THE STRATIGRAPHY OF THE SAN EMILIANO FORMATION AND ITS RELATIONSHIP TO OTHER NAMURIAN/WESTPHALIAN A SEQUENCES IN THE CANTABRIAN MTS., N W SPAIN

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TRABAJOS DE GEOLOGIA

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La Formación San Emiliano fue descrita informalmente por Brouwer y van Ginkel (1964) en esta localidad tipo del norte de León. La falta de una descripción formal ha conducido a atribuir a esta formación otras sucesiones de la Zona Cantábrica en base a semejanzas litológicas sin considerar el control bioestratigráfico.

En este trabajo se realiza una revisión de la estratigrafía original y se establece una descripción rigurosa de la Formación. La formación comprende más de 1.800 m de rocas clásticas y carbonatadas, divisibles en tres miembros de acuerdo con la variación en la proporción de estas rocas. El miembro inferior (Miembro Pinos) está constituido por pizarras negras homogéneas que hacia arriba pasan a una alternancia de siltitas y areniscas. El miembro medio (Miembro La Majua) está formado por secuencias clásticas formadas en deltas regresivos y en medios marinos someros, separados por 8 unidades mayores de calizas. El miembro superior (Miembro Candemuela) está predominantemente formado por sedimentos detríticos formados en deltas regresivos y medios marinos someros, con algunas intercalaciones finas de calizas. En base a la existencia de foraminíferos (fusulínidos) se establece una edad Bashkiriense tardío/Moscoviense temprano para los miembros La Majua y Candemuela; la presencia de plantas y microesporas indica a su vez una edad Yeadoniense tardío a Westfaliense A temprano para el total de la formación.

La Formación San Emiliano puede ser correlacionada con las Capas de Villanueva, formadas por una sucesión de turbiditas, avenidas de derrubios calizos y sedimentos clásticos de plataforma que afloran unos 30 Km al E de San Emiliano, en el valle del río Bernesga. Una secuencia semejante a las Capas de Villanueva aflora en el valle de Robledo de Caldas, unos 10 Km al E de San Emiliano. Así mismo, las formaciones Perapertú y Carmen del N de Palencia tienen una edad equivalente a esta formación.

The San Emiliano Formation was informally described by Brouwer and van Ginkel (1964) from its type area in N. León. The lack of a formal description for the formation led to the attribution of the formational name to other successions in NW Spain on the basis of lithological similarities without bothering with biostratigraphic control. The paper presents a revision of the original stratigraphy and the erection of a formal description for the formation.

The formation comprises at least 1,800 m of alternating clastics and carbonates, divisible into three members according to variations in the proportion of clastics to carbonates. The lower or Pinos Member comprises homogeneous black shales passing upwards into interbedded siltstones and sandstones. The middle or La Majua Member consists of regressive deltaic and shallow marine clastic sequences, separated by 8 major limestone units. The upper or Candemuela Member is dominated by regressive deltaic and shallow marine clastics with occasional thin limestones.

Fusulinid foraminifera indicate a late Bashkirian/early Moscovian age for the La Majua and Candemuela members, whilst plant macrofossils and microspores indicate a late Yeadonian to Westphalian A age for the whole succession.

The San Emiliano Formation can be correlated with the Villanueva beds, a succession of turbidites, carbonate debris flows and shelf clastics, exposed c. 30 km E of San Emiliano in the Bernesga river valley. A similar sequence to the Villanueva beds is exposed in the valley of Robledo de Caldas c. 10 km E of San Emiliano.

Strata of equivalent age to the San Emiliano Formation in Palencia are the Perapertú and Carmen formations.

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The San Emiliano Formation was first established by Brouwer and van Ginkel (1964), for the sequence of terrigenous clastics and carbonates which cropped out in the vicinity of San Emiliano in northern León, extending northwards as far as Teverga in Asturias (Fig. 1). Their description of the formation does not follow the procedure suggested in the International Stratigraphic Guide (Hedberg 1976); no formal description with measured and accurately located stratotypes and boundary stratotypes was proposed and details of the geographical extent of the formation and its range in age were not given. In the informal type section of Brouwer and van Ginkel (1964) which is located between the villages of Pinos and Villargusán (Fig. 2) much of the lower and upper parts of the formation have been eliminated by tectonism.

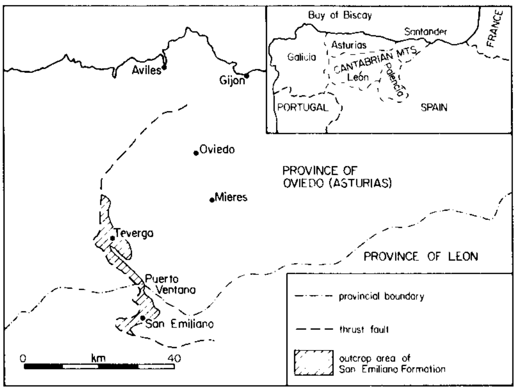

Fig. 1.–Map of NW Spain showing the area of outcrop of the San Emiliano Formation.

Recent investigations of the San Emiliano Formation by the present author, mainly in its type area in northern León (Bowman 1980), permit a revision of Brouwer and van Ginkel's original stratigraphy and the erection of formal stratigraphic subdivisions for the formation, together with accurately located and fully described stratotypes.

PREVIOUS WORK

The earliest mention of Carboniferous strata in the San Emiliano-Teverga region was by Monreal (1859); this was followed by Barrois (1882) who included the rocks in his «Assise de Lena» subdivision of the Asturian Carboniferous.

The first major works on the general geology of the San Emiliano and Teverga districts together with simplified maps were published by Gómez de Llarena and Rodríguez Arango (1948) and García-Fuente (1952, 1959). Other work on the San Emiliano Formation has been concerned with general mapping (Martínez Alvarez, 1962; Marcos, 1968; van den Bosch, 1969a), sedimentology (Bowman, 1979, 1980) and with aspects of the palaeontology and biostratigraphy of the rocks, namely fusulinids (van Ginkel, 1965), brachiopods (Winkler Prins, 1963; Martínez Chacón, 1977, 1978, 1979; Martínez Chacón and Winkler Prins, 1979) and plant macrofossils (Wagner, 1959, 1962; Stockmans and Willière, 1966). References to the formation can also be found in the reviews of Palaeozoic and specifically Carboniferous geology in the Cantabrian Mts. by Wagner (1970, 1971a), Reading (1970) and Wallace (1972). Wagner and Martínez García (1974) and Heward and Reading (1980) briefly mention the formation in their outlines of the tectonic evolution of Northwest Spain.

DESCRIPTIVE PROCEDURE

The San Emiliano Formation is described below following the procedure outlined in the International Stratigraphic Guide (Hedberg, 1976). Composite stratotypes and boundary stratotypes have been erected and precisely located for the different subdivisions (members) of the formation. Where it was not possible to designate a stratotype for a particular section or boundary because of tectonic disturbance or poor exposure, one or more outcrop sections have

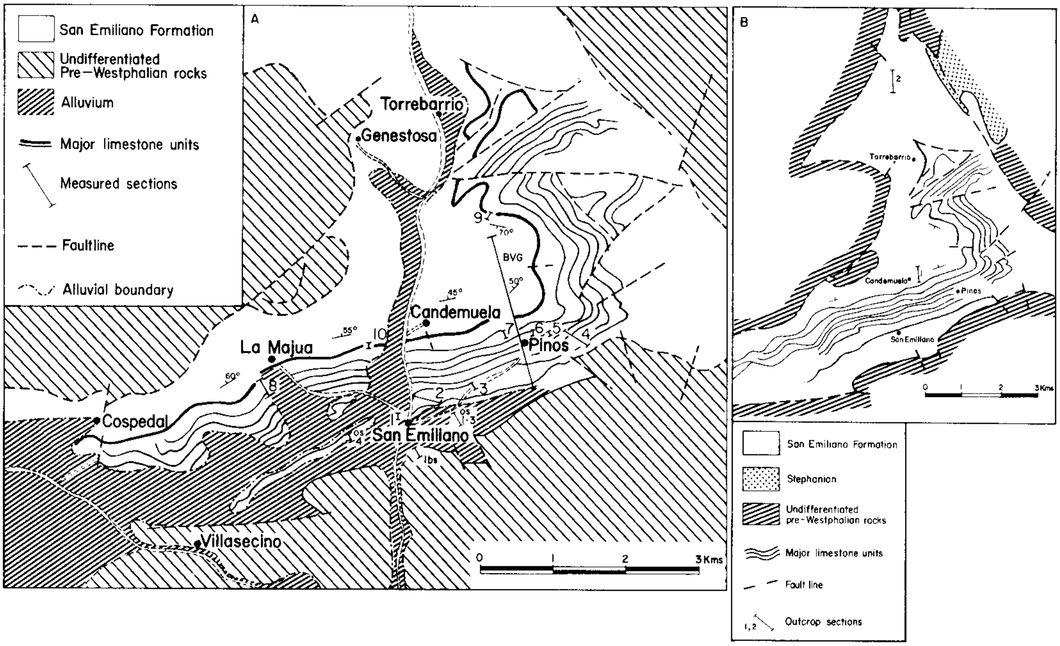

Fig. 2.–Outline geological maps of the San Emiliano Formation showing:
(a) The location of Brouwer and van Ginkel's type section (BVG), the lower boundary stratotype (lbs), outcrop sections 1-4 for the Pinos Member (0S1-4) and component stratotypes 1-10 of the La Majua Member.
(b) Outcrop sections for the Candemuela Member.

been defined. Detailed stratotype descriptions and measured sections are presented in Bowman (1980).

LATERAL EXTENT

The San Emiliano Formation as defined by the present author is restricted to the clastic and carbonate succession which crops out in the type locality in the San Emiliano valley, northern León, and extends as far as Teverga and Quirós in Asturias. It has a roughly triangular outcrop pattern bounded for much of its extent by major faults (Fig. 1).

LITHOSTRATIGRAPHIC SUBDIVISIONS

A formal tripartite division of the San Emiliano Formation is based upon variations in the proportions of clastic to carbonates (Fig. 3). The formation can be traced from the type locality at San Emiliano northwards to Teverga in Asturias.

The lower or Pinos Member is about 250 m thick. It consists of homogeneous black shales passing upwards into bioturbated siltstones with thin, sharp based sandstone interbeds. A lenticular limestone band occurs 20 m from the top of the member.

The La Majua Member is conformable with the Pinos Member. The member consists of about 1050 m of rhythmic deposits including 8 major transgressive limestone units. They separate thicker regressive deltaic and shallow marine, coarsening upwards clastic sequences. It is in the La Majua Member that limestones are thickest and most consistently developed.

The upper or Candemuela Member is over 500 m thick; it is dominated by coarsening upwards, rhythmic clastic sequences of deltaic and shallow marine origin with abundant, generally thin coals. Thin, often discontinous limestones are also present.

FORMATION BOUNDARIES

The San Emiliano Formation conformably overlies and is laterally equivalent in its lower part to the Valdeteja Formation, a thick, mainly

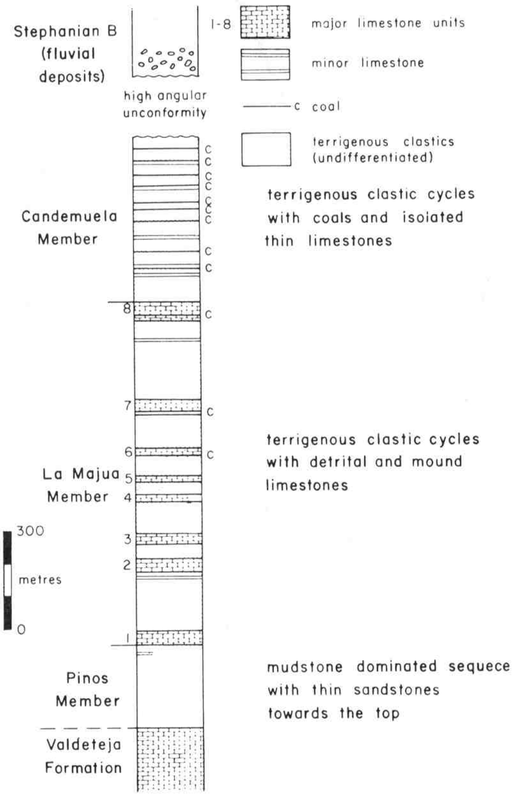

Fig. 3.–The stratigraphic subdvisions of the San Emiliano Formation.

Yeadonian carbonate succession defined by Winkler Prins (1971). The transition between the two formations can be seen at one locality, c. 400 m South of San Emiliano village (42°58'03''N 2°18'30''W) (Fig. 2), which is designated the boundary stratotype of the San Emiliano Formation. Elsewhere the contact is either not exposed or has been eliminated by faulting (Fig. 4). The exposure of the Valdeteja/San Emiliano boundary briefly described by García-Fuente (1952) from a disused railway cutting to the South of San Martín de Teverga (Asturias) is now overgrown.

The stratotype consists of just over 5 m of interbedded calcareous shales and impure, sharp-based limestones which overlie a sequence of brachiopod and crinoid dominated bioclastic limestones representing the top of the Valdeteja Formation. Outcrops are patchy and surrounded by limestone scree, derived from the upper slopes of the hill, c. 400 m South of San Emiliano.

Extensive dolomitisation has destroyed much

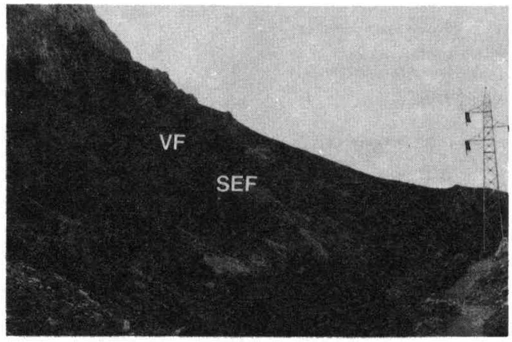

Fig. 4.–Thrust contact between the San Emiliano Formation (SEF) and the Valdeteja Formation (VF) East of Pinos.

of the primary fabric in the Valdeteja Formation of the San Emiliano region. The upper bioclastic limestone beds referred to in the boundary stratotype have only been seen in one small exposure: they represent an unusual development of the formation which is generally dominated by pale grey algal micritic limestones which appear almost unfossiliferous at outcrop.

The San Emiliano Formation is unconformably overlain by a sequence of alluvial conglomerates and sandstones with some coals which crops out from Páramo, South of Teverga to Puerto Ventana, North of the San Emiliano valley. Plant macrofossils from this succession indicate a late Stephanian B age (Wagner, 1966; Wagner, 1970). Consequently, the upper boundary of the San Emiliano Formation cannot be determined because there is no immediately overlying formation present.

The unconformable contact between the San Emiliano Formation and the late Stephanian B sequence is not seen in the type locality because of poor exposure and tectonic disturbance. An exposure near Páramo mentioned by García-Fuente (1952) could not be found by the present author. A presumably non-tectonised contact occurs in the grass and scree covered area along the lower slopes of Peña Ubiña, to the North-East of Torrebarrio in the San Emiliano valley. All other contacts between the two successions in the type locality are faulted.

Pinos Member

Description

The member is named after the village of Pinos, 2 km ENE of San Emiliano. It forms the belt of low ground to the South of San Emiliano, extending southwestwards from Pinos for at least 5 km. East of Pinos the succession is extensively tectonised with faulted contacts (Fig. 4). West of the type area a presumably faulted contact with the underlying Valdeteja Formation is concealed beneath the alluvial valley of the Rio Luna (Fig. 2).

The succession consists of black shales in the lower part, passing gradually upwards into homogeneous, often bioturbated mudstones and siltstones with thin, generally sharp-based sandstone interbeds. There is not sufficient exposure to designate a stratotype for the member; consequently a number of outcrop sections have been designated together with the lower boundary stratotype.

The basal black shales are particularly poorly exposed and only three short sections have been found (outcrop sections 1-3), along a path to the East of San Emiliano (Fig. 2). The shales exhibit varying degress of fissility. They contain scattered finely comminuted plant debris together with occasional, small pectinoid bivalves, turreted gastropods and productid brachiopods.

The sandstones and siltstones at the top of the member are better exposed than the shales. The upper 40 m are represented by homogeneous siltstones containing scattered marine fossils, mainly brachiopods, with a thin, lenticular limestone band 20 m from the top. The limestone contains abundant remains of large phylloid algae. The succession is best seen along a track c. 2 km SW of San Emiliano which is defined as outcrop section 4 (Fig. 2).

The lower boundary stratotype of the Pinos Member is equivalent to the formation boundary stratotype described earlier. The upper boundary is defined by the appearance of the first laterally continous limestone unit which marks the beginning of the alternating clastic and carbonate succession of the La Majua Member. Good exposures of the upper boundary can be seen in the hillside gullies and paths to the West of San Emiliano (Fig. 2). The boundary occurs in outcrop section 4.

Sedimentary synthesis

During Dinantian and Namurian times the San Emiliano area was part of a carbonate platform (the Cantabrian Block of Radig, 1962). Carbonate sedimentation was terminated when the northern faulted margin of a mobile basin reached the area. The black shales at the base of the Pinos Member represent the first major phase of sedimentation within the basin. They reflect an environment characterised by low energy currents and reduced rates of sedimentation. Anoxic conditions within the sediment prevented the development of a benthic fauna. Water depth cannot be precisely defined but it is unlikely to have exceeded a few hundred metres and it may have been much shallower. Allodapic limestones interbedded with the shales at the base of the member, represent turbulent suspensions of carbonate detritus carried into the basin from the edge of the carbonate platform.

The alternating sandstones and siltstones with the algal limestone band at the top of the member, were deposited in shallow, open marine waters. They recorded the approach of a clastic shoreline which defined the southern and western margin of the basin.

LA MAJUA MEMBER

Description

The member is named after the village of La Majua, approximately 2 km NW of San Emiliano (Fig. 2). The rocks are exposed in the flanks of the open syncline which forms the main tectonic element in the San Emiliano valley (Fig. 5). North of Torrebarrio and West of Cospedal the succession is eliminated by faulting (Fig. 2).

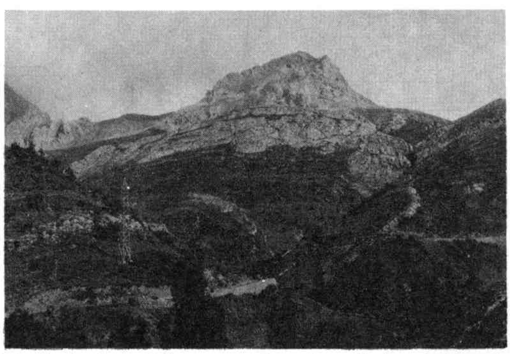

Fig. 5.–A view of the core and southern flanks of the main syncline in the San Emiliano valley, showing the major limestone units of the La Majua Member curving around the core of the fold.

The succession consists of alternating clastics and carbonates, approximately 1,050 m thick. The clastics are represented by regressive deltaic and shallow marine coarsening upwards sequences with occasional thin coals; they are separated by 8 major transgressive carbonate dominated intervals, namely limestone units 1-8 (Figs. 6, 7 y 8).

Patchy exposure renders it impossible to designate any single section as a unit stratotype. The limestones are the most completely and continuously exposed units, the clastics being exposed only in road cuttings and hillside gullies. However, the stratigraphy of the member has been fully elucidated by lateral tracing and the complete succession is defined by 10 component stratotypes (Fig. 2): together these constitute a composite stratotype.

The upper boundary of the La Majua Member lies at the top of the highest major limestone band in the succession, limestone unit 8. This contact is generally obscured either by scree or grass, or is affected by faulting. However, a reasonably complete section across the boundary can be seen along a path just North of Villargusán (42°59'50''N 2°17'55''W) where the upper, well-bedded interval of limestone unit 8 is overlain by 16 m of fossiliferous mudstones representing the base of the Candemuela Member. Minor faulting between the limestone and the less competent mudstones has eliminated a small part of the boundary sequence.

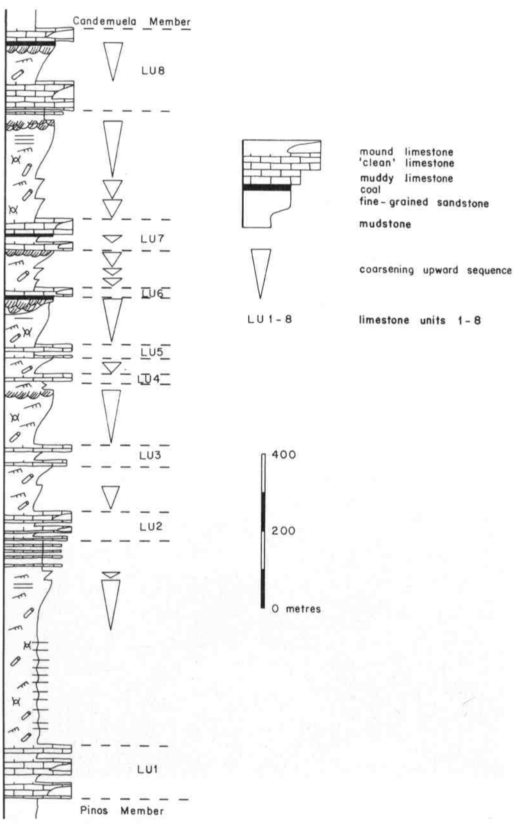

Fig. 6.–Generalised stratigraphic section through the La Majua Member.

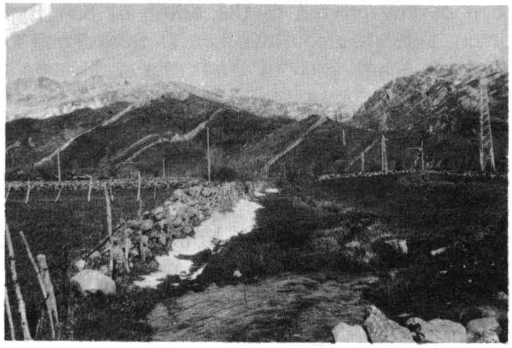

Fig. 7.–General view of the La Majua Member in the San Emiliano valley showing major limestone units 2-8 in the southern flank of the main syncline.

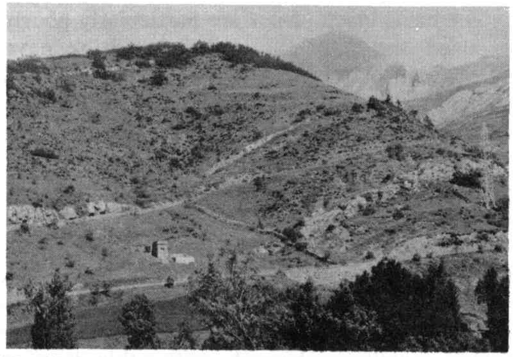

Fig. 8.–General view of the middle part of the La Majua Member near Pinos, showing limestone units 5, 6 and 7 separating less well exposed terrigenous clastic intervals.

Component stratotype 1.–This section comprises the lowest major limestone unit, viz. limestone unit 1. The basal beds can be correlated with the boundary stratotype. The stratotype is provided by the high crag on the northwestern outskirts of San Emiliano (42°55'21''N 2°18''54''W).

The limestone is 70 m thick. It consists of three bands, the lowest of which is 19.50 m thick; it is separated from the middle band by a 12 m clastic interval. The middle and upper bands are 23 and 9.50 m thick, respectively. They are separated by a 6 m thick clastic interval which wedges out eastwards along strike until between Pinos and San Emiliano the upper two bands form a continuous sequence. Carbonate mud mounds containing the problematic alga *Donezella* form the middle parts of the lower two limestone bands.

Component stratotype 2.–The section is *c.* 190 m thick. It comprises the regressive deltaic clastic interval between limestone units 1 and 2. Its top is defined by the lowest band of limestone unit 2 (Fig. 6).

The section is dominated by homogeneous, often bioturbated mudstone and siltstones with occasional thin sandstones. Thicker, more continuous sandstone sequences are restricted to the upper 40 m. Thin, impure oolitic and oncolitic limestones occur in the top 25 m.

Exposures of this interval are very poor compared with the remainder of the La Majua Member. The stratotype is provided by discontinuous outcrops alongside the path connecting the San Emiliano to Pinos road with the main Puerto Ventana road just North of San Emiliano (Fig. 2). Part of the section was measured from temporary exposures which became available during the construction of a villa just North of San Emiliano. This was the only exposure of that interval in the type area, hence its inclusion in the section. Exposures of equivalent beds to parts of the stratotype can be seen at Pinos and South of La Majua.

Component stratotype 3.–This stratotype comprises limestone unit 2 which is the second lowest stratigraphically of the major limestone units in the La Majua Member. Exposures occur along a path midway between San Emiliano and Pinos (Fig. 2).

The limestone is 36 m thick in the type section. It consists of three bands, the lowest of which is 4 m thick; it is separated from the middle band by a thin clastic interval. The middle and upper bands are 8 m and 14 m thick, respectively. These are separated by a poorly exposed sequence of mudstones and impure limestones. *Donezella* mounds occur in the middle of the upper two limestone bands.

Five sections have been measured within the limestone of which only the type section is completely exposed. The stratigraphy of the other sections has been fully elucidated by lateral tracing (Bowman 1979).

Component stratotype 4.–This is one of the thickest and best exposed of the component stratotypes for the La Majua Member. The interval is *c.* 210 m thick. It comprises the succession between the top of limestone unit 2 and the top of limestone unit 5 (Fig. 6). Exposures are provided by the low crags along the upper path between 500 m and 1000 m East of Pinos (Fig. 2).

The limestones of units 3, 4 and 5 are bedded wackestones and packstones: they do not contain the *Donezella* mounds (bafflestones) which occur in units 1 and 2. Units 3 and 5 are composed of two limestone bands separated by thin clastic intervals. Limestone unit 4 consists of a single carbonate band. Minor faulting causes the repetition of limestone unit 5 at the top of the section.

The terrigenous clastic intervals between the limestone units are large scale coarsening upwards sequences of deltaic origin. Exposure of the lower parts of these sequences is always rather patchy; the upper, sandstone-dominated intervals are more completely exposed.

Component stratotype 5.–The section comprises the regressive clastic interval between limestone units 5 and 6 (Fig. 6). Exposures occur along the sides of the upper track between 200 m and 300 m East of Pinos (Fig. 2). At the type section its upper boundary is defined by a coal bed overlying a thick cross-bedded barrier sandstone; much of this coal has been extracted superficially for local use. Other exposures of the interval can be seen immediately to the North and West of Pinos.

Component stratotype 6.–The section comprises limestone unit 6 which is the thinnest of the major limestone units (Fig. 6). It consists of one band which separates two major regressive intervals. The interval is exposed above the abandoned coal working at the eastern end of Pinos (Fig. 2). Small *Donezella* mounds occur in the middle of the band South and West of La Majua.

Component stratotype 7.–The stratotype is exposed on the hillside to the North of Pinos (Fig.

2). It comprises the regressive clastic coarsening upward sequence between limestone units 6 and 7 (Fig. 6); it is 114 m thick. Exposure of the upper part of the succession is poor compared with the remainder of the interval and the top 14 m of strata immediately below limestone unit 7 are not exposed. Other sections, North of San Emiliano and South of La Majua, are also incomplete in their upper half.

Component stratotype 8.–The section is *c.* 200 m thick. It includes limestone unit 7, the clastic interval between limestone units 7 and 8 and the lower band of limestone unit 8 (Fig. 6). The rocks crop out along the hillside to the West of La Majua (Fig. 2). Exposure is generally good. The only major gap occurs at the top of the section where the upper beds of limestone unit 8 are covered.

Limestone unit 7 consists of two bands (8 m and 13 m thick) separated by a 15 m thick coarsening upwards clastic sequence. The upper boundary of the clastic sequence is defined by a coal overlying a barrier sandstone. *Donezella* mounds occur in the middle of the two limestone bands and the upper parts of the two bands contain distinctive beds, rich in phylloid algal remains.

The clastic sequence between the two major limestone units is a composite coarsening upwards sequence with an over 8 m thick channel sandstone body near the top. Thin impure oolitic and bioclastic limestones are interbedded with the clastics at the top of the interval.

The lower band of limestone unit 8 has been extensively dolomitised: this has destroyed much of the rock's primary fabric. Mound-shaped bodies are discernible in the upper parts of the band.

Other exposures of this interval, East of La Majua, South of Candemuela and North of Pinos are either less completely exposed or slightly tectonised.

Component stratotype 9.–The stratotype is 41 m thick: it represents the clastic interval separating the lower and upper bands of limestone unit 8. The most productive coal seam in the La Majua Member is found within this sequence (Fig. 6). Exposures occur along a path immediately North of Villargusán (Fig. 2).

The only other good exposure of the interval is approximately 1250 m East of La Majua where a totally different succession with no coal is exposed.

Component stratotype 10.–This interval is exposed along the lower slopes of the hillside between Candemuela and La Majua (Fig. 2). The section marks the top of the La Majua Member. It comprises the upper band of limestone unit 8 which is 13 m thick (Fig. 6). Massive *Donezella* mounds form the middle part of the band. The top of the section can be correlated with the upper boundary stratotype at Villargusán, described earlier.

Sedimentary synthesis

The alternating clastic and carbonate succession of the La Majua Member represents a second phase of sedimentation in the San Emiliano region.

The mainly coarsening upward clastic sequences demonstrate the advance of a delta-dominated shoreline along the southern and western side of the basin. Sedimentation mostly took place in shallow marine, prodelta or delta front environments. On-delta conditions rarely reached the San Emiliano region during the second depositional phase. The deltas advanced into a shallow, low energy basin in which marine processes were suppressed.

Clastic sedimentation was periodically interrupted by major marine transgressions across the shallow basin. These caused the seas to clear and temporarily established carbonate deposition over the deltaic coastline.

Each limestone unit records a transgressive event followed by the early stages of the next regression. This results in a distinctive suite of facies, each representing a particular depositional environment developed during the transgressive and regressive phases. The composite nature of some units with two or three limestone bands separated by thin clastic intervals, resulted from minor transgressive episodes within the main regression.

Facies variations within the limestones are related to depth and energy changes and proximity to areas of clastic deposition. Algae, particularly the problematic tubiform alga *Donezella,* played an important role in the various communities that developed within the carbonate sea. Impure facies record deposition in nearshore areas adjacent to the clastic belt whilst the purer *Donezella* dominated limestones were deposited in clearer, deeper and more tranquil conditions further offshore. A detailed description of the depositional environments of a single limestone band (limestone unit 2) has been made by Bowman (1979).

CANDEMUELA MEMBER

Description

The member is named after the village of Candemuela, on the eastern side of the Puerto Ventana road, midway between the San Emiliano valley and in the roughly triangular, fault bounded area which extends northwards from Torrebarrio to Puerto Ventana and into Asturias (Fig. 2).

The succession consists of deltaic and shallow marine clastics with seatearths and coals. Thin (< 10 m), often laterally discontinus carbonate horizons represent a minor part of the sequence, contrasting with the thick, composite limestone units of the La Majua Member (Fig. 9). A number of coals have been worked locally but they are of low quality and often extensively sheared; consequently no major mining operations have existed in the area.

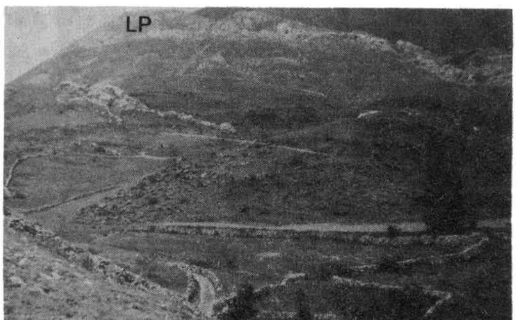

Fig. 9.–General view of the area W of La Majua that is occupied by the Candemuela Member. The low crags in the background are composed of Lower Palaeozoic (LP) successions which are thrust over the San Emiliano Formation.

No stratotype has been defined for the Candemuela Member because of poor exposure and tectonic disturbance (Fig. 10). The lower 300 m of the succession are continuously exposed West and East of Candemuela. Elsewhere exposures are restricted to isolated sections up to

Fig. 10.–Intensely folded terrigenous clastic dominated succession in the Candemuela Member, N of Torrebarrio.

200 m thick (Fig. 9). which cannot be correlated because of the lack of reliable marker bands. Consequently two thick outcrop sections have been selected which are considered to define the succession adequately. No upper boundary can be given for the Candemuela Member which is overlain unconformably by Stephanian B sediments in the area of Puerto Ventana.

Outcrop section 1.–The section is exposed along the hillsides North and East of Candemuela (Fig. 2). It comprises a continuous succession through the lower 300 m of the member (Fig. 3), and is correlated with a less complete succession cropping out along the western side of the San Emiliano valley, midway between Candemuela and La Majua.

There is a stratigraphic gap of about 30 m between the base of the section and the underlying La Majua Member. This interval is exposed just North of Villargusán above the La Majua/Candemuela boundary stratotype.

The succession is dominated by shallow water deltaic clastic sequences: rootlet beds are common but only 4 coals have been recorded of which two are over 20 cm thick. Five carbonate bands ranging in thickness from 0.5 m to 7 m also occur within the succession; four of these provide useful markers for correlation with other sections. The upper parts of the succession are dominated by interbedded shallow marine mudstone and thin sandstones with a rich fauna.

Outcrop section 2.–The section is exposed in a cutting along the private road leading to the Puerto Ventana coal mine (Fig. 2). It consists of *c.* 185 m of shallow marine and deltaic clastic rhythmic units with seatearths and thin coals. Three limestone bands occur in the lower part of the succession.

Minor faults caused the local elimination and repetition of some parts of the succession and prevent accurate measurements of thickness.

The exact stratigraphic position of this section in the Candemuela Member cannot be determined because of poor exposure and tectonic disturbance.

There is a 60 m exposure gap along the mine road between outcrop section 2 and a less complete, more tectonised succession to the South. This section is *c.* 210 m thick and contains similar facies and sequences to outcrop section 2.

Sedimentary synthesis

The clastic dominated succession of the Candemuela Member represents the last stage of basin fill across the area. Conditions become more uniform and major marine transgressions were less common. Shoal water deltaic sedimentation was dominant with numerous thin coals representing periods of emergence on the delta top. Limestones are isolated, generally thin and impersistent. These bands are dominated by impure facies and represent restricted areas of carbonate sedimentation along the deltaic coastline.

AGE

The San Emiliano Formation contains rich and diverse assemblages of marine fossils and more sporadic non-marine ones. They provide general information about stratigraphic age.

Fusulinid foraminífera collected from the lower part of the La Majua Member (van Ginkel 1965) and the Candemuela Member (van Ginkel 1965, Rumyantseva *in litt.)* indicate a late Bashkirian to early Moscovian age (Kashirsky Horizon) (Fig. 11).

Plant macrofossils (Wagner 1959 and pers. comm.) and recent miospore discoveries (Gueinn and Neves pers. comm.) from the upper part of the Pinos Member and the La Majua Member indicate late Yeadonian and early Westphalian A ages, with an approximate position of the Namurian-Westphalian boundary in

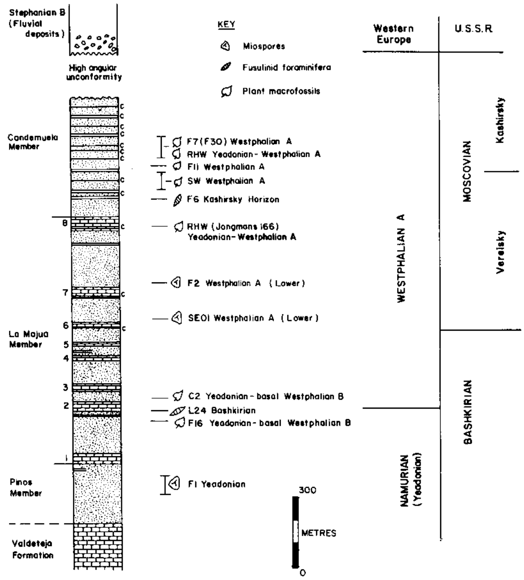

Fig. 11.–A generalised stratigraphic section through the San Emiliano Formation showing the location of the main fossil localities used in dating the succession together with the Russian and W. European stratigraphic schemes. Lithological symbols as used in Fig. 3. Determinations of the floras were made by: Neves, F1, F2; Gueinn SE01; Rumyantseva, F6; Stockmans and Willière, SW; Wagner, C2, F7, F11, F16, RHW 979 (Wagner 1959), RWH (Jongmans loc. 166) (Wagner 1959); van Ginkel L2.4 (1965).

the lower part of the La Majua Member (Fig. 11).

Fossil lists will be given elsewhere (Wagner and Bowman, in prep.).

CORRELATION

In the past, correlations between the San Emiliano Formation and other successions of similar age in the Cantabrian Mountains have been based almost entirely upon isolated samples (Wagner 1959, van Ginkel 1965). There has also been a tendency for lithological comparison to be used for the identification of the San Emiliano Formation without adequate regard to biostratigraphic control. This has led to the attribution of this formational name to other successions with thin limestone bands. Consequently, there is some confusion surrounding the distribution and age of the San Emiliano Formation and its relationships to other sequences. Information obtained during the present study has permitted a reappraisal of existing correlations.

The Valdeteja Formation which underlies the San Emiliano Formation (Fig. 3) has been dated generally as Yeadonian (Wagner *et al.* 1971). The miospores collected from the top of the Pinos Member in the San Emiliano Formation indicate a late Yeadonian age. Consequently, the carbonate sedimentation which continued into basal Westphalian A in the Bernesga Valley (Moore *et al.* 1971) was interrupted by clastic incursions towards the end of the Yeadonian in the San Emiliano region.

A succession of turbidites, carbonate debris flows and shallow water siltstones (*c.* 250 m thick) of equivalent age to part of the San Emiliano Formation (basal Westphalian A) is exposed in the northern flank of the Cármenes syncline in the Bernesga Valley. It overlies the Valdeteja Formation, cropping out to the West of Cármenes, between the Valle El Ejío, NNW of Rodiezmo, and the area to the North of Villanueva de la Tercía (Fig. 12). A detailed description and sedimentological analysis of this sequence is in preparation: it is considered sufficiently distinct in facies and distribution to be informally referred to as the Villanueva beds (Fig. 13). The upper part of this succession has

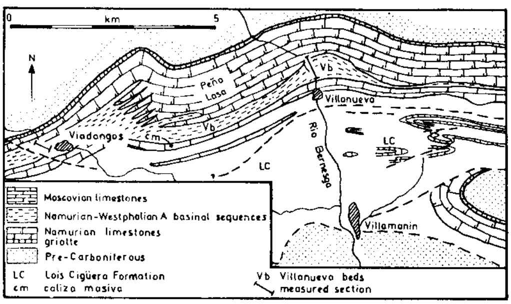

Fig. 12.–Outline geological map of the Cármenes Syncline in the Bernesga valley region (modified from Moore *et al.* (1971), showing the distribution of Carboniferous rocks, including the Villanueva beds.

been dated as early Westphalian A (Neves in Moore *et al.* and pers. comm.). It is separated by a major disconformity from the overlying caliza masiva (lower Westphalian B) *(op cit.)*. This stratigraphic break has not been recorded in the San Emiliano area where sedimentation was continuous during Westphalian A.

The Westphalian B-C (Kashirian-early Podolskian) succession exposed in the core of the Cármenes syncline (Moore *et al.* 1971), has been mistakenly referred to as the San Emiliano Formation by some workers before Moore *et al.* became available (Brouwer and van Ginkel

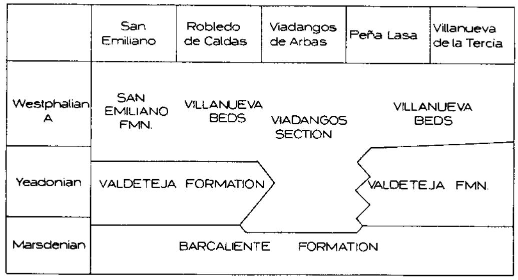

Fig. 13.–Correlation chart of the different Namurian to Westphalian A basin-fill and platform successions in northern León.

1964, van Ginkel 1965, Rácz 1964, Evers 1967, Winkler Prins 1968, Boschma and van Staalduinen 1968, Riding 1970, Vilas Minondo 1971, van Staalduinen 1973). Since then, Riding (1979) has also mistakenly referred to the San Emiliano Formation in the Cármenes syncline. The succession is included here in the Lois-Cigüera Formation (Brouwer and van Ginkel 1964, de Meijer 1971) which has its type area some 30 km East of the Bernesga Valley (Fig. 12).

The outcrop area of the Lois-Cigüera Formation can be extended westwards from the Bernesga valley as far as the village of Truébano, *c.* 4 km South of San Emiliano. Recent miospore discoveries from a coal at Truébano (Dorning pers. comm.) indicate a Westphalian B age. Consequently, the clastic and carbonate succession exposed at Sena de Luna and Cubillas de Arbas which has previously been included in the San Emiliano Formation (Winkler Prins 1968, Marcos 1968, van den Bosch 1969a, b, van Staalduinen 1973) must be regarded as a correlative of the Lois-Cigüera Formation.

The succession of carbonate debris flows with clastic and limestone turbidites which crops out in the valleys of Robledo de Caldas and Caldas de Luna *c.* 7 km SE of San Emiliano, is probably similar in age to the San Emiliano Formation. However, it is sufficiently distinct lithologically to be regarded as a separate unit which is comparable to the Villanueva beds (Fig. 13).

Correlations have been made between the San Emiliano Formation and the succession of coal measures of Pendleian to Westphalian B age in the La Camocha mine near Gijón (Wagner 1959, 1962, 1970, Neves 1964). In contrast to the San Emiliano Formation the La Camocha succession has a more terrigenous aspect with thicker and more abundant coals and fewer limestone intercalations.

Strata of Westphalian A age are probably absent from most of the region of central and eastern Asturias which corresponded to a platform area, the Cantabrian Block (Radig 1962). The Carboniferous succession in this area has been described by Julivert (1961, 1967a, 1967b, Sjerp (1967), Wagner (1971a), García-Loygorri (1974) and Reuther (1977). García-Loygorri *(op. cit.)* has briefly described a possibly continuous succession from the Nalòn Valley in the southern part of the Central Asturian coalfield. However, more detailed investigations are necessary before the stratigraphic history of this area is completely understood.

A thin, condensed sequence of cherts and mudstones with limonitic and manganese nodules (the Ricacabiello Formation) overlies the Barcaliente Formation in South-Central Asturias. It seems likely that this sequence corresponds to the Valdeteja Formation which may have been restricted to the margins of the Cantabrian Block. The Ricacabiello Formation is overlain disconformably by a Westphalian B succession of clastics and carbonates (van Ginkel 1965).

The Yeadonian-Westphalian A sequences in northern Palencia and NE León are very different to their NW Leonian/Asturian correlatives. They are found in major nappe structures and in the underlying autochthon; a clear difference exists between these allochthonous and autochthonous successions (Wagner 1971b).

Strata of equivalent age to the San Emiliano Formation in the autochthon are the Perapertú and Carmen formations (Wagner 1971b). The Perapertú Formation is of Yeadonian to Westphalian A age; it consists of mudstones, limestones and carbonate debris flows. The formation overlies the Santa María Limestone, a thick carbonate succession equivalent to the Valdeteja Formation of northern León (Wagner 1971b).

The Carmen Formation is a flysch sequence tentatively dated as Westphalian A (Wagner 1971b); it unconformably overlies the Perapertú Formation in the autochthon. The Carmen Formation is also present in the nappe sequence where it cuts further down into the succession than in the autochthon. The Perapertú Formation is completely eliminated by the pre-Carmen unconformity and in places the underlying Santa María (Valdeteja) limestone has also been removed (Wagner 1971b).

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