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THE *ORTHASPIDOCERAS UHLANDI* (OPPEL) RECORD AND THE MAXIMUM FLOODING IN THE EASTERN ALGARVE DURING THE LOWER KIMMERIDGIAN

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ABSTRACT

Detailed field work on Upper Jurassic outcrops in all of the eastern Algarve Basin, together with puntual observations, leads to the improvement of our knowledge of the Lower Kimmeridgian in the area. The sediments belong to the Peral Formation, the upper part of which shows buildup remains dominated by sponges and algae, and to the lowermost Jordana Fm. The previously favourable environment for ammonites therefore decreased.

The consistent ammonite record in the Divisum Zone (Uhlandi Subzone), within or directly above reefal complexes or related sediments, is taken as proof of an episodic improvement of the environment for cephalopods. This event coincides well with the transgressive interval in the eustatic curves proposed by the Exxon Group, and especially with the maximum flooding of the epicontinental eastern Algarve Basin during the uppermost Lower Kimmeridgian.

Keywords: Ammonites, Biostratigraphy, Eustasy, Upper Jurassic, Lower Kimmeridgian, Algarve, South Portugal.

RESUMEN

El análisis realizado en afloramientos del Jurásico Superior en toda la cuenca del Algarve Oriental, en perfiles y observaciones puntuales, ha permitido una significativa mejora del conocimiento del Kimmeridgense Inferior. Los sedimentos estudiados pertenecen a la Formación Peral, en cuya parte superior se desarrollan bioconstrucciones dominadas por esponjas y algas, así como a la parte basal de la Formación Jordana. En este contexto sedimentario disminuyeron, en términos generales, las condiciones favorables para los ammonites.

El registro de ammonites en la Zona Divisum (Subzona Uhlandi), en el interior o directamente sobre los complejos arrecifales y sedimentos relacionados, evidencia una mejora episódica de las condiciones de vida para los cefalópodos. Este evento coincide con el intervalo transgresivo reconocido para el Kimmeridgense Inferior en las curvas eustáticas propuestas por el Grupo Exxon, y especialmente con la máxima inundación de la cuenca epicontinental del Algarve Oriental durante la parte terminal del Kimmeridgense Inferior.

Palabras Clave: Ammonites, Bioestratigrafía, Eustatismo, Jurásico Superior, Kimmeridgense Inferior, Algarve, Sur de Portugal.

INTRODUCTION

During the Upper Jurassic, an epicontinental sea occupied the South of Portugal, where two platform systems can be distinguished on the present-day emerged lands. The first of these —a carbonate platform system— occupied the western part of the Algarve and can even be recognised in off-shore records. This system constitutes the "Southern Sector" as it is called by Marques & Olóriz (1989 a). The other carbonate-terrigenous shelf system occupied the eastern part of the Algarve. This system, known as the "Northern Sector" by Marques & Olóriz (op. cit.), has a marked Tethysian orientation. During the Upper Jurassic, sedimentation in this region, which stretches from Lagoa to Tavira, took the form of carbonate rhytmites in depressed areas and was para-reefal or reefal in raised sites. Sporadic increases of siliciclastic inputs are recorded.

This study is mainly concerned with the eastern Algarve (or Northern Sector of the Algarve) and its purpose is to characterise the upper part of the Lower Kimmeridgian, which is not yet well known. Numerous punctual observations were made and some sections were analysed where outcrop conditions were favourable (Fig. 1).

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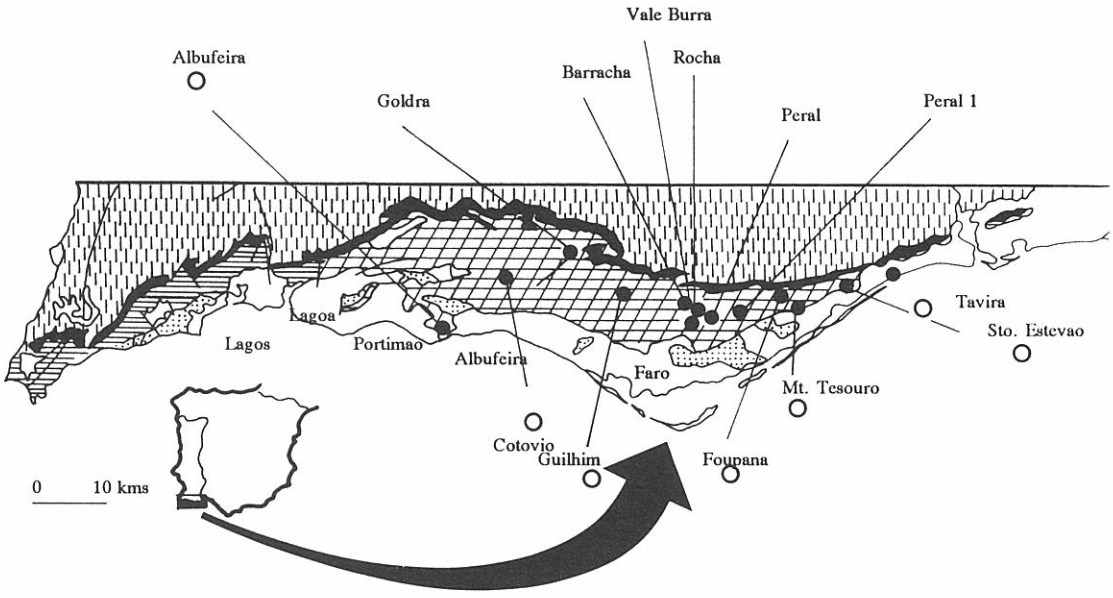


Figure 1. Location and geological sketch for exposed outcrops in the Algarve.
Paleozoic in vertical broken lines; black for the "grès de Silves"; horizontal ruling for carbonate platform systems; Eastern Algarve Basin in crossed framework; stippled for Cretaceous; Cenozoic in white. Studied sections in black circles; open circles for punctual observations.

STRATIGRAPHICAL FRAMEWORK

The materials studied here belong to the upper part of the Peral Fm. (Marques 1983) and partially to the Jordana Fm. (Marques, 1985). The time interval analyzed corresponds to the upper part of the Hypselocyclum Zone and to the Divisum Zone of the Lower Kimmeridgian, although significant ammonite data were only found in the Divisum Zone.

From a lithological point of view, the Peral Fm. is made up of compact clayey grey micritic limestones (mudstones-wackestones), which alternate with marly levels and are more or less rich in cephalopods. Small buildups are recorded rather irregularly and are dominated by sponges, with associated corals and algae. The bioconstructiones are more developed towards the top of the Peral Fm. According to the recent study by Ramalho (1988), these bioconstructions are dominated by stromatoliths, siliceous sponges, serpulids and benthic foraminifers, accompanied by sporadic bivalves, gastropods, echinoderms, brachiopods, corals, briozoa and ostracods. Ramalho (op. cit). also pointed out the existence of juvenile ammonite remains covered by algal encrustments in the reefal buildups and the micritic character of the filling sediments in the buildups. Marques & Olóriz (1989 b) recognised and dated the presence of ammonites in the upper levels of the Peral Fm. in both reefal and non-reefal facies.

The Jordana Fm. is made up of siliceous limestones with concretionary or interstratified chert, carbonate nodules and a component of detrital quartz which is at times significant. Levels were also recorded with silicified fossil remains (mainly benthic), which constitute grainstone-packestone horizons. Micritised internal surfaces are frequent in these horizons, as too are pisoliths, vadose ooliths and quartz grains.

In the sequential organization proposed for the eastern Algarve (Marques & Olóriz, 1989b), the interval studied here belongs to the *troisième séquence majeure* of *megaséquence* M_1 and, more precisely, to the interval located between discontinuities D_9 and D_{11}. In the general context of the South Iberian margin, the interval under analysis can be included in the S_1 *supersequence* and, more exactly, in the KII major sequence (Fig. 2) proposed by Marques *et al.* (1989, 1990). In the KII major sequence, the materials analyzed mainly correspond to the *Transgressive interval* which concludes with the *Condensed section* recorded at the top of the Lower Kimmeridgian in the third order eustatic cycle 4.4. proposed by Haq *et al.* (1987, 1888), Vail *et al.* (1987) and V. Wagoner *et al.* (1988).

The interpretation proposed here coincides well with the northward expansive record of Divisum Zone outcrops in the region (Fig. 3), which reveals the transgressive effect of the sea-level-rise event recorded towards the upper part of the Lower Kimmeridgian. This study once again demonstrates the high potentiality for correlation of the *Transgressive intervals,* as was already recognised by Marques *et al.* (1989, 1990). This is particularly true of the associated *condensed sections* and the *maximum flooding/downlap surfaces* even in sedimentary contexts, such as that examined here, where the ecosedimentary environments were not the most favourable for reliable correlations based on the continuous ammonite record (Fig. 2).

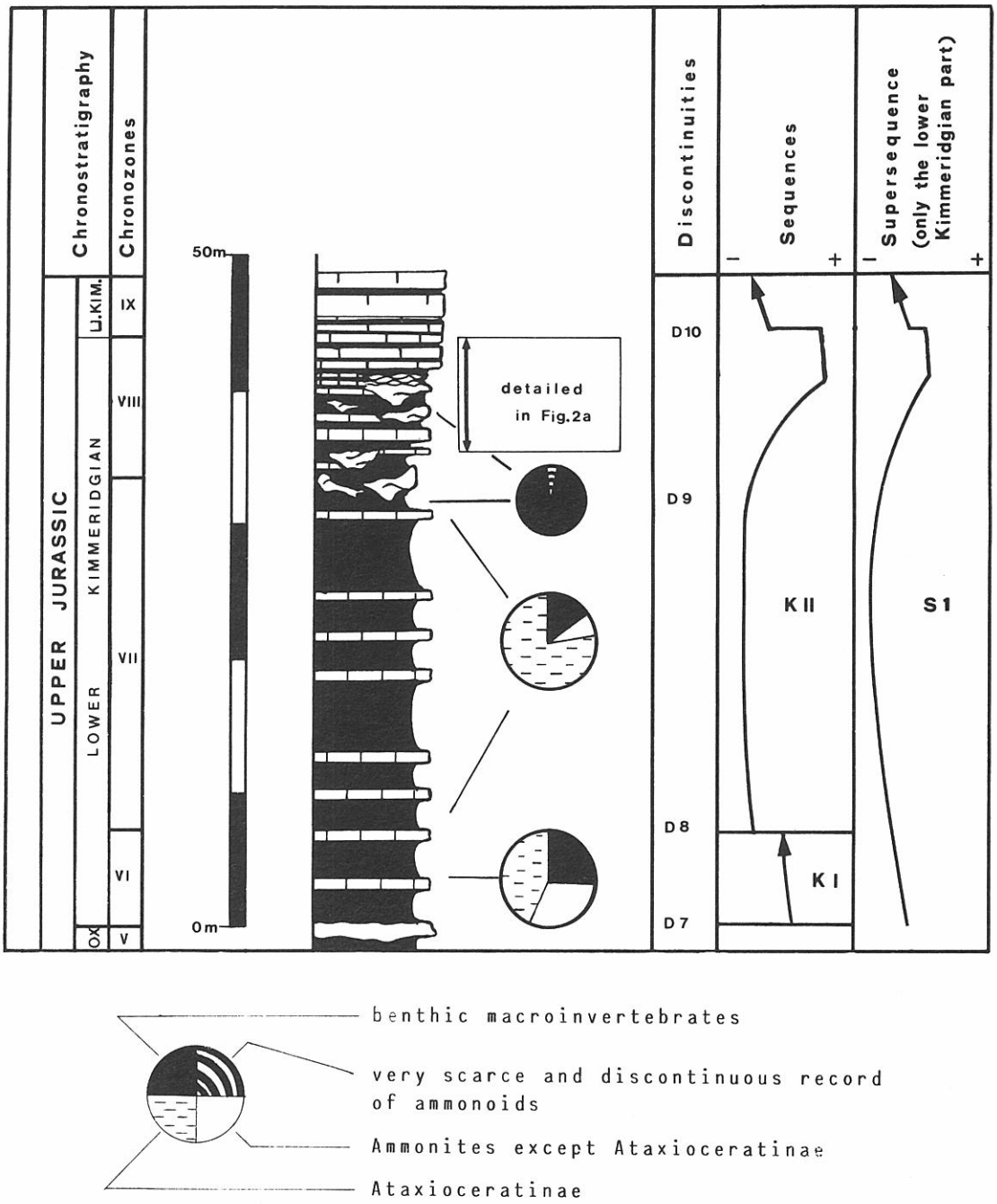


Figure 2. Synthetic profile of the Lower and lowermost Upper Kimmeridgian in the Eastern Algarve Basin. Discontinuities from Marques & Olóriz (1989b). Sequences and Supersequences adapted from Marques *et al.* (1990). Chronozones: V = Plánula; VI = Platynota, VII = Hypselocyclum, VIII = Divisum, IX = lower Acanthicum. Circular diagrams for faunal spectra belonging to chronozones VI-VII according to Marques & Olóriz (1989a); upper diagram shows the standar faunal composition from reefal and related facies.

FAUNAL ASSOCIATIONS AND BIOSTRATIGRAPHY

An especially detailed control was carried out on the macrofauna in these outcrops. The general distribution of ammonites in the Peral Fm. was made known by Marques (1983). The standard chronozones for the Oxfordian and Kimmeridgian in Submediterranean Europe have been recognised in the Peral Fm. The Platynota, Hypselocyclum and Divisum Zones were identified (Marques 1983, 1984) in the Lower Kimmeridgian. The associations are typical of Submediterranean regions, but the comparative scarcity of *Sutneria, Nebrodites, Mesosimoceras,* aspidoceratids and idoceratids is noteworthy. As can be deduced from Marques (op. cit.) the best known chronozone is the Platynota

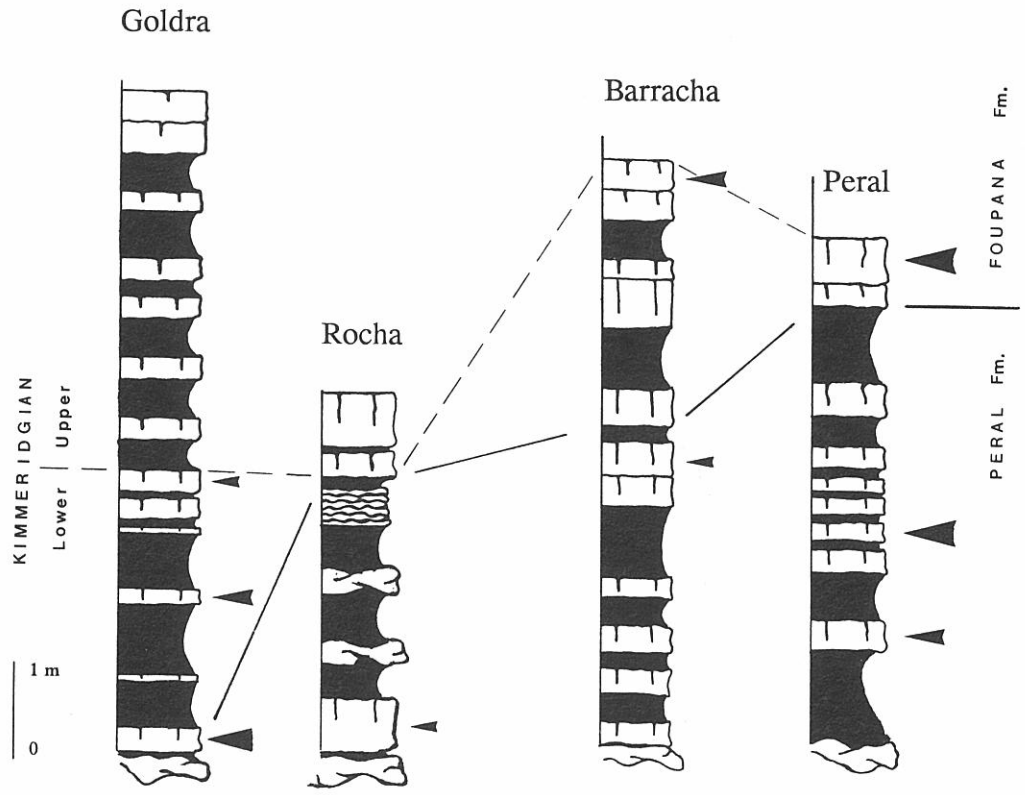


Fig. 2a. Selected sections of the uppermost Lower Kimmeridgian in the Eastern Algarve Basin. Increasing size of arrows shows, respectively, 1, 2, and more than 4 specimen of *Orthaspidoceras uhlandi* (Oppel). Solid line separating the Peral Fm. below from the Jordana Fm. above. Broken line for the recognized boundary between Lower and Upper Kimmeridgian. Note the relationship between reefal facies and normal facies with record of *Orthaspidoceras uhlandi* (Oppel).

Zone and the least well characterised is the Divisum Zone.

The composition of the associations in some significant levels was provided by Marques & Olóriz (1989a) and Olóriz *et al.* (1990). Fig. 2 shows the variation of faunal spectra. During the Lower Kimmeridgian macroinvertebrate associations are recorded in which ammonites are predominant among the vagile epibenthic-epipelagic fauna, whereas bivalves predominate in the benthos. Control of the associations recorded in parareefal sites shows that stromatoliths and sponges are predominant, but there are also algae, corals, serpulids, briozoa, echinoderms, brachipods and molluscs, ammonites being relatively rare in these sites. Consequently, the generalisation of a reefal-parareefal regime towards the upper part of the Hypselocyclum Zone correlates well with a marked decrease in ammonites, which also seems to bear certain relation to the increase in the detrital component in sedimentation and in the development of marly levels previously.

Cephalopods (ammonites and belemnites) are rare in the Jordana Fm., whereas bivalves and gastropods, accompanied by crinoids and corals, are frequent. This confirms that the development of the Jordana Fm. represents the beginning of the generalisation of carbonate platform sedimentation, whether bioconstructed or not, and the fall in the ammonite record.

The deviations observed in the composition of the macroinvertebrate faunal spectra around the boundary between the Peral and Jordana Fms. are worthy of special attention. Horizons were recorded in the upper levels of the Peral Fm. in which the predominance of cephalopds over other macroinvertebrates can be detected. This record, which is not transitional, reveals the abrupt inversion of the trend shown by the standard records known for the upper part of the Peral Fm. and it can at times be related to a change in the lithofacies. A detailed study of these levels shows that the most frequent ammonites belong to the genera *Crussoliceras, N. (Mesosimoceras), N. (Nebrodites)* and *Orthaspidoceras,* accompanied by *Taramelliceras* and rare specimens of *G. (Lingulaticeras)* and *Sutneria*. The most significant species in the association are *Crussoliceras sp. gr. divisum* (Quenstedt), *N. (Mesosimoceras) teres* (Neumayr), *N. (Nebrodites) agrigentinum* (Gemmellaro), *Taramelliceras sp. gr. trachynotum* (Oppel) and *Orthaspidoceras uhlandi* (Oppel). This association was widely recognised in the Algarve, between Lagoa and Tavira (Fig. 1), with a stratigraphic distribution clearly limited to the

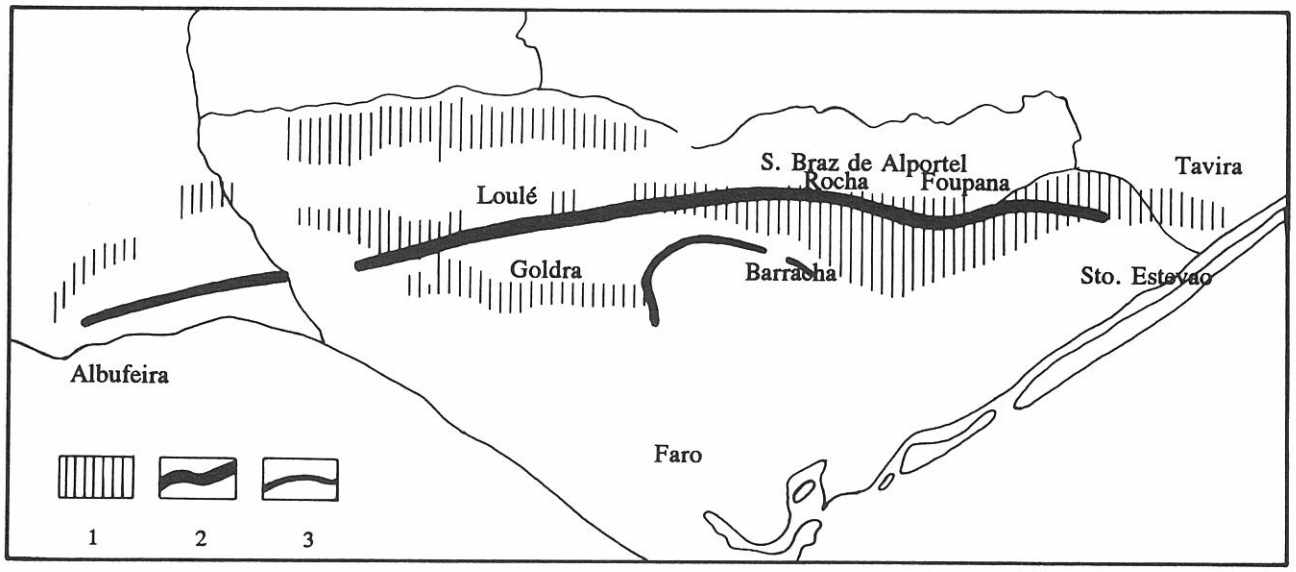
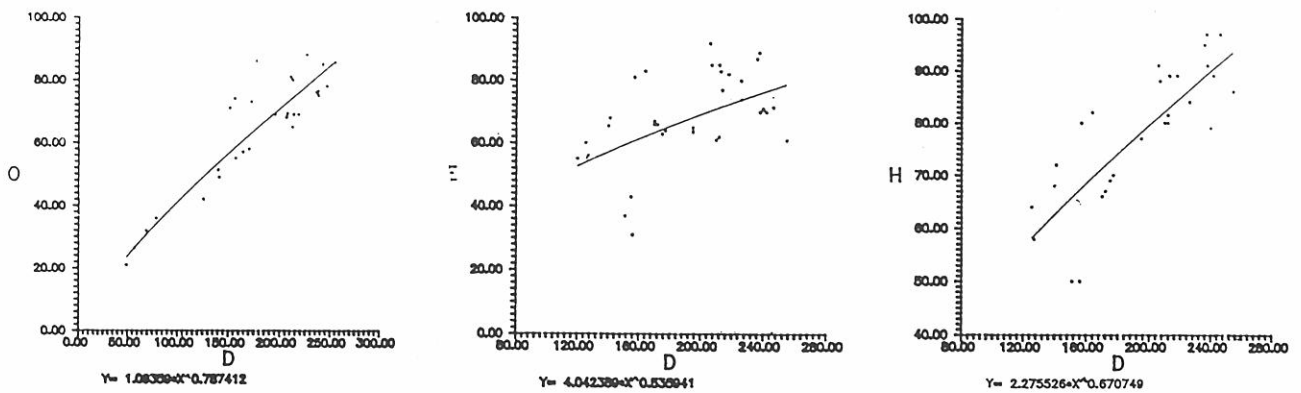


Figure 3. Distribution of Lower Kimmeridgian facies.
1 - Biohermal limestones from Cerro da Cabeça Fm.
2,3 - Northern limit for outcrops belonging to the Divisum Zone with record of *Orthaspidoceras uhlandi* (Oppel): 2, this paper, 3 from Marques (1983).



Dm	U/D	H/D	W/D	REGISTERED FORMS IN THE ALGARVE
50	m=M			MORE EVOLUTE
100	m~M (m≥M)			
120			m<M	(COMPARATIVELY
130		m<M (5%)		INVOLUTE TO
150	m>M (5%)			GREATER SIZES)
160		m<M	m<M	
200	m>M (10%)	m<M (10%)	m<M (5%)	INTERMEDIATE WHORL-SECTION
250	m>M (10%)	m<M	m<M (5%)	

m= Submediterranean , M= Mediterranean (from Checa, 1985)

Table 1. Upper: regression curves for U/D, W/D and H/D. Lower: concise comparison between Mediterranean, Submediterranean and Algarvian populations of *Orthaspidoceras uhlandi* (Oppel).

terminal part of the Peral Fm., and to transition levels and the basal part of the Jordana Fm.

On the basis of the data obtained, there would seem to be a relation between the development of significant (50-100 cm) marly intercalations and the impoverishment of the *Ortaspidoceras uhlandi* (Oppel) record. This was observed in the Goldra and Barracha profiles, whereas the opposite (less marls together with an increase in the *uhlandi* record) was found in the Peral profile (Fig. 2). A connection can likewise be made between the development of calcareous-marly calcareous horizons which interrupt the parareefal facies and the first-appearance-datum of *Orthaspidoceras uhlandi* (Oppel), as can be observed in the Goldra, Peral and Rocha profiles (Fig. 2).

According to the information obtained, a non-basal interval can be recognised in the Divisum Zone, in which *Orthaspidoceras uhlandi* (Oppel) is a characteristic species. This interval can be correlated with the Uhlandi Subzone proposed by Olóriz (1978) for the central Subbetic in southern Spain. Among the ammonites collected, a special study was carried out of the populations of *Orthaspidoceras uhlandi* (Oppel), which had previously been considered scarce and was only occasionally recorded in the eastern Algarve (Marques 1983, 1984). The new biostratigraphic information significantly improved the previous one obtained by Marques & Olóriz (1989a, b).

ORTHASPIDOCERAS UHLANDI (OPPEL) POPULATIONS IN THE EASTERN ALGARVE

Orthaspidoceras uhlandi (Oppel) is probably one of the most easily identified species among all the Upper Jurassic fauna. It is characterised by a voluminous shell sculptured with a row of prominent lateral tubercles and the development of ribs in the ventral area. The only other morphologically similar species are *Aspidoceras rafaeli* (Oppel) and *Simaspidoceras irregulare* Dacque. The Oppel species develops two rows of tubercles in the adult stage and its age is terminal Kimmeridgian-Lower Tithonian. The Dacque species, which is very scarce in the western Tethys, presents a very typical polygonal whorl section with some alternation of latero-ventral tuberculations and its lateral tubercles remain on the umbilical edge during all of the ontogenetic development.

For a detailed study of *Orthaspidoceras uhlandi* (Oppel) the reader is referred to the most recent revision of kimmeridgian aspidoceratids with Mediterranean affinities (Checa, 1985). Our subsequent comments are restricted to a comparative study of the populations in the South of Portugal.

Some 50 specimens and fragments of *Osthaspidoceras uhlandi* (Oppel) were analyzed from the collected material. In many cases these were large size specimens (frequently » 180 mm), with strong, coarse sculpture, made up of a row of large tubercles towards the middle of the flank, connected to spaced ribs, which are partially eroded to varying degrees due to the effects of differential preservation.

The number of tubercles per whorl was reliably controlled in 15 specimens of diameters between 120 and 255 mm. The following comments are based on a comparison with the material studied by Olóriz (1978) and Checa (1985):

The data obtained indicate that between 120 and 140 mm the forms from the Algarve are similar to those of the Betic Cordillera, with from 6 to 8 tubercles per half whorl, perhaps with more restricted variability between 7 and 8 tubercles, although 9 tubercles per half worl were observed in one specimen of 125 mm; between 140 and 160 mm the Portuguese forms generally develop 6 tubercles per half whorl (although only a few specimens were studied and in one of them 8 tubercles were found at 158 mm), while in the Subbetic forms the spectrum of variation, although wide (between 4 and 9 tubercles), generally seems to be 6-7 tubercles; between 180 and 200 mm the number of tubercles per half whorl in the Algarve forms is similar to that of the Subbetic forms (between 5 and 7), and one specimen was even observed which coincides with the cases of dense tuberculation (9 tubercles) found in the South of Spain; at more than 200 mm the Subbetic forms develop between 7 and 8 tubercles per half whorl, as do the German forms, which present a wider spectrum of tuberculation density (5 to 8 elements), while the Portuguese forms seem to develop between 6 and 7 tubercles per half whorl.

According to the foregoing, the Portuguese forms, when compared to the Subbetic forms, frequently reach a considerable size and develop a similar density of tubercles, although their range of variability is lesser and they present less frequent deviations as regards the most representative values.

A representation is given in Table 1 of the values obtained for coiling (umbilicus), width and height of the whorl. Comparison with Mediterranean (mainly Subbetic) and Submediterranean (Submediterranean Europe) populations was carried out following the parametral data provided by Checa (1985). The following observations are relevant:

— The Algarve specimens are more globulous and present a whorl height which is intermediate between those normal for Mediterranean and Submediterranean populations. This fact is particularly clear around 200 mm, which is the size at which the Mediterranean and Submediterranean forms are most different.

— Coiling is practically equivalent in the Mediterranean and Submediterranean populations between 50 and 100 mm, although at this size the populations of the South of Portugal are more evolute.

— At over 100 mm the Portuguese populations tend to develop more involute shells, which are therefore more similar to those of the Mediterranean forms.

— Overall the most obvious parametral differences between the forms studied here and the Mediterra-

PLATE 1
Figure 1. *Orthaspidoceras uhlandi* (Oppel).
PER-3. Vista lateral derecha (x0.8)
Peral. Zona Divisum, subzona *Uhlandi.*

nean and Submediterranean forms are found around 200 mm.

CONCLUSIONS

1) This study permits a better characterisation of the top of the Lower Kimmeridgian in the eastern Algarve (South of Portugal), where an interval was recognised in which *Orthaspidoceras uhlandi* (Oppel) is a characteristic species. This interval is therefore correlatable with the Uhlandi Subzone recognised in the central Subbetic (South of Spain).

2) *Orthaspidoceras uhlandi* (Oppel) is represented in the South of Portugal by specimens which normally reach large size, which develop globulous whorls and which reach comparatively more involute morphologies during ontogeny. The similarity of the Portuguese forms with those of the Subbetic and Southern Europe is variable throughout all of the ontogenetic development.

3) In the southwest margin of Iberia, except in those areas subjected to carbonate platform systems, the interval studied here (Hypselocyclum Zone p.p.-Divisum Zone) allows the recognition of a significant fluctuation in the macroinvertebrate associations of the Divisum Zone (Uhlandi Subzone). This fluctuation gives rise to the predominance of cephalopods, whose record had begun to decrease in the course of the Hypselocyclum Zone.

4) The recovery of the cephalopds coincides with changes in sedimentation, which on the whole presents a decrease in marly levels and even, at times, the development of condensed levels which can sporadically interrupt and/or crown the bioconstructions of the upper part of the Peral Fm.

5) The geographical distribution of the outcrops studied here shows a generalised extension of the sedimentation correspondign to the Divisum Zone (Uhlandi Subzone), in the Eastern Algarve. The correlation of this distribution with the proposal of a sea-level-rise event by the Exxon Group takes on special interest. Consequently, the *Orthaspidoceras uhlandi* (Oppel) record can and should be considered as evidence of the generalised flooding of this region on the southwest margin of Iberian during the Lower Kimmeridgian, which can be recognised by the extension of outcrops of materials of this age towards the north as a consequence of the transgressive effect associated with the sea-level-rise.

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