THE JURASSIC SEDIMENTATION IN ASTURIAS (N SPAIN)

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TRABAJOS DE GEOLOGIA

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La serie jurásica de Asturias comporta dos tipos de secuencias sedimentarias superpuestas, separadas entre sí por una disconformidad. Cada una de ellas representa a su vez un modelo de sedimentación diferente. La secuencia inferior, de edad Hettangiense a Bajociense Inferior, es eminentemente carbonatada y margosa, comprendiendo las Fms. Gijón y Rodiles. Sus depósitos comenzaron a acumularse en llanuras micromareales carbonatado-evaporíticas, así como en *lagoons* restringidos y someros. Posteriormente, y debido al efecto de una etapa transgresiva, el ambiente de depósito evolucionó hacia una plataforma epicontinental parcialmente restringida y somera, que se fue haciendo progresivamente más inestable e irregular, a la vez que su fondo se enriquecía en oxígeno por aumento de la circulación de agua sobre el mismo al desintegrarse aquella; el proceso culminó finalmente en una emersión acompañada de intensa meteorización. La segunda secuencia, predominantemente siliciclástica, superpuesta a la anterior y de edad Dogger?-Kimmeridgiense, comienza por descargas de siliciclásticos gruesos que rellenan paleovalles y evolucionan luego a facies de abanicos aluviales (Fm. La Ñora), después de la colmatación de aquellos. Lateralmente hacia el E y NE, estas facies pasan a otras fluviales con cauces de alta sinuosidad (Fm. Vega). A continuación tiene lugar otro pequeño evento transgresivo, durante el cual se acumula la Fm. Tereñes, que comienza por facies litorales fangosas con descargas fluviales esporádicas, que pasan hacia arriba a otras de plataforma restringida de baja energía, o a un extenso *lagoon* con abundantes intervalos lumaquélicos. Finalmente, una nueva reactivación del área madre da lugar al depósito de pequeños deltas alargados de dominio fluvial (Fm. Lastres), que desembocan en un ambiente restringido similar al que reinaba durante el depósito de la Fm. Tereñes. Se destaca finalmente el potencial interés económico del estudio de esta sucesión sedimentaria.

Palabras clave: Jurásico, ciclos sedimentarios, facies, sabkhas, plataformas carbonatadas, abanicos aluviales, ambientes fluviales, deltas, icnofauna, lutitas negras.

The jurassic succession of Asturias is composed of two superposed sedimentary sequences bounded by a disconformity. Each one represents in turn a different sedimentation model. The lower sequence, Hettangian to Lower Bajocian in age, is mainly carbonated and marly, including the Gijón and Rodiles Fms. Their deposits were accumulated on carbonate-evaporite microtidal flats and shallow restricted lagoons, which go up to an epicontinental shallow platform, partially restricted that becomes progressively more irregular and unstable while more and more oxygen is reaching its floor. Finally an emersion with intensive weathering is produced. The upper sequence, mainly siliciclastic, overlying to the first one and Dogger?-Kimmeridgian in age, begins with thick coarse siliciclastic sediments, filling palaeovalleys which change up into alluvial fans (La Ñora Fm.). These deposits pass laterally, towards the E and NE, to high sinuosity fluvial facies (Vega Fm.). Then, another transgressive event occurs in which the muddy shoreline facies of the Tereñes Fm. are accumulated; this gives way upwards to a restricted low energy shelf or extensive lagoon with very frequent shell beds. Finally, a new reactivation in the source area causes the deposition of small fluvial-dominated elongate deltas (Lastres Fm.), which flow into a restricted environment similar to the previous one. The economic potential interest of this sedimentary succession is also detached.

Key words: Jurassic, sedimentary cycles, facies, sabkhas, carbonate platforms, alluvial fans, fluvial environments, deltas, ichnofauna, black-shales.

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INTRODUCTION

The best outcrops of the Jurassic sediments in Asturias are located on the sea cliffs between Gijón and Ribadesella localities (Fig. 1). For this reason, the present study is mainly focused on the coastal area.

In the last years, several authors have stated that the Lower Jurassic was a transgressive period in many areas of the world, a trend which led to a progressive increase in the extension of shallow epicontinental seas (Brandt 1985). In Asturias, early Jurassic sea transgressed over the Permo-Triassic sediments, which had been reduced previously to a peneplain.

STRATIGRAPHIC UNITS

The Jurassic of Asturias is divided into six units and several subunits from the bottom to the top (Fig. 2): Gijón Fm., Rodiles Fm. (Buerres and Santa Mera Members), La Ñora Fm., Vega Fm., Tereñes Fm. (Lower and Upper Members) and Lastres Fm.

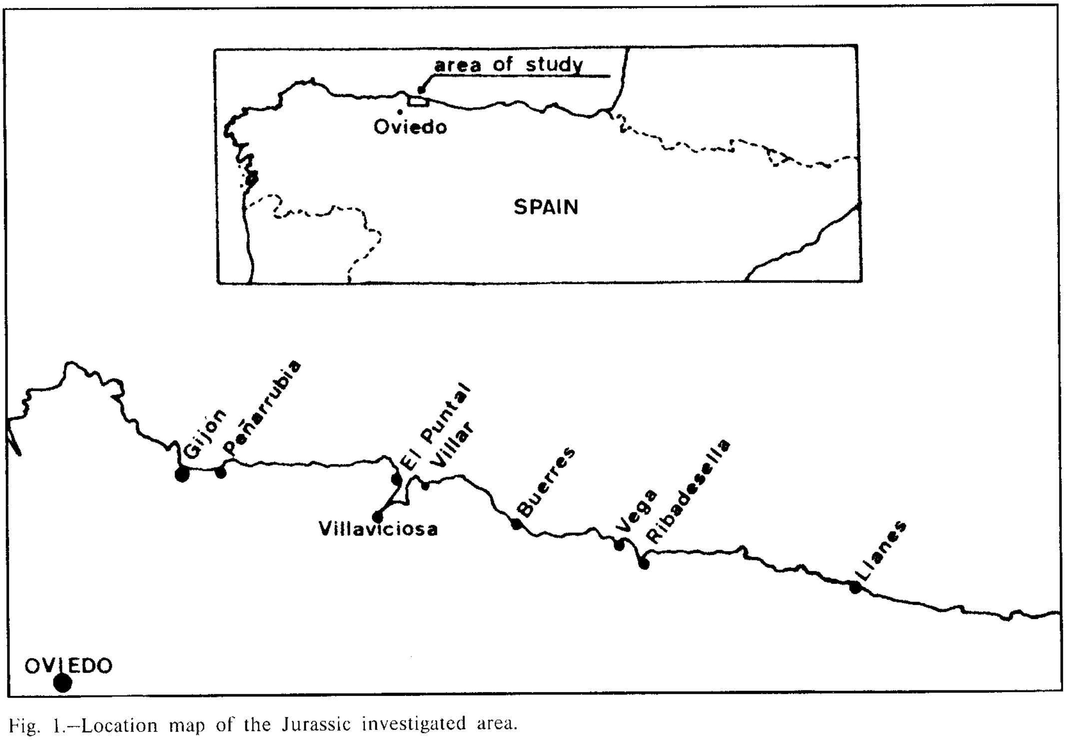
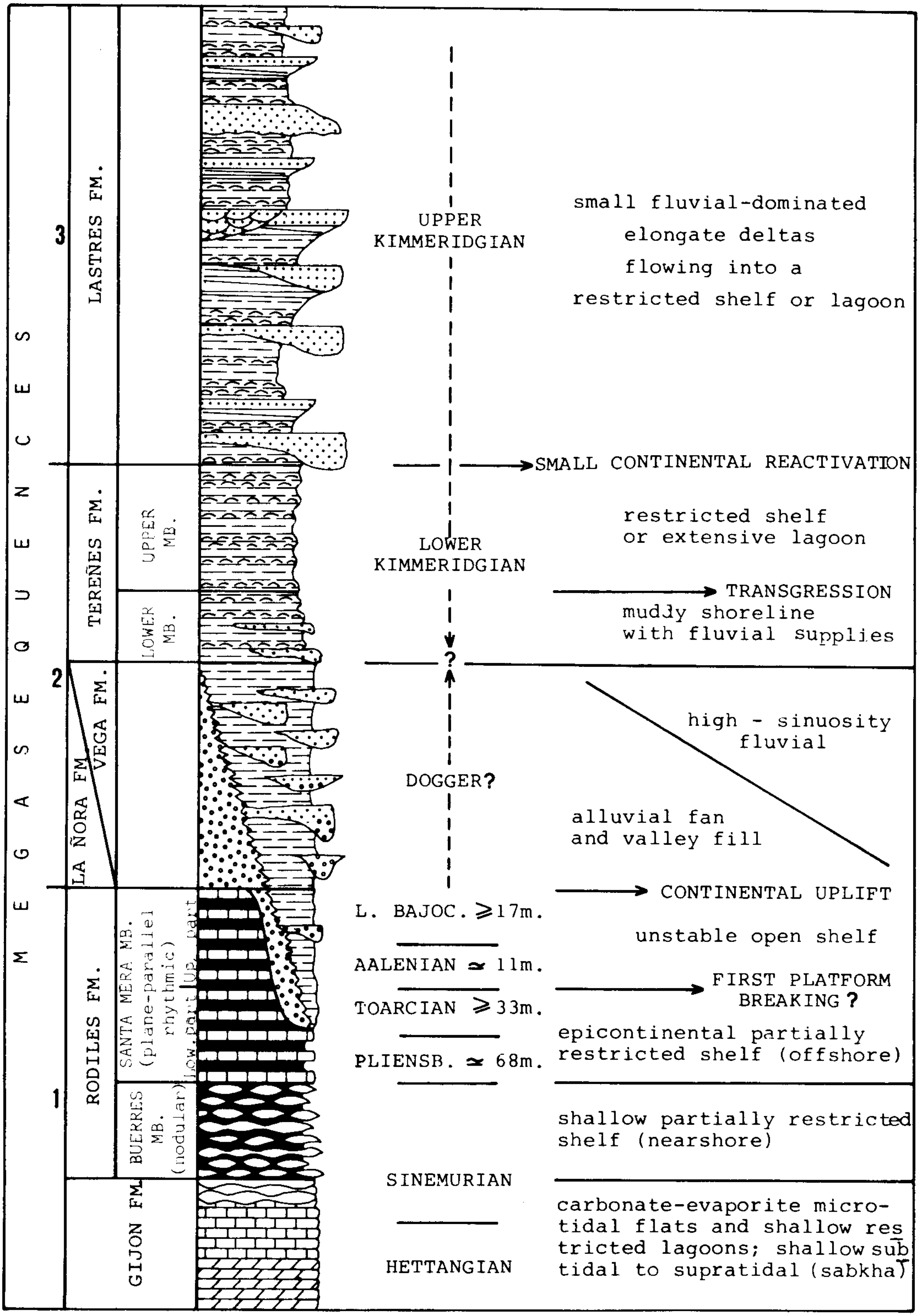


Fig. 1.–Location map of the Jurassic investigated area.

Fig. 2.–General lithological succession of Jurassic sediments in the sea cliffs between Gijón and Ribadesella (Asturias). Datation after Ramírez del Pozo (1969) and Suárez Vega (1974).


MEGASEQUENCES
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LASTRES FM.
TEREÑES FM.
UPPER MB.
LOWER MB.
LA ÑORA FM.
VEGA FM.
RODILES FM.
SANTA MERA MB. (plane-parallel rhythmic)
Low. part
Up. part
BUERRES MB. (nodular)
GIJON FM.
UPPER KIMMERIDGIAN
LOWER KIMMERIDGIAN
?
DOGGER?
L. BAJOC. ≥17m.
AALENIAN ≃ 11m.
TOARCIAN ≥33m.
PLIENSB. ≃ 68m.
SINEMURIAN
HETTANGIAN
small fluvial-dominated elongate deltas flowing into a restricted shelf or lagoon
SMALL CONTINENTAL REACTIVATION
restricted shelf or extensive lagoon
TRANSGRESSION
muddy shoreline with fluvial supplies
high - sinuosity fluvial
alluvial fan and valley fill
CONTINENTAL UPLIFT
unstable open shelf
FIRST PLATFORM BREAKING ?
epicontinental partially restricted shelf (offshore)
shallow partially restricted shelf (nearshore)
carbonate-evaporite micro-tidal flats and shallow restricted lagoons; shallow subtidal to supratidal (sabkha)

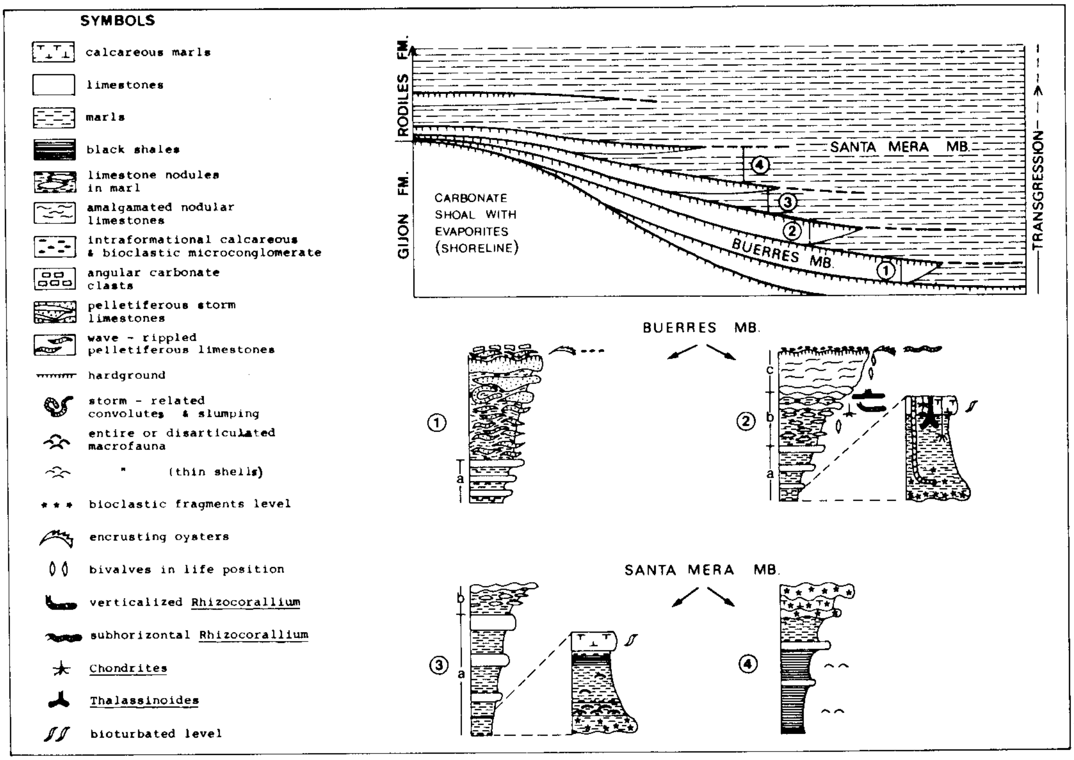


Fig. 3.—Sedimentation rate lowering and shoaling sequences in a transgressive succession (Hettangian to Toarcian of Asturias, N Spain).

Gijón Formation

The mainly calcareous, dolomitic and gypsiferous beds of Gijón Fm. (Hettangian-Lower Sinemurian) were deposited in shallow restricted lagoons and in carbonate-evaporite microtidal flat environments, ranging from shallow subtidal to supratidal (sabkha) facies. Often the conditions were unfavourable for the establishment of normal marine life; gastropod and bivalve shell beds are locally the most common macrofaunal remains. The Gijón Fm. consits of a superposition of cyclic deposits, which include several facies and sedimentary structures such as: micritic limestones, more or less dolomitized, localy with fenestral fabric, tepee structures 0,1-7 m in diameter, cryptalgal laminites, algal stromatolites forming small domes and ridges (Fig. 5a), dissoltion and collapse breccias (Fig. 5b), tepee breccias, ooid and bioclastic shoals and channels, desiccation cracks (Fig. 5c), ripple marks, storm reworked breccias and scarce trace fossils of *Planolites* sp. and *Thalassinoides* sp.

Rodiles Formation

The Rodiles Fm. (Upper Sinemurian-Lower Bajocian) is composed of marl-limestone rhythmic bedding, in which two members are differenciated: the lower one is the Buerres Mb. and the upper one is Santa Mera Mb. (Figs. 2 and 3).

The nodular Buerres Mb. exhibits a characteristic repetitive pattern, arranged in first and second order cyclic sequences reflecting periodic events (Valenzuela *et alt.* 1985). Storm deposits with hummocky-swaley cross stratification and parallel lamination associated to wave ripples, convolutions, slumps (García-Ramos *et alt.* 1986a) and reworked hardgrounds, are particulary frequent in the lower part of the Buerres Mb. (Figs. 5d, e). These deposits represent even shallower marine conditions than the remainder succession.

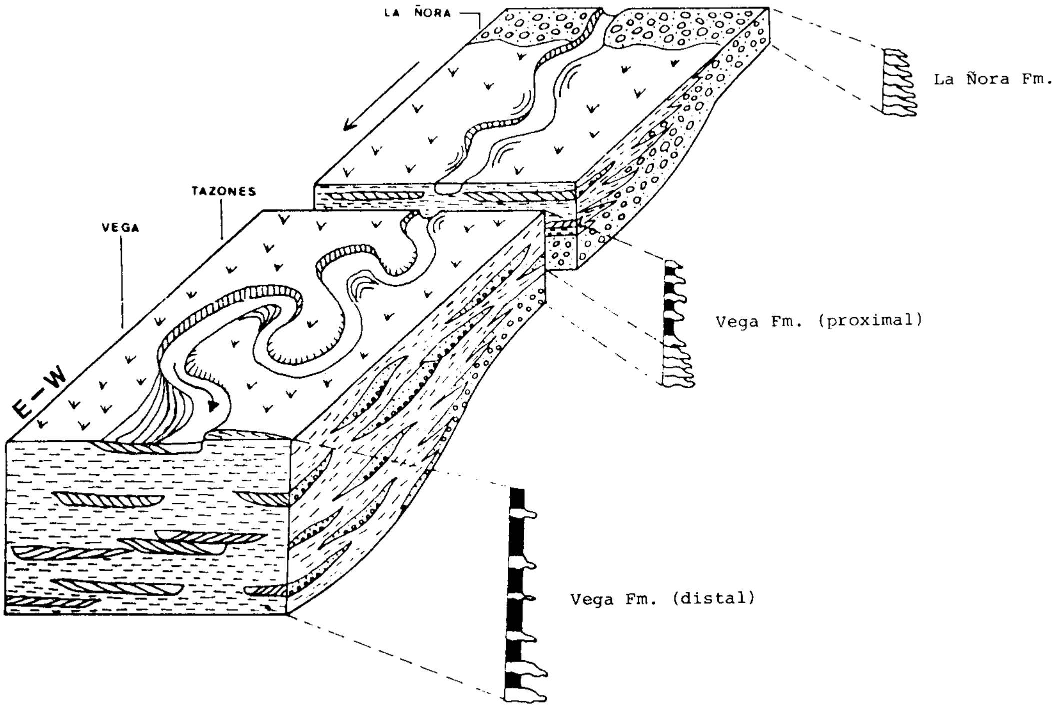


Fig. 4.–Environmental evolution and correlation between the La Ñora and Vega Fms. After Valenzuela (1979).

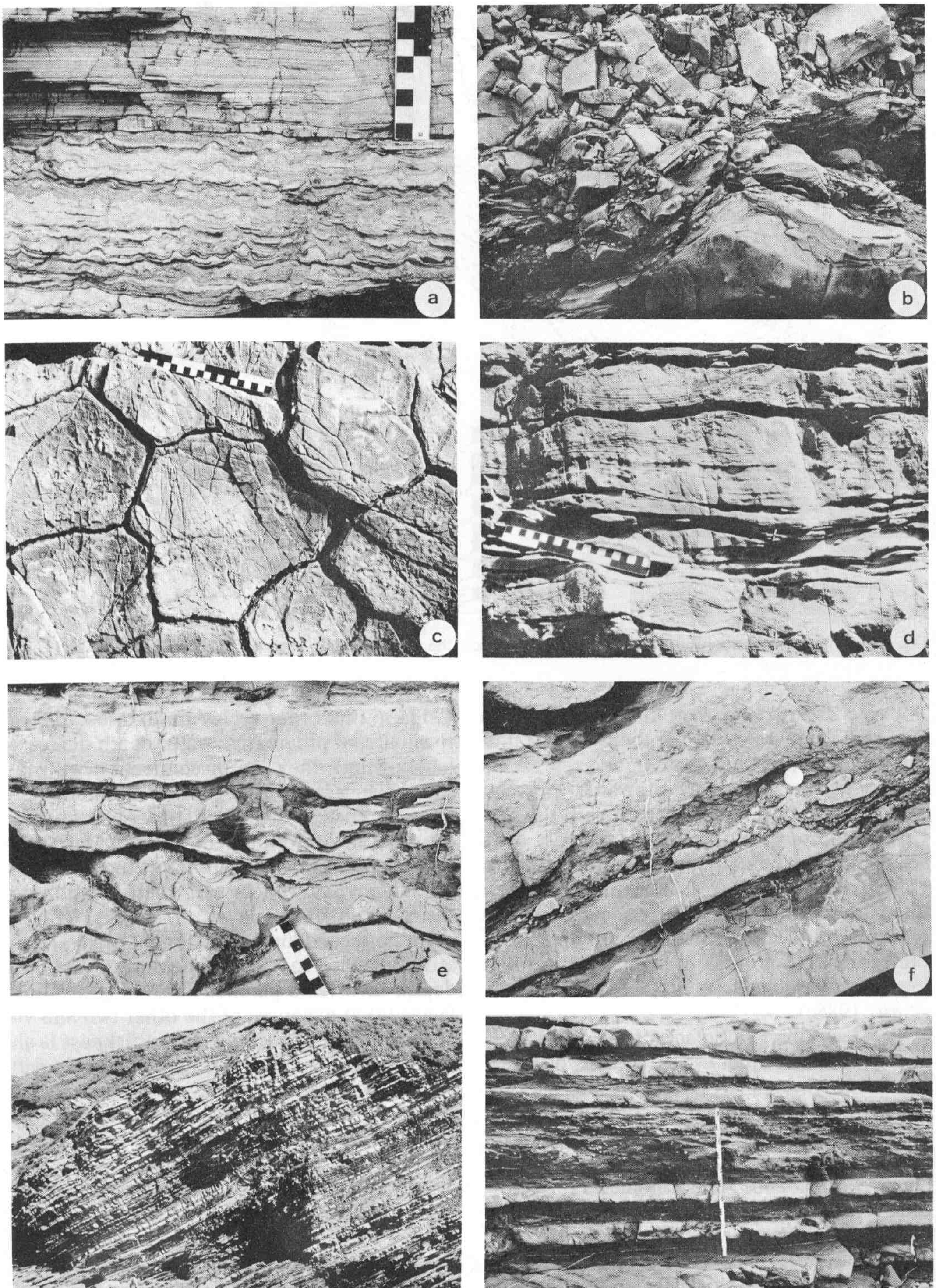
There are two types of first order cycles, from dm to m scale. One of them is typical of the lower part of the Member, and represents a regressive shallowing upwards process, which finishes on the upper part with the previous mentioned storm layers; the last ones are habitually overlained by a reworked hardground (Fig. 5f). The second one, in which there are up to three vertically superposed heterolithic lithofacies named (a), (b) and (c), is the result of a process of sedimentation rate lowering (Valenzuela *et alt.* 1985; Valenzuela *et alt.* 1986c).

The lower part (lithofacies «a») of this second type of first order cycles, consists of plane-parallel rhythmic marl-limestone alternations. Lithofacies (b) is similar in composition, but the limestones show a nodular aspect of different origin and age in the diagenesis (Valenzuela *et alt.* 1986b). The lithofacies (c) is formed of mudstone to packstone limestones, which are locally capped or amalgamated by condensation levels and hardgrounds, usually overlained by thin bioclastic and intraclastic microconglomeratic layers.

These first order cycles are likewise related to small and progressive water depth decrease (shallowing); they are in connection with local and successive fine grained sediment supplies, or eustatic sea level falls. Their characteristics and development are also probably related with small variations in the sea floor topography, as well as with their location on the shelf (Valenzuela *et alt.* 1986c).

In the second kind of first order cycles, a relative increase in the sedimentation rate and depth, involves a parallel thickening of lithofacies (a) at expenses of the other two and vice versa; then, the whole cycle thickness is also increased. On the other hand, the main part of the fine-grained muddy supplies is probably longitudinal to a shallow depositional trough bordering the carbonate shoal area.

These major shallowing-upward cycles are usually separated by sharp non-depositional surfaces, probably in relation with instantaneous relative sea-level rises. Therefore the main deposition occurs in aggradational episodes like to «Punctuated Aggradational Cycles», (PACs), of Goodwin and Anderson (1985).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The second order cycles, a few cm to 2 dm thickness, are specially evident in the lithofacies (a) of the previous ones, and usually consist of superposed marl-limestone couplets, which represent respectively alternations in bedload and suspension deposits. Sediment grain-size, sedimentary structures, trace and body fossils indicate a decreasing environmental energy towards the top of these small-scale cycles. Their origin was probably related to comparatively short periods of higher sedimentation rate with fine-grained terrigenous or bioclastic debris (i.e. storms, continental supplies) alternating with others of no-deposition or slow pelagic accumulation. Secondary diagenetic modifications sometimes make difficult the observation of the original sedimentary processes.

Trace fossil association in both cycles include: *Rhizocorallium jenense, Rhizocorallium irregulare, Chondrites* sp., *Planolites* sp., *Thalassinoides* sp., *Teichichnus* sp., *Conichnus* sp., *Diplocraterion* sp., borings and bivalve burrows (Valenzuela *et alt.* 1986a). Macrofauna is dominated by bivalves and brachiopods. Other groups represented are: echinoderm fragments, gastropods and rare ammonites.

The Santa Mera Mb. consists of marl-limestone alternations, mainly disposed in planoparallel beds (Figs. 5h and 6a, b), although some intervals of more irregular or nodular limestones similar to the lithofacies (b) of the Buerres Mb. are present.

It is possible to distinguish two subunits in it. The Lower Subunit (Pliensbachian-Toarcian) contains several beds of organic-rich black or bituminous shales (i.e. a part of *margaritatus* Zone), some of them including complete brachiopods and small tectonic microfissures, both of them filled with oil (i.e. *jamesoni* Zone); there is a relatively good lateral correlation, sometimes bed to bed, and progressive horizontal changes in thickness.

This Subunit is characterized by several trace fossil associations which include specimens of *Arenicolites* sp., *Conichnus* sp., *Chondrites* sp., (Fig. 6c), *Diplocraterion* sp., *Kulindrichnus* sp., *Planolites* sp., *Rhizocorallium* sp., *Teichichnus* sp., and *Thalassinoides* sp. (Fig. 6c). Macrofaunal content mainly includes: brachiopods, bivalves, ammonites, belemnites, crinoids and some gastropods, but there are not reef-builders.

First order shallowing-upward cyclic sequences of several meters in thickness and laterally persistent are common here (Fig. 5g); often, their lower part consists of black or bituminous shale/limestone alternations, which gradually evolve towards the upper cycle part that is formed by bioclastic-rich and irregular bedded marl/limestone couplets, with frequent erosive amalgamations and *Diplocraterion – Arenicolites* assemblages (i.e. transition of *margaritatus* to *spinatum* Zones). This Subunit was accumulated in several offshore subenvironments, all of them located below the wave-base on an epicontinental partially restricted platform, with slightly irregular bottom topography (Valenzuela *et alt.* 1986c).

The Upper Subunit (Aalenian-Lower Bajocian), although with similar external aspect (Fig. 6d), is differenciated of the previous one in the following aspects:

– Trace fossil associations include by the first time abundant *Zoophycos,* the occurrence of which represents the platform breaking and the end of the partially restricted conditions (García-Ramos *et alt.* 1986b).

– Occurrence here of the first sponge bioherms, mainly in the Aalenian *(concavum* Zone).

– More diversified fauna.

– Rapid lateral changes both in facies and thickness between different outcrops.

– Absence of the typical laminated black or bituminous shale facies.

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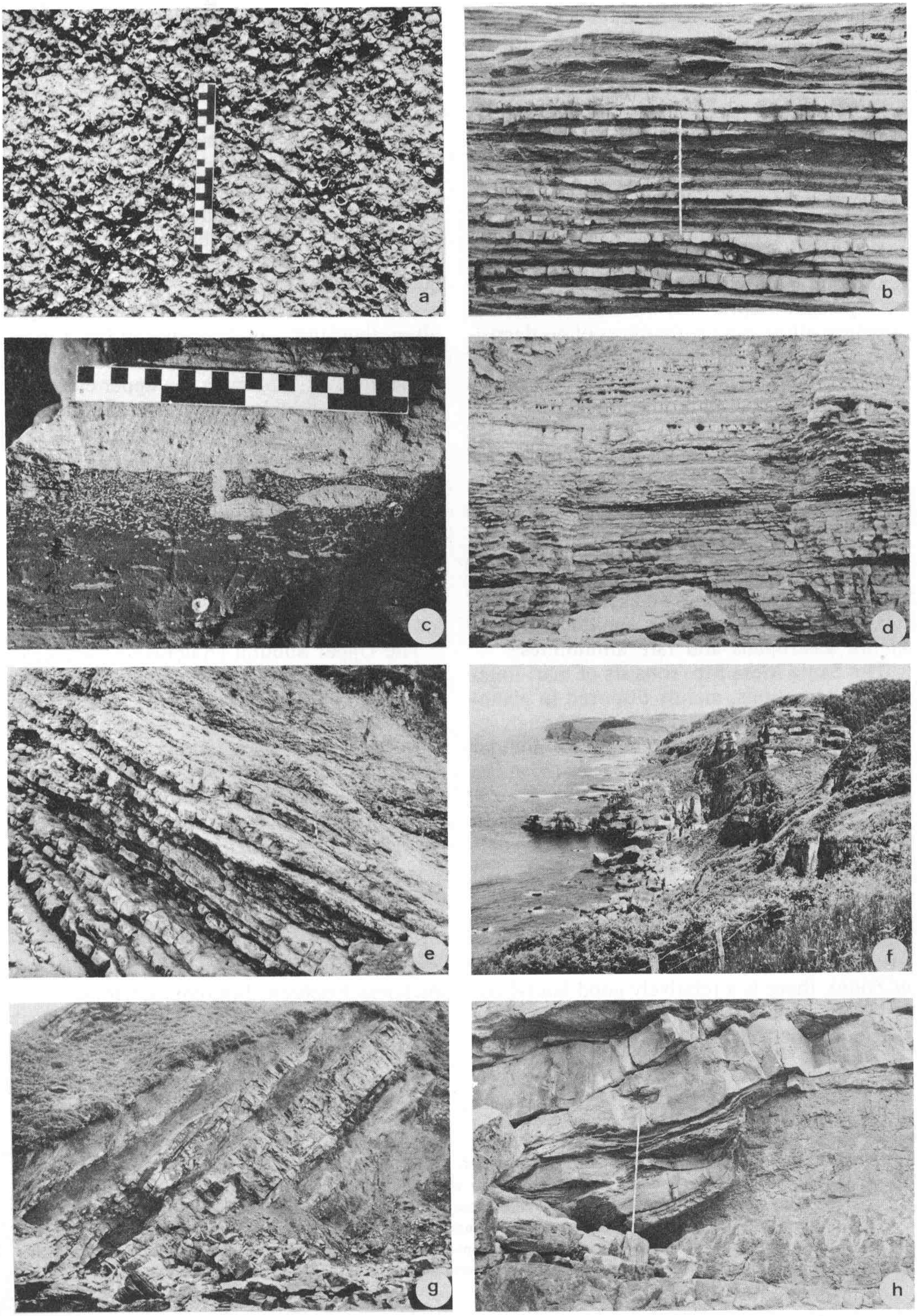
Fig. 5.–a) Algal stromatolites and laminated dolomicrites. Gijón Fm. b) Collapse and tepee breccias. Gijón Fm. c) Desiccation cracks on bedding surface. Gijón Fm. d) Storm deposits with hummocky cross-stratification and wave ripples. Buerres Mb. Villar section (Villaviciosa). e) Storm deposits and associated deformation structures. Buerres Mb. Villar section. f) Reworked hardground. Buerres Mb. Punta La Llastra section (Villaviciosa). g) First order shallowing upward cyclic sequence. Santa Mera Mb. (Lower Subunit). Playa de Vega section (Ribadesella). h) Brachiopod-rich beds in marl-limestone alternations. Santa Mera Mb. (Lower Subunit.). Punta La Llastra section, near Villar.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— Deeper penetration of trace fossils in the bottom sediment and apparent absence of *Diplocraterion* and *Arenicolites.*

This Upper Subunit was deposited in an unstable, well oxygenated and open platform with a progressively irregular bottom topography representing a prelude to the initial rifting phase (Valenzuela *et alt.* 1986c). The platform was connected to the South with the proto-Atlantic Hispanic Corridor (Tethys) by means of the Soria Strait.

Actually a detailed bed to bed and cyclic correlations between several outcrops of the Santa Mera and Buerres Mbs., as well as an investigation concerning the cycle formation processes, and the origin, age and classification of different nodular carbonates, are being carried out. The first conclusions on these aspects are recorded in Valenzuela *et alt.* (1986a, b, c) and García-Ramos *et alt.* (1986b).

Close to the top of the Rodiles Fm., clearly heterochronous local condensation marine levels and subaerial palaeosols are present (Fig. 6e), in relation with the emersion previous to the first coarse terrigenous input of the Vega and La Ñora Fms., both of which begin with the infill of a previously created palaeorelief.

La Ñora and Vega Formations

Over the disconformity, begins La Ñora Fm. (Fig. 6f), mainly composed of siliceous conglomerates with occassional sandy lenses, both arranged in amalgamated fining — upward cycles, belonging to an alluvial fan environment developed after the previous palaeovalleys were filled up. Laterally it passes to the E and NE into the fluvial facies of the Vega Fm. (Fig. 4). The accurate age of both siliciclastic formations is not known.

Detailed observations on the Vega Fm. sediments reveal the existence of several good examples of mixed-load high-sinuosity sandy stream deposits (Fig. 6g, h), characterized mainly by fining-upward cyclic arrangements, as well as lateral accretion structures typical of small fluvial point bars with often episodic discharge (Valenzuela 1979; García Ramos *et alt.* 1979). The interchannel areas are dominated by red mudstones, which often include caliche deposits, root traces, desiccation cracks, crevasse splay sediments, dinosaur tracks and invertebrate trace fossils such as: *Muensteria* sp., *Ancorichnus* sp. and *Planolites* sp.

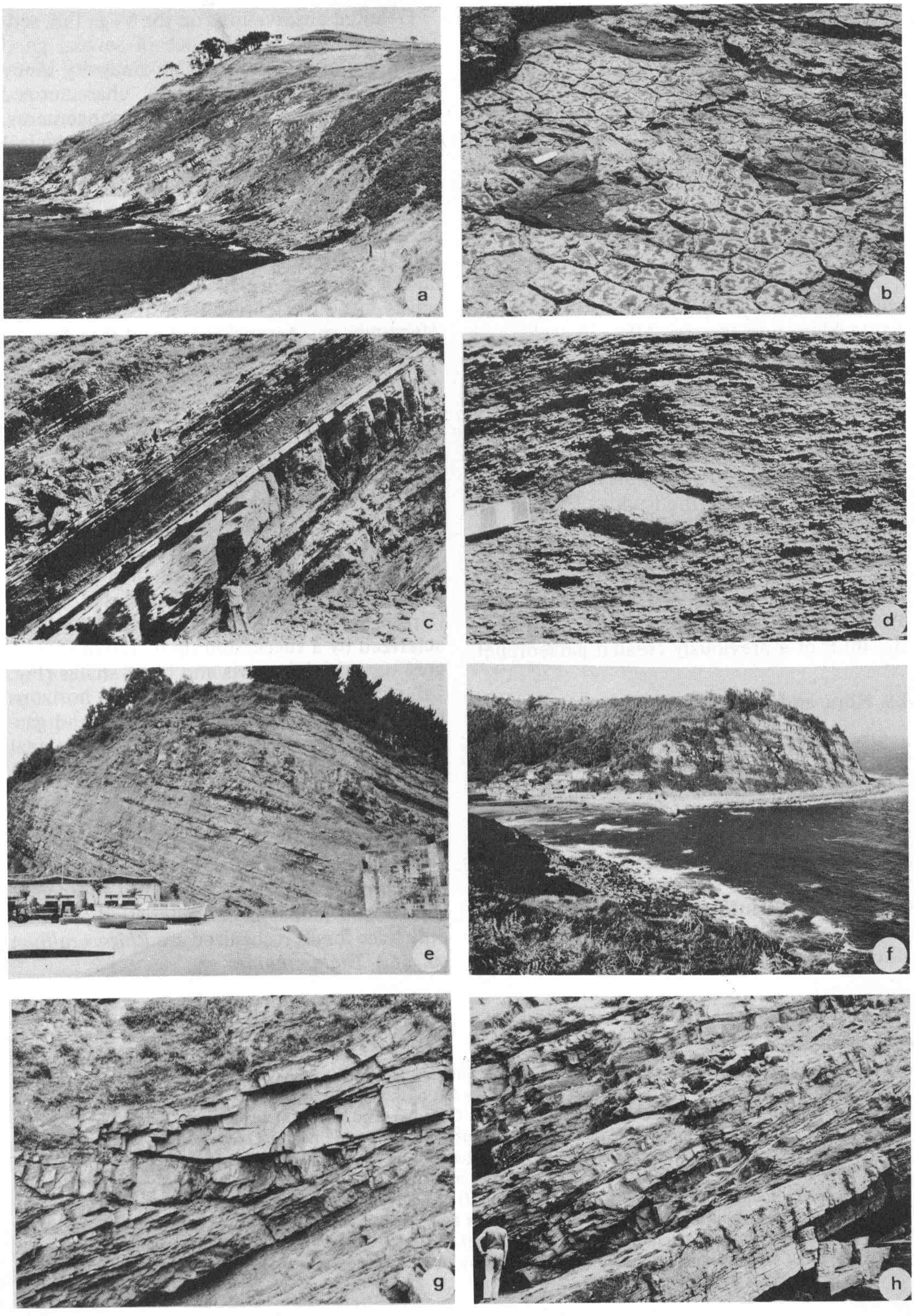
Tereñes Formation

The previous mostly red alluvial sediments grade upwards and distally to a dark grey muddy shoreline deposits, which include fluvial intercalations: Lower Mb. of the Tereñes Fm., which is never thicker than 20 m (Fig. 7b).

A subsequent transgressive stage is represented by the establishment of a restricted low energy shelf or extensive closed lagoon (Upper Mb. of the Tereñes Fm.), mainly characterized by a succession up to 120 m of dark grey organic-rich marls and black shales (Fig. 7a), with intercalations of limestone horizons and nodules, very abundant bivalve and gastropod shell beds (Fig. 7d), and occassional thin evaporitic layers (gypsum, halite).

Into the Upper Mb. the beds have a very good lateral correlation (Fig. 7c); the terrigenous content of deltaic influence suffers a gradual increase in a proximal or lateral direction to its present outcrops. The nearly absence of cephalopod faunas is characteristic here. The only trace fossils recognized are *Rhizocorallium* sp. and *Thalassinoides* sp.

Fig. 6.—a) Oil-filled brachiopods. Santa Mera Mb. (Lower Subunit.) Buerres section (Colunga). b) Typical marl-limestone alternations. Santa Mera Mb. (Lower Subunit). To left of the scale a small calcareous scour. Punta La Llastra section, Scale length = 2 m. c) Cross-section whith *Chondrites* and *Thalassinoides* burrows in the marl-limestone boundary. Note the upward increase in the bioturbation density. Punta La Llastra section. Santa Mera Mb. (Lower Subunit). d) General aspect of the Santa Mera Mb. (Upper Subunit). Santa Mera section (Villaviciosa). e) Marl-limestone alternations with superimposed condensation levels and subaerial paleosols in the boundary between Rodiles and Vega Fms. Buerres section. f) General view of the conglomeratic La Ñora Fm. Playa de Serín section (Gijón). g) Fluvial facies of the Vega Fm. showing channel sandstones between fine-grained red mudrocks. Note the lateral accretion in the upper sandstone body. Playa de Vega section (Ribadesella). h) Detail of a cutbank in a channel deposit covered by another channelized sandstone unit with lateral accretion. Vega Fm. Luces section (Colunga).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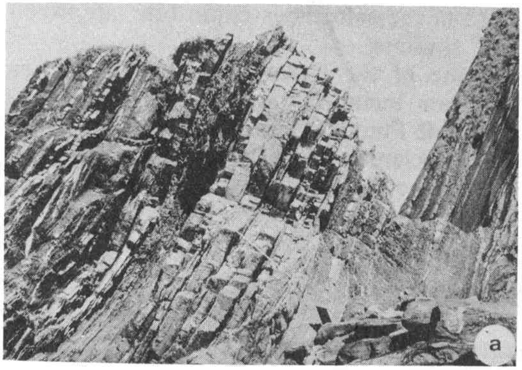

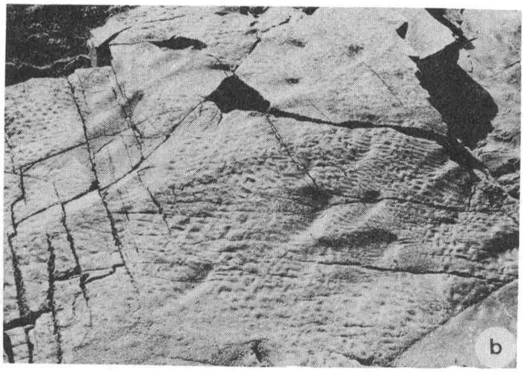

Fig. 8.—a) Coarsening-upward sequence of a small distributary-mouth bar. Deltaic facies of the Lastres Fm. Section near Ribadesella. Top to the left. b) Lunate megaripples with superimposed small-scale ripples. Deltaic facies of the Lastres Fm. Section between Tereñes and Ribadesella.

Lastres Formation

This unit, more than 450 m thick is represented by multiple intercalations of sandstones, marls and black shales with several intervals rich in calcareous shell-beds.

A new reactivation in the source area, or a lateral migration of the terrigenous entries, originates the emplacement of small fluvial-dominated deltaic systems. Remarkable examples of depositional sequences are shown in the deltaic model (Fig. 7e, f, g, h), including prodelta, distal bar, distributary mouth-bar (Fig. 8a, b), channel and levee, interdistributary bay, swamp, etc., as well as the typical delta abandonment facies.

Sedimentation was repeatedly interrupted by local or more widespread but small transgressive events recorded by laterally extensive shell beds like those of Tereñes Fm.

The more representative faunal assemblages are dominated here by some gastropods and abundant bivalves. Rare ammonoids allow to date this formation as Lower and Upper Kimmeridgian. Dinosaur tracks and trackways are here very frequent (García-Ramos and Valenzuela 1977a, b). Other trace fossils (García-Ramos and Valenzuela 1979) include: *Ophiomorpha* sp., *Thalassinoides* sp., *Rhizocorallium jenense, Rhizocorallium irregulare, Arenicolites* sp., *Diplocraterion* sp., *Teichichnus* sp., *Planolites* sp., *Pelecypodichnus* sp., *Gyrochorte* sp., *Monocraterion* sp. and *Palaeophycus* sp.

APPLICATIONS OF THE ASTURIAN JURASSIC STUDY

The economic interest of these jurassic deposits consist on the fact that some parts of them, as the black or bituminous shales of the Lower Subunit in the Santa Mera Mb., Upper Mb. of the Tereñes Fm., or the thick muddy intercalations into the Lastres Fm., may be potential source rocks for oil and gas below the actual marine offshore areas to N of Asturias (Bay of Biscay).

On the other hand, a great part of the ancient buildings of the coastal areas located

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Fig. 7.—a) General view of the Tereñes Fm. (Upper Mb.) The boundary with the Lastres Fm. is located to the left. Tereñes section (Ribadesella). b) Desiccation cracks and bipedal dinosaur tracks. Tereñes Fm. (Lower Mb). Tereñes section. c) Local aspect of the Tereñes Fm. (Upper Mb.). The thin laterally continuous limestone horizon separates a marly facies to the right and a shelly mudstone facies with calcareous nodules to the left. Tereñes section. d) Early diagenetic limestone nodule embedded in a shelly mudstone. Tereñes Fm. (Upper Mb.). Tereñes section. e) Contact between the Tereñes and Lastres Fms. Lastres section. f) General aspect of the deltaic Lastres Fm. Tazones section (Villaviciosa). g) Crevasse-channel with several filling episodes. Deltaic facies in the Lastres Fm. Section between Tereñes and Ribadesella localities. h) Channel with lateral accretion in the deltaic facies of the Lastres Fm. Section near Tereñes locality.

between Gijón and Ribadesella localities are built with jurassic stones, such as Gijón and Rodiles Fms. limestones, and very specially with the Lastres Fm. sandstones. In the Lower Mb. of the Tereñes Fm., and specially in the Lastres Fm. are frequent jet remains which were already used in Asturias for jewellery, several centuries ago. Moreover, some portions of the calcareous Gijón Fm., are excellent aquifers.

Some of the jurassic sections in the sea cliffs are included into the «Inventario Nacional de Puntos de Interés Geológico» (officially declared areas of main geological interest) by the «Instituto Geológico y Minero de España» (Agueda *et alt.*, 1985).

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