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CHARACTERISTICS AND REGIONAL IMPLICATIONS OF A BELT OF HIGH-ENERGY COASTAL DEPOSITS IN THE BARREMIAN OF PROVENCE (SE FRANCE)

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ABSTRACT

In the Barremian Orgon limestone of southern Provence, a belt of high-energy coastal deposits of regional extent can be traced over approximately 90 km along an east-west axis from the border of the Massif des Maures to Martigues.

In this belt, coarse-grained beach beds are closely associated with muddy protected shallow marine or intertidal deposits. Such an alternation is typical for a system of migrating carbonate spits and their protected lagoons, as observed in the Recent of the Persian Gulf.

The Barremian belt of coastal deposits seems not to coincide with an ancient regional shore line. It appears to be controlled by east-west striking structural trends, which have been active in Provence since the Late Jurassic.

The formation of this belt anticipates the most conspicuous tectonic event in this area during Cretaceous times – the Albian uplift, known in literature as "Isthme Durancien".

RÉSUMÉ

Un facies de sédiments côtiers à haute énergie et d'importance régionale a été reconnu en Provence méridionale, dans le "Orgon limestone", d'age barrêmien. Ce facies peut être suivi d'est en ouest sur à peu près 90 km, depuis la bordure du Massif des Maures jusqu'à Martigues.

Dans cette région, des formations de plage à grain grossier sont intimement associés à des vases déposées en milieu marin peu profond et protégé ou en milieu "intertidal". Une telle alternance est typique pour un système mouvant de pouliers calcaires et de lagunes qu'ils protègent, comme cela à été observé dans le Récent du Golfe Persique.

La bande de dépôts côtiers barrêmiens semble ne pas coincider avec une ancienne ligne de rivage d'ordre régional, mais semble plutôt être contrôlée par des influences structurales d'orientation est-ouest, dont l'activité a commencé en Provence à partir du Jurassique tardif. La formation de cette bande de dépôts côtiers précède le plus remarquable évènement tectonique des temps crétacés en cette région: le soulèvement albien, connu dans la littérature sous le nom d' "Isthme Durancien".

INTRODUCTION

Thick carbonate sequences of Barremian to Aptian age occur from the French Mediterranean coast, northwards along the outer margin of the Alps as far as the Helvetic nappes in Switzerland.

These limestones have often been referred to in literature as Urgonian. However, this name cannot be maintained as a stage, since the limestones are diachronous; in Provence, for example, they are of Barremian age in the south and Aptian in the north. The Lower Cretaceous Colloquium (1965, p. 159) has therefore abandoned the term Urgonian in its time-stratigraphic sense, but recommended its use as a facies name (urgonian, without capital initial letter, limited to limestones with *Toucasia* and their direct associates). A properly defined rock-stratigraphic subdivision of these Barremian to Aptian carbonates is still lacking and will, for the Provence area, be dealt with by J.P. Masse in his forthcoming thesis on the "Urgonian" of this region. In the present paper, the

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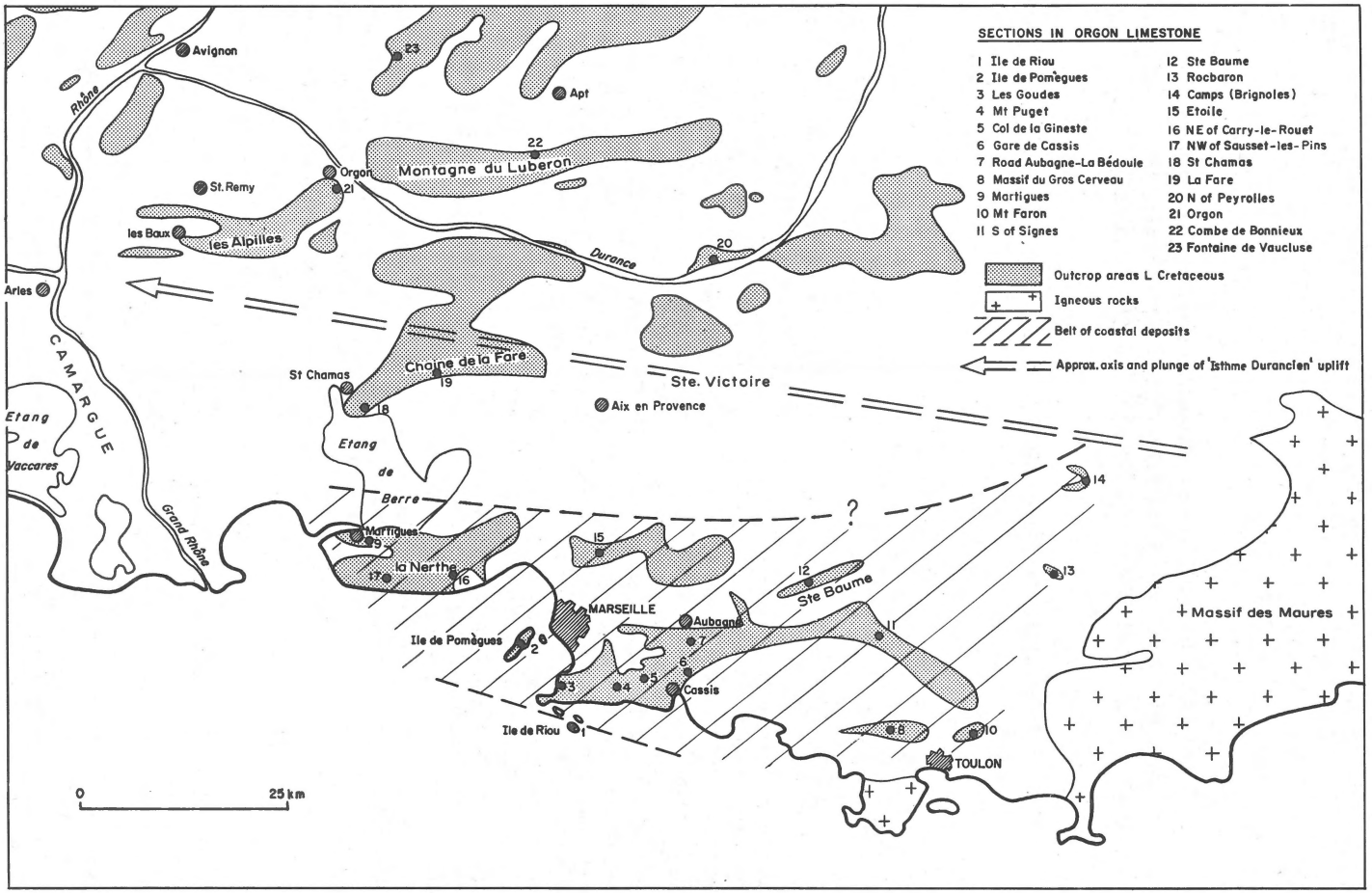
SECTIONS IN ORGON LIMESTONE
1 Ile de Riou
2 Ile de Pomègues
3 Les Goudes
4 Mt Puget
5 Col de la Gineste
6 Gare de Cassis
7 Road Aubagne-La Bédoule
8 Massif du Gros Cerveau
9 Martigues
10 Mt Faron
11 S of Signes
12 Ste Baume
13 Rocbaron
14 Camps (Brignoles)
15 Etoile
16 NE of Carry-le-Rouet
17 NW of Sausset-les-Pins
18 St Chamas
19 La Fare
20 N of Peyrolles
21 Orgon
22 Combe de Bonnieux
23 Fontaine de Vaucluse
Outcrop areas L. Cretaceous
Igneous rocks
Belt of coastal deposits
Approx. axis and plunge of 'Isthme Durancien' uplift
Avignon
Apt
Rhône
Montagne du Luberon
St. Remy
Orgon
les Baux
les Alpilles
Durance
Arles
CAMARGUE
Etang de Vaccares
Grand Rhône
St Chamas
Chaine de la Fare
Ste. Victoire
Aix en Provence
Etang de Berre
Martigues
la Nerthe
MARSEILLE
Aubagne
Ste Baume
Massif des Maures
Ile de Pomègues
Cassis
Ile de Riou
TOULON
0
25 km

Fig. 2
Alternation of coarse onkoidal and fine bioclastic grainstones with keystone vugs. Note inclined internal bedding. Beach beds, upper Orgon limestone, section Gorges du Gros Cerveau.

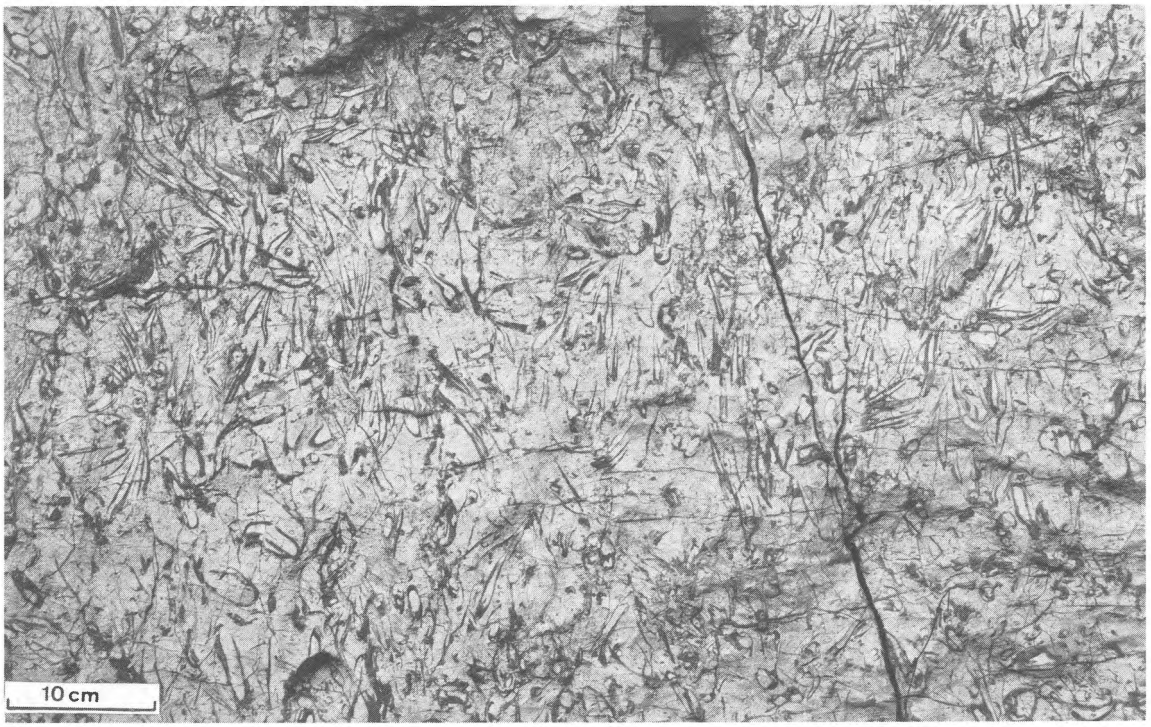

Fig. 3
Protected muddy deposits underlying beach beds shown in fig. 2. Note monopleurid rudists and thin-shelled (bysally attached) oysters in life position. Thin sections show abundant miliolid Foraminifera. (Photographed at about right angle to bedding)

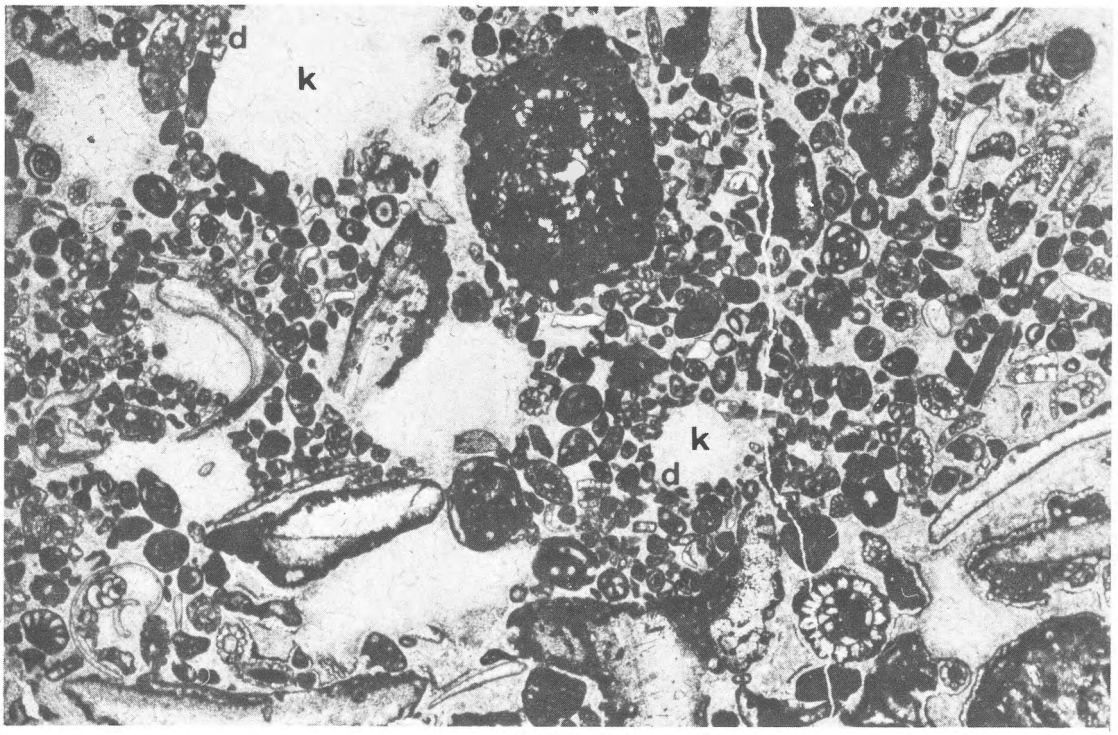

Fig. 4
Bioclastic grainstone with keystone vugs (k). Note that the vugs are considerably larger than surrounding particles. The structures were formed by trapped air bubbles and preserved by early lithification (drusy cement: d on photo). Particles are very varied but they are exotic and of no environmental significance. Beach beds, upper Orgon limestone, road Marseille-Cassis, (thin section, 10x).

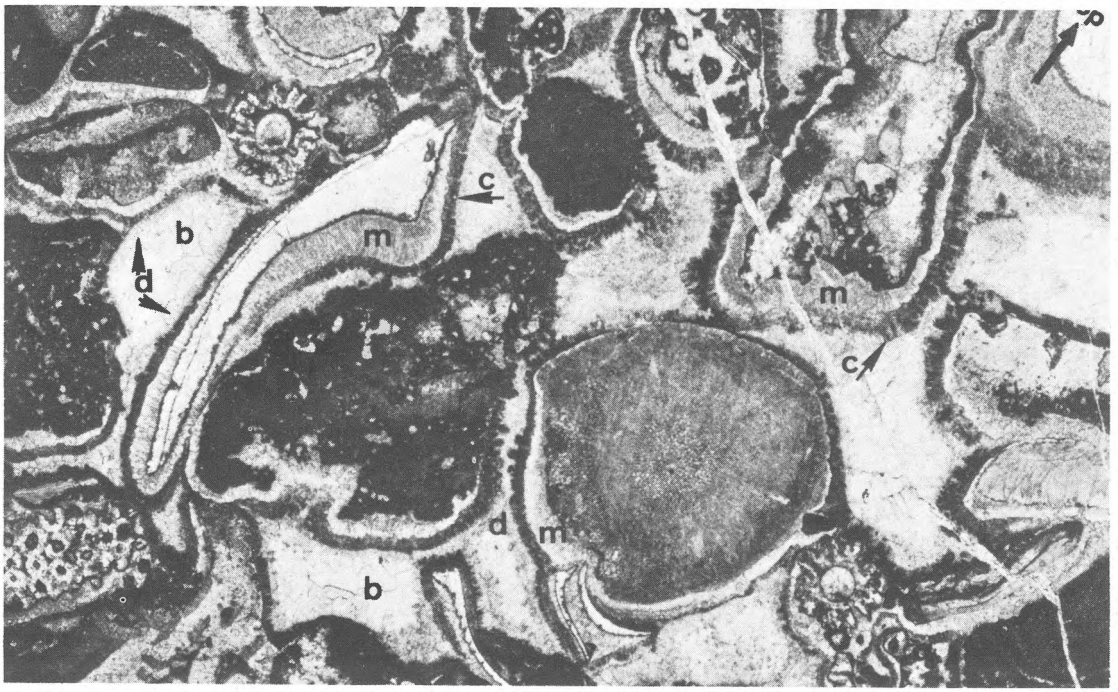

Fig. 5
Bioclastic grainstone with complex diagenetic history; the main features being: 1. microstalactitic druse formed in a system of intermittent wetting and drying (m), 2. corrosion of the druse by undersaturated pore wares (c), 3. infill of the remaining interparticle pore space by drusy cement (d) and blocky calcite (b). Beach beds, upper Orgon limestone, section Ile de Pomègues, (thin section, 10x).

informal rock-stratigraphic term "Orgon limestone" is used for the entire body of Barremian to Aptian carbonates (Orgon being the village near the classic outcrops where d'Orbigny defined the Urgonian in 1850).

In southern Provence (fig. 1), the Orgon limestone begins with bioclastic packstones and grainstones (terminology after Dunham, 1962), which are found overlying argillaceous limestones and marls. The bioclastic limestones pass up regressively into coral biostromes and bioherms and thence in the upper part of the Orgon limestone into very shallow marine to intertidal sediments with requieniid-rudist packstones-wackestones, occasional dolomites, birdseye mudstones, faecal-pellet packstones-grainstones and beds with various beach features.

Studies of Recent, high-energy carbonate coasts in the Persian Gulf, carried out by the Koninklijke/Shell Exploratie en Produktie Laboratorium, Rijswijk, The Netherlands, have provided an analogue with which the upper part of the Orgon limestone in southern Provence can be interpreted to be a spit-lagoon system. The sedimentary features, palaeogeographic position and structural control of this Barremian coastal belt are discussed below.

SEDIMENTARY FEATURES

A. Beach beds, spit-lagoon system

Beach beds can be defined as moderate- to high-energy coastal deposits with signs of intermittent emersion. Recent carbonate beaches are characterised by: low-angle accretion bedding; particle lineation; rapid vertical changes in grain size, sorting and grain type; and, as prime diagnostic features, indications of early lithification such as microstalactitic druse (Purser, 1969) and keystone vugs (Dunham, 1970).

In the upper part of the Orgon limestone in southern Provence, beach beds with these typical features occur frequently (figs. 2, 4, 5, 7). Often, these generally coarse-grained beach beds overlie muddy, low-energy deposits. Such contacts between high- and low-energy sediments are found repeatedly within a section (fig. 8).

The muddy sediments contain a low-diversity fauna, e.g. abundant miliolid Foraminifera, high-spired gastropods, requieniid/monopleurid rudists, etc. (fig. 3). Sedimentary structures include birdseyes, root marks and occasional stromatolites.

The association of beach beds and muddy, shallow marine to intertidal deposits is typical of the interplay between migrating spit systems and the muddy lagoons that they protect, as may be observed today in the Persian Gulf (figs. 6,9). Spits are formed by active longshore sediment transport and accumulation. The sediment consists of material produced elsewhere, and the particles themselves are therefore not indicative of the beach environment. The lagoonal sediments, on the other hand, frequently contain indigenous, low-diversity infaunal assemblages that are often indicative of restricted marine conditions (Murray, 1970).

The Barremian spit-lagoon system in the upper part of the Orgon limestone can be traced over a distance of approximately 90 km (see below and fig. 1), but because of limited outcrop control, the orientation of the spits cannot be determined.

B. Faecal-pellet limestones

In the uppermost Orgon limestone, the low-energy lagoonal deposits include beds with abundant *Favreina* (Masse, 1966). These faecal pellets resemble those produced by modern anomuran Crustacea, such as *Galathea* (Brönniman and Norton, 1960).

Faecal pellets produced by present-day infaunal-sediment feeders occur in many different low-energy environments at almost any depth, but they must stand a much higher chance of being preserved when they are lithified early. This appears to be the case in very shallow to intertidal environments, where the hardened faecal pellets winnow out and may form extensive layers of faecal-pellet sand (e.g. in the protected coastal environments of the Persian Gulf).

Additional evidence that the pellets of the Orgon limestone were lithified early, stems from the fact that they are not deformed by early compaction and are sometimes ooidally coated (fig. 10). This proves that they were sufficiently hard to be transported and coated in an environment of higher energy.

In southern Provence, the *Favreina* beds can be traced in the Orgon limestone over more than 1000 km^2, and the area involved coincides closely with that of the spit-lagoon system described here (compare our fig. 1 with Masse, 1966, fig. 2).

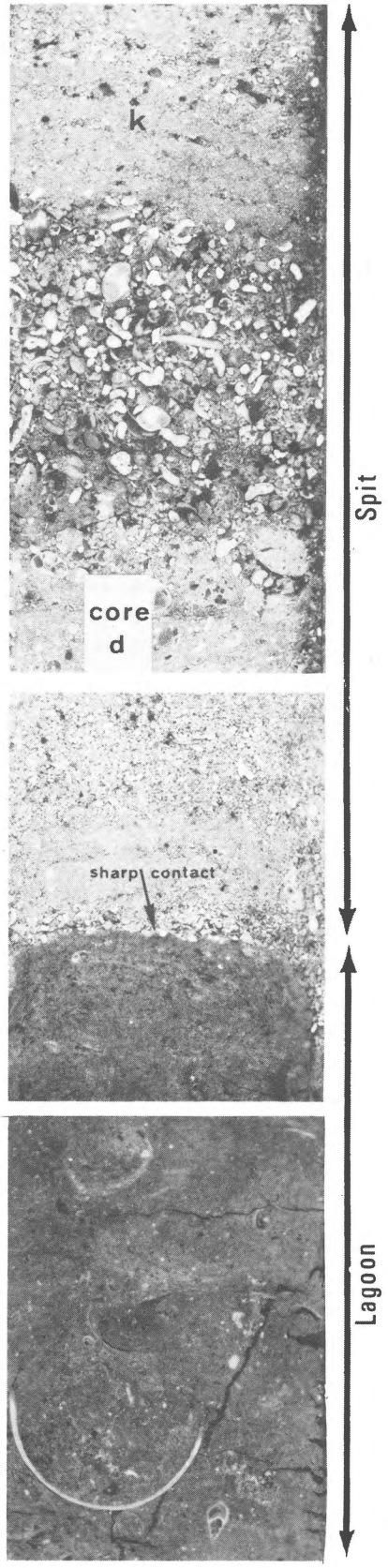

Fig. 7
Polished slab of Barremian beach bed showing similar features to those exhibited by top of core slab shown in fig. 6. Section Gorges du Gros Cerveau, (nat. size).

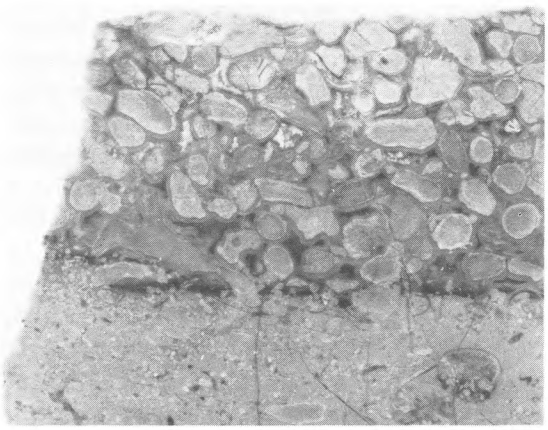

Fig. 8
Polished slab showing lagoonal sediments overlain (with a sharp contact) by split deposits. Upper Orgon Limestone, section Mont Faron, (nat. size).

Fig. 6
Split-forming beach beds consisting of alternating coarse and fine bioclasts, overlying muddy, protected lagoonal deposits. Note cross-bedding, keystone vugs (k) and abrupt changes in grain-size in spit, and miliolids and high-spired gastropods in lagoonal sediments. Figure shows parts of a Recent spit-lagoon sequence cored by Shinn on the coast of NE Qatar (Dakhira), Persian Gulf, (2/3 of nat. size).

PALAEOGEOGRAPHY, GEOMETRY AND CONTROL BY REGIONAL STRUCTURE (fig. 1)

The features described in the preceding paragraph are restricted to the southern part of a shelf which, during the Barremian, extended from the Marseille area as far north as Mont Ventoux, before dipping into a deeper area, the "Fosse Vocontienne".

The most northerly occurrence of the coastal spit-lagoon system has been observed for some 90 km along a mainly east-west line from Camps (Brignoles, section 14) over the Marseille area to Martigues (section 9). This northern border of the spit-lagoon system represents the maximum build-out of coastal sediments towards the north-northwest. To the east and to the west of this line, control is lost as the outcrops of the Orgon limestone disappear. In the east, the Mesozoic sediments lap onto the igneous rocks of the Massif des Maures, while in the west the Cretaceous rocks are covered by the sediments of the Rhône delta. The length of 90 km for the belt of coastal deposits is therefore a minimum estimate.

In the southern and eastern sections, the coastal sediments occupy progressively greater proportions of the upper Orgon limestone.

However, the east-west striking coastal belt does not seem to represent a regional Barremian shore line bordering a major land mass. The middle and upper parts of the southernmost outcrops of the Orgon limestone in the Marseille area (section 1, Ile de Riou) show a monotonous sequence of very shallow marine, lagoonal sediments containing abundant miliolid Foraminifera and requieniid/monopleurid rudists. No high-energy coastal deposits occur, and intertidal features are very rare (occasional birdseyes). We therefore assume that, in the Marseille area, the high-energy belt merely represents a system of banks and shoals on the Barremian inner shelf giving protection to a slightly deeper, low-energy lagoon further to the south – a situation comparable to the Great Pearl Bank and Khor al Bazam lagoon in the present Persian Gulf (K e n d a l l and S k i p w i t h, 1969).

Current knowledge of the continuation of Barremian deposits south of the Ile de Riou is based on subsurface data. Information from offshore wells published by the French government (see reference list) shows that the Lower Cretaceous cannot be traced far beneath the present Mediterranean sea. In wells Mistral-1 and Sirocco-1, Neogene sediments directly overlie Palaeozoic basement or igneous rocks.

P h i l i p (1970, p. 379, figs. 72, 74) reports very considerable siliciclastic influx from the south during Cenomanian and later Cretaceous cycles. This source land mass could be the "missing link" in the east-west alignment of Hercynian massifs, which can be observed from the Pyrenees to the Massif des Maures. P h i l i p (1970, p. 380) also suggests the existence of such a southern land mass during the Albian.

A somewhat different situation could perhaps be assumed for the eastern part of the belt, where the outcrops of the Orgon limestone fringing the Massif des Maures show a particularly extensive development of the spit-lagoon system. Here, it may represent a Barremian shore line along the western side of the massif, although it should be kept in mind, that, due to erosion, Orgon limestone deposits are absent on and around this massif.

In summary, the belt of coastal deposits reveals three main trends:

a. a widening of the belt to the east
b. an increasing abundance of coastal deposits within the Orgon limestone southwards to a line running roughly from Marseille to Toulon
c. a similar increase in abundance following the axis of the belt from west to east.

The combination of these three trends evidences a roughly east-west striking high (attached to the Massif des Maures?), plunging to the west.

According to the literature, east-west structures with a westward plunge have been active in Provence since the Late Jurassic and have controlled sedimentation patterns and tectonics from Cretaceous to Recent times (A u b o u i n and M e n n e s s i e r, 1963, p. 94). The most conspicuous event on this structural trend was the "Isthme Durancien" uplift in Albian times (B l a n c and G o u v e r n e t, 1967), which also had a westward axial plunge (fig. 1).

It is reasonable to infer that the origin of the structural trend that controlled the belt of coastal deposits, which predates the "Isthme Durancien" uplift, can probably be connected with this important tectonic event. Similar Early Cretaceous movements have been reported from Provence by B l a n c and G o u v e r n e t (1967).

The present palaeogeographic interpretation provides an interesting example demonstrating that a major belt of coastal deposits need not be directly

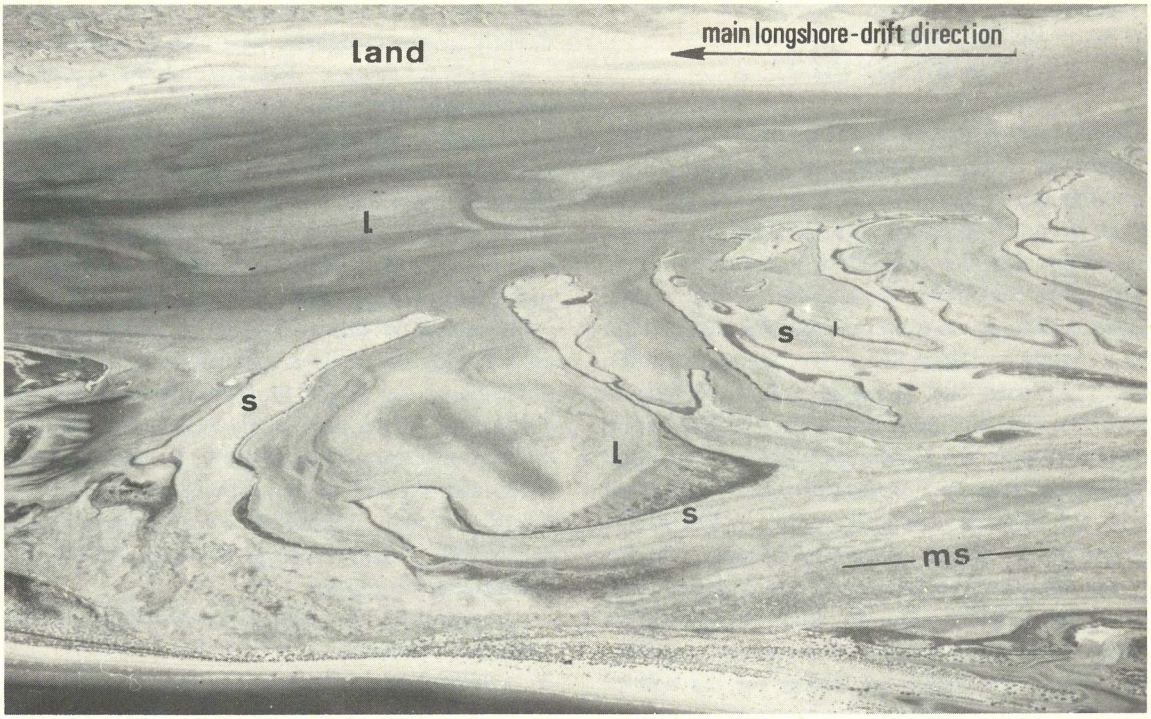

Fig. 9
Aerial photograph of a Recent spit-lagoon system (Umm al Qawain, Trucial Coast, Persian Gulf; length of coastline in foreground ± 1 km). Dark area at the bottom of the photograph is open sea; the spits (s) are creating protected lagoons with shallow-marine to supratidal conditions (lagoons: l on photo; the darker areas fringing the spits are stromatolitic algal mats; – ms – = axis of main spit).

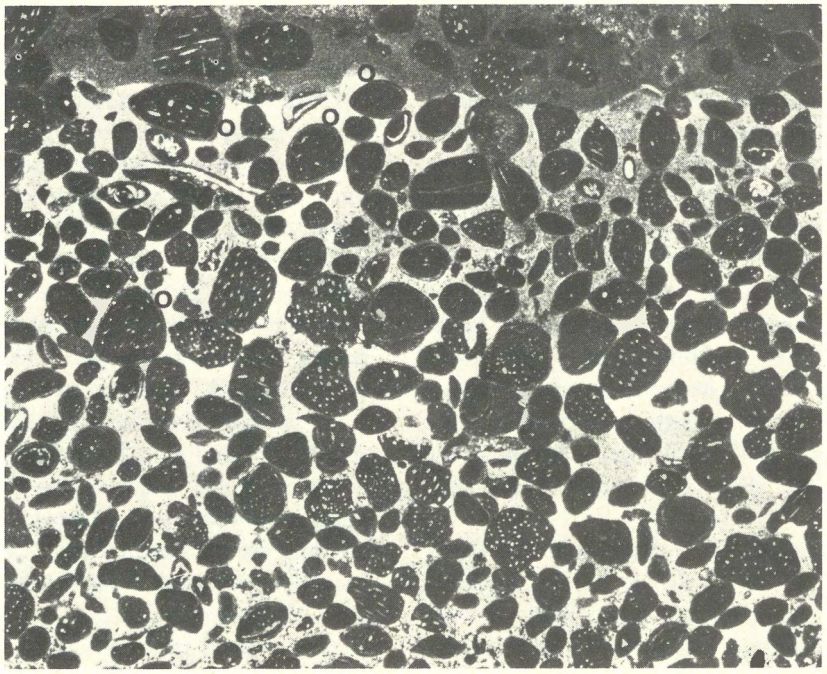

Fig. 10
Fabreina pack/grainstone. The faecal pellets are produced by certain Crustacea. The perforations within the pellets are produced by anatomical features within the gut of the animals. The faecal pellet is apparently stiff enough to preserve the canals (Elliot, 1962) before lithification. o = ooidal coatings. Upper Orgon limestone, section Gare de Cassis, (thin section, 10x).

connected with the shore line of a major land mass.

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