

Carboniferous stratigraphy of the Sierra del Brezo in northern Palencia: evidence of major uplifts

R.H. Wagner¹, and C. F. Winkler Prins²

¹ Jardín Botánico de Córdoba, Avenida de Linneo, s/n, 14004 Córdoba, Spain.

² Nationaal Natuurhistorisch Museum, Postbus 9517, 2300 RA Leiden, The Netherlands.

Recibido el 13 de Octubre de 1998.

Aceptado el manuscrito revisado el 31 de Diciembre de 1998.

Abstract: Carboniferous lithostratigraphic units are analysed for the Sierra del Brezo area south of the Ruesga Fault at which the northern branch of the Cantabric-Asturian orogen overrides the southern branch in northern Palencia. These belong to the Asturian-Leonese facies realm and prolong the northward facing thrust units of northern León eastwards in the most tightly compressed part of the Palaeozoic orogen of the Cantabrian Mountains (Figs. 1, 2). Two subareas are the Valsurbio-Almonga anticlinal structure and the Rebanal-Ventanilla subarea where the axial planes are reversed and considerable shearing took place. As in northern León, the uppermost Famennian - lowermost Tournaisian Ermita Formation overlies progressively older Devonian strata northwards with an erosional contact (Fig. 3). The upper Tournaisian to lowermost Namurian Genicera Formation (with three constituent members) follows all over the area after a generalised stratigraphic break. A 600 to 800 m thick development of Namurian "caliza de montaña" (Barcaliente and Valdeteja formations) in the South passes northwards into much thinner (c. 40-85 m) limestones with a partial (sometimes total) elimination of the Barcaliente Formation (Figs. 4, 5). Carbonate debris flows and bioclastic limestones in shales characterise the top of the Valdeteja Formation. An erosional contact separates the Valdeteja Limestone Formation in the northern subarea from overlying shales and turbidites of the Carmen Formation. The marked stratigraphic breaks noted in the northern subarea match those found at exactly the same levels in the Revilla Nappe, some 30 km eastwards in northern Palencia. The Revilla Nappe succession, with low-angle unconformities separating an even thinner Valdeteja Formation (30 m) from Genicera Fm underneath and Carmen Fm above, apparently corresponds to the same palaeogeographic area characterised by repeated uplift as the northern subarea of the Sierra del Brezo (Fig. 6). It probably represents a strip of terrain suppressed by the Ruesga Fault which represents very considerable tectonic shortening attributable to the pre-Curavacas Palentian phase of deformation (dated as late Langsetian).

Key words: Carboniferous, Tournaisian, Viséan, Namurian, Westphalian, Stratigraphy, Palaeogeography.

Resumen: Se analizan las unidades litoestratigráficas del área de la Sierra del Brezo (Palencia) al Sur de la Falla de Ruesga donde la rama norte del orógeno cántabro-astórico cabalga a la rama sur. Pertenecen al dominio astur-leonés y están en continuidad lateral con las estructuras cabalgantes de vergencia norte en el Norte de León. Es ésta la parte más apretada del haz de pliegues arqueado del Paleozoico cántabro-astórico (Figs. 1, 2). Se distinguen dos subáreas, la estructura anticlinal de Valsurbio-Almonga en el Sur de la Sierra del Brezo y la subárea de Rebanal-Ventanilla en el Norte, donde los planos axiales están invertidos y existe una laminación tectónica importante.

Al igual que en el Norte de León, la Formación Ermita, del Fameniense superior y Tournaisiense más inferior, cubre formaciones devónicas cada vez más inferiores hacia el Norte, con un contacto erosivo (Fig. 3). La siguiente formación de Genicera, con sus tres miembros constituyentes, se encuentra como siempre después de un hiato estratigráfico generalizado. Una "caliza de montaña" (Fm Barcaliente y Fm Valdeteja), bien desarrollada (600 a 800 m), comparable al que se conoce del Norte de León, sigue sin hiato aparente en la parte meridional, pero este espesor disminuye de

modo espectacular hacia el Norte donde se llega a un máximo de 85 m (Figs. 4, 5) y una eliminación parcial y a veces total de la Fm Barcaliente. El techo de la Formación Valdeteja muestra a menudo el desarrollo de debris flow calcáreos. Un contacto erosivo separa la Fm Valdeteja de las lutitas y turbiditas siliciclásticas de la Fm Carmen. Los mismos hiatus estratigráficos señalados en la subárea norte de la Sierra del Brezo se encuentran en el Manto de Revilla, unos 30 km más al Este en la misma provincia de Palencia, donde están asociados a discordancias poco angulares y donde la sucesión estratigráfica está aún más disminuida (sólo un máximo de 30 m para la Fm Valdeteja). Se interpreta que el Manto de Revilla representa una parte aún más al Norte de la misma área paleogeográfica caracterizada por levantamientos repetidos en los tiempos carboníferos mencionados, y que se insertaría en la franja de terreno eliminado por la Falla de Ruesga que representa un acortamiento tectónico muy importante. Esta falla es de edad Langsettiense (pre-Conglomerado de Curavacas).

Palabras clave: Carbonífero, Tournaisiense, Viséense, Namuriense, Westfaliense, Estratigrafía, Paleogeografía.

The arcuate fold belt of the Palaeozoic (pre-Stephanian C) Cantabrian Mountains, which is known to consist of thrust sheets and nappes directed towards and molded around a relatively stable foreland spur, the Cantabrian Block of Radig (1962), shows a history of progressive tightening leading to opposing vergencies (compare Pérez-Estaún *et al.*, 1988). Palaeomagnetic measurements by Ries *et al.* (1980) have shown that the original arcuate configuration in c. 60° was modified tectonically to the present situation which shows strikes changing 180° in structures involving Cambrian to Carboniferous strata. Geophysics have confirmed the thin-skinned nature of the tectonic structure in which the basement is not involved (Pérez Estaún *et al.*, 1994; Pulgar *et al.*, 1995). Tightening is most severe in the eastern part of the Cantabrian Mountains and this explains the more major extent of thrusting in this area with large-scale displacement perpendicular to the strike and the development of important nappe structures in northern Palencia, involving a clear distinction, both stratigraphically and structurally, between autochthon and allochthon (Wagner, 1971). Large-scale tectonic shortening explains the juxtaposition of areas of different palaeogeographic origin, showing differences in stratigraphic development. Nowhere is this more apparent than in northern Palencia where a major fault line, the Ruesga Fault of Kanis (1956), separates the northern branch of the Cantabric-Asturian tectonic orogen from the southern branch, with the former overriding the latter (Fig. 1). This major fault line has had a complicated history with different kinds of displacement at different times, from early

Westphalian into Cretaceous/Tertiary, but its most important effect is apparent from the opposing vergencies, with the northward facing Palaeozoic structures of the Sierra del Brezo being cut off by NNW-ESE striking thrust units facing south (Fig. 2). At this fault line two quite different facies areas meet, i.e. the Asturian-Leonese and Palentian facies areas, which are most apparent in Middle and Upper Devonian strata (Brouwer, 1964a, b; see also García-Alcalde *et al.*, 1988), but which also show a rather different development for the Carboniferous (Wagner *et al.*, 1983). This obvious facies difference was one of the main reasons for De Sitter (1961) to propose a "León Line" as a fundamental fracture zone separating two different areas of sedimentation. Although he based his "León Line" primarily on the Ruesga Fault, he linked this fault to one of similar characteristics in northern León. (For a discussion of the León Fault see Marcos, 1968.) The concept of a León "Line" implies a fundamental fracture involving the basement which is alien to the tectonic structure of the Palaeozoic Cantabrian Mountains. Although the "León Line" is still occasionally invoked (e.g. Kullmann and Schönerberg, 1978, in a paper criticised by Marcos, 1979), the concept is generally allowed to lapse. Although the Ruesga Fault produced a line of weakness subsequently exploited by Mesozoic movements (compare Wagner *et al.*, 1984, and Espina *et al.*, 1996), the original fault seems to have been a thrust leading to very severe tectonic shortening. The different history of Carboniferous strata south and north of the Ruesga Fault has been investigated by the present writers for about a decade, with major emphasis on

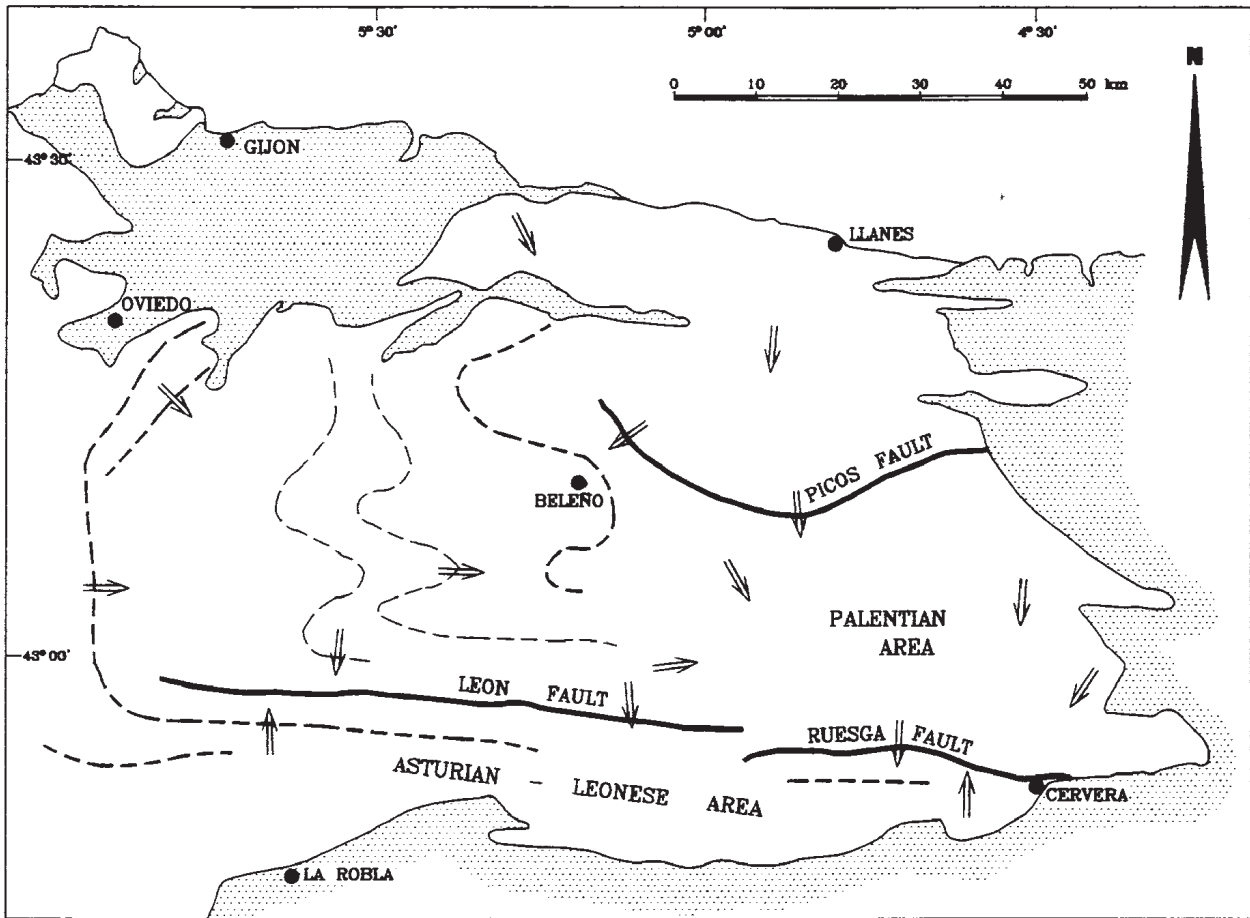


Fig. 1. Tectonic sketch of the Cantabrian Mountains showing the turnaround of vergencies (arrows) and major thrust faults at which tectonic shortening occurred as an accommodation to tightening of the arcuate fold belt. The Ruesga Fault, of early Westphalian age, is the earliest and most major of these thrust faults. This important tectonic fracture was reactivated in different ways in later, partly Mesozoic-Tertiary times. Stippled area: Permian-Mesozoic-Tertiary cover.

the more poorly known area north of the fault. Stratigraphic dating relied mainly on conodonts, studied by M. van den Boogaard in Leiden, more incidental foraminiferal sampling by E. Villa (Oviedo), and occasional finds of goniatites. The present paper focuses on the stratigraphic developments south of the Ruesga Fault, an area which has been the subject of recent work by Marín *et al.* (1996) and Marín (1997), whose conclusions and interpretations do not always agree with the field observations and perceptions of the present writers (compare Wagner and Winkler Prins, 1997).

Geological outline of the Sierra del Brezo

This area south of the Ruesga Fault was mapped initially by Quiring (1939) and Kanis (1956) followed by Koopmans (1962), who described a

large anticlinal structure in the southern part of this mountainous area as the Valsurvio Dome, a misnomer which was maintained by later authors. This structure, which can be matched in northern León by a similar change from southward dipping, northward facing thrust units to northward facing units with a reversed dip, is probably the same as that described by Kanis (1956) as the Almonga Anticline (Fig. 2). The reversal of the dip in the northern part of the Sierra del Brezo, leading to northerly dips of 25° to 50° (usually around 25°-40° N), has provoked the local elimination of strata due to shearing which has led to lenticular occurrences of the thinner formations. In the Valsurvio-Almonga anticlinal structure and in thrust slices in the area near Rebanal de las Llantas, San Martín de los Herreros, and Ventanilla, in the northern part of the Sierra del Brezo, a succession of Middle and Upper Devonian

strata crops out with characteristics which allow a direct comparison with the formations described by Comte (1959) for northern León (Wagner *et al.*, 1984; Marín, 1997). Although acknowledging the similarity, a different set of formational names was introduced by Koopmans (1962) for the Sierra del Brezo. These names were adopted by Savage (1977) for a mapping synthesis in which he included the maps produced by Kanis (1956) and Koopmans (1962). Similarly, Lobato *et al.* (1985) employed these formational names which seem to represent an unnecessary proliferation of local stratigraphic names, and which imply a negation of the readily apparent lateral continuity of the Sierra del Brezo with northern León. The only one of Koopmans's formations that may be kept as a convenient unit, is the Camporredondo Quartzite Formation at the top of the Devonian succession in the southern and eastern parts of the Sierra del Brezo, where it has not yet been possible to separate the Nocado Sandstone Formation from the overlying Ermita Sandstone Formation. On the other hand, the Ermita Formation can be distinguished unequivocally as a separate unit in the general vicinity of San Martín de los Herreros, where this upper Famennian-lower Tournaisian formation overlies Givetian limestones of the Portilla Formation with a clearly erosional contact (Fig. 3). The different contacts correspond to the late Famennian uplift described by Comte (1938) and subsequent authors.

The southward dipping, northward facing structures on the southern flank of the Valsurbio-Almonga Anticline (Fig. 2) coincide with a 600 to 800 m thick development of Namurian limestone, traditionally referred to as "caliza de montaña", which follows upon a relatively thin formation of siliceous shales and nodular limestones. This is the Genicera Formation of Wagner *et al.*, 1971 (also called Villabellaco Formation or Alba Formation, depending on the different authors). A much thinner development of "caliza de montaña" (40 to 85 m) occurs in the northern part of the Sierra del Brezo (see Fig. 5) where uplift provoked the removal of most of the lower part of the limestone (Barcaliente Formation) and probable non-deposition of some of the higher part (Valdeteja Formation). This is interpreted differently by Marín *et al.* (1996) and Marín

(1997), who adopts the term Brezo Limestone, used informally by Reuther (1982), for the "caliza de montaña" in the Rebanal-San Martín subarea. Marín (1997) records alternate thinly bedded (Barcaliente) and more massively bedded (Valdeteja) facies which the present writers attribute to small scale tectonic repetition such as occurs in a thrust slice south of San Martín de los Herreros. Where less tectonised sections occur (uncommonly) it proves possible to distinguish between Barcaliente and Valdeteja formations, it being understood that thinly bedded limestones may be found intercalated between more massive, sometimes clearly bioclastic limestones in the Valdeteja Formation. The Barcaliente Formation is uniformly thinly bedded.

There is an apparently gradual contact between the thick limestone development (Valdeteja Formation) and overlying mudstones in the southern flank of the Valsurbio Anticline where *Proshumardites morrowanus* Gordon (C. H. T. Gents, *det.*) has been found in mudstones exposed north of Villafría (loc. 2676). This goniatite of the Morrow (lower Pennsylvanian) of Arkansas, U.S.A. (Gordon, 1964), suggests a mid to late Namurian age. In the northern part of the Sierra del Brezo the Valdeteja Limestone Formation, much diminished in thickness, shows carbonate debris flows in shales at the top of the formation, a facies development that is not uncommon at the top of this formation in northern León. An erosional contact separates these strata from several hundred metres of overlying shales and sandstones, generally of a turbiditic nature. This is the Carmen Formation which is called the Cervera Formation by Marín *et al.* (1996), using a later synonym (as explained by Wagner *et al.*, 1984).

The initial mapping by Kanis (1956) and Koopmans (1962), used for the regional synthesis at 1:50,000 scale by Savage (1977), was superseded by the work of Pulgar (1973), which was incorporated in the general overview at 100,000 scale published by Lobato (1977) and also in the Geological Survey map to the scale of 1:50,000 (Camporredondo sheet) published by Lobato *et al.* (1985). The adjacent Geological Survey map (Barruelo sheet) produced by Wagner *et al.* (1984) includes the eastern end of the Sierra

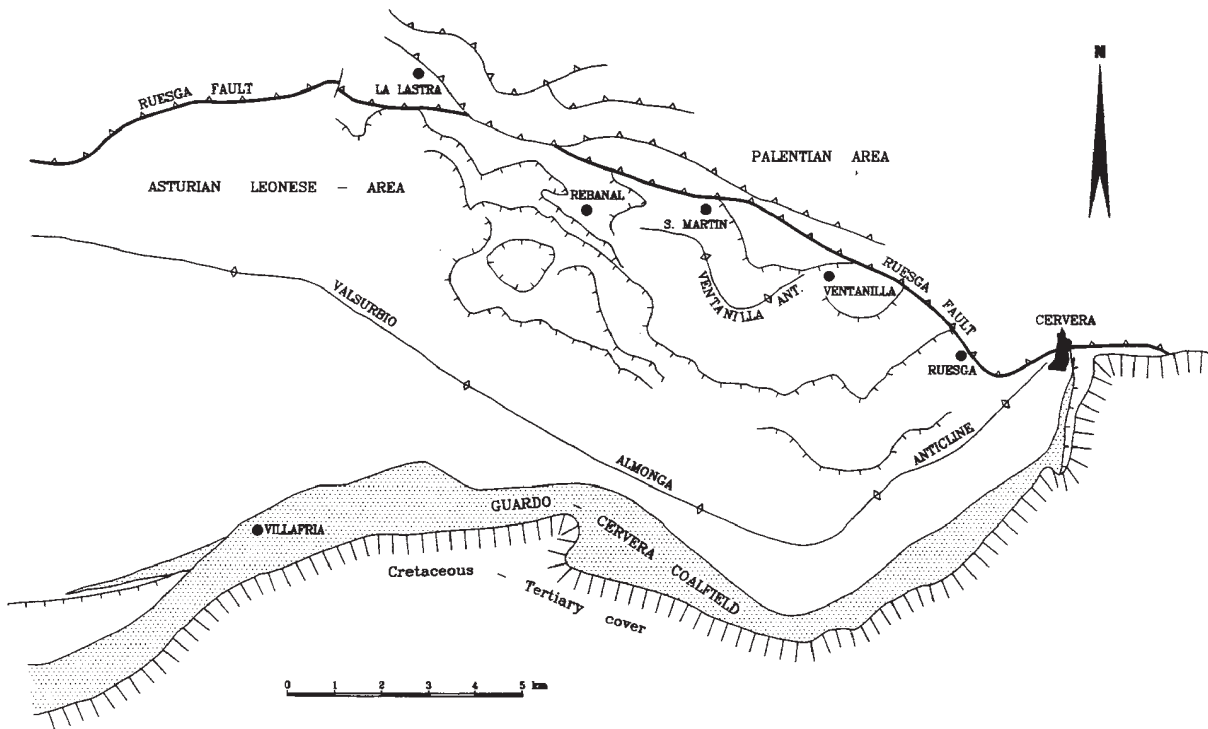


Fig. 2. Tectonic elements of the northward verging structural area of the Sierra del Brezo in northern Palencia, containing Devonian and Carboniferous (up to lower Westphalian) strata of Asturian-Leonese facies. It is delimited to the north by the Ruesga Fault, originally a southward directed thrust at which the southward verging Palentian area overrides the Asturian-Leonese area. It is delimited to the south by unconformable upper Westphalian D and lower Cantabrian strata of the Guardo-Cervera Coalfield. Outline based partly on the map of Marín (1997), with modifications. Broken lines with black triangles are southward directed thrust faults of the Palentian area; broken lines with simple cross lines represent northward directed thrust faults of the Asturian-Leonese area (Sierra del Brezo).

del Brezo structural area. Wagner *et al.* (1984) emphasised the significance of the Ruesga Fault which they regarded as representing major tectonic shortening. It is noted that the Barruelo and Camporredondo map sheets render the geological structure of the Sierra del Brezo more reliably than that published by Savage (1977). Finally, the unpublished map by Marín (1997), also to the 1:50,000 scale, provides a more detailed picture of the geological structures in the Sierra del Brezo, although the complexity of this area still requires mapping to a smaller scale. Some of the earlier map data were overlooked by Marín, as is apparent from an illustration in his thesis where the Carboniferous strata underlying unconformable Cretaceous conglomerates are shown as “Grupo Cea” (here meant to represent upper Westphalian D), whereas these belong in fact to the Carmen Formation (compare the Barruelo sheet by Wagner *et al.*, 1984). Marín

(1997) emphasises the Mesozoic role of the Ruesga Fault rather than its importance for the Palaeozoic structures, which the present writers regard as more significant. The trace of the Ruesga Fault, which delimits the first southward facing thrust slice north of the Sierra del Brezo structural area is not everywhere shown accurately on Marín’s map. The Devonian and Carboniferous strata in the general area of the Sierra del Brezo are bordered to the south by an angular unconformity with upper Westphalian D marine and coal-bearing deposits of the Guardo-Cervera Coalfield. This contact is partly tectonised, but the faulting is relatively minor and partly **within** the upper Westphalian D and lowermost Cantabrian strata above the unconformity, as is shown on an unpublished 1:10,000 map of the Guardo-Cervera Coalfield which is on open file in the Instituto Tecnológico Geominero in Madrid as part of a report by the Empresa Nacional Adaro de

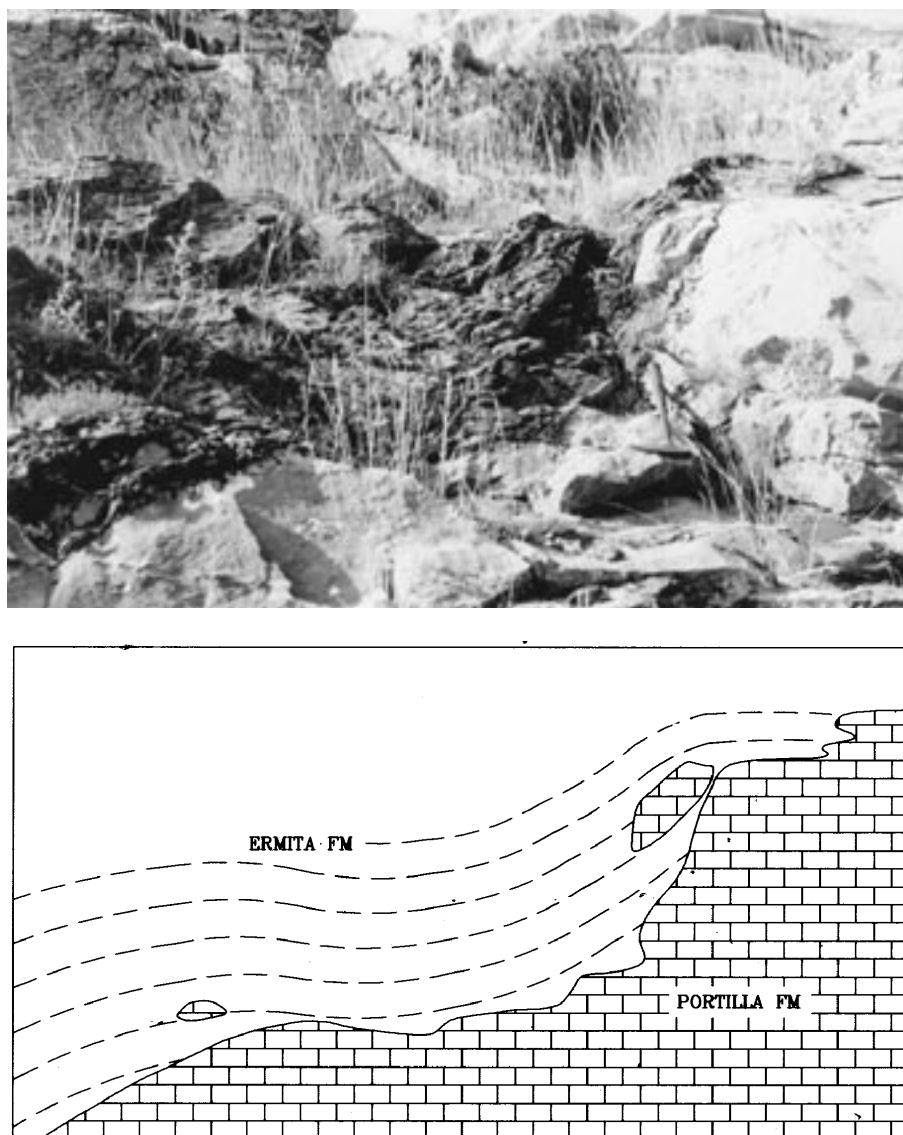


Fig. 3. Erosion surface (palaeokarst?) on Portilla Limestone (Devonian) filled in by sandstones of the Ermita Formation (Famennian-lower Tournaisian). Note limestone blocks in the sandstone fill. Exposures at 1,800 m east of Rebanal de las Llantas.

Investigaciones Mineras (see also Wagner and Fernández-García, 1983, 1984).

Discussion of the Carboniferous succession

In the Sierra del Brezo the Middle and Upper Devonian deposits corresponding to the Santa Lucía, Huergas, Portilla and Nocado formations are followed by the Ermita Sandstone Formation, which is mainly late Famennian in age but which reaches into the lower Tournaisian (Raven, 1983).

This is followed by the Genicera Limestone and Shale Formation, the Barcaliente Limestone Formation (mainly eliminated by uplift in the northern part of the area), the Valdeteja Limestone Formation, and the Carmen Shale and Sandstone Formation of turbiditic characteristics.

Ermita Sandstone Formation

In the Valsurbio-Almonga Anticline and in the eastern part of the anticlinal structure of Ventanilla

(Fig. 2), the Ermita Sandstone Formation has not been distinguished from the Nocedo Sandstone Formation, and has been incorporated with the Camporredondo Quartzite Formation of Koopmans (1962). However, in the northern part of the Sierra del Brezo, in the region of Rebanal de las Llantas and San Martín de los Herreros, the Ermita Formation rests upon Givetian limestones of the Portilla Formation, and is clearly delimited at its base by an erosional contact (Fig. 3). Also in the area southwest of La Lastra, near the Camporredondo reservoir, a similar contact between Portilla limestone and coarse sandstones of the Ermita Formation allows the latter to be distinguished without ambiguity. A magnificent exposure near the main road about halfway Rebanal and San Martín shows a well-developed erosion surface on top of the limestone, i.e. a palaeokarst surface with a hollow of 5 to 6 m depth and the remains of a limestone breccia plastered onto the sides of the hollow (Fig. 3). A thinly bedded sandstone fills in the hollow as a strictly local deposit. It is followed by 4 m of coarse-grained sandstone with occasional small pebbles, which onlaps on the sides of the erosional hollow. Sandy limestone, 0.50 m thick, follows in succession. Another 0.20 m of coarse-grained quartzose sandstone constitutes the top part of the Ermita Formation in this important locality. A sharp contact separates this formation from 6.80 m of mainly grey nodular limestone with some reddish mottling, representing the Genicera Formation. Shearing has eliminated the middle part of this formation in the locality described (Fig. 4-I). The Genicera limestones are followed by c. 20 m of massive-bedded grey limestones, partly of a bioclastic nature, which are attributed to the Valdeteja Formation.

Within the same structural unit, but further towards Rebanal de las Llantas, a section occurs with 1.40 m of coarse-grained quartz sandstone of the Ermita Formation (Fig. 4-II). Although the contact with the underlying Portilla Limestone Formation is exposed in this section, the exposure is not sufficiently large to show the irregularities of an erosional surface. The relatively thin development of sandstone of the Ermita Formation suggests that only the top part of this formation is represented

here as a result of onlap on the higher part of a palaeotopography.

At c. 1100 m south of San Martín de los Herreros a small cross-fold in Portilla Limestone Formation, Ermita Formation, and Genicera Formation allows further stratigraphic observations. This locality (Fig. 4-III) shows 2 m of coarse-grained sandstone with occasional small pebbles lying on top of Portilla Limestone with a sharp contact. It is followed by 1.80 m of sandy, bioclastic limestone, and this is succeeded in turn by 1.40 m of coarse-grained sandstone. This succession is the one shown by Raven (1983, fig. 20), who mentions the *costatus* conodont zone of the highest Famennian and the *Polygnathus* fauna of the basal Tournaisian, but without citing the faunal contents. Famennian conodonts were also obtained from this locality by A. C. Higgins (*pers. comm.*) and a lower Tournaisian *Polygnathus* fauna corresponding to the *Gattendorfia* goniatite zone by M. van der Boogaard (*pers. comm.*): *Polygnathus communis communis* Branson and Mehl, 1934; *P. inornatus inornatus* Branson, 1934; *P. purus purus* Voges, 1959; *P. purus subplanus* Voges, 1959; *P. longiposticus* Branson and Mehl, 1934; *Polygnathus* sp.; *Pseudopolygnathus triangulus inaequalis* Voges, 1959; *P. dentilineatus* Branson, 1934; *P. cf. brevipennatus* Ziegler, 1962; *Pseudopolygnathus* sp.; *Bispathodus aculeatus aculeatus* Branson and Mehl, 1934; *Spathognathodus crassidentatus* Branson and Mehl, 1934; *Spathognathodus* sp.; *Ozarkodina* sp.; ramiform elements; bryozoan remains; fish teeth and placoid scales.

Fig. 4 depicts variations in the occurrence of the Ermita Formation as described above.

Genicera Limestone and Shale Formation

This formation occurs commonly in the Sierra del Brezo, but is generally found incomplete as a result of shearing within thrust slices or because it functioned as a detachment horizon at the base of subsidiary thrust units. However, an apparently complete succession has been found in a hillside at c. 1 km ESE of Rebanal de las Llantas. Complementary data were collected in the same

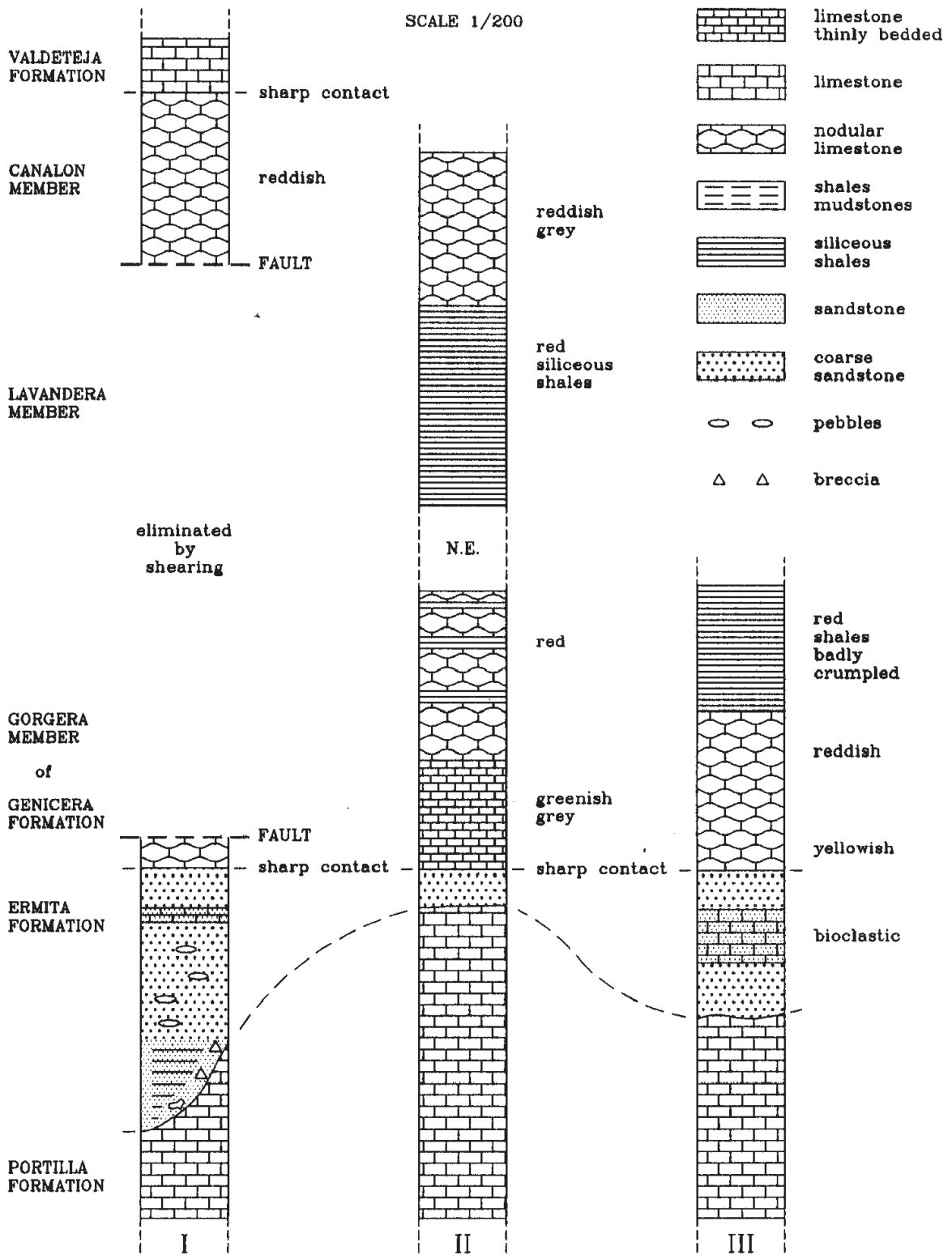


Fig. 4. Stratigraphic sections at scale 1:200 of Ermita and Genicera formations, showing variations in relation to the palaeotopography filled in by the Ermita Formation. I. At 1,800 m east of Rebanal de las Llantas. II. At c. 1 km ESE of Rebanal. III. At 1,100 m south of San Martín de los Herreros.

tectonic structure at about 1,100 m south of San Martín de los Herreros, where it has been possible to check on parts of the formation that are not so well exposed in the hillside ESE of Rebanal (Fig. 4-II, III). Three different members can be recognised in obvious comparison with the type section of the Genicera Formation in northern León (Wagner *et al.*, 1971). The lower (Gorgera) member is exposed in both sections on top of the Ermita Sandstone Formation. In the hillside ESE of Rebanal 4.20 m of greenish grey, near-white flaser limestones are followed by 5.60 m of red nodular limestones with red shale interlayers. South of San Martín 1.10 m of yellowish grey, rather massive nodular limestones are followed by 4.50 m of reddish, also rather massive nodular limestones. In both cases the next unit (Lavandera Member) consists of dark red siliceous shales, 7 to 8 m thick. It is noted that the first-mentioned locality shows more tectonised strata which appear more thinly bedded because of subparallel cleavage. The more important thickness observed in this locality may be partly due to the difficulties inherent to measuring strata which are incompletely exposed. The red siliceous shales that follow in succession (Lavandera Member) are often found heavily crumpled. In the hillside ESE of Rebanal de las Llantas the red shales of the Lavandera Member are followed by 4.60 m of reddish grey (red mottled) limestones (Canalón Member) which are succeeded in turn by 0.80 m of wavy-bedded, alternating grey and reddish limestones attributable to the same member. A subsequent unit of 19.00 m of grey, well-bedded, partly mottled limestones constitute a transitional facies to the Barcaliente Formation. Indeed, the next part of the section consists of a little under 14 m of thinly bedded, partly laminated limestones which are characteristic of the Barcaliente facies (Fig. 5).

The same gradual transition from nodular and wavy-bedded limestones to thinly bedded darker grey limestones attributable to the Barcaliente Formation also occurs in the northern flank of a small anticline just north of the Ruesga Dam. Here, the Genicera Formation is incompletely represented due to shearing. Both nodular limestones and shales occur. Some of the nodular limestone bands contain chert nodules.

The Gorgera Member has been sampled for conodonts in the locality at 1,100 m south of San Martín de los Herreros with the following results (M. van den Boogaard *det.*) (both are lower Viséan faunas):

Basal grey nodular limestones: *Gnathodus bilineatus semiglaber* Bischoff, 1957; *Vogelgnathus campbelli* Rexroad, 1957; *Polygnathus inornatus inornatus* Branson, 1934; *Pseudopolygnathus triangulus triangulus* Voges, 1959. Similar results were obtained previously by Van Adrichem Boogaert (1967, figs 49-50).

Base of the upper reddish part: *Gnathodus antetexanus* Rexroad and Scott, 1964; *G. bilineatus semiglaber* Bischoff, 1957; *G. cf. cuneiformis* Mehl and Thomas, 1947; *Angulodus* sp.; *Hindeodella* sp.; *Lonchodina* sp.; *Ozarkodina* sp.; prioniodinian element.

Conodont finds mentioned by Marín *et al.* (1996) are from the first thrust slice north of the Ruesga Fault, where the Genicera Formation shows a different development which will be discussed in a later paper. Marín (1997, fig. 2.8) presents sections from the Sierra del Brezo in which the three different members can be distinguished, but these are not named. Important thickness variations are noted by Marín (1997), who attributes the occasional elimination of the Alba (= Genicera) Formation to erosion, citing a breccia which he also seems to regard as a lateral equivalent (?). Marín (1997) mentions that this formation occurs commonly at the base of thrust slices, and the present writers concur. Field observations confirm that tectonic shearing is common at this horizon and that undisturbed sections of the Genicera Formation are rare. This being the case, the important thickness variations observed by Marín are to be attributed to shearing and not to stratigraphic variations (which are denied by the detailed examination of relatively undisturbed sections - see Figs 4, 5). The erosional contact observed in some localities by Marín (1997) is apparently related to the erosion preceding the deposition of the overlying Valdeteja Limestone Formation.

Barcaliente Limestone Formation

This formation of thinly bedded, dark grey limestones is probably developed with several

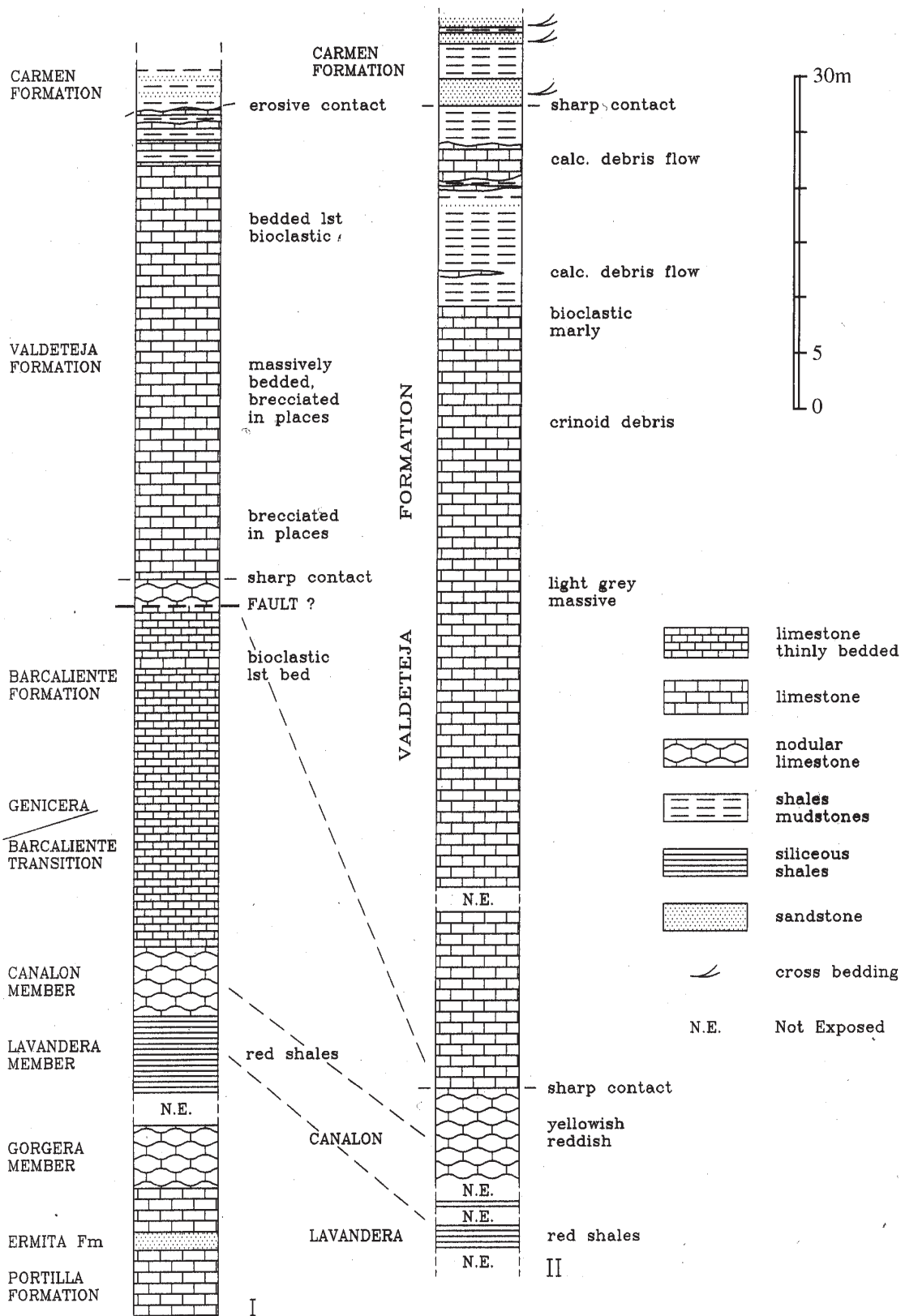


Fig. 5. Stratigraphic sections at scale 1:500 of Genicera, Barcaliente, and Valdeteja formations in the northern part of the Sierra del Brezo. I. At c. 1 km ESE of Rebanal de las Llantas. II. At 2,200 m south of San Martín de los Herreros.

hundred metres thickness in the southern part of the Sierra del Brezo (southern flank of the Valsurbio Anticline), but cannot be identified here on lithological characters due to recrystallisation and jointing. In the northern part of the Sierra del Brezo, i.e. in the region of Rebanal de las Llantas and San Martín de los Herreros, the Barcaliente Formation is poorly represented due to uplift and discontinuity below the subsequent Valdeteja Limestone Formation. Marín (1997) shows the Barcaliente Formation to be present in the vicinity of Ventanilla and in structures WNW of San Martín de los Herreros, but these strata apparently belong to the first thrust slice north of the Ruesga Fault. They thus represent a different palaeogeographical area, where transitional facies were developed between the Barcaliente Limestone Formation of the Asturian-Leonese facies and a somewhat different, more shallow water limestone which is developed characteristically in thrust slices of the Palentian area. Up to 80 m of well bedded, bluish grey limestones have been measured by the present writers in different localities of the first thrust slice north of the Ruesga Fault (e.g. at La Lastra). Conodont faunas from this limestone range in age from late Viséan-earliest Namurian to Chokierian (M. van den Boogaard and T. Nemirovskaya, pers. comm.). The Palentian facies and structural area north of the Ruesga Fault will be dealt with more fully in a later paper.

This 80 m thickness is rather more than is represented in the northern part of the Sierra del Brezo near San Martín de los Herreros and Rebanal de las Llantas. In the section at c. 1 km ESE of Rebanal de las Llantas (Fig. 5-I), south of the Ruesga Fault, only about 14 m of limestone are clearly attributable to the Barcaliente Formation. In this section the Barcaliente limestone is overlain by nodular limestones which are shown as a repetition of Alba (= Genicera) Formation by Marín (1997: map), and these are in sharp contact with massively bedded, light grey limestones of the Valdeteja Formation. The possibility of a tectonic repetition of the upper part (Canalón Member) of the Genicera Formation is lessened by the fact that the Barcaliente Formation is not repeated, which is surprising given the close proximity. However, the generalised erosion prior to the Valdeteja Limestone

deposition in the Rebanal-Ventanilla subarea makes the elimination of Barcaliente Limestone Formation in a subsequent (small) thrust slice a distinct possibility, which conodont work in progress should be able to resolve in the near future. The original thickness of the Barcaliente Formation in the northern part of the Sierra del Brezo cannot be established, since an early uplift may well have been accompanied by non-deposition. However, the presence of 600 to 800 m of undifferentiated Barcaliente and Valdeteja limestones in the southern flank of the Valsurbio Anticline, in the southern part of the Sierra del Brezo, suggests that the Barcaliente Limestone Formation in this part of the general area may have been hundreds of metres thick originally (as in northern León). No direct dating of the Barcaliente Formation south of the Ruesga Fault is available as yet, but its gradational contact with the underlying Genicera Formation makes an early Namurian age most likely.

Marín (1997) admits the presence of the Barcaliente Formation in the general vicinity of San Martín de los Herreros, but places it on top of his Brezo Limestone in the stratigraphic columns of his fig. 2.11. This position of the Barcaliente Formation is anomalous with regard to the general information on this lithostratigraphic unit in the Cantabrian Mountains, and the direct observation of stratigraphic sections in the Sierra del Brezo by the present writers does not support Marín's interpretation.

Valdeteja Limestone Formation

The characteristic facies of this formation as described from northern León (Wagner *et al.*, 1971) is that of light grey, massive-bedded limestones with scattered crinoid debris. However, darker more thinly bedded limestones are found intercalated, and a full range of shallow water limestones may be present. In the absence of a proper facies analysis backed by thin section work, the presence of light grey, massive and massively bedded limestones with occasional crinoid debris characterises the formation. Reuther (1977) described the presence of a limestone breccia at the base of the massively bedded limestones in the Sierra del Brezo, using the terms Brezo Breccia

and Brezo Limestone, which were adopted by Marín *et al.* (1996) and Marín (1997). A direct comparison with northern León was made by Wagner *et al.* (1983) and Wagner *et al.* (1984), who identified the Valdeteja Formation. They pointed out that the Valdeteja Formation sometimes overlies the Genicera Formation directly in (the northern part of) the Sierra del Brezo, but that a thin remnant of Barcaliente Formation is found in part of the (sub)area. This is ascribed to uplift and erosion which eliminated most if not all of the Barcaliente Formation. Erosion is also admitted by Reuther (1982).

The Valdeteja Formation is recognisably present with a thickness of 400-500 m of limestone in the southern flank of the Valsurbio Anticline, where it is fully exposed in the road to the sanctuary of Nuestra Señora del Brezo, north of Villafría. It thins markedly northwards, and in the area of Rebanal de las Llantas and San Martín de los Herreros thicknesses of 40 to 85 m have been measured, including the carbonate debris flows in shales at the top of the formation (Fig. 5). This probably means that sedimentation set in again at slightly different times after the movements of uplift which eliminated most and in some parts of the northern subarea all of the Barcaliente Formation.

At the base of the Valdeteja Formation in the northern part of the Sierra del Brezo there is often a breccia which corresponds to the Brezo Breccia of Reuther (1977). Although commonly present, it is laterally discontinuous. Marín *et al.* (1996) record this breccia also from the first thrust slice north of the Ruesga Fault (their "Lámina de los Arroyos"), but an examination of the exposures in this thrust slice has shown this record to be in error. Their highly diagrammatic section (Marín *et al.*, 1996, fig. 3 - column III) is misleading (Wagner and Winkler Prins, 1997), and although Marín *et al.* (1997) reply that this breccia occurs not in the published section but elsewhere in the same thrust slice, a detailed examination of the exposures has failed to yield proof of the correctness of this assertion. In fact, the Brezo Breccia seems to be absent in the area north of the Ruesga Fault, where the stratigraphic development is rather different, also for the Carboniferous succession below the Carmen Formation.

The top of the Valdeteja Formation in the northern part of the Sierra del Brezo shows carbonate debris flows and bioclastic limestones alternating with shales in a number of localities. This suggests that shallow carbonate platform areas were swept of bioclastic debris and released limestone blocks and rubble from the margins in order to become incorporated into a more low-lying mud basin. Carbonate debris flows are also known from the top of the Valdeteja Formation in northern León, where this carbonate formation ends at different stratigraphic levels. From a locality at some 500 m south of Rebanal de las Llantas, in the northern part of the Sierra del Brezo, Villa (*in* Marín *et al.*, 1996) recorded a small foraminiferal fauna from a limestone band in shales at the top of the Valdeteja Formation. This fauna was identified as Tashastinsky Horizon of the basal upper Bashkirian, *i.e.* approximately middle to upper Namurian. Although Marín *et al.* (1996) attributed this limestone band to the overlying Carmen Formation (mentioned as Cervera Formation in their paper), an examination of their locality shows that the irregularly developed carbonate debris flows and bioclastic limestones in shales are linked to the Valdeteja Limestone Formation. Indeed, the top of the limestone shows debris flow streamers coming off the limestone. A similar development of limestone bands showing carbonate debris flows within shales, is found at the top of the Valdeteja Formation at some 200 m south of the Ruesga Dam site. In the latter locality these limestones and shales are cut by an irregular erosion surface cutting down to different levels, and with hollows in the limestones showing shapes suggesting a palaeokarst surface. Limestone breccia has not been preserved, presumably because it was washed out when flooded at the commencement of marine sedimentation of the Carmen Formation afterwards. Calcite deposits associated with the apparent palaeokarst surface fit the interpretation. Subsequent deposits in this locality are well exposed shales with fine-grained turbiditic sandstone bands with sole markings including groove and tool marks as well as biogenic markings. These belong to the Carmen Formation, which is widely developed both south and north of the Ruesga Fault, and which is instantly recognisable on facies characteristics.

A section at 2,200 m south of San Martín de los Herreros (Fig. 5-II) shows a sharp contact between nodular limestones of the Genicera Formation and an 88 m thick succession attributable to the Valdeteja Formation. This commences with 33 m of grey, bedded limestones (20 to 30 cm bedding interval), followed by 16 m of grey massive limestone, continued by another 20 m of grey bedded limestone with at least one bed containing crinoid debris and 2 m of bioclastic limestone at the top unit; this is brecciated in the upper 70 cm. Successive deposits are 19 m of shales alternating with carbonate debris flows. A sharp contact separates these rocks attributed to the Valdeteja Formation from cross-bedded sandstones with shale intercalations which may be assigned to the Carmen Formation. The two sharp contacts observed apparently correspond to stratigraphic breaks between the different formations (Fig. 5-II; compare Fig. 6).

Since Marín *et al.* (1996) interpreted the limestone/shale succession at the top of the limestone south of Rebanal de las Llantas as belonging to the overlying Cervera (= Carmen) Formation, they attributed a Baskirian age to the latter. The arbitrary nature of this interpretation was pointed out to them privately before their paper was published, and subsequently in Wagner and Winkler Prins (1997). However, Marín (1997) continues to ascribe this part of the succession to the Cervera (= Carmen) Formation. He consequently concludes that there is stratigraphic continuity between this formation and the underlying limestone. It has already been explained that a sharp contact is found between the limestone-shale succession with debris flows at the top of the limestone and the overlying shale-turbidite succession, and that this contact is a clearly erosional one in at least one locality with full exposure. Marín *et al.* (1996) have thus dated the top of the limestone (here identified as the Valdeteja Formation), and not the overlying shale-turbidite succession (Carmen Formation) which is undated here.

Carmen Sandstone and Shale Formation

This formation was originally described from the Revilla Nappe in the vicinity of Barruelo de

Santullán (Wagner and Wagner-Gentis, 1963; Wagner, 1971), where the succession of strata and the stratigraphic breaks observed in this succession invite comparison with the northern part of the Sierra del Brezo (Wagner *et al.*, 1983). A later synonym is the Cervera Formation which was introduced by Brouwer and Van Ginkel (1964) for the same succession of strata near Cervera de Pisuega, north of the Ruesga Fault (compare Wagner *et al.*, 1984). The Carmen Formation occurs both north and south of the Ruesga Fault with the same lithological characteristics which include quartzite conglomerate lenses as well as turbidites. A thickness of up to 1,100 m is recorded north of the fault (Wagner *et al.*, 1984), and several hundred metres of thickness are known to occur in the Sierra del Brezo. Since this is the highest formation known prior to the completely unconformable Curavacas Conglomerate Formation, the recorded thickness is likely to be less than that originally present. This formation overlies the Valdeteja Limestone Formation with a sharp contact (Fig. 5) which is clearly erosional in the locality south of the Ruesga Dam site, south of the Ruesga Fault. North of the fault it overlies the lower Moscovian Perapertú Formation, also with an erosional contact (see Wagner *et al.*, 1983 and Wagner *et al.*, 1984).

Summary of the Carboniferous succession

In the northern part of the Sierra del Brezo a thin development of Ermita Sandstone and Limestone overlies different formations of the Devonian succession with a markedly erosive contact (Figs 3, 4). This is followed after an stratigraphic break by limestones and shales of the Genicera Formation which can be subdivided into the Gorgera, Lavandera, and Canalón members, as in northern León. The overlying Barcaliente Formation of thinly bedded, dark grey limestones, often with internal lamination, occurs in gradual transition. In the Rebanal-San Martín-Ventanilla subarea, the subsequent Valdeteja Limestone Formation variously overlies beds of the Genicera Formation or a thin remnant of the Barcaliente Formation. At and near the base of the Valdeteja Formation one often finds a limestone breccia, the Brezo Breccia of Reuther

(1977). The Valdeteja Formation is developed with 400 to 500 metres thickness in the southern part of the area, in the southern flank of the Valsurbio Anticline, whereas a much thinner development, 40 to 85 m thick, is present in the northern part of the Sierra del Brezo. Carbonate debris flows in shales are commonly found at the top of the Valdeteja Formation and it is from this part of the succession that an upper Bashkirian (Tashastinsky) foraminiferal fauna has been recorded by Marín *et al.* (1996). An erosional surface corresponding most likely to a washed-out palaeokarst in at least one locality is associated with the top of the Valdeteja Formation, which is overlain by shales and turbidites including quartzite conglomerate lenses of the Carmen Formation. The different thicknesses and the position of stratigraphic breaks are indicated in the diagram of Fig. 6.

Comparison with the Revilla Nappe

The major breaks in the stratigraphic succession of Carboniferous rocks in the northern part of the Sierra del Brezo are matched by those found in the Revilla Nappe SSW of Barruelo de Santullán, in northeastern Palencia (Wagner, 1971). In this nappe structure of southern derivation a remnant of a Givetian succession of limestones, sandstone and shales, 15.5 m thick, is overlain with angular unconformity by nodular and wavy-bedded limestones of the Genicera Formation (Gorgera and Canalón members; the Lavandera Member is not developed here), which has yielded conodont and goniatite faunas of late Tournaisian to late Viséan ages (Higgins and Wagner-Gentis, 1982) and which reaches into lower Namurian Pendleian Stage in the head of the nappe (Wagner-Gentis, 1980). A low-angle unconformity separates the Genicera Limestone Formation from the overlying Valdeteja Limestone Formation which has a preserved thickness of 30 m and which grades laterally into a carbonate debris flow deposit. Van Ginkel (1965) obtained Bashkirian foraminifera from the debris flow limestones. There is no sign of the Barcaliente Formation which was probably removed by uplift. Another angular unconformity underlies the subsequent Carmen Shale and Sandstone Formation, which cuts down variously to Valdeteja

Formation and Genicera Formation as the low-angle unconformable contact is followed along the strike. A well-developed palaeokarst has been recorded at the contact between Genicera Formation and Carmen Formation in the exposure of the head of the nappe (Wagner, 1971) as well as in the main outcrop of the nappe structure. A pinnule of *Linopteris* found in shales in the lowermost part of the Carmen Formation suggests an age not earlier than Westphalian (*op. cit.*). A separate exposure (small klippe) of the Revilla nappe structure shows breccia with goniatite-bearing angular clasts of the Genicera Formation. This is comparable to the Brezo Breccia.

All the evidence points to an area of repeated uplift with stratigraphic breaks at the same levels as recorded in the northern part of the Sierra del Brezo (Wagner *et al.*, 1983), but with more angular contacts and a more considerable removal of strata. Since the southern part of the Sierra del Brezo contains a more complete succession of strata, and the unconformities are developed similarly in the northern part of the Sierra del Brezo, the Revilla Nappe should be assigned a relative position which is close to the latter, although presumably a little further north, corresponding to an area of more considerable uplift (Fig. 6). The tectonic shortening associated with the Ruesga Fault, along the line of which the northern branch of the Cantabric-Asturian orogen overrides the southern branch, has apparently suppressed this more central part of the palaeogeographical area corresponding to the repeated uplifts recorded. The recognition of a more central part of the area of repeated uplift, north of the Rebanal-Ventanilla subarea of the Sierra del Brezo, suggests that the Ruesga Fault suppressed a very wide zone transitional between the Asturian-Leonese and Palentian facies areas. This would explain the unusual facies of Givetian strata found in the Revilla Nappe as well as the absence of the Upper Devonian below the Genicera Formation in this allochthonous structure. The Revilla Nappe succession is thus seen as corresponding to the more intensely mobile part of the palaeogeographical area with repeated uplifts, which is also represented in the Rebanal-San Martín-Ventanilla subarea of the Sierra del Brezo. It furnishes a rare glimpse of the very substantial region overridden by the very

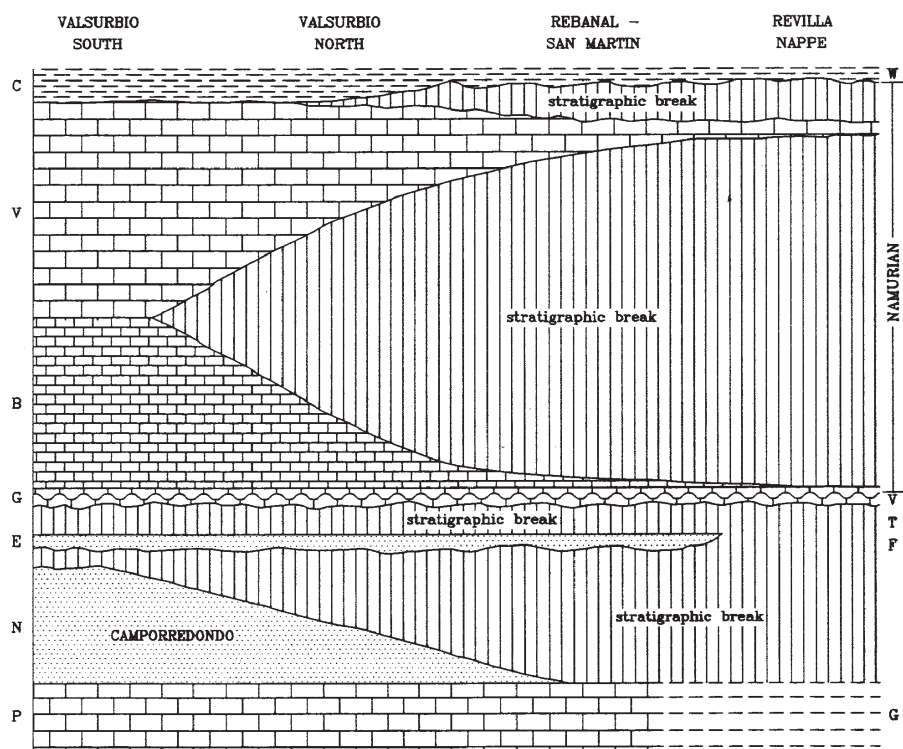


Fig. 6. Diagram showing thickness variations in the different upper Devonian and Carboniferous formations as a result of uplift and consequent erosion and non-deposition in the area south of the Ruesga Fault (Sierra del Brezo and Revilla Nappe). P - Portilla Fm, N - Nocedo Fm, E - Ermita Fm, G - Geticera Fm, B - Barcaliente Fm, V - Valdeteja Fm, C - Carmen Fm; G. Givetian, F. Famennian, T. Tournaisian, V. Viséan, W. Westphalian.

major, southward directed thrust known as the Ruesga Fault, which presently places the Asturian-Leonese and Palentian facies and structural areas in juxtaposition.

The Ruesga Fault

It is clear that this fault at which the Asturian-Leonese facies area, with northward facing structures, is overthrust by the Palentian area with southward facing structures (northern branch of the Cantabric-Asturian orogen overriding the southern branch), represents very major tectonic shortening with the elimination of a transitional zone between these two areas of different palaeogeographical position. Although the amount of shortening cannot be established with precision, it must be of the order of many tens of kilometres, particularly if the stratigraphic succession in the Revilla Nappe is read as being representative of part of the intermediate area suppressed by this major thrust fault. In the area north of the Ruesga Fault there

are a number of southward facing thrust slices which are oriented more or less parallel to the major fault. Some of these less important, but still quite major southward directed thrusts are sketched in on Fig. 2. Although this Palentian facies and structural area will be dealt with in detail in a later paper, it may be noted here that facies changes observed in the different E-W striking thrust units north of the Ruesga Fault indicate that quite considerable tectonic shortening occurred also on the (less important) thrust faults involved. It should be mentioned in passing that the so-called León Line of De Sitter (1961), proposed in part to explain the different facies developments on the two sides of the Ruesga Fault, is placed by Kullmann and Schönberg (1978) at one of these subsidiary thrust faults north of the Ruesga Fault. Marcos (1979) has already criticised Kullmann and Schönberg's tectonic interpretations which seem widely off the mark.

The trace of the Ruesga Fault is not always easy to follow. Indeed, the map by Kanis (1956), which has been incorporated in the geological synthesis

published by Savage (1977), shows this fault to disappear below the Cretaceous unconformable cover south of Cervera de Pisuerga, whereas in fact it runs north of the church in Cervera and continues eastwards up to the point where its trace turns south-eastwards to coincide with the Barrio de Santa María Fault, which seems to be a Mesozoic-Tertiary reactivation of the Ruesga fracture zone (Wagner *et al.*, 1984, p. 91-92; for a more extensive account of the later tectonic movements see Espina *et al.*, 1996). It is the later reactivation of the Ruesga Fault that has been interpreted as an oblique reverse fault by Espina *et al.* (1996). There is no doubt that the Ruesga Fault line was reactivated in Mesozoic and post-Mesozoic times (it probably played its part in the position of the Mesozoic basin margin since the Triassic and Jurassic strata thin and disappear near this fault line), but its main significance is as a major thrust fault in the Palaeozoic separating the Asturian-Leonese and Palentian facies and structural areas.

The trace of the Ruesga Fault can be followed westwards from less than a hundred metres north of the Ruesga Dam site to a locality east of Ventanilla where it appears as a sheared fault zone, several metres wide, in which fragments (horsts) of several formations are found, with lithologies apparently including upper Devonian nodular limestones of Palentian facies, lower Carboniferous nodular limestones, and carbonate debris flows with rounded quartzite pebbles which are identifiable as lower Moscovian Perapertú Formation, also of the Palentian facies area. Further westwards, the trace of the Ruesga Fault apparently runs with a line marked by intrusives and it continues into the clearly faulted contact between shales of the Perapertú Formation, north of the fault, and Devonian strata to the south, at c. 800 m south of the village of La Lastra. Its trace continues westwards following a line of quartz porphyrite intrusions and it apparently delimits the outcrop of the Camporredondo Quartzite Formation further westwards to where the Ruesga Fault disappears below the unconformable upper Westphalian D and lower Cantabrian succession of the Guardo Coalfield. There is no apparent continuity with the León Fault which is shown as the same fault zone in a number of regional syntheses, and which

Marín's (1977) structural sketch map also attempts to justify, but unconvincingly.

The age of the Ruesga Fault follows in part from that of the highest deposits implicated, which belong to the Carmen Formation, and partly from that of the Curavacas Conglomerate Formation which overlies with total unconformity the various thrust slices of the Palentian area which commences with the Ruesga Fault. The Carmen Formation is regarded as early Westphalian (Langsettian) in age (Wagner *et al.*, 1984), whilst the Curavacas Formation belongs to uppermost Langsettian and lower Duckmantian (see Wagner and Álvarez-Vázquez, 1995). This means that the original and most important movements on the Ruesga Fault, placing the Palentian facies and structural area in juxtaposition with the Asturian-Leonese area of the Sierra del Brezo, took place in Langsettian (early Westphalian) times.

Tectonic structure

The configuration of southward directed thrust units north of the Ruesga Fault overriding and interfering with the northward facing units of the Sierra del Brezo structural area south of the fault implies that the Palentian and Asturian-Leonese palaeogeographic areas are basically still in the same relative position, although the distances were shortened very considerably. Indeed, the stratigraphic comparison with the Revilla Nappe which is interpreted as representing an area palaeogeographically just north of the Rebanal-San Martín-Ventanilla region in the northern part of the Sierra del Brezo, suggests that the Ruesga Fault acted as a major overthrust which suppressed a wide zone transitional between the Palentian area to the north and the Asturian-Leonese area to the south. Carboniferous facies observed in the first thrust slice north of the Ruesga Fault and comparison with different facies developments in strata of the same Viséan and early Namurian ages in successive thrust slices further north provide confirmation of large-scale tectonic shortening as a result of the southward directed thrusting. (The detail of the facies changes observed in this Palentian area north of the Ruesga Fault will be given in a forthcoming paper, which is in preparation.)

This information is contrary to the idea published by Frankenfeld (1984), who proposed that the Palentian area would originally have lain to the south of the Sierra del Brezo and to have been moved across the Sierra del Brezo northwards. According to this interpretation it would have been part of the West Asturian - Leonese Zone of Lotze (1945), which is now covered by Cretaceous and Tertiary sediments of the Castilian and Leonese Meseta. Frankenfeld adduced stratigraphic information which can also be interpreted differently. He further postulated northward movement of a large Montó-Arrauz nappe structure which in fact consists of two geographically separate structures, viz. the Gildar-Montó klippe in northeastern León and the Polentinos nappe in northern Palencia. However, the folds and thrusts within the Polentinos nappe verge southwards and not northwards (compare Ambrose, 1972), and one of the present writers (RHW) has recently ascertained the position of the head of this nappe, with Carazo quartzite of the Silurian-Devonian transition stuck into lower Westphalian shales and turbidites (Carmen Formation), also indicating a southward movement. Despite all the factual data to the contrary, Frankenfeld's ideas have found support among structural geologists (e.g. Rodríguez-Fernández and Heredia, 1988; Pérez-Estaún and Bastida, 1990). Detailed fieldwork is obviously desirable before tectonic theory is propounded.

Conclusions

1. The Sierra del Brezo in northern Palencia belongs to the Asturian-Leonese facies and structural area, and constitutes the eastern continuation of Palaeozoic structures and facies development in northern León. Recognition and use of the same formations is recommended.
2. The marked northward thinning of Namurian carbonate units identified as Barcaliente and

Valdeteja formations is accompanied by evidence of erosional contacts showing pre-Valdeteja and pre-Carmen Fm uplifts of mid-Namurian and latest Namurian/earliest Westphalian ages, respectively. Stratigraphic dating still needs to be improved.

3. These two stratigraphic breaks of different Namurian ages developed in the same northward direction as the late Famennian break underlying the Ermita Formation, and they show the presence of an area of repeated uplifts in the northern part of the Sierra del Brezo.

4. Stratigraphic breaks at the same level occur in the Revilla Nappe, about 30 km to the east, where they are accompanied by unconformities and even more elimination of strata. The succession in the Revilla Nappe suggest its original position to correspond to a more central part of the area of repeated uplifts.

5. The Ruesga Fault at which the northern branch of the Cantabric-Asturian tectonic orogen overrides the southern branch, places the Palentian facies and structural area in juxtaposition with the Asturian-Leonese area. It suppresses a wide strip of transitional facies, which includes a substantial part of the area of repeated uplifts mentioned above.

6. The Asturian-Leonese and Palentian facies and structural areas remained in the same relative palaeogeographic position, although a wide strip of transitional terrain was suppressed by southward thrusting on the Ruesga Fault. Frankenfeld's (1984) theory that the Palentian area would have moved in from the south across the Asturian-Leonese area in the Sierra del Brezo runs counter to the factual data.

Acknowledgements

Conodont samples taken by the present writers were processed by Drs M. van den Boogaard, A.C. Higgins, and T. Nemirovskaya (work still in progress). L. Fernández-García is acknowledged for the goniatite find near Villafra, and C.H.T. Gents for the identification. Two anonymous referees have made critical comments which have acted as a spur to provide a more detailed explanation of data and their proper use in a geologically complicated region.

References

Adrichem Boogaert, A. C. van (1967): Devonian and Lower Carboniferous conodonts of the Cantabrian Mountains (Spain) and their stratigraphic application. *Leidse Geologische Mededelingen*, 39: 129-192.

Ambrose, T. (1972): *The stratigraphy and structure of the pre-Carboniferous rocks North-West of Cervera de Pisuerga, Cantabrian Mountains, Spain*. Ph. D. Thesis University of Sheffield, 208 p. (unpublished).

Brouwer, A. (1964a): Deux faciès dans le Dévonien des Montagnes Cantabriques. *Breviora Geológica Astúrica*, VI: 49-51.

- Brouwer, A. (1964b): Deux faciès dans le Dévonien des Montagnes Cantabriques méridionales. *Breviora Geológica Astúrica*, VIII (1-4): 3-10.
- Brouwer, A. and Ginkel, A. C. van (1964): La succession carbonifère dans la partie méridionale des Montagnes Cantabriques (Espagne du Nord-Ouest). *Compte Rendu V Congrès International Stratigraphie et Géologie du Carbonifère, Paris 1963*, I: 307-319.
- Comte, P. (1938): La transgression du Famennien supérieur dans la Cordillère Cantabrique. *Comptes rendus Académie des Sciences, Paris*, 206: 1741-1743.
- Comte, P. (1959): Recherches sur les terrains anciens de la Cordillère Cantabrique. *Memorias Instituto Geológico Minero de España*, 60: 1-440 (published 1963).
- Espina, R. G., Alonso, J. L. and Pulgar, J. A. (1996): Growth and propagation of buckle folds determined from syntectonic sediments (the Ubierna Fold Belt, Cantabrian Mountains, N. Spain). *Journal of Structural Geology*, 18 (4): 431-441.
- Frankenfeld, H. (1984): Deckenbewegungen im Namur des östlichen Kantabrischen Gebirges und die damit verbundenen Vorstellungen über die Paläogeographie der Namur- und Prä-Namur-Schichten. *Zeitschrift deutschen geologischen Gesellschaft*, 135: 223-241.
- García-Alcalde, J. L., Montesinos, J. R., Truyóls Massoni, M., García López, S., Arbizu, A. and Soto, F. (1988): El Silúrico y el Devónico del Dominio Palentino (NO de España). *Revista Sociedad Geológica de España*, 1 (1-2): 7-13.
- Ginkel, A. C. van (1965): Spanish Carboniferous fusulinids and their significance for correlation purposes. *Leidse Geologische Mededelingen*, 34: 171-225.
- Gordon, M. (1964): *Carboniferous Cephalopods of Arkansas*. U.S. Geological Survey Professional Paper, 460: 322 p.
- Higgins, A. C. and Wagner-Gentis, C. H. T. (1982): Conodonts, goniatites and biostratigraphy of the earlier Carboniferous from the Cantabrian Mountains, Spain. *Palaeontology*, 25 (2): 313-350.
- Kanis, J. (1956): Geology of the eastern zone of the Sierra del Brezo (Palencia - Spain). *Leidse Geologische Mededelingen*, 21 (2): 377-445 (Spanish translation: Investigaciones geológicas en la zona oriental de la Sierra del Brezo. *Estudios Geológicos*, XVI (1960): 109-156).
- Koopmans, B. N. (1962): The sedimentary and structural history of the Valsurvio Dome, Cantabrian Mountains, Spain. *Leidse Geologische Mededelingen*, 26: 121-232.
- Kullmann, J. and Schönnenberg, R. (1978): Facies differentiation caused by wrench deformation along a deep-seated fault system (León Line, Cantabrian Mountains, North Spain). *Tectonophysics*, 48: 15-22.
- Lobato, L. (1977): *Geología de los valles altos de los ríos Esla, Yuso, Carrión y Deva (NE de León, NO de Palencia, SO de Santander)*. Instituto Fray Bernardino de Sahagún, Diputación Provincial de León: 192 p.
- Lobato, L., Velando, F., Heredia, N., Matas, J. and Rodríguez Fernández, L. R. (1985): Mapa Geológico de España 1:50.000, Hoja n.º 106 (16-7) (Camporredondo de Alba). Memoria explicativa por L. R. Rodríguez Fernández, N. Heredia y F. Velando, 98 p. (1985). *Instituto Geológico y Minero de España*, Madrid.
- Lotze, F. (1945): Zur Gliederung der Varisziden der Iberischen Meseta. *Geotektonische Forschungen*, 6: 1-12 (Spanish translation by J.M. Ríos, 1950: Observaciones respecto a la división de los variscides de la Meseta Ibérica. *Publicaciones Extranjeras sobre Geología de España*, V: 149-166).
- Marcos, A. (1968): Nota sobre el significado de la "León Line". *Breviora Geológica Astúrica*, XII (3): 1-5.
- Marcos, A. (1979): Facies differentiation caused by wrench deformation along a deep-seated fault system (León Line, Cantabrian Mountains, North Spain). Discussion. *Tectonophysics*, 60: 303-309.
- Marín, J. A. (1997). *Estructura del domo de Valsurvio y borde suroriental de la región del Pisuerga-Carrión (Zona Cantábrica, NO de España)*. Tesis doctoral, Universidad de Oviedo (unpublished).
- Marín, J. A., Pulgar, J. A. and Alonso, J. L. (1995): La deformación alpina en el Domo de Valsurvio (Zona Cantábrica, NO de España). *Revista Sociedad Geológica de España*, 8 (1-2): 111-116.
- Marín, J. A., Villa, E., García-López, S. and Menéndez, J. R. (1996): Estratigrafía y metamorfismo del Carbonífero de la Zona de San Martín-Ventanilla (Norte de Palencia, Cordillera Cantábrica). *Revista Sociedad Geológica de España*, 9 (3-4): 241-251.
- Marín, J. A., Villa, E., García-López, S. and Menéndez, J. R. (1997): Réplica. *Revista Sociedad Geológica de España*, 10 (1-2): 200-202.
- Pérez-Estaún, A. and Bastida, F. (1990): Structure. Cantabrian Zone. In: *Pre-Mesozoic geology of Iberia* (R.D. Dallmeyer and E. Martínez García, Eds.), Springer Verlag, Berlin: 55-69.
- Pérez-Estaún, A., Bastida, F., Alonso, J. L., Marquínez, J., Aller, J., Alvarez-Marrón, J., Marcos, A. and Pulgar, J. A. (1988): A thin-skinned tectonics model for an arcuate fold and thrust belt: the Cantabrian Zone (Variscan Ibero-Armorican Arc). *Tectonics*, 7 (3): 517-537.
- Pérez-Estaún, A., Pulgar, J. A., Banda, E., Alvarez-Marrón, J. and ESCIN Research Group (1994): Crustal structure of the external variscides in northwest Spain from deep seismic reflection profiling. *Tectonophysics*, 232: 91-118.
- Pulgar, J. A. (1973): La zona de escamas de San Martín-Ventanilla y su posible relación con el domo de Valsurvio. *Breviora Geológica Astúrica*, XVII (4): 55-64.
- Pulgar, J., Pérez-Estaún, A., Gallart, J., Alvarez-Marrón, J., Gallastegui, J., Alonso, J. L. and ESCIN group (1995): The ESCIN-2 deep seismic reflection profile: a traverse across the Cantabrian Mountains adjacent Duero Basin. *Revista Sociedad Geológica de España*, 8 (4): 75-86.
- Quiring, H. (1939): Die ostasturischen Steinkohlenbecken. *Archiv für Lagerstättenforschung*, 69: 1-66 (Spanish translation by A. de Alvarado, 1943: Cuencas hulleras al Este de Asturias. *Boletín Instituto Geológico Minero de España*, LVI: 453-538).
- Radig, F. (1962): Zur stratigraphie des Devons in Asturien (Nord-Spanien). *Geologische Rundschau*, 51: 249-267.
- Raven, J. G. M. (1983): Conodont biostratigraphy and depositional history of the Middle Devonian to Lower Carboniferous in the Cantabrian Zone (Cantabrian Mountains, Spain). *Leidse Geologische Mededelingen*, 52: 265-339.
- Reuther, C. D. (1977): *Das Namur im südlichen Kantabrischen Gebirge (Nordspanien); Krustenbewegungen und Faziesdifferenzierung im Übergang Geosynklinale - Orogen*. Clausthaler Geologische Abhandlungen, 28: 122 p. (Doctoral Thesis).
- Reuther, C. D. (1982): The Lower Carboniferous facies levelling and the first Upper Carboniferous tectonic events in the Cantabrian Mountains and the Pyrenees (Spain) - A comparison. *Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen* 163 (2): 244-250.
- Ries, A. C., Richardson, A. and Shackleton, R. M. (1980): Rotation of the Iberian arc: Palaeomagnetic results from North Spain. *Earth and Planetary Science Letters*, 70: 301-310.
- Rodríguez Fernández, L. R. and Heredia, N. (1988): Evolución tectonosedimentaria de una cuenca de antepaís ligada a una cadena arqueada: el ejemplo de la unidad del Pisuerga - Carrión (Zona Cantábrica, N.O. de España). *III Congreso Geológico de España. Granada. Simposio sobre cinturones orogénicos*: 65-74. Sociedad Geológica de España.
- Savage, J. F. (1977): Sheet Carrión. In: J. Savage and D. Boschma, 1980. *Geological maps of the southern Cantabrian Mountains (Spain)*. *Leidse Geologische Mededelingen*, 50 (2): 75-114.
- Sitter, L. U. de (1961): The structure of the southern slope of the Cantabrian Mountains: explanation of a geological map with sections (scale 1:100.000). *Leidse Geologische Mededelingen*, 26: 255-264.
- Wagner, R. H. (1971): Carboniferous nappe structures in north-eastern Palencia (Spain). *Trabajos de Geología, Universidad de Oviedo*, 4 (2): 431-459.
- Wagner, R. H. and Álvarez-Vázquez, C. (1995): Upper Namurian/lower Westphalian of La Camocha, Asturias: Review of floral and faunal data. *Coloquios de Paleontología*, 47:151-176.
- Wagner, R. H., Carbal leira, J., Ambrose, T. and López Rico, J. (1984): Mapa Geológico de España 1:50.000, Hoja n.º 107 (17-7) (Barruelo de Santullán). Memoria explicativa por R. H. Wagner, J. Carballeira, T. Ambrose y E. Martínez García, 113 p. (1984). *Instituto Geológico y Minero de España*, Madrid.
- Wagner, R. H. and Fernández-García, L. (1983): Upper Westphalian D and Cantabrian strata in the Guardo Coalfield: Tectonics, Sedimentation, Stratigraphy. In: R. H. Wagner, L. Fernández-García and R. M. C. Eagar: *Geology and Palaeontology of the Guardo Coalfield (NE León - NW Palencia), Cantabrian Mts*: 11-55. Instituto Geológico Minero de España, Madrid (Serie Informes).

- Wagner, R. H. and Fernández-García, L. G. (1984): Late Westphalian D and Cantabrian Strata in the Guardo Coalfield (NW Spain): Tectonics, Sedimentation, Stratigraphy. *Compte Rendu 9^e Congrès International Stratigraphie et Géologie du Carbonifère, Washington and Champaign-Urbana*, 3: 345-366.
- Wagner, R. H., Martínez García, E., Winkler Prins, C. F. and Lobato, L. (1983): Carboniferous stratigraphy of the Cantabrian Mountains. *X International Congress Carboniferous Stratigraphy and Geology, Madrid, 1983, Guidebook Field Trip A*: 212 p.
- Wagner, R. H. and Wagner-Gentis, C. H. T. (1963): Summary of the stratigraphy of Upper Palaeozoic rocks in NE. Palencia, Spain. *Proceedings Koninklijke Nederlandse Akademie van Wetenschappen, B*, 66 (3): 149-163.
- Wagner, R. H. and Winkler Prins, C. F. (1997): Estratigrafía y metamorfismo del Carbonífero de la Zona de San Martín-Ventanilla (Norte de Palencia, Cordillera Cantábrica): Discusión. *Revista Sociedad Geológica de España*, 10 (1-2): 197-199.
- Wagner, R. H., Winkler Prins, C. F. and Riding, R. E. (1971): Lithostratigraphic units of the lower part of the Carboniferous in northern León, Spain (with a Note on some goniatite faunas by C. H. T. Wagner-Gentis). *Trabajos de Geología, Universidad de Oviedo*, 4 (2): 603-663.
- Wagner-Gentis, C. H. T. (1980): Goniatites from the Viséan-Namurian junction beds in Palencia, NW Spain. *Scripta Geologica*, 55: 1-43.