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CARBONIFEROUS NAPPE STRUCTURES IN NORTH-EASTERN PALENCIA (SPAIN)

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ABSTRACT

Two superimposed nappe structures (Revilla and San Julián Nappes) are described from the region south-west of Barruelo de Santullán in north-eastern Palencia (text-figs 1-5). The lower nappe contains Middle Devonian, Viséan to Lower Namurian, Bashkirian (Namurian C?) and probable Lower Westphalian strata in a succession with three unconformities, representing a stratigraphic development which is different in several respects from that of the autochthon. The upper nappe contains Silurian and Lower Devonian strata, resting on Middle and Upper Devonian as well as Carboniferous deposits. The allochthonous nappe structures are folded rather gently in comparison with the autochthonous strata which are characterized by steeply dipping, small isoclines, showing anomalous contacts as the result of faulting. The lower (Revilla) nappe appears to have moved from south to north since the probable head of this nappe has been found a little north-east of the main outlier (text-figs 2-3). The different facies of some of the stratigraphic units in the Revilla Nappe are interpreted as the record of sedimentation on a geosynclinal ridge developed south of the area represented by the autochthonous rocks. The dating of the various stratigraphic units is discussed.

RESUMEN

En este trabajo se describe la superposición de dos mantos de corrimiento, el Manto de Revilla y el Manto ó Klippe de San Julián, en la zona al SW de Barruelo de Santullán, en el nordeste de la provincia de Palencia (ver figuras 1 a 5, intercaladas en el texto). El manto inferior (Revilla) contiene cuatro unidades estratigráficas, del Givetiense, Viséense/Namuriense A, Bashkiriense (¿Namuriense C?) y Westfaliense inferior, respectivamente, que están separadas por discordancias de tipo angular y de tipo «disconformity», poco angular. La secuencia estratigráfica desarrollada en el Manto de Revilla tiene rasgos especiales que la distinguen del autóctono por debajo de este manto. El Manto superior (San Julián), se compone de rocas silúricas y del Devónico inferior. Tanto estas como los estratos del Manto de Revilla se presentan más suavemente plegados que los estratos autóctonos que participan en pequeñas estructuras isoclinales falladas. El Manto de Revilla parece tener una derivación meridional, presentándose la cabeza del manto a poca distancia al NE del asomo principal. Los rasgos especiales de su desarrollo estratigráfico, que incluye discordancias probablemente ausentes en el resto de la Cordillera Cantábrica, están interpretadas como debidos a un umbral al sur del área representada por los estratos autóctonos.

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INTRODUCTION

The general geological maps published by the present writer in 1955 and 1960 show an area of allochthonous Lower Devonian strata (and incorporating some Upper Silurian) in the mountains west of Valle de Santullán, in the general vicinity of Barruelo in north-eastern Palencia. These rocks form a tectonic klippe on younger strata (Middle and Upper Devonian as well as Carboniferous) which are more steeply folded. There is a marked difference in tectonic style between the autochthonous and the allochthonous strata, the latter being found as a synclinorium forming the high ground west of Valle de Santullán. This area is dominated by the San Julián mountain top, in Upper Silurian to Lower Devonian quartzitic sandstone, and the allochthonous structure has therefore been referred to as the San Julián Klippe (WAGNER 1955).

An alternative interpretation of the structures at San Julián has been given by DE SITTER (1955) and FRETS (1965). They regarded these Silurian and Lower Devonian strata as forming an island in the Carboniferous sea, and mapped the outcrop accordingly. The present writer (WAGNER 1966b) has already criticized FRETS' and DE SITTER's map which shows the presence of Carboniferous strata where, in fact, Middle Devonian fossils have been found, and which attempts to show Carboniferous overlying Devonian where the reverse is the case. The unconformity between the Silurian and Lower Devonian rocks of San Julián and overlying Carboniferous strata, as interpreted by DE SITTER and FRETS, is contrived and completely untenable when it is realised that various different units of the Carboniferous, mainly of Moscovian age, are involved. These Moscovian rocks are nowhere seen to lie with angular unconformity on older strata, and the orogeny implied by FRETS' and DE SITTER's data cannot be placed in the sequence of orogenic events known for the Cantabrian Cordillera. The matter becomes even more confused by the nomenclature employed by these authors, who call their unconformity «Bretonic»!

Further mapping by the present writer in the area south-west of Barruelo de Santullán has shown that the klippe of San Julián is not an isolated phenomenon. In fact, the Silurian rocks on the eastern side of this klippe are found to overlie Westphalian strata (probably Lower Westphalian) which participate in another nappe structure incorporating also Bashkirian and Viséan to Lower Namurian strata as well as Middle Devonian. This outlier, situated in the area west of Revilla de Santullán, lies on a shallowly dipping thrust plane which cuts through the successive stratigraphic units in the nappe as well as through the underlying autochthonous rocks. The latter, which participate in steeply dipping, small isoclinal structures, are repeatedly seen to pass almost at right angles underneath the nappe west of Revilla. The Revilla Nappe also shows a stratigraphic sequence which differs in several respects from that of undoubted autochthonous strata.

The newly discovered Revilla Nappe underlies the San Julián Klippe recorded in 1955, and this relationship provides further proof of the allochthonous nature of the latter.

Additional evidence of nappe structures has recently been found a little further westwards, in the vicinity of Mudá (text-fig. 1), and it may be assumed that this kind of structure is more common in the Palaeozoic of northern Palencia than has been suspected. Although the nappe structure near Mudá is outlined in the general map of text-fig. 1, the present paper is restricted to a description of the Revilla and San Julián nappes which have been mapped in more detail.

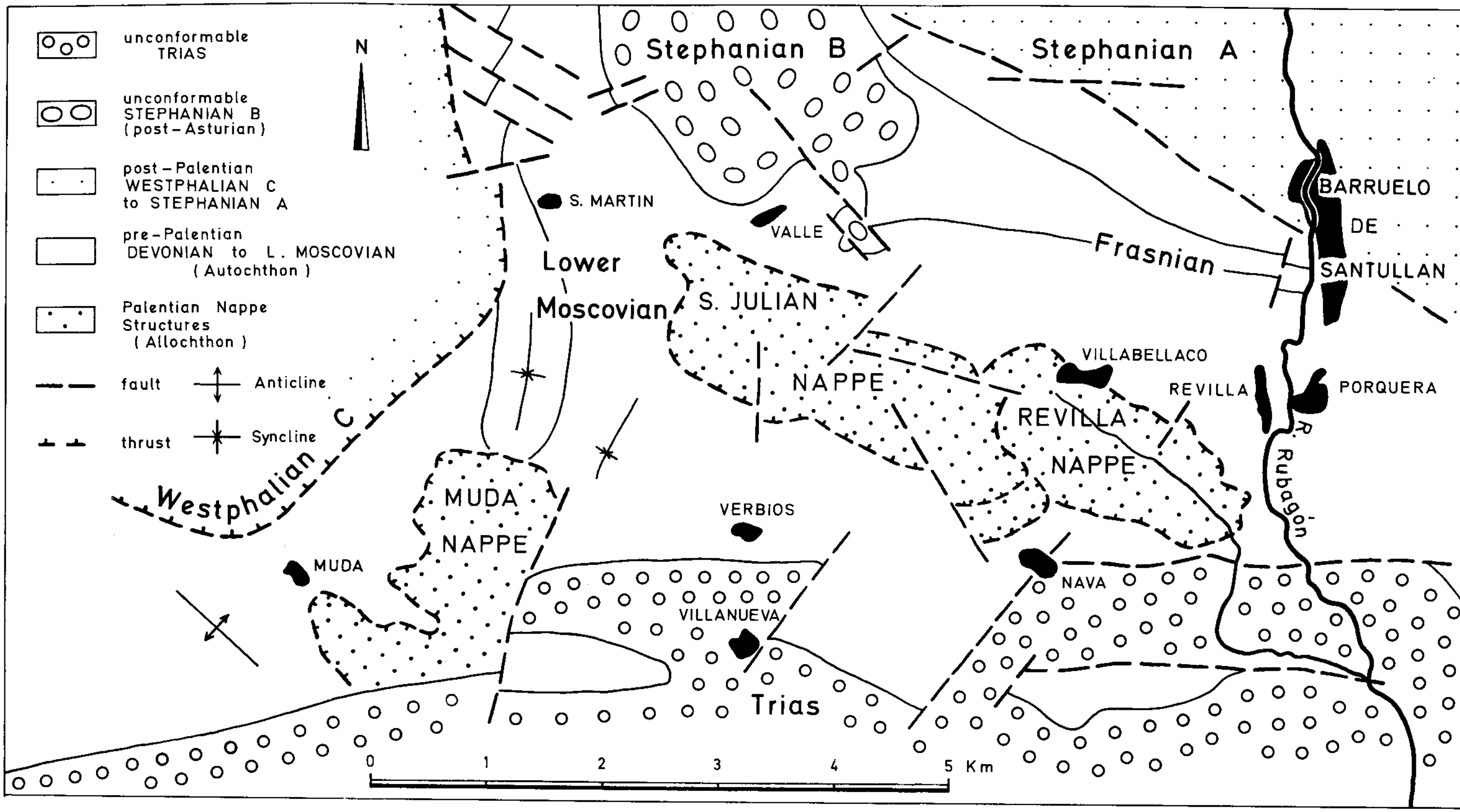
Acknowledgements.—The writer is much indebted to his wife, Mrs. C. H. T. WAGNER-GENTIS, who assisted with the mapping and identified goniatite faunas, an indispensable aid in stratigraphic dating. Dr. C. H. C. BRUNTON, of the British Museum (Natural History) kindly identified a Middle Devonian brachiopod fauna; Dr. C. F. WINKLER PRINS (Rijksmuseum van Geologie en Mineralogie, Leiden) supplied data on Carboniferous brachiopods; Dr. A. C. HIGGINS (University of Sheffield) and Dr. W. J. VARKER (University of Leeds) provided information on conodonts, Dr. F. H. CRAMER (University of Florida) on microplankton, and Mr. J. A. VAN HOEFLAKEN (University of Leiden) on Devonian brachiopods. Warmest thanks are given for all the specialist advice received.

REVILLA NAPPE

General description

Immediately south-west of Barruelo de Santullán, in N. E. Palencia (text-fig.1), two branch roads enclose a small area of mainly argillaceous rocks forming low ground with meadows in which small elevations correspond to local exposures of harder rocks. A ridge of shallowly dipping Carboniferous limestone (Pl. 1) forms the immediate background, and this is followed by rolling country in shales with sandstone beds and rare conglomerates. Both the limestone and the shale/sandstone sequence are dipping at angles which vary a good deal but which generally produce an undulating structure with gradually younger rocks appearing in the south-western part of the area occupied by these stratigraphic units (text-fig. 2). These younger strata show a strike and dip which are at an angle to more vertical, east-west striking Devonian or older rocks in exposures near Santa María de Nava. The contact between these two sets of strata is clearly anomalous and cannot be ascribed to an unconformity, since it is the upper part of the Carboniferous shale/sandstone succession forming the generally undulating structure, which is in contact with the Devonian.

The limestone succession underlying the shale/sandstone sequence forms a prominent ridge south-west of Revilla de Santullán (text-fig. 2). The outcrop, though varying in width, is apparently continuous or almost continuous, and on the maps published by WAGNER (1955) and FRETS (1965), it has been shown as a single limestone unit. From different localities in this limestone unit a variety of goniatites and brachiopods have been recorded by WAGNER-GENTIS (*in* WAGNER 1955, p.153), who concluded upon a Viséan and Namurian age. The facies of the limestone varies however quite considerably from one locality to another, and a more careful examination of the exposures has shown that two different units are involved, viz. a lower

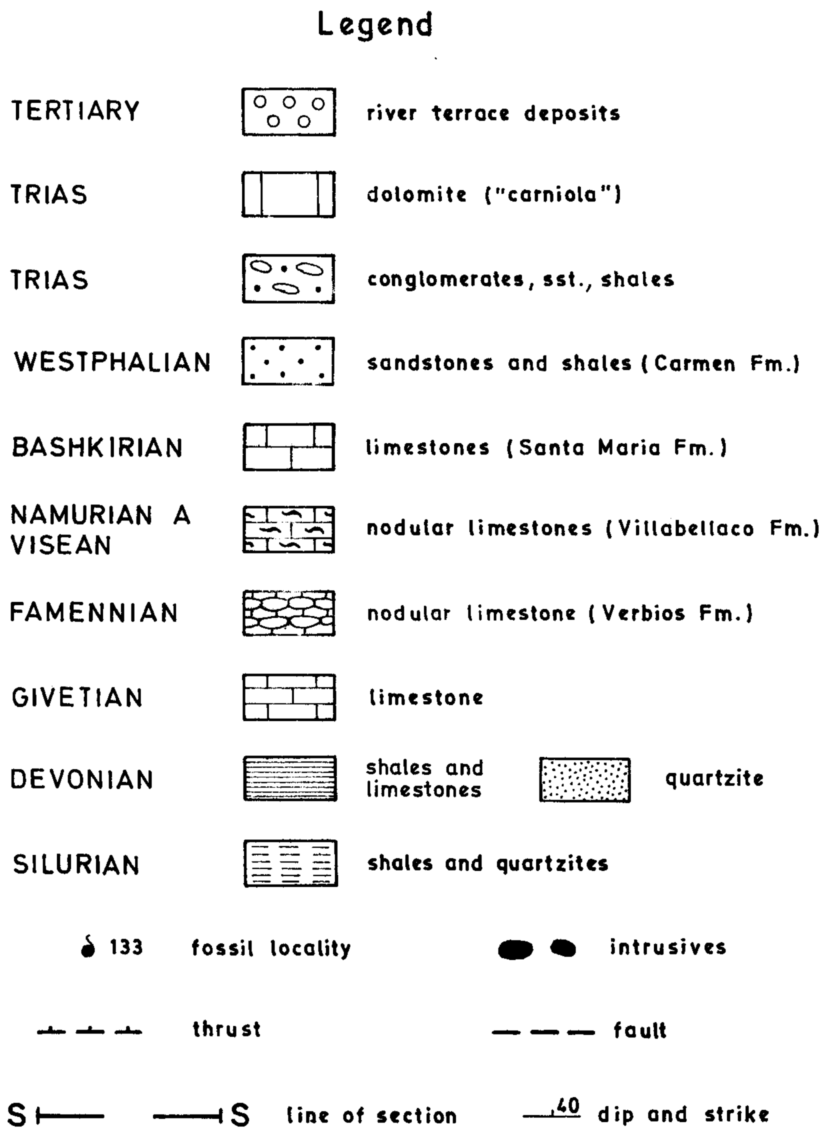


Text-fig. 1.—General map of the geology of north-eastern Palencia showing the nappe structures of San Julián, Revilla and Mudá.

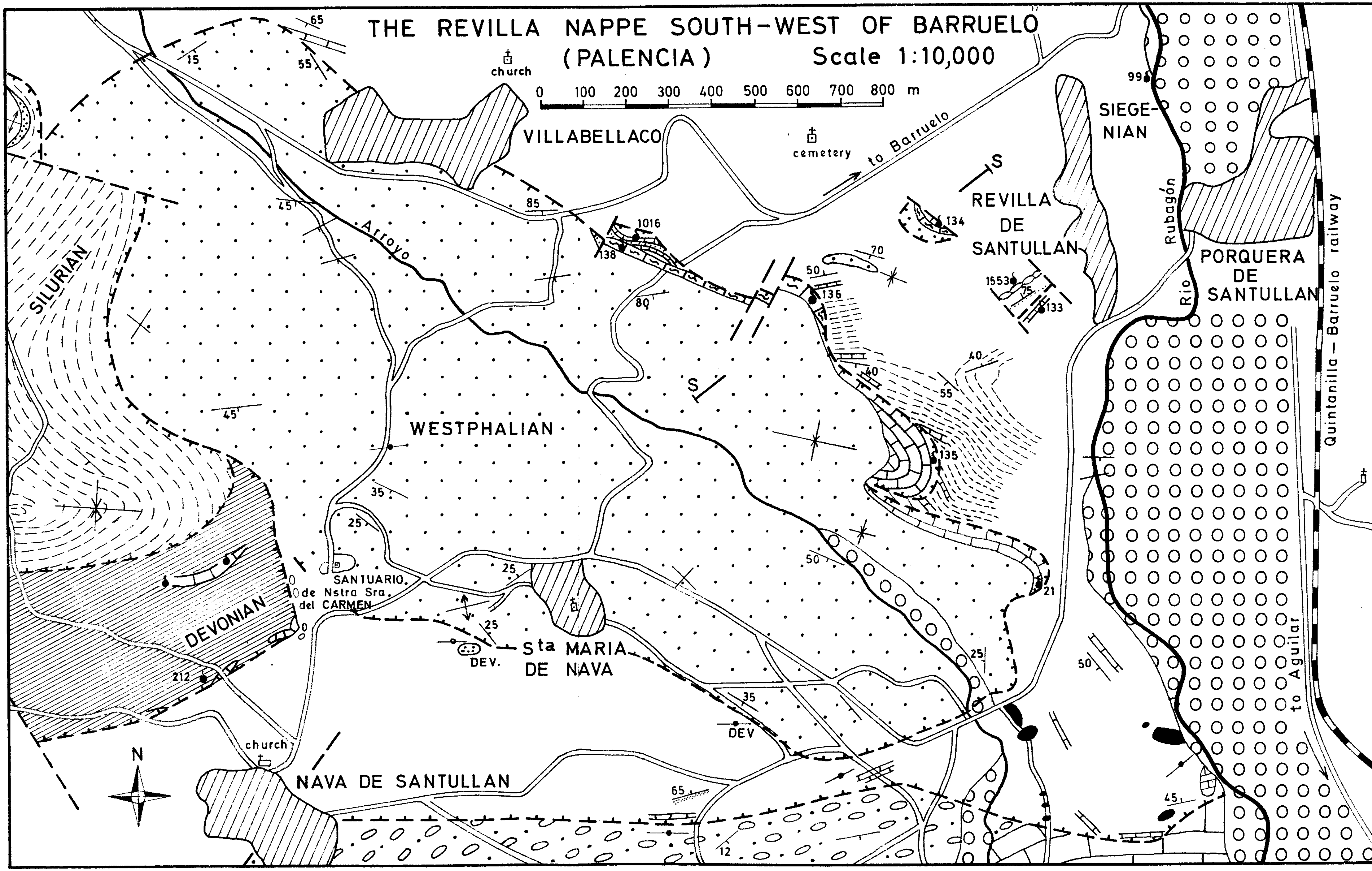
unit of nodular and wavy-bedded limestone containing goniatite faunas, and an upper unit of more massive and massively bedded limestone with brachiopods, tabulate corals (e.g. *Chaetetes*), etc. The lower limestone unit has been recorded as the Villabellaco Limestone Formation by WAGNER & WAGNER-GENTIS (1963) and the upper one as the Santa María Limestone Formation (*op.cit.*). The Villabellaco Formation is mainly represented in the north-western part of the limestone outcrop, commencing at *ca.* 300 metres south-east of Villabellaco and extending 100 metres beyond locality 135 (text-fig.2). Just south of locality 136 (text-fig.2), the Santa María Limestone is first seen above the Villabellaco Formation, and this limestone widens its crop southwards until, at a point some 100 m south of loc.135, it is the only one present. At this point the Villabellaco Limestone disappears. The Santa María Limestone is lost in turn at locality 21, where it disappears rather suddenly.

The facies of these two limestone formations is totally different. The Villabellaco Formation is a condensed limestone deposit of a kind which is widespread throughout the Cantabrian Chain and which has been recorded as «marbre griotte» (BARROIS 1882), Alba Formation (VAN GINKEL 1965) or Genicera Formation (WAGNER, WINKLER PRINS & RIDING 1971) in northern León and Asturias. A strongly wedging habitus is wholly at odds with the nature of this deposit. The Santa María Limestone, on the other hand, shows the characteristics of a much more quickly deposited limestone with «reefs» or biogenetic banks (compare VAN DE GRAAFF 1971), and this formation may be wedging fairly abruptly. These two formations constitute fundamentally different stratigraphic units which show no apparent transition. On the contrary, an erosional surface and, locally, a slightly angular unconformity is found between these two formations (Pl. 4). Stratigraphic dating on fossils provides further confirmation. The Villabellaco Limestone Formation contains goniatite faunas of Lower Viséan to Lower Namurian ages (WAGNER-GENTIS 1963), whilst locality 21 of the Santa María Formation yielded Bashkirian fusulinids to VAN GINKEL (*in* DE GROOT 1963, p.109). This would tend to indicate either Namurian C or basal Westphalian A (compare MOORE, NEVES, WAGNER & WAGNER-GENTIS 1971). There is consequently an appreciable time gap between the Villabellaco and Santa María formations, and the low-angle unconformity between these formations represents an important uplift.

An even more important unconformity exists below the shale/sandstone succession which overlies the two limestone formations. This unit, which was named the Carmen Formation by WAGNER & WAGNER-GENTIS (1963), immediately overlies the Villabellaco Limestone at locality 138 (south-east of Villabellaco) where an irregular, probably erosional surface at the top of the limestone shows signs of having been filled in by the terrigenous clastic strata. Following the base of the Carmen Formation eastwards along the strike (i.e. from loc.138), it continues to be in contact with the Villabellaco Limestone Formation until a point south of loc.136 is reached, where the Santa María Limestone is interposed. Further southwards, gradually more of the Santa María Formation emerges below the unconformable base of the Carmen Shale/Sandstone Formation, and there is a suggestion that the shallow syncline at locality 135 may have been initiated before the Carmen Formation was deposited.



Text-fig. 2.—Outcrop pattern of the allochthonous strata of the Revilla Nappe and its relationship with the autochthonous rocks.


THE REVILLA NAPPE SOUTH-WEST OF BARRUELO
(PALENCIA)
Scale 1:10,000
0 100 200 300 400 500 600 700 800 m
church
VILLABELLACO
cemetery
to Barruelo
SIEGENIAN
REVILLA DE SANTULLAN
PORQUERA DE SANTULLAN
Rio Rubagón
Quintanilla — Barruelo railway
SILURIAN
Arroyo
WESTPHALIAN
DEVONIAN
SANTUARIO de Nstra Sra. del CARMEN
Sta MARIA DE NAVA
DEV.
DEV
church
NAVA DE SANTULLAN
to Aguilar
N
1016
138
136
134
1553
133
135
21
212
99

Following the base of the Carmen Formation southwards, it continues to be in contact with the Santa María Limestone. It is clear that the unconformity below the Carmen Formation cuts through the Santa María Formation into the Villabellaco Formation near loc.136, and there is obviously an angular relationship. A small exposure west of locality 138, and beyond a transcurrent fault figured on the map (text-fig.2), seems to show a contact between Carmen Formation and a Devonian sandstone, and this exposure would therefore provide further proof of an angular unconformity below the Carmen Formation. However, this exposure is not quite as good as the other outcrops mentioned.

Below the Villabellaco Limestone Formation south-east of Villabellaco (loc.138), an angular unconformity is observed between this limestone and a short sequence of Devonian limestones and sandstone which are apparently folded on a rather small scale. These small folds appear to have been formed prior to the deposition of the overlying, Viséan limestone. It is noted that this is the only well documented locality for an angular unconformity below strata of Lower Viséan age anywhere in Northwest Spain (WAGNER 1962). Everywhere else in the Cordillera Cantábrica this contact appears to be disconformable, with uplift but no folding associated with the Lower Carboniferous movements.

The length of outcrop of the Devonian limestone/sandstone sequence below the Villabellaco Limestone is only some 200 metres. On the other side of the path east of loc.138 (text-fig.2) the Devonian strata disappear, and contacts are found between the lower part of the Villabellaco Limestone Formation and underlying shales with intercalated, rather thinly bedded, unfossiliferous limestones which are sometimes parallel to the strike of the Villabellaco Limestone and sometimes at a marked angle. There is little or no continuity in the sporadic exposures of limestone in the underlying shale succession, and it seems that these strata are caught up in small scale structures which are clearly at odds with the much more continuous structure of the overlying Villabellaco Limestone. Following the base of the Villabellaco Limestone to the south and south-east, one sees that the lower horizons of this limestone formation are progressively cut out, up to the point where the overlying Santa María Limestone is in immediate contact with the folded shales and thinly bedded limestones underneath. Near locality 135 the contact between higher levels of the Villabellaco Limestone Formation and the underlying shales and limestones is well exposed, and it is very clear in this area that this contact is tectonic. A shallow thrust plane is found a little south of locality 135, where limestones and shales of the underlying sequence are striking underneath and at a large angle to the rather gently dipping strata of the Villabellaco and Santa María formations. At the exposure of this thrust plane a thin layer (1 to 2 cm) of fault clay is encountered. South of locality 135 the thrust plane cuts through progressively higher strata, eliminating first the higher beds of the Villabellaco Formation, and subsequently the Santa María Formation. Beyond locality 21 the Santa María Limestone is no longer found, as the result of this thrusting, and one finds the Carmen Formation lying immediately on top of the shales and limestones which occur below the Villabellaco Formation at locality 135.

The progressive nature of the elimination of units within the overlying sequence of strata (Villabellaco Fm., Santa María Fm., Carmen Fm.) shows that the thrust plane makes a shallow angle with these rocks. It cuts much more drastically through the underlying sequence, and it thus seems to be linked to the overlying strata. From the distribution of rocks within the overlying, thrust sequence (text-fig.2), it is clear that the thrust plane is cutting upwards in the south-western part of the area depicted on the map, since it is near Villabellaco and Santa María de Nava that progressively higher levels of the Carmen Formation are being found in contact with underlying mudstones, shales, limestones, sandstones and quartzites of many different ages, and including Carboniferous, Devonian and possible pre-Devonian. The Carmen Formation is very shallowly dipping in the general vicinity of Santa María de Nava, and there is a striking contrast between the attitude of these rocks and that of the underlying, vertical beds of the Devonian in this area.

It is clear from the structural difference between the overlying and underlying rock sequences, that the former belongs to a thrust sheet which moved relative to the more steeply folded underlying strata. The direction of movement of the thrust unit cannot be established in the area discussed so far, but a clear indication of movement to the north-east is found in a separate exposure of Villabellaco Limestone which occurs 300 metres west of Revilla de Santullán at locality 134 (text-fig.2).

This exposure shows an overturned contact between Villabellaco Limestone and unconformable shales and sandstones of the Carmen Formation which filled in the potholes of an irregular erosion surface (Pl. 3, fig.1). Besides this contact, showing the overturned relationship of strata, the younging of the beds in the Villabellaco Limestone, as shown by successive goniatite faunas (WAGNER-GENTIS 1963), indicates that they are upside down in this exposure. Structurally, these strata constitute a synform which, on the stratigraphic evidence, is found to be downward facing. Such a configuration would be in agreement with the overturned synformal structure which is often present at the head of a nappe, where the thrust unit plunges into the autochthonous strata and the movement on the thrust sheet stopped (text-fig. 3). Since the apparent head of the nappe is found to the north-east of the main occurrence of the thrust sheet west of Revilla, it appears that the Revilla Nappe moved in an approximate south-west to north-easterly direction.

The general movement of this nappe thus seems to have been established, but the total amount of movement is still conjectural. The exposed width of the Revilla Nappe is *ca.* 1.5 km, and since it is nowhere found to be rooted, the total displacement must be in excess of two kilometres. This is probably a minimum figure and it will be necessary to gauge the actual displacement by a comparison between allochthonous and autochthonous facies.

Structurally, the autochthonous strata are very different, as they are folded into steeply dipping, closely compressed, probably isoclinal folds of very small radius. An example of these folds is encountered in a locality between the head of the nappe (loc.134) and the main area of the thrust sheet (loc.136). This exposure shows a tightly compressed, steeply dipping syncline in sandstone which follows upon a mudstone with limestone lenses. The sandstone in this exposure is very similar to that of the Carmen Formation and the mudstone/limestone unit underneath is comparable in facies to the Perapertú Formation, of Lower Moscovian age, which is found below the Carmen Formation in autochthonous strata 4 to 5 km west of the Revilla Nappe structures.

Another steeply dipping autochthonous succession is found at 100 metres west of the southern tip of Revilla de Santullán, where Upper Devonian strata occur in near-vertical beds. A Siegenian limestone occurs in almost vertical strata exposed in the Rubagón river east of the northern tip of Revilla.

The varied dating of the autochthonous strata, combined with the evidence of tightly compressed structures, indicate the probable presence of isoclinal folds affected by faulting. There is a marked lack of continuity in the outcrop of competent strata in the mudstone sequence of the autochthon below the Revilla Nappe, and this can only be explained by faulting.

The general strike of the autochthonous strata below the Revilla Nappe is approximately east-west, but in the immediate vicinity of the nappe thrust this strike is often modified to one which apparently brings the competent beds of the autochthon in line with the strike of the overlying thrust sheet. This local modification of the strike may be ascribed to movement along and parallel to the thrust plane.

The autochthonous strata are obviously quite intensely disturbed by folding and faulting, and the allochthonous rocks of the Revilla Nappe form the only large cohesive tectonic unit in the triangle formed by the villages of Villabellaco, Santa María de Nava and Revilla de Santullán (see text-fig. 2).

Stratigraphy of the rock units within the Revilla Nappe.

The stratigraphic succession in the Revilla Nappe differs in several respects from that encountered in the autochthon (see later in this account). The oldest strata found in the nappe structure are Devonian in age. They occur underneath the Villabellaco Limestone in the locality at 300 to 500 metres south-east of Villabellaco (text-fig.2), and form the following sequence (from top to bottom):

— 4.00 m grey, bedded limestone with intercalated shales. This limestone contains a fauna of brachiopods and trilobites; also conodonts of the genera *Icriodus* and *Polygnathus* (A. C. Higgins *det.*).

— 7.00 m massively bedded sandstone, cream coloured.

— 4.50 m grey, bedded limestone with abundant fauna consisting mainly of brachiopods. Samples from this limestone (loc. 1016) were examined by Dr. C. H. C. Brunton (British Museum, Nat. Hist.), who identified the following elements: *Rhipidomella* sp., cf. *Protoleptostrophia* sp., *Leptaena* sp., *Longispina* cf. *subcalva* Imbrie, *Devonochonetes* cf. *scitulites* (Cooper), *Spinulicosta* cf. *multicosta* Imbrie, «*Rhynchonella*» *sappho* Hall, *Athyris* sp., *Cyrtina* cf. *hamiltonensis* Hall, cf. *Allanella* sp., *Cryptonella* sp., *Craniops* sp.; furthermore the strongly lamellate bivalve *Cypriocardinia* cf. *indenta* (Conrad), and other bivalves such as *Leiopteria* cf. *L. nitida* Hall and *Nuculites* sp., the gastropod *?Platyceras* sp., trilobites (*Phacops* s. s.), crinoid columnals, bryozoa and ostracodes. According to Brunton (*in litt.* 7.XI.1968), this fauna is of Givetian age, and belongs probably to the lower part of this stage.

— A small, unmeasured thickness of brown, fine-grained shales.

It is noted that the facies of these Givetian rocks is different from that of the autochthonous strata which is characterized by *Posidonia* shales. Nowhere else in the general region have brachiopod limestones been recorded for the Givetian.

There is a clearly marked angular unconformity between these Givetian strata south-east of Villabellaco and the overlying Lower Carboniferous (Viséan) rocks of the Villabellaco Formation (Pl. 1), which cut off the gentle fold structures in the Devonian (text-fig. 2). These folds are rather weak, particularly in comparison with the tight, isoclinal folds observed in the autochthonous strata. It is also noted that the present dip of 45° to 50° of the Givetian limestones and sandstone is the result of later folding, together with the Viséan limestone. The original dip, prior to the deposition of the Villabellaco Limestone Formation, was of the order of 20°.

This is the only well documented case of an angular unconformity, as the result of folding, between the nodular limestones of Viséan age and underlying deposits. Everywhere else in Northwest Spain, these Viséan limestones are found lying disconformably on Tournaisian or late Upper Devonian strata. The important stratigraphic gap and the evidence of folding prior to the deposition of the Viséan limestone are both highly unusual features which set the sequence in the Revilla Nappe well apart from the autochthonous rock succession which shows a full representation of Upper Devonian strata.

There are a few isolated exposures of the Villabellaco Formation in the general vicinity of the Revilla Nappe, but these are too heavily faulted to show undoubted stratigraphic contacts with adjacent strata. However, some 16 km westwards, near Cervera de Pisuerga, a disconformable relationship is observed between Viséan nodular limestone and underlying Upper Devonian rocks (compare KANIS 1956).

The succession of nodular limestones of the Villabellaco Formation is most complete in its lower part immediately above the «Bretonic» unconformity south-east of Villabellaco, i.e. in the general locality 138, (text-fig.2). The following stratigraphic units are found here (compare WAGNER 1962):

— 12.50 m grey, nodular and wavy-bedded limestones with goniatites of the *Goniatites striatus-granosus* group (Upper Viséan cu III).

— 3.50 m grey, somewhat marly nodular limestones. The following goniatites were found in the interval from 1.50 to 2.80 metres above the base (C. H. T. WAGNER-GENTIS *det.*): *Ammonellipsites kayseri* (SCHMIDT) GORDON, *Nautellipsites hispanicus* (FOORD & CRICK) WAGNER-GENTIS, *Merocanites subhenslowi* WAGNER-GENTIS, the latter species being the most common one present (Lower Viséan cu IIγ). A well preserved *Beyrichoceras* found below this interval has not yet been identified specifically.

It is likely that this succession spans the entire Viséan, since the basal 1.50 m have not yet yielded an identifiable fauna and the sequence appears to be very condensed. At locality 138 the nodular and wavy-bedded limestones of the Villabellaco Formation are limited upwards by a potholed erosion surface which is filled in by shales and sandstones of the unconformable Carmen Formation. The angularity of this unconformable contact is not immediately obvious in locality 138, but the absence of the Santa María Limestone Formation which appears less than 500 metres eastwards along the strike, from which point it rapidly increases in thickness, clearly shows that the area of loc.138 was tilted upwards with respect to the more easterly exposures where the Santa María Limestone has been preserved.

Not only the Carmen unconformity shows the result of tilting in this area. Also during the earlier uplift prior to the formation of the Santa María Limestone, a certain amount of tilting took place. This is shown by the different ages of the top part of the Villabellaco Formation in different parts of the Revilla Nappe. In the main outcrop of Villabellaco Limestone, along the ridge of limestone exposures east of Villabellaco and extending to beyond loc.135, the top beds of this formation are of Upper Viséan age. This fact is particularly clear at loc.135, where several bands of goniatites have been found (Pl.2). In this locality a goniatite of the *Goniatites granosus* group has been found at 64 cm below the disconformity with the Santa María Limestone Formation. One metre below the layer with *Goniatites* ex gr. *granosus* PORTLOCK a bed with goniatites contains *Goniatites crenistria* PHILLIPS. This proves the presence of cu III ß-γ faunas (Upper Viséan) in the highest beds of the Villabellaco Limestone in locality 135. Another goniatite band was found at 4 metres below the *G. crenistria* band (loc.1912) and this contains rather poorly preserved *Goniatites* ex gr. *striatus* (Upper Viséan).

At 4.30 m below this band the Villabellaco Limestone is limited by the nappe thrust which eliminated the more marly Lower Viséan sequence in this locality*.

The record from locality 135 shows that the Santa María Limestone cuts down to the level of the Upper Viséan *Goniatites granosus* Zone (Pl. 2). However, sedimentation of the Villabellaco Limestone Formation continued well into the Lower Namurian, as is proved by localities 134 and 133 west of Revilla de Santullán where the Lower Namurian horizons have been dated by goniatites (WAGNER-GENTIS 1963). The most important of these localities is the head of the nappe (loc. 134) which shows an overturned sequence of Villabellaco Limestone and Carmen Formation, separated by a very irregular erosion surface (Pl.3, fig.1). From a salient of the erosional surface and approximately 2 metres below the highest point of this salient, specimens of *Somoholites cadiconiformis* (WAGNER-GENTIS) and *Goniolobocera declive* WAGNER-GENTIS have been collected. These are representatives of the Lower Namurian E_2 goniatite faunas in Northwest Spain. One metre lower in the stratigraphic succession a specimen of *Delepinoceras eothalassoide* WAGNER-GENTIS, an element of the E_1 Zone, has been encountered. Approximately one metre further down the succession specimens of *Stenopronorites uralensis* (KARPINSKY) SCHINDEWOLF and *Mesoglyphioceras granosum* var. *aciculare* PAREYN were obtained. These are also regarded as indicative of E_1 **.

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* It seems likely that this was the locality where KULLMANN (1961, pp. 227-228) sampled the Villabellaco Limestone, and that the nappe thrust is responsible for his statement that the Lower Viséan was not deposited in this area (KULLMANN 1963, p. 178 — footnote).

** The writer is indebted to Mrs. C. H. T. WAGNER-GENTIS for the identification of goniatite faunas. With the exception of one new identification, the elements quoted are the same as those mentioned in WAGNER-GENTIS 1963, but new collections have permitted some improvement in establishing the relative position of faunas *in situ*.

These Lower Namurian goniatite faunas occur in nodular limestones which are more marly than the wavy-bedded, purer limestones of the Upper Viséan both in loc.134 and in the main nappe exposures extending from loc.138 to loc.135 and beyond.

Evidently, the Santa María Limestone unconformity is a low angle one which does not cut down to the same level of Villabellaco Limestone in loc.134 (head of the nappe) as in loc.135 (main nappe exposure). The angularity of the unconformity, which is not usually evident in any single exposure, has been observed in one locality (Pl. 4) where the Santa María Limestone cuts obliquely through the underlying Villabellaco Limestone. Assuming that the unconformity associated with the Carmen Formation affects the area containing localities 138, 137, 136 and 134 equally (which appears to be indicated by the absence of Santa María Limestone in all these localities), the overall angle of the Santa María unconformity can be deduced from the gain of *ca.* 4 metres of Villabellaco Limestone in loc.134 with regard to localities 136 to 138. A reconstruction indicates an angle which is not in excess of 1°. The Santa María unconformity therefore appears to be a disconformity or mappable unconformity, the angle of which could not have been reconstructed if the very detailed subdivisions of the condensed Villabellaco Limestone had not come into play. Since the Santa María unconformity cuts down further into the Villabellaco Formation in the more southerly exposures, it may be assumed that tilting off a southerly uplift is involved.

The diminishing importance of the Santa María unconformity northwards is also clear from an examination of the exposures remaining in a small, abandoned quarry, just west of the southern tip of Revilla de Santullán (loc. 133—see text-fig. 2). Most of the original exposure was removed by the quarrying operations, but enough remains to observe the presence of grey nodular limestone which is overlain by a fairly spectacular limestone breccia (Pl. 3, fig.2). From this breccia a well characterized conodont fauna of early Lower Namurian age has been recovered by Dr. W. J. VARKER (personal communication).

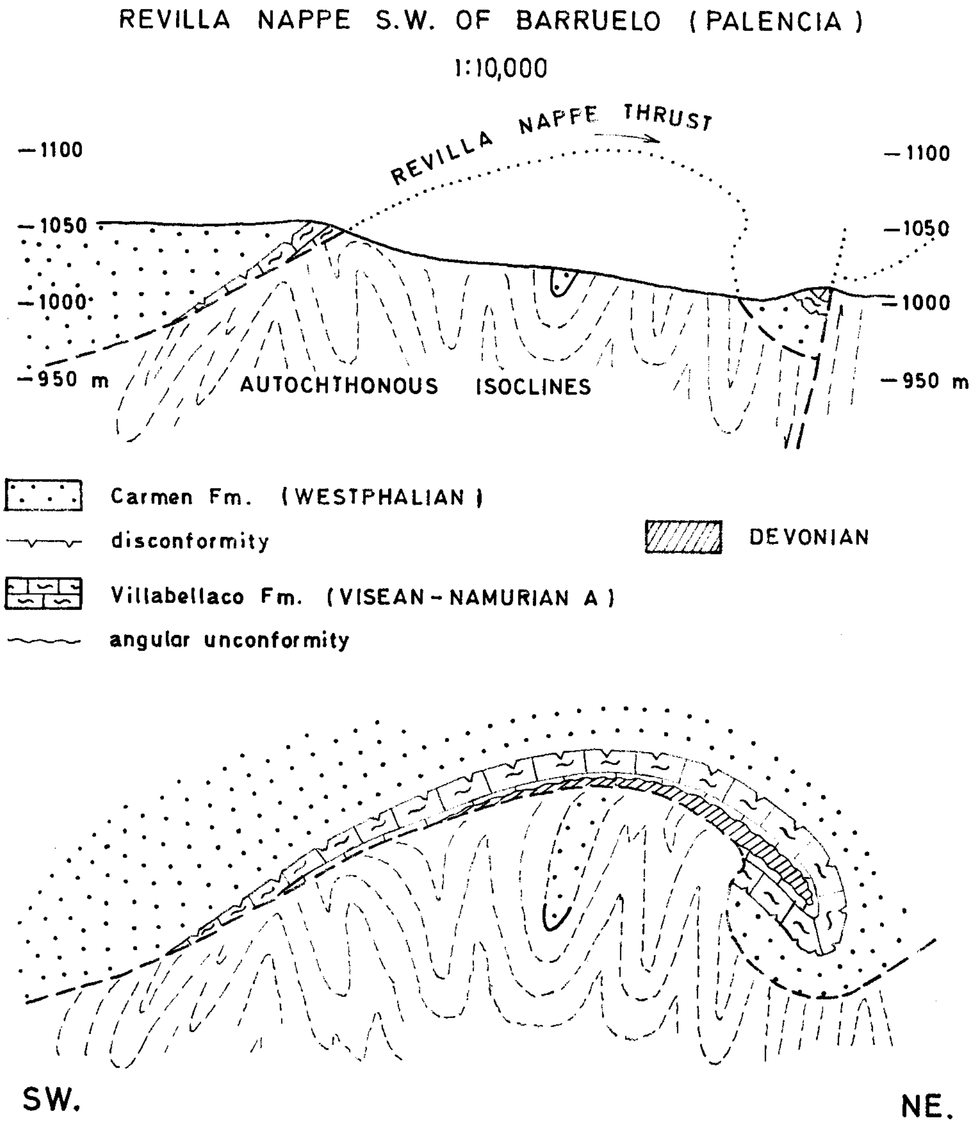
It would seem likely that this breccia marks the base of the Santa María Formation which, in more than one locality, appears to be associated with limestone breccias immediately above the plane of unconformity. The breccia at loc.133, containing elements of Lower Namurian limestone of the Villabellaco Formation, apparently confirms that the Santa María unconformity did not cut quite as far down into the Villabellaco Formation in the more northerly exposures as in the main exposures of the Revilla Nappe.

The massive and massively bedded limestones of the Santa María Formation were removed by erosion prior to the deposition of the Carmen Formation in loc.134 (and possibly also in loc. 133, where faulting prevents the observation of a normal stratigraphic sequence beyond the limestone breccia with Lower Namurian elements). The Santa María limestones are well developed however in the main nappe exposure, particularly in the vicinity of locality 135 and further south (Pl. 5, fig. 1, Pl. 6, figs. 1-2, and Pl. 7, figs 1-2; see also text-fig. 2). Parts of the Santa María Limestone Formation appear as coarse breccias, with boulders of fairly massive limestone being found in a marly matrix. The coarsely detrital aspect of the Santa María Limestone increases southwards and south-eastwards where this formation is characterized by large and small, rounded limestone boulders set in a marly groundmass. These boulders are often fossiliferous, with common *Chaetetes* and reasonably common rugose corals of compound and dissepimented solitary types (DE GROOT 1963, p.109). They also contain crinoid debris, brachiopods (e.g. *Productus concinnus* SOWERBY as identified by WINKLER PRINS 1968, Table 6), and other marine fossils including fusulinid foraminifera. The latter were studied by VAN GINKEL from locality 21 (which is quoted as P 54 by VAN GINKEL 1965) and proved to belong to a lower to middle Bashkirian assemblage. This may be read as either late Namurian C or early Westphalian A (compare MOORE, NEVES, WAGNER & WAGNER-GENTIS 1971). Consequently, there is an appreciable time gap between the Villabellaco Formation, of Viséan and lower to middle Namurian A age, and the Santa María Formation which is at least as young as late Namurian C.

The facies and age of the Santa María Formation invite comparison with the Valdeteja Formation of northern León (WAGNER, WINKLER PRINS & RIDING 1971). The latter represents the upper part of the «caliza de montaña» (or «calcaire des cañons» of BARROIS 1882) and follows upon a thinly bedded, micritic limestone of several hundred metres thickness, the Barcaliente Formation (*op.cit.*). This thinly bedded limestone forms a gradual transition with the preceding nodular and wavy-bedded limestones of the Genicera Formation which is the equivalent of the Villabellaco Formation of north-eastern Palencia. It is found that the Valdeteja Formation is generally absent in the central part of the Cantabric-Asturian area, corresponding to the Cantabrian Block (compare RADIG 1962, WAGNER 1970), whereas the Barcaliente Formation is always present in northern León and apparently also in the Asturias (compare MARTÍNEZ-GARCÍA 1971). Therefore, the unconformity eliminating upper Namurian A and Namurian B rocks (i.e. the equivalent of the Barcaliente Formation) from the area represented by the succession in the Revilla Nappe, is highly unusual. It is rather unfortunate that the autochthonous strata in the vicinity of the Revilla Nappe fail to show a tectonically undisturbed sequence of Lower and Middle Namurian strata, the nearest complete succession being found to the west of Cervera de Pisuerga, at a distance of some 17 kilometres. These exposures, in the Sierra del Brezo, have not yet been studied in sufficient detail (KANIS 1956, KOOPMANS 1962), but reports of a Lower Bashkirian foraminiferal fauna (VAN GINKEL 1965) suggest a comparison with the Santa María Limestone Formation.

The unconformity underlying the Carmen Sandstone/Shale Formation may be a little more angular than that found between the Villabellaco and Santa María formations. The Carmen unconformity has eliminated the Santa María Limestone entirely from the area covered by the more northerly exposures (localities 138, 137, 136 and 134). A steadily increasing amount of this formation emerges from beneath the Carmen Formation as the exposures in the main nappe structure are followed southwards.

The Carmen Formation is poorly dated, but a single pinnule of *Linopteris* found in the vicinity of loc.134 indicates a post-Namurian age. This is also evident from its stratigraphic position above the Lower Bashkirian Santa María Limestone. It is likely that this formation is of Lower Westphalian age.



Text-fig. 3.—A SW - NE trending section through the main outlier and head of the Revilla Nappe just west of Revilla de Santullán, and (below) a reconstruction of the head of the nappe before erosion and before the normal faulting which cut off part of the head on its north-eastern side.

Beds of the Carmen Formation are also found in isoclinal, autochthonous structures in the vicinity of San Martín de Perapertú, 4 to 5 km WNW of the Revilla Nappe exposures. Here, as in the nappe, the most characteristic strata are coarse, apparently mixed sandstones which are massively bedded and which alternate with silty lutites showing the common presence of comminuted plant debris. At San Martín a sandstone breccia occurs immediately above the unconformity which does not appear to be angular in this locality and which may be better described as a disconformity.* It is also noted that the Carmen Formation near San Martín de Perapertú lies on mudstones with limestones of the Perapertú Formation which, on the evidence of fusulinid foraminifera (VAN GINKEL 1965), is Lower Moscovian (Vereyan) in age. The Carmen Formation is therefore not only less strongly unconformable in the autochthon at San Martín de Perapertú, but also does not cut quite as far down into the stratigraphic succession as in the Revilla Nappe where it rests on Bashkirian and Upper Viséan/Lower Namurian strata. It must be concluded that the uplift associated with the Carmen unconformity was more substantial in the area from where the Revilla Nappe was derived.

From the above discussion of the stratigraphic features of the succession of Devonian and Carboniferous rocks in the Revilla Nappe it follows that the area of deposition of these strata was a good deal more mobile than that of the autochthonous deposits. The presence of several angular unconformities, albeit mainly low angle ones, constitutes clear evidence to this effect. Particularly striking is the evidence of pre-Viséan folding and erosion down to the level of Givetian rocks in the Revilla Nappe, in contrast to the autochthonous area which contains a substantial thickness of Frasnian and Famennian deposits (see later in this paper and compare WAGNER & WINKLER PRINS 1970, p.494 and text-fig.1). The facies of the Givetian strata in the Revilla Nappe is also different from that of the autochthonous Givetian (compare page 449). The important differences noted between the sequence and development of strata in the Revilla Nappe, and those of the autochthonous area, provide a clear indication for the rather remote origin of the strata represented in the Revilla Nappe, which must have been derived from a fairly distant area. Since the movement has been approximately from south-west to north-east, it appears that the Revilla Nappe provides a glimpse of a development of strata which are mainly hidden under the unconformable blanket of Mesozoic and Tertiary strata of the Castilian Meseta.

SAN JULIAN KLIPPE

General description.

Immediately west of the rolling country occupied by the (Lower?) Westphalian strata of the Carmen Formation a complex of hills forms the higher ground which separates the villages of Valle de Santullán and Verbios (text-fig.4), and which is dominated by the mountain top of San Julián, at 1389 metres altitude. The rocks found in this area are older than any occurring in the vicinity, and belong to the Silurian and Lower Devonian. They form a unit which is structurally distinct from the surrounding strata, and which maps out as a synclinorium. Like the Revilla Nappe, it shows open fold structures which differ markedly from the tightly folded and apparently

* FRETS (1965) recorded for this region a strongly angular unconformity, with a markedly different strike for the rocks underlying the Carmen Formation (which he calls the Molino Formation). The data on his map are misleading and the angular unconformity shown on the map is due to linking up points at the base of the Carmen Formation across transcurrent faults, which were disregarded.

much more disturbed rocks surrounding this unit. The contacts between the San Julián Synclinorium and the surrounding rocks are invariably tectonic*, and there are several localities where the Silurian and Lower Devonian strata of the San Julián unit are seen to overlie the surrounding rocks which are dated as Middle and Upper Devonian and Carboniferous. This configuration of older strata forming an outlier on top of younger deposits, has led to the interpretation of the San Julian unit as a tectonic klippe (WAGNER 1955). A different interpretation was put forward by DE SITTER (1955), who saw the San Julián unit as an island in the Carboniferous sea and thus interpreted it as a massif. The fact that the San Julián unit, on its eastern side, is found to overlie the Carmen Formation in the Revilla Nappe, makes it clear that DE SITTER's interpretation is untenable.

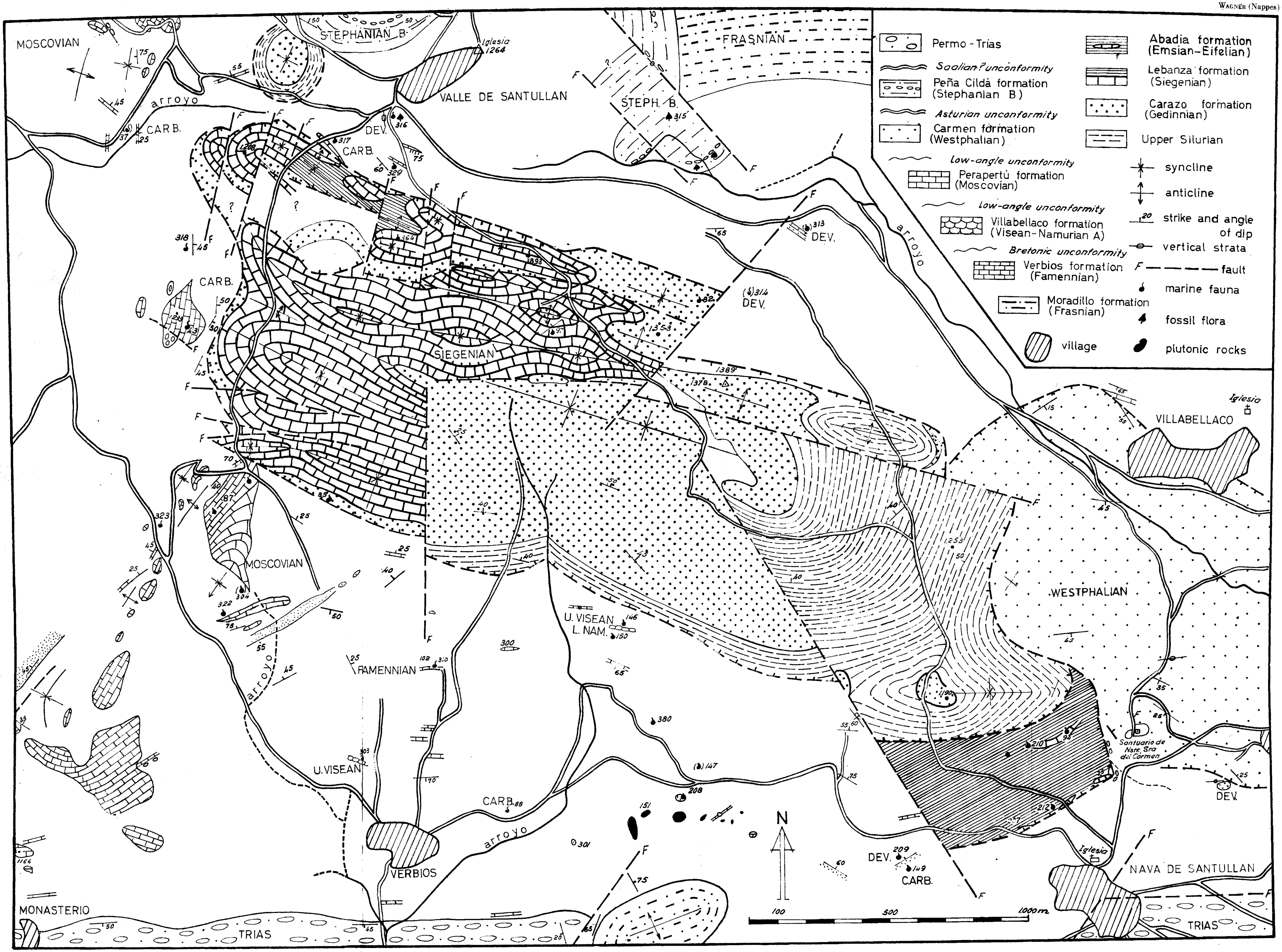
Like the Revilla Nappe, the synclinorium of San Julián forms a coherent tectonic unit which can be mapped fairly easily and which contains a recognizable succession of strata. The general strike of this unit is WNW-ESE. It consists of five synclines with the intervening anticlines, some of which are disturbed by strike faults (text-fig.4). The northern part of the unit shows generally steeper dips than the southern portion, and also in this respect there is a marked analogy with the Revilla Nappe which shows its steepest dips in the area near Villabellaco (text-fig.2). In the southern part of the San Julián unit relatively gentle dips prevail and the structure consists here of open folds with dips varying between 25° and 40°. These dips are markedly less steep than those found in the surrounding, mainly Carboniferous strata which participate in isoclinal structures. The San Julián Klippe is also affected by normal faults approximately perpendicular to the strike. These faults are generally seen to hinge within the Klippe.

Stratigraphic succession in the San Julián Klippe.

The stratigraphic succession found in the San Julián Klippe has been described in general outline by WAGNER (1955, p.149), and a more detailed section of these strata has later been provided by DE SITTER & BOSCHMA (1966, text-fig.4). The oldest strata consist of alternating shales and thin quartzite beds which are attributed to the Silurian. These are followed by massively bedded quartzites and sandstones (partly calcareous) which are mainly assigned a Gedinnian age. They are succeeded in turn by Siegenian limestones and shales.

The lower part of this succession, at least 250 metres thick, is only exposed in the southern and eastern parts of the San Julián Klippe. The following sandstone/quartzite unit (*ca.* 150 metres) is characterized by ferruginous beds. It also contains beds

* Non-tectonic, stratigraphic contacts are shown for the northern and western boundaries of the San Julián unit on the map published by FRETS (1965) and DE SITTER & BOSCHMA (1966). The information with regard to these boundaries is found to be inaccurate and this map has proved to be misleading in more than one respect. For example, a limestone of Carboniferous age is shown as lying parallel to the Devonian/Carboniferous contact on the south-western boundary of the San Julián unit, whereas, in fact, this limestone strikes perpendicularly to the structure of the Devonian strata and is seen to be overlain by the latter (compare text-fig. 4 of the present paper).



Text-fig. 4.—Map of the San Julián Klippe and the immediately surrounding area. Scale 1: 10,000.

with leached calcareous shell remains (mainly brachiopods) and some impressions of trilobites. This thick unit of sandstone/quartzite forms upstanding ridges in the terrain (e.g. the Monte San Julián). It forms the most conspicuous part of the Carazo Formation as described by DE SITTER & BOSCHMA (1966). There is a thin development of black shales with tentaculites above this sandstone unit and before the well bedded Siegenian limestones are reached. The latter, up to 180 metres thick, constitute the highest stratigraphic formation preserved in the main part of the San Julián Klippe. They contain abundant brachiopods of Lower to Middle Siegenian age (FRETS 1965, p. 118). These limestones are identified with the Lebanza Formation of an area more to the west in northern Palencia, where they were most recently studied by BINNEKAMP (1965). The Lebanza Limestones are generally continuous in the San Julián Klippe, but there are localities where they are seen to wedge into light brown shales, e. g. south of Valle de Santullán (text-fig. 4).

A similar facies of brown shales with lenses of limestone has been observed in the extreme south-eastern part of the San Julián Klippe, in the vicinity of Nava de Santullán (text-fig.4). Here, however, the limestones are more massive and contain *Favosites*. Brachiopods and trilobites were collected from certain localities in the area (localities 212 and 207, particularly) and submitted for identification to Mr. J. A. VAN HOEFLAKEN (University of Leiden), whose preliminary examination of these faunas suggested a possible Eifelian age (*in litt.* 11. IV. 1960): *Leptaena rhomboidalis* WAHLENBERG, *Atrypa reticularis* LINNÉ, *Cyrtina heteroclita* DEFRANCE, *Athyris* spp. Further collections from this locality (212) should be made in order to confirm this age determination. It is, however, supported by the facies of these deposits which can be matched without difficulty by the sequence known for the Abadía Formation, of Emsian/Eifelian age, occurring west of Lebanza in another part of northern Palencia (T. AMBROSE, pers. comm.). The Devonian strata immediately N. N. W. of Nava de Santullán are therefore marked as Abadía Formation on the map of text-fig. 4. They are apparently overlain by Silurian strata of the San Julián Klippe, and it seems likely that these Emsian?-Eifelian deposits represent a separate fragment of a thrust sheet which may or may not be linked to the San Julián unit. These Devonian rocks near Nava de Santullán appear as Silurian on the map published by FRETS (1965) and DE SITTER & BOSCHMA (1966).

AUTOCHTHON

Devonian strata.

Devonian rocks of many different ages occur with parts of the Carboniferous in the autochthonous strata surrounding the nappe structures. These rocks are found in fragmentary sequences which have to be pieced together in order to obtain a stratigraphic succession. Under these conditions the thickness of the constituent parts is largely a matter of conjecture. Attempts at reconstructing the Devonian succession in the general area of north-eastern Palencia have been made by WAGNER & WAGNER-

GENTIS (1963), FRETS (1965) and, most recently, WAGNER *in* WAGNER & WINKLER PRINS (1970, pp. 494-495, and text-fig. 1: stratigraphic column). A more complete discussion of the Devonian strata found in the autochthonous area, is presented below.

Probably the oldest autochthonous rocks, either early Devonian or pre-Devonian, are the quartzites which crop out in an isolated exposure at 750 metres west of Nava de Santullán (text-fig. 4). The facies of these undated rocks suggests the lower to middle part of the Carazo Formation. Other parts of the Carazo Formation may be present at loc. 209, at 500 metres west of Nava de Santullán, and at loc. 313, some 1400 metres south-east of Valle de Santullán (text-fig. 4). Locality 209 has yielded Devonian brachiopods from ferruginous sandstone showing a faulted contact with Carboniferous strata, and locality 313 contains strongly ferruginous sandstone which is overlain by alternating beds of coarsely detrital limestone and ferruginous sandstone. This very characteristic facies can be matched with that of the top Carazo Sandstone Formation in an area further west in northern Palencia (personal communication by Mr. T. AMBROSE), and these deposits may therefore be of Gedinnian age.

The Siegenian limestones of the Lebanza Formation crop out in several localities mentioned by ALVARADO & SAMPELAYO (1945), WAGNER (1955), WAGNER & WAGNER-GENTIS (1963) and FRETS (1965). Within the area of text-fig.2 a lens of massive limestone with *Favosites* occurs in the Rubagón river bed near the northern tip of the village of Revilla de Santullán. Next to this lens a small exposure of bedded limestone has yielded brachiopods, among which Mr. J. A. VAN HOEFLAKEN (pers. comm.) identified *Spirifer rousseaui* ROUAULT, a Siegenian element. This locality, reported by WAGNER & WAGNER-GENTIS (1963, p. 151), was also visited by FRETS (1965, p. 118), who recorded a more complete list of Siegenian brachiopods.

Dated Emsian deposits are rare in north-eastern Palencia, but a sandstone at 400 metres north of Verbios (text-fig. 4) has yielded *Trigeria robustella* (FUCHS) to DAHMER & QUIRING (1953, p. 474), who obtained the same species from an Emsian assemblage near Ventanilla, west of Cervera de Pisuerga, outside the region discussed in the present paper. Some 3.5 km west of Verbios (outside the area represented by text-fig.4), an Emsian goniatite, *Mimagoniatites*, was recorded by KULLMANN (1960, p.469) from calcareous mudstone outcropping just east of the village of Mudá. This occurrence is in autochthonous strata which strike underneath the Mudá Nappe (text-fig.1), and which are probably in sequence with a Devonian limestone containing brachiopods* and conodonts. Among the latter Dr. A. C. HIGGINS (pers. comm.) identified *Icriodus sigmoidalis* CARLS & GANDL, a species ranging from the late Lower Emsian to the early Upper Emsian (CARLS & GANDL 1969). Assuming that the calcareous mudstone with *Mimagoniatites* represents a higher level in the Emsian than the brachiopod and conodont bearing limestone, it is noted that a quiet water facies with pelagic fauna first appears in the higher Emsian.

* A list of brachiopods collected by C. H. T. WAGNER-GENTIS and identified by J. A. VAN HOEFLAKEN was quoted from this locality by FRETS (1965, p. 119), who was apparently unaware of the ownership of this collection.

This is relevant in connection with subsequent Middle Devonian strata which are characterized by fine-grained mudstones and shales containing bands with abundant *Posidonia* and less common goniatites, trilobites and other lamellibranchs. The oldest dated locality found in these strata are *Posidonia* shales which occur near the south-western tip of the village of Valle de Santullán (loc.316 — see text-fig.4). This locality is near the occurrence of Carboniferous limestones at localities 317 and 320, and proves again the tectonically disturbed nature of the autochthonous strata. In loc. 316 the extremely abundant remains of *Posidonia* are associated with rare goniatites and even rarer drifted remains of land plants. Among the goniatites, which are generally flattened and quite difficult to identify, a well preserved specimen in sideritic ironstone shows the suture as well as the shape of *Sobolewia* (C. H. T. WAGNER-GENTIS *det.*). The species is regarded as new but is closely comparable to Upper Eifelian and Lower Givetian species. It is associated with a fragmentary impression of a goniatite showing the ornament of *Aulatornoceras*, and this tends to indicate Givetian rather than Eifelian (C. H. T. WAGNER-GENTIS, pers. comm.). The plant remains found in this locality (316) belong to *Aneurophyton* and *Hyenia*, which thus confirm the Middle Devonian age of these *Posidonia* shales. This locality is significant in that it gives the earliest established age for *Posidonia* shales to occur in the autochthonous strata of north-eastern Palencia.

Probably later, clearly Givetian deposits of the same *Posidonia* shale facies (with *Agoniatites*) occur also in autochthonous strata in the area west of Barruelo de Santullán, near the Barruelo coalfield (compare text-fig.1 and WAGNER & WINKLER PRINS 1970, text-fig.1: map).

The same facies is also present in the Frasnian rocks which occur between Barruelo and Revilla de Santullán (WAGNER & WINKLER PRINS 1970, text-fig.1), and which show fine-grained shales with intercalated bedded limestones at the base of a succession reaching upwards into a thick sandstone unit with shale partings. The main shale unit has yielded *Tornoceras* (C. H. T. WAGNER-GENTIS *det.*) and a shale parting in the sandstone unit has provided a specimen of *Aulatornoceras bicostatum* (HALL). It is noted that the development of a thick sandstone unit of Frasnian age is widespread in northern Palencia (Moradillo Sandstone Formation of WAGNER 1955, WAGNER & WAGNER-GENTIS 1963; Camporredondo Formation of KOOPMANS 1962; Murcia Formation of VAN VEEN 1965). The *Posidonia* shales, on the contrary, are more restricted in their occurrence and appear most commonly in the autochthon of north-eastern Palencia, as discussed here. In fact, there seems to be no other region in northern Palencia, which shows such an early and general development of *Posidonia* shales, from the Givetian onwards. It is noted that the *Posidonia* shale facies of the autochthonous Givetian strata is rather different to the brachiopod limestone of Givetian age in the Revilla Nappe.

Posidonia shales have also been recorded from a short succession of Famennian strata found at 150 metres west of Revilla (loc.1553 — text-fig.2). After a little trenching the following broad sequence was established in this exposure of nearly vertical strata (see overleaf):

— 4.30 m greenish mudstone with thin chert layers and one band of quartzitic sandstone, 0.60 m thick; some crinoid debris in the upper 0.40 m of mudstone which is marly.

— 13.00 m quartzitic sandstone, which is finely and regularly laminate.

— 7.00 m alternating marls and marly sandstones with some mudstone; unit mainly ochreous in colour and sometimes greenish (mudstones); near the base of this unit a 0.50 m thick nodular limestone occurs.

— 1.80 m compact, greenish marl with brownish weathering limestone nodules (loc.1553) containing abundant clymenids and goniatites, and occasional *Posidonia*, trilobites, etc. The ammonoid fauna has not yet been studied in detail, but the following elements have been provisionally identified by C. H. T. Wagner-Gentis (pers. comm.): *Gonioclymenia* cf. *subcarinata subcostulata* Petter, *Sporadoceras* sp., which indicate an Upper Famennian to V age.

— 11.50 m compact mudstone, greenish to maroon in colour.

— 6.80 m compact mudstone, greenish, and containing bands full of *Posidonia* with rare goniatites (*Prionoceras* sp. — C. H. T. Wagner-Gentis *det.*) and conodonts on bedding planes.

— 1.00 m compact mudstone.

Although top and bottom criteria are lacking or difficult to interpret in this section, it seems that the mudstones with *Posidonia* occur at the base of this short sequence and that the mudstone with chert layers represents the highest unit. A strike fault separates this unit from exposures which contain the Lower Namurian limestone of loc.133 (text-fig.2). One may speculate about the age of the highest strata in this interesting succession which may be found to reach into the early Lower Carboniferous. Samples collected for a palynological study were kindly investigated by Dr. F. H. Cramer (University of Florida), but the microplankton material found was too poorly preserved to be identifiable. Conodont samples from this section have not yet been studied.

A similar development of nodular limestone to that recorded from loc. 1553 was found at 600 metres north of Verbios (text-fig. 4), in locality 102 (= 310). This is the locality referred to by Wagner & Wagner-Gentis (1963) for their Verbios Formation. The Upper Famennian (to V) ammonoids *Kosmoclymenia undulata* Wedekind and *Sporadoceras biferum sulciferum* Lange were found here by Mr. J. A. van Hoeflaken and identified by C. H. T. Wagner-Gentis (pers. comm.). Apparently the same locality was visited by Frets (1965, p. 121), who recorded a list of Upper Famennian conodonts which were identified by van Adrichem Boogaert.

The Verbios Formation, of Upper Famennian age (to V Zone), expands westwards into the thicker and more comprehensive Vidrieros Formation of van Veen (1965) which has yielded Lower Famennian to Lower Tournaisian conodont faunas (*quadrantinodosa* Zone to *kockeli-dentilineata* Zone) to van Adrichem Boogaert (1967). Both formations show the same facies and it appears that one and the same lithostratigraphic unit is involved. The earlier named Verbios Formation has priority, but it has not been adequately described from the intended stratotype north of Verbios. The outcrop of Upper Famennian limestone north of Verbios is a very restricted one (only a few tens of metres long and 3 to 5 metres wide), as is the one west of Revilla, and these exposures apparently confirm the tectonically disturbed nature of the autochthonous strata in north-eastern Palencia, which are correspondingly difficult to fit together as a continuous stratigraphic succession.

Carboniferous strata.

The autochthonous rocks around the San Julián Klippe also comprise Carboniferous strata of various ages. The oldest dated Carboniferous in this area (text-fig. 4) has been found at 250 metres north-west of Verbios, at locality 303, where *Goniatites* sp. has been collected from grey nodular limestone. A slightly later fauna with *Goniatites granosus* var. *acicularis* (PAREYN), *Goniatites subcircularis* MILLER and *Stenopronorites uralensis* (KARPINSKY) SCHINDEWOLF has been found in grey nodular limestone at 1 kilometre north-east of Verbios (loc.146). It indicates a Lower Namurian (E_1) age, which is confirmed by conodonts reported by HIGGINS (1962).

Carboniferous fossils, including fusulinid foraminifera, were found in several more or less isolated limestone occurrences in the predominant mudstones surrounding the San Julián Klippe. Samples from loc. 43, west of the San Julián Klippe, were examined by VAN GINKEL (1965), who reported a Lower Moscovian (Vereyan) assemblage (quoted under P 70 by VAN GINKEL). This Vereyan limestone belongs to a band of carbonate rocks, possibly biohermal, which participate in tightly compressed upright folds striking SW-NE and SSW-NNE in the area west and south-west of the San Julián Klippe. These rocks have been recorded as the Perapertú Formation (compare WAGNER & WAGNER-GENTIS 1963), which may be of Westphalian A age. This formation is overlain disconformably by the Carmen Formation (sandstones and shales) immediately west of the village of San Martín de Perapertú. Rugose corals from the Perapertú Formation were studied by DE GROOT (1963) and the brachiopods by WINKLER PRINS (1968). A brachiopod locality at 1300 metres north-west of Verbios (loc.323) yielded the following species (WINKLER PRINS *in litt.* 9.VI.71): *Krotovia granulosa* (PHILLIPS), *Alitaria frechi* (PAECKELMANN), *Eomarginifera lobata* (SOWERBY), *Reticularia?* aff. *huecoensis* (KING), *Coledium* sp., *Phricodothyris* sp. Dr. WINKLER PRINS also found *Brachymetopus?* sp., *Platyceras* sp. and *Amblysiphonella barroisi* STEINMANN. This fauna could be either Upper Bashkirian or Lower Moscovian in age (WINKLER PRINS, pers. comm.).

The overlying Carmen Formation is, by inference, probably of Lower Moscovian (or Lower Westphalian) age. Only a pith cast of *Calamites* cf. *vandergrachti* KIDSTON & JONGMANS was collected from the Carmen Formation west of San Martín de Perapertú.

Later Carboniferous strata in the general neighbourhood belong to a post-orogenic sequence formed after the Palentian phase of folding (Westphalian B), and are basically unconformable to the successions and structures discussed here. They were folded into large scale isoclinal structures during Stephanian times, and appear to be independent from the nappe structures and underlying autochthonous strata discussed in the present paper.

Structure of the autochthonous strata.

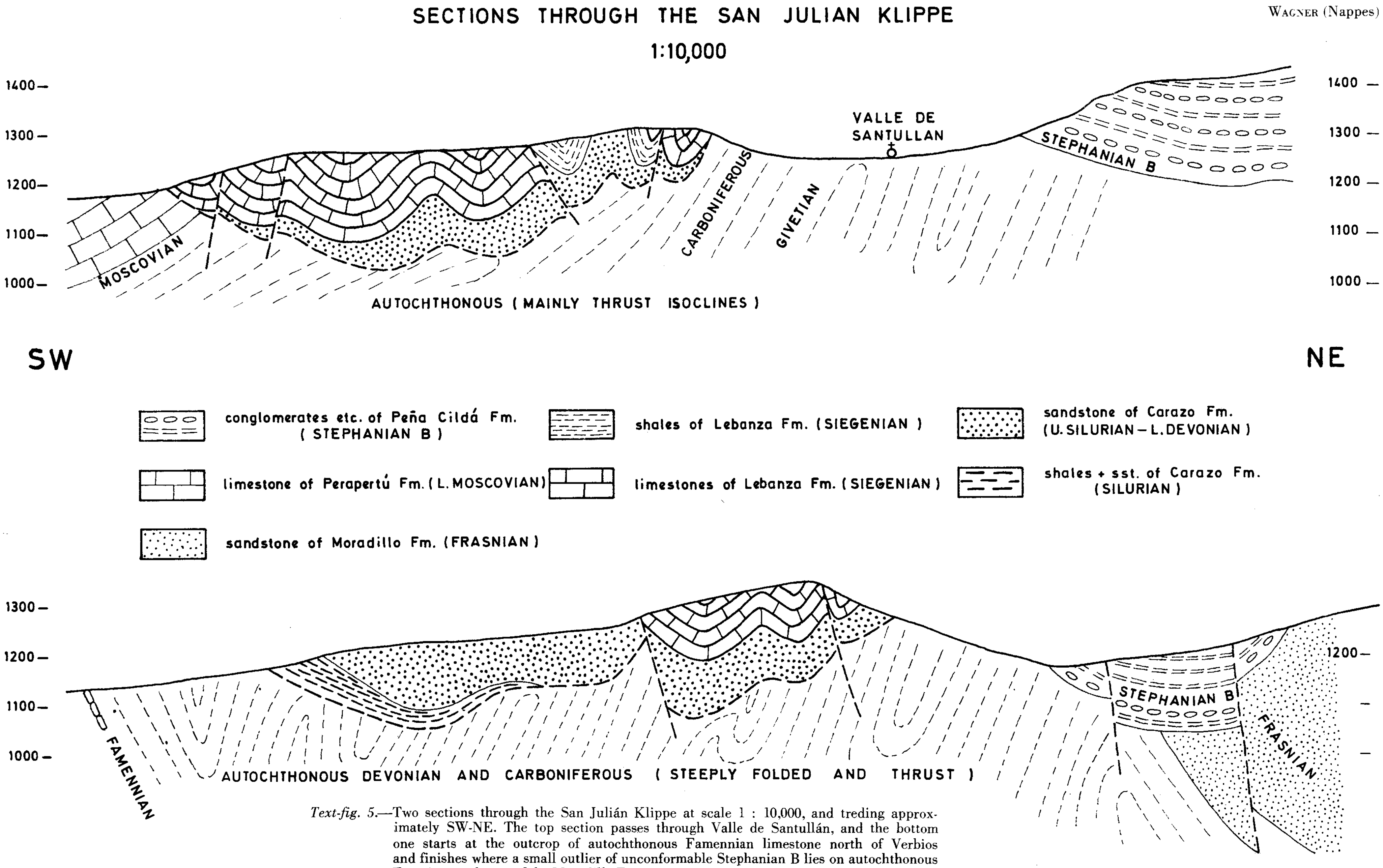
Most of the localities in the autochthonous strata surrounding the Revilla and San Julián nappes are in rocks which participate in tightly folded structures with little continuity. There appears to have been considerable faulting which affected isoclinal folds and fragmented them. The presence of predominant mudstones in the Middle and Upper Devonian succession and in the Lower Moscovian strata of the Perapertú Formation appears to have allowed considerable squeezing to take place, with the result that often quite small fragments of competent rock are found within a mass of crumpled mudstone. The only coherent structures among the autochthonous ones are those involving the Perapertú Formation to the west and south-west of the San Julián Klippe (text-fig.4). These structures, striking SW-NE to SSW-NNE, are isoclinal with a general southeasterly dip. Several synclinal and anticlinal hinges are found, and these strata are very tightly folded indeed, with steep plunges.

Relationship of the autochthon to the San Julián Klippe.

The strike of these autochthonous structures in the Perapertú Formation, and the isoclinal folding, are totally different from the WNW-ESE strike and open folds found in the San Julián Klippe. Apparently, the compression is much more severe in the autochthonous strata. The general southeasterly dip of the autochthonous structures west of the San Julián Klippe also appears to put the Carboniferous strata underneath the Devonian of the klippe in those localities where the strike of the Carboniferous is approximately parallel to the western culmination of the synclinorium which constitutes the San Julián unit. On the south-western corner of the San Julián Klippe, in fact, the steeply inclined isoclines of the Perapertú Formation are seen to be cut off and overthrust by Siegenian limestones of the Lebanza Formation. The nappe thrust in this locality strikes almost at right angles to the autochthonous structure, whilst cutting obliquely through the overlying allochthonous rocks (text-fig. 4).

The allochthonous strata occupy everywhere the higher ground, thus emphasizing their position as a tectonic outlier. Two localities along the western border of the San Julián Klippe clearly show the superposition of Devonian strata of the allochthon on Carboniferous of the autochthon. One of these, at loc.34 (text-fig.4), shows the Vereyan limestone and associated mudstones of the Perapertú Formation dipping underneath the top part of the Carazo Formation (Gedinnian) and the lower part of the Lebanza Formation (Siegenian). The second locality, at the north-western corner of the San Julián Klippe, shows a fossil locality with Carboniferous brachiopods (loc.37) dipping into a hillside which leads to a synclinal core in Lower Devonian limestone capping the hill.

Along the northern boundary of the San Julián Klippe the steeply folded strata of the allochthon (mainly Lebanza Limestone) are less clearly superimposed on the steeply dipping autochthonous strata which contain Carboniferous localities near the boundary fault and Middle Devonian *Posidonia* shales at loc. 316, in the immediate vicinity of Valle de Santullán. However, the shales in the vicinity of loc.329, with Carboniferous fossils, show a 60° dip towards the Lower Devonian limestone which therefore does appear to be superposed. Further along the strike, south-east of Valle de Santullán, the most northerly syncline of the San Julián outlier lies clearly on top of the autochthonous rocks. The nappe thrust is seen here to cut through various levels



Text-fig. 5.—Two sections through the San Julián Klippe at scale 1 : 10,000, and treding approximately SW-NE. The top section passes through Valle de Santullán, and the bottom one starts at the outcrop of autochthonous Famennian limestone north of Verbios and finishes where a small outlier of unconformable Stephanian B lies on autochthonous Frasnian sandstone of the Moradillo Formation.

of the Carazo Sandstone and Quartzite Formation and into the basal part of the Lebanza Limestone Formation. This contact can be mapped without difficulty. A transcurrent, probably vertical fault interrupts the contact between autochthonous and allochthonous strata. There is little exposure north of the San Julián top (1389 metres altitude), but the two most northerly synclines of the San Julián outlier apparently disappear as the result of relative uplift of the strata on the south-eastern side of the transcurrent normal fault. This upthrow seems to have brought the autochthon to the level of present day erosion, since there is no sign of the hard, not so easily weathered beds of the Carazo and Lebanza formations to the north of the San Julián top. It appears likely that the thrust plane underlying the San Julián Klippe is an undulating one, and that the base of the tectonic outlier is not very far from the erosion surface north-west of the transcurrent normal fault.

This nappe thrust seems to dip down to lower levels of the allochthonous strata in the eastern part of the San Julián Klippe, where Silurian mudstones appear below the prominent sandstone of the Carazo Formation. It is on the eastern border of the San Julián Klippe, that the clearest evidence of an allochthonous nappe structure is found. Silurian strata dipping some 40° to 50° westwards lie here on shallowly dipping and, locally, even horizontal strata of the (Lower?) Westphalian Carmen Formation (text-figs 2, 4). Only a relatively shallow dipping thrust plane could produce such a contact. This thrust relationship is of particular importance in that it shows the allochthonous strata of the San Julián unit overlying the allochthonous ones of the Revilla Nappe. The superposition of two tectonic outliers provides proof of the relative importance of nappe structures in this area.

On the south-eastern border of the San Julián Nappe some Devonian mudstones and limestones of probable Eifelian age are again clearly overlying more steeply dipping and less continuous strata of the autochthon which includes the Carboniferous. These Devonian rocks are apparently covered in turn by Silurian strata, and constitute a thrust slice of unknown relationship to the San Julián Klippe. A transcurrent fault hinging within the San Julián Klippe separates the south-eastern corner of this klippe, and the Emsian? - Eifelian thrust slice N. N. W. of Nava de Santullán, from the region north and north-east of Verbios where the nappe thrust is seen to cut slightly obliquely through progressively higher strata of the Silurian and basal Devonian. Another transcurrent normal fault then changes the contact between Silurian and autochthon to one between the Gedinnian sandstone and the autochthonous strata. The vertical nature of these transcurrent faults is evident from the signs of drag within the fault zones, where vertical bedding planes have been observed. A certain degree of strike-slip movement also seems to have been present, as is shown by occasional strikes in the direction of the fault which have been measured within the fault zone itself. In the area north of Verbios the tectonic outlier of San Julián forms the higher ground and the north-northeasterly dips of the allochthonous strata in this region show very clearly their superposition on top of autochthonous deposits which incorporate dated Lower Namurian and Upper Famennian.

Altogether, the thrust plane underlying the San Julián Klippe appears to be an undulating plane which generally follows the shape of the synclinorium. However, this general impression of adaptation of the thrust plane to the fold structure (and subsequent faulting) of the allochthonous rocks merely shows that this plane of movement was folded together with the allochthonous strata after they were emplaced in this area. This indicates that the original structure must have been that of a shallowly dipping thrust sheet, with the underlying nappe thrust at a narrow angle to the bedding of the allochthonous strata. Since this thrust cuts out less of the allochthonous succession in the eastern and south-eastern parts of the San Julián Klippe, it seems to have dipped south-eastwards.

The massif hypothesis of DE SITTER (1955) and FRETS (1965).

In a general article on the Palaeozoic of northern Palencia, DE SITTER (1955) postulated that the San Julián unit would represent an island at the time when the marine Carboniferous deposits around this «massif» were laid down. This interpretation was the exact opposite to that put forward by the present writer (WAGNER 1955).

It is readily apparent that the varied contacts between the San Julián unit and different strata of the surrounding area preclude any interpretation relying on an unmodified stratigraphic unconformity. The map produced by FRETS (1965) consequently admits fault contacts on the eastern and southern sides of the San Julián unit. The eastern boundary fault, which shows the superposition of the San Julián unit on the Revilla Nappe, is conveniently ignored in the explanatory drawing provided by FRETS (1965, text-fig.18), who only discussed the southern boundary. He admitted this to be determined by a thrust fault, but dismissed it as a later tectonic feature. FRETS' discussion concentrated on the western boundary, where he figured Carboniferous limestones striking parallel to this boundary of the San Julián unit. The more detailed map published in the present paper (text-fig. 4) makes it clear that the information presented by FRETS is only partially correct. The south-western boundary of the San Julián unit shows the presence of a Moscovian limestone which is cut off and overridden by Devonian strata. The dips found in the Carboniferous rocks near this western boundary also indicate that the Devonian strata form the (tectonically) overlying unit.

It is noted that the map published by FRETS (1965) and DE SITTER & BOSCHMA (1966) shows the San Julián unit as totally surrounded by Carboniferous, the inference being that these would be generally of the same age. In fact, the ages established for the various outcrops of fossiliferous rocks in the immediate vicinity of the San Julián unit, show a good deal of variation ranging from Middle Devonian to Moscovian.

FRETS (1965, p. 149) also pointed at the apparently less steeply folded strata of the Carboniferous near Santa María de Nava, and assumed that the Devonian rocks of the San Julián unit would have been folded prior to the deposition of these Carboniferous rocks. It is apparent, however, that he refers to the Carmen Formation which participates in the Revilla Nappe, and that he has chosen to ignore the isoclinal structure existing in the Moscovian rocks of the Perapertú Formation west of the San Julián unit. Both DE SITTER and FRETS failed to appreciate the fundamentally different tectonic style in the San Julián rocks on the one hand and the surrounding strata on the other. The open folds of the San Julián unit are clearly less tightly compressed than the isoclines found in the Perapertú Formation. This difference in tectonic style is perfectly understandable in terms of allochthon and autochthon. FRETS is factually incorrect when he refers to the Devonian strata of the San Julián unit as being more intensely folded than the surrounding Carboniferous.

Relationship between San Julián Klippe and Revilla Nappe.

The superposition of the San Julián Klippe on the Revilla Nappe may be explained by either the independent movement of two unrelated thrust sheets or the overriding of one fragment of the same nappe by another. The two tectonic outliers share the same general WNW-ESE strike, but this is no proof of their belonging to one and the same unit. More likely, this common trend is the result of later folding, well after the emplacement of the allochthonous units, which affected both nappes in the same way. Since the WNW-ESE strike roughly parallels the NW-SE strike of the lower Stephanian rocks in the neighbouring coalfield of Barruelo, which owe their isoclinal structure to the Asturian phase of folding (of intra-Stephanian age), it seems likely that the present-day strike of the two allochthonous units is the result of Asturian fold movements modifying an already existing east-west strike. The shallowly dipping thrust sheets must have been easier to deform than the steeply dipping autochthonous strata underneath, and the latter therefore may have retained their original structure to a far greater extent.

In the Revilla Nappe the most complete representation of allochthonous strata occurs in the area south-east of Villabellaco, where the Givetian is preserved in the basal part of this nappe. Towards the east and south the Revilla Nappe Thrust cuts upwards into progressively higher strata. It is therefore clear that this thrust was originally dipping north-northwestwards.

In the San Julián Klippe, on the contrary, the oldest strata of the allochthonous unit are preserved in the south-eastern part of this unit. It therefore appears that the nappe thrust in this case was originally dipping south-eastwards. In view of the completely different attitude of the thrust plane in these two different, though superimposed thrust units, it seems likely that they should be regarded as separate entities and not as two parts of one and the same nappe which split up at some stage of its emplacement.

This implies that the San Julián thrust unit travelled further than the Revilla Nappe which terminates at the head of this nappe in the exposure west of Revilla de Santullán. The San Julián unit may possess another outlier just west of Valle de Santullán where sandstones which apparently show the facies of the Carazo Formation, seem to lie on top of Carboniferous.

The small thrust slice of Emsian?-Eifelian strata N. N. W. of Nava de Santullán may be a separate unit intercalated between the Revilla and San Julián nappes.

CONCLUSIONS

The tectonic style of the Revilla and San Julián nappe units, which are structurally coherent and which show open folds with opposing dips, is completely different to that of the underlying autochthonous strata which are characterized by steeply dipping isoclinal structures which are strongly disturbed by faulting. Structurally, there is a clear difference between allochthonous and autochthonous strata in this area.

This difference is further emphasized by considerations of stratigraphic and facies development. The Givetian rocks in the Revilla Nappe consist of brachiopod limestones with an intervening sandstone, whereas the autochthonous Givetian is only known to consist of *Posidonia* shales. Since the head of the Revilla Nappe has been found in an exposure west of Revilla de Santullán, i.e. north of the main exposure of this nappe, it is likely that this nappe travelled in a northerly or north-easterly direction. The allochthonous Givetian brachiopod limestones therefore may represent a facies developed in an area to the south or south-west, and it must be concluded that this area was of a more shallow marine facies than the basinal *Posidonia* shales. Of course, this assumes that all the Givetian in the autochthonous sequence is represented by *Posidonia* shales, an assumption which is reasonable in view of the fact that a quiet water facies with pelagic fauna already appears in the Emsian of the autochthonous strata and that *Posidonia* shales are apparently common in the Givetian as well as in the Frasnian and Famennian of the autochthon. On the other hand, the autochthonous succession is so much disturbed tectonically, that a complete succession has not yet been established.

A better sequence is known for the autochthonous Carboniferous which also shows marked differences in its stratigraphic history vis-à-vis the allochthonous sequence as exposed in the Revilla Nappe. These differences are not so much in the facies of the various lithostratigraphic units, which are apparently the same for allochthonous and autochthonous strata, but in the presence and much greater importance of stratigraphic gaps and associated unconformities in the allochthonous succession. Nowhere else in the Cantabrian Cordillera has such a clearly angular unconformity been found below the Viséan nodular («griotte») limestone as in the Revilla Nappe, and the associated elimination of Devonian rocks down to the level of Lower (?) Givetian is not matched by the autochthon which shows the presence of a full Upper Devonian succession. The greater mobility and relative importance of uplifts in the palaeogeographic area represented by the allochthonous strata of the Revilla Nappe are also shown by the elimination of Namurian B strata at the Santa María unconformity and, particularly, by the angularity and downcutting to different Namurian levels of the Carmen unconformity. The latter is known to exist as a relatively unimportant disconformity in the autochthonous strata near San Martín de Perapertú, where the Lower Moscovian Perapertú Formation is found underneath. There can be no doubt that the Carboniferous succession in the Revilla Nappe reflects a position on a mobile palaeogeographic area, which is very different from the autochthonous region, and which was probably situated well south of this region. Since it is known from the exposures of Namurian rocks in northern León, that the limestone facies (*ex* «caliza de montaña») represents deposition on the foreland area of the Cantabrian Block, and that a basinal area with turbidites was situated south of this block (compare WAGNER, WINKLER PRINS & RIDING 1971), it may be concluded that the allochthonous strata of the Revilla Nappe represent a region akin to the Block and outside the flysch basin. Both the angular unconformity below the Viséan nodular limestone and the elimination, as the result of uplift, of Namurian B deposits which are apparently found everywhere on the Cantabrian Block, indicate that this succession is probably not to be assigned to this block. It may well correspond to a submarine swell south of the flysch basin, which is now mainly underneath the Mesozoic and Tertiary strata of the Castilian Meseta. This would imply that the Revilla Nappe travelled possibly the full width of the flysch basin. The nearest deposits corresponding to the latter are encountered some 15 km westwards in the region of Cervera de Pisuerga (compare KANIS 1956, FRETS 1965).

The marked difference in tectonic style and stratigraphic development between allochthonous and autochthonous strata in this region of north-eastern Palencia is apparently unique, and unmatched by any other large scale thrust structures in the Cordillera Cantábrica. The nappes described by DE SITTER (1962) and JULIVERT (1965, 1967) do represent large scale thrust units, but these do not seem to produce the superposition of different kinds of stratigraphic sequence and tectonic structure, and therefore appear to qualify as thrust slices rather than nappes. Of course, the overall compressional style is similar, and one may assume that the kind of nappe structures found in northern Palencia —with clearly different allochthonous and autochthonous areas— evolved from the type of large thrust slices found elsewhere in the Cantabrian Chain.

It has already been noted that the fold structures found within the Revilla Nappe and, particularly, the San Julián Klippe, probably represent the result of movements later than those which emplaced the allochthonous units. These later movements apparently fit within the general trend of Asturian phase structures in north-eastern Palencia. The actual emplacement of the nappes must have been earlier, and it seems likely that the Palentian phase, of Westphalian B age, was responsible. The Palentian folding phase is known to have produced isoclinal structures which are overlain by post-orogenic, late Westphalian B conglomerates which are strongly unconformable (compare KANIS 1956, DE SITTER 1958, WAGNER 1960, 1966[a]). The autochthonous strata underneath the Revilla Nappe and the San Julián Klippe seem to be always of pre-Palentian age, and this is another indication that the Palentian phase may have produced the movements responsible for the emplacement of these nappes. This is also the first important folding phase in northeastern Palencia, the Asturian phase being the second. Movements also occurred both before and after the Palentian phase, but these gave rise to disconformities and low-angle unconformities which were not associated with large scale folding.

It is still a matter of conjecture how widespread the Palentian nappe structures are in this part of the Cordillera Cantábrica. Additional to the Revilla and San Julián nappes an allochthonous structure involving Bashkirian limestones has been found in the vicinity of Mudá (text-fig.1), but this structure has not yet been mapped in detail.

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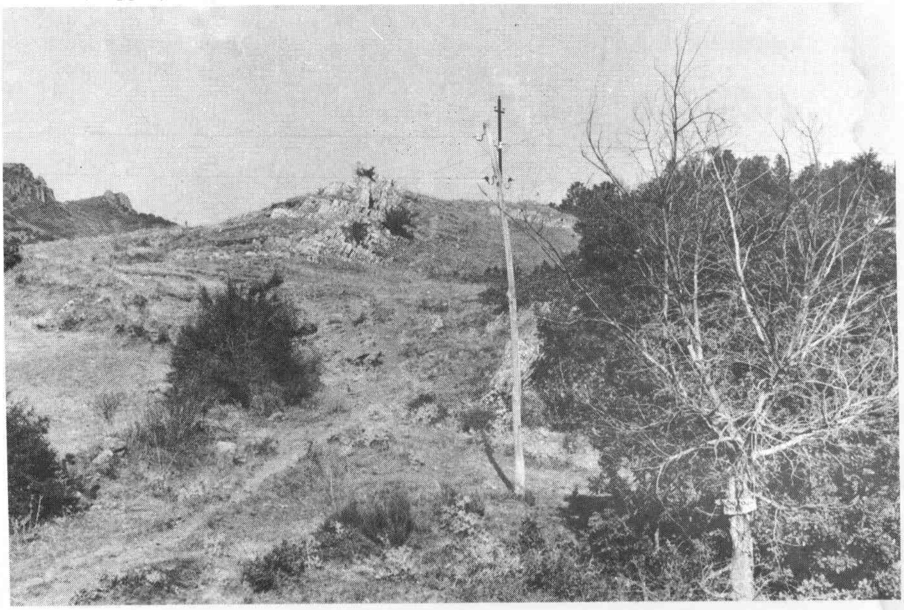
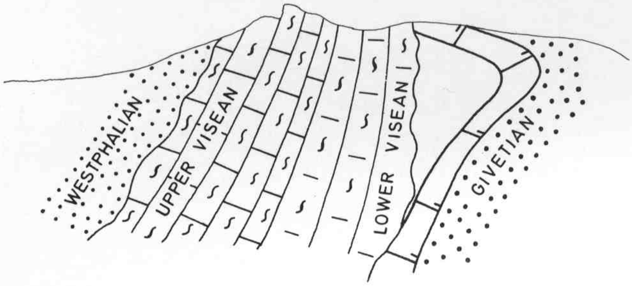
PLATE 1

The angular unconformity between Viséan (Villabellaco Formation) and previously folded Givetian strata in the Revilla Nappe as found in the exposures 400 metres south-east of Villabellaco. The photographs look westwards.




WESTPHALIAN
UPPER VISEAN
LOWER VISEAN
GIVETIAN

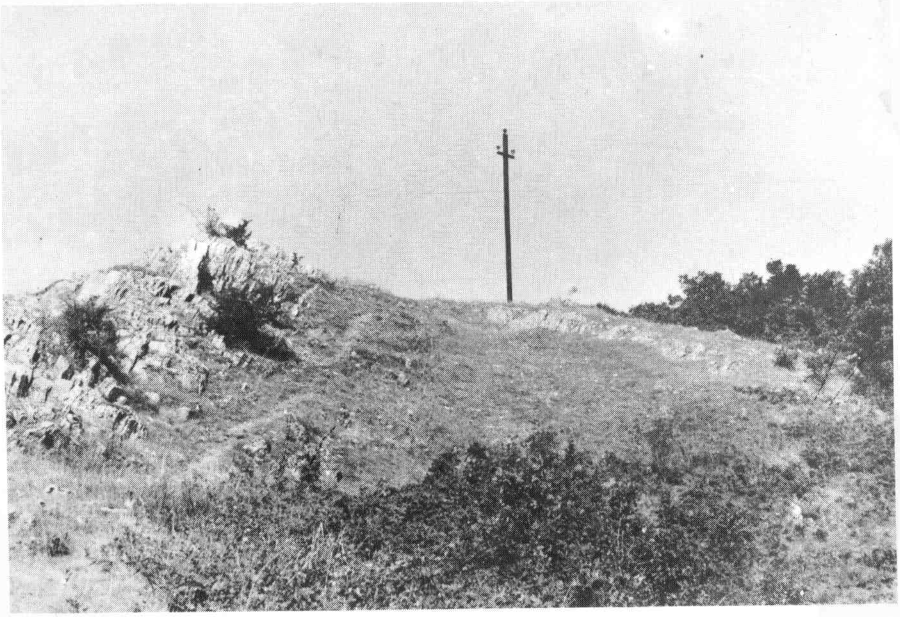
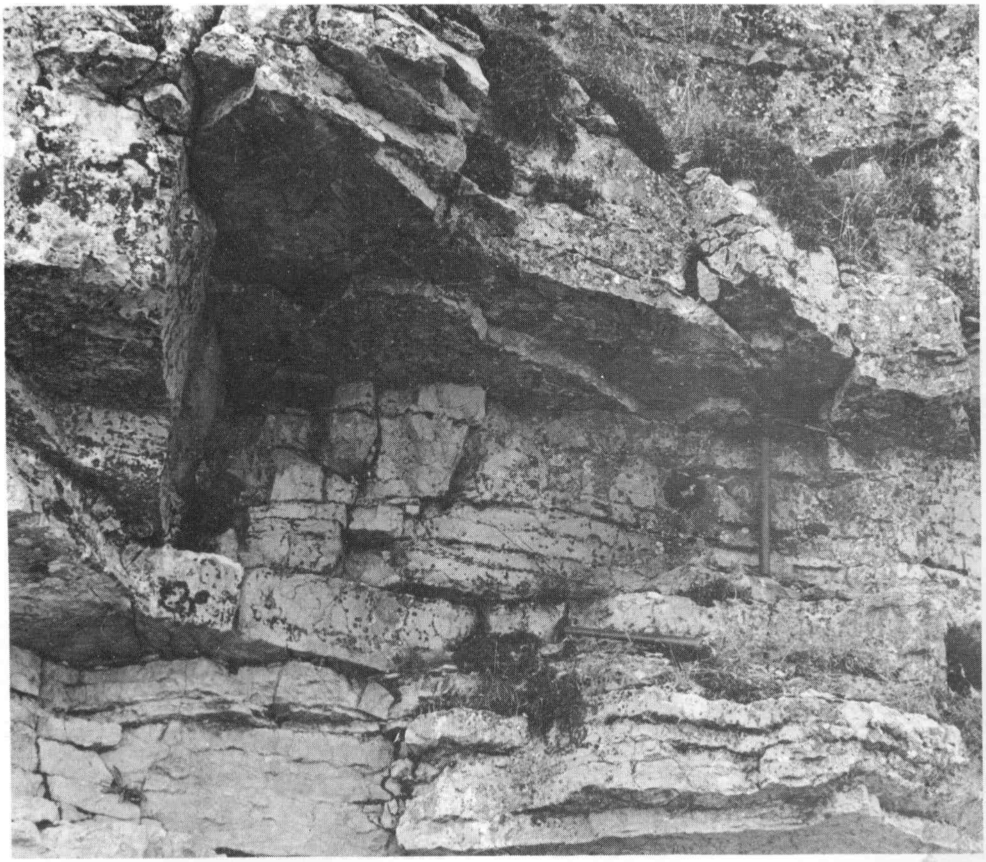


PLATE 2

The Upper Viséan part of the Villabellaco Formation, with *Goniatites* ex group *granosus* PORTLOCK on the overhanging bedding plane, as exposed in loc. 135, 500 metres south-west of Revilla de Santullán.




SANTA MARIA LST.
disconformity
BASHKIRIAN
0.64 m
G. granosus band
1 m
G. crenistria band
VISEAN
"griotte"
4 m
loc. 1912
G. ex gr. granosus band
VILLABELLACO LST.
VILLABELLACO LST.

PLATE 3

Fig. 1.—Limestone breccia of the overturned erosion surface found in the downward facing synform of loc. 134, interpreted as the head of the Revilla Nappe. The breccia was formed at the expense of Lower Namurian strata of the Villabellaco Formation. The unconformity is that below the Carmen Formation.

Fig. 2.—Limestone breccia with elements of the Lower Namurian (E_1) Villabellaco Limestone as found 100 metres west of the southern tip of Revilla de Santullán. It probably marks the Santa María unconformity.

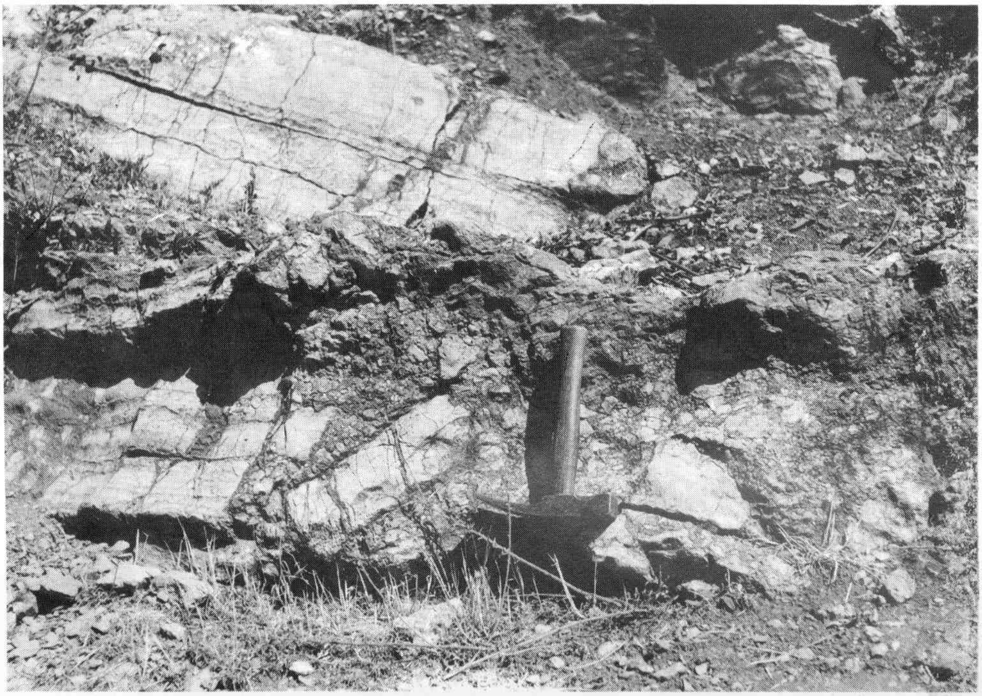


Fig. 1

Fig. 2

PLATE 4

The locality north of loc.135, at some 500 metres south-west of Revilla de Santullán, where the Santa María Limestone (Bashkirian, i.e. probable Namurian C) cuts obliquely through the Upper Viséan of the Villabellaco Limestone, and thus shows the fundamentally angular nature of the unconformity.


FORMACION DE SANTA MARIA
discordancia
FORMACION DE VILLABELLACO

PLATE 5

Fig. 1.—The massive and massively bedded Santa María Limestone lying disconformably on well bedded Villabellaco Limestone only a short distance from the locality of Pl.4, showing an angular contact between these two lithostratigraphic units.

Fig. 2.—The nodular aspect of the well bedded Villabellaco Limestone, showing sections of goniatites. The shaft of the hammer is 35 cm long.

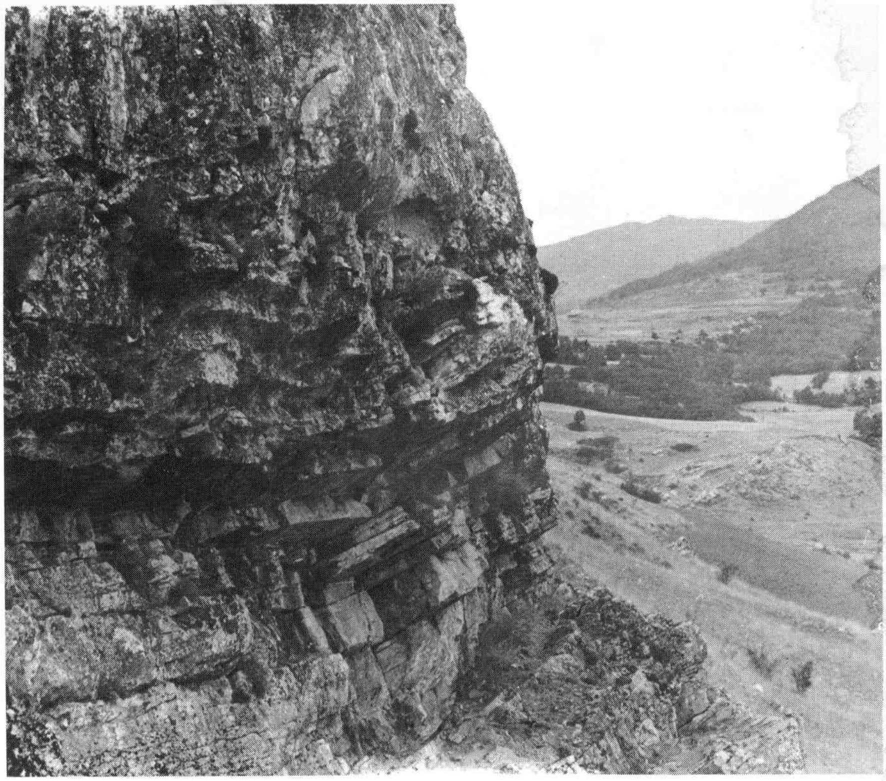


Fig. 1

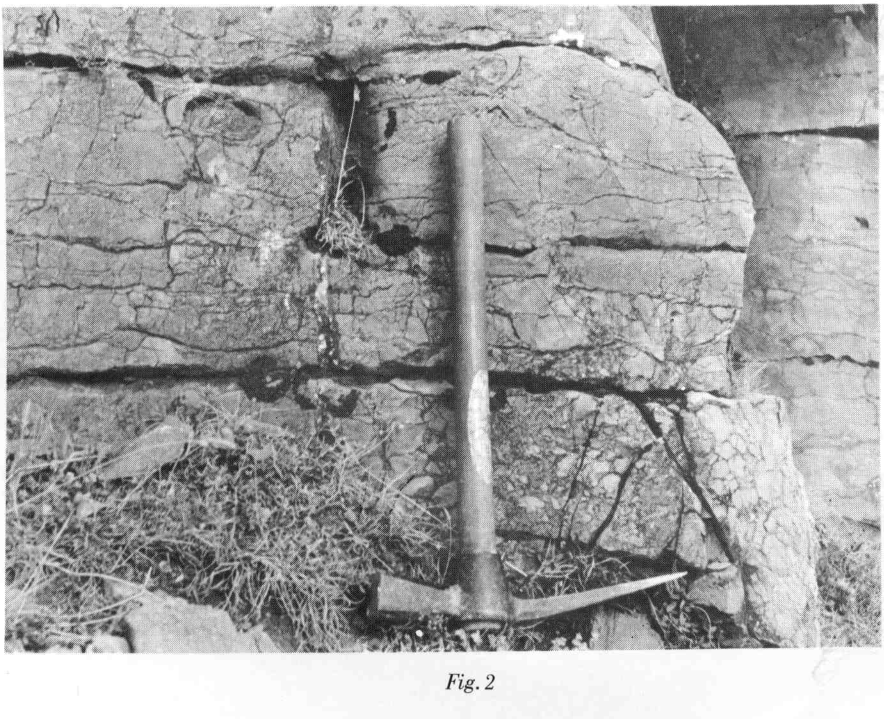


Fig. 2

PLATE 6

Two aspects of the disconformity (or low-angle unconformity) separating the massive to massively bedded Santa María Limestone (Bashkirian) from the rather thinly bedded nodular limestone of the Villabellaco Formation. General view at the top, looking southwards from a position south of loc. 135, and detail of the contact (indicated by the head of the hammer) as photographed in the same exposure (lower photograph).

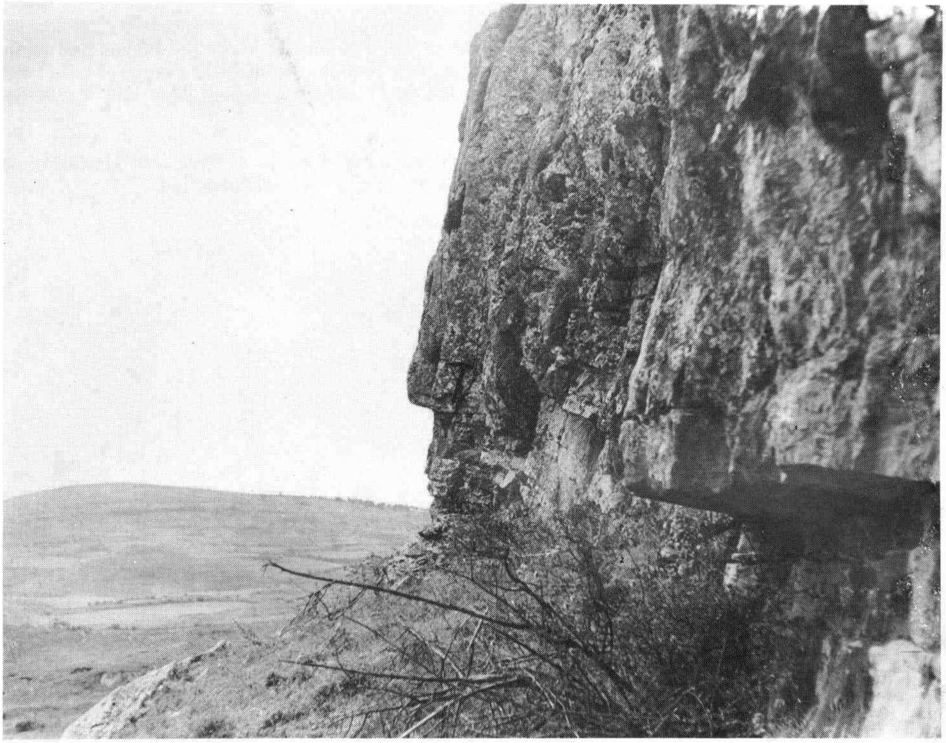


PLATE 7

Fig. 1.—Large boulders of possible «reef» limestone as found in loc. 21 where the higher part of the Santa María Limestone Formation is last seen before the Revilla Nappe Thrust cuts through it and upwards into the unconformable Carmen Formation. This locality yielded Bashkirian fusulinids.

Fig. 2.—Large boulders amongst smaller limestone clasts in an exposure of the Santa María Formation immediately north of loc. 21, at 600 metres south of Revilla de Santullán.

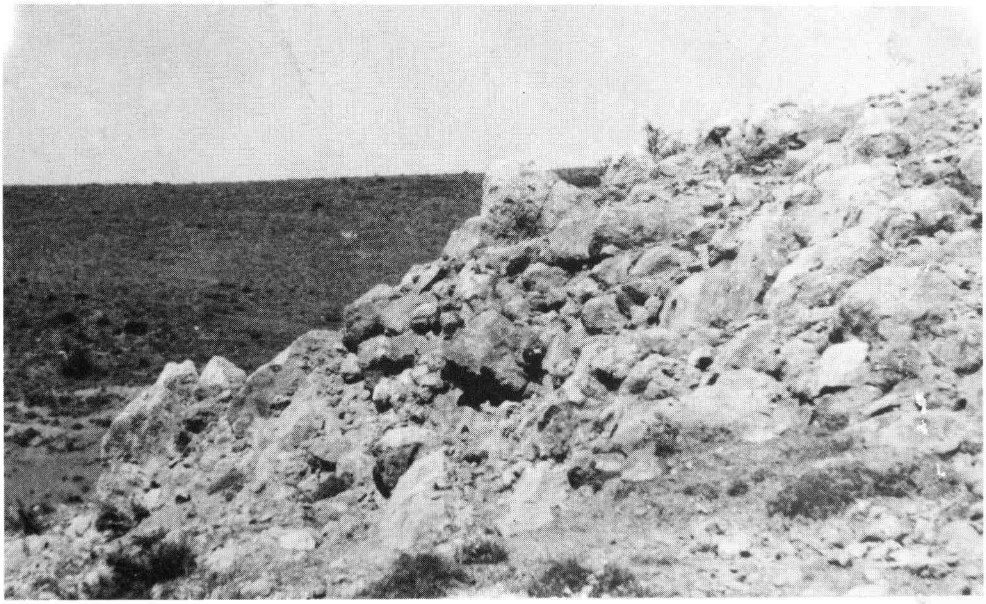


Fig. 1

Fig. 2