unit names. Some of these have been maintained in preference to the chronostratigraphic names previously used, or because the formations described might represent only part of corresponding or correlatable formations, mostly established in Asturias or on the north coast.

For a description of the stratigraphical sequence encountered reference is made to table 1. Some highlights and specific remarks of general interest are given below.

OLLO DE SAPO AND VILLALBA FORMATIONS

During the Precambrian a detrital volcanic deposition occurred on the treshold separating the miogeosyncline from the eugeosyncline to the west of it. These deposits form the porphyroids of the thick Ollo de Sapo Formation. Capdevila (1970) noticed a gradual diminishing of the 'eyes', not only upwards but also from W to E. Farther to the east, as in the area under review, a thick sequence of pelitic or greywacke sediments of the Villalba Formation occurs in the miogeosyncline. The contact between these two formations has never been observed. In greywackes of the Villalba Formation Capdevila (1969) found feldspars probably derived from the same granitic source as those in the Ollo de Sapo. On that basis he assumed that the Villalba beds were probably deposited far away to the east below the sea, thus representing a different facies development, equivalent in time at least to the upper part of the Ollo de Sapo.

The hypothesis of a supply of detrital material derived from a geanticline in the W during late Precambrian time is a very useful one. The monotonous character of the Villalba, its vast distribution, its pelitic nature with fine intercalations of silty arkoses or greywackes indicate a sedimentation far offshore in quiet and relatively deep water.

Towards the top of the formation an uppermost more pelitic and graphitic section was found, as can be seen in the Sierra do Edramo S of Samos, indicating a shallowing of the sea leading to a more abundant organic growth. The few quartzite beds found elsewhere near the top of this uppermost Villalba are forerunners of changing conditions, which begin clearly to take effect with the deposition of the Cándana formations.

CÁNDANA GROUP

A regressive tendency is marked by a sudden supply of fresh detrital material. The sands and silts of the Lower Cándana Quartzites must have been derived from a landmass not very far to the W. They were deposited in varying thickness in a relatively shallow sea along the coast. The hinterland corresponds most likely with the region W of the area studied

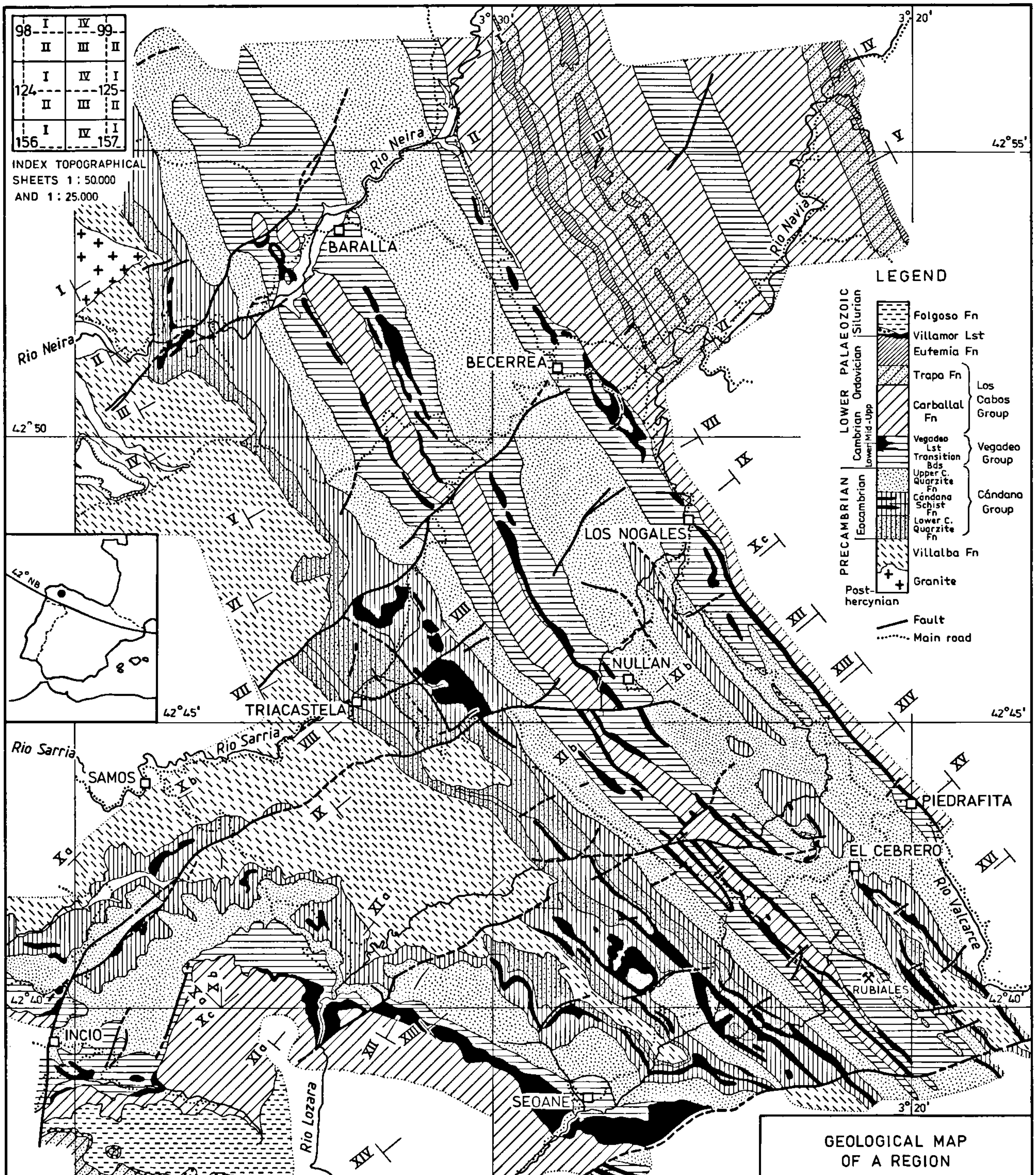

Fig. 2. Geological map of the region SE of Lugo.

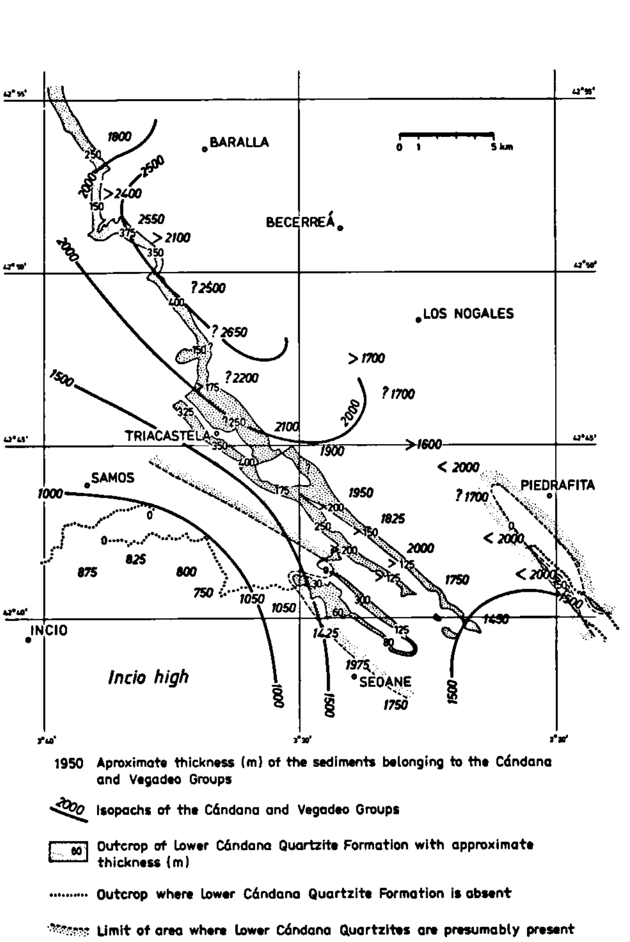

Fig. 3. Isopachs of the Cándana and Vegadeo Group sediments and the distribution of the Lower Cándana Quartzite Formation.

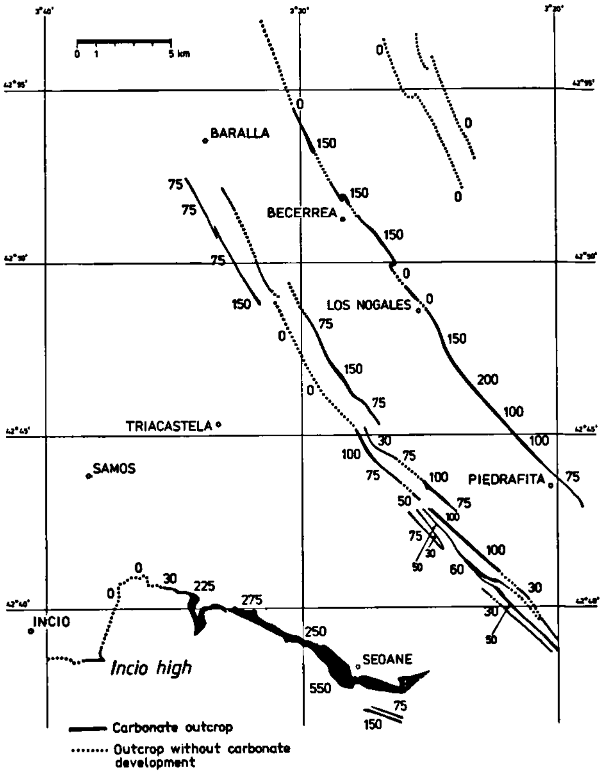

Fig. 4. Distribution of carbonates in the Vegadeo group with approximate thickness in meters.

where uppermost Precambrian and Lower Cambrian deposits are missing and the equivalent of the Carballal Formation overlies Ollo de Sapo Formation directly. In the area studied the base of the Cándana Group appears conformable in the field. The same relationship has been found between Villalba beds and the Cándana Schist Formation in an area around Incio. Significant emersion needs not to be assumed, but sedimentation was at places perhaps much reduced, consisting locally of finer grained sediments. Maybe many diastems occurred, or both. The large amount of coarser clastics was deposited in presumably deeper parts around this High of Incio (figure 3 and figure 5 sections Xa, b and c).

The Cándana Schist Formation seems to mark a transgressive phase. The size of the detrital components is finer and the bedding thinner in general, whilst the presence of carbonates indicates perhaps a somewhat quieter shallow marine environment. The term transgressive here does not necessarily imply a rise of sea level. The effect might also be the result of an interruption of the rise of the hinterland and its erosion.

Typical for the mainly detrital and pelitic Cándana Schist Formation is the occurrence of carbonate material and the intercalation of carbonate layers, so called Cándana Limestones. Sometimes two such horizons were found, which could be followed in a limited area, but elsewhere several minor limestone layers or even a single thick zone occurred like the one being quarried near Mao to supply a cement factory at Oural.

In the field the Cándana limestones show often a striation, reminiscent of algal growth or algal mats, despite sometimes strong metamorphism and recrystallization. Under the microscope the striae appear to be caused by organic carbon or fine sericite-rich laminae. Irregular white crystalline carbonate nodules occur in layers between algal mats at certain places. Possibly they represent evaporite concretions replaced by carbonate. In connection herewith the 14 meter thick magnesite deposits in the Cándana Schists of Rubian, near the road Sarria-Monforte (Guillou, 1970) come to mind. The general environment is reminiscent of platforms or shoals with algal or stromatolite growth, which dried up locally and from time to time, so that evaporite precipitation became possible under supratidal conditions. At a later stage evaporite crusts broke up to form corrugated masses or fragments. Similar phenomena have been described by Hoffmann(1974) from the Lower Proterozoic in Canada.

The discovery of an imprint, probably of a representative of the Precambrian Ediacara fauna (Glaessner 1971, Stanley 1976) is significant. This find seems to corroborate the uppermost Precambrian age allocated to the Cándana Formation by Parga (1971) on the basis of a comparison with other areas. (Dozy,1983 in press). Another regressive-transgressive hemicycle follows above the Lower Quartzites and the Cándana Schist Formations. The upper Cándana Quartzites represent again an abundant supply of detrital material from the same hinterland as the Lower Quartzites. This time the Incio High is also covered by the sandy sediments, although in a reduced thickness. The thick ledges of quartzites composed of rounded quartz grains and probably cemented by hydrothermal quartz, which stand out clearly in the landscape over tens of kilometers in the zone of Baralla and El Cebrero, are noteworthy.

VEGADEO GROUP

The Vegadeo Group represents the transgressive phase of the second hemicycle. It is difficult to adhere strictly to the stratigraphical subdivisions used elsewhere because of horizontal and vertical facies changes. It is therefore considered that these represent subdivisions of a Vegadeo Group. Its lower part corresponds with the Transition Beds, a formation established by Lotze (1957). The Upper Cándana Quartzites lose their predominant sandy character upwards and are replaced by more pelitic and generally thinner bedded sediments. These contain occasionally a carbonate admixture and intercalations of sandy limestones or thin carbonate beds. This largely pelitic and detrital sedimentary sequence is common in the Vegadeo Group as a whole. In the Lor Valley, however, these Transition Beds are followed by a thick carbonate sequence, comparable with the Vegadeo Limestone from other areas. In the northeastern part of the area carbonates are restricted to certain thicker or thinner ledges and layers, and at places even entirely missing. Different local members of the Vegadeo Group are thus based on the presence of more or less well identifiable limestone or dolomite layers.

The sedimentary environment is illustrated by the carbonate distribution (figure 4). An area without much carbonates can be recognized again, coinciding with the late Precambrian Incio High. It looks as if it were too high to accommodate much carbonate secreting growth. It is not excluded that here a hiatus, or even some erosion occurred before it was covered by the next younger formation. Considerable probably biohermal and biostromal carbonate deposition occurred, however, on its slopes, exposed in the Lózara and Lor Valleys. Some features are reminiscent of fringing reefs.

Despite often strong recrystallization an algal striation or lamination similar to that observed in the Cándana Limestones can be seen. Other layers show onkolitic structures. In the area between say Baralla and Piedrafita limestone development is much thinner but more uniform in ledges with a total carbonate thickness of say 50 to 150 meter. Zamarreño and Perejón (1976) demonstrated the tidal flat character of this type of limestones near Piedrafita. It is typical that such limestone deposits are locally absent. The interruptions probably correspond with tidal channels, where only detrital sedimentation took place. Again farther to the NE a carbonate development seems entirely lacking and the whole sequence consists of detrital pelitic sediments. It is possibly a deeper sublittoral or neritic facies present in the central part of the miogeosyncline.

The limestones contain, apart from algal-mat striae occasionally irregular carbonate nodules like those described from the Cándana limestones, so that possibly evaporitic conditions occurred again on the carbonate shelves. Besides stromatolitic-type limestones, onkolitic and even clearly pisolitic carbonates were found in accordance with the general environment.

The limestone ledges illustrated schematically in figure 4 do not represent necessarily the same stratigraphic level. Shelves may have shifted. They do not always form the uppermost member of the Vegadeo Group in general. Silification of the limestones has been observed, especially of the uppermost limestone beds.

In the marly sandy shales and limestones of the upper part of the Vegadeo Group Archaeocyatha have been found and described by Debrenne and Zamarreño (1975), Zamarreño, Hernosa, Bellamy and Rabu (1975), also by Gilissen from the Rubiales mine (Dozy, in press). The age of this fauna is Lower Cambrian, but an uppermost member of the Group belongs already to the lowermost Middle Cambrian. Thus the base of the Vegadeo Group might be considered tentatively to coincide with the beginning of the Cambrian as postulated already by Parga (1971).

LOS CABOS GROUP

The sediments of the Los Cabos Group mark a new sedimentary regime. The detrital material is now derived from a source in the E and the environment is probably deeper marine as borne out by the thickness of an order of 1000 meter of monotonous fine grained shaly material alternating with millimeter thick intercalations of silts or quartzites which often show grading under the microscope. Occasionally thicker quartzitic beds are intercalated. This flysch-like Carballal Formation, named after Mt. Carballal S of Seoane, is followed upwards by thick 0.5 - 30 meter quartzitic sandstone beds, alternating with

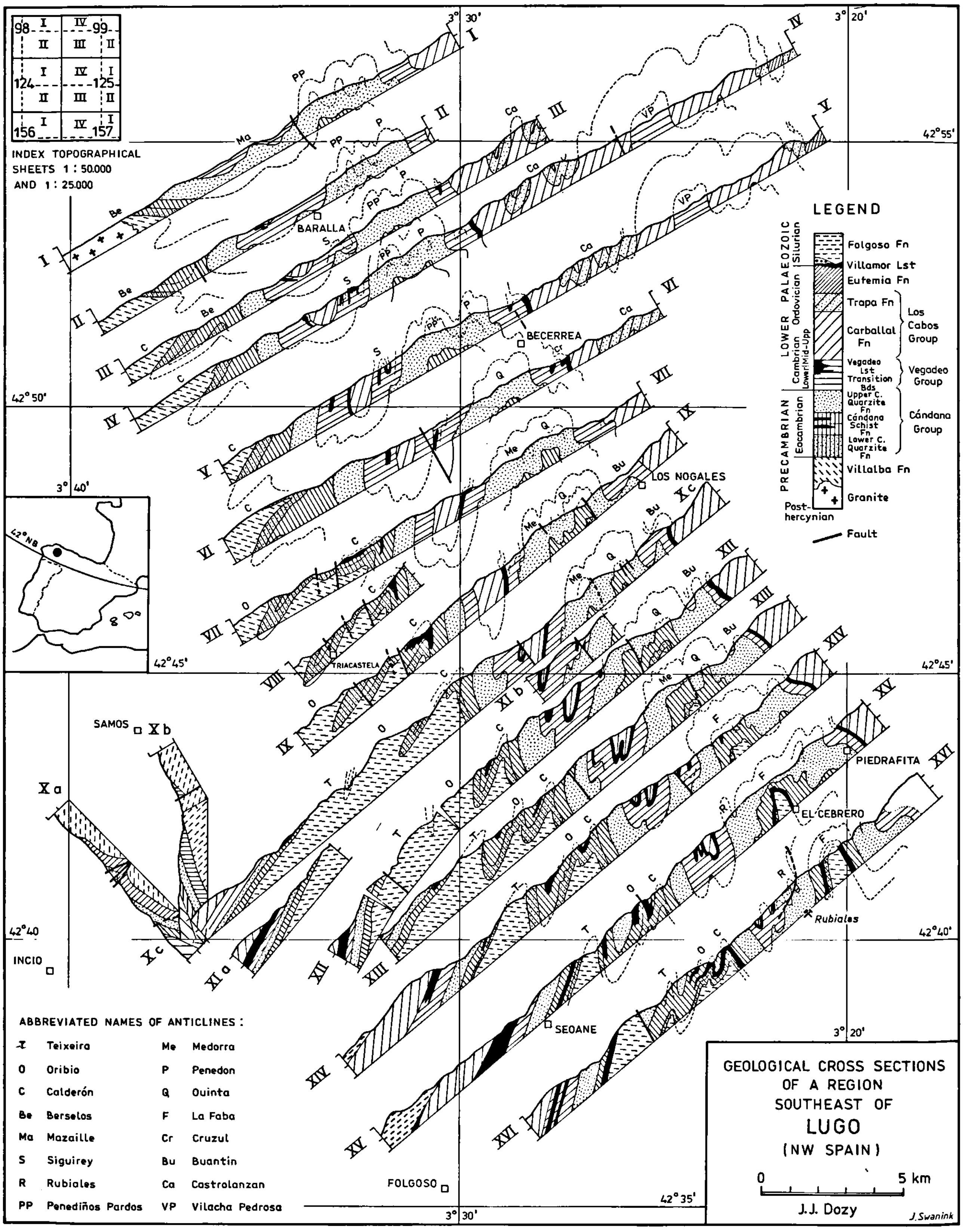

Fig. 5. Geological cross sections of the region SE of Lugo. For location of sections see figure 2 and 6.

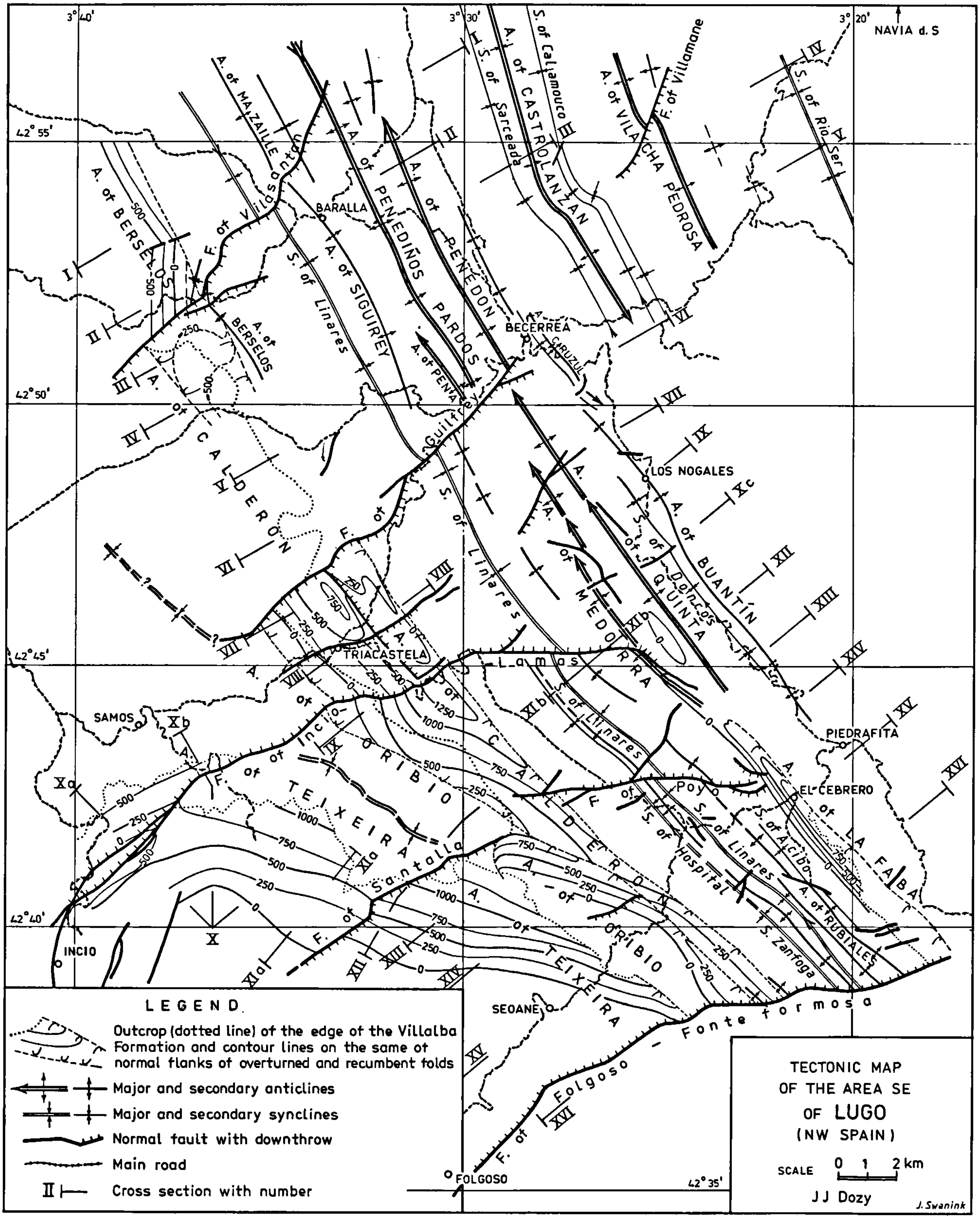

Fig. 6. Tectonic map of the area SE of Lugo.

Carballal-type schists, which have been named the Trapa Formation after the Sierra of that name SW of Folgoso. Jaritz and Walter (1970) recognized three facies-types in the sediments of the Cabos Group. The Carballal corresponds with their distal Villamea facies, the Trapa with their Cabos facies. It is preferable to maintain the name Cabos Group from Lotze's (1957) "Cabos Serie" instead of Jaritz and Walter's (1970) "Upper Clastic Series", which might cause confusion.

EUFEMIA AND VILLAMOR FORMATIONS

The pelitic Eufemia Formation, named after the locality of Sta Eufemia on the road from Quiroga to Folgoso, may correspond with a part of the Luarca Formation in Asturias. It is overlain in certain places by a white crystalline limestone (sometimes accompanied by black ampelites) which has been named after the hamlet of Villamor on the Lor River below Folgoso. With this Villamor Formation the Ordovician sedimentation came to an end.

SILURIAN UNCONFORMITY AND FOLGOSO FORMATION

Silurian sediments cover different Ordovician formations with a gentle but clear unconformity. In the Lor Valley near Ferreiros de Abajo Trapa and Eufemia Formations had been removed by erosion. The presence of two very limited remnants of Villamor limestone may suggest that the erosion occurred already during early Ashgill time. In the overturned flank of the Caurel anticline the Trapa Formation on the Monte Sapeira-Monte Legua appears fairly complete, with only the Eufemia schists missing. Here a several meters thick ledge of grey, occasionally ferruginous or breccious sandstone forms the base of the Silurian. North of this mountain range and in the normal flank S of the Balneario de Incio even part of the Carballal Formation appears to be missing. Here some 600 to 800 meters of sediment have been removed.

Thus a fairly important local uplift must have occurred, culminating again in the general area of Incio, before the deposition of the Silurian Folgoso Formation took place. The movement appears to reflect a Taconian tectonic phase, but there is no reason to assume orogenic activity.

The black chloritoid schists of the Folgoso Formation, well exposed along the Rio Lor above the village of Folgoso, are rich in carbon. They represent a metamorphosed bituminous sedimentary sequence, deposited in an environment of restricted circulation. Shales of similar age are oil source rocks, for example in the Algerian Sahara.

CONCLUDING REMARKS

A significant change occurred in the almost exclusively detrital sedimentary environment during the time dealt with above. The sediments of the Proterozoic Villalba Formation derive from a source relatively far to the west. With the onset of the Upper Brioverian the sea became shallower and a land mass must have existed closer to the area studied. A western source for the detrital material continued up to the Middle Cambrian, when the sea level rose and not only the area under review but also the land to the west became covered by the flysch deposits of the Cambro-Ordovician Cabos Group that had their origin in the east (Jaritz & Walter 1970). From that time onward the stratigraphy is related to the stratigraphy of the Cantabrian zone, where also the older sediments have an eastern origin.

This picture is of course in line with the idea of an early Palaeozoic geosyncline as described by Parga (1970). The isopachs of the Cándana and Vegadeo sediments (figure 3) and the facies distribution in the Vegadeo Group (figure 4) corroborate the idea.

The tremendous amount of often monotonous detrital material that filled the West Asturian-Leonese geosyncline during the roughly 200 million years covered, is remarkable. Much of the material is pelitic and travelled long distances on ocean floors as fine turbidity currents. The Villalba and Carballal Formations are typical examples. An unhampered and strong erosion of the mainland is indicated and it should of course be realised that land plants did not yet or hardly occur.

3. IGNEOUS ROCKS

Granites, common around Lugo and Sarria are not exposed in the area studied, except for an extreme eastern tip of the granite of Sarria, which has been described by Capdevila (1969).

A few rare dykes have been encountered. In the Lor valley a sill of a dark grey yellowish weathering trachite porphyry, distinguished by its concoidal fracture, has been intruded on the boundary between Vegadeo Limestone and Carballal Formation. Under the microscope it shows remains of pyroxenes altered to epidote and chlorite, and basic zonal plagioclase in a matrix of biotite and basic plagioclase (altered to carbonate, chlorite, epidote etc.).

In the neighbourhood of Otero, not far N of the Ponteformosa fault, a dyke running in the strike of the Vegadeo Formation was found, consisting of an olivine dolerite with an ophitic structure, the basic plagioclase altered to calcite and serpentinized olivine. To the S of the same fault blocks of quartz porphyry were found near Capeloso Bajo. Phenocrysts of quartz (up to 5 mm long), white and reddish feldspar and muscovite occurred in a light greenish aphanitic groundmass.

4. TECTONICS

GENERAL

From a structural point of view the area can be subdivided into three NW-SE directed zones, representing successively structurally lower steps proceeding towards the NE (figure 5).

(1) The zone of Lugo-Sarria consists of outcropping Villalba schists and their immediate sedimentary cover.
(2) The zone of Baralla is characterized by outcropping Cándana and Vegadeo Formations.
(3) The zone of Navia de Suarna exposes mainly formations of the Los Cabos Group.

A fault pattern of regional significance affects the folds and will be dealt with separately. For the location of individual structures refer to figure 6.

ZONE OF LUGO-SARRIA

This zone comprises the SE plunging extension of the Lugo High and forms part of Matte's (1968) anticlinorium of Mondoñedo-Lugo-Sarria. The cover of Eocambrian sediments preserved on the SE plunge shows the anticlinorium to be composed of four anticlines. They are recumbent folds in the NW but straighten themselves gradually to become overturned in the SE. Finally the three most important folds form a relatively narrow bundle exposing Lower Cándana Quartzites and Cándana Schists in their axes (Section XVI, figure 5). These anticlines of Teiseira, Oribio and Calderón are well exposed in the valleys of the Lor and Lózara Rivers. The synclines can be followed for a limited distance towards the NW within the area of outcropping Villalba schists. The folded and disturbed white quartzite beds, exposed in the uppermost Villalba Formation on the S slopes of the Mte Oribio betray the presence of the syncline between the Teixeira and Oribio anticlines. The Precambrian core of the Calderón anticline is exposed in the hairpin of the road from El Cebrero to Triacastela about 4 km before reaching the latter village (see also Section Xc, figure 5).

On the other side of the basin of Triacastela the Villalba core of the Calderón anticline reappears again in the SE flank of the Mte Meda. Above it the summit region exposes rather flat lying Lower Cándana Quartzites belonging to the upper or SW limb of the recumbent Calderón fold (Section VI, figure 5). The aerial photographs of the mountains SW of the Mte Meda show a straight depressed zone between the hamlets or villages of Lousada, Furela and Cima de Vila. This may betray the presence of the syncline between the Oribio and Calderón anticlines.

A fourth fold could be recognized near the hamlet of Berselos, where it emerges in front of the Calderón anticline as a ridge within the Cándana Schist Formation (Section III, figure 5). North of the Vilasantán fault the fold has been further uplifted. Its core exposes Villalba schists in an overturned position as evidenced by the cleavage dipping northeastward (Section I and II, figure 5). The syncline between the Calderón and Berselos folds is exposed in the left flank of the Neira valley, near the hamlets of Acibido and San Andrés.

ZONE OF BARALLA

A steep flank leads in general down towards this structurally lower level upon which the prominent syncline of Linares and the anticlinorium of El Cebrero are located. However, near the Folgoso-Fonteformosa fault in the SE the difference in tectonic level with the Lugo-Sarria anticlinorium does not exist and structures of both units show a similar style (Sections XV and XVI, figure 5). While the axes of the anticlines pertaining to the Lugo-Sarria zone ascend from here to the NW, those of the zone of Baralla plunge in the same direction.

The syncline of Linares,rather narrow and complex in the SE, deepens at first towards the NW and contains a core of Carballal Formation. Beyond the Guilfrey fault the axis rises again and the structure broadens and flattens to such an extent that it terminates NW of the Vilasantan fault almost as a half basin (Section I, figure 5).

The anticlinorium of El Cebrero appears to become, in the SE, one major anticline exposing Villalba schists in its core near La Faba village (Section XVI,figure 5). This steep and narrow structure plunges also northwestward. To the NW of El Cebrero a broad inlier of tightly folded Cándana Schist Formation is exposed below Upper Cándan Quartzites in the headwaters of the Rio Navia (Section XIV, figure 5). Further to the NW two major anticlines can be recognized. The axis of the Medorra anticline follows from the asymmetry of parasitic folds in resistant quartzite beds on its flanks. Th core of the Quinta anticline is exposed as a long and narrow inlier of Cándana Schist Formation. Both structures plunge fairly strongly towards the Guilfrey fault. On the NW side of the fault the trend of both features continues in the anticlines of Penidiños Pardos and Penedón. Resistant quartzite beds in the Upper Cándana Formation indicate the folded nature and the location of the axes, as can be seen, for example, along the main road N-VI between Baralla and Becerreá and in the valley of the Neira River above Baralla.

In addition to the above mentioned structures many secondary features can be recognized. Secondary anticlines within the outcrop of the Vegadeo Formation show often crumpled limestone layers in the crestal parts. It may seem as if secondary anticlines on the flanks of major structures form continuous zones. They may,however, relieve each other en échelon. Superimposed on all these structures still narrower smaller parasitic folds occur ubiquitously, especially in the crestal parts

ZONE OF NAVIA DE SUARNA

Here the most conspicuous feature is a pair of synclines, those of Sarceada and Calamouco, with Eufemia Formation in their core, separated by the anticline of Castrolanzán (Sections III, IV, V, figure 5). The latter exposes the Carballal Formation and disappears towards the SE into Trapa beds (Section VI, figure 5). A single synclinal trend of Trapa Formation continues toward the SE outside the area mapped. This composite synclinorium might be compared with the Linares syncline of the zone of Baralla.

The next structural element is the broad anticline of Vilacha Pedrosa (Sections IV and V, figure 5). Secondary folds and parasitic folding are present. The last most north-easterly feature observed is a syncline, well developed in the lower reaches of the Rio Ser (Section IV, figure 5). It represents probably the southern extension of the syncline of Rebera de Piquin (Capdevila 1965)

THE FAULT SYSTEM

Normal cross- or oblique faults intersect the fold features more or less at right angles (figure 6). Within the area of the Lugo-Sarria anticlinorium these faults strike slightly E of NE with the exception of the Fonteformosa fault. The latter shows, together with the faults in the Baralla zone a deviation towards the ENE and E in accordance with a direction of shear. The complementary shear direction towards the NNE occurs also (e.g. Guilfrey and Vilasantan faults).

The shift of stratigraphic boundaries in the field and on the map can, in general, be explained satisfactorily by the inclined nature of the strata and the fold axes in combination with a vertical displacement. Transverse movements have therefore probably been of limited importance.

Two pairs of important faults occur (figure 6).

(1) A northern pair, those of Vilasantan and Guilfrey, with downthrow to the SE. They show a tendency to deflect to the left, or towards the NNE.
(2) A southern pair, those of Incio-Lamas and Folgoso-Fonteformosa with downthrow to the the NW. These tend to bend to the right, or towards the E.

The northern faults have not been observed for any great distance within the Villalba schists. Their throw seems greatest near the syncline of Linares: about 400 meter for the Vilasantan fault and perhaps almost 1000 meter for the Guilfrey fault. They loose their importance gradually towards the NE. On the aerial photographs a fault in the outcrop of the Vegadeo Formation of the Vilacha-Pedrosa anticline was recognized. This fault of Villamane represents possibly an extension of the Guilfrey fault, which then might continue at depth from Becerreá towards the NE, its throw being expressed in the overlying Cabos Group formations as a flexure.

The two most important southern faults originate in the core of the recumbent Caurel fold S of the area reviewed. The shift of the syncline between the Oribio and Calderón anticlines by the Incio-Lamas fault is clearly visible in the N-flank of the Oribio Mountain from a point of the road El Cebrero - Triacastela near Filloval. Its maximum throw near the Linares syncline amounts to some 800 meter. The trace of the fault becomes lost between the Medorra and Quinta anticlines. The Folgoso-Fonteformosa fault begins in the core of the Caurel folds in the Lor valley. To the E of Seoane it follows increasingly an eastward shear direction. The fault proceeds northwestward beyond the area studied, crosses (according to the aerial photographs) the Valcarce and bends northward towards the neighbourhood of the village of Balboa.

Other faults have in general a more limited throw, with the exception to the fault of El Poyo, which might perhaps come close to 1000 m near the Linares syncline. Remarkable are the curved faults near its eastern termination. They might indicate a limited dextral displacement.

HISTORY OF FOLDING AND FAULTING

The present structures can be explained as the result of progressive compression and shortening, causing initially simple folds, then secondary ones and finally smaller parasitic folds. At the same time cleavage and schistosity developed becoming gradually more intense. The compressive stress was apparently strongest in the south.

The folds of the Lugo-Sarria anticlinorium, recumbent in the NW, redress themselves - as mentioned above - to become gradually merely overturned in the SE. At the same time their amplitude diminishes. The width of the anticlinorium measures some 20 to 25 km across near Sarria. In the Rio Lor section E of Seoane its crestal zone, comprising three structural elements measures not more then 4 of 5 km.

The formations immediately adjacent to the northern faults show a SE dip, betraying a SE drag along these faults. This can be observed in the Villalba schists near the Vilasantan fault and the Guilfrey fault, or in the outcrop of the Upper Cándana Quartzites NW of both faults. The down-to-the-SE throw accentuates the SE plunge of the Lugo-Sarria anticlinorium. These faults originated probably before the folds reached their final shape and well before the compression reached its maximum. The clear NW plunge of the Medorra

CHRONOSTRATIGRAPHY		LITHOSTRATIGRAPHY		THICKNESS meters	LITHOLOGY		CORRELATIONS	
SILURIAN		FOLGOSO FORMATION				black chloritoid schists; at the base locally grey, occ.ferruginous sandstone		Obere Ordogot Schiefer (Riemer 1963)
ORDOVICIAN	ASHGILLIAN	VILLAMOR FORMATION		0 - 40		white crystalline limestone and black ampelites		
ORDOVICIAN	LLANDEILIAN	EUFEMIA FORMATION		300		blue-grey pelitic shales, varicoloured weathering, occ.ellipsoidal concretions		Luarca Formation p.p. Schistes bleutés à Calymene (Matte 1968) Untere Ordogot Schiefer (Riemer 1963)
ORDOVICIAN	ARENIGIAN TREMADOCIAN	LOS CABOS GROUP	TRAPA FORMATION	0 - 300		ledges of quartzites with intercalations of silty or sandy schists; "Cabos facies"	Upper Clastic Series (Jaritz & Walter 1970)	Armorican Quartzites (various authors) Eo Schichten (Jaritz & Walter 1970) Quartzit Folge (Riemer 1963)
UPPER & MIDDLE CAMBRIAN		LOS CABOS GROUP	CARBALLAL FORMATION	1000 (at Incio 200)		dark grey flysch-like schists, occ.intercalations of quartzite beds; "Villamea facies"	Upper Clastic Series (Jaritz & Walter 1970)	Villamea Schichten(Jaritz & Walter 1970) Montes Schichten (Riemer 1963)
LOWER CAMBRIAN		VEGADEO GROUP	VEGADEO FORMATION S.STR.	300 - 500	entirely detrital facies in the NE.	greenish-grey silty schists, in upper part carbonate layers, algal mats, reefs calc. sandstones and calc. schists with Archaeocyatha	Limest.& schists of Vegadeo (Barrois 1882)	greenish schists w.fauna (Parga 1967) Obere Rio Torto Schichten (Jaritz & Walter 1970) Vegadeo Limestones (various authors)
LOWER CAMBRIAN		VEGADEO GROUP	TRANSITION BEDS	300 - 500	entirely detrital facies in the NE.	greenish-grey silty schists with carbonate admixture and carb. intercalations which diminish downward; at base occ.black schists	Limest.& schists of Vegadeo (Barrois 1882)	Uebergangs Schichten (Lotze 1957)
PRECAMBRIAN	EOCAMBRIAN (UPPER BRIOVERIAN)	CANDANA GROUP	UPPER CANDANA QUARTZITES	200 - 1000		sandy and quartzitic schists, occasional silty occasional quartzite ledges	Lower Clastic Series (Jaritz & Walter 1970)	Cándana Quartzit (Lotze 1957)
PRECAMBRIAN	EOCAMBRIAN (UPPER BRIOVERIAN)	CANDANA GROUP	CANDANA SCHIST FORMATION	200 - 400		wellbedded grey, greenish-grey sandy and silty schists, calc. sandstones and carbonate layers, stromatolite limestone, occ. calc. nodules evaporitic origin?	Lower Clastic Series (Jaritz & Walter 1970)	Cándana Limestones (various authors)
PRECAMBRIAN	EOCAMBRIAN (UPPER BRIOVERIAN)	CANDANA GROUP	LOWER CANDANA QUARTZITES	0 - 400		dark bluish-grey dirty sandy or quartzitic schists, occ.intercalations of bluish slates near the base	Lower Clastic Series (Jaritz & Walter 1970)	
PRECAMBRIAN	(MIDDLE & LOWER BRIOVERIAN)	VILLALBA FORMATION		1000 plus		dark grey occ.graphitic sericite chlorite phyllite; near the top occ. quartzite layer monotonous sequence of phyllitic schists with laminae of subgraywacke		Villalba Formation (Barrois 1882)

Table 1. Summary of the stratigraphy of the region to the SE of Lugo.

and Quinta anticlines on the downthrown side, and the different character of the anticline on the upthrown block seems to indicate that after the fault occurred folding continued, having a different effect on either side of the Guilfrey fault.

The southern faults with their downthrow on the NW side seem to be younger. The structures between the Lamas and Fonteformosa faults strike about N 135° E, about 15° less than in the area to the NW. The folds are narrower and compression seems to have been stronger. Drag along the faults is limited to the faultzone itself as can be observed in the quartzite quarry in the Lamas fault along the road El Cebrero - Triacastela near Lamas. Folds maintain their shape on either side of the southern faults. Thus it may be concluded that faulting occurred here in a later stage of the folding and was perhaps connected with a late strong compression, which affected the southern half of the area more than the northern half. In this connection the pronounced development of the eastern shear direction might be significant, while the curved termination of the El Poyo fault W of El Cebrero and its dextral component corroborates a counterclockwise rotation of a compressive stress.

The area between the faults of Guilfrey and Incio-Lamas represents a transverse graben, coinciding with the hinge between the above indicated N 150° E structural trend in the NW and N 135° E trend to the SE of it. The broken up nature of the Calderón folds in the basin of Triacastela shows that it must have originated at a later stage of the compression when the southern blocks were uplifted.

Matte (1968) attributes the described structures to a Sudetic folding phase. In the present work continuously increasing compression and folding was observed and no evidence for Matte's second folding phase (described by him further north) was found.

Much of the parasitic folding and many minor cross faulting must have occurred during a final stage.

5. MINERAL DEPOSITS

The mineral deposits of the area are typical of a sedimentary environment. Iron minerals in very minor quantities are common. The iron rich water of the small bathing resort of Herreria de Incio comes from an old working along the Silurian unconformity. Sulfides of Fe, Pb, Zn and Cu are relatively common in the area. Pyrite is a notable mineral of the Folgoso Formation, but is also common in the black shales at the base of the Vegadeo Group. Also in the Villalba Formation it occurs fairly frequently. Besides pyrite one may find galenite, sphalerite and some copper as malachite in abandoned adits. Chalcopyrite was observed occasionally in the Villalba formation of the Lor valley.

An important zinc-lead deposit is exploited by "Exploración Minera Internacional

(España) S.A." (EXMINESA) at Rubiales on the S-flank of the La Faba anticline (Section XVI, figure 5). The Vegadeo Formation is partly silicified and mineralized. It appears that both phenomena are related. Carbonate and quartz have been mobilized. The clearly epigenetic minerals, mainly sphalerite with subordinate galenite, have probably been deposited from solutions ascending along the more permeable cleavage connected with a secondary narrow anticline. The deposit as a whole is discordant to the stratigraphic sequence. The rare igneous phenomena in the neighbourhood, described above, do not provide a valid argument for a genetic relationship or a volcanic origin. Probably formation fluids circulating upwards along cleaved zones and with anomalous metal content, perhaps derived from the black shales of the base of the Transition Beds, the algal remains of the Vegadeo and Cándana limestones or even from the upper Villalba Formation, may have precipitated these sulfides, possibly in accordance with the mechanism described by W.J. Phillips (1972). The strong compression in the Linares syncline, the high heatflow causing regional metamorphism at depth could explain the expulsion of the fluids and the precipitation of the sulfides under diminishing temperature at higher levels.

The orebody is affected by minor crossfaults, causing displacements, so that the mineralisation should have taken place during a very late phase of the compression.

Cándana and Vegadeo limestones are being quarried at different places for a cement factory, roadbuilding and construction material.

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