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Ammonite-rich Oxfordian Limestones from the Base of the Continental Slope off Northwest Africa[1])

By OTTO RENZ[2]), RALPH IMLAY[3]), YVES LANCELOT[4]) and WILLIAM B. F. RYAN[4])

ABSTRACT

During a recent cruise of R/V VEMA off the Moroccan continental margin, ammonite-rich limestones were dredged from the lower part of the Mazagan Escarpment. The macrofauna indicates a Middle Oxfordian age (*Gregoryceras transversarium* zone) that corresponds to the first major Mesozoic marine transgression in southwestern Morocco, the Nova Scotia Shelf and the Gulf of Mexico region. These facies might reflect an abrupt flooding of the young Atlantic rift after a period of dessication during which evaporites were deposited on both the continental edge and a deeper oceanic floor

ZUSAMMENFASSUNG

Wahrend einer kurzlich ausgefuhrten Kreuzfahrt der R/V VEMA westlich des marokkanischen Kontinentalrandes wurden Kalke mit zahlreichen Cephalopoden vom untern Abschnitt des Mazagan-Escarpment gehoben Die Makrofauna weist auf Mittel-Oxfordian (*Gregoryceras transversarium*-Zone), was mit der ersten regionalen marinen mesozoischen Transgression im sudwestlichen Marokko, auf dem Neuschottland-Schelf und im Golf von Mexiko ubereinstimmt. Die Fazies konnte eine plotzliche Überflutung der noch jungen atlantischen Spalte reflektieren, die auf eine Trockenperiode folgte, wahrend welcher Evaporite sowohl am Kontinentalrand als auch auf dem anschliessenden tieferen Ozeanboden abgelagert wurden.

Introduction

A broad reconnaissance geological and geophysical survey of the continental margin off the Atlantic coast of Morocco was undertaken in November 1973 during Cruise 30-13 of R/V VEMA. During the survey, a limited region of the Moroccan slope northwest of the city of El-Jadida at 33°30′ N was discovered to be exceptionally steep and, for the most part, free of superficial unconsolidated sediments. This precipitous slope is herein referred to as the Mazagan Escarpment. It was subse-

[1]) Lamont-Doherty Geological Observatory Contribution No. 2224.

[2]) Museum of Natural History, Basel (Switzerland).

[3]) United States Geological Survey, Washington, D.C

[4]) Lamont-Doherty Geological Observatory of Columbia University, Palisades, N.Y 10964 (USA)

quently mapped (Fig. 1) by seismic-reflection profiling along with continuous recordings of gravity and magnetic field intensity, and then by piston core sampling, dredging, and sea-floor photography.

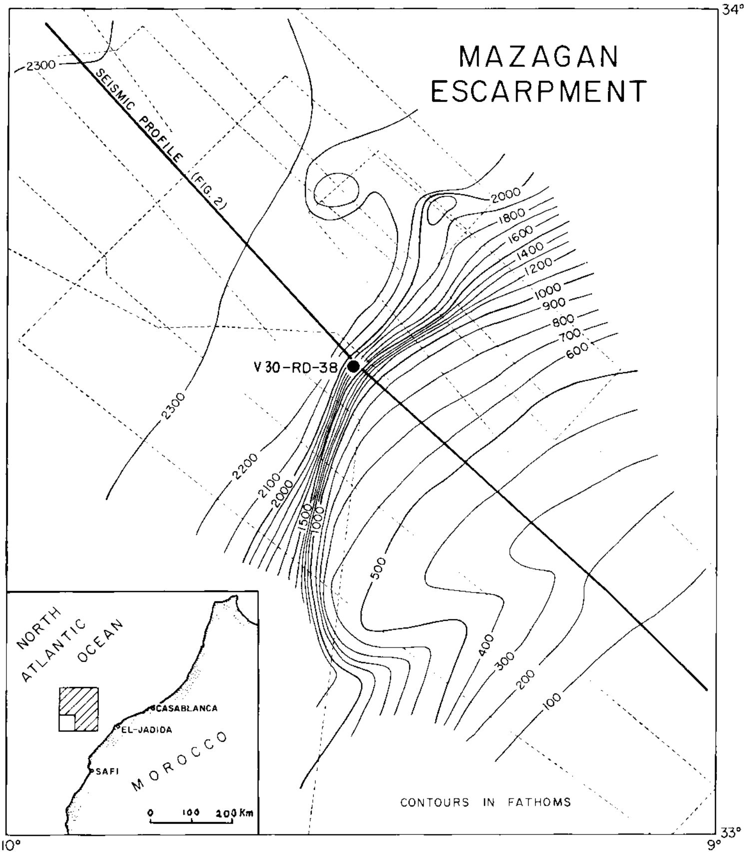


Fig. 1. The northwest-facing Mazagan Escarpment. Dotted lines indicate the seismic-reflection coverage. Heavy line is the profile illustrated in Figure 2. Contours are in fathoms (1 fathom = 1/400 second).

Sampling stations were concentrated in two areas: one along the steeper lower part of the escarpment where outcrops of consolidated rock were visible, and the other at the top of the escarpment where the topographic gradient noticeably decreases and where unconsolidated sediments have been exposed by erosion. One of six successful dredging attempts on the steep lower face of the Mazagan Escarpment yielded many limestone blocks and fragments containing abundant and well-preserved ammonites.

Structural setting of the Mazagan Escarpment

A network of seismic-reflection profiles was obtained along closely spaced tracks, roughly perpendicular to the escarpment, in order to determine its structural characteristics and its relation to buried strata of the adjacent deep basin. The plain at the base of the escarpment, a perched eastern arm of the Seine Abyssal Plain, is underlain by a thick sedimentary sequence (in excess of 4 kilometers) showing conformable bedding disrupted by many diapiric structures. Subsurface mapping revealed these structures to be linear features resembling elongated salt domes or possibly ridges. The escarpment is very steep in its lower half and moderately steep in its upper half. The upper part is characterized by outcrops of reflectors which were sampled by coring and identified as Lower to Middle Eocene glauconitic marls and clastic rocks.

The dredge haul containing the ammonite-rich rocks was positioned at 33°34.3′ N and 09°28.7′ W. The approximate sampling path of the dredge upward along the escarpment between 3300 and 3150 meters below sea level is depicted on Figure 2. It is, of course, difficult to estimate the precise depth at which the samples were recovered. The mixing of several lithologies apparently indicates that the dredge apparatus was able to collect from more than one formation. The actual time during which the dredge was in contact with the sea floor was relatively short. Our calculations of wire

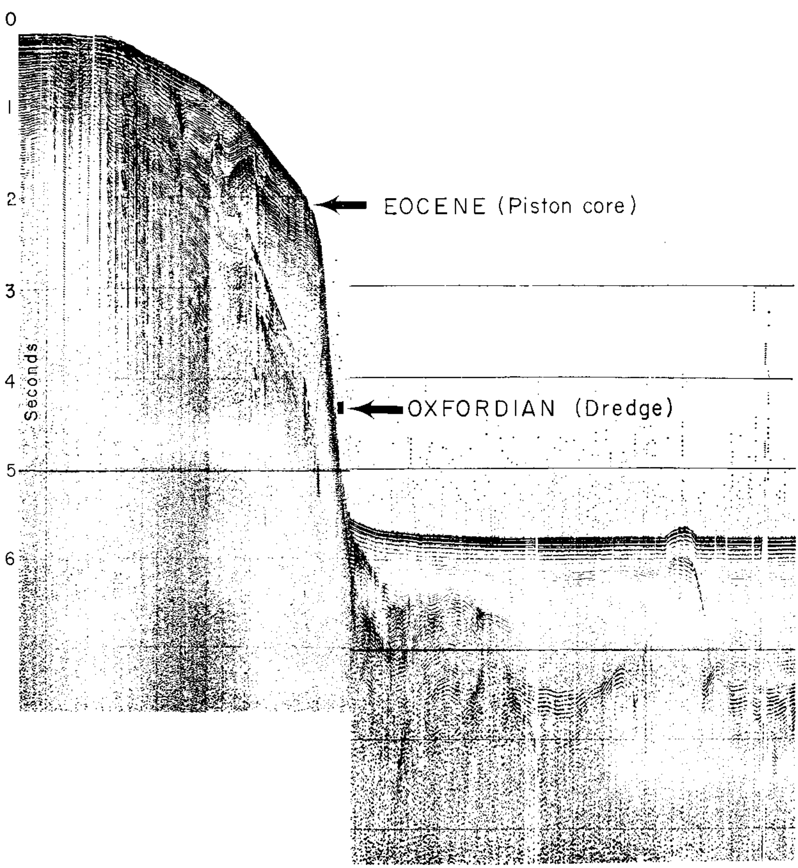


Fig. 2. Reflection profile across Mazagan Escarpment showing location of sampled outcrops. The diapir-like feature in the basin to the right is a crossing of a linear salt ridge. Vertical scale is in seconds (two-way travel time). Vertical exaggeration is approximately 1:18.

angles and lengths, indicate that the dredge reached no higher than 3150 meters below sea level

The recovered sedimentary rocks

The material recovered from dredge haul V30-RD38 consists of many rock fragments which fall into two categories, a yellowish-brown slightly crumbly limestone and a rather hard white limestone These two types contain very distinct faunas and most likely are derived from different formations

1 Yellowish-brown limestone

a) Lithology and stratigraphy

The rock fragments show some freshly broken surfaces, although many of them appear partially coated with iron and manganese oxides Some downslope transport of the rocks cannot be ruled out However, none of the many bottom photographs taken along the slope shows a noticeable accumulation of isolated rock fragments We believe, therefore, that most samples were obtained from actual outcrops (Fig 3)

The limestone is dense, relatively hard, and very fine grained and has many small irregularly shaped vugs often coated with drusy calcite (Fig 4b) The carbonate content averages 95% The insoluble fraction consists of a light-brownish extremely fine grained mud containing small quartz grains, a few muscovite flakes and clay minerals, including some glauconite aggregates (Fig 4a) The quartz grains are rather uniform in size and shape and are predominantly sharp-edged and transparent Their diameters range from 0 07 to 0 14 mm They might represent windblown detritus from the African shield in a manner similar to those found in Upper Jurassic sediments from the southern part of the North American basin (RENZ 1974, p 512)

A few samples have been examined by Ch Kapellos, from the Museum of Natural History in Basel, for their nannoplankton content, but no determinable nannoflora could be detected

Some agglutinated shells of arenaceous Foraminifera, composed of quartz grains, have been observed, thin sections, examined by R Lehmann from ESSO-EPR E, Bordeaux, France, show the presence of lagenids and *Protoglobigerina*, together with echinoid fragments (including *Saccocoma*), ostracodes and fragments of aptychi The limestone contains also siliceous and ferruginous reticular structures that could be remains of Spongiae

The macrofauna consists predominantly of Cephalopoda, which are all preserved as internal molds In addition, two undeterminable fragments of bivalves and a small belemnite have been found

In thin sections the yellowish-brown limestone reveals a calcarenitic texture Predominant are small subspherical grains with diameters ranging between 0 1 and 0 4 mm, accumulated in irregularly shaped patches (Fig 4c) They consist of a central grain, which might be a Foraminifera (Fig 4a) or a fragment of micritic material derived from the surrounding formation The radius of these particles often exceeds the thickness of the accretionary layers deposited around them They consist of finely structured algal material, which is more or less impregnated by limonite These grains are embedded in a microclastic carbonate matrix containing detrital

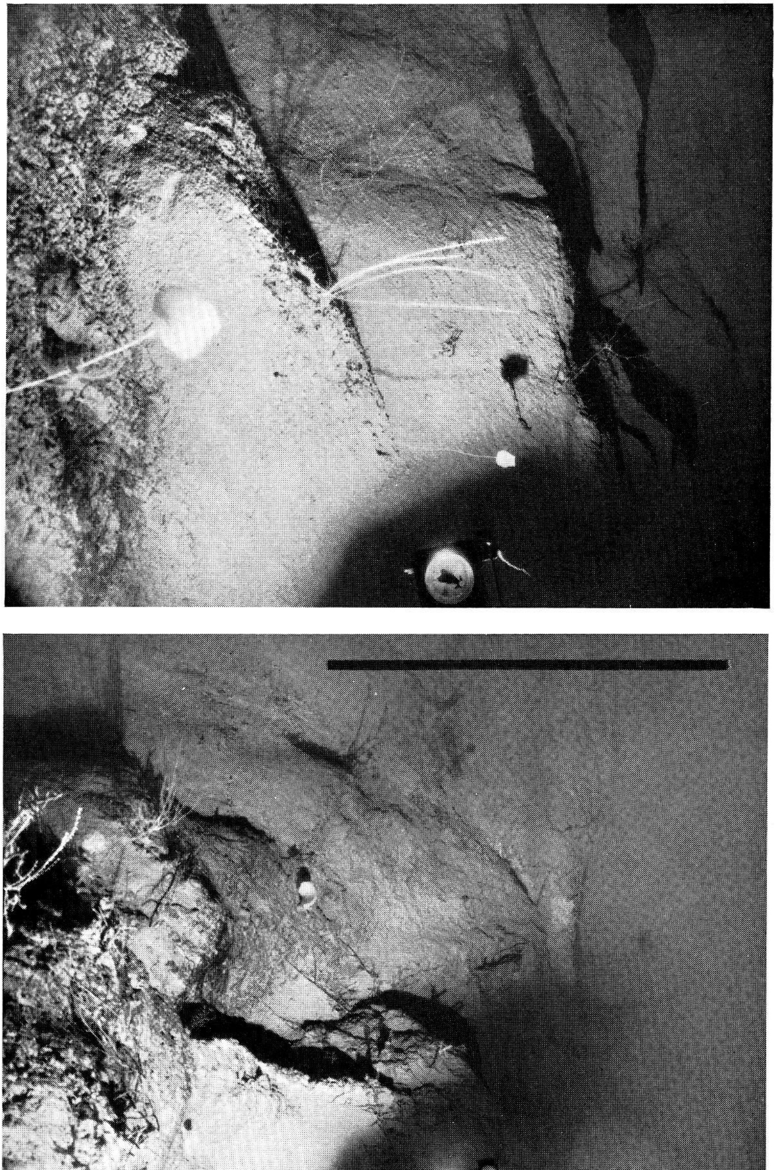


Fig. 3. Outcrops of regularly and irregularly bedded strata from the lower, steep face of the Mazagan Escarpment near the location of dredge sample V30-RD38. Scale bar approximates 1 meter.

quartz grains, undefined skeletal debris and locally very small undefinable pellets, possibly fecal pellets (Fig. 4b, 4d).

Larger semirounded oncolites (diametres up to 5 mm) occur abundantly. Their cores predominantly consist of a fine grained calcarenitic matrix with skeletal grains, and well preserved Foraminifera (*Protoglobigerina*, Miliolidae). Grains enveloped by algae seem to be missing here. Also these oncolites are generally encrusted by a thin cover of algal material (Fig. 4a). Other oncolites typically consist for their major part of Algae (Fig. 4c). The algal growth developed around a small central particle as faint irregularly concentric structures separated by layers of sediment.

On Figure 4d we observe a molluscan fragment affected by casts of algal bores filled with micritic sediment. They are similar to those described by GYGI (1969, Pl. 3, Fig. 10, p. 44) from the Oxfordian (Birmenstorfer Schichten) in the Swiss Jura mountains. Similar boring Algae densly traverse the algal cover of several grains and oncolites.

This lithology suggests deposition in a relatively shallow subtidal environment, which was clearly open marine and non-restricted and also situated within the photic zone. We envisage a deposition of autochthonous carbonate with some admixed pelagic grains in a general carbonate platforme setting.

The ammonite fauna consists of 6 genera and subgenera and 7 determined species which are:

Sowerbyceras (*Sowerbyceras*) *protortisulcatum* (POMPECKJ), 6 specimens
Sowerbyceras (*Holcophylloceras*) cf. *zignodianum* (D'ORBIGNY), 1 specimen
Trimarginites arolicus (OPPEL), 6 specimens
Trimarginites cf. *trimarginatus* (OPPEL), 1 specimen
Lissoceratoides erato (D'ORBIGNY), 5 specimens
Glochiceras (*Coryceras*) cf. *crenatum* (OPPEL), 1 specimen
Glochiceras (*Glochiceras*) sp., 1 specimen

Some additional undeterminable ammonite remains probably represent a lytoceratid and a perisphinctid.

The considerable number of identified ammonites obtained from a relatively small amount of rock is quite impressive and suggests the presence of a very fossiliferous formation at the dredging site.

The age determination is mainly based on the occurrence of *Glochiceras* (*Coryceras*) cf. *crenatum*, *Trimarginites arolicus*, and *Sowerbyceras* (*S.*) *protortisulcatum*.

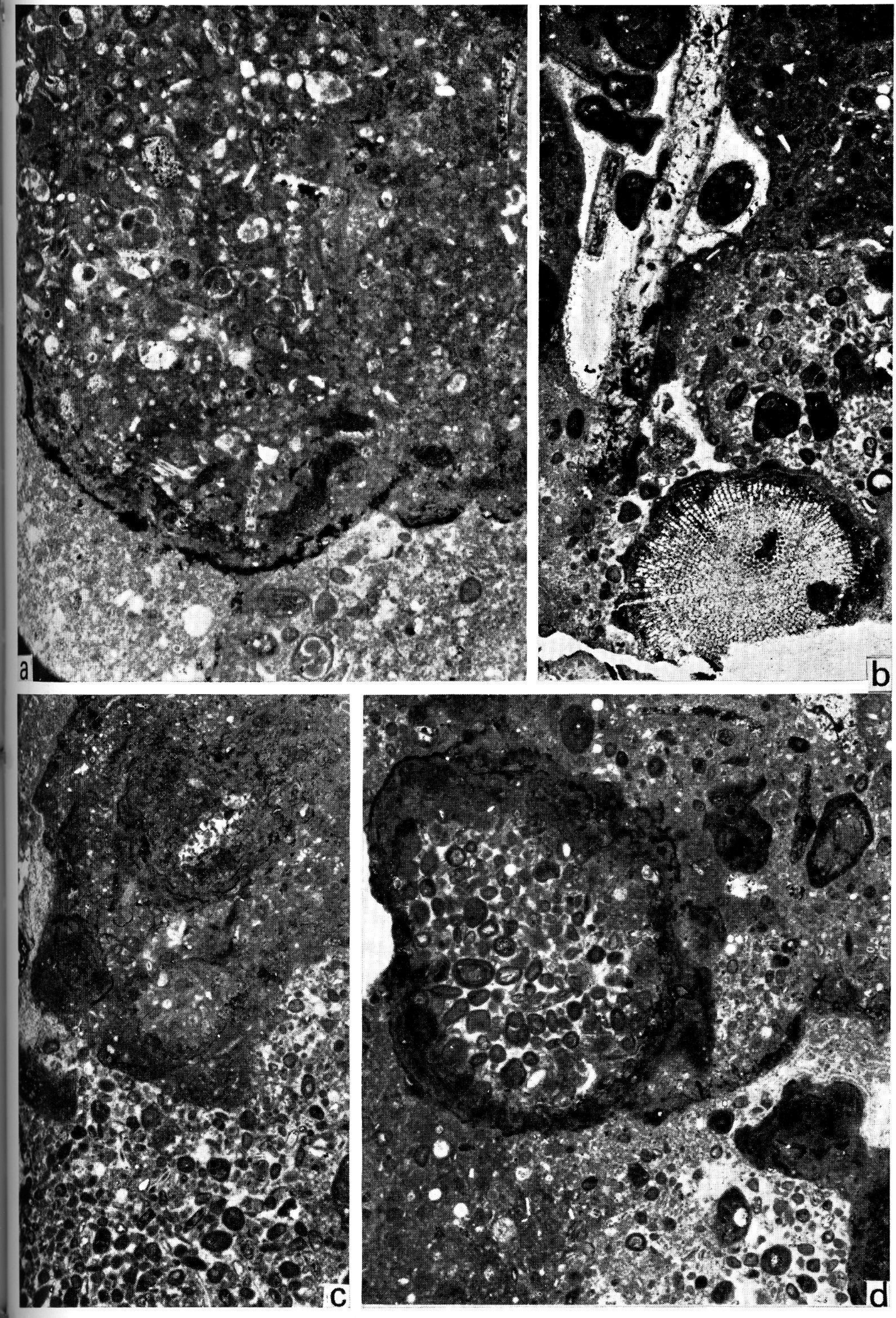
Fig. 4. Yellowish-brown limestone (sample RD 38/33).

a) Part of a large pellet of skeletal micritic limestone with *Protoglobigerina* and *Ostracoda* in a similar matrix. This pellet seems encrusted by a thin layer of possible algal material impregnated by limonite (40 ×).

b) The walls of one of the numerous cavities, as well as pellets covered by a layer of possible algal origine, are coated by scalenohedral calcite cement. Nearby a larger molluscan fragment has been densly bored by Algae. Below a small, algal encrusted, solitary coral has been preserved (20 ×).

c) A larger oncolite composed of micritic and algal material is embedded in a micritic matrix containing abundant small algal grains. True ooliths grains were not observed (20 ×).

d) A larger rounded oncolite consisting of smaller grains covered by algal encrustations. The oncolite itself is surrounded by a thick layer of algal origin, impregnated by limonite and traversed by boring Algae. In the lower right corner Algae free of limonite show a concentrically laminated pattern (20 ×).


a
b
c
d

In southwestern Germany, *Glochiceras* (*C.*) *crenatum*, according to ZIEGLER (1957, p. 572; 1958, Fig. 66, p. 156), had its widest development during the Middle Oxfordian (*Gregoryceras transversarium* zone and the *Terebratula impressa* marls). In the Jura mountains of Switzerland, *Glochiceras* (*C.*) *crenatum* is also found within the *transversarium* zone (Birmenstorfer Schichten, JEANNET 1951, p. 101).

Trimarginites arolicus, one of the commonest ammonites from the dredge haul, had its greatest development within the *Gregoryceras transversarium* zone (mainly in the Birmenstorfer Schichten, CHRIST 1961, p. 315). It continued to live during late Oxfordian time (*Idoceras planula* zone). Its abundance within the present fauna suggests a correlation with the *transversarium* zone rather than with the *planula* zone.

Sowerbyceras protortisulcatum occurs, according to POMPECKJ (1893, p. 203), in the Lower Malm (Weisser Jura α and β). Its vertical distribution in the Mediterranean region is as yet poorly known.

An Oxfordian age (*transversarium* zone) seems to be best in accord with the few ammonite species available.

The yellowish-brown limestones probably formed on a carbonate platform situated to the south of a western extension of the Tethyan ocean, which bordered the continental margin toward the north and the west. The small amount of terrigenous components suggests an open-sea environment. Relatively shallow water conditions are further suggested by the occurrence of peri-reefal limestone of undetermined age in another dredge haul in the immediate vicinity of RD 38. These rocks might be considered a shallow-water equivalent of the relatively deep Ammonitico Rosso facies that crops out in southern Spain and northern Morocco, and that has also been recognized by drilling in the North American basin (BERNOULLI 1972; LANCELOT et al. 1972). A tentative correlation, based on the extension of the main reflective seismic horizons both in the western and eastern North Atlantic, suggests the presence of the deep-water Oxfordian facies also under the abyssal plain adjacent to the slope along which the dredging was performed.

The ammonites described here presumably represent only a subordinate part of a much richer fauna that lived during Oxfordian time in this area. The Perisphinctidae, known worldwide from Oxfordian sediments, are represented by undeterminable fragments only. Likewise, no traces of the genera *Gregoryceras*, *Ochetoceras*, and *Euaspidoceras* have been found. Clearly, far-reaching paleogeographical conclusions cannot be based on the few fossils present.

We know, however, that all identified species occur abundantly within the Mediterranean region, as well as in the Jura mountains of southern Germany, western France, and Switzerland. Thus, close faunal relations with these regions must have existed during Oxfordian time.

Far less clear are the faunal relations with the Andean geosyncline (v. HILLEBRANDT 1970, p. 191, 203) where Oxfordian deposits are rare and not very fossiliferous. Only two species, *Glochiceras* (*C.*) cf. *crenatum* from Mexico and *Trimarginites arolicus* from northern Chile are known to occur in the Tethys as well as in the Andean and Mexican geosynclines.

None of the ammonites recorded here is listed from the Upper Jurassic in North America (IMLAY 1965, Textfig. 6A, 6B, p. 1032–1033).

List of macrofossils identified from dredge haul V30-RD38.

	Sample identification V30	Macrofauna	Illustrations
Yellowish brown limestone	RD38/18	*Trimarginites arolicus* (OPPEL)	Pl. 1, Fig. 6-8 suture Fig. 8b
		Sowerbyceras (Sowerbyceras) protortisulcatum (POMPECKJ) *Lissoceratoides erato* (D'ORBIGNY)	Pl. 1, Fig. 9
	21	*Trimarginites arolicus* (OPPEL)	Pl. 1, Fig. 7
		Sowerbyceras (Sowerbyceras) protortisulcatum (POMPECKJ)	Pl. 1, Fig. 1-3 suture Fig. 1d
		Lissoceratoides cf. *erato* (D'ORBIGNY)	Pl. 1, Fig. 10 suture Fig. 10c
		Glochiceras (Glochiceras) sp. small fragment of a *Perisphinctes* sp. small belemnite, 24 mm long	Pl. 1, Fig. 13
	30	*Sowerbyceras (Sowerbyceras)* sp.	
	31	*Sowerbyceras (Sowerbyceras)* sp. remains of a ? *Lytoceras*	
	32	undetermined lamellibranch	
	33	*Sowerbyceras (Holcophylloceras)* cf.*zignodianum* (D'ORBIGNY)	Pl. 1, Fig. 4 suture Fig. 4d
		Trimarginites cf. *arolicus* (OPPEL)	
	34	*Sowerbyceras (Sowerbyceras)* sp. small *Lissoceratoides* sp.	
	35	fragment of *Sowerbyceras (Sowerbyceras)* sp.	
	36	fragment of *Sowerbyceras (Sowerbyceras)* sp.	
	37	undetermined pelecypod	
	38	*Glochiceras (Coryceras)* cf. *crenatum* (OPPEL)	Pl. 1, Fig. 12
	39	*Lissoceratoides* cf. *erato* (D'ORBIGNY)	Pl. 1, Fig. 11 suture Fig. 11c
	40	fragment of an undetermined pelecypod	
	41	*Trimarginites* cf. *trimarginatus* (OPPEL)	Pl. 1, Fig. 5 suture Fig. 5c
	42	fragment of *Lissoceratoides* sp.	
	43	small *Sowerbyceras (Sowerbyceras)* sp.	
	44	remains of ammonites	
	45	*Sowerbyceras (Sowerbyceras)* sp.	
	47	*Lissoceratoides* sp.	
White limestone	RD38/16 & 17	*Nucleata nucleata* (SCHLOTHEIM)	Pl. 1, Figs. 15 and 16
		Sowerbyceras (Sowerbyceras) cf. *tortisulcatum* (D'ORBIGNY)	Pl. 1, Fig. 14
		Perisphinctes (Orthosphinctes) sp.	Pl. 1, Fig. 17
		fragment of a *Calliphylloceras* Lamellaptychus sp. (fragment)	
	46a	*Nucleata nucleata* (SCHLOTHEIM)	

b) Paleontological descriptions (see complete list of macrofossils in the table, p 439)

Family *Phylloceratidae* ZITTEL 1884

Genus *Sowerbyceras* PARONA & BONARELLI 1895

Subgenus *Sowerbyceras* (WIEDMANN 1963, p 257)

Sowerbyceras (*Sowerbyceras*) *protortisulcatum* (POMPECKJ)

Pl 1, Fig 1 3, suture Fig 1d

1893 *Phylloceras protortisulcatum* POMPECKJ, p 203, Pl 3, Fig 1 (Holotype)
1961 *Sowerbyceras protortisulcatum* (POMPECKJ), SCHINDEWOLF, p 707, Fig 34 (suture)

In the yellow-brown limestone, *Sowerbyceras* seems to occur abundantly, as 23 specimens were obtained, of which 6 are determinable specifically as *S. protortisulcatum*

Dimensions (mm)	Dm	Wh		Ww		U	
Holotype	49 8	22	(0 44)	21 3	(0 43)	10 8	(0 22)
Pl I, Fig 1	40	16	(0 40)	17	(0 42)	9 5	(0 24)

Characteristic of this species are strongly biconcave periodic constrictions They distinctly show two inflections directed adorally. The ventral inflection placed at the ventrolateral shoulder, is acute, tonguelike, and very pronounced (Fig 1b) Over the broad venter, a foldlike ridge rises along the median line of the constriction, which here is flat and broad (Fig 1c) Towards the inner whorls, these foldlike ribs gradually disappear

The external suture (Fig 1d) almost exactly coincides with the drawing by POMPECKJ (1893, Fig 8, p. 193). The designations of the lobes are based on the ontogenetic studies of this species by SCHINDEWOLF (1961, Fig 34, p 73)

In western Germany, according to POMPECKJ (1893, p 205) this form seems to be confined to the Middle and Upper Oxfordian (*Gregoryceras transversarium* to *Epipeltoceras bimammatum* zone) From the Mediterranean basin (northern Africa), it has not been mentioned from the Oxfordian, but possibly it has been misinterpreted there as *Sowerbyceras tortisulcatum* (ARKELL 1956, p 268–275)

Subgenus *Holcophylloceras* SPATH 1927

Sowerbyceras (*Holcophylloceras*) cf *zignodianum* (D'ORBIGNY)

Pl I, Fig 4, suture Fig 4d

1848 *Ammonites Zignodianus* D'ORBIGNY, p 439, Pl 182
1900 *Phylloceras Zignoanum* D'ORBIGNY, LORIOL, p 15, Pl 2, Fig 10, 11 (suture Fig 2, p 16)
1951 *Holcophylloceras Zignodianum* D'ORBIGNY, JEANNET, p 28, Pl 5, Fig 7
1961 *Holcophylloceras zignodianum* (D'ORBIGNY), SCHINDEWOLF, p 75, Fig 35 (suture)

A single example (sample RD 38/33) of *Holcophylloceras*, showing the inner whorls, closely resembles a small specimen figured by LORIOL from the Oxfordian near Châteauneuf (Dépt Jura)

Dimensions (mm)	Dm	Wh		Ww		U	
Pl I, Fig 4	23	11	(0 48)	6 5	(0 20)	5	(0 22)
LORIOL, p 15	8–21		0 48		0.33		0 19

The spacing of the constrictions, characterized by median lateral kneelike bends, are nearly identical on both specimens

The suture (Fig 4d) shows more primitive diphyllic saddles, comparable with those of *Sowerbyceras* (*Sowerbyceras*) at equal size The designations of the lobes are based on Besnossow 1958 in Schindewolf (1961, p 709, Fig 35)

Haas (1955, p 26, Pl 4, Fig 6–14) described several similarly flattened *Sowerbyceras* from the Oxfordian of Mt Hermon in Syria, which might be related to the present form Their umbilicus is, however, noticeably wider

For a closer age designation, this specimen seems to be only of subordinate value.

Family ***Oppeliidae*** Bonarelli 1894

Subfamily ***Ochetoceratinae*** Spath 1928

Genus *Trimarginites* Rollier 1909

Within 4 samples obtained from VEMA dredge haul are remains of 10 individuals that are characterized by distinct tricarinate venters We assume that all are *Trimarginites*, which therefore appears to be the genus secondmost abundantly represented

Trimarginites arolicus (Oppel)

Pl I, Fig 6–8, suture Fig 8b

1863 *Ammonites Arolicus* Oppel, p 188, Pl 51, Fig 1 2 (Holotype)
1923 *Trimarginites Arolicus* Oppel, Stehn, p 63, Pl 2, Fig 4, suture, text-Fig 5 (Chile)
1956 *Trimarginites arolicus* (Oppel), Arkell, p 275 (Tunisia)
1960 *Trimarginites arolicus* (Oppel), Christ, p 78, Pl 4, Fig 3 (Sicily)
1961 *Trimarginites arolicus* (Oppel), Christ, p 283, Pl 16, Fig 2–3, cum synon

Dimensions (mm)	Dm	Wh	Ww	U
Holotype	74	0 54	0 22	0 12
Pl I, Fig 6	30	15 5 (0 52)	7 (0 22)	4 (0 12)

The best preserved specimen (Fig 6) shows the beginning of flat, broad folds on the ventral half of the whorl at a diameter of 27 mm On a smaller specimen (Fig 7), the appearance of the tricarinate venter can be observed at a diameter of 9 mm The suture (Fig 8b) is characteristic of the genus (Schindewolf 1964, p 379)

In the Jura mountains of Switzerland, *T arolicus* has its greatest development within the *transversarium* zone of the Middle Oxfordian (Birmenstorfer Schichten) In the Mediterranean Basin, *Trimarginites* is found far less abundant, but it has been recorded by Fallot (1934, p 101) from the Oxfordian of Ibiza Of special interest are occurrences in northern Africa, where *T arolicus* has been determined by Arkell (1956, p 275) from the *transversarium* zone at Jebel Ben Saidane in Tunisia There the Oxfordian is represented by a pelagic Ammonitico Rosso facies, similar to the facies sampled by deep-sea drilling in the western North Atlantic (Bernoulli 1972)

Trimarginites arolicus is the only species of the present fauna that is also known from the Oxfordian in the Andes of South America It has been figured by Stehn (1923) from the Caracoles section in northern Chile. It occurs there together with *Lissoceratoides* and *Ochetoceras canaliculatum* (v Buch), which are known also from the *transversarium* zone in the Ammonitico Rosso facies in Andalusia (FALLOT 1934, p. 101) and Algeria (ARKELL 1956, p. 275).

Trimarginites cf. *trimarginatus* (OPPEL)

Pl. I, Fig 5; suture Fig 5c

1863 *Ammonites trimarginatus* OPPEL, p 159, Pl 50, Fig. 2 (Holotype).
1960 *Trimarginites trimarginatus* (OPPEL), CHRIST, p. 79, Pl. 4, Fig. 4 (Sicily).
1961 *Trimarginites trimarginatus* (OPPEL), CHRIST, p. 286, Pl. 16, Fig. 1, cum synon (Switzerland)

Sample RD 38/41 contained a small specimen of *Trimarginites*, which differs from *T. arolicus* only by its wider umbilicus.

Dimensions (mm):	Dm	Wh	Ww	U
Holotype:	54	0.51	0 195	0 175
Pl. I, Fig. 5:	16	8 (0.50)	4 (0 25)	3,5 (0 22)

In the Mediterranean Basin, this species has been described from Rocca Busambra in Sicily by CHRIST (1960).

Family ***Haploceratidae*** ZITTEL 1884

Genus *Lissoceratoides* SPATH 1923

Lissoceratoides erato (D'ORBIGNY)

Pl. I, Fig. 9–11; suture Fig. 10c, 11c

1847 *Ammonites Erato* D'ORBIGNY, p. 531, Pl 201, Fig 3–4 (Holotype)
1955 *Lissoceras erato* (D'ORBIGNY), HAAS, p. 28, Pl. 4, Fig. 15–19, cum synon. (Syria).
1956 *Lissoceras erato* (D'ORBIGNY), ARKELL, p 275 (Algeria)
1960 *Lissoceras* (*Lissoceratoides*) *erato* (D'ORBIGNY), CHRIST, p. 65 (Sicily).

Dimensions (mm):	Dm	Wh	Ww	U
Pl. I, Fig. 9:	29	13 (0.45)	7 (0 24)	7 (0 24)

The largest specimen (Fig. 9), reaching a diameter of 29 mm, just shows the beginning of the body chamber. Several smaller individuals, not permitting a safe specific determination, might also belong to this species (Fig. 10, 11).

The lobe formula, as far as reconstructable from our specimens is:

$$E\ L\ U_2\ U_3\ U_5\ U_6\ U_7 : U_4\ U_1\ I$$

Lissoceratoides erato has been mentioned predominantly from the Oxfordian In the western Mediterranean Basin, it has been determined by ARKELL (1956, p. 275) from the *transversarium* zone in Algeria. CHRIST (1960) described it from the Oxfordian in Sicily (Rocca Busambra).

Genus *Glochiceras* HYATT 1900

Subgenus *Coryceras* ZIEGLER 1958

Glochiceras (*Coryceras*) cf. *crenatum* (OPPEL)

Pl. I, Fig. 12

1887 *Ammonites dentatus* QUENSTEDT, Pl. 85, Fig. 31, Neotype of *G.* (*C.*) *crenatum*.
1887 *Oppelia crenata* BRUG., BUKOWSKI, p. 122, Pl. 25, Fig. 10 (Poland).
1912 *Creniceras* sp. indet., BURCKHARDT, p. 15, Pl. 7, Fig. 15–17 (Mexico).
1951 *Creniceras crenatum* BRUG., JEANNET, p. 101, Pl. 31, Fig. 17, 18 (Switzerland).
1957 *Creniceras crenatum* (BRUG.), ZIEGLER, p. 570, Fig. 13g, cum synon.
1958 *Glochiceras* (*Coryceras*) *crenatum* (OPPEL), ZIEGLER, p. 120, Pl. 11, Fig. 4.

Glochiceras (*C.*) *crenatum* is a characteristic ammonite for the Middle Oxfordian (*transversarium* zone and the *Terebratula impressa* marls) in southwest Germany (ZIEGLER 1957, p. 572). It thus represents one of the important ammonites recovered from VEMA dredge haul V30-RD38.

The specimen represents the adapical part of an adult body chamber that has smooth flanks, a moderately wide umbilicus, a vertical umbilical wall, and fairly large laterally compressed tubercles on the venter. Assignment to the subgenus *Coryceras* rather than to the genus *Creniceras* is favored by the width and shape of the umbilicus, which shows that the body chamber was uncoiling gradually instead of contracting abruptly near the adapical end of the body chamber.

The easternmost record for this species is from the Oxfordian of Poland (BUKOWSKI 1887, Pl. 25, Fig. 10, p. 122). As far as we know, this species has not been mentioned from the western Mediterranean regions. Of interest is the occurrence of a single deformed *Coryceras* from San Pedro del Gallo (Estado Durango) in Mexico. It derives from the lower part of the Cerro del Volcán Formation, corresponding to the Middle Oxfordian. According to BURCKHARDT (1912, p. 16), this specimen shows similarities to *Creniceras crenatum*, as figured by LORIOL (1902) on Plate 3, Figure 23.

Subgenus *Glochiceras* HYATT 1900

Glochiceras (*Glochiceras*) sp.

Pl. I, Fig. 13a, b

A clearly preserved peristome of a *Glochiceras*, having all characteristics necessary for a subgeneric determination, was extracted from sample RD 38/21. The dorsal end of the mouth border retreats adapically towards the umbilical seam. On the venter, the mouth border extends into a hoodlike feature (compare Fig. 2a, p. 98, by ZIEGLER 1958). There is no trace of a mediolateral channel. The whorl height reaches 4.6 mm and the whorl width 3 mm. This results in a reconstructed diameter of not much more than 14 mm for this specimen.

2. White limestone

a) Lithology

A smaller amount of the rocks recovered from dredge haul V30-RD38 consists of white, dense, very hard limestone. The carbonate values range from 90% to 95%, and the insoluble residue consists of a fine-grained light-grey mud that contains small

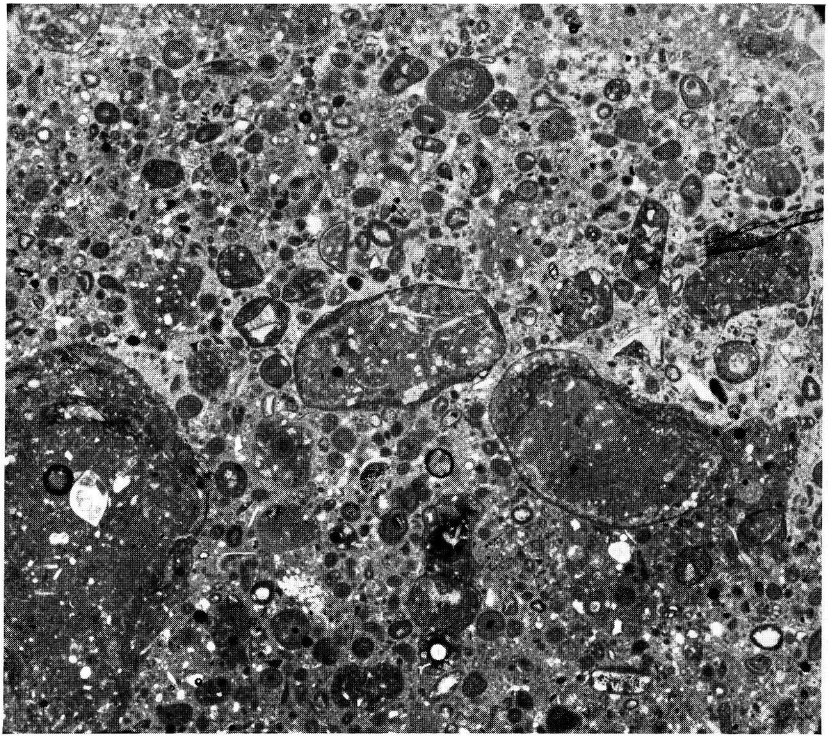


Fig. 5. White limestone (sample RD 38/16, 17). Algal encrusted skeletal debris, Foraminifera (*Lenticulina*) and particles of the surrounding micritic matrix predominate. The larger pellets seem to be coated with a thin layer of algal origin (20 ×).

quartz grains identical in shape and size with those from the yellowish-brown limestone.

The environmental conditions during deposition of the somewhat younger white limestone were comparable to those prevailing during deposition of the yellowish-brown limestone. Thin sections show small algally encrusted subspherical oncolites reaching diameters between 0.05 and 0.5 mm. Their nuclei consist of fragments of the surrounding micritic sediment, skeletal debris and foraminiferal tests (Fig. 5). The algal crust frequently shows concentric structures and the oncolites then might appear as ooliths grains. Numerous larger pellets, up to 2.5 mm in size are coated with a thin layer of probable algal origin.

The rock has been investigated by Ch. Kapellos for its nannoplankton content. Only a few poorly preserved remains could be detected; these possibly belong to the genus *Ellipsagelosphaera*. Thin sections examined by R. Lehmann revealed a very poor microfauna including some lagenids, arenaceous Foraminifera, ostracodes and possibly some globochaetes, together with *Lenticulina*, "*Ammodiscus*" and fragments of echinoids and aptychi.

The macrofauna consists exclusively of Cephalopoda and Brachiopoda. All ammonites are preserved as internal molds. They have been very difficult to extract because tests and septa were partly dissolved before fossilization. The small fauna recovered is listed in the table, p. 439.

The presence of fragments of *Calliphylloceras* and Lamellaptychus in the white limestone suggests probably somewhat deeper water conditions than during deposition of the yellowish-brown limestone.

b) Paleontological descriptions

Subfamily ***Perisphinctidae*** STEINMANN 1890

Genus *Perisphinctes* WAAGEN 1869

Perisphinctes (*Orthosphinctes*) sp.

Pl. I, Fig. 17

The following description has been prepared by R. A. Gygi (Museum of Natural History, Basel) working on a revision of the late Jurassic ammonite fauna of the Swiss Jura mountains and adjacent regions.

The specimen is the outermost quarter-whorl of an *Orthosphinctes* body chamber: No sutures are visible, and in front of the last constriction the cast (steinkern) continues at the level of the rib crests for a distance greater than the normal rib intervals. Therefore, this flat area is part of a lappet at the peristome. Although the whorl fragment is too incomplete to be attributed to a species, it bears a close resemblance to *Perisphinctes* (*Orthosphinctes*) *tizianiformis* CHOFFAT in SCHAIRER (1967, p. 40, Pl. 4, Fig. 3) from the lowermost *platynota* zone (lowermost Kimmeridgian) of Ursheim, southern Germany. SCHAIRER's identification cannot possibly be correct because *P. tizianiformis* CHOFFAT is from the *plicatilis* zone (Middle Oxfordian) of the neighbourhood of Torres-Vedras, Portugal. The specimen has also an affinity to *Perisphinctes delgadoi* CHOFFAT (1893, p. 50, Pl. 12, Fig. 1) from horizon NR. 12 at Cabanas de Torres, in which it occurs together with *Taramelliceras kobyi* CHOFFAT, the latter being an easy-to-identify late Oxfordian species from Portugal, Switzerland, and Germany.

Sowerbyceras (*Sowerbyceras*) cf. *tortisulcatum* (D'ORBIGNY)

Pl. I, Fig. 14a, b

Many poorly preserved *Sowerbyceras* (*S.*) probably representing the species *tortisulcatum*, are of little help for a more accurate age determination.

Family ***Pygopidae*** MUIR-WOOD 1965

Genus *Nucleata* MUIR-WOOD

Nucleata nucleata (SCHLOTHEIM)

Pl. I, Fig. 15, 16

1868 *Terebratula nucleata* SCHLOTHEIM, QUENSTEDT, p. 358, Pl. 47, Fig. 93 (Holotype).
1965 *Nucleata nucleata* (SCHLOTHEIM) 1820, MUIR-WOOD, p. H 802, Treatise.

Two well-preserved individuals were obtained from samples RD 38/16 and 17; a third one is represented by sample RD 38/46. This number indicates an abundant occurrence of the species within the white limestone. The holotype is from the Lower Kimmeridgian in Bavaria (Weisser Jura γ). In Switzerland this species is also well known from the Middle Oxfordian (Birmenstorfer Schichten). Its vertical range is thus considerable.

Discussion and conclusions

To our knowledge, the rocks described herein are the oldest sediments ever dredged from outcrops in the deep ocean. Rocks of similar age have been reached by drilling in the North American basin (HOLLISTER, EWING et al. 1972). These authors have shown that the age of the North Atlantic basin was probably not older than early Jurassic. The Oxfordian argillaceous limestones recovered from the North American basin represent a relatively deep open-marine facies (LANCELOT et al. 1972) that has been found to be very similar to the Ammonitico Rosso facies of the Tethyan realm (BERNOULLI 1972). Rocks of the same age outcropping in the Essaouira Basin in southwest Morocco indicate a shallow-water, open-marine environment abruptly transgressive over strata of a fluviatile and lagoonal facies. The rocks dredged by VEMA near the base of the Moroccan continental slope are intermediate between those two different facies. They indicate the presence of carbonate banks marking the outer edge of the submerged African continental platform during the Middle Oxfordian.

In the North American basin, the Oxfordian limestones have been found directly over the oceanic basement (layer 2) (HOLLISTER, EWING et al. 1972). In southwestern Morocco, they result from the first invasion of marine waters of normal salinity across the coastal plains. Nothing is presently known about the nature of the rocks immediately underlying the Oxfordian either at the base of the Moroccan slope or in the deep adjacent basin. No truly Atlantic deep-water facies older than Oxfordian has ever been observed on the continents surrounding the central North Atlantic. In adjoining eastern North America, as well as in Morocco, the Oxfordian represents the first widespread open-marine conditions of Atlantic origin after an epoch characterized mostly by fluviatile, lagoonal, and evaporitic environments.

We suggest that the Oxfordian carbonate banks facies dredged by VEMA could result from the growth of reefs at the outer edge of a rifted continental margin, thus reflecting an evolution of the Mazagan Escarpment comparable with that of the Blake Escarpment off the southeastern coast of the United States. Only deep drilling in the oceanic basin near the Moroccan margin will provide information about the nature of the pre-Oxfordian sediments in the basin itself. The seismic profiles indicate thick sedimentary layers beneath what we believe could be Oxfordian limestone equivalent to that sampled in the North American basin. The sedimentary layer, thought to be late Jurassic in age, appears to wedge out on the oceanic basement toward the west in the vicinity of the outer edge of the magnetic quiet zone, an isochron during the opening of the Atlantic assigned to an approximate Oxfordian age (HOLLISTER, EWING et al. 1972; PITMAN & TALWANI 1972). If the deepest layers observed on the seismic profiles predate the first major Atlantic transgression, they may represent either relatively restricted marine facies deposited in a very young ocean or a thick accumulation of detrital material during an erosional phase resulting from eustatic sea level changes during the Middle Jurassic. The occurrence of evaporites on the seismic profiles in the form of salt diapirs in the deep basin seems to favor the latter explanation.

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M. Langseth and A. Bé from Lamont-Doherty Geological Observatory critically read the manuscript.

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Plate I

Yellowish-brown limestone, Middle Oxfordian

Fig. 1a–d *Sowerbyceras* (*Sowerbyceras*) *protortisulcatum* (POMPECKJ). RD 38/21, J 22847. 440
1a: Arrow indicates beginning of the body chamber. – 1:1
1b: Ventrolateral shoulder. – 1:1
1c: Ventral view. – 1:1
1d: External suture at a whorl height of 12 mm. – 2.5 ×

Fig. 2a–b *Sowerbyceras* (*Sowerbyceras*) *protortisulcatum* (POMPECKJ). RD 38/21, J 22848, juvenile stage. – 1:1 440

Fig. 3a–b *Sowerbyceras* (*Sowerbyceras*) *protortisulcatum* (POMPECKJ). RD 38/21, J 22849, juvenile stage. – 1:1 440

Fig. 4a–d *Sowerbyceras* (*Holcophylloceras*) cf. *zignodianum* (D'ORBIGNY). RD 38/33, J 22850. 440
4a: Lateral view. – 1:1
4b: Ventral view. – 1:1
4c: Frontal view. – 1:1
4d: External suture and ventral part of internal suture at a whorl height of 9 mm. – 4 × ; p. 440

Fig. 5a–c *Trimarginites* cf. *trimarginatus* (OPPEL). RD 38/41, J 22851, juventile stage . 442
5a: Lateral view. – 1.5 ×
5b: Ventral view. – 1.5 ×
5c: Suture at a whorl height of 7 mm. – 4 ×

Fig. 6a–b *Trimarginites arolicus* (OPPEL), RD 38/18, J 22852, the beginning of the sculpture is clearly visible. – 1:1 441

Fig. 7a–b *Trimarginites arolicus* (OPPEL), RD 38/18, J 22853, juvenile stage. – 1.5 × . . 441

Fig. 8a–b *Trimarginites arolicus* (OPPEL), RD 38/18, J 22854 441
8a: Lateral view. – 1:1
8b: External suture at a whorl height of 13 mm. – 4 ×

Fig. 9a–b *Lissoceratoides erato* (D'ORBIGNY), RD 38/18, J 22855, arrow indicates the end of the phragmocone. – 1:1 442

Fig. 10a–c *Lissoceratoides* cf. *erato* (D'ORBIGNY). RD 38/21, J 22856, juvenile stage . . 442
10a: Lateral view. – 1.5 ×
10b: Ventral view. – 1.5 ×
10c: Suture at a whorl height of 6 mm. – 5 ×

Fig. 11a–c *Lissoceratoides* cf. *erato* (D'ORBIGNY), RD 38/39, J 22857, juvenile stage. . . 442
11a: Lateral view. – 1.5 ×
11b: Ventral view. – 1.5 ×
11c: External suture at a whorl height of 4.5 mm. – 5 ×

Fig. 12a–b *Glochiceras* (*Coryceras*) cf. *crenatum* (OPPEL), RD 38/38, J 22858, body chamber. – 1.5 × 443

Fig. 13a–b Peristome of a *Glochiceras* (*Glochiceras*) sp., RD 38/21, J 22859 443
13a: Ventral view. – 2 ×
13b: Lateral view. – 2 ×

White limestone, Upper Oxfordian to Lower Kimmeridgian

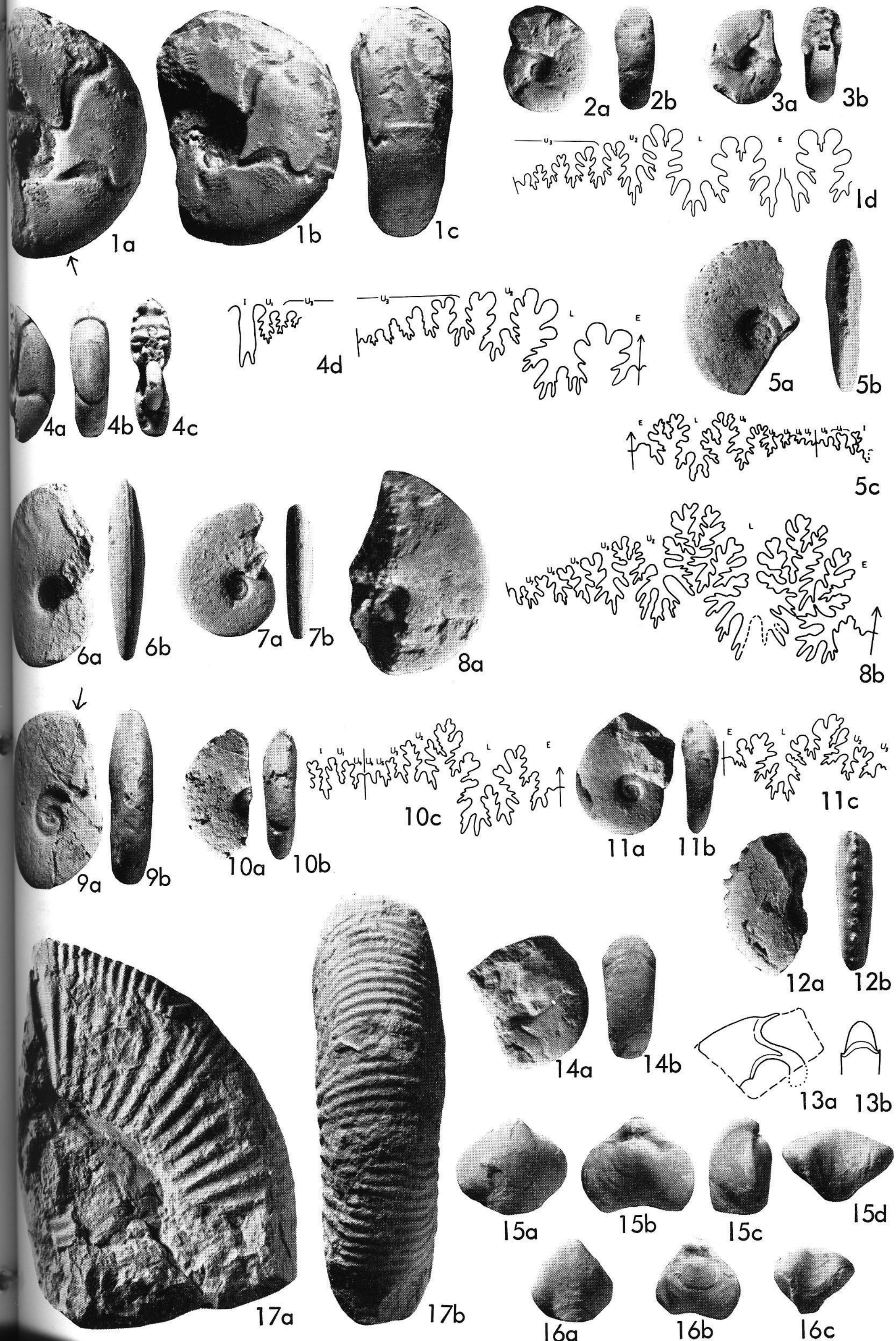
Fig. 14a–b *Sowerbyceras* (*Sowerbyceras*) cf. *tortisulcatum* (D'ORBIGNY), RD 38/16 + 17, J 22860, several poorly preserved specimens are present. – 1:1 445

Fig. 15a–d *Nucleata nucleata* (SCHLOTHEIM), RD 38/16 + 17, L 4450. – 1:1 445

Fig. 16a–c *Nucleata* cf. *nucleata* (SCHLOTHEIM), RD 38/16 + 17, L 4451. – 1:1. 445

Fig. 17a–b *Perisphinctes* (*Orthosphinctes*) sp. RD 38/16 + 17, J 22861, body chamber with beginning of the aperture. – 1:1. 445

The material is deposited in the Department of Geology, Museum of Natural History, Basel, Switzerland.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