EVIDENCE FOR STRIKE-SLIP MOVEMENT ALONG THE SABERO-GORDON AND ASSOCIATED FAULTS IN THE LUNA-PORMA AREA, LEON, NW SPAIN

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TRABAJOS DE GEOLOGIA

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Structural mapping in the Aviados, Llomberas and Geras areas (León, NW Spain) is now possible with more accuracy because of a better understanding of the lithostratigraphy of the area. It reveals a complicated pattern of thrusting and folding, associated with the main stress during the tectogenetic phase of the Cantabrian Mountains. This structural evidence and additional sedimentological evidence allows a hypothesis suggesting late Hercynian strike-slip movement along the Sabero-Gordón Fault Zone associated with local collapse of structures.

El conocimiento actual de la litostratigrafía del área de Aviados, Llomberas y Geras (León, NW de España) permite realizar una cartografía más precisa de dicha área. Esta cartografía pone de manifiesto la existencia de un modelo complicado de cabalgamientos y pliegues, asociados con el esfuerzo principal producido durante la génesis de la Cordillera Cantábrica. A partir de esta evidencia estructural, así como de los datos sedimentológicos adicionales, se sugiere una hipótesis según la cual, durante los últimos estadios de la deformación hercínica, tendría lugar movimientos de desgarre a lo largo de la falla Sabero-Gordón asociados con colapsos locales de estructuras.

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INTRODUCTION

The southern Cantabrian Mountains (province León, NW Spain) has been subject of several structural studies resulting in a series of detailed geological maps (Rupke 1965; Evers 1967, Fig. 1.; v. Staalduinen 1973, Figs. 2, 3).

Following structural mapping regional stratigraphic and sedimentologic studies were undertaken. Late Devonian - Early Carboniferous strata were studied by Adrichem Boogaert (1967), Frankefeld (1981) and Raven (1983). Reijers (1972) and Mohanti (1973) studied the Givetian - Frasnian Portilla Formation; de Coo (1974) and Méndez-Bedia (1976) the Emsian - Couvinian Sta. Lucía Formation. A considerable effort has been (and is still being) put on unravelling stratigraphic and sedimentologic relations in Carboniferous strata. From these studies it is increasingly clearer that sediment distribution is controlled by a number of fundamental lines. According to Heward and Reading (1980) these lines are associated with a late Hercynian (Stephanian) continental strike-slip system on the southern margin of the Biscay-North Pyrenean fault. The question, whether these lines already controlled sediment distribution and facies during the Devonian has been a matter of some arguments (Marcos 1968; Julivert 1971; Wagner & Martínez-García 1974) but recently published evidence (Kullmann & Schönenberg 1978; Savage 1978; Reijers 1980, 1984; Krans 1982; Raven 1983) makes it increasingly more likely. The nature of the activity both during the Devonian and the Carboniferous is in a number of cases, still a matter of conjecture. It is likely that block movement and epeirogenetic movements were dominant during the Devonian, whereas strike-slip movements were dominant during the Stephanian. Such strike-slip movements could have interfered with the expected normal sedimentary facies trends in Devonian sediments. The tracing of such trends and reporting of structural complex

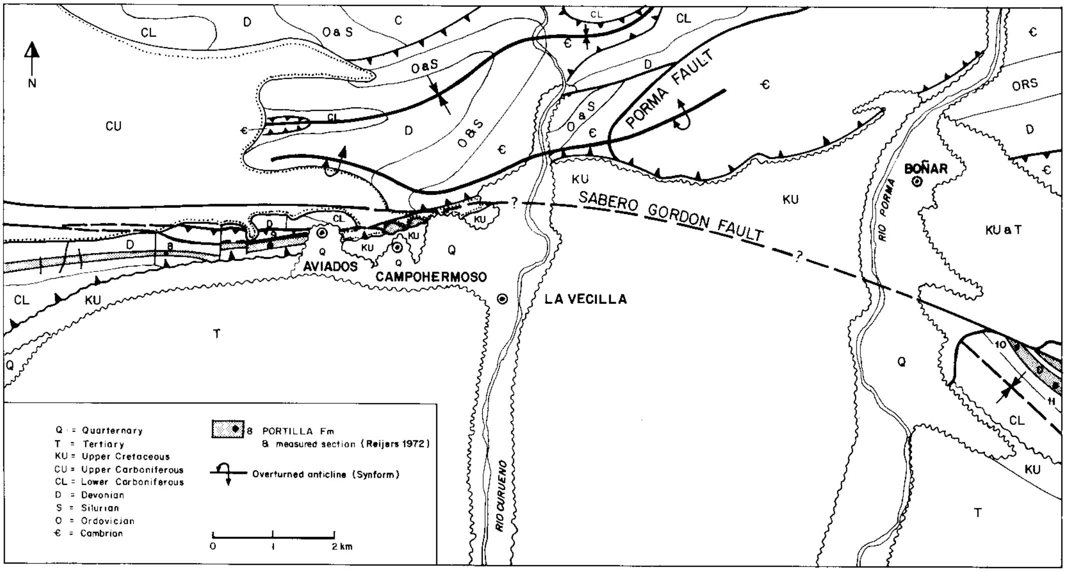


Fig. 1.–Simplified geological map of the Aviados-Boñar area (León, NW Spain) according to Evers (1967).

field relations in a few areas, are the main topics in the present paper.

Regional Structures

The fundamental E-W directed Sabero-Gordón fault zone is one of the mapped features on which interest focused the last few years. Bastida, Marcos, Arboleya and Méndez-Bedia (1976) suggested for the Esla area a left-lateral movement of approximately 20 km along this zone. Previous workers considered this fault zone to be an expression of a normal basement fault which was several times reactivated.

For the Esla area a timing of strike-slip movement with respect to the emplacement of the Esla nappe is suggested by Reijers, van der Baan and van der Sluys (1984). This is based on an analysis of the structures in the Peñola area NW of La Ercina, León (Reijers 1984), facies gradients in the Portilla Formation (Reijers and ten Have 1983) and established chronostratigraphic markers in the Portilla Formation that link the various sub-areas within the Esla area (Reijers *et alt.* 1984). These data collectively support sinistral wrench movement along the Sabero-Gordón fault zone within the Esla area, but such movements have not yet been demonstrated along this fault zone further to the west. Palaeogeographic reconstructions assuming such movements (Raven 1983) thus have to be regarded as somewhat premature. In the summer of 1983 and 1984 the author studied a number of key exposures in the Curueño-Torío-Bernesga area. Along the Sabero-Gordón fault zone activity is detectable in the areas near Aviados (Fig. 1), Llomberas (Fig. 2) and Feliciano (Fig. 3).

Local Stuctures

Aviados area (Figs. 1, 4)

In the structurally complex area west of Aviados and near Campohermoso middle Devonian to Lower Carboniferous strata are outcropping. The Tertiary mountain boundary fault separates the area to the south from Upper Cretaceous and Tertiary strata. To the north Stephanian deposits overly unconformably older Palaeozoic sediments.

Evers (1967, p. 127; see Fig. 4) remarked that detailed mapping in this area... «revealed at least two more or less continuous E-W trending faults. The sharply folded Sta. Lucía Formation in the Peña area clearly shows the broken assymetrical folds. The less competent La Vid and Huergas Formations apparently acted as local detachment planes, because the upthrusts bring the Sta. Lucía and Portilla limestone in fault contact with younger beds...» To this description the present author adds the following: The outcrop of the Portilla Formation N of Cam-

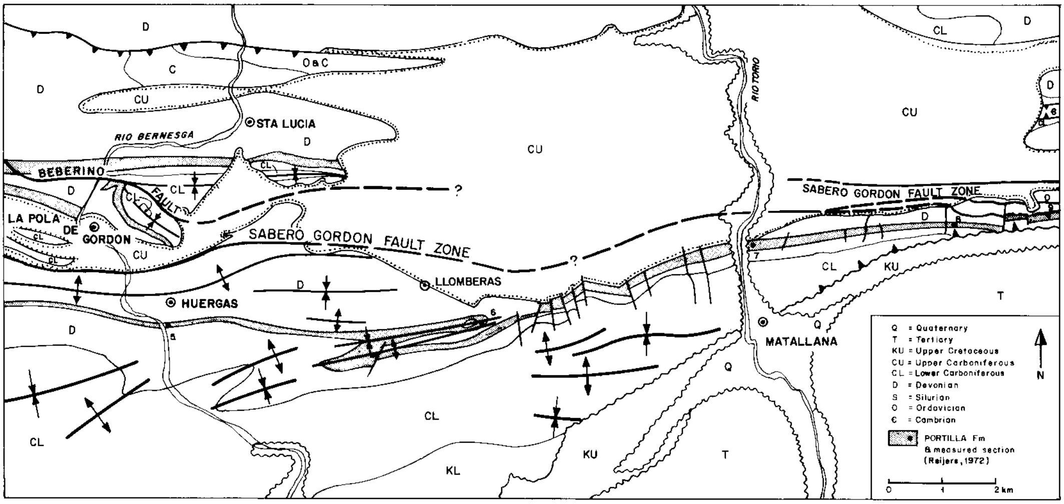


Fig. 2.–Simplified geological map of the Pola de Gordón-Matallana area (León, NW Spain) according to Staalduinen (1973).

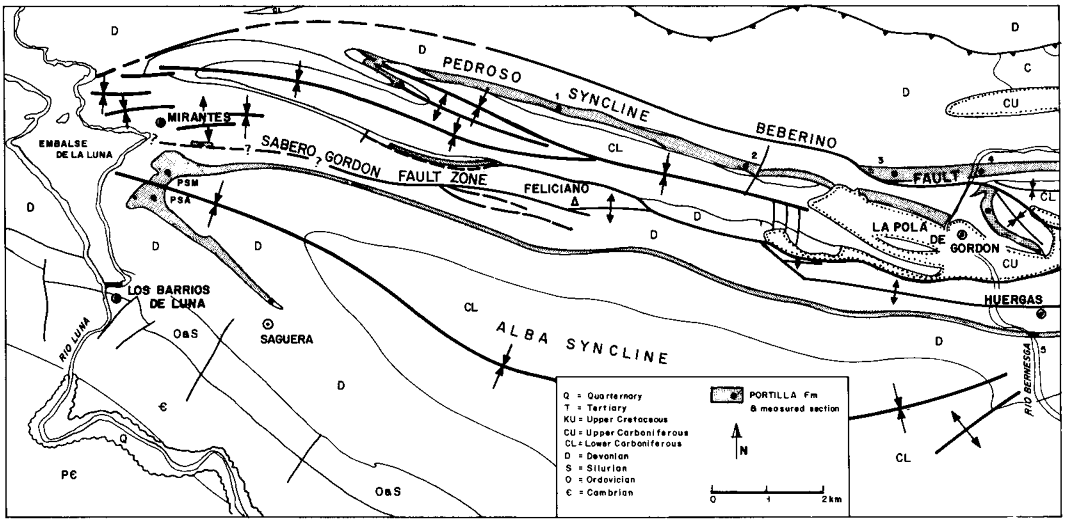


Fig. 3.–Simplified geological map of the Mirantes-Huergas area (León, NW Spain) according to Staalduinen (1973).

pohermoso is complete but part of the lower Portilla is repeated. Drag-related folds on the Northern block (the foot wall) strike 85/55 with axial plunges around 65° N. This suggests a sinistral oblique-slip component to the thrust. The fault is further marked by intensive dolomitisation.

Fig. 4 shows differences in the mapping of the Aviados area, now detectable due to a better understanding of the facies of the Portilla Formation (Reijers 1972). Evers (1967, p. 96) remarked: ...«SW of Aviados a conspicuously thick section (of Portilla limestones) is measured of 170 m. This is primarily due to a greater supply of debris and sand but undetected strike faults might also occur...».

The cross-sections (Fig. 4) show two main thrusts and a number of subsidiary faults separate a few blocks together constituting an anticlinal structure. To the N this anticlinal structure continues into a syncline which is either disconformably covered by Stephanian sediments, or it forms part of the intramontane basin in which Stephanian sediments accumulate.

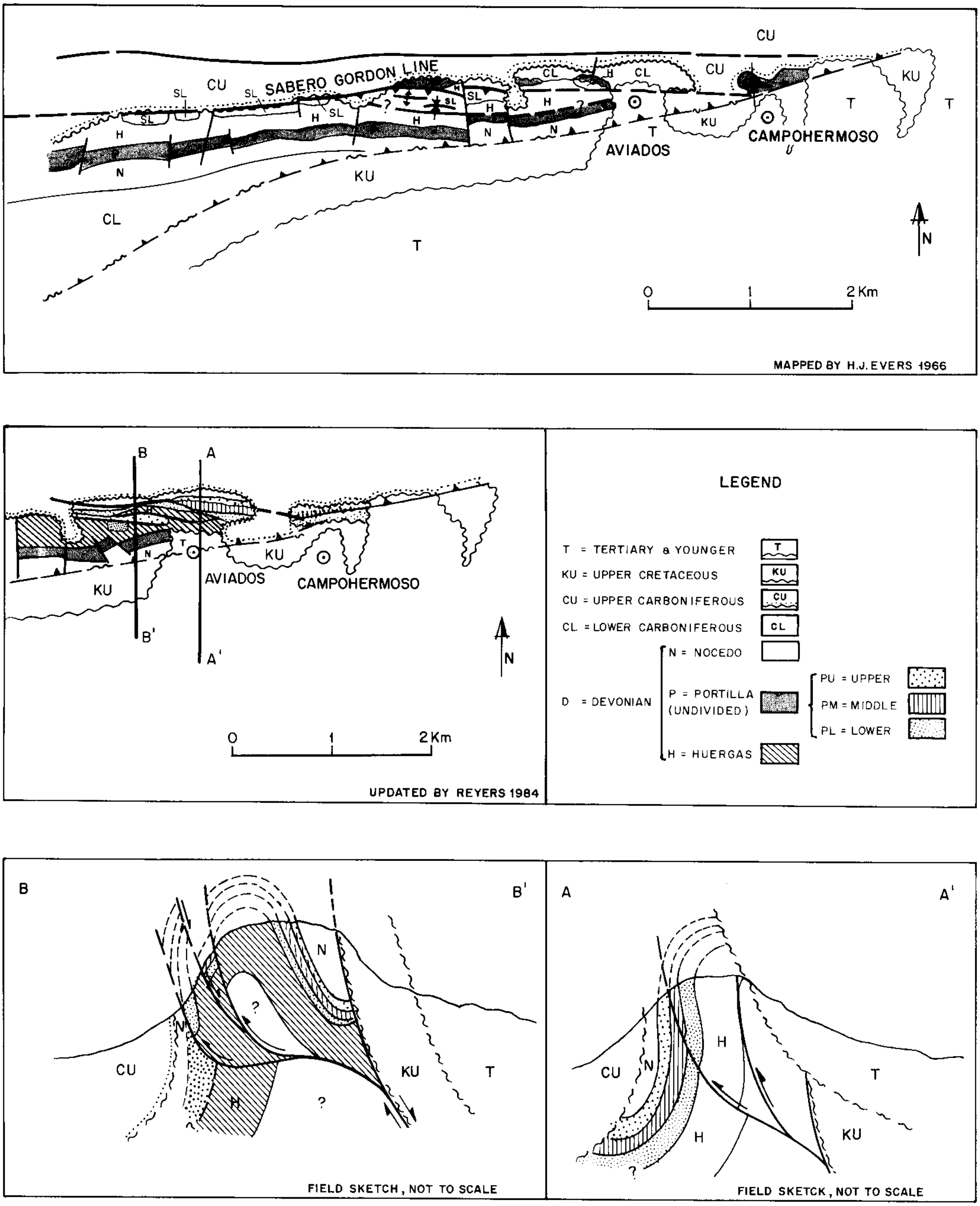
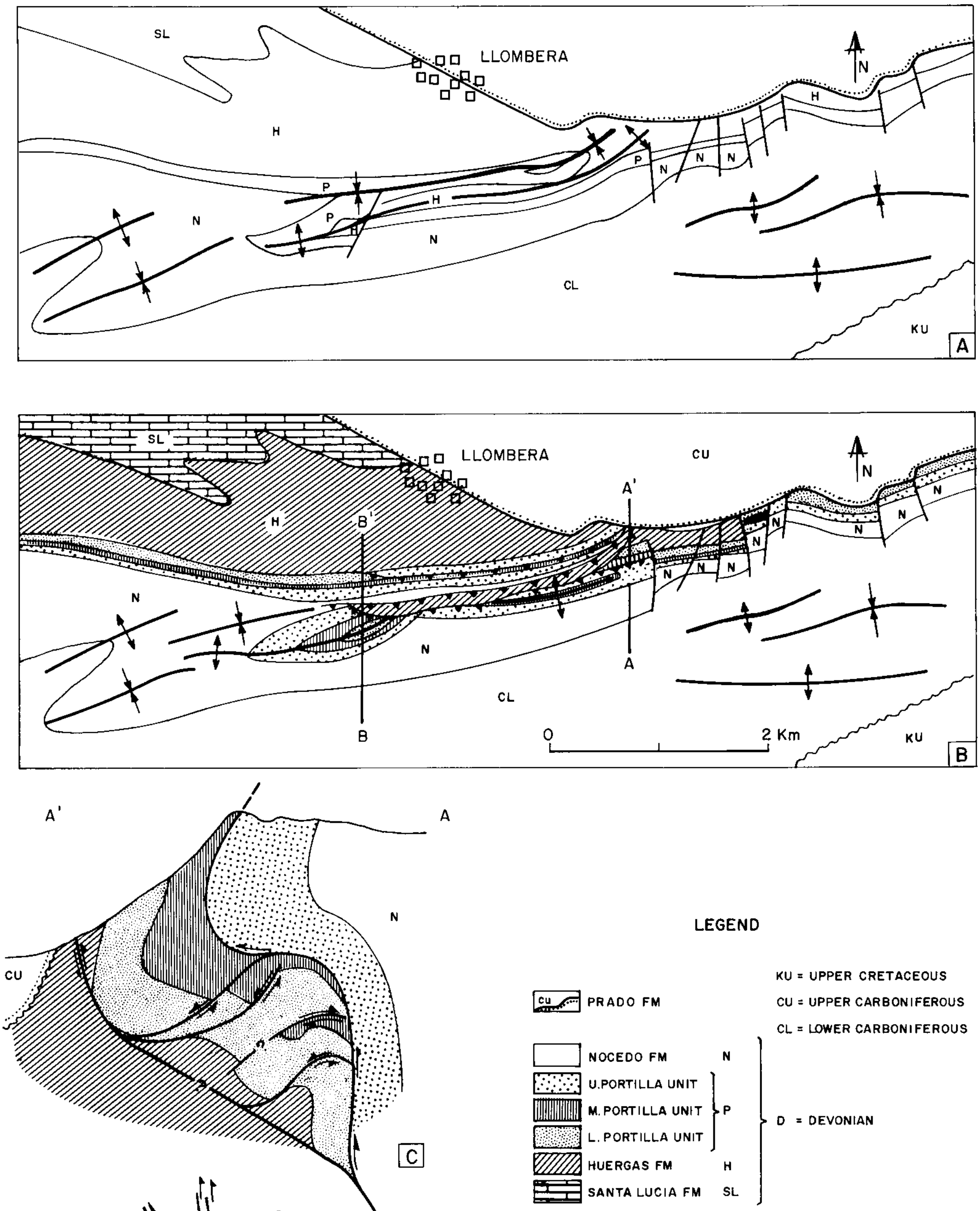


Fig. 4.–Detail map of the Aviados area as mapped by Evers (A), and modified by Reyers (B). Two field-sketches are presented, depicting N-S cross sections respectively west and east of Aviados (C and D).

Llombera area (Figs. 2, 5, 6)

The structure S of Llombera (Fig. 5 A), on the N-flank of the Alba syncline, has been mapped by Staalduinen (1973) as a tight syncline (N) and an anticline (S) in the Portilla Formation. In the cores of these structures the Nocedo and the Huergas Formations crop out.

The cross section A-A' (Fig. 5 C) and the field photograph (Fig. 6) show these features



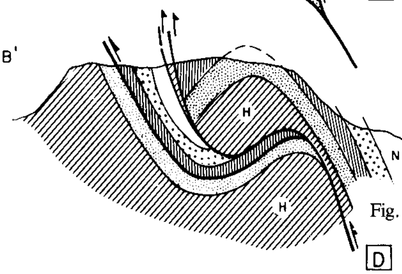


Fig. 5.–A. Geological map of the Llombera area according to Staalduinen (1973).
B. Update of same by Reyers.
C. Cross section after photograph (see Fig. 6).
D. Cross section after field sketch.

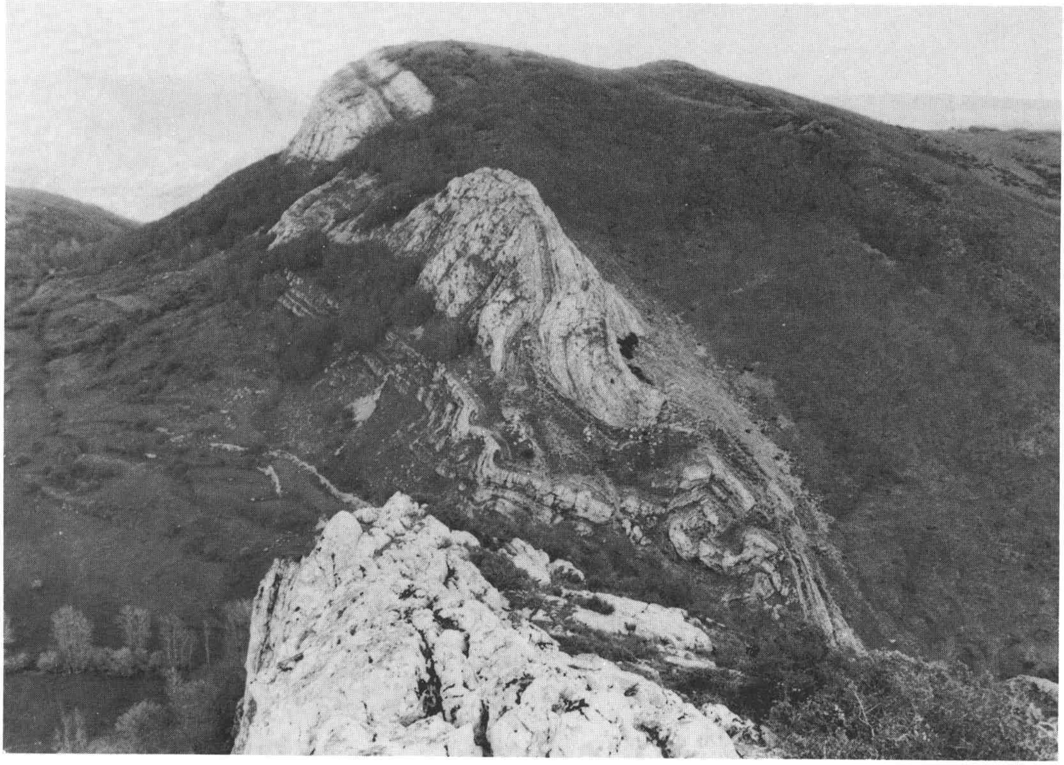


Fig. 6.–Photograph taken in easterly direction over structure at Llomberas. Photostation is due S of Llomberas (see Fig. 5 B).

but they also demonstrate a complex system of smaller and bigger (folded) thrusts and normal faults, while the Portilla Formation is not entirely complete in either of the structures. Cross section B-B' shows the southerly anticline overriding the northerly syncline; a feature not shown on Staalduinen's map.

Feliciano area, south of Geras (Fig. 3).

Due south of Geras the Pedroso and Alba synclines are separated by a complexly faulted zone. The most persistent fault in an E-W direction continues south of Mirantes before it disappears below the artificial lake of the river Luna. It then continues N of Mallo. Near the Feliciano mountain three splays of this fault have been mapped, along which van Staalduinen indicates repetitions of the Sta. Lucía limestone and the Huergas shales. The nature of the fault is thrusting to the north. A number of anticlinals and synclinals further characterise this fault zone. North of the Feliciano another E-W striking thrust occurs. Collectively this area is referred to as the Sabero-Gordón fault zone and in cross-section (Fig. 7) the overall configuration appears to be a broken and thrusted anticlinorium.

SEDIMENTOLOGICAL DATA

The sedimentology, in particular the facies distribution of a number of Devonian formations in the discussed area, is well studied (see above). These studies allowed definition of a number of problems for which in the past not always a fully satisfactory explanation could be given. Examples are the following:

There exists a distinct difference between facies of the Portilla Formation in the Pedroso and the Alba synclines (Fig. 3; see also Reijers 1972, pp. 203, 209; Raven 1983). These differences have been linked to synsedimentary activity of the Sabero-Gordón Fault Zone which separates the areas, but no explanation of the precise nature of the activity has been offered. Additional field data, collected in 1983 and in 1984, support the facies difference already observed. The section of the Portilla at Beberino contains in its lower unit (± 20 m from the

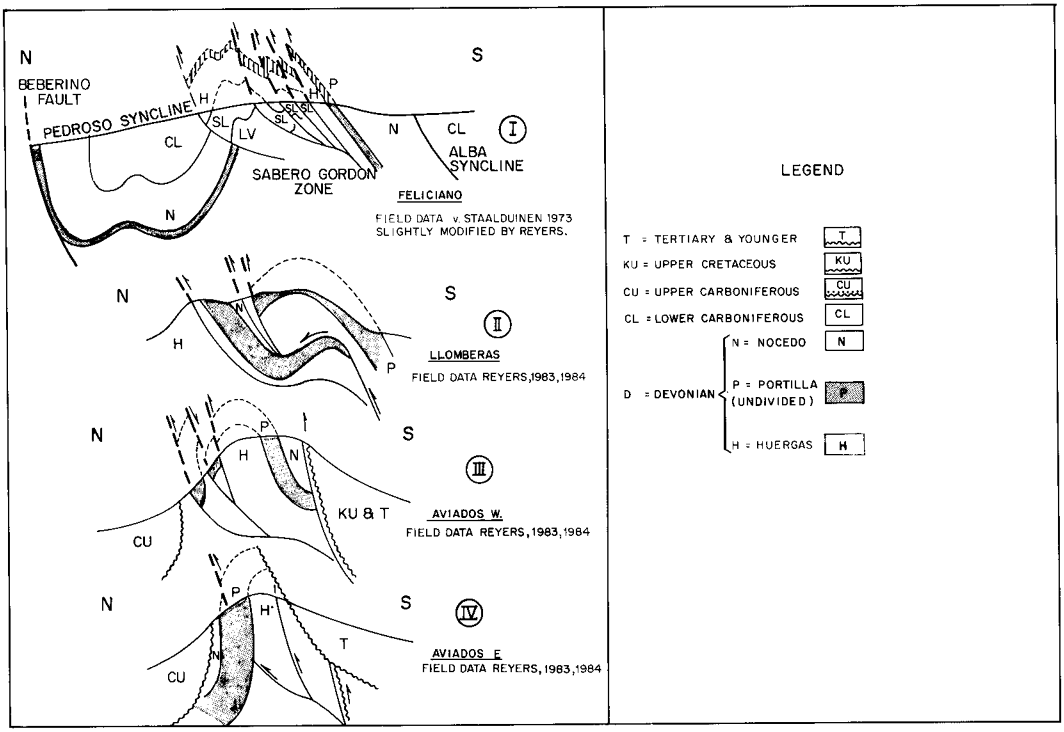


Fig. 7.–A series of cross-sections over the Sabero-Gordón zone and associated structures shows similarities and differences between:
I.–The Feliciano area.
II.–Llomberas.
III.–Aviados W.
IV. Aviados E.

base) a two-metre thick interval of oolith which was not earlier recognised. This makes this section (and the whole outcrop N of the Beberino fault) different from those in the N-flank of the Pedroso syncline. This outcrop differs also in its reefoid aspect (biostromes at the base of the section at Vega de Gordón and bioherms (accentuated by erosion) at the top at Beberino) and in its rapid facies changes (base Beberino section is calcarenitic as is the top of the Vega de Gordón section).

The small, isolated unit of Upper Devonian which is present NE of La Pola de Gordón and S of the Beberino fault offers also surprising elements. It consists of 40 m of calcarenitic carbonates (alternating encrinitic grainstones and packstones intercalating with argillaceous intervals) which start with 5 m of a yellow-brownish cross-bedded and channelled oolith not unlike the oolith present at Valdoré (Reijers and ten Have 1983). The lower Portilla (Veneros Member and member B; Reijers 1972) is followed by a 12 m thick poorly exposed siliciclastic unit (member C) and 20 m of member D which is biostromal with *Thamnopora* sp., *Alveolites* sp. and *Coenites* sp. followed by an encrinitic packstone to grainstone. This section shows a remarkable similarity to those in the N-flank of the Pedroso-syncline and it is also very similar to the carbonate lenticles at Mirantes (Reijers 1972; Raven 1983) south of which (and not N, as indicated on van Staalduinen's map) a fault is present which belongs to the Sabero-Gordón fault zone.

Thus it appears that the Pedroso syncline as far as facies in the Portilla are concerned, is remarkably uniform. It is also markedly different from the Alba syncline, from which it is separated by the Sabero-Gordón fault zone, and from the Beberino-Vega de Gordón outcrop, from which it is separated by the Beberino fault (Reijers 1972, 1973). In the Alba syncline area the Portilla facies are reefoid (NW of Los Barrios de Luna). In a southerly direction a fore reef slope is present (slumping near Sagüera). Near Huergas de Gordón the facies is also distinctly fore-reef like which is also the case, albeit to a less degree, near Matallana. More towards Aviados the Portilla is increasingly more present in a grainstone/packstone facies whereas the biostromal/biohermal aspect diminishes. This aspect appears to link with the overall facies characteristics of the Portilla in the Pedroso-syncline.

Differences in facies in the Portilla between the areas S of the Sabero-Gordón fault zone (reefoid to fore-reef facies), between the Sabero-Gordón fault zone and the Beberino fault (calcarenitic) and N of the Beberino fault (biostromal, biohermal, rapidly changing in facies into calcarenites), are rather similarly also present in the Sta. Lucía Formation (Reijers 1980, Fig. 7). In facies the aspect of the Sta. Lucía Formation S of Geras (N of the Beberino fault) is very similar to that in the Portilla in Vega de Gordón, and the section S of Pola de Gordón (in the Alba syncline) is predominantly a calcarenite (grainstone-packstone).

Discussion and a new hypothesis

The observed irregular patch-quilt-like distribution of facies in the Portilla Formation throughout the area discussed, is difficult to interpret. The picture that emerges from other areas where the Portilla has been studied (Reijers 1972, 1973, 1974; Reijers and ten Have 1983; Raven 1983) is that a carbonate regime established at the end of the Givetian, which is represented by a calcarenitic unit in which ooids occur. Along an active basement fault biostromes established, which form a reef-track accentuating the transition of the carbonate shelf to the carbonate slope. In places this transition is accentuated by calcarenitic banks rather than by biostromes. Tidal currents gave rise to tidal delta complexes (Reijers and ten Have 1983). Towards the open marine side of this protecting barrier increasingly deeper facies are present, whereas to the North a lagoon exists in which patch reefs occur.

The data discussed above suggest the presence of a reef track crossing the Alba syncline and essentially just S of the Sabero Gordón fault zone, whereas further to the S deeper facies prevailed. This is in line with the expected model. However, the facies in the Portilla in the Pedroso syncline are of an unexpected nature. The calcarenites could have formed bars that could have taken over the protecting function of the reefs if they did not occur in close juxtaposition with such reefs. A striking example is the calcarenitic section at Mirantes, only ± 1 km N of a massive reef.

Another strange coincidence is the calcarenitic occurrence of the section NE of La Pola de Gordón, only 500 m to the south of reefs occurring in the Beberino-Vega de Gordón outcrop. Obviously a further explanation is required.

The described structures E and W of Aviados, S of Llomberas and in the vicinity of the Feliciano Mountain (Fig. 7) demonstrate the presence of a zone of folded thrustplanes just N of the continuous outcrop of the Portilla between the nose of the Alba syncline and Aviados (Figs. 1-3). Such a zone N of the Peña Corada unit in the Esla area (see also Reijers 1984) is the site of a considerable amount of sinistral strike slip movement (Reijers *et alt.* 1984). It appears that this zone from Aviados via Llomberas to Feliciano is the westward continuation of the most important branch of the fundamental Sabero-Gordón fault.

The Beberino fault, separating rather different facies zones in the Portilla and along which evidence of dextral strike-slip is present (see below) is another fundamental fault. Thus the areas in which the various facies have been recognised are separated from each other by fundamental faults. Close inspection of the maps by van Staalduinen (1973) and Evers

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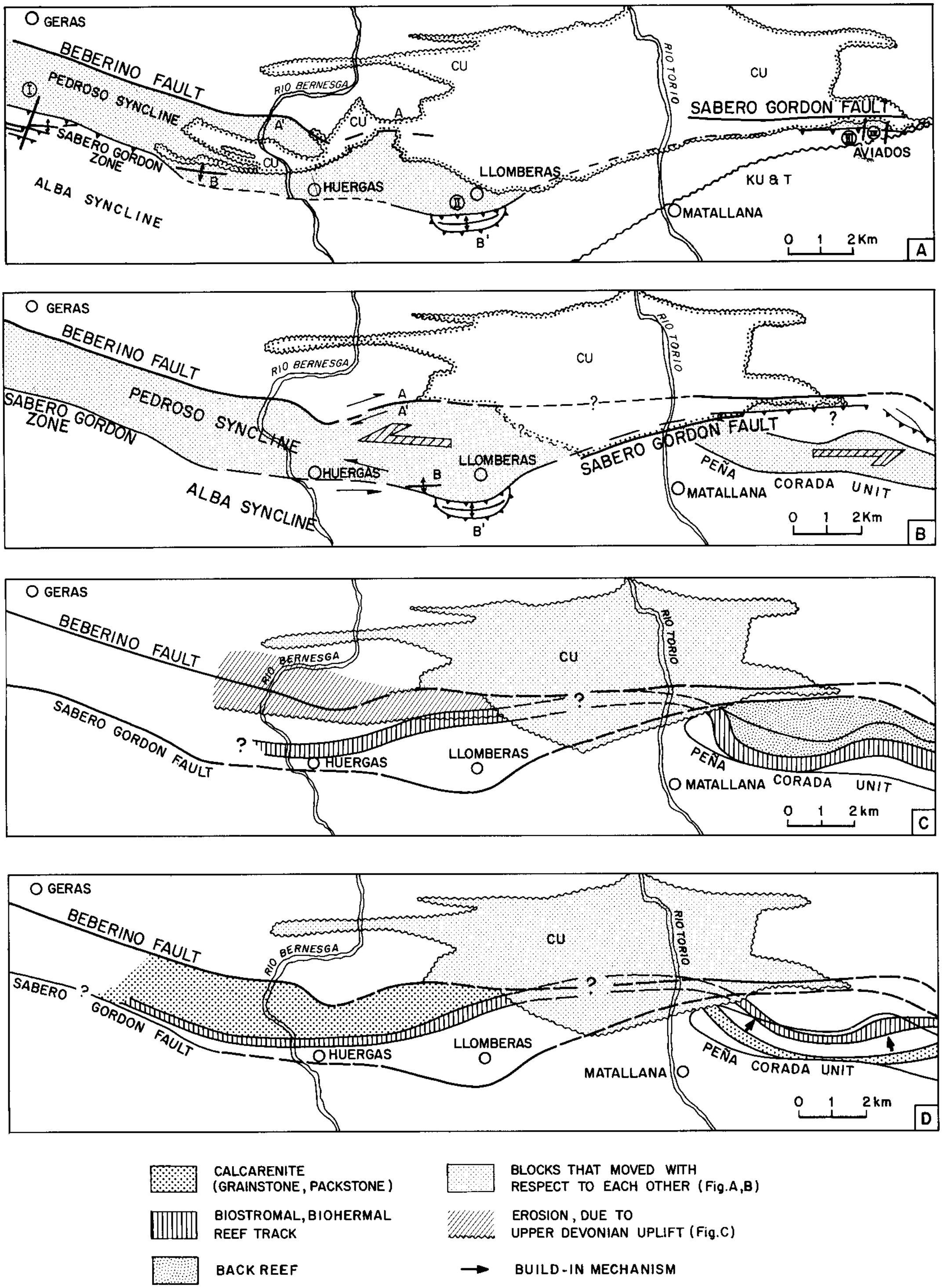
Fig. 8.–Reconstruction of geological events in area between nose of the Alba syncline (W) and the Esla area (E).

A. Present day distribution of structural elements in studied area. This reflects the situation following the Stephanian strike-slip movements along the Sabero-Gordón fault zone, and the Beberino fault.

B. Prior to dextral wrench faulting along the Sabero-Gordón zone, a number of structural elements, discussed in the text (A-A', B-B'), were much closer to each other. The parting of the «Pedroso syncline-block» and the «Peña Corada unit-block» is partially responsible for the Matallana basin.

C. Palaeogeography pre wrench faulting. Note the natural lateral continuing of the reef track developed in the upper Portilla.

D. Palaeogeography pre wrench faulting. Note the shifting of the biostromes and bioherms, together forming a reef track away from the zone with predominant calcarenitic bars towards a more shelf interior position (building in).


GERAS
BEBERINO FAULT
PEDROSO SYNCLINE
SABERO GORDON ZONE
ALBA SYNCLINE
RIO BERNESGA
RIO TORIO
CU
SABERO GORDON FAULT
AVIADOS
KU & T
LLOMBERAS
HUERGAS
MATALLANA
A
A'
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0 1 2 Km
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MATALLANA
PEÑA CORADA UNIT
0 1 2 km
D
CALCARENITE (GRAINSTONE, PACKSTONE)
BIOSTROMAL, BIOHERMAL REEF TRACK
BACK REEF
BLOCKS THAT MOVED WITH RESPECT TO EACH OTHER (Fig. A, B)
EROSION, DUE TO UPPER DEVONIAN UPLIFT (Fig. C)
BUILD-IN MECHANISM

(1967) show a number of unexplained features along these faults.

Along the Beberino fault:

- The mapping of the Sta. Lucía Formation N of the Pedroso syncline suggests the possibility of dextral strike-slip of approximately 2 km.
- The Portilla Formation in the syncline NE of La Pola de Gordón (point A', Fig. 8 A), could have a dextral offset of approximately 3 km with respect to the southflank of the tight syncline south of the village Santa Lucía (point, A, Fig. 8 A).

Along the Sabero Gordón fault:

- From mapping it appears possible to continue the E-W striking anticlines in the Sta. Lucía - La Vid Formations at Los Barrios de Gordón (point B, Fig. 8 A), into the overthrusted anticlinal structure at Llomberas (point B', Fig. 8 A).
- The complexly broken anticlinal structure S of the Feliciano mountain, south of the Sabero Gordón fault zone (Fig. 7), could have its pre-movement equivalent N of the Sabero-Gordón fault zone in the anticlinorium which continues E-W from the villages Mirantes to Mallo.
- The complexly folded Sta. Lucía N of the road between Huergas de Gordón and Llombera, N of the Sabero-Gordón fault zone, could have its pre-movement equivalent S of the Sabero-Gordón fault zone in the Aviados area.

Total sinistral movement along the Sabero-Gordón fault zone could thus be in the order of 10 km, and with the 2-3 km dextral offset along the Beberino fault, the nett offset between certain areas N of the Beberino fault and S of the Sabero-Gordón fault could be 7-8 km.

The picture arrived at above is only a preliminary one. A substantial amount of detailed structural field work is now required, to work out the details. A new phase of structural mapping is thus indicated. However, if the picture arrived at is correct in outline, then an explanation can be given for the ostensibly patch-quilt-like facies distribution of the Devonian Portilla Formation. The area appears to be broken up in individual fault-bounded blocks along which strike-slip movements of variable magnitude took place during the late Hercynian phase of compression. Based on the admittedly limited areal facies control and the reconstructed nature and magnitude of movement along these faults, the depositional situation can be approximately reconstructed (Fig. 8 C, D). During the late Hercynian compressional phase sinistral movement of approximately 10 km along the Sabero Gordón fault and dextral movement of approximately 3 km along the Beberino fault took place which resulted in a relative westward movement of the «Pedroso-syncline» block with respect to the «Alba-syncline» block. It could be speculated that the «tearing apart» of the Pedroso syncline block from the Alba-syncline block at least partly gave rise to the formation of the Matallana Stephanian basin.

Like in the Peña Corada unit in the Esla area (Reijers *et alt.* 1984) the question here also arises about which block moved absolutely with respect to the other block. To resolve this question a decidedly stable point of reference is needed and it appears that such a point is nonexistent in the area under discussion.

The author feels, however, guided by discussed information on facies trends in the Portilla and Sta. Lucía Formations, that the mosaic of structurally defined blocks has much more moved mutually by strike-slip movement, than was the case in the Esla area. Thus individual movement distances were much less in absolute terms than in the Esla area. On the present data there is no reason to assume a 20 km westward autochthonous position of the Alba unit with respect to the more northerly units; a maximum of 7-8 km is considered the most likely. Like in the Esla area (Reijers 1984) it is thought that the structural history can be summarised as follows.

SUMMARY

During the tectogenetic period of the Cantabrian Mountains a main compressional phase produced a nappe in the Esla area and a series of folded thrustfaults in the area west of the Pardomino high. Based on patch-quilt-like facies distribution in Devonian formations, and on local structural features wrench faulting is postulated to have taken place after this phase and Stephanian sediments were deposited in the Matallana basin which was perhaps partly created by the strike-slip movements. Folding of the thrusts (see e.g. Fig. 7) has been observed at several places along the southern boundary of this basin. It suggests syn-Stephanian movements, perhaps mainly associated with the southernmost branch of the Sabero-Gordón

fault zone and with the Beberino fault. Strike-slip movement further to the N in the Matallana basin (along the Beberino fault, but perhaps also along other faults), created relief which was subject to active erosion. Stephanian alluvial fan and slope apron debris are the result (Heward & Reading 1980). This stands in contrast to collapse that occurred along the south rim of the Matallana basin, triggered by ongoing movements along the Sabero-Gordón fault zone during deposition of paralic material of Stephanian age. Consequently thrusted and refolded Devonian is locally present in disconformable contact with Stephanian sediments.

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