Jurassic Coral Reefs of the Northeastern Paris Basin

(Luxembourg and Lorraine)

by

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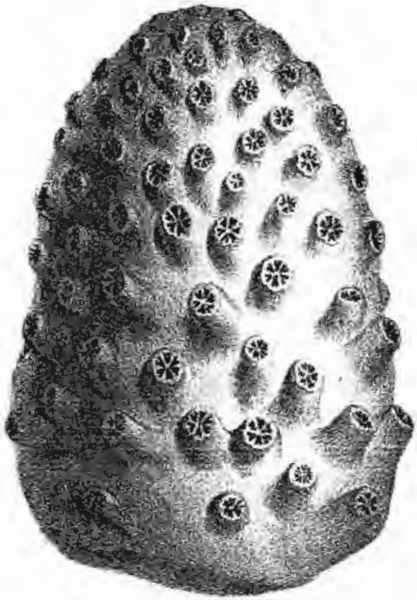
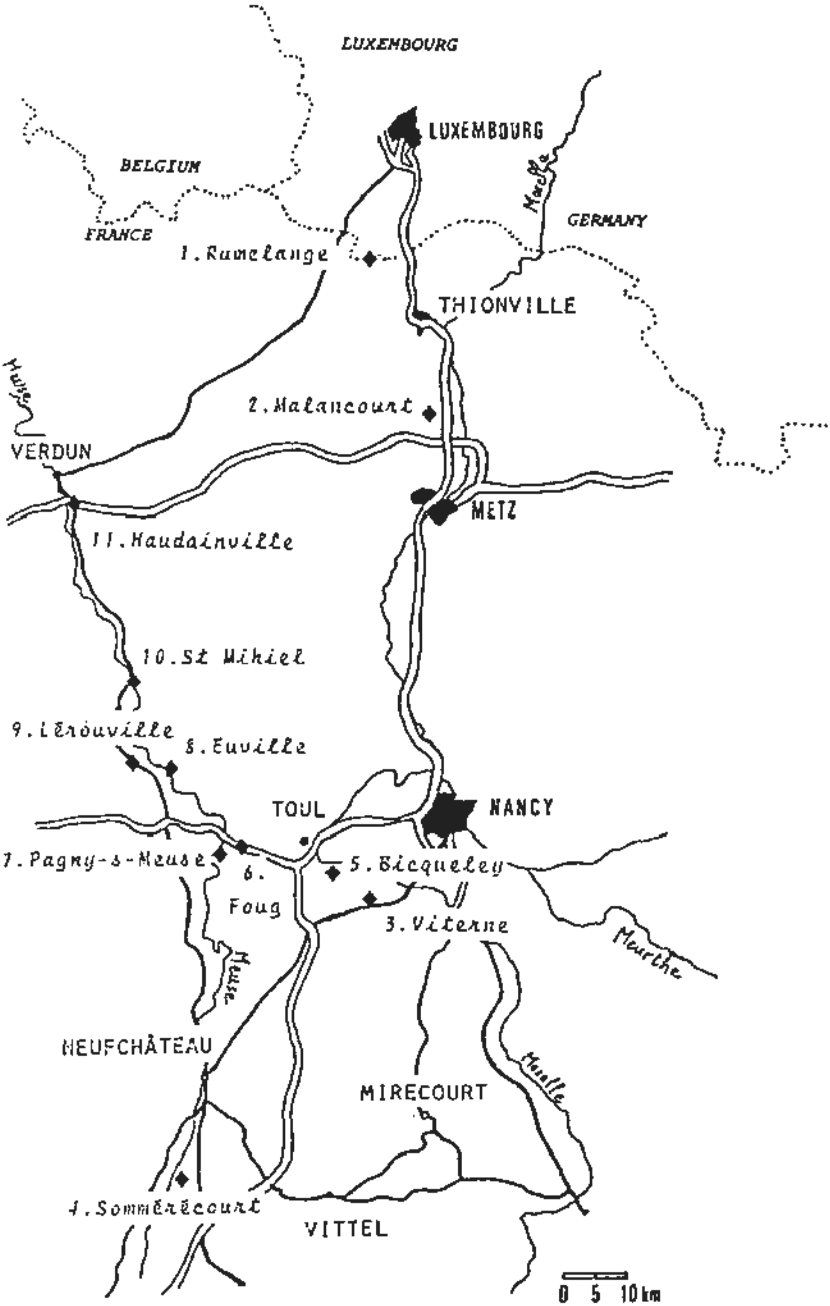


Astrea tumularis Michelin

1991

Contents



Itinerary of excursion to the Middle and Upper Jurassic coral formations of Luxembourg and Lorraine. Excursion Stops 1 to 11 are indicated.

1. General introduction

1.1 Framework of Jurassic stratigraphy of the northeastern Paris Basin

The Jurassic deposits of the northeastern part of the Paris Basin represent a complete sedimentary megacycle (fig.1). After the period of continental sedimentation in the Late Triassic, the area was inundated as a consequence of the Liassic transgression. The flooding by the Liassic sea is recorded by a thick sequence of predominantly clayey, ammonite-bearing marine sediments. These are overlain by the Aalenian iron oolite deposited in a shallow-marine environment. The latter beds, known as the "Minette" iron ores have been heavily exploited in the past. In fact, Minette ores, nearby coal measures and Triassic salt provided the basis for a formerly flourishing industry in Lorraine.

The following period of sedimentation is characterized by the development of a wide carbonate platform in the Middle Jurassic. This platform, mainly of Bajocian age in Lorraine, was subsequently drowned under a thick sequence of clay beds. The carbonate platform was reinstalled in Middle Oxfordian times. A general shallowing-upward trend persisted throughout the Middle and Upper Jurassic, and the Portlandian sediments already indicate restricted environments. The final emersion of the deposits towards the end of the Portlandian concluded the Jurassic sedimentary megacycle.

The geological history of this part of the Paris Basin, as briefly summarized above, is directly reflected by its present-day geomorphology. A slight but regular westward dip of the strata and the differential erosion of the alternating limestone and clay sequences contributed essentially to shape a conspicuous relief of successive subparallel cuestas ("côtes" in French). These cuestas constitute the dominating feature of today's landscape and may be easily traced from eastern France to the centre of the Paris Basin (fig. 2). The Jurassic cuestas are the following:

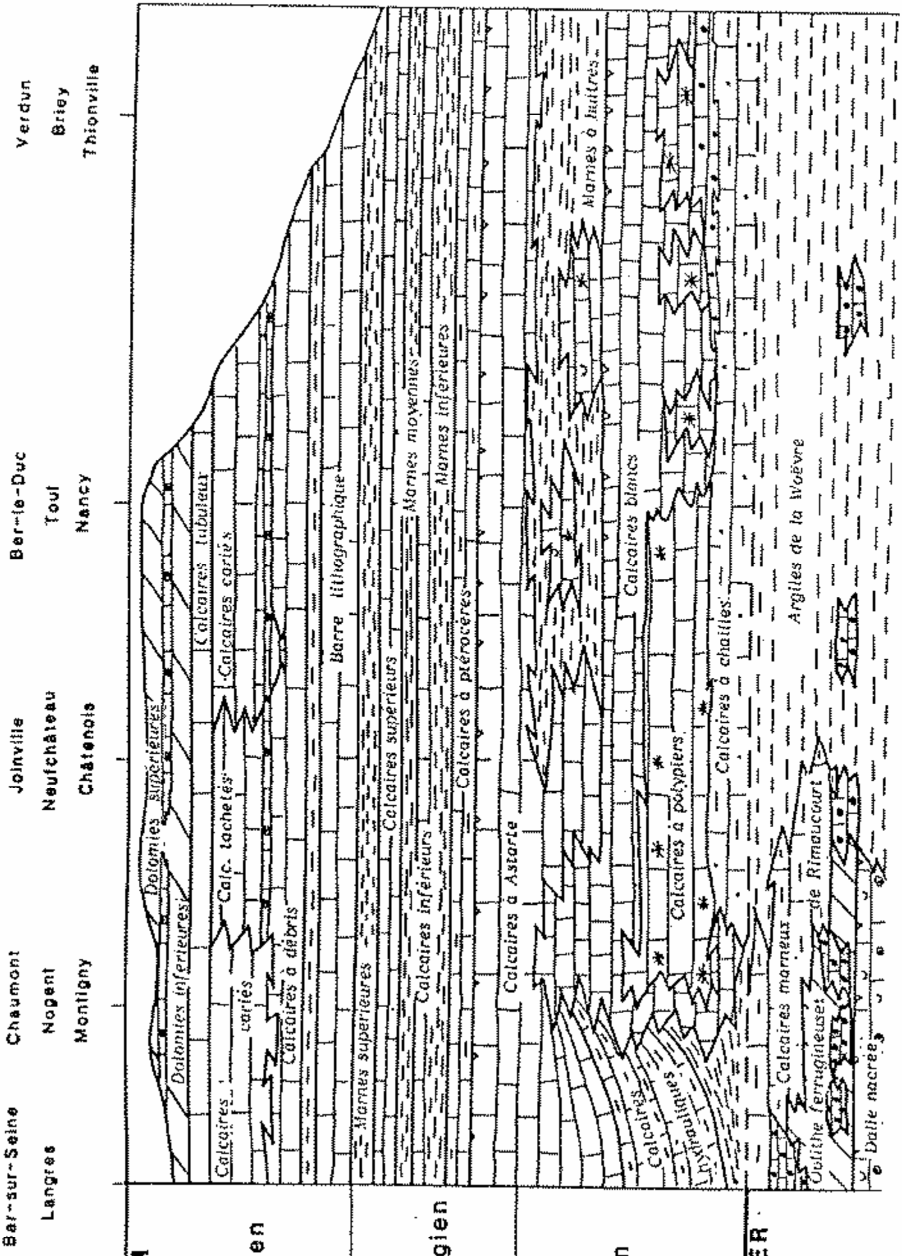
- côte infraliasique (Hettangian and Sinemurian s.s.)
- côte de Moselle (Bajocian)
- côte de Meuse (Oxfordian)
- côte des Bars (Portlandian)

Our excursion itinerary will follow the Bajocian "côte de Moselle" from Luxembourg to Nancy and Sommérécourt in the south. From the Toul area to Verdun in the north, the Oxfordian reefs will be visited in the "côte de Meuse".

1.2 Jurassic reef corals of Lorraine

Scleractinian corals may be found in rocks of several stages of the Jurassic period in Lorraine. The first reef corals appear during Hettangian and Sinemurian times. These coral colonies are only known from poor outcrops in the border region of Luxembourg, Belgium and France and were already described by TERQUEM & PIETTE (1865). Solitary corals were present over a larger area and were studied in detail by M. LEJEUNE and published under the unfortunate title of "les Montlivaultia" (LEJEUNE 1935).

Corals are also present and very abundant in the Bajocian (*humphriesianum* zone) of Lorraine. Long known to have been important frame-builders of reef complexes that extended over a wide area in eastern France (see fig.3), these reefs and their coral fauna will be one of the two main topics of this guide book. Recently, a number of


Bar-sur-Seine
Langres
Chaumont
Nogent
Montigny
Joinville
Neufchâteau
Châtenois
Bar-le-Duc
Toul
Nancy
Verdun
Briey
Thionville
MALM
Portlandien
Kimméridgien
Oxfordien
DOGGER
Callovien
Dolomies inférieures
Dolomies supérieures
Calcaires tubuleux
Calcaires cariés
Calc. tachetés
Calcaires cariés
Calcaires à débris
Barre lithographique
Marnes supérieures
Calcaires supérieurs
Marnes moyennes
Calcaires inférieurs
Marnes inférieures
Calcaires à ptérocères
Calcaires à Astarte
Marnes à huîtres
Calcaires blancs
Calcaires à polypiers
Calcaires à chailles
Calcaires hydrauliques
Calcaires marneux
Oolithe ferrugineuse de Rimaucourt
Dalle nacrée
Argiles de la Woëvre

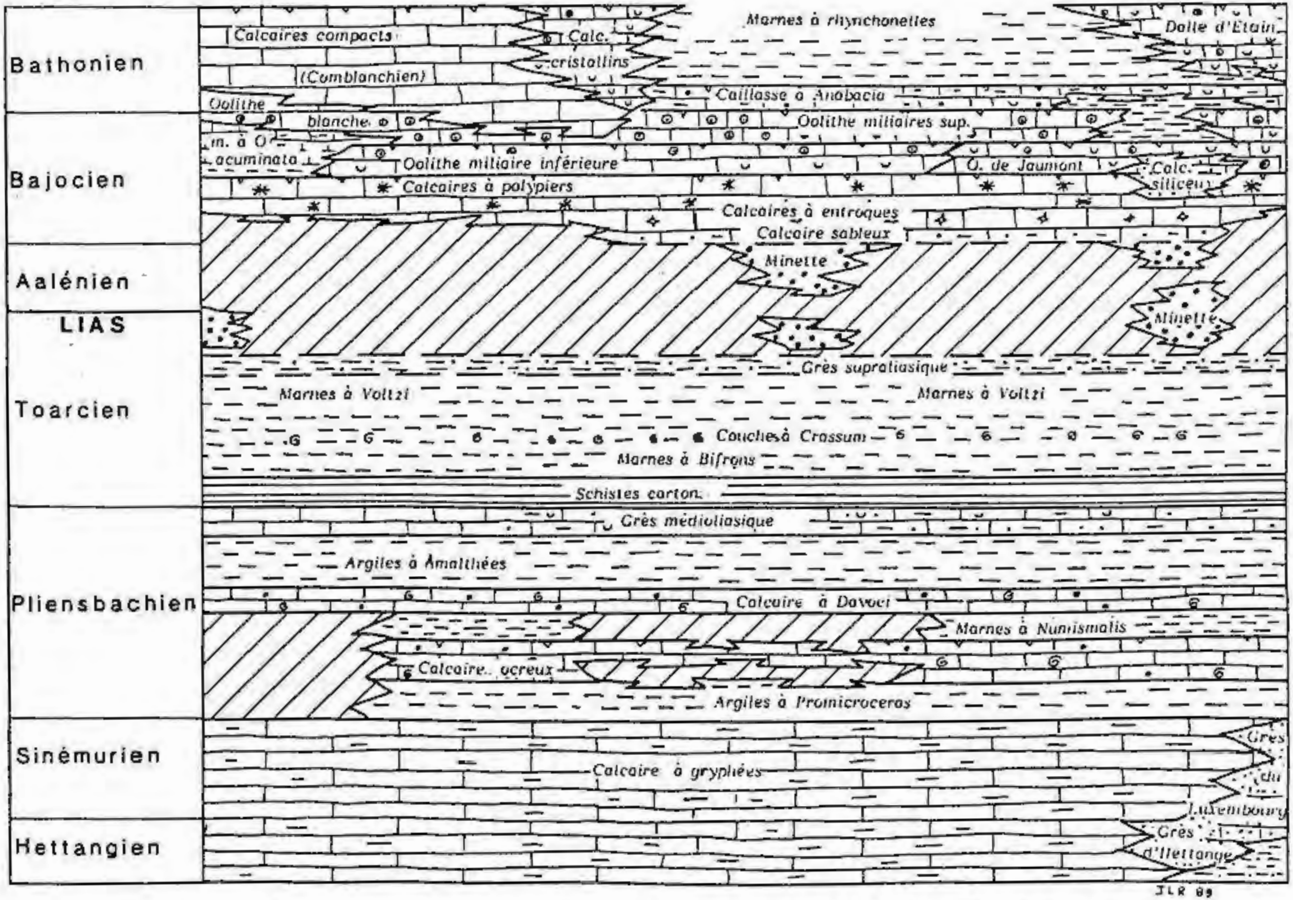


Fig.1 : Lithostratigraphic scheme of the Jurassic deposits of Lorraine. By LE ROUX, from DURAND et al. (1989).

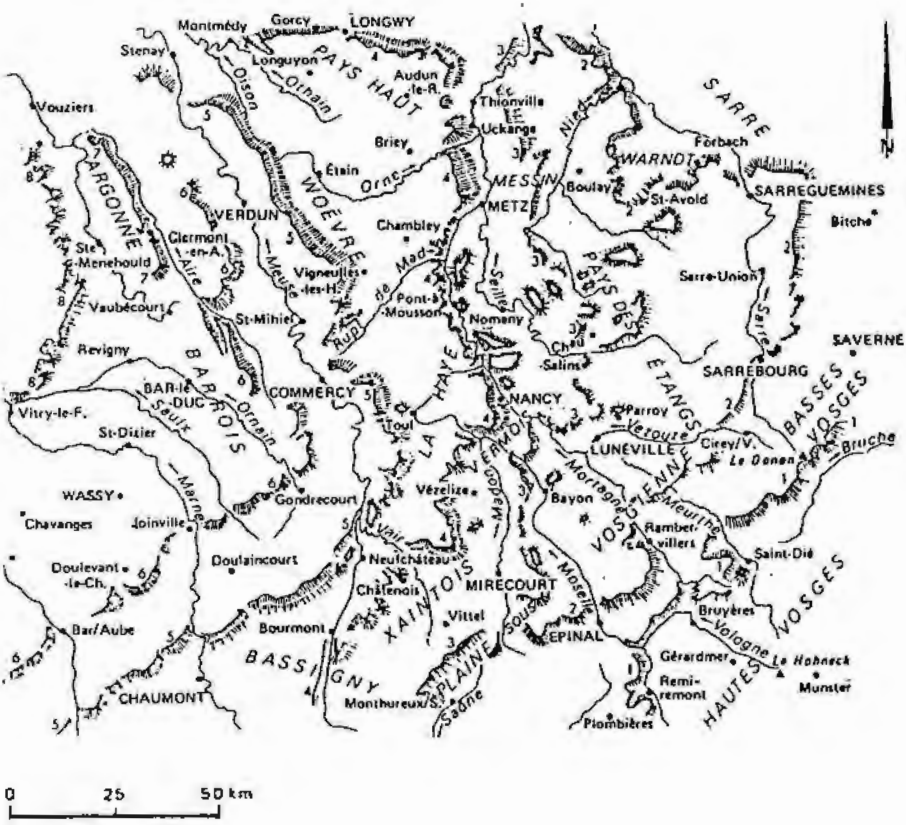


Fig. 2: The geomorphology of Lorraine characterized by a succession of subparallel cuestas of Mesozoic strata. From E to W the following cuestas can be distiguished:

1. eastern margin of the "Grès vosgien" (Buntsandstein)
2. côte du Muschelkalk
3. côte infraliasique (Hettangian and Sinemurian)
4. côte de Moselle (Bajocian)
5. côte de Meuse (Oxfordian)
6. côte des Bars (Portlandian)
7. côte de l'Argonne (Albian)
8. côte de Champagne (Coniacian-Turonian)

From HILLY & HAGUENAUER (1979)

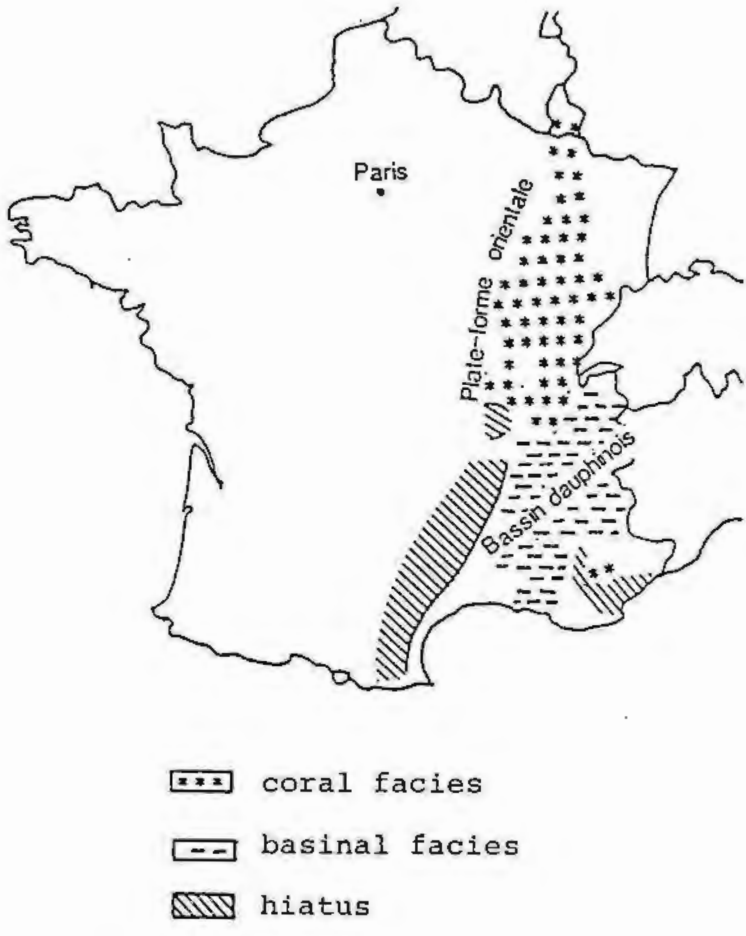


Fig. 3: Distribution of the reef coral facies in France and Luxembourg during the *humphriesianum* zone. By LATHUILIERE, from DURAND et al. (1989).

Genus name from Beauvais	Genus name from Michelin	Species name	Eix	Damvillers	Oleue	Dompcevrin	Dun	Goussaincourt	Hannonville	Haudainville	Lérouville	Maxey / Vaize	Mécrin	Montsec	Ornes	St Mihiel	Sampigny	Sorcy	Verdun	Vignol
Adelocoenia		semiradiata Et														+				
	Agaricia	elegans M										O								
	Agaricia	graciosa M															O			
	Agaricia	granulata Goldf			O				O							O	O		O	O
	Agaricia	rotata Goldf	O																	
	Agaricia	sommeringii (Goldf)							O				O							
Alloiteaucoenia	Astrea	pentagonalis Goldf in Beauv					O													
Allocoenia		furcata Et				+														
	Alveopora	incrustata M											O							
	Alveopora	tuberosa M														O				
	Anthophyllum	excavatum M												O						
Aplosmilia	Lobophyllia	aspera M														●				
Aplosmilia	Lobophyllia	semisulcata M										O				●			O	
	Astrea	burgundiae Blainv.														O				
	Astrea	castelium M						O									O			
	Astrea	cristata Goldf														O				
	Astrea	depravata M															O			
	Astrea	meandrites M					O										O			
	Astrea	tumularis M														O				
Aulophyllia	Caryophyllia	cornuta M														●				
Aulophyllia	Caryophyllia	subcylindrica M														●				
Brachyseris		curtata Beauv				+										+				
Calamophylliopsis	Lithodendron	flabellum M										O							O	
	Caryophyllia	calvimontii Lam																	O	
	Caryophyllia	clavus M														O				
	Caryophyllia	dilatata M										O				O				
	Caryophyllia	elongata Defr														O				
	Caryophyllia	moreausiaca M														O				
	Caryophyllia	vasiformis M		O								O								
Cladophyllia	Lithodendron	funiculus M														●				
Cladophyllia	Lithodendron	dichotoma (Goldf)					O					O				+			O	
Comoseris	Pavonia	meandrinoides M									+						O			
Cryptocoenia		cartieri K														+				
	Cyathophora	richardi M														O				
Dendraraea	Alveopora	racemosa M														+	O			
	Dendrophyllia	dichotoma										O				O			O	
	Dendrophyllia	glomerata M														O				
Dermoseris	Lithodendron	laeve (Blainv)						O				O							O	
Dermosmilia		crassa K														+				
Dimorpharaea		cf expansa Et									+									
Diplocoenia	Astrea	rotularia M														O				
Diplocoenia		sanctimihieli M											O			+				

Table 1: Check-list of Oxfordian corals from the Department of Meuse after MICHELIN (1841-43) and BEAUVAIS (1964).

O = cited by MICHELIN X = cited by BEAUVAIS

Genus name from Beauvais	Genus name from Michelin	Species name	Eix	Damvillers	Dieue	Dompcevrin	Dun	Goussaincourt	Hannonville	Haudainville	Lérouville	Maxey / Vaize	Mécrin	Montsec	Ornes	St Mihiel	Sampigny	Sorcy	Verdun	Vignol
Enallocoenia	Astrea	crassoramosa M										o				o				
Isastrea		gresslyi Et									+									
Isastrea	Astrea	helianthoides (Goldf)					o													
Isastrea		tenuisepta K														+				
	Lobophyllia	buvignieri M														o				
	Lobophyllia	cylindrica M																	o	
	Lobophyllia	incubans M														o				
	Lobophyllia	meandrinoides M					o													
	Lobophyllia	pseudoturbinolia M														o				
	Lobophyllia	turbinata M															o			
	Lithodendron	articulatum M					o												o	
	Lithodendron	edwardsii M																	o	
	Lithodendron	moreausiacum M																	o	
	Lithodendron	pseudostylina M					o													
	Madrepora	obeliscus M					o	o				o				o				
	Meandrina	lamellodentata M															o			
	Meandrina	lotharinga M														o	o			
	Meandrina	montana M														o				
	Meandrina	raulinii M														o				
Meandrophyllia	Meandrina	corrugata M														o				
Meandrophyllia	Meandrina	edwardsi M														⊕	o			
Microphyllia		curtata Et														+				
Microsolena		sp									+									
Microsolena		mosensis Beauv.											+							
Microsolena		thurmanni K														+				
Myriophyllia	Meandrina	rastellina M														o				
	Pavonia	hemispherica (Blainv)										o				o				
	Pavonia	tuberosa Goldf																	o	
Pseudocoenia	Madrepora	sublevis M						o				o					o			
Rhipidogyra	Lobophyllia	deshayesiaca M														o				
Rhipidogyra	Lobophyllia	flabellum M														⊕				
Stereocoenia	Astrea	araneola M														⊕				
Stereocoenia		concinna (Goldf.)									+									
Stylina		limbata (Goldf.)														+	o			
Stylina		stellata Et														+				
Stylina	Astrea	trochiformis (Mich)														+	o			
Stylina		tubulifera M. Ed				+														
	Stylina/Astrea	tubulosa														o		o		
	Stylina	gaulardi M					o													
Stylosmilia		michelini M. Ed														+				
Thamnasteria		bourgeati K				+														
Thamnasteria	Thamnasteria	lamourouxi/ dendroidea Les								o					o	o				
Thamnasteria	Agaricia	lobata (Goldf.)							o							+	o		o	o

scleractinian genera of these reefs have undergone a taxonomic revision (LATHUILIERE 1984, 1988, 1989, 1990).

Some more localized Upper Bajocian outcrops also yielded a coral fauna which was noticed by GARDET (1943). In addition, the lowermost formation of the Bathonian, regionally known as "Caillasse à *Anabacia*" is extremely rich in *Chomatoseris*, a solitary mobile coral formerly known as *Anabacia* (GILL & COATES 1977). The Middle Jurassic corals from Lorraine have been described in a monograph by MEYER (1888).

Without doubt, the Oxfordian scleractinians are the most famous corals in the area, mainly due to the early work of MICHELIN (1840-1843), and because they were later treated in detail in the thesis work of L. BEAUVAIS (1964)(see table 1). Consequently, the extraordinary Oxfordian reef formations and their rich coral fauna will be the second main topic of this guide book.

2. Introduction to the Lower Bajocian coral formations

Cyclic Middle Jurassic sedimentation in the Paris Basin documented by recurring regressive sequences (KLÜPFEL 1919, PURSER 1969) has been attributed to important eustatic fluctuations of sea level (HALLAM 1963, 1988; see also VAIL et al.1987). Within the Bajocian, two successive eustatic cycles are separated by a time lapse of less than one ammonite zone.

Within the Lower Bajocian at least two successive shallowing-upward sequences are observed. The first sequence beginning with micaceous marls, silty limestones and crinoidal limestone, passes vertically into shallow-water coralline limestones and terminates with a bored hardground. In the second sequence , the basal unit is formed by various limestones with occasional ammonites. These are overlain by a second complex of shallow-water coralline limestones which terminates with a bored hardground.

During the Bajocian (*humphriesianum* zone) there was an extensive coral reef development on the eastern shelf of the Paris Basin (fig.3). This was the first time in earth history that scleractinian corals, almost exclusively, constructed reefs which extended over an entire carbonate platform. Thus, these coral build-ups represent primitive climax communities in the history of Mesozoic coral reef ecosystems.

These Bajocian coral reefs occur within two distinct superposed reef complexes, each corresponding to one of two shallowing-upward sequences. These two coral-bearing limestone complexes were already known to early stratigraphic workers (see KLÜPFEL 1919) and were designated as the "Lower Coral Limestone" ("Unterer Korallenkalk", "Calcaire à polypiers inférieur") and "Upper Coral Limestone" ("Oberer Korallenkalk", "Calcaire à polypiers supérieur"). In addition, KLÜPFEL (1919:316-317) mentions a "Mittlerer Korallenkalk" ("Middle Coral Limestone") from the area of Metz.

Based on rare ammonite findings the Lower Coral Limestone has been attributed to the *humphriesianum* subzone and the Upper Coral Limestone to the *blagdeni* subzone (CONTINI 1970). The coral reefs described in this guide book belong both to the Lower and Upper Coral Limestones. They crop out between Luxembourg and Sommérécourt (Lorraine) some 150 km to the south.

2.1 Geometry and geomorphology of reefs

The reefs show an irregular outline and belong exclusively to the patch reef type. They include lens-shaped reef bodies a few meters in diameter, together with dome-shaped build-ups up to 10 m thick and 10 to 20 m broad. Additionally, there are large reef masses often up to 20 m thick and extending laterally more than 100 m. There are no barrier reef structures, and no landward and seaward zonation of the patch reefs is apparent. Major reef bodies are usually truncated at their tops by the hardground discontinuity that terminates the sequence.

The submarine relief of the reefs was low and averaged generally less than 0.5 m. Even in the vicinity of major build-ups it rarely surpassed 2 m and no steep or vertical reef walls were developed. Thus, even larger reef bodies rose gently as low mounds above a rather level sea floor, although lateral transition from reef to inter-reef facies was generally abrupt.

2.2 Reef ecology and biota

Substratum and reef initiation
Initiation of reefs occurred during shallowing phases when the substratum was colonized by hermatypic corals. Numerous small coral reef bodies with conical bases developed contemporaneously and by lateral fusion produced large reef masses within the first meter of vertical growth.

Reef framework
The reef bodies are formed by a dense and coherent rigid framework of a paucispecific coral fauna. The fauna is composed mostly of large platy hermatypic colonies (predominantly *Isastrea* spp.) with additions of more massive colonies of the same genus, platy representatives of the genera *Kobyastraea* and *Periseris* and rare branching corals. Only at Sommérécourt branching corals play locally a major role in framework construction. The reef rock may be formed by more than 70 % of coral skeletons. The red alga *Solenopora* was found in reefs of the Upper Coral Limestone at Malancourt.

The Bajocian reefs of the northeastern Paris Basin belong to the rare examples of Mesozoic reefs that show a rigid and coherent framework comparable to well-developed Quaternary coral reefs.

Growth rates and carbonate production
The epithecae of some of the platy and massive corals show rhythmic growth ridges at rather regular intervals of 1 to 3 mm (fig.4). Assuming the ridges are yearly, they would indicate the growth rate of the colony. Skeletal density banding recognizable in longitudinal sections of recrystallized massive *Isastrea* (fig.5) are very similar to Recent growth bands. They suggest growth rates of the same magnitude.

Calculated from growth band data, the gross carbonate production of one particular Bajocian coral reef was fairly low but remains within the range of its Holocene counterparts (GEISTER 1986a, 1989).

Currents and waves
Currents and possibly wave action were active at several levels in the section as evidenced by the frequent large scale crossbedding of the rather coarse inter-reefal sediments formed mainly by the debris of crinoids and sea shells. The fine fraction was winnowed out and has been apparently trapped as intra-reefal sediments in the interstices of the reef framework (GEISTER 1984a). As a consequence, the coral colonies of some of these reefs that have a rather shallow aspect appear embedded in

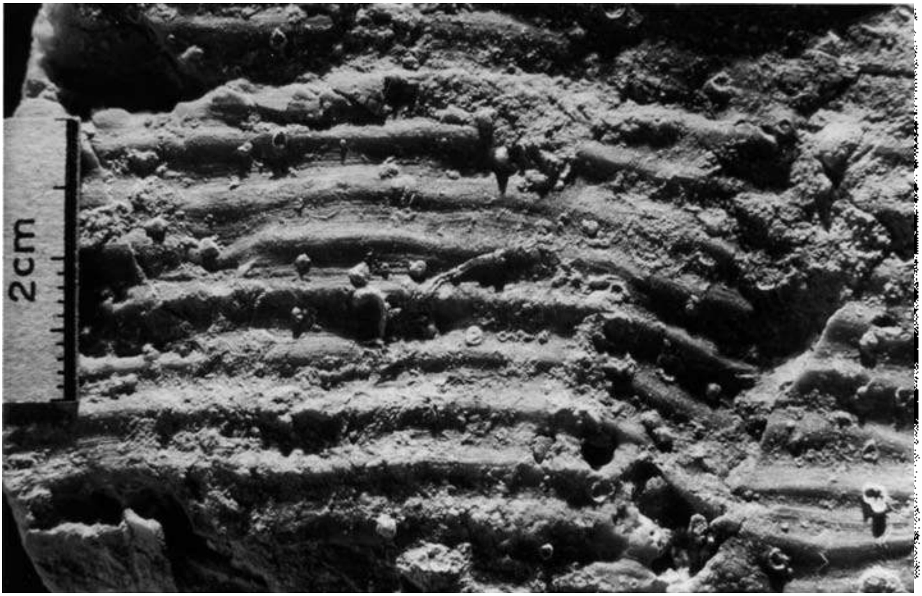


Fig.4: Annual epithecal growth banding of a Bajocian reef coral (presumably *Kobyastraea* sp., Carrière Blanche, Rumelange (Luxembourg).

a matrix of mudstone with an unusually high silica content up to 31% (HARY 1970:439).

Some of the smaller reefs observed in the lower cycle lived in a regime of increasing sedimentation rates that finally surpassed their net growth rate, so that they became suffocated by onlapping inter-sediments. These build-ups are embedded in clearly-stratified argillaceous limestone that testifies to the absence of extensive bioturbation and reworking of sediments. They appear to have developed in deeper water below wave base. Reef debris flanking the build-ups is almost non-existent in both reef types.

Reef zonation

No lateral nor distinct vertical ecological zonation has been recognized in these reefs. This is probably due both to the very low diversity of the frame-building biota that lack the necessary ecological spectrum and to the apparently insignificant environmental gredients that prevailed over the growing surface of the reefs.

The coral fauna

The low-diversity coral fauna recovered from the reefs corresponds to that described for the whole area by MEYER (1888). It is dominated by nearly 70% of generally platy but also massive colonies of the genus *Isastrea*. Some of the larger platy *Isastrea* colonies attain diametres of more than 1 m with thicknesses surpassing 10 cm. Also dome-shaped massive colonies are frequently encountered in some outcrops. Such a colony of *Isastrea* collected at Rumelange (Luxembourg) and figured by HARY (1970) attained a diametre of nearly 30 cm at the ambitus. The high diversity of

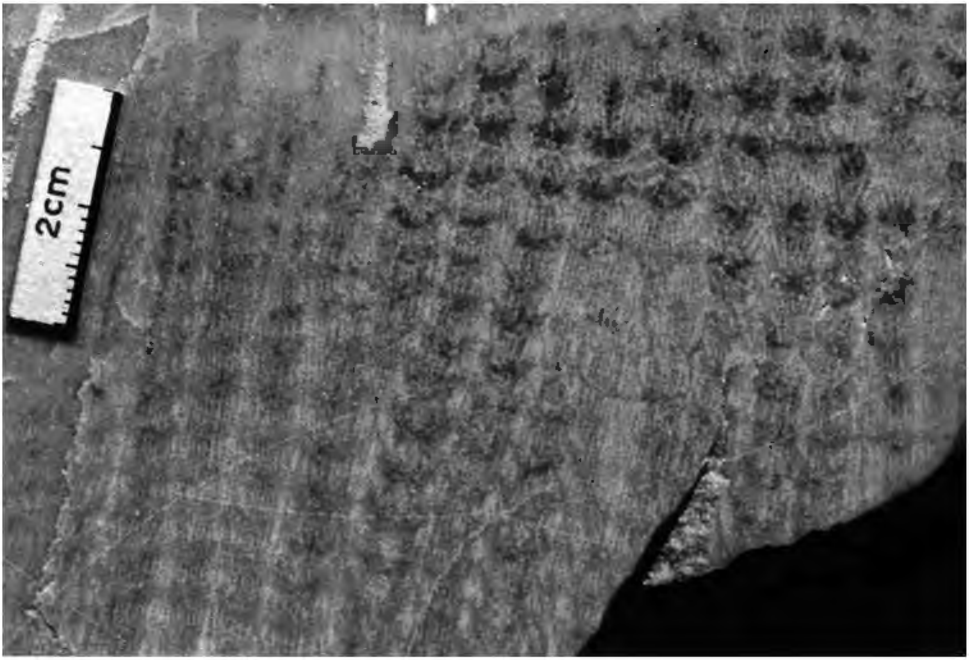


Fig.5: Annual density growth banding of a Bajocian reef coral (*Isastrea* sp.) highlighted by diagenetic alteration of the coral skeleton. Carrière Blanche , Rumelange (Luxembourg).

coral morphology observed in the reefs is mainly due to the extraordinary intraspecific variation studied among colonies of *Isastrea bernardiana* (see LATHUILIERE 1988). In addition to the abundant *Isastrea bernardiana*, only very rare colonies of *Isastrea tenuistriata* have been observed.

Less abundant are platy *Kobyastraea* and the recently revised variable species *Periseris elegantula* (see LATHUILIERE 1990). The phaceloid *Stylosmilia* and *Thecosmilia* are more rare in this association. Dendroid branching corals *(Dendraraea)* contribute only locally to the framework construction.

Many lamellar colonies exhibit a strange mode of branching with several superposed irregular lamellae connected by small skeletal necks (HALLAM 1975, GEISTER 1984a). This phenomenon, not described from Recent reef corals, appears to be due to partial burial of the living coral by sediment, subsequent regeneration by upgrowth and renewed spreading of the colony above the sediment level. For some colonies of *Isastrea* this regeneration may be accompanied by an unusual transition from the cerioid to the phaceloid growth habit and vice versa (see LATHUILIERE 1989).

Cryptic biota
The platy coral colonies mostly formed an interlocking rigid framework. Notable is the

total absence of major cavities within the Bajocian reef framework which contrasts to modern coral reefs. However, a coelobite fauna fixed to the lower face of the corals demonstrates that these colonies have not been entirely encrusting. Thus, the platy colonies formed relatively small shelters for a fairly diversified cryptic fauna (fig.6). Among the cryptobionts the following groups have been recognized:

endolithic: sponges, lithophagans (at least two species), annelids or sipunculids, phoronids (?), algae

sessile: pedunculated brachiopods (rhynchonellids and terebratulids), thecidean brachiopods (*Moorellina*), serpulids, bryozoans (*Plagioecia*), nubecularian foraminifera.

Other fossils:
Within the coral framework the following pelecypods may be observed: *Chlamys*, *Plagiostoma* and *Lopha*. *Chlamys* is most abundant and appears

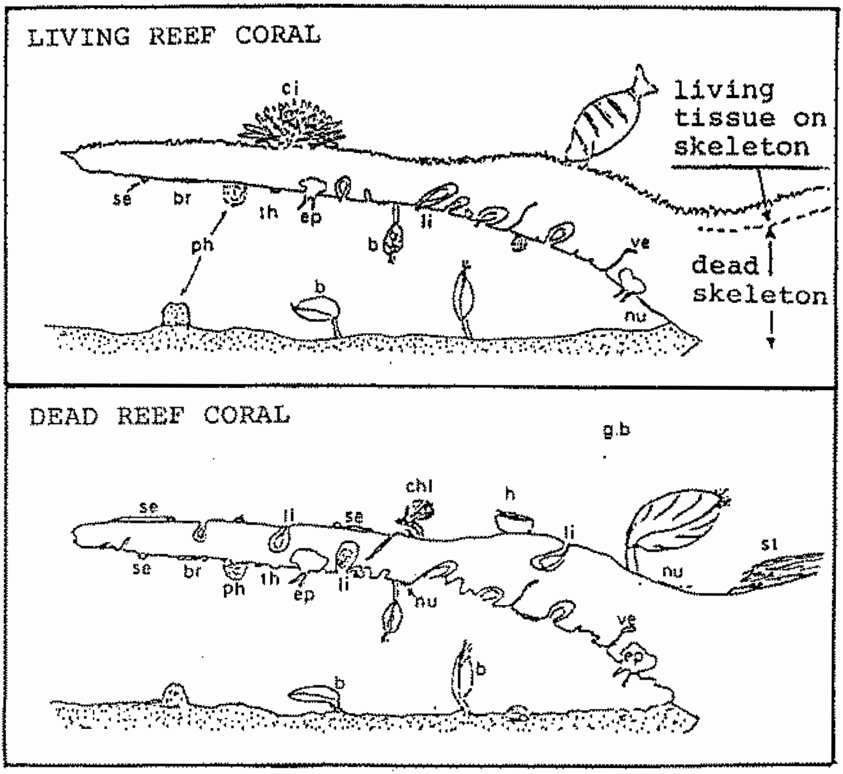


Fig. 6: Organisms associated with platy Bajocian reef corals

se = serpula
br = bryozoan
ph = pharetronid
th = thecidean
st = stromatolite
ep = boring sponge
b = small brachiopod
li = lithophagan
ve = vermiform boring
nu = nubecularian
ci = cidarid
chl = *Chlamys*
lgb = large brachiopod

Modified from LATHUILIERE (1982)

tightly associated with the boundstone facies, probably because of its obligatory byssal fixation to hard substrates. Among echinoids, two species may be commonly encountered: *Caenocidaris cucumifera* and *Paracidaris zschokkei*.

The macrofaunal association of the inter-reef facies is more diverse, mainly due to the nature of the substrate. This is especially true for the "Lower Coral Limestone" where a soft substrate is more common. The following pelecypod genera have been encountered: *Lopha, Ctenostreon, Plagiostoma*, other Limidae, *Trichites, Chlamys, Entolium, Cavilucina bellona* and *Pseudotrapezium* as well as *Pholadomya*. Large gastropod shells of the genus *Bourguetia* are very common. Terebratulid and rhynchonellid brachiopods are also common. The predominant macrofossils are, however, *Isocrinus* ossicles and spines of *Paracidaris zschokkei*.

2.3 On the differences between Bajocian and Quaternary coral reefs

Typical Quaternary reefs preferably settled on a hard substratum provided by an older reef and other limestone forming outer terrace margins or topographic highs on a freshly inundated sea floor. Pioneering reef-building biota are frequently represented by medium diversity associations of incrusting and massive scleractinians that lived above wave base. Initiation of reef growth on soft substratum seems to be exceptional. Prevailing growth rates of the massive corals vary from less than 10 to 25 mm/year depending on systematic affinity, depth (light level) and temperature of the water. Holocene shallow-water reefs were growing to thicknesses up to 20 m within several thousand years.

By contrast, Bajocian reefs settled on a perfectly level sea floor covered by sand and/or sandy mud and, as reported by KLÜPFEL (1919:313), on nests of rhynchonellid brachiopods. These are frequently underlain by oolitic and crinoidal limestone and more rarely by ammonite-bearing sediments. Reefs were initiated as coral biostromes of very low diversity. Their pioneer coral fauna consisted of supposedly deep-water morphotypes of otherwise massive scleractinians (mostly *Isastrea* spp.) and thin disc-like *Kobyastraea* sp. and *Periseris* sp. with growth rates around 1 mm/year. They resemble the growth habits of modern deeper-water agariciids.

Growth analyses of a number of well-preserved coral specimens from a Bajocian reef in Luxembourg indicates very low distal growth rates ranging from 3.0 mm/ year in the massive to less than 1 mm/year in the more flattened colonies. These observations, supplemented by sedimentological evidence, point to an onset of reef growth at water depths well below wave base. The shallow and uppermost part of the original Bajocian reef bodies is not preserved today as a result of the bioerosion during the formation of the hardground that terminated the sequence. In one particular case, the gross growth rate of a Bajocian patch reef was calculated from individual coral growth rates, suggesting that it needed some 10,000 years for the upgrowth of the 18 m thick reef body (GEISTER 1989).

By contrast, the shallow-water framework of Quaternary coral reefs is commonly dominated by fast-growing branching acroporids and poritids with growth rates of 3 to more than 20 cm/year. These have no ecological equivalent in the Bajocian coral reefs of the eastern Paris Basin.

Moreover, the Quaternary reef coral fauna is highly diverse (with 80 genera in the Indopacific and 35 genera in the Atlantic) as compared to the 12 odd coral genera present in the Bajocian of eastern France. But this observation of lower diversity might be biassed by the fact that the shallowmost reef crest associations of all the Bajocian reefs were truncated and by their marginal position within the Bajocian tropical belt (GEISTER 1989). The latter observation alone suggests a reduced diversity of the hermatypic scleractinians. Ecological zonation is common in the Quaternary (GEISTER 1980, 1982,1983) but absent in the Bajocian reefs of the area.

Disruptions of reef growth caused by natural physical and biological disturbances and subsequent recolonization are common in the Quaternary but seemingly are rare in the Bajocian coral reefs examined. Erosion by boring bivalves and even more intensively by clionid sponges is widespread in the Quaternary. It was more restricted in the Bajocian corals, however, where lithophagan borings are most obvious.

Cheilostomate and cyclostomate bryozoans play a certain ecological role as encrusters in the framework of Recent reefs. But in the Bajocian reef framework only negligible amounts of small and encrusting or branching colonies of cyclostomates have been observed. Binding calcareous algae which are well-represented in Quaternary reefs, are restricted to local occurrences of *Solenopora* in the Bajocian reefs.

Literature:
DURAND et al. (1989), GEISTER (1980, 1984a, 1984b, 1986a, 1986b), KLÜPFEL (1919), LATHUILIERE (1981,1982)

2.4 Field guide to Bajocian and Bathonian coral formations

Stop 1 Bajocian coral reefs and inter-reef sediments at Rumelange south of Grand-Duchy of Luxembourg)

The outcrop to be visited is a large abandoned limestone quarry ("Carrière Blanche" or "Weiss-Kaul") situated SW of the town of Rumelange at the southern border of the Grand-Duchy of Luxembourg. The quarry was formerly worked to extract limestone for the local steel industry. It is approximately 600 m wide from E to W and its quarry walls are up to 25 m high exhibiting most of the "Lower Coral Limestone" ("calcaire à polypiers inférieur") and overlying ammonitic beds. But the hardground on its base is not visible in this quarry.

The outcrops give a fine overview of lateral facies transitions within the "Lower Coral Limestone" and show its relation to the overlying ammonitic beds. They are renowned for their well-developed reef formations.

Stratigraphy:
"Calcaire d'Audun-le-Tiche" or "Other Kalk" which corresponds to the Lower Coral Limestone of Lorraine. It is overlain by the "marnes sableuses d'Audun-le-Tiche" or "Other Mergel". Both are referred to the *humphriesianum* zone of the Lower Bajocian.

Most conspicuous fossils
Reef framework of "Calcaire d'Audun-le-Tiche": *Isastrea bernardiana* (predominant), *Kobyastraea*, *Periseris*, one single but large colony of *Stylosmilia; Lopha, Lima*, pectinids and other pelecypods; gastropods; rhynchonellid and terebratulid brachiopods; echinoids; encrusting serpulids and bryozoans. HARY (1970) mentions rare findings of ammonites.

Inter-reef facies of "Calcaire d'Audun-le-Tiche": *Bourguetia*, crinoid ossicles

Hardground: numerous boring organisms (lithophagans, *Potamella?, Polydorites?* etc.), and encrusting oysters.

"Marnes sableuses d'Audun-le-Tiche": numerous pelecypods (abundant small Oxytomidae), stephanoceratid ammonites etc.

Access to "Carrière Blanche":
The town of Rumelange is situated some 6 km due SE of Esch-sur-Alzette, the centre of the Luxembourg steel industry. From Rumelange city centre follow road sign indicating "musée des mines, champs de tir". Leave the car at the shooting range ("champs de tir") which is just beside the entrance to the eastern end of the quarry area. From here the outcrops may be easily reached by foot.

Coordinates : (GAUSS-Luxembourg) x = 68,28 to 68,72 y = 57,54 to 57,96

Topographic maps 1:50 000 : XXXIII-11 (Audun-le-Roman)
1:20 000 : VI(XXXIII-10)-Nos.7-8bis.(Esch-sur-Alzette)
Geologic map 1:25 000 : Nr.1 (sheet Esch-s.-Alzette)

Literature :
GEISTER (1984a,1986a,1989), HARY (1970), LUCIUS (1945), STAMM (1975), WATERLOT et al.(1973:150, 159-160)

1: 20 000

Because of its large size, the outcrop will be visited at 2 stations (A and B) in order to show the best-developed and most easily accessible reef formations.

Station 1A: Easternmost sector of the quarry area adjacent to the shooting range

Access:

From the parking area of the "champs de tir" walk down the quarry road which is closed for vehicles by a barrier. After about 100 m the road widens into the southeastern sector of the "Carrière Blanche".

The outcrop

Reef framework:

Of interest is the southern quarry wall which exhibits a remarkable reef structure, which has already been studied to some detail (GEISTER 1984a,1989). This patch reef has a stem-like base that is topped by a wide roof truncated by a bored hardground giving it an overall mushroom-like shape (fig.7). The vertical thickness of the reef as exposed in the quarry wall is about 18 m.

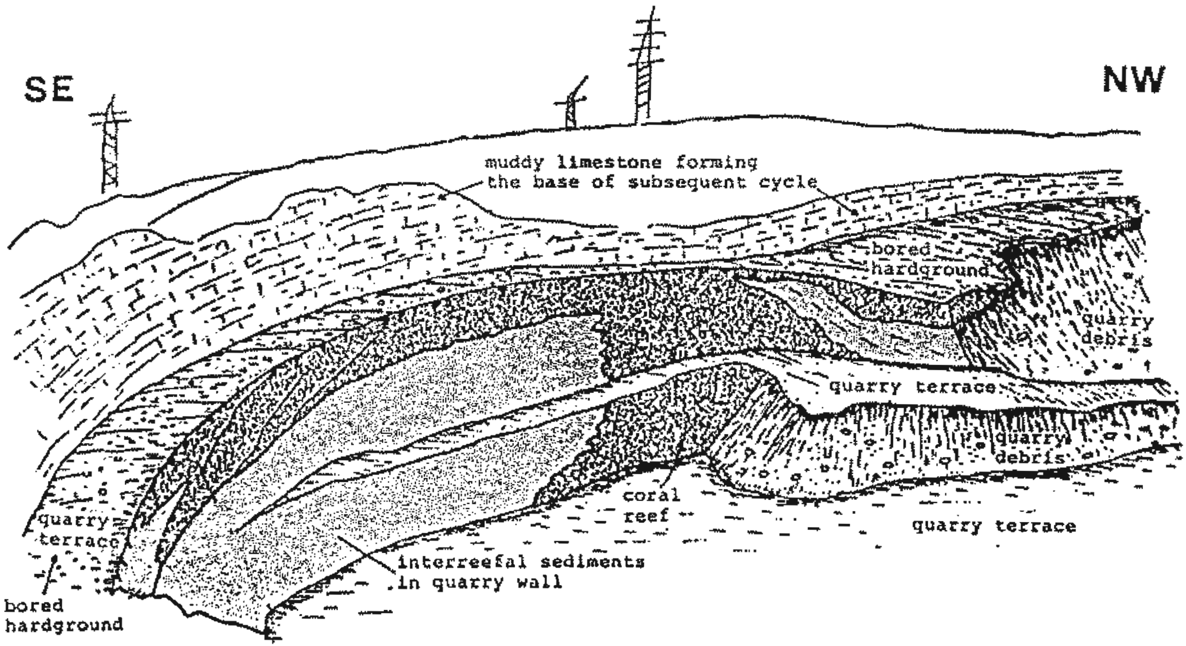


Fig.7: Stop I. Panoramic sketch of quarry face at "Carrière Blanche", Rumelange, Luxembourg (Station 1A). The mushroom-shaped patch reef developed during a shallowing-upward cycle of the Lower Bajocian (Lower Coral Limestone, *humphriesianum* subzone) and is truncated on top by a bored hardground. The hardground is overlain by muddy to calcarenitic limestone ("Marnes sableuses d'Audun-le-Tiche") representing the deeper-water phase of a subsequent shallowing-upward cycle. A hardground present near the base of the patch reef does not crop out in this quarry. Height of the reef body as visible in outcrop is approximately 18 m. From GEISTER (1989).

As the mushroom developed, the patch reef appeared as a low mound that rose gently above a level sea-floor. Lateral transition from reef to inter-reef facies was abrupt. No onlapping sediments can be observed. During a later growth stage, corals simultaneously colonized much of the surrounding sediment surface, thus forming the "head" of the mushroom. Sedimentation rate equalled roughly the growth rate of the adjacent reef.

From this patch reef, the growth rate and life span of a number of coral colonies with well-developed growth banding (fig.5) were studied. The estimated accretion rate of the entire densely packed reef body (fig.8) was close to 2.2 mm/year. Therefore the 18 m thick reef body represents at least 10,000 years of reef growth. The gross carbonate production, as calculated from skeletal geometry, coral cover and coral growth rates should have been around $1.6\text{-}1.8 \times 10^3$ g/m^2/yr. This is rather low as compared to Recent patch reefs (GEISTER 1989).

Note the fine silty matrix trapped within the interstices of the framework (fig.9).

Inter-reef sediments:
Sediments of the Lower Coral Limestone are fairly coarse, well-sorted, winnowed and rippled, indicating a rather high-energy shallow-water environment. This contrasts to central and southern Lorraine where the inter-reef sediments of the Lower Coral Limestone indicate a more quiet and possibly deeper water depositional environment, which would have been more distant from the Rhenish continent.

To the left of the quarry wall the hardground truncating the top of the reef (fig.10) and the overlying beds of the fossiliferous "Marnes sableuses d'Audun-le-Tiche" are readily accessible.

Station 1B : Western sector of the quarry area

Access:
From the parking area of the "champs de tir" drive westward for 300 m to enter that wide and extensive quarry area.

Outcrop:
The southern outcrop wall shows a good example of onlap of inter-reef sediment onto a large reef body (fig.11). The transition here is not at all abrupt. There is some interfingering of coral-rich and coral-poor sediments parallel to the reef slope. It appears that the reef body was gradually drowned by onlapping inter-reef sediments. Likewise reef and inter-reef sediments are truncated at their top by the hardground.

Nearby, there are 3 smaller reef bodies that have been completely drowned in the sediments well below the truncation surface.

Fig. 8: Stop 1. Interlocking framework formed by densely packed platy to massive Bajocian scleractinians (predominantly *Isastrea* sp.). Stem of mushroom reef (fig.7) at Station 1A. Hammer (32 cm) for scale.

Fig. 9: Stop 1. The fines winnowed out from nearby inter-reef sediments were trapped in the interstices of the Bajocian reef framework.

Fig. 10: Stop 1. Bored hardground truncating the top of mushroom reef of fig.7. Note numerous boreholes of varying size and encrusting oysters. Station 1A. Hammer 32 cm.

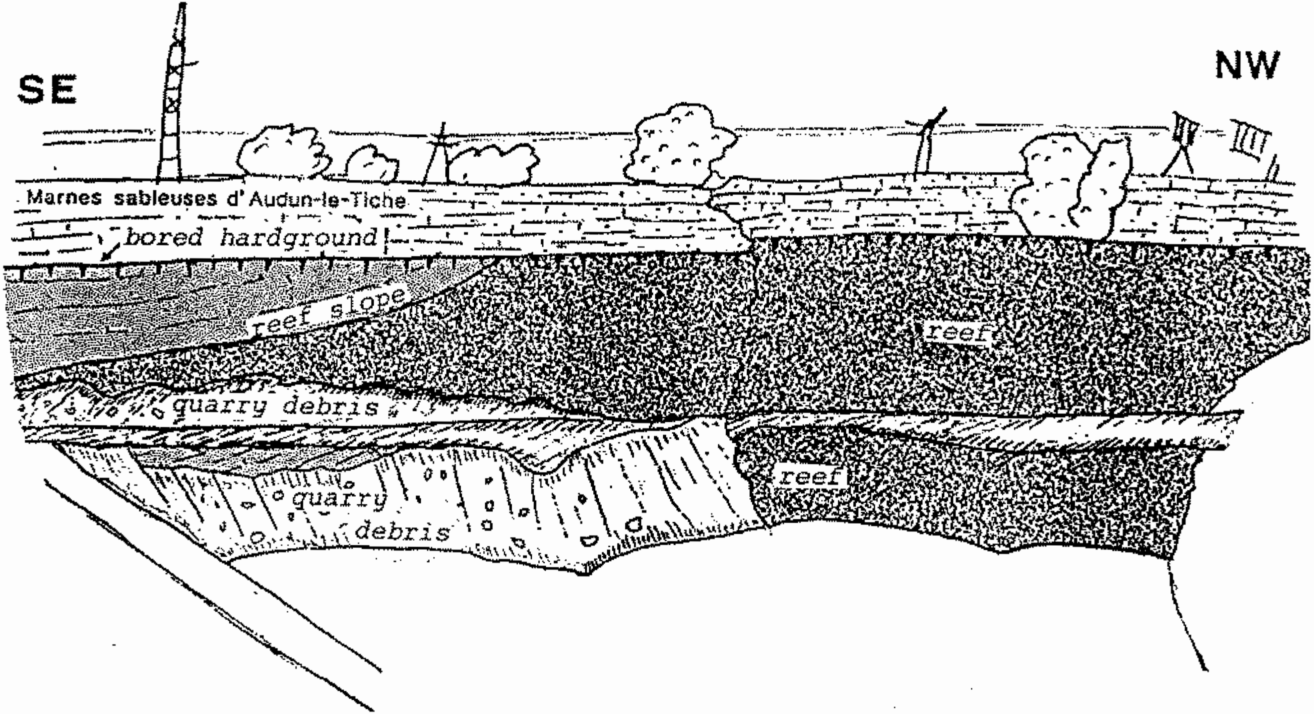


Fig. 11: Stop 1. Panoramic sketch of quarry face at "Carrière Blanche" (Station 1B). Lower Coral Limestone ("Calcaire d'Audun-le-Tiche") with reef and inter-reef facies is separated from the overlying deeper-water sediments ("Marnes sableuses d'Audun-le-Tiche") by bored hardground. Note onlap of inter-reef sediments on slope of large reef body (ca.18 m thick). From GEISTER (1984a).

Stop 2 Bajocian coral reefs and inter-reef sediments at Malancourt (Lorraine)

The outcrop to be visited is a huge limestone quarry ("Carrière des Anges") that was used by the cement industry. The exceptionally large quarry wall (some 400 m wide and more than 30 m high) exhibits a unique panorama both of the Lower and Upper Coral Limestones and the suprajacent "marnes de Longwy"(Longwy marls).

The "Carrière des Anges" at Malancourt-la-Montagne

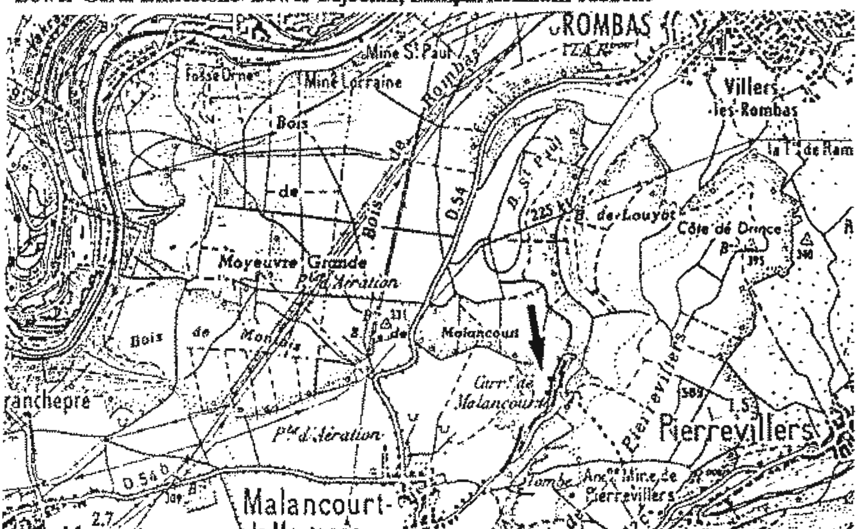
Access to quarry:

The small village of Malancourt is situated in the hills of the "côte de Moselle" which forms the western flank of the Moselle valley between Metz and Luxembourg. Lying some 18 km due SSW from the centre of Thionville, it may easily be reached by car after driving for 11 km from the highway exit of Mondelange (S Thionville) via Rombas. The modern road crosses the cuesta to Montois-la-Montagne. From Montois there is also an easy connection to the exit of the highway Verdun-Metz at Ste. Marie-aux-Chênes which is 12 km from Malancourt.

Pass through Malancourt from the N and follow direction "Pierrevillers/Roncourt". Near the end of village turn left into small street ("rue de la Potence") and continue for several 100 m to its end (barrier). Proceed downhill by foot on quarry road for some 500 m until the panorama of the quarry wall can be seen to the left. The top of the quarry may easily be visited by walking up a forest lane from the right side of the quarry.

Stratigraphy:

"Marnes de Longwy": lowermost Upper Bajocian, *subfurcatum* zone
Upper Coral Limestone: Lower Bajocian, *blagdeni* subzone
Lower Coral Limestone: Lower Bajocian, *humphriesianum* subzone



1 : 50 000

Coordinates: x = 872,4 y = 176,45

Topographic and geologic maps 1:50 000: Nr.XXXIII-12 (sheet Briey)

Literature:

DURAND et al. (1989), GEISTER (1984a), HALLAM (1975), HILLY & HAGUENAUER (1979), KLÜPFEL (1921), LATHUILIERE (1989), MAUBEUGE (1972)

Fig.12 shows the facies distribution seen in the quarry wall. Details are shown in figs.13, 14, 15 and 16.

Lower Coral Limestone

Bedded limestones and marls very rich in bioclasts and fossils. The fauna is dominated by pelecypods, but includes also ammonites, belemnites, nautilids, the gastropod *Bourguetia*, brachiopods and echinoids (see list in HALLAM 1975). In addition, there are *Thalassinoides* burrows.

Within the lower part of the quarry wall, at least 9 coral build-ups are visible, built mainly by thin platy corals (*Isastrea* and *Periseris* dominant, with some *Kobyastraea*). Some of the reefs are at least 16 m high. But their original submarine relief was very low. Much of the apparent topography, indicated by onlapping sediments, is due to differential compaction. The depositional environment was more quiescent and deeper than in the corresponding reefs visited at Rumelange.

The top of the Lower Coral Limestone is truncated by a hardground bored by *Trypanites*. This lower hardground is accessible at the left side of the quarry wall. It corresponds in age to the hardground seen at Rumelange.

Cherty limestone ("faciès à Chailles")

These are thin-bedded, poorly fossiliferous limestones with irregular chert nodules which correspond to a preferential silicification of *Thalassinoides* burrows. According to HALLAM (1975) this unit contains abundant calcite-replaced spicules of the siliceous sponge *Rhaxella*, indicating a probable source for the diagenetic chert nodules, but there are also detritical quartz grains in these beds.

The Upper Coral Limestone

This is mostly inaccessible in the upper part of the vertical quarry wall. The inter-reef sediments are characterized by large-scale cross-bedding of mostly winnowed and sorted bioclastic sands comparable to the Lower Coral Limestone at Rumelange. Reef initiation occurred by growth of numerous small conical reef bodies which joined to form a large reef structure within the first metre of vertical growth (fig.15). The framework is densely packed and built predominantly by fairly thick platy colonies, presumably of *Isastrea*. Some of the colonies became very large up to 1.5 m across. Locally, the onlapping sediments are rich in thalli of the the red alga *Solenopora*.

The top of the Upper Coral Limestone is truncated by the upper bored hardground which is easily accessible on top of the quarry.

The "Longwy Marls" ("marnes de Longwy")

These are yellow sandy limestones containing abundant shells of the small oyster *Praeexogyra acuminata*. The beds form the top of the quarry.

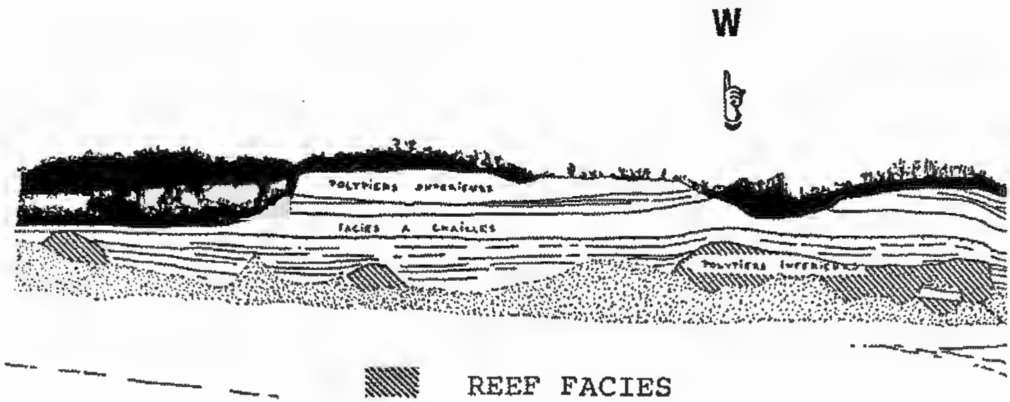


Fig.12: Stop 2. Panoramic sketch of the "Carrière des Anges" at Malancourt featuring the Lower Coral Limestone ("polypiers inférieurs") truncated by hardground and overlain by cherty limestone ("facies à chailles") and the Upper Coral Limestone ("polypiers supérieurs"), Lower Bajocian.
By LATHUILIERE, from DURAND et al. (1989).


N
FACIES A CHAILLES
B.L.

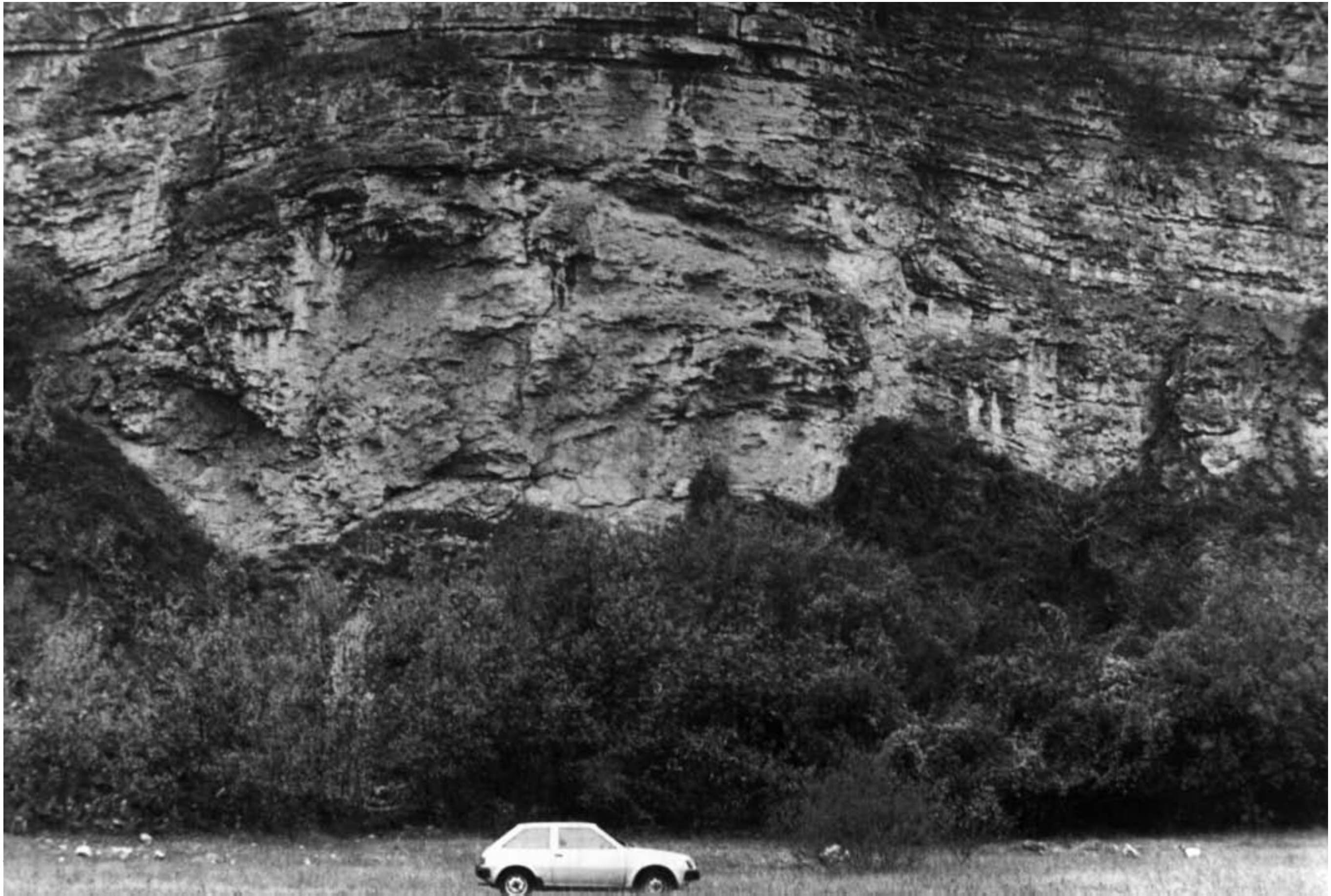


Fig. 13: Stop 2. Large reef body of the Lower Coral Limestone exposed at the base of the Malancourt quarry. This reef was not truncated by the hardground but was drowned under sediments well below the truncation plane.

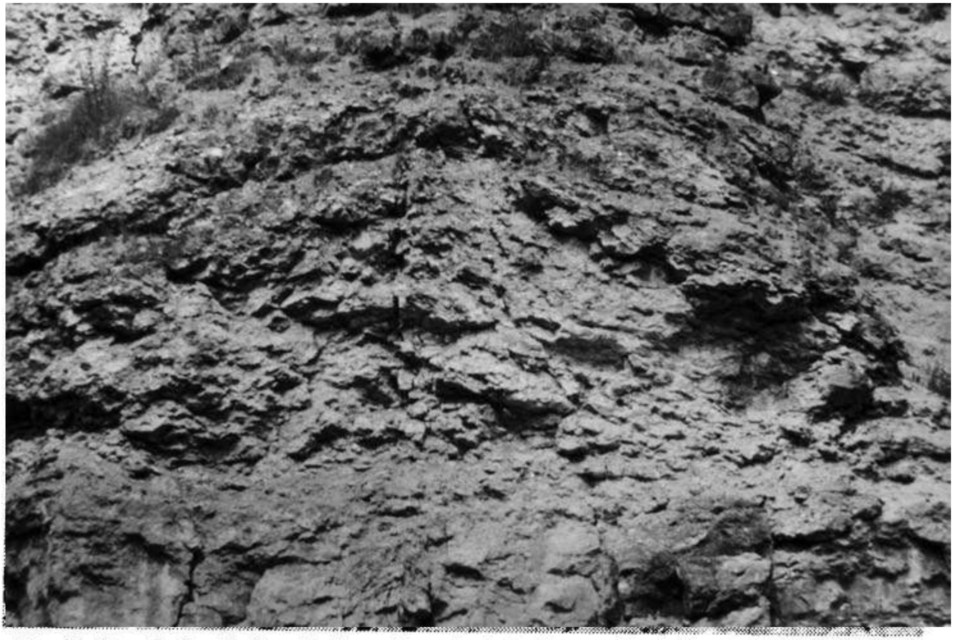


Fig. 14: Stop 2. Small (2m high) patch reef of the Lower Coral Limestone drowned under inter-reef sediments. Malancourt quarry.

Fig. 15: Stop 2. Initiation of reef facies by small contemporaneous coral reef bodies with conical bases which by lateral fusion produced the large reef mass of the Upper Coral Limestone. Malancourt quarry.

Fig. 16: Stop 2. Build-up of the Lower Coral Limestone (LC) and the Upper Coral Limestone (UC). Stratified sediments are inter-reef sediments of the Lower Coral Limestone overlain by cherty limestone. Top of the quarry walls formed by the "Longwy marls". Face of the Malancourt quarry.

Stop 3 : Bajocian coral reefs of Viterne (SW of Nancy)

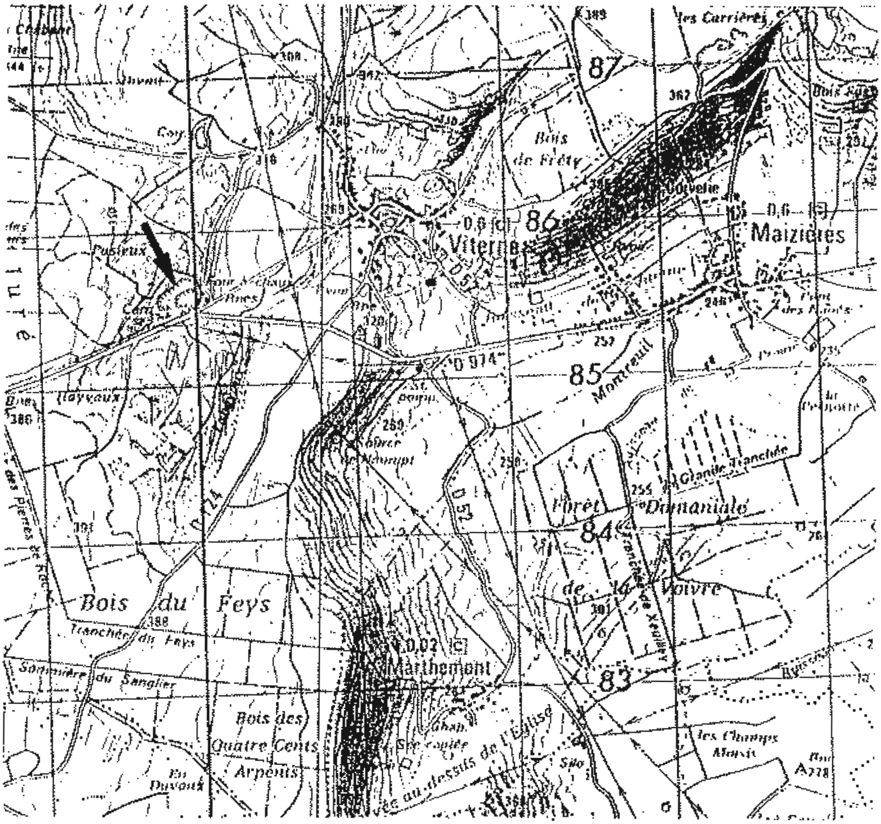
The outcrop is an abandoned quarry where limestone has been extracted at 4 quarry levels which are easily accessible to the visitor. The quarry exhibits a complete, partly three-dimensional view of a sequence of both coral limestones including the underlying beds and the overlying "marnes de Longwy".

The quarry of Viterne

<u>Access to quarry:</u>

The village of Viterne is situated about 20 km SW of Nancy to the N of Route National RN 74 = D 974 which connects Nancy to Dijon. The quarry lies immediately N of this road, about 1.2 km WSW of Viterne village. It can already be seen from far when approaching on this road from the E.

The floor and lowermost wall of the quarry can be visited from the main entrance at the roadside. For the higher strata you must continue for some 250 m on paths on the right or left sides of the quarry. From there the 3 upper quarry terraces are easily accessible.



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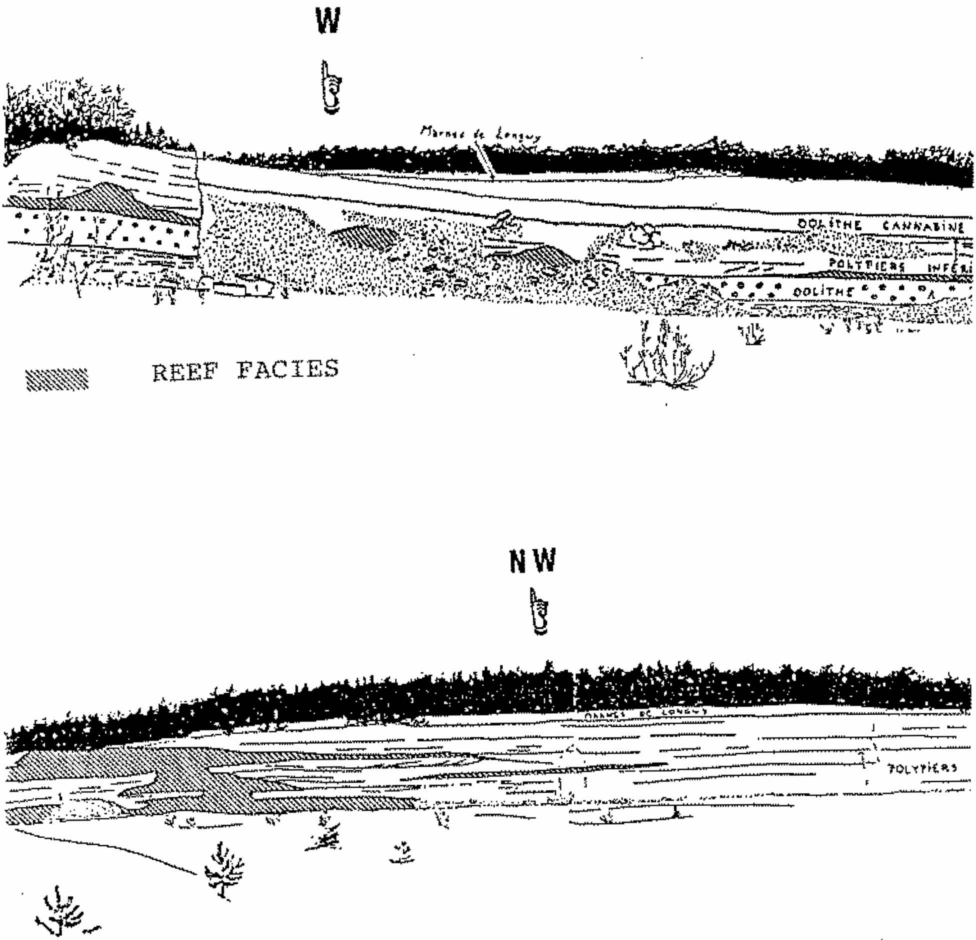
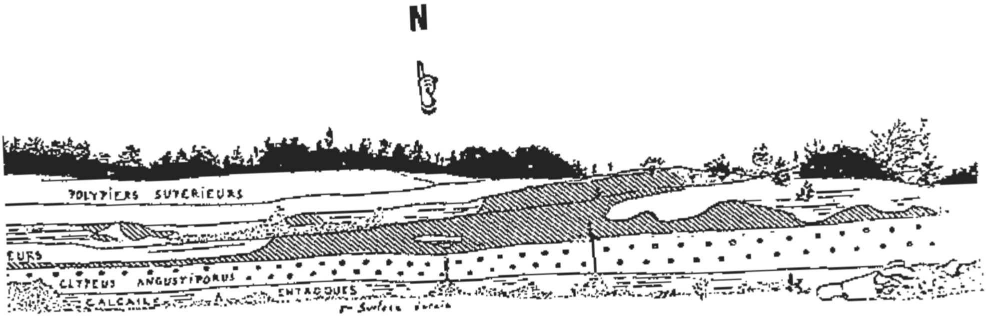
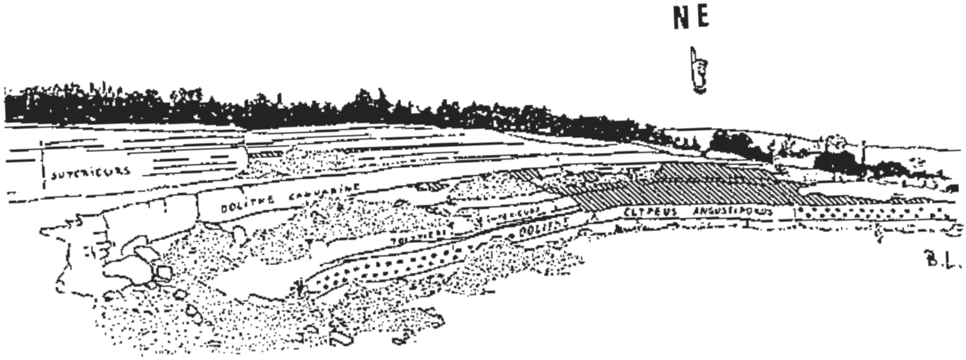


Fig. 17: Stop 3. Panoramic sketches of the Viterne quarry face featuring the Lower ("polypiers inférieurs"): and Upper Coral Limestones ("polypiers supérieurs"), underlying and overlying strata and their relationship to the two hardgrounds. Lower Bajocian. By LATHUILIERE, from DURAND et al. (1989).


N
POLYPIERS SUPERIEURS
EURS
CLYPEUS ANGUSTIPORUS
ENTROQUES
CALCAIRE


NE
SUPERIEURS
OOLITHE CANNABINE
CLYPEUS ANGUSTIPORUS
OOLITHE
B.L.

Stratigraphy: Upper and Lower Bajocian.
"Marnes de Longwy": Upper Bajocian, *subfurcatum* zone
Upper Coral Limestone: Lower Bajocian, *blagdeni* subzone
"Oolithe cannabine": *humphriesianum* zone
Lower Coral Limestone: Lower Bajocian, *humphriesianum* subzone
"Oolithe à *Clypeus angustiporus*" : Lower Bajocian
"Calcaire à entroques": Lower Bajocian

Coordinates: x = 871,2 y = 104,6

Topographic and geologic maps 1:50 000: Nr.3316 (sheet Vézelise)

Literature: DURAND et al. (1989)

A panoramic sketch of the whole quarry (fig.17) shows the facies distribution within this extensive outcrop.

At the base of the quarry we observe for the first time the sediments and the hard-ground underlying the Lower Coral Limestone. These are the "calcaire à entroques" (a crinoidal grainstone) and the "oolithe à *Clypeus angustiporus*" (an oobiosparitic to oosparitic grainstone). The latter terminates with a bed formed by resedimented and bored oolite pebbles ("lag deposit").

Lower Coral Limestone

There are build-ups up to 8 m high and 60 m broad at the base. Inter-reef facies are more or less argillaceous with a texture varying from wackestone to grainstone with bioclasts, ooids, some intraclasts and pellets.

Most conspicuous fossils:
Isocrinus, pelecypods *(Chlamys, Camptonectes, Lopha, Trichites)*, gastropods, pedunculated brachiopods and *Moorellina* (a thecidean brachiopod), echinoids *(Paracidaris zschokkei* and *Clypeus* sp.*)*, bryozoans, serpulids and a few foraminifera.

The Lower Coral Limestone terminates with KLÜPFEL's "Lucinenbank" containing a rich mollusk fauna (*Cavilucina bellona*, *Pseudotrapezium* sp., *Pholadomya* sp., *Modiolus* sp., *Bourguetia striata*). The shells are only preserved as moulds in the upper part of the "Lucinenbank" which is itself clearly truncated by the lower hardground already known from Rumelange and Malancourt. This hardground is covered by a shell bed rich in *Entolium* valves.

"Oolithe cannabine"

Beds 3.2 m thick and very rich in oncoids. The latter are formed by the encrusting tests of *Nubecularia reicheli* RAT which alternate with algal crusts.

Upper Coral Limestone

The lateral extensions of the coral reef formations are rather irregular because they were intermittantly suffocated by onlapping ooid and bioclastic sediments. There are lateral transitions from true framework to incohesive communities of *in situ* coral colonies scattered in the sediments. The framework is mainly formed by platy scleractinians.

The limestone terminates with the upper hardground, marked by borings and encrustations. Also this hardground, already visited at Malancourt, is widely known from western Europe where it truncates the deposits of the Lower Bajocian (*humphriesianum* zone).

"Longwy marls"

These are rich in brachiopods and pelecypods and form the top of the quarry. Their age is lowermost Upper Bajocian.

Stop 4: Bajocian coral reefs at Sommérécourt (south of Neufchâteau)

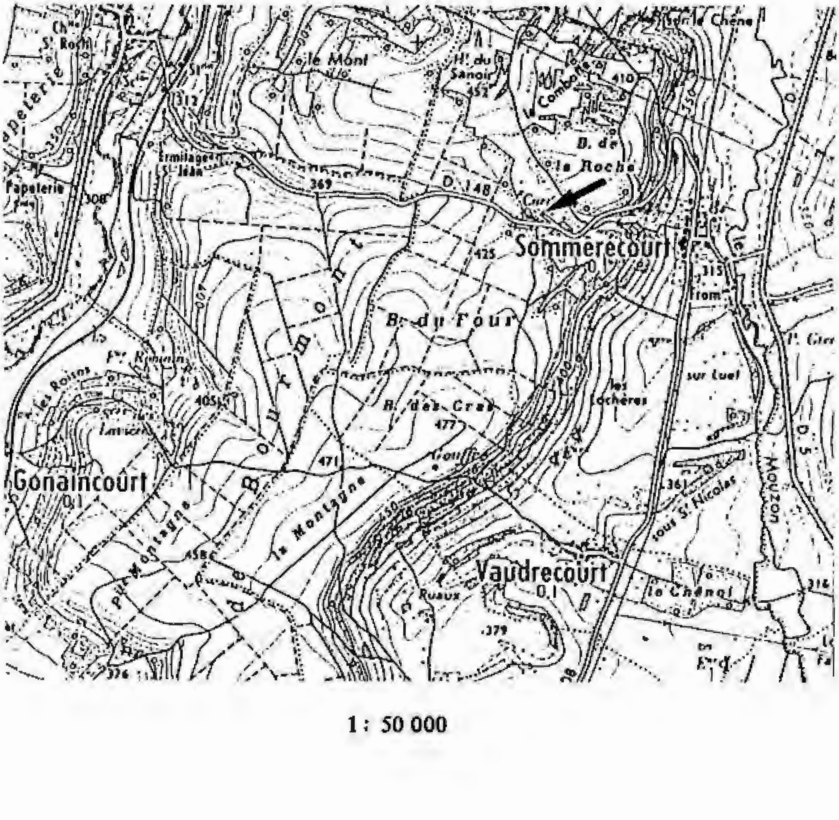
The reefs of Sommérécourt will be visited in a quarry which is at present not worked. The rocks cropping out in the 150 m wide and 30 m high quarry face, comprise the Lower and Upper Coral Limestones which exhibit interesting coral reef formations. Both coral limestones are separated by a hardground which is overlain by the "oolithe cannabine".

The quarry of Sommérécourt

Access to quarry:

The village of Sommérécourt is situated in the southern part of Lorraine, some 16 km to the south of the provincial town of Neufchâteau. From Neufchâteau take road D1 to Lamarche. From Sommérécourt take road D148 to Goncourt. The quarry will be visible to the right in the wood some 2.4 km after leaving the outskirts of Sommérécourt. After entering the quarry area, there is a small elevation visible to the left from where a beautiful panorama of the whole outcropping series can be observed. The wide extension of the outcrops and the presence of 3 quarry terraces give easy access to all the facies units visible in the quarry face.

Stratigraphy: Lower Bajocian, *humphriesianum* zone
Upper Coral Limestone: *blagdeni* subzone
"Oolithe cannabine": *humphriesianum* zone
Lower Coral Limestone: *humphriesianum* subzone



1 : 50 000

Coordinates: x = 845,8 y = 64,2

Topographic and geologic maps 1: 50 000: Nr.XXXII-18 (sheet Bourmont)

Literature: DURAND et al.(1989), HILLY & HAGUENAUER (1979:62-63)

The panoramic sketch of fig.18 shows the facies relations within this extensive quarry area.

Lower Coral Limestone

The framework is rather different from that seen at Rumelange, Malancourt and Viterne where the corals generally formed a true coherent framestone. At Sommérécourt, the coral communities appear more loosely bound. They cover and encrust the sediments to form bindstone. This may explain the relatively small number of cryptobionts (coelobites) present under the platy colonies. The communities of branching corals which are surprisingly frequent at Sommérécourt, trapped the sediments to form bafflestone.

The composition of the fauna is also fairly unusual: the massive and platy colonies of *Isastrea* do not dominate everywhere the framework. The genus *Periseris* is very abundant, showing different growth habits of its colonies. The dendroid *Dendraraea* is also very frequent and hosts a diverse fauna of small invertebrates (mainly brachiopods and gastropods). Pelecypods of the genus *Chlamys* and the echinoid *Caenocidaris cucumifera* are more abundant here than in the corresponding beds of the preceding outcrops.

The inter-reef facies is similar to that of Viterne with a texture of packstone and grainstone. Clasts are mainly echinoderm and pelecypod fragments, and coated grains (ooids and nubecularian oncoids). Dolomitization is locally important.

The Lower Coral Limestone terminates with KLÜPFEL's "Lucinenbank" which is locally rich in dissolved coral skeletons. Also here, the "Lucinenbank" and the tops of adjacent reef bodies are sharply truncated by a hardground corresponding to that seen at Viterne.

Within the Lower Coral Limestone a large (2 m diametre) resedimented block of reef rock is easily recognized (fig. 19). The resedimented character of the block is indicated by the exclusively vertical orientation of the dominating platy corals and of the micrite/sparite interface in the geopetals. The block lies on an argillaceous bed with a strong lateral dip which is rich in debris of large oysters.

The "Oolithe cannabine"

It shows the same microfacies as at Viterne.

The Upper Coral Limestone

This facies is very similar to that observed at Viterne, although the benthic communities characterized by *Dendraraea* are more common. Here again, the top of this rock unit is truncated by the upper bored hardground.

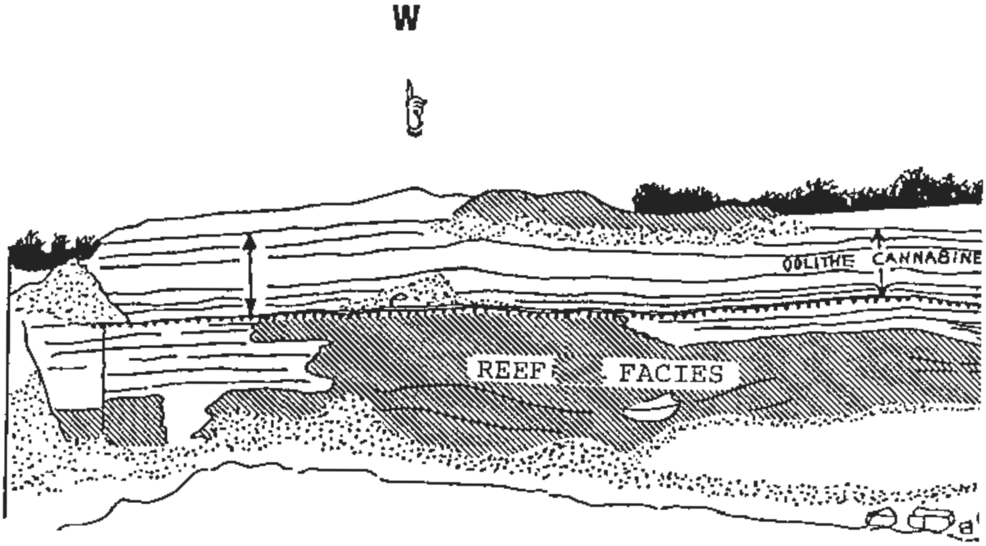
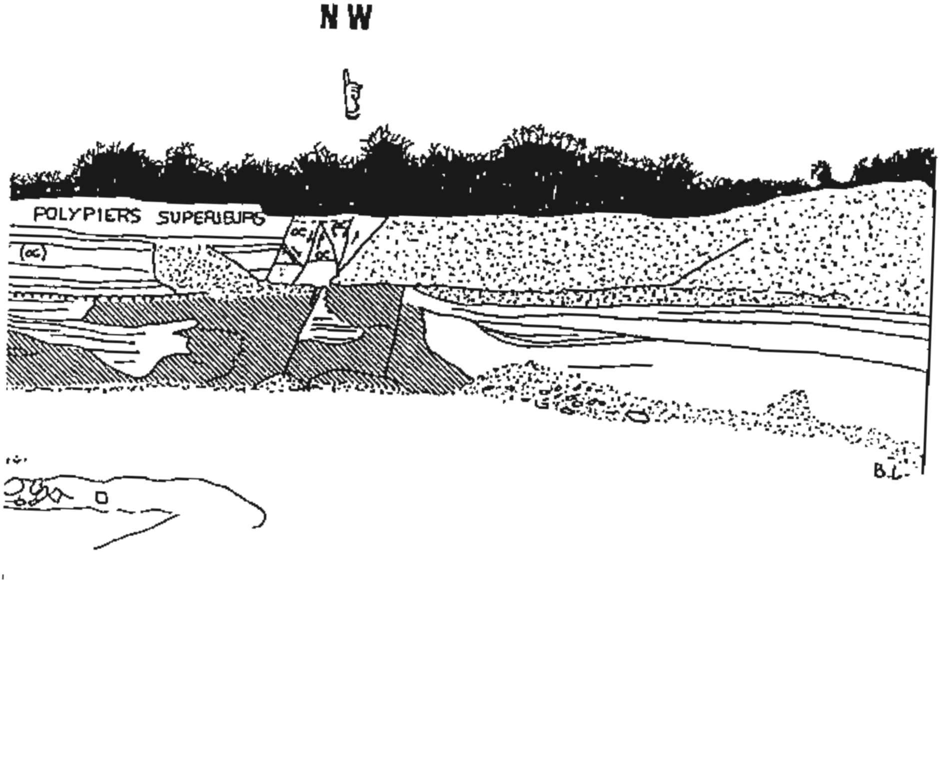


Fig.18: Stop 4. Panoramic sketches of the Sommérécourt quarry face featuring the Lower ("polypiers inférieurs") and Upper Coral Limestones ("polypiers supérieurs"), hardground and related facies. Lower Bajocian.
By LATHUILIERE, from DURAND et al. (1989).


NW
POLYPIERS SUPERIEURS
(oc)
B.L.

<u>Fig. 19</u>: Stop 4. Resedimented block (B) in the Lower Coral Limestone of the Sommérécourt quarry. Lower Bajocian. Diametre of block is approximately 2 m.

Stop 5: "Caillasse à *Anabacia*" with underlying coral patch and oolitic tidal facies at Bicqueley near Toul

The village of Bicqueley is situated some 6 km S from the centre of Toul on the road D904 which leads to Thuilley-aux-Groseilles. Two outcrops of Bicqueley were selected for this guide book because they exhibit a fossil equivalent of a Bahama Bank type environment with oolite shoals and coral patches. These very shallow-water deposits are truncated by a bored hardground which itself is overlain by deeper-water deposits of the "Caillasse à *Anabacia*" of lowermost Bathonian age. The two topics of Stop 5, an oolite shoal and a coral patch will be visited at Stations 5A and 5B which are from each other some 1.2 km apart.

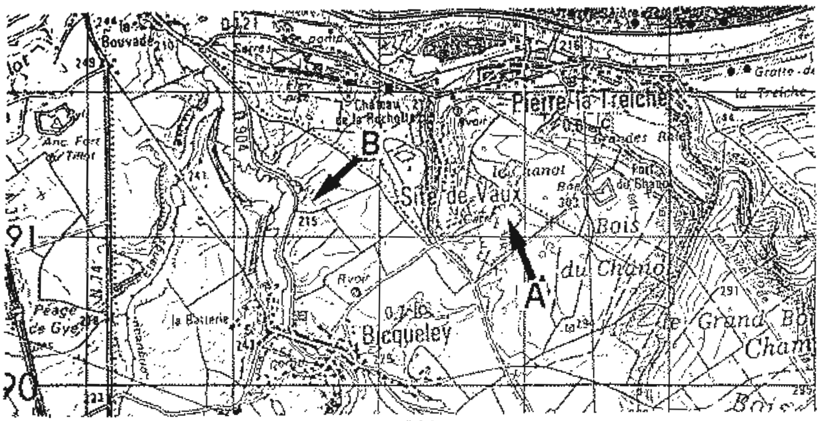
Stratigraphy:
Caillasse à *Anabacia* : lowermost Bathonian (*zigzag* zone) (see MANGOLD et al. 1991)

Oolithe miliaire supérieure: Upper Bajocian (*parkinsoni* zone) (see MANGOLD et al. 1991)

Most conspicuous fossils
Oolithe miliaire supérieure: undetermined massive coral colonies, gastropods, pelecypods and brachiopods.

Caillasse à *Anabacia*: *Chomatoseris* spp., numerous pelecypods, brachiopods and echinoids (see GARDET 1929)

Topographic and geologic maps 1:50 000: Nr.XXXIII-15 (sheet Toul)



1: 50 000

Literature: DURAND et al. (1989), LEDIT (1985)

Station 5A: Quarry 2 km NE Bicqueley

Access to quarry:
After entering Bicqueley from Thuilley turn right within village centre into small road that leaves the village and crosses the fields to the edge of the forest (1.3 km). Continue straight into the forest for 600 m keeping slightly to the right at the crossroads, until the road widens into an extensive quarry in the "0olithe miliaire supérieure" (fig.20).

Coordinates LAMBERT 1 : x = 864,8 y = 1110,0

Fig.20 : Stop 5. View of the quarry face of Station 5A at Bicqueley with foresets and reactivation surfaces in the "Oolithe miliaire supérieure" (Upper Bajocian) interpreted as ebb spill-over lobes. The terrace above and the background is formed by deposits of the "Caillasse à *Anabacia*" (lowermost Bathonian).

<u>The outcrop</u> (fig.20)
The interest in this outcrop is threefold:

1.) Here we can observe the contact of the uppermost formation of the Bajocian ("Oolithe miliaire supérieure") with the overlying lowermost Bathonian ("Caillasse à *Anabacia*") both separated by a bored hardground. But the latter is not well visible here due to poor outcrop conditions.

2.) The "Oolithe miliaire supérieure" is a grainstone formed by well-sorted true ooids alternating with more bioclastic layers. There is a conspicuous crosslamination visible in the outcrop (fig.20) with bundles assembled to units up to 4 m thick. These allowed to study in detail the hydrodynamics of a fossil marine sand belt which is comparable to Recent examples described from the Bahama Bank. These deposits have been interpreted as "ebb spill-over lobes" directed from the platform to the open sea which would indicate the probable influence of the tides (see LEDIT 1985 and DURAND et al. 1989). Note numerous massive circumrotatory corals ("coralliths"), around 4 cm in diametre, in the uppermost part of the "Oolithe miliaire supérieure".

The "Caillasse à *Anabacia*" , an unsorted bioclastic limestone, is very rich in the small solitary coral *Chomatoseris* (formerly *Anabacia*) whose skeletal structure suggests a mobile mode of life (see GILL & COATES 1977).

3.) Noteworthy is also a set of faults directed N 140 E which parallel the small tectonic graben of Bicqueley situated several 100 m to the W. The faults prove the activity of distensive synsedimentary tectonics towards the end of the Bajocian. The faces of the faults are impregnated by several centimetres to decimetres of iron oxyde. The material of the joint filling is similar to that found within the boreholes of the hardground above.

Station 5B: Outcrops 1.3 km N of Bicqueley

<u>Access to outcrops:</u>
About 1.3 km N of the village , a small quarry becomes visible on the right in a slight left turn of road D904. The vertical and inaccessible quarry face shows a beautiful section of the "Oolithe miliaire supérieure" truncated by the hardground and overlain by the "Caillasse à *Anabacia*" (fig.21).

Immediately before the curve a field path branches off to the right, leading after a few metres to a pit dug into the "oolithe". Behind there is a low ridge of wasteland overgrown by small shrubs and with a solitary pine-tree on top. It is capped by the "Caillasse".

<u>Coordinates LAMBERT I:</u> x = 863,3 y = 1110,2

<u>The outcrops:</u>
On the hilltop around the pinetree there are some good outcrops of the bored hardground. It truncates a large massive Upper Bajocian coral. This coral head attains a diametre of 80 cm. Density banding highlighted by recrystallisation of the skeleton is very conspicuous showing yearly growth bands (fig.20) of 2.5 - 3.0 mm, indicating a total life span of the colony in the order of 130 to 150 years.

The hardground is overlain by the bioclastic deposits of the "Caillasse" with numerous well-preserved *Chomatoseris*.

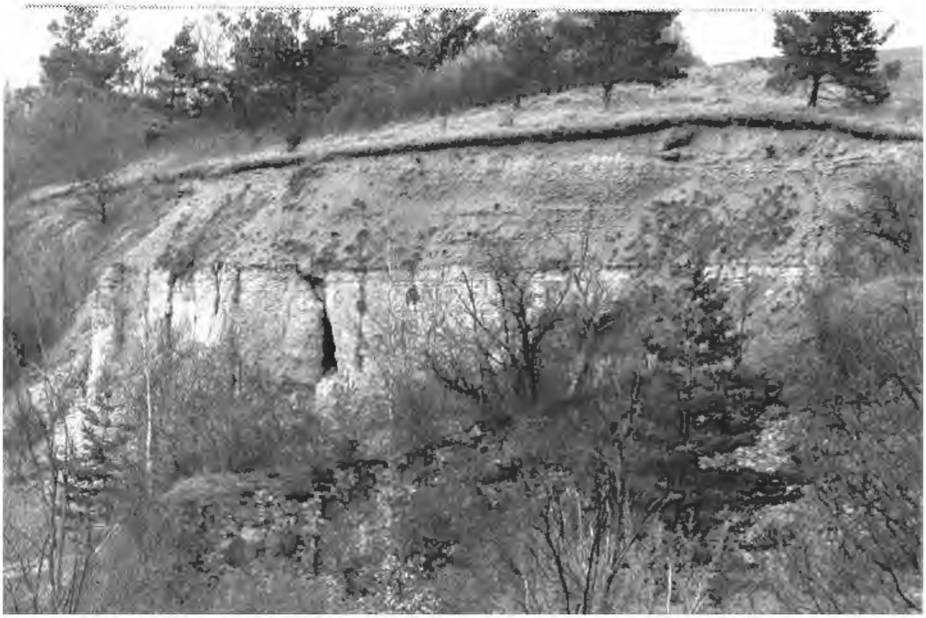


Fig.21: Stop 5. The "Oolithe miliaire supérieure" truncated by the hardground and overlain by the "Caillasse à *Anabacia*". Quarry N of Bicqueley, Station 5B.

Fig.22: Stop 5. Massive coral colony with its top truncated by the hardground. Upper Bajocian. Station 5B at Bicqueley.

3. Introduction to the Oxfordian reef formations

3.1 Lithostratigraphic nomenclature and age

The "Formation récifale de Lorraine"

In Lorraine, the Oxfordian stage begins within the clayey formation of the "Argiles de la Woëvre", the upper part of which has been attributed to the Lower Oxfordian *mariae* zone. It grades upward into the "Terrain à Chailles" which is characterized by a progressive upward intercalation of limestone beds. This formation terminates with a hardground formed by a pavement of large bored oyster valves or with an iron oolite. The "Terrain à Chailles" is overlain by the "Formation récifale de Lorraine" formed by two distinct superposed reef complexes.

The reef formations of the Oxfordian of Lorraine have been known for a long time. Their long history of investigation and the natural complexity of facies interrelationships led to an unreasonable proliferation of formation names. As a consequence of this, in many geological maps and regional studies these reef rocks have been named "Corallien" and subsequently "Calcaire Corallien" or "Argovo-Rauracien" . Other more or less informal terms have also been applied: "Complexe récifal des Hauts de Meuse" (HILLY & HAGUENAUER 1979, ENAY & BOULLIER 1981) or "Complexe récifal des Côtes de Meuse" (ENAY & BOULLIER 1981). In spite of some disagreement with the international rules of stratigraphical nomenclature, in this paper the term "Formation récifale de Lorraine" will be applied which was proposed in a catalogue of formation names of the Paris Basin (MENOT 1980).

The lower and upper reef complexes

The "Formation récifale de Lorraine" was deposited during two succeeding reef-building events that resulted in the formation of a lower and an upper reef complex.

The lower reef complex was originally named "faciès glypticien", subsequently renamed "zone construite inférieure" by HUMBERT (1971), "Complexe récifal inférieur" by HILLY & HAGUENAUER (1979) or "Episode récifal inférieur " by MENOT (1980). It is characterized by abundant lamellar microsolenid corals, bivalves and echinoids. Its thickness varies from 5 to 35 m. Between the two reef-building events an oncoidal limestone was deposited south of the Commercy area while a crinoidal limestone ("Pierre d'Euville-Lérouville") was deposited to the north (fig. 23).

The upper reef complex was named "zone construite supérieure" by HUMBERT (1971) or "Complexe récifal supérieur" by HILLY & HAGUENAUER (1979) and "Episode récifal supérieur" by MENOT (1980). It corresponds to a 10-20 m thick suite of limestones, partly composed of boundstones. The latter are built by a diverse coral fauna whose colonies are embedded in a white, more or less chalky matrix. These reefs were subsequently drowned under the pure white chalky mud. Therefore, the higher section of the upper reef complex is almost devoid of corals and represents a 40-80 m thick suite of chalky limestone beds ("Calcaire de Creue"). In the area visited by the field trip, these rocks are heavily exploited today in quarries providing excellent outcrops. The industry is highly interested in these beds because of the chemically pure quality of the calcium carbonate and, naturally, less in the beauty of the corals below!

The nomenclature of the subordinate sedimentary units is hardly clearer. Some units keep a formation rank and a formation name (examples: Pierre d'Euville-Lérouville, Calcaire de Creue...). HUMBERT (1971) numbered and HILLY & HAGUENAUER (1979) lettered these sedimentatry units.

In spite of this nomenclatural confusion, the section drawn by HUMBERT (1971) in his remarkable but poorly known thesis provides a clear idea of the relationships between the different sedimentary units which constitute the "Formation récifale de Lorraine" (see fig. 23).

The age of the "Formation récifale de Lorraine" and overlying formations

Today, the "Formation récifale de Lorraine" can be considered of Middle Oxfordian age on the basis of biochronological data provided by ammonites and brachiopods (see ENAY & BOULLIER 1981). However, these results conflict with an Upper Oxfordian age proposed both by BEAUVAIS, HAGUENAUER & HILLY (1980) on the basis of reef corals and by HUMBERT (1971) on the basis of ostracods determined by OERTLI.

The "Formation récifale de Lorraine" is bounded by a hardground at its base and frequently by another hardground at its top. It is overlain by the "Argiles à Huîtres". At Void and Pagny-sur-Meuse in central Lorraine, some rare small and poorly known coral build-ups developed during the deposition of this muddy and clayey formation (MAUBEUGE 1968b). According to the stratigraphical synthesis provided by MARCHAND & MENOT (1980), the formations overlying the "Argiles à Huîtres" are the "Oolithe de Lamothe", the "Calcaires à *Astarte*" and the "Calcaires rocailleux à Ptérocères".

The boundary between the Oxfordian and Kimmeridgian has not yet been clearly established. The only fossils of biostratigraphic value are ammonites of the Oxfordian *bifurcatus* zone found immediately above the upper hardground of the "Formation récifale de Lorraine" (ENAY & BOULLIER 1981) and the ammonite *Rasenia cymodoce* in the lowermost part of the "Calcaires rocailleux à Ptérocères" indicating a Kimmeridgian age (MAUBEUGE 1953b, 1955, 1968a).

3.2 Reef ecology and biota

Reefs and platform development

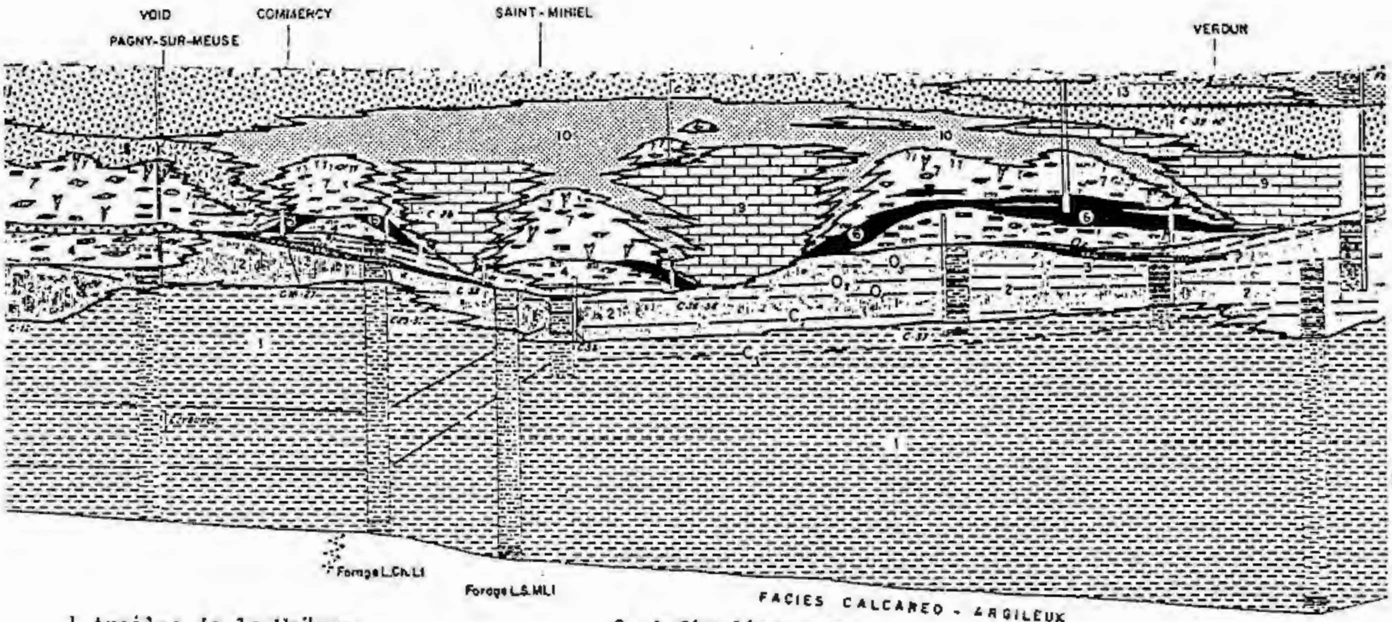
The Oxfordian reef complexes of Lorraine show a clear arrangement in facies belts (see fig. 24). Southward of the platform edge is the fore-reef area, and outcrops of the reef crest are found in the Marne valley. According to LE ROUX, well-logging data indicate that reef crest environments persisted during Upper Oxfordian times over a large part of the Paris Basin (see fig.1). In the subsurface , the Middle Oxfordian reef crest has been sketched by DEBRAND PASSARD (1980).

The back-reef area is localized in the northern part of the platform, between the Marne valley and the Ardennes landmass. The fossil environments accessible in the Carrière du Revoi at Pagny-sur-Meuse (Stop 7) are representative of the Oxfordian back-reef area of the eastern Paris Basin.

Environmental factors

The general pattern in the evolution of the environments may be most easily explained by a persistent shallowing-upward trend recognizable within the reef complexes as a whole. Therefore, only two examples will be discussed here which demonstrate that this trend generated the diverse biotopes that may be observed in the outcrops.

The "zone construite inférieure" corresponds to a poorly illuminated environment, as illustrated by the outcrops at Foug (Stop 6). Our main arguments in favour of a low light level are the thin-platy morphology of coral colonies and the total absence of red algae. Both phenomena may be most easily explained by a relatively deep bathymetric position of the sea floor, lying probably within the infralittoral zone. However,



1 Argiles de la Woëvre
2 Terrain à chailles
3 Oolithe ferrugineuse
4 zone construite inférieure (boundstone)
5 oncolitic limestone
6 crinoidal limestone
7 zone construite supérieure (boundstone)
8 chalky limestone
9 sublithographic beige limestone
10 white granular bioclastic limestone (chalky cement)
11 slightly beige granular bioclastic limestone (chalky cement)
13 granular limestone, breccia-like layers.
C1, C2, O1...: isochronous (according to Humbert 1971)

Fig. 23: Facies relationships of the Oxfordian strata in Lorraine. Note especially the position of the Lower Reef Complex (unit 4, "zone construite inférieure"), of the oncolitic and crinoidal limestones (units 5 and 6) and the Upper Reef Complex (unit 7, "zone construite supérieure"). Adapted from HUMBERT (1971).

according to GYGI (1986) who studied a lateral equivalent in Switzerland (Liesberg Member), this low light level may also be attributed to a turbid environment at a shallow water depth (possibly less than 20 m). In the lowermost part of this "zone construite inférieure", also the water energy was low as indicated by depositional textures and the abundance of micrite. A position below wave base cannot be ruled out. During this early stage of Oxfordian reef growth only build-ups of very low relief developed in the area.

The build-ups of the upper reef complex are illustrated by the outcrops in the quarry at Pagny (Stop 7). They indicate a fairly different environmental setting. The presence of *Solenopora* and the dome-shaped growth habit and rather high growth rates of the massive coral colonies observed, suggest well-illuminated shallow-water conditions. Nevertheless, the energy level of the environment remained low. The great amount of chalky sediments and the abundance of thin-branched colonies are interpreted as indicative of a rather calm and sheltered back-reef environment. However, for a firm conclusion a detailed study would be necessary which should include depositional features related to waves, tides and storms. It would also have to examine the eventual role of blue-green algae in the stabilization of the sediments.

Another environmental factor must be taken into consideration: the rate of sedimentation. As indicated by rhythmic (?annual) growth rings of vertically growing phaceloid branching scleractinians, the sedimentation rate was very high and finally surpassed the probable maximum coral growth rate in the order of 14 mm/year.

The coral fauna

As compared to other Mesozoic reefs, especially older ones, the Oxfordian coral build-ups of Lorraine were constructed by a highly diverse fauna of reef-building scleractinians. Table 1 provides a check-list of the Oxfordian corals of the Department of Meuse as determined by MICHELIN (1841-43) and BEAUVAIS (1964). The number of species listed, is probably exaggerated. But the tentative (and possibly premature) identification key of the genera presented here (see appendix) also indicates that the Oxfordian coral fauna of the area was at least twice as diverse as that of the Bajocian.

Some additional observations on the Oxfordian scleractinian corals of Lorraine should be pointed out:

- their diverse colonial morphology with lamellar, dendroid, phaceloid and dome-shaped colonies present
- their diverse colonial structure comprising phaceloid, cerioid, thamnasteriod, but also plocoid and meandroid colonies
- the abundance of corals with perforate septa
- the higher generic diversity in the upper reef complex as compared to the lower reef complex which is dominated by platy microsolenids

Accompanying organisms

The lower reef complex of the "Formation récifale de Lorraine" shows a "glyptician" facies characterized by the presence of numerous echinoids (including *Glypticus hieroglyphicus*) and pelecypods. It hardly recalls the biocenotic structure of the Bajocian reefs. The platy corals (here mainly microsolenids) provided a suitable substrate for a diverse cryptic fauna (coelobites) and for crusts of blue-green algae showing a photopolarity. Both probably furnished abundant food for the diverse

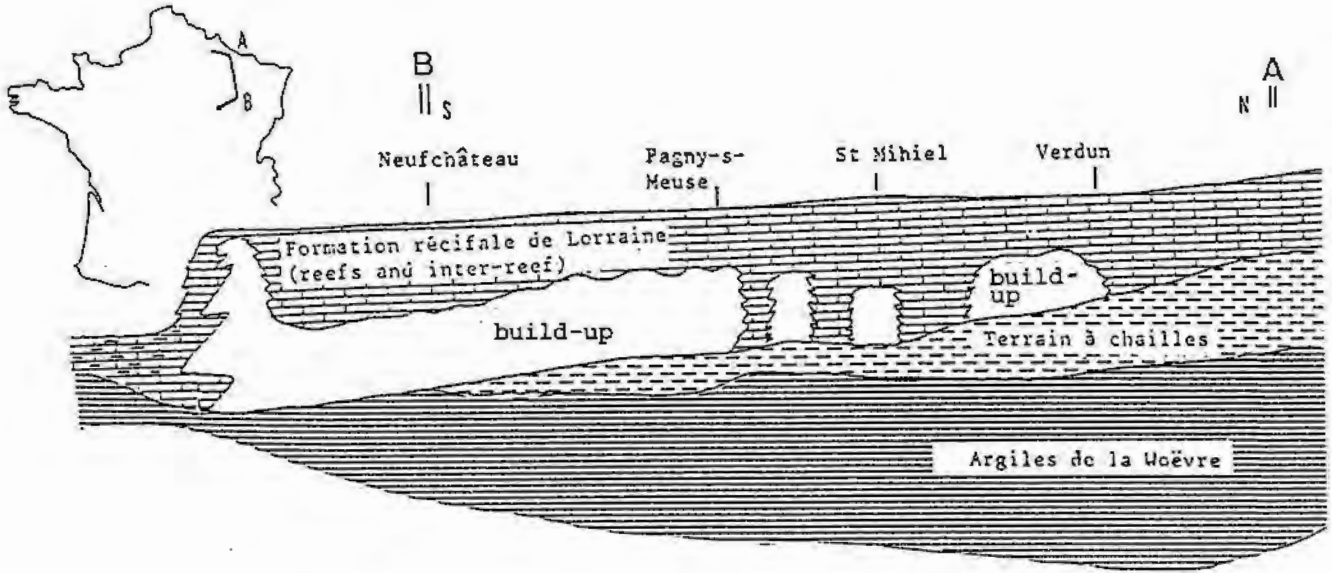


Fig. 24: Schematic sketch of the reef facies development on the Oxfordian carbonate platform of Lorraine. Redrawn from HUMBERT (1971), very simplified.

fauna of grazing echinoids (VADET 1987).

In the upper reef complex, the red alga *Solenopora* is an important secondary framebuilder. Blue-green algae are probably also important here and played a major role in the genesis of inter-reef sediments. The rudist *Diceras* and nerinean gastropods are locally abundant in the upper reef complex. They are characteristic of some of the inter-reef facies. The presence of numerous additional mollusks (both pelecypods and gastropods) should be noticed.

3.3 Sequence of benthic environments

The succession of Oxfordian sedimentary strata is controlled by palaeoenvironments changing in time and space, in part due to eustatic fluctuations of the sea-level. On the whole, the succession of strata observed from the "Argiles de la Woëvre" to the "Terrain à Chailles" and continuing into the "Formation récifale de Lorraine", corresponds to a shallowing-upward sequence. The "Argiles de la Woëvre" and the "Terrain à Chailles" are characterized by ammonite-bearing basinal sediments deposited in a calm environment, the benthic fauna being that of the circalittoral zone. The progressive enrichment in carbonates and the increase of the biomass, especially of epibenthic biota adapted to firm and hard substrates confirms the shallowing-upward trend. The transition from the "Terrain à Chailles" to the "Formation récifale de Lorraine" should correspond to the photic boundary that separates the circalittoral zone from the infralittoral zone. In detail, the facies development may be more complex within the "Formation récifale de Lorraine", but the shallowing-upward trend persisted.

This evolution of the depositional environments is indicated by the following observations:

a) The presence of abundant coral colonies with thin-platy growth habit at the base of the lower reef complex (Stop 6), suggesting a low light level i.e. a probable deeper-water environment.

b) A more diverse coral fauna including dome-shaped massive corals in the upper reef complex (Stops 7-11) suggests a shallower, well-lit environment.

c) The final emersion of the top of upper reef complex. This emersion has been demonstrated by sheet cracks and asymmetric cements (HUMBERT 1971, 1976).

Hence, this shallowing-upward sequence of the depositional environments may be summarized by the following succession of stages: circalittoral › infralittoral › mediolittoral (for definitions see PERES & PICARD ,1964).

Surprisingly, this evolution coincides globally with a eustatic rise of the sea-level. The study of the geometry of the sedimentary units as described by HUMBERT (1971, pl.89) confirms this conclusion. The "Argiles de la Woëvre" are defined as a large sigmoidal unit of clay deposits with its depocentre situated approximately at the latitude of Verdun. These detritic deposits are interpreted as a "low stand wedge". With the "Terrain à Chailles", the depocentre is displaced northward and landward. Finally, due to limited accomodation space the "Formation récifale de Lorraine" had to prograde southward towards the shelf edge.

This general view of the Oxfordian transgression is compatible with the interpretations of GYGI (1986) in Switzerland and of VAIL et al. (1987) in the Paris Basin. The subordinate inflexion of the eustatic sea-level curve remains a matter for further discussion.

3.5 Field guide to Oxfordian reef formations

Stop 6: Shallowing-upward sequence from ammonitic marls ("Terrain à Chailles") to reef limestone (lower part of the "Formation récifale de Lorraine", Oxfordian). Highway cut W of Foug.

Between the villages of Foug and Pagny-sur-Meuse, the highway Toul- St.Dizier is cut for several hundred metres into two low-lying hills. There are major fresh outcrops on both sides of the highway within these two cuts exposing a section at the base of the Oxfordian reef complex. Best accessible and most complete is the northern flank of the easternmost cut (fig.25). From there a beautiful panorama of the southern flank of the cut can also be observed across the highway (fig.26) showing a mirror image of the outcrop to be visited.

The outcrop exhibits a beautiful example of a coral reef formed during a shallowing-upward sequence. The reef complex became established on muddy deeper water sediments and continued to grow during a coarsening-upward sedimentary sequence to biodetrital and oncolitic sands.

Within this sequence the following facies units will be examined at Stop 6 (from top to bottom):

- **oncolitic limestone**

- **coral beds** formed by:
  coral limestone and inter-reef sediments
  coral marls and inter-reef sediments

- **ammonitic marls** ("Terrain à Chailles") terminating with a secondary hardground (oyster bed)

<u>Stratigraphy:</u>
Lowermost 20 m of the "Formation récifale de Lorraine" (Middle Oxfordian) overlying limestones and marls ("Terrain à Chailles") of Lower to Middle Oxfordian age.

<u>Access to outcrop</u>:
Leave highway at interchange of Foug. After entering Foug village turn left at the war memorial. At the end of road turn left again and proceed to three single houses situated close to the highway. From there the outcrop may be reached by foot, walking uphill for some 200 m on a small forest lane.

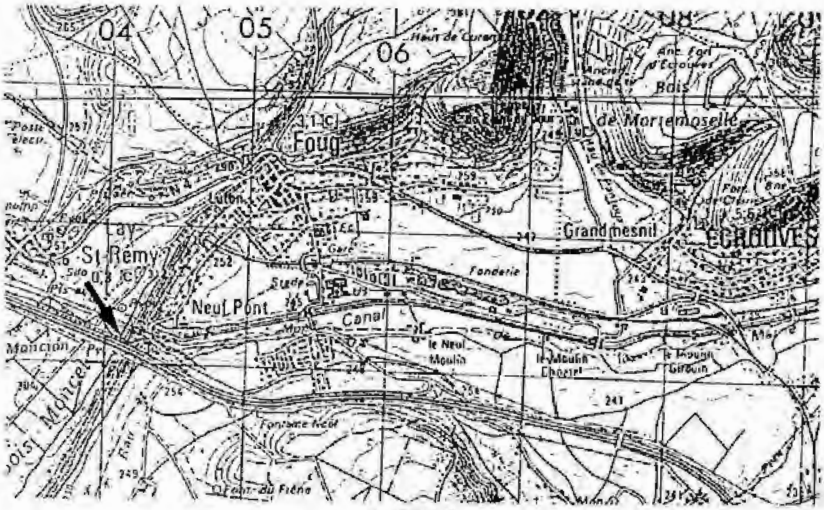
<u>Coordinates LAMBERT I</u>: x = 852,5 y = 1113,7 to 1114,2

<u>Topographic and geologic maps 1: 50 000</u> Nr.XXXII-15 (sheet Commercy)

<u>Literature</u>: POIROT (1986,1987), VADET (1987)

<u>Caution</u>:
Because of heavy high-speed traffic absolutely stay within the outcrops. Never step on margin of highway !

The outcrop will be visited at 3 stations (A to C) in order to cover the whole section exposed.



1 : 50 000

Station 6A: Base of the outcrop at level with highway. Exposures of the "Terrain à Chailles" and the "coral marl" (figs. 27, 28, 29)

"Terrain à Chailles"

Uppermost 8 m of a fossiliferous marl complex with intercalated muddy limestone beds exposed at the base of the highway cut. The top of the sequence is marked by a secondary hardground formed by a thin continuous bed of 2 to 3 superposed valves of the oyster *Deltoideum delta*. Both left and right valves were found in the oyster bed. Upper sides of oyster shells are commonly perforated by clionid sponges, occasional lithophagan pelecypods and other organisms. Serpulids and thecidean brachiopods incrust the undersides of many valves which formed temporary shelters for these coelobites.

Most obvious faunal elements :

Highly diverse pelecypod fauna (fig.30) comprising both infaunal *(Pholadomya, Pleuromya, Goniomya)* and epifaunal elements (*Isognomon, Eopecten, Arcomytilus, Gryphaea dilatata, Lopha, Nanogyra, Plicatula, Modiolus* etc.). This is the pelecypod fauna studied by DECHASEAUX (1931) along the eastern margin of the Paris Basin.

Ammonoids: *Perisphinctes (Otosphinctes) montfalconensis, Perisphinctes (Dichotomosphinctes)* sp., *Cardioceras* spp., *Euaspidoceras perarmatum*, etc., representing the *cordatum* and *plicatilis* zones of Lower to Middle Oxfordian age (POIROT 1987).

Brachiopods: *Thurmannella, Galliennithyris, Septaliphoria*

Crinoids: *Millericrinus, Apiocrinus*

Echinoids: *Collyrites*
For a more complete list see POIROT (1986,1987) and VADET (1987).

"Coral marls" (figs. 28, 29, 31)

Patchy coral growth initiated on muddy bottom some 15 to 20 cm above the oyster bed. Coral patches reaching 5 to 15 m in horizontal diameter are dominated by a pioneering fauna of small and thin foliaceous colonies forming a true interlocking framework in a muddy matrix. One species is clearly dominant: the microsolenid *Dimorpharaea koechlini*.

Undersides of the foliaceous corals are incrusted by sciaphile thecidean brachiopods and serpulids and bored by lithophagan bivalves and clionid sponges. The upper faces of the lamellar coral skeletons are frequently covered by thin crusts of photophile stromatolites similar to those described from Oxfordian sponge/algal bioherms (GAILLARD 1983) and Bajocian coral build-ups (LATHUILIERE 1982). There are very few branching and solitary corals in this coral community.

Distinct bedding indicates an apparent maximum relief of coral patches rising above the surrounding muddy inter-reef sediments for some 1 to 1.5 m. But this is largely due to differential compaction. Inter-reef sediments are heavily burrowed (fig.31). Debris of *Apiocrinus* and *Paracidaris florigemma* is common.

The "coral marls" are approximately 3.5 m thick and significantly more clayey than the overlying "coral limestone".

Most obvious fossil genera:

Corals: *Dimorpharaea*

Pelecypods: *Nanogyra, Chlamys, Camptonectes, Ctenostreon, Plagiostoma, Pterocardia*

Crinoid: *Apiocrinus*

Echinoids: *Glypticus, Paracidaris, Hemicidaris, Rhabdocidaris, Pseudodiadema, Stomechinus*

The species of some of these genera are cited in POIROT (1987) and VADET (1987)

Station 6B: First terrace of highway cut and vertical wall above (figs.25, 27)

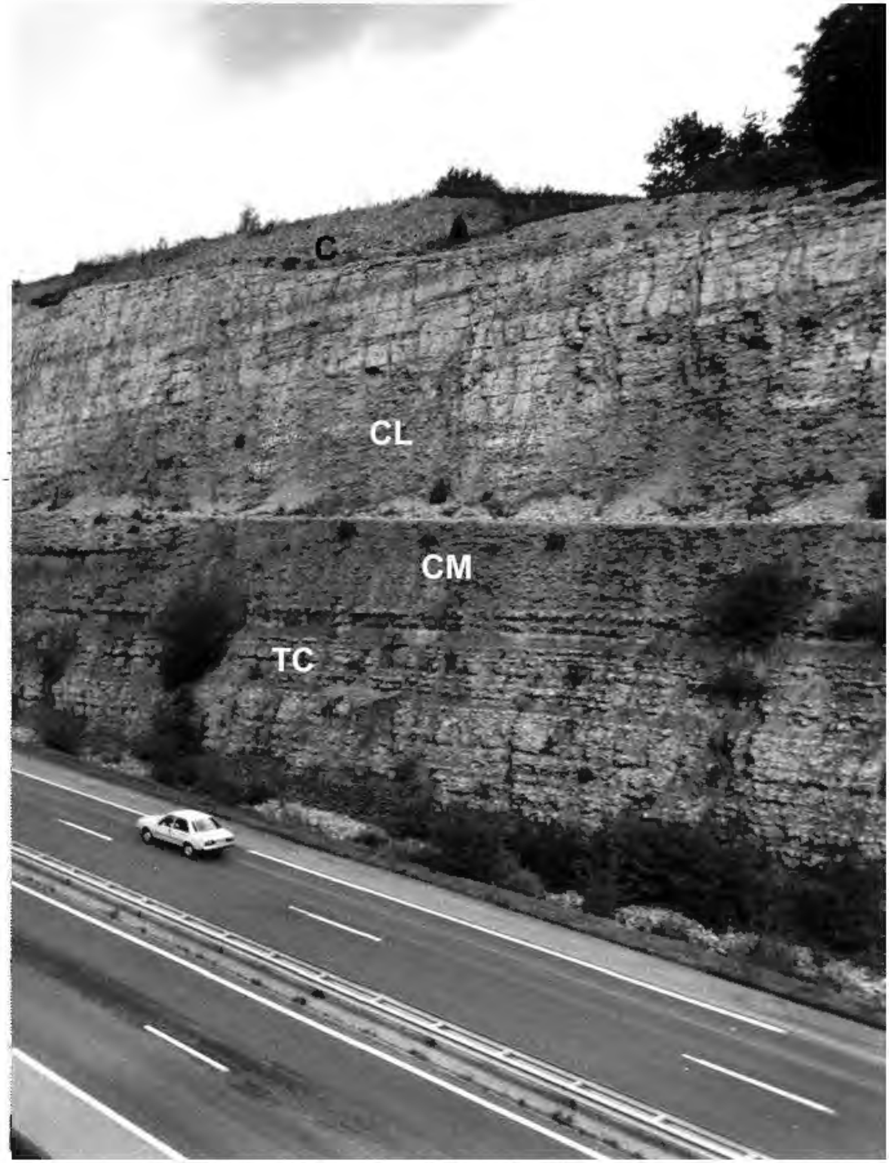
"Coral limestone" (figs. 32, 33, 34)

Within the reef and inter-reef facies we observe a sudden decrease of terrigenous material. This is clearly recognizable at a distance from the outcrops, as differential weathering produces a slight overhang of the upper coral beds over the underlying muddier strata (fig.31). This distinct horizon can be traced from the reef to the inter-reef facies and defines the limit between the upper coral beds ("coral limestone") and lower coral beds ("coral marls").

Coral patches from the lower coral beds generally continued to grow across this limit into the upper coral beds where they form ill-defined build-ups. Their framework is less dense and interlocking in the "coral limestone" than in the underlying "coral marls", and there is a rather gradual transition from loose coral communities to coral-free inter-reef sediments. The coral colonies are thicker (2-5 cm) here than in the lower coral beds with diameters around 0.5 m. But, there are also exceptionally large corals which are 0.4 m thick with horizontal diameters ranging up to 1.5 m. The framework of the "coral limestone" is easily accessible in the cut of the forest lane, some 80 m uphill from the highway cut (fig.34).

The taxonomic composition of the coral fauna is clearly different from that of the "coral marl". Microsolenids are still dominant, but colonies of the genus *Microsolena*

Fig. 25: Stop 6. Panoramic view of highway section at Foug. Stations 6A to 6C (marked A-C) are indicated. Middle Oxfordian.



TC = "Terrain à Chailles" CM = coral marl
CL = coral limestone OL = oncolitic limestone

Fig. 26: View from Stop 6 to opposite (southern) face of highway section at Foug. TC = "Terrain à Chailles"
CM = coral marl CL = coral limestone OL = oncolitic limestone

are here most abundant. Paying special attention to septal thickness and septal density the shift in the faunal composition will be clearly revealed in the field (fig. 35).

The inter-reef sediments are biodetrital carbonates showing indistinct bedding. As it appears from the bedding planes, the submarine relief of these build-ups was insignificant, reaching less than 1 m in height. Most of this apparent submarine relief, however, is due to differential compaction. Nevertheless, in the outcrops these build-ups appear as several metres high hillocks within the sediment.

It is remarkable that the tops of the hillocks are clearly bent to the E (fig. 25,27). This might be due to storm wave action during reef growth which deposited coral fragments in the lee of the reefs where they became suitable substrates for the subsequent coral generation. In contrast, the presumed windward side of the reefs was gradually suffocated by encroaching wind-driven inter-reefal sediments. Finally, the whole reef was submerged by bioclastic sediments rich in micritized coral debris and covered by oncolitic limestone.

The "coral limestone" is approximately 8 m thick. It probably terminates with a hardground, but this has not been located due to the inaccessibility of the steep outcrop wall.

"Coral marls" and "coral limestone" together constitute the **lower reef complex** ("zone construite inférieure" or "unit 4" of HUMBERT 1971).

Station 6C: Uppermost terrace of the highway cut exposing the oncolitic limestone facies which covers the upper coral beds (figs.25, 27)

Access to outcrop:
This terrace may easily be visited by proceeding for some 150 m on the forest lane to the top of the plateau and then returning from there across the woodland to the upper end of the highway cut.

Oncolitic limestone
The oncolitic sands which are at least 6 m thick, were mainly responsible for the final suffocation and burial of the reefs. The bedding is horizontal but not well-defined. The micro-oncoids (up to 2 mm) are formed by algae and nubecularian foraminifera encrusting tiny skeletal fragments. The rock is a poorly sorted, early cemented grainstone to packstone.

Most conspicuous fossils are pelecypods (*Arcomytilus, Plagiostoma, Aequipecten, Velata?, Gervilleia* and *Chlamys*) and gastropods (nerineans and several smaller forms), perisphinctid ammonoids, terebratulid brachiopods, echinoids (*Clypeus* ?) and some coral fragments. There is a pavement of large oriented pelecypod valves suggesting strong current influence.

The rocks of the **upper reef complex** ("zone construite supérieure") overlying the oncolitic limestone, are not preserved in the area of the highway cut. They will be visited at the following excursion stop.

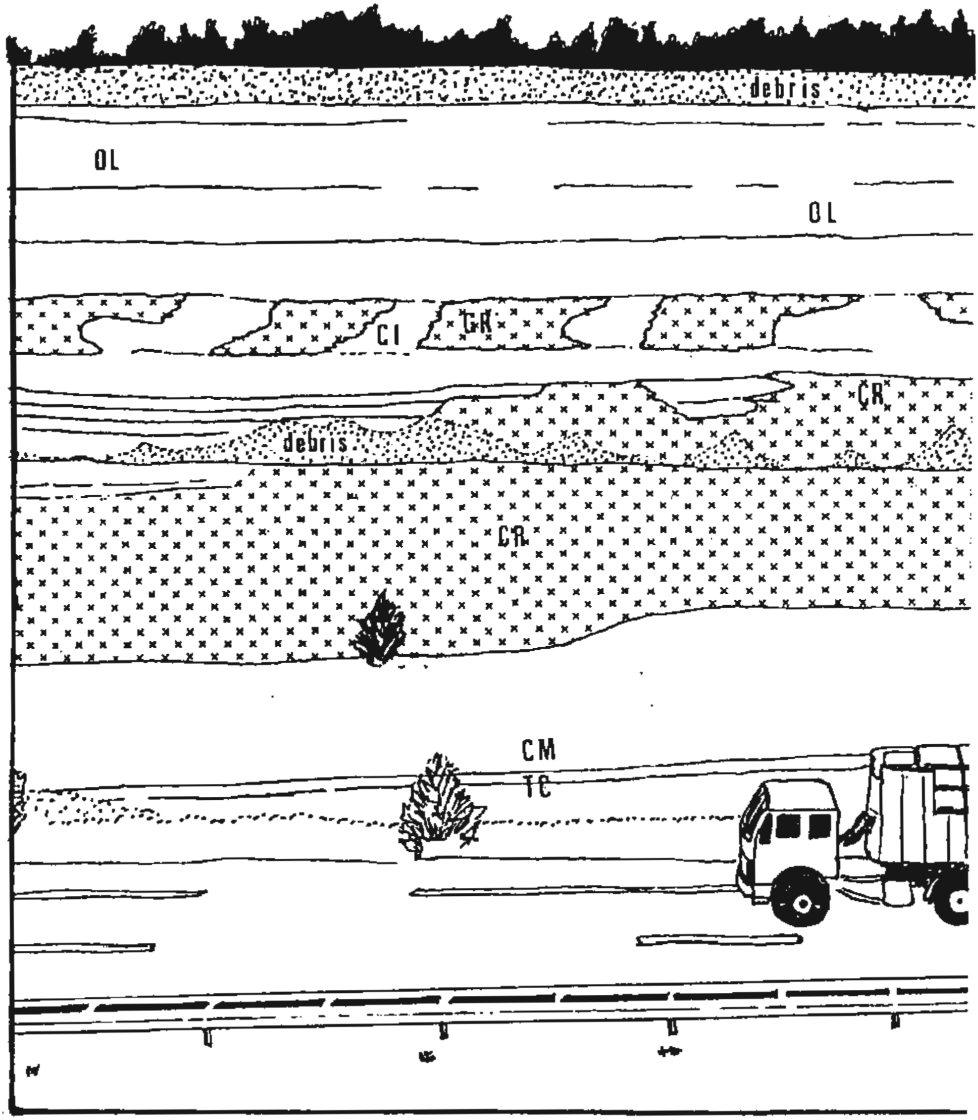
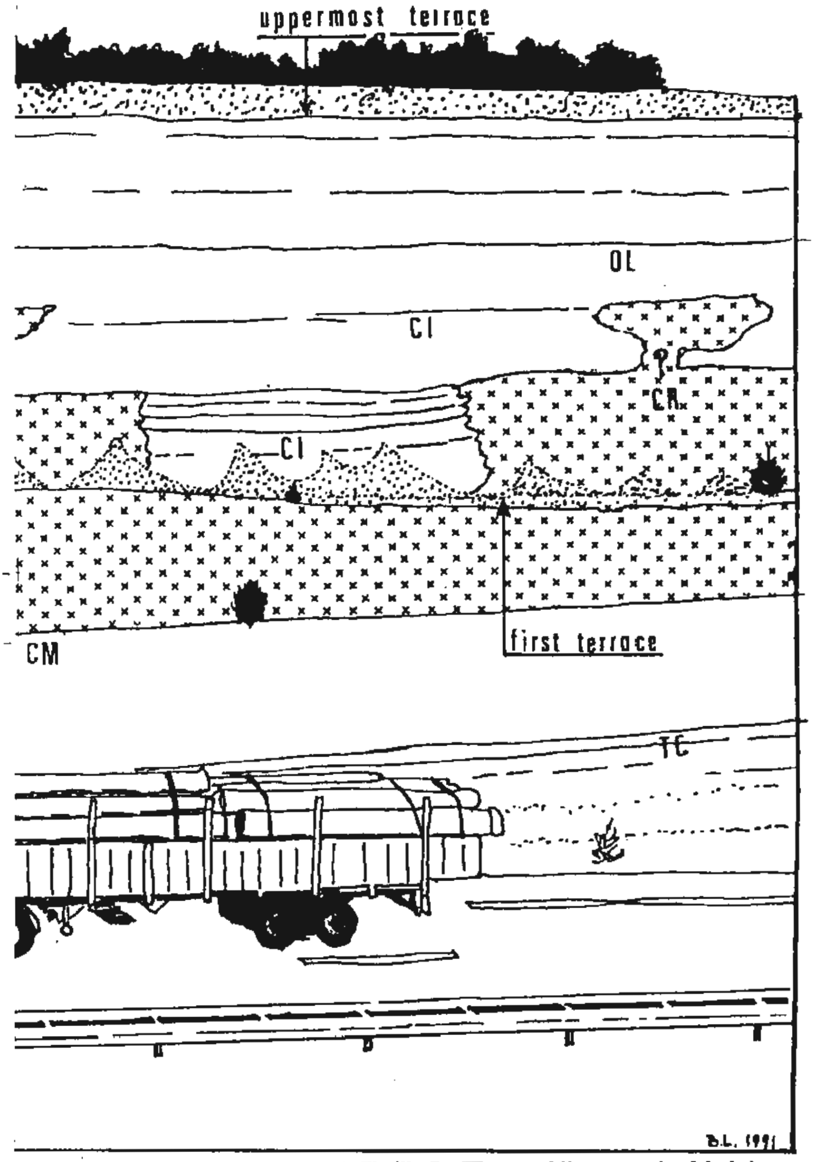


Fig. 27; Stop 6. Northern face of highway section at Foug showing the following facies units :

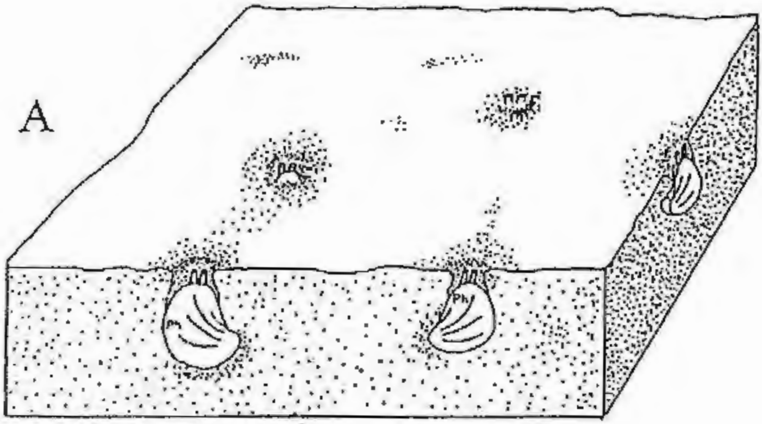


TC = "Terrain à Chailles" CR = coral limestone (reef facies)
CM = coral marl CI = coral limestone (inter-reef facies)
OL = oncoidal limestone

Stations 6A and 6B

Fig. 28: Stop 6 . Coral marls overlying the Terrain à Chailles. Hammer (32 cm) points to oyster bed. Foug, Station 6A.

Fig. 29: Stop 6. Basis of coral marls. Oyster bed recognizable below hammer. Foug, Station 6A.



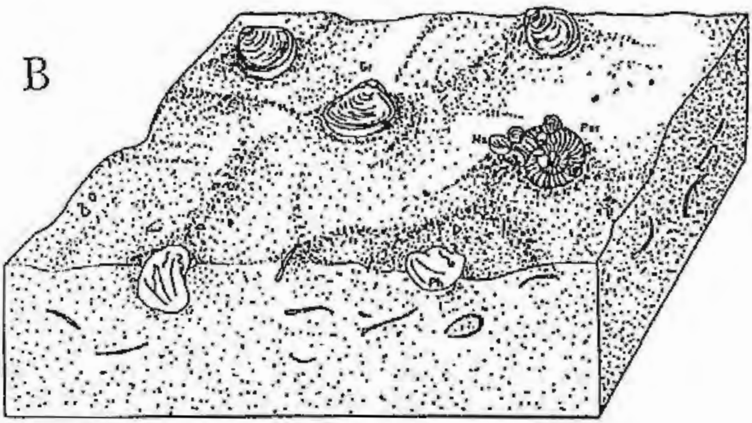
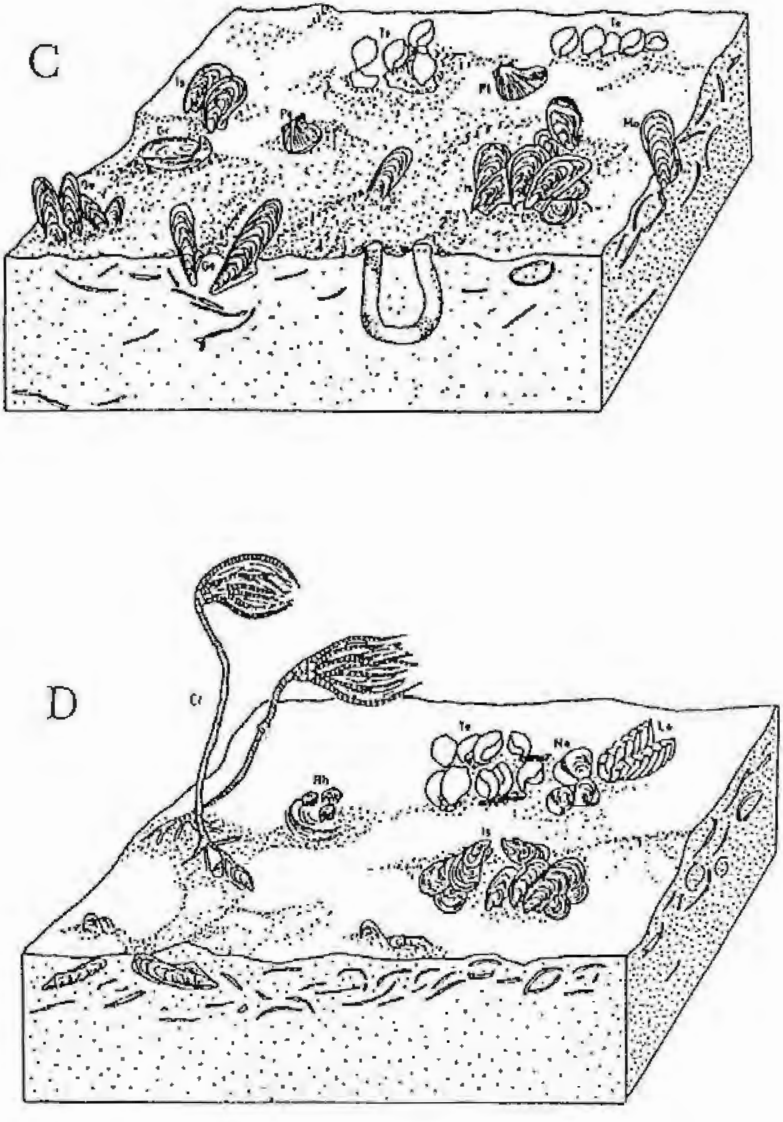


Fig. 30: Stop 6. Reconstruction of faunal shift during the evolution from a soft bottom (A) to a hard bottom (D). Uppermost "Terrain à Chailles". From POIROT (1987).



Ph *Pholadomya*
Gr *Gryphaea*
Na *Nanogyra*
Pe perisphinctid

Ge *Gervillella*
Is *Isognomon*
Mo *Modiolus*
Pe pectinid

Pl *Plagiostoma*
Te terebratulid
Rh rhynchonellid
Cr crinoid

Lo *Lopha*

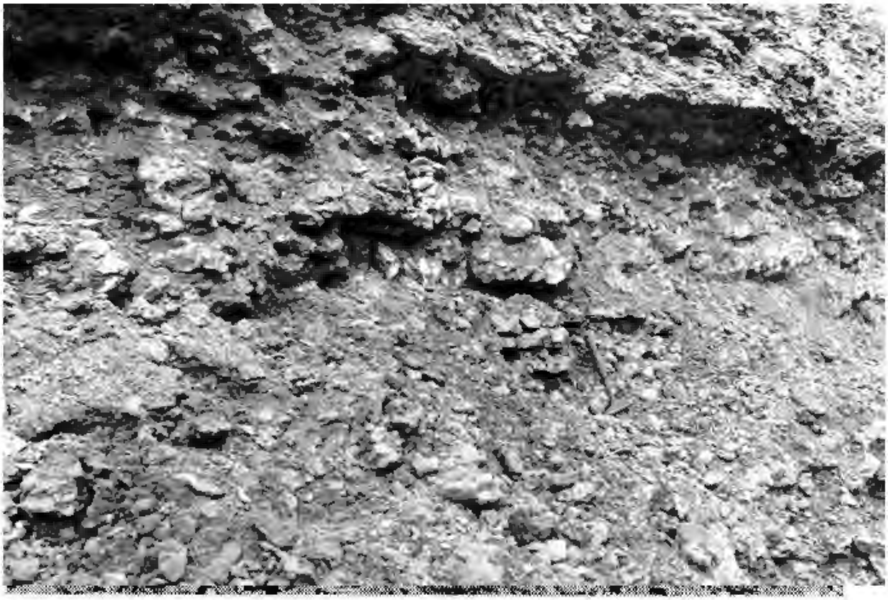


Fig. 31: Stop 6. Heavily burrowed inter-reef sediments. Coral marls. Station 6A, Foug.

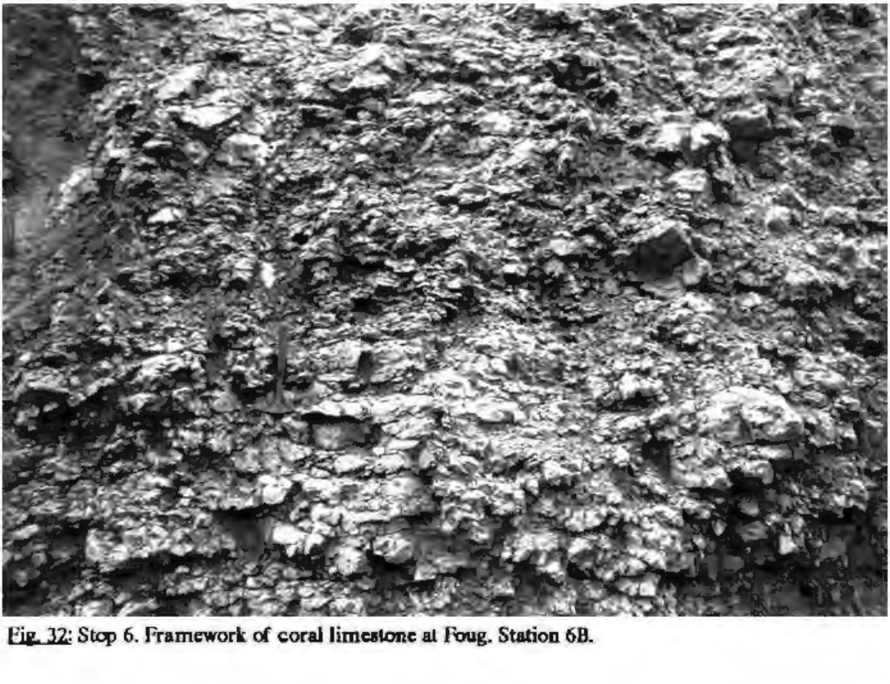


Fig. 32: Stop 6. Framework of coral limestone at Foug. Station 6B.

Fig. 33: Stop 6. Bedded inter-reef sediments of the coral limestone at Station 6B, Foug.

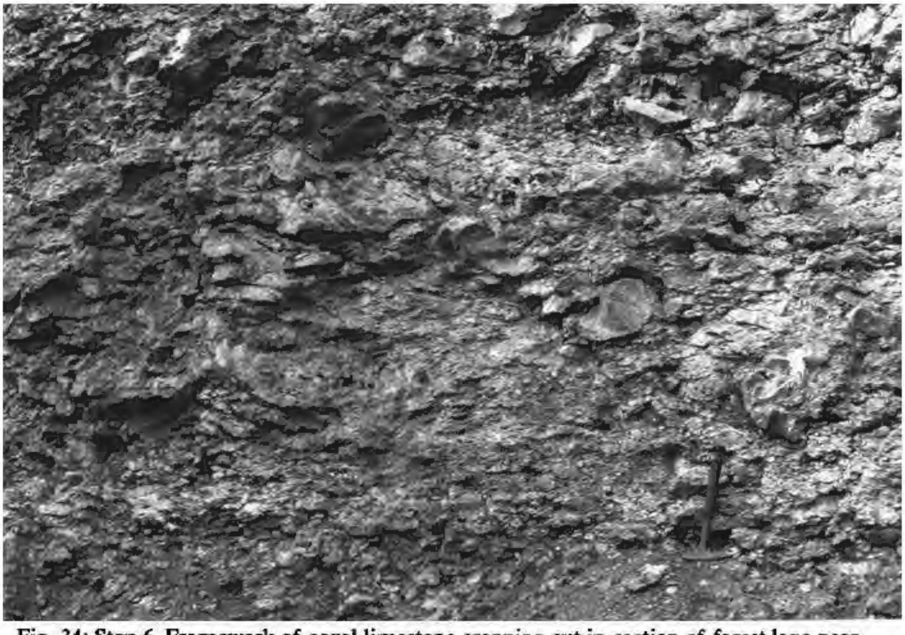


Fig. 34: Stop 6. Framework of coral limestone cropping out in section of forest lane near Station 6B, Foug.

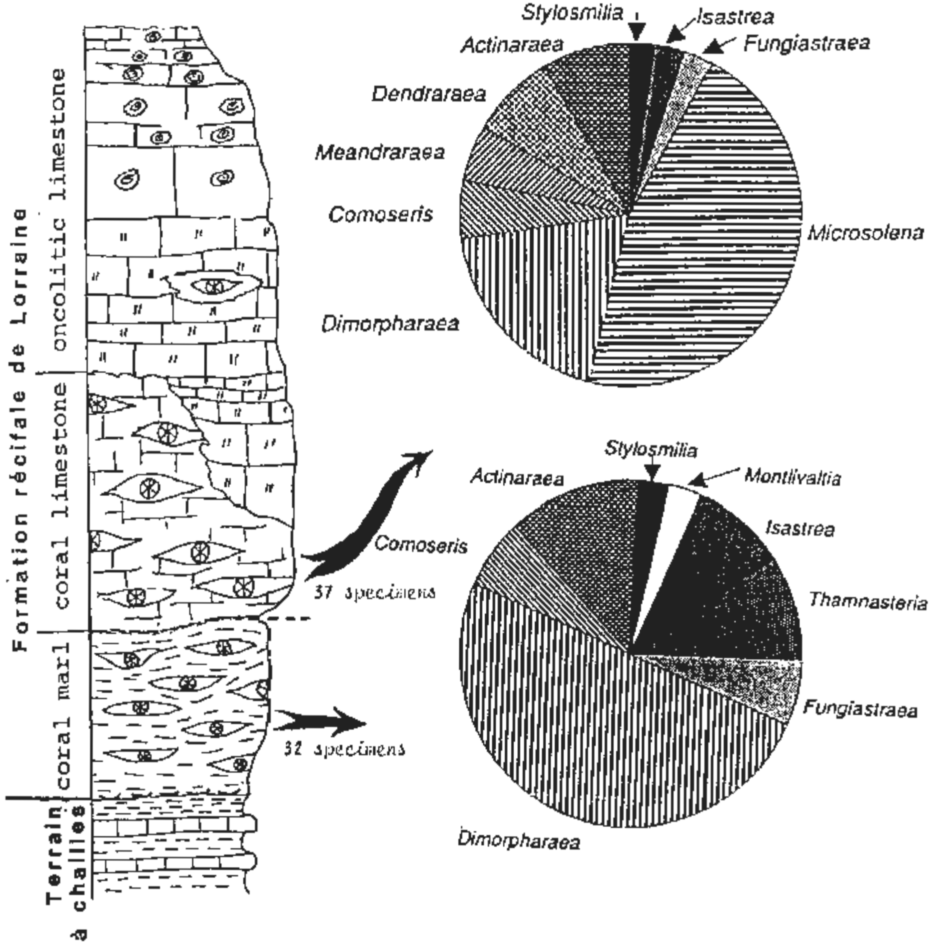


Fig. 35: Stop 6. Shift in generic composition of coral fauna from Oxfordian coral marl to coral limestone at Foug.

Stop 7: Coral thickets in a chalky matrix exposed in quarry at Pagny-sur-Meuse

The quarry to be visited, "Carrière du Revoi", is situated on a hilltop to the SE of the village of Pagny. It is operated by the Rhône-Poulenc Company which extracts pure limestone for the chemical industry.

The quarry exhibits a fresh and extensive, more than 50 m high section of the Oxfordian strata lying above those visited in the highway cut of preceding Stop 6.

Our visit will be limited to the lowermost 10 m of the outcrops where we shall examine coral thickets of the upper reef complex ("zone construite supérieure") embedded in a chalky matrix.

Stratigraphy:
Upper part of "Formation récifale de Lorraine" of Middle Oxfordian age.

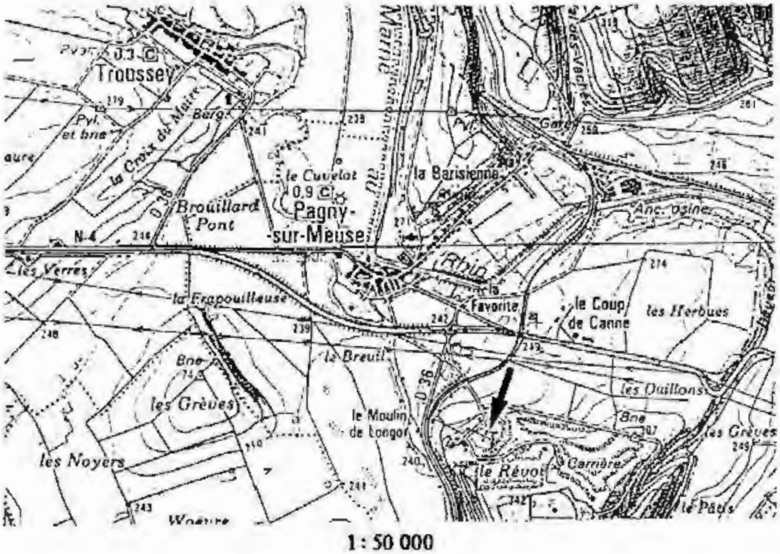
Access to outcrop:
Leave car at the administration bureau at the entrance of quarry and walk some 150 m eastward down to the lowermost excavation level of the quarry. There, the most beautiful coral formations are presently exposed in the southern outcrop wall.

The outcrop may only be visited with a special permit from the director of the quarry!

Coordinates: x = 849,9 y = 114,1

Topographic and geologic maps 1:50 000: Nr.XXXII-15 (sheet Commercy)

Caution: The subvertical quarry walls are up to 20 m high. They are formed by fairly loose rock material that might collapse when sampled by hammer. Therefore, observe the coral thickets in the walls from a safe distance and get your samples from the abundant coral debris at the foot of the quarry walls.



1 : 50 000

Fig. 36: Stop 7. Dense thickets of *Aplosmilia* colonies in "Carrière du Revoi" at Pagny-sur-Meuse. Middle Oxfordian. Hammer 32 cm.

Fig.37: Stop 7. Dense thicket of *Stylosmilia* colonies in "Carrière du Revoi" at Pagny-sur-Meuse, Middle Oxfordian.

Coral thickets of the "zone construite supérieure"
Branching corals are grouped in thickets 5 to 10 m high and measuring up to 10 m in horizontal diameter. Coral growth is restricted to the lowermost 10 m of the quarry wall. Most conspicuous are large thick-branched *Aplosmilia* colonies which reach 5 to 10 m in height and apparently, kept pace with the rising sediment level (figs. 36, 38). Also thin-branched smaller *Stylosmilia* are frequent (fig. 37). The skeleton of these branching scleractinians was frequently dissolved ("mouldic porosity") and the moulds were partly or entirely refilled by sparry calcite. Somewhat less abundant are *Thecosmilia* and octomeral branching *Pseudocoenia*.

There are also some massive plocoid colonies (including the genus *Stylina*) and undetermined platy colonies with perforated septal structure. In addition, a few isolated dome-shaped colonies can be observed, the largest measuring 1.3 m in horizontal diametre (fig.39). Density bands recognizable in sections of some of these massive colonies indicate yearly growth rates of about 1 cm. Some circumrotatory massive corals ("coralliths") attain diameters beween 5 and 15 cm. One of them which has been sampled and slabbed, revealed a "nucleus" of *Comoseris* and a "cortex" of *Thamnasteria*.

Frequent large thalli of the red alga *Solenopora* attain diameters of more than 20 cm. They show beautiful purple (? yearly) growth rings.

Further conspicuous fossils:
Large thin-shelled bivalves, gastropods, rhynchonellid brachiopods and echinoid spines.

Matrix:
SEM photographs and field observations revealed that the very pure carbonate material making up the chalky matrix of the corals and forming the inter-reef sediments consists in detrital crystals of micrite (HUMBERT 1971,p.330). Within the coral beds it is evenly distributed throughout the quarry. We presume that the fine-grained material was produced mainly elsewhere on the Oxfordian carbonate platform where the fines were winnowed out and became trapped as calcareous mud within the sheltered area of the coral thickets. From the known growth rates of the branching corals (more than 1 cm/year) it may be calculated that 10 m of chalky mud were deposited in less than 1000 years.

A similar, if not identical facies of branching corals in a chalky matrix has been described from Oxfordian patch reefs of St. Ursanne, Switzerland (PÜMPIN 1965) and from Oxfordian coral assemblages of Poland (RONIEWICZ & RONIEWICZ 1971).

Recent shelf reefs formed almost exclusively by a branching coral association and thriving in a turbid carbonate environment have been described from the Gulf of Guacanayabo of Cuba (see ZLATARSKI 1980:243). In several respects, such as size, growth form of corals, calm environment and heavy carbonate mud sedimentation, they appear very similar to the Oxfordian coral thickets of Pagny.

"Argiles à *Ostrea*"
In the highest part of the quarry, some 30-40 m above the coral thickets, the Oxfordian carbonate sequence is truncated by a hardground, incrusted by oysters. The unconformity is overlain by oyster marls ("Argiles à *Ostrea*" or "Argiles à huîtres") with nodular limestone beds containing platy reef corals. The age attributed to this sedimentary cycle is Upper Oxfordian.

Literature: MAUBEUGE (1968b)

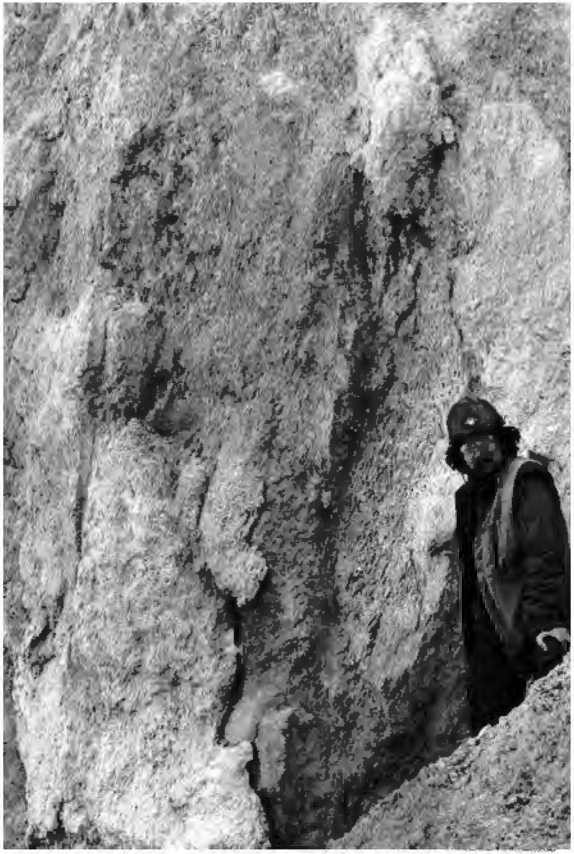


Fig. 38: Stop 7. *Aplosmilia* colonies in quarry wall at Pagny.

Fig. 39: Stop 7. Dome-shaped scleractinian colony at Pagny.

Stop 8: The "Formation récifale de Lorraine" and intercalated crinoidal limestone ("entroquite"). Middle Oxfordian of Euville

The village of Euville was an important center of limestone quarrying in the first half of this century. Main target of the formerly booming quarry industry was the "Pierre d'Euville", a coarse crinoidal limestone. Due to its reputation of being frost-resistant, it was widely used at the time in the construction of public buildings and in the sculpturing of monuments. The "Opéra" house of Paris and the pedestal of the "Liberty Statue" in New York are said to have been built with the "Pierre d'Euville".

In the quarry, the "Pierre d'Euville" is intercalated into the "Formation récifale de Lorraine". It is underlain by coral-bearing limestones ("lower reef complex") and overlain by chalky to biodetritic limestones that laterally merge into true coral reef rock ("upper reef complex").

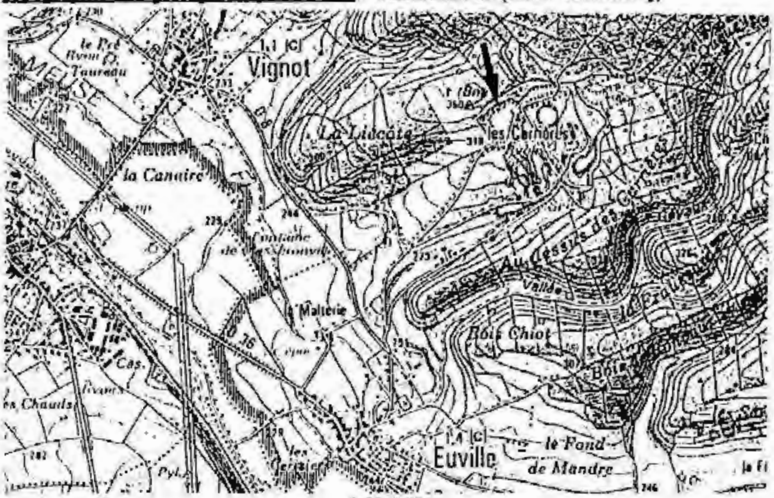
The sequence will be visited in the "Carrière des Côtillons" which is today abandoned. This quarry produced most of the material used in the construction of the historical buildings.

Stratigraphy:
"Formation récifale de Lorraine" of Middle Oxfordian age.

Access to quarry:
From the church of Euville follow road sign indicating "Carrières" to the northeastern outskirts of village. After the branching-off of the road to Vignot, leave the asphalt road (which leads to the modern quarries) and take the next gravel road to the left (no signboard). It follows the crest of a low and inconspicuous ridge and after 1.5 km will lead you directly to the old abandoned quarry ("Carrière des Côtillons").

Coordinates: x = 842,7 y = 124,5

Topographic and geologic maps 1:50 000 : Nr.XXXII-15 (sheet Commercy)



1:50 000

Literature:
HUMBERT (1971), HILLY & HAGUENAUER (1979)

The "Carrière des Côtillons" (fig.40)

The lower reef complex

The undulating topography of the quarry floor corresponds to the original submarine morphology of reefs and inter-reef depressions which were covered by the advancing sandwaves of the crinoidal limestone. As the overlying crinoidal limestone was removed to a large extent by the quarry industry, the upper surface of this reef complex, its horizontal faunal distribution, and the final stage of reef morphology may be studied today in great detail. As compared to Foug, there is an astounding original relief of at least 20 m between reef crest and inter-reef depressions within 100 m of uncovered surface of the reef complex. By contrast, only 3 m of the lower reef complex are exposed in two very localized quarry sections.

The rocks of the quarry floor as exposed consist mainly of:

a) detrital biogenic limestone in the inter-reef depressions
b) considerable amount of coral debris at reef slopes
c) locally true reef framework towards the topographic crests

The top of the lower reef complex is marked by a locally well developed hardground (lithophagan boreholes, incrusting oysters etc.).

Near the vertical wall at the NNW side of the quarry, the coral rock is formed by a dense framework of platy scleractinians (see fig. 40) which rises steeply (30° for some 7 m) towards the quarry face of the overlying crinoidal limestone. It thus forms a true topographic and structural coral reef exhumed at the hardground interface by the quarry works.

Below this steep rise, the slope of the former sea floor was much smoother, descending for more than 10 m within a horizontal distance of some 100 m towards the quarry center. Here the former sandy sea floor was littered by abundant debris, mainly of corals, echinoderms and mollusks, indicating submarine slope deposits downslope of an actively growing reef. The surfaces of both reef and slope deposits are visibly drilled by boring organims, thus indicating hardground formation before burial under the crinoidal sand-waves.

Most common fossil in the inter-reef sediments:
Spines of *Paracidaris florigemma* (statistically oriented N 265°)

The crinoidal limestone ("Pierre d'Euville")

The crinoidal limestone is fully exposed in the vertical quarry walls. Within the quarry it varies in thickness between 6 and 13 m, which corresponds to the crest and trough of the stabilized sandwaves but also to the antecedent submarine topography. The two crests visible in the outcrop are some 150 m apart. The constituant particles of the rock are predominantly coarse crinoid ossicles, the fines having been winnowed out. According to HUMBERT (1971), the isopach map of the "Pierre d'Euville" shows a giant dune 2.5 km long with a longitudinal axis oriented approximately E-W. The width of the dune (in N-S direction) is 600 m and its maximum thickness reaches 20 m. The steep slope is directed northward. At the top, also the crinoidal limestone is truncated by a hardground unconformity as indicated by boreholes and incrusting oysters.

Most obvious macrofossils:
Crinoid fragments (*Pentacrinites*), cidarid echinoid spines, pelecypods.

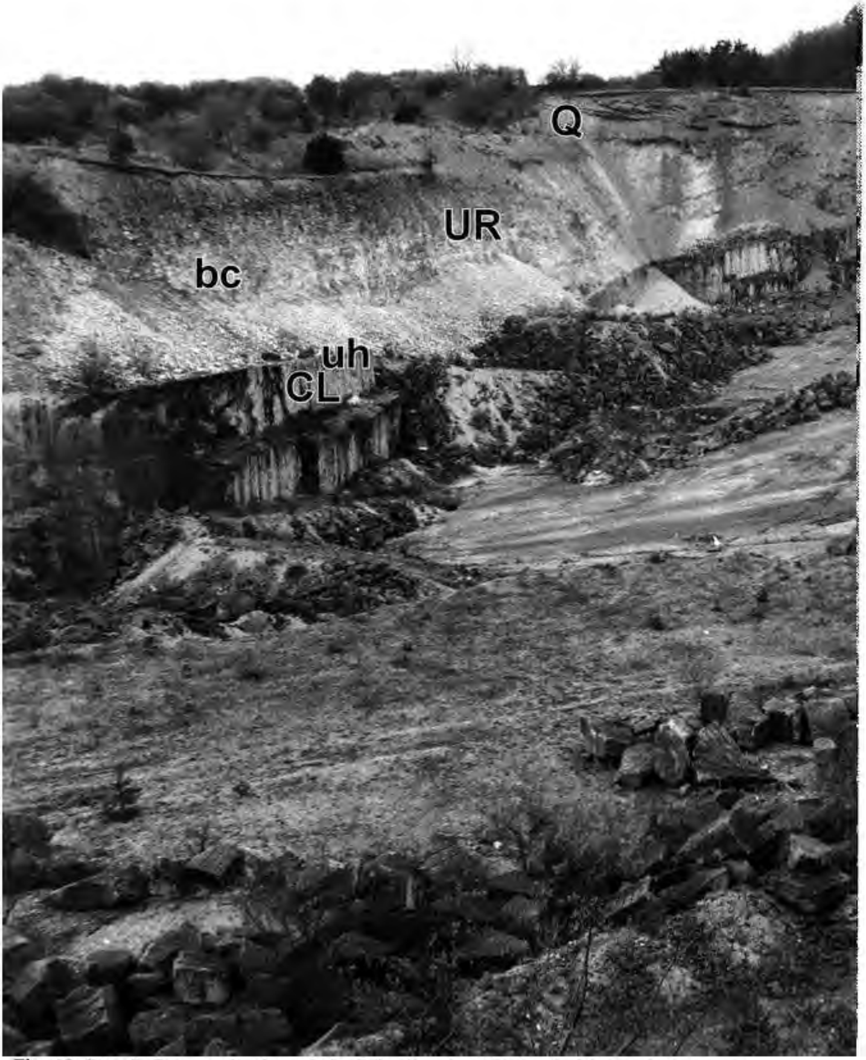
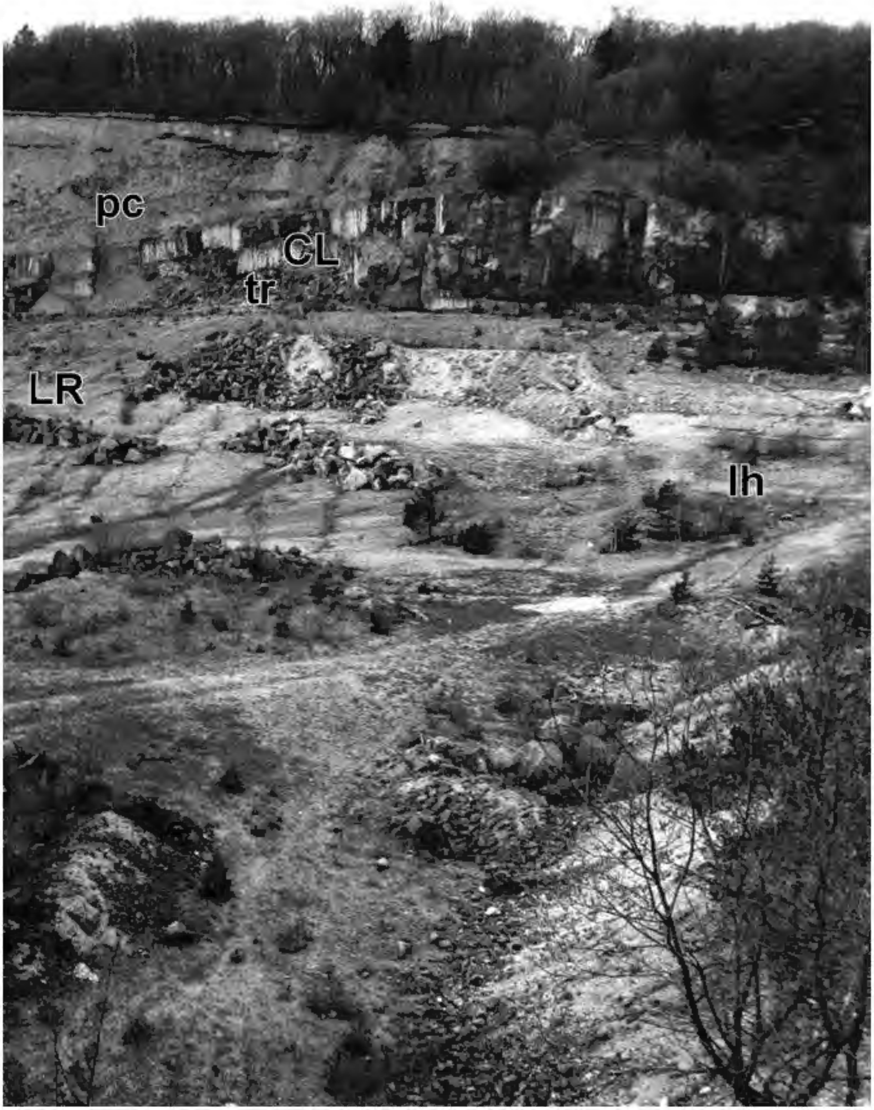


Fig. 40: Stop 8. Panoramic view of the "Carrière des Côtillons", Middle Oxfordian of Euville.



LR = lower reef complex lh = lower hardground bc = branching corals
CL = crinoidal limestone tr = topographic reef pc = platy corals
UR = upper reef complex uh = upper hardground
Q = Quaternary deposits

The upper reef complex

The upper reef complex may be observed in the vertical quarry wall above the crinoidal limestone but is not easily accessible. The thickness observable below the overlying Quaternary gravels is about 10 m. The rock is chalky to biodetritic, locally, with extensive thickets of branching corals, debris of resedimented branching corals and frameworks of platy corals (microsolenids). A reef formation of platy microsolenids can be followed in the NW wall of the quarry for a distance of 80 m and attains a thickness of 5 or more metres (fig.40).

Channelling in the chalky muds testifies to the temporary presence of eroding currents. Channels have been filled and recolonized by branching corals which became subsequently embedded *in situ*. Among the resedimented corals a beautiful dendroid colony of *Dendraraea racemosa* can be observed.

Facies and stratigraphic position of this reef complex correspond approximately to the coral thickets visited at Pagny.

Most obvious fossils:

Reef corals, terebratulid brachiopods, gastropods, perisphinctid ammonites.

Stop 9: "Formation récifale de Lorraine" and intercalated crinoidal limestone ("entroquite"). Middle Oxfordian of Lérouville

The quarry to be visited is the "Carrière de la Mézengère", one of the three large quarries situated at the outskirts of Lérouville, at both sides of Saulx river valley. These witnesses of a formerly flourishing stone industry for the crinoidal limestone ("Pierre de Lérouville") are almost abandoned today. They show approximately the same strata as the Euville quarry, but the framework of the upper reef complex is better developed and more easily accessible in the "Mézengère" quarry.

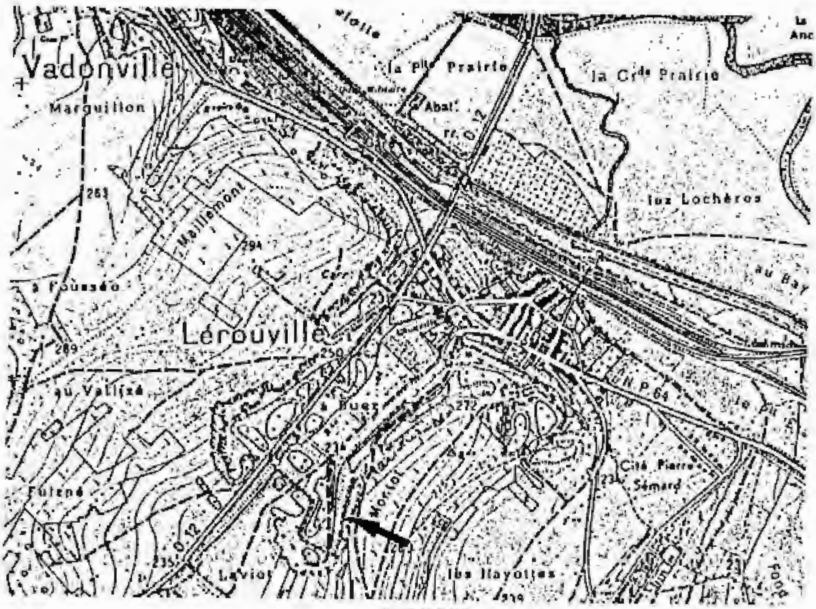
Access to quarry:
At Lérouville take road to the villages of Chonville/ St.Aubin. After about 1 km, immediately at the road sign indicating "end of Lérouville", turn left and follow small gravel road (sign "stade") for 200 m which will lead you directly into the abandoned "Carrière de la Mézengère".

Stratigraphy:
"Formation récifale de Lorraine" of Middle Oxfordian age.

Coordinates: x = 835,1 y = 125,5

Topographic and geologic maps 1:50 000 : Nr.XXXII-4 (sheet St. Mihiel)

Literature:
BEAUVAIS (1964), HILLY & HAGUENAUER (1979), HUMBERT (1971)



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The "Carrière de la Mézengère" (figs.41, 42)

The lower reef complex

As at Euville the target of the Lérouville stone industry was the crinoidal limestone ("entroquite"). Thus, a large surface area of the underlying lower reef complex was also exhumed here, giving a fairly accurate image of the submarine topography before its burial by the submarine dunes of crinoidal sands.

The following facies units can be examined on the fossil sea floor:

a) **Structural and topographic coral** reef rising at least 20 m above the inter-reef depressions. Where visible, the reef body is formed by a dense interlocking framework including branching corals. Among them a large colony of *Dendraraea racemosa* has tumbled down the slope (fig.43). The slope angle of the reef is about 30 degrees in the uppermost 14 m.

b) **Sedimentary slope covered with coarse biodetrital sediments and coral debris.** It forms a belt at the deeper slope of the coral reef between 14 and 20 m below the reef crest. The slope angle is smoother, 6 to 10 degrees, as compared to the upgrowing framework.

c) **Sandy deposits of inter-reefal depressions** showing locally the formation of ripples (fig. 44).

As at Euville the interface between the lower reef complex and the overlying crinoidal limestone is locally drilled by numerous boreholes, thus indicating hardground formation.

Most obvious fossil: *Dendraraea racemosa*

The crinoidal limestone ("Pierre de Lérouville")

It is composed of sandwaves formed predominantly by coarse crinoid ossicles deposited in foresets similar to the Euville quarry. The sandbody reaches a thickness of over 14 m in the vertical quarry wall. Its top is not easily accessible. It is truncated by a bored hardground.

Most obvious fossil: *Pentacrinites*

The upper reef complex

After the deposition of the crinoidal limestone the sea-floor became colonized by predominantly platy and some branching scleractinian corals forming a mostly loose and incoherent framework about 2 m high. This became later buried under several metres of biodetrital sediments.

A new phase of reef formation resulted in an approximately 4 m thick extensive reef body formed by a dense interlocking framework of platy corals (fig.45). This reef body may be followed over the whole extension of the quarry which is about 350 m wide. There is no indication of a significant topographic build-up within this framework. The reef rock is very similar to the framework of platy corals as shown by well developed Bajocian coral reefs.

The inter-reefal sediments are white biodetrital limestones, not winnowed and indistinctly bedded. The bioclasts, mainly echinoderm debris and partly dissolved shell fragments, are strongly micritized. They appear as cortoids and correspond to the early phase of oncoid formation (algal/nubecularian oncoids). The cement shows a granular fabric which appears as an overgrowth around the grains. The incomplete cementation is responsible for the important porosity of the rock.

Most conspicuous fossils:

Echinoderms: crinoid ossicles, *Paracidaris florigemma*

Pelecypods: *Lopha, Chlamys, Entolium* (rare), *Ctenostreon* (rare)

Corals: *Isastrea, Calamophylliopsis,* and thin platy corals (*Meandraraea, Thamnasteria, Fungiastraea, Actinaraea, Microsolena*) .

Boring organisms

The most interesting features of the quarry may most conveniently be visited at the following Stations A to C:

Station 9A: Floor of quarry (see figs.41, 42)

From here we have the best panoramic view of the whole outcrop. The following features may be examined in detail in the lower reef complex:

The submarine topography and facies distribution towards the end of the formation of the lower reef complex (sandy inter-reef depressions locally rippled, coral reef framework and reef slope deposits, and the bored reef top).

The topographic and structural reef is best developed in the steep slope just below the quarry wall, which is unfortunately largely covered by quarry debris. Nevertheless, a beautiful framework of branching corals (Fig.43) may be examined in several spots near the reef crest and the coral debris of the reef slope is readily accessible. Note that there is a total original submarine relief of more than 20 m between reef crest and inter-reef depressions within the extent of the quarry.

The lower part of the crinoidal limestone is only accessible from the floor of the quarry. The horizontal and vertical facies relations of reef and inter-reef facies of the upper reef complex may be well observed in the vertical quarry wall at a distance.

Station 9B: Lower quarry terrace

Access:
Proceed uphill on the forest lane from the eastern end of the quarry floor. Turn right at junction into small road to reach the uppermost level of the quarry outcrop. From here a narrow trail will lead to the western end of the quarry wall from where it is possible to descend safely to the lower terrace.

From this station the uppermost crinoid limestone may be examined as well as the loose framework of platy and branching corals and biodetrital sediments immediately above. A coherent framework dominated by thin *Meandraraea* colonies can also be observed. The hardground truncating the top of the crinoid limestone is not well exposed here. It is accessible with difficulty on the same terrace at the eastern end of the quarry face.

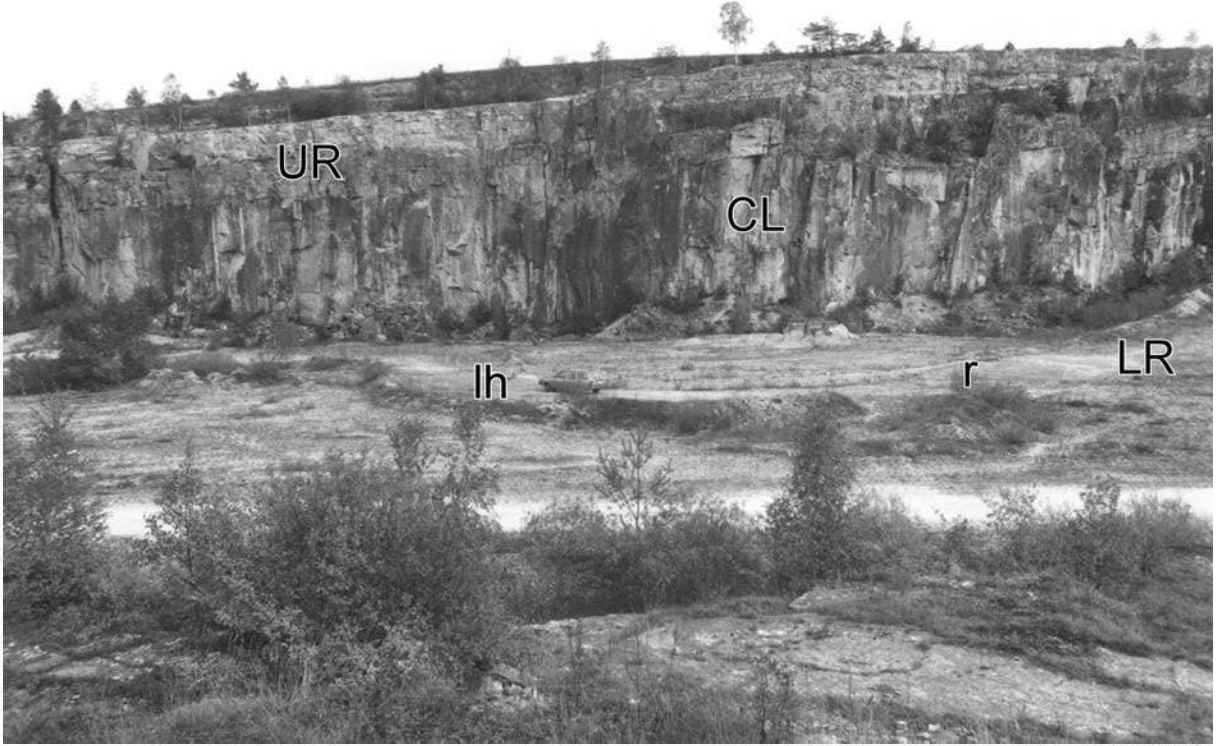


Fig. 41: Stop 9. Carrière de la Mézengère at Lérouville. Northern part of the quarry wall. Middle Oxfordian.

LR = lower reef complex CL = crinoidal limestone UR = upper reef complex lh = lower hardground
r = ripples uh = upper hardground pc = platy corals

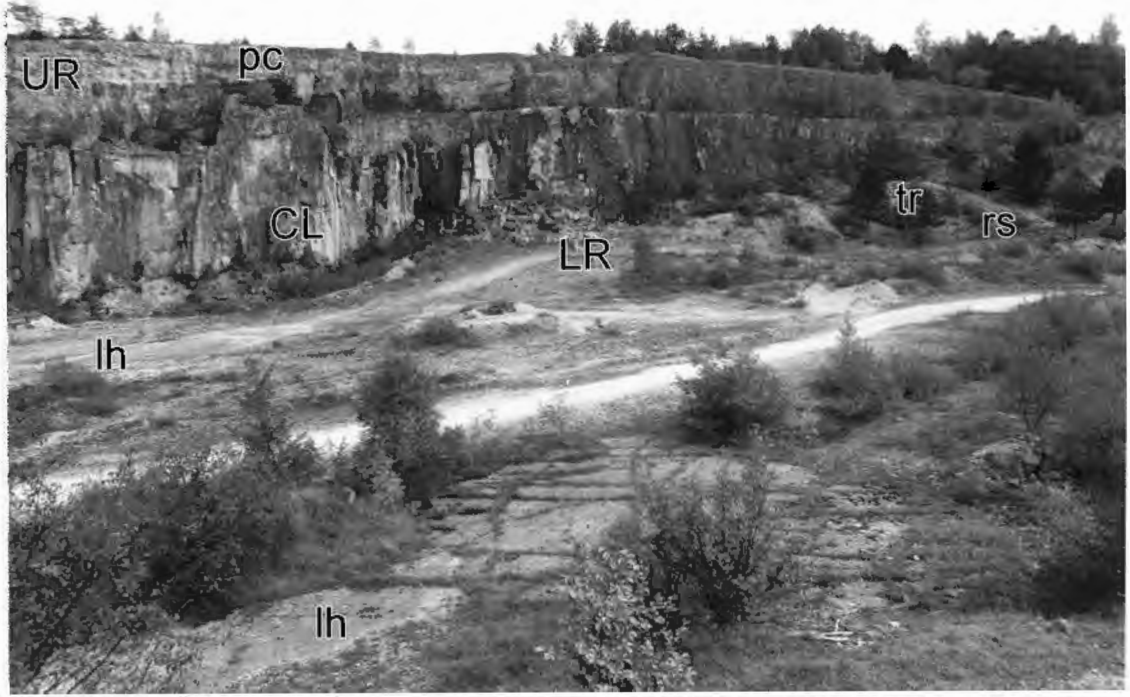


Fig. 42: Stop 9. Carrière de la Mézengère at Lérouville. Southern part of quarry wall. Middle Oxfordian. Stations 9A to 9C (marked A to C).
LR = Lower reef complex CL = crinoidal limestone UR = upper reef complex lh = lower hardground tr = topographic reef rs = reef slope
pc = platy corals

Fig. 43: Stop 9. Framework of branching corals (*Dendraraea racemosa*) near topographic crest of lower reef complex. Station 9A, Lérouville.

Fig. 44: Stop 9. Ripples in inter-reef depression. Lower reef complex. Station 9A, Lérouville.

Station 9C: Second quarry terrace and adjacent road cut

From here the dense and coherent framework of platy and massive corals (some 4 m thick), and related sediments are easily accessible (fig. 45). The coral fauna is somewhat more diverse. The genus *Isastrea* is especially abundant and represented by large (up to 1 m) and thick (up to 11 cm) platy colonies. These coral communities are covered by several metres of biodetrital limestone.

Fig. 45: Stop 9. Dense framework of platy and massive corals with abundant *Isastrea* sp. Upper reef complex at Station 9C, Lérouville.

Stop 10: Oxfordian coral thickets exposed in ancient riverside bluffs at St. Mihiel-sur-Meuse

The picturesque bluffs ("Sept Roches") are situated in a public riverside park in the northern outskirts of the small town of St. Mihiel (fig.46). Most easily accessible for geological examination is the southernmost bluff with steps leading up to a crypta and to the top of the cliff. From there we have a beautiful panoramic view on the town and Meuse river. The base of the cliffs was used as rock shelters by the local population during Upper Palaeolithic times. This is evidenced by excavations that yielded animal and human remains, charcoal and artifacts of the Magdalenian culture (HILLY & HAGUENAUER 1979).

Coral thickets are best visible in the wall of the bluff just above the entrance of the crypta and some 15 m to the N from there. They are embedded in a bioclastic matrix. The next bluff immediately to the N of the crypta equally exhibits beautiful coral thickets in rather fresh outcrops.

The most conspicuous branching corals visible in the bluffs belong to *Thamnasteria dendroidea*. There are also some conspicuous massive colonies. According to BEAUVAIS (1964) the scleractinian fauna of the bluffs includes 25 species of the following genera:

Adelocoenia, Aplosmilia, Astraraea, Aulophyllia, Brachyseris, Cladophyllia, Cryptocoenia, Dendraraea, Dermosmilia, Diplocoenia, Isastrea, Meandrophyllia, Microphyllia, Microsolena, Rhipidogyra, Stereocoenia, Stylina, Stylosmilia, Thamnasteria.

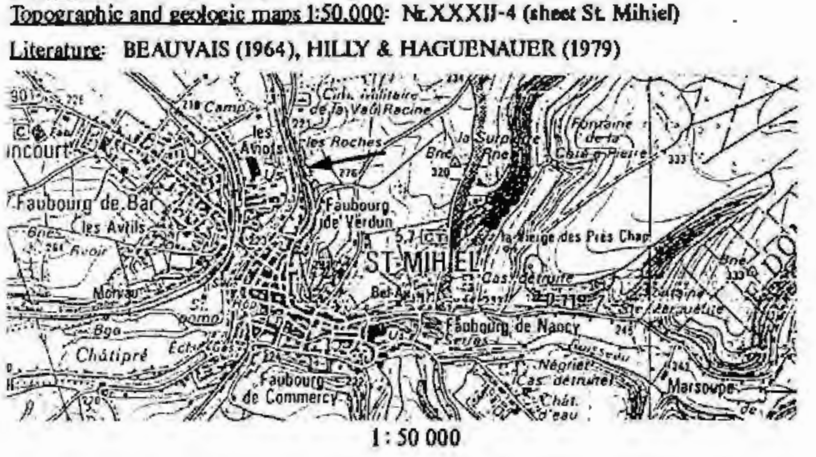
Further fossils: *Diceras* and nerineans

St. Mihiel is the type area of most Oxfordian corals described by MICHELIN !

Stratigraphy:
"Formation récifale de Lorraine", Middle Oxfordian. The outcrop is situated in the upper part of the section. It corresponds approximately to the coral thickets at Pagny and to coral beds above the crinoidal limestone visited at Euville and Lérouville.

Coordinates: x = 835,0 y = 138,5
Topographic and geologic maps 1:50.000: Nr.XXXII-4 (sheet St. Mihiel)

Literature: BEAUVAIS (1964), HILLY & HAGUENAUER (1979)



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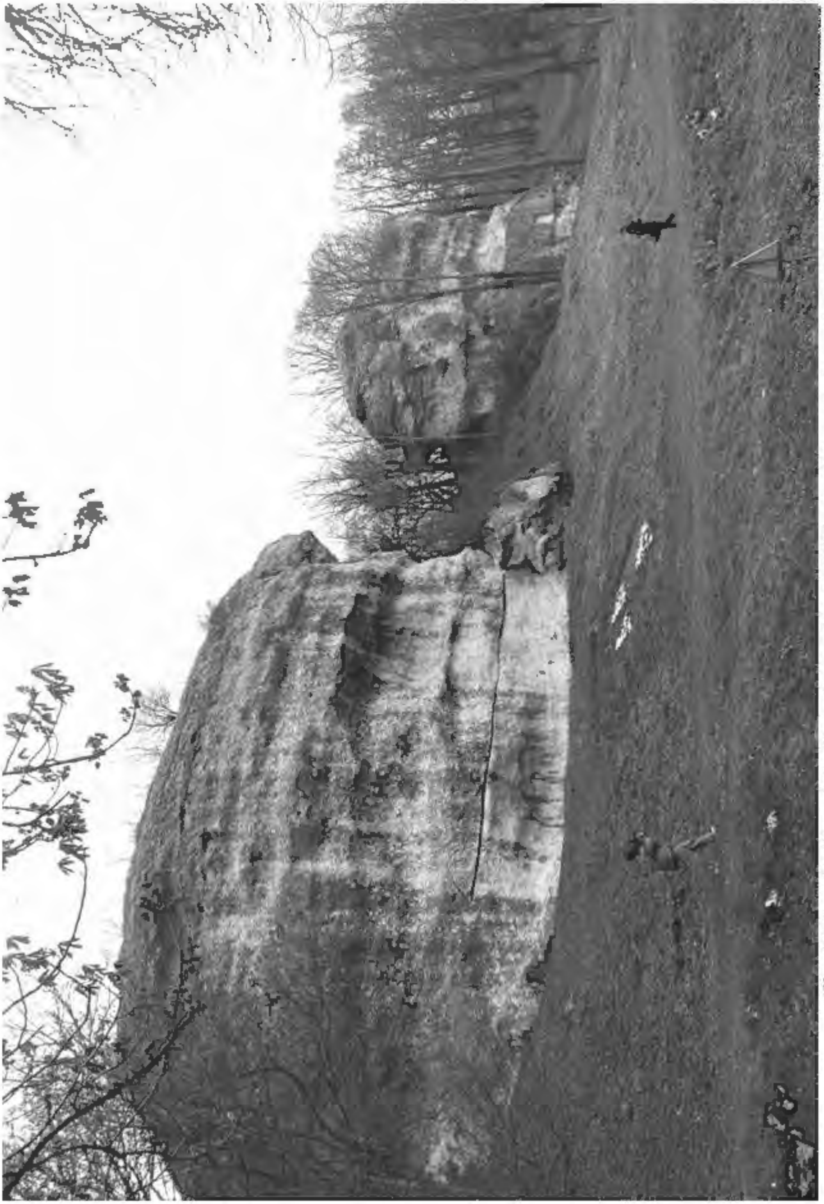


Fig. 46: Stop 10. Two of the "Sept Roches" at St. Mihiel-sur-Meuse, Middle Oxfordian.

Stop 11: Road cuts of interchange and adjacent highway into Middle Oxfordian reefs at Haudainville, S of Verdun

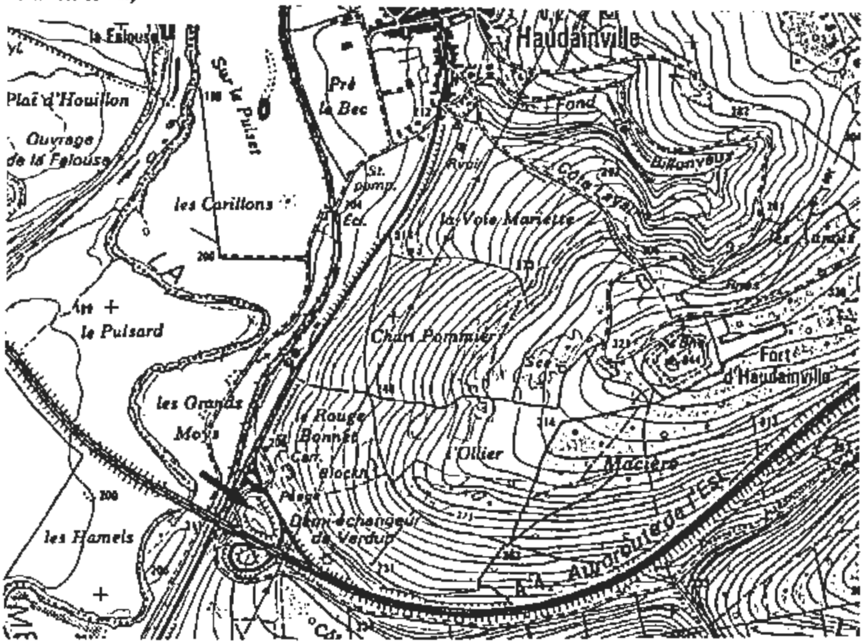
The extensive outcrops give a unique three-dimensional view of the internal structure and facies relationships within a fossil reef complex. The growth history of the reefs may be fully traced from their initiation on unstable substratum through their build-up and final burial by biodetritic sediments.

<u>Stratigraphy</u>:
"Formation récifale de Lorraine", Middle Oxfordian. The outcropping rocks correspond roughly to the upper part of the crinoidal limestone and overlying reef formations/inter-reef sediments visited at Euville and Lérouville.

<u>Access</u>:
By car to the highway interchange Verdun (south of Haudainville village). Leave the car at the toll check-point and proceed by foot.

<u>Coordinates</u>: x = 824.5 y = 160.5

<u>Topographic and geologic maps 1: 50 000</u> : Nr.XXXII-13 (sheet Vigneulles-lès-Hattonchâtel)



1 : 25 000

<u>Literature</u>:
BEAUVAIS (1985), BEAUVAIS et al.(1980), ENAY & BOULLIER (1981), HANZO, LE ROUX et al. (1982), HILLY & HAGUENAUER (1979)

<u>Important note</u>:
This outcrop may only be visited with a special permit from the highway authorities !

The Hardainville reefs

The three-dimensional outcrop conditions permit a detailed observation and reconstruction in time and space of the installation and burial of a fossil coral reef (fig. 47). Reef growth initiated on the eroded upper surface of a crinoidal limestone complex probably equivalent of the crinoidal limestones visited at Euville and Lérouville. Reef initiation is preceded by successive deposition of prograding detrital limestone beds (storm events?) which became subsequently colonized by a loose association of massive reef corals. These beds were themselves successively colonized by equally progreding thickets of a dense association of robust branching corals dominated by *Thamnasteria dendroidea*. In some places, these thickets which are 1 to 2 m high, were finally overgrown by finer branched colonies which by trapping sediment formed conspicuous build-ups about 6 m high. The build-ups were finally drowned completely by rather muddy onlapping inter-reef sediments.

Higher in the section, there is evidence of a renewed attempt of colonization of the soft substratum by large massive coral colonies. However, many of these were uprooted, rolled and redeposited probably during a major storm event. They are concentrated within a distinct layer of coarse debris and covered by finer grained sediments.

We did not find any clear horizontal coral zonation within the build-ups that might reflect ancient wave energy levels, i.e. a wave-exposed and a wave-protected side of the reefs as has been described from Quaternary reefs (GEISTER 1977,1980). And there are no growth forms or growth directions of coral branches that might be indicative of persistant palaeocurrent directions. The outcrops, although large and three-dimensional, are insufficient to show possible geomorphological trends of the build-ups such as the formation of elongated ridges and their predominant orientation.

A striking phenomenon within these outcrops is the presence of numerous brown marker horizons. These are centimetre- or even millimetre-scale silty layers of pure brownish carbonate material which may be traced from inter-reef sediments into the coral thickets and build-ups. At the marker horizons coral thickets died frequently and became recolonized by another species. Some more robust branching colonies of *Thamnasteria dendroidea*, however, survived the noxious events and continued growing during at least 2 periods separated by such marker horizons. Yearly (?) growth rings of these colonies indicate that the periods between the deposition of two successive brown marker horizons ranged from about 10 to 100 years.

Available evidence suggests that the corals lived in a rather calm protected environment and were possibly ravaged periodically by exceptionally violent storms. The storms smashed many coral skeletons, eroded their tops and stirred up also a great amount of mud on the surrounding shelf. This mud settled subsequently in areas protected from waves and currents suffocating most of the surviving corals. Each mud layer represented in the outcrop as a brown marker horizon would indicate a storm event.

The outcrops of Stop 11 will be examined along an itinerary beginning with the lowermost facies units and leading step by step to the top of the section. Detailed explanations to Stop 11 will be given at 8 stations (A to H) as shown on accompanying plan (fig. 48).

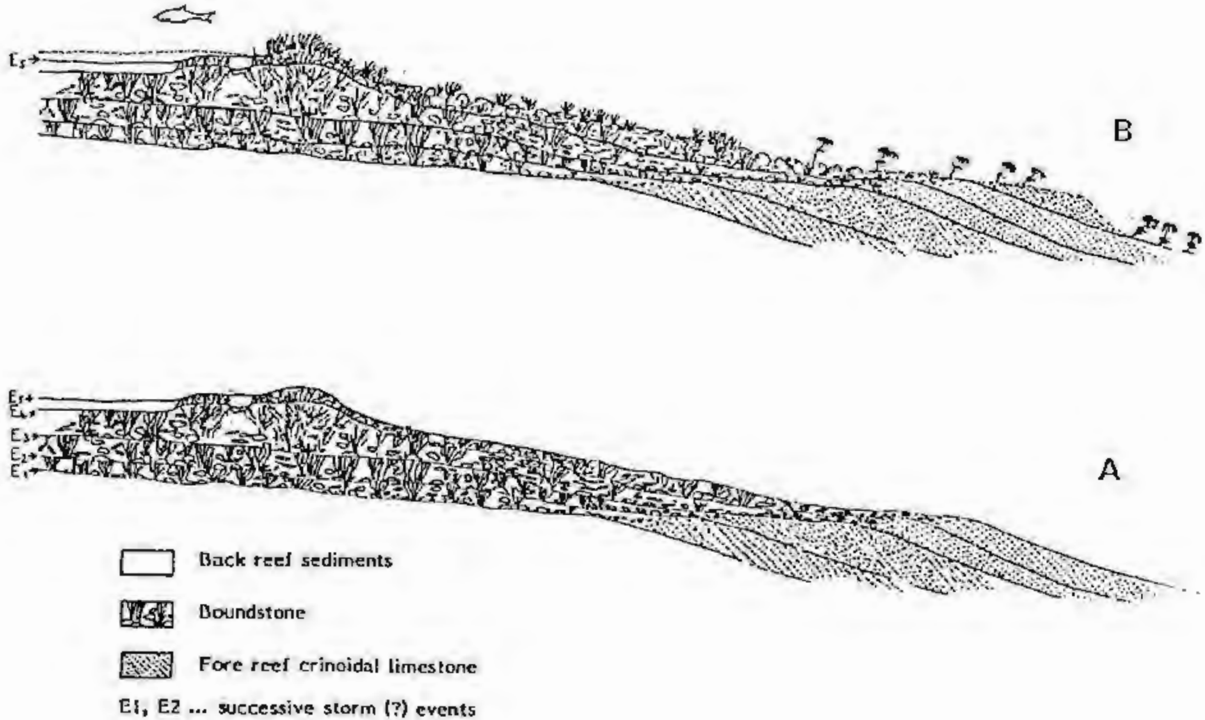


Fig. 47: Stop 11. Generalized sedimentation model of the Middle Oxfordian reef formations at Haudainville.

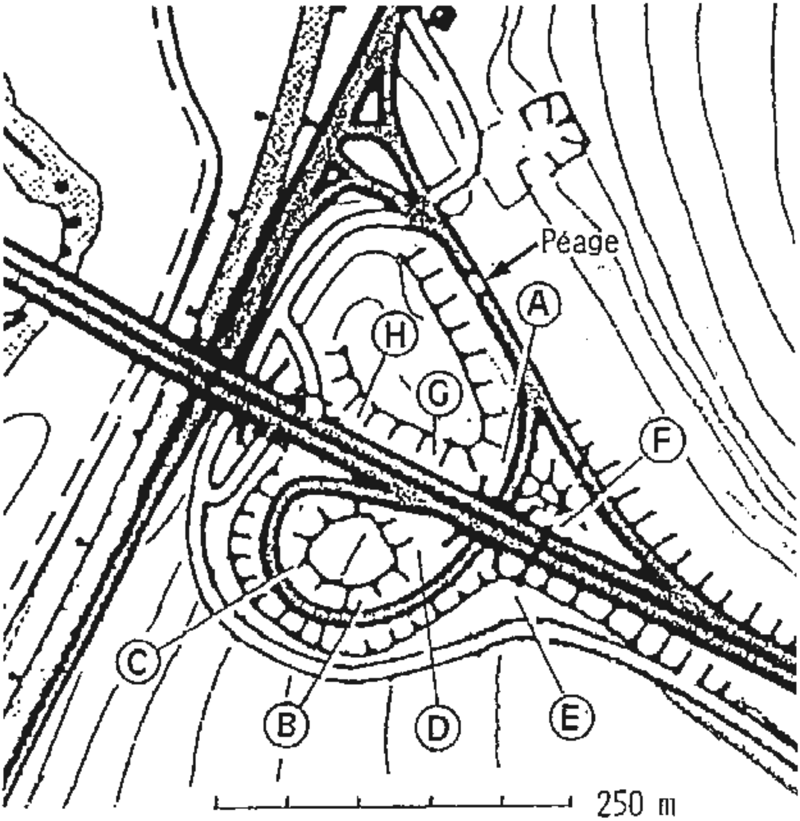


Fig. 48: Stop 11. Plan of highway interchange at Haudainville. Stations 5A to 5H marked A to H.

Station 11A: Cut of access road to highway before and after highway bridge (fig.49).

Uppermost 5 m of a crinoidal limestone complex (grainstone to rudstone) with well-defined foresets and reactivation surfaces. It is truncated at the top and underlies the reef formations. The foresets are directed to the SW in the lowermost part of the section, but are succeeded by foresets directed to the NE (fig.50). Within the foresets there is fining-upward from coarse fossil debris to sand-sized particles. The reactivation surfaces may correspond to storm events. The microfacies is characterized by a mixture of unaltered bioclasts (mainly crinoid ossicles or fragments) and some already micritized grains which are poorly cemented.

Obvious fossils in debris of foreset slope:
Crinoids (*Pentacrinites*), coral fragments, echinoid spines (*Paracidaris florigemma* and others), small gastropods, pelecypod fragments, serpulids, bryozoans.

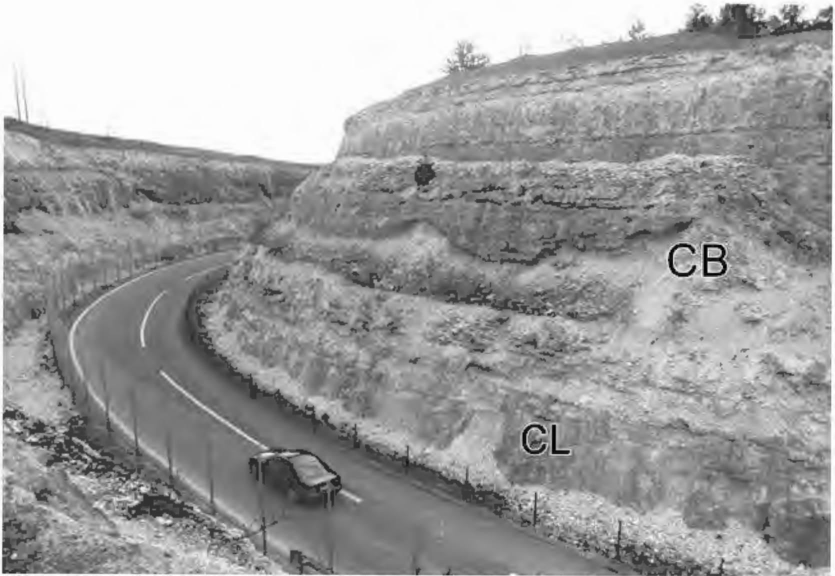


Fig. 49: Stop 11. Cut of access road to highway after highway bridge.
Station 11A. CL = crinoidal limestone CB = coral build-up

Fig. 50: Stop 11. Foresets of crinoidal limestone (below) succeeded by prograding beds of coral pavement. Facies of branching corals on top. Station 11A, Middle Oxfordian, Haudainville.

Station 11B: Both sides of above road cut 100 m after highway bridge (fig.50, 51)

Initiation of reef facies on a truncation surface of crinoidal limestone. Progradation of reef facies to SW. Vertical and lateral succession of facies units. Base of reef facies formed by a loose, incoherent pavement mostly of massive corals. Progradation of pavement towards fore-reef slope ending in a tongue of fossil debris. At least 5 prograding pavements are recognizable, which themselves are subsequently buried under an equally prograding facies of dense coral thickets (figs.50, 51).

Cyclic interruption of reef growth is indicated by thin marly layers forming excellent brown marker horizons. Reinitiation of reef growth above marker horizon generally by different genera. Few, generally larger colonies of *Thamnasteria dendroidea* survived the event and continued to grow in subsequent cycle.

Most obvious fossils:
Dense thickets of *Thamnasteria dendroidea*, 1 m high, overgrown by branching *Calamophylliopsis*, massive perforated scleractinians (possibly *Actinaraea* or *Meandraraea*), *Isastrea* and *Comoseris*?

Station 11C : Curve of road cut 175 m after highway bridge (fig.52-54)

Two coral build-ups, up to 6 m high and 15 m broad at the base, crop out in the section. The base is formed by a dense coral thicket of *Thamnasteria dendroidea* succeeded vertically by predominantly thin-branching and foliaceous corals (*Fungiastraea*). Between both build-ups there is a colony of *Dendraraea racemosa* (1 m high and 3 m wide) and a massive *Allocoenia* with lateral horizontal platy outgrowths. The build-ups were drowned by more than 5 m of biodetrital sediments. Brown marker horizons may be traced from inter-reef sediments into the build-up.

Further scleractinians recognized:
Isastrea, Calamophylliopsis, Fungiastraea

Further macrofossils:
rhynchonellid and terebratulid brachiopods, pelecypods, nerinean gastropods, *Solenopora*. Further gastropods are abundant and diverse in the inter-reef facies.

Station 11D : Panorama of road cut visited in stations A to C (fig.55)

Overview over the whole outcrop. Vertical and lateral facies successions. From bottom to top the following sequence may be recognized:

- **Prograding of reef facies onto crinoidal limestone.** At least 5 en echelon beds each about 0.2 to 0.3 m thick, suggest a stepwise reef progradation
- **Disruptions of coral growth** as indicated by several brown marker horizons with subsequent phases of reinstallation of coral growth. Formation of dome-shaped build-ups some 6 m high and distant from each other some 7 to 15 m.
- **Final drowning of build-ups** under biodetrital limestone (3 m)

Fig. 51: Stop 11. Dense thicket of *Thamnasteria dendroidea* overlying prograding beds of coral pavement. Haudainville, Station 11B.

Fig. 52: Stop 11. Curve of road cut 175 m after highway bridge. Stations 11B (B) and 11 C (C) are indicated

Fig. 53: Stop 11. Major coral build-up buried under inter-reef sediments. Base formed by thickets of *Thamnasteria dendroidea* succeeded by thin-branched corals. Station 11C, Haudainville.

- **Reinitiation of large massive scleractinians on unstable substratum** within the biodetrital sediments (fig.56). Some of these corals were uprooted, rolled and resedimented on a reactivation surface. They were subsequently embedded in a 5 cm thick brown bed of carbonate silt. This conspicuous silt layer represents an unusually thick brown marker horizon, suggesting a major storm event.
- **Continuation of normal biodetrital sedimentation** (ca.8 m to the upper end of outcrop). These sediments show a large proportion of micritized clasts and a texture varying from packstone to grainstone.

Station 11E : Cut along south side of highway E of highway bridge (fig.54)

Internal structure of interlocking framework within coral build-ups, formed by large lamellar, unifacial (*Actinaraea*) (see fig.57) and branching (*Thamnasteria dendroidea*) scleractinians.

Further scleractinians recognizable in outcrop:
About 15 m E of bridge, there is a large massive coral head (1 m broad, 0.8 m high) formed by several different coral genera as well as by *Solenopora* (fig. 58). Branching corals present include: *Dendraraea, Calamophylliopsis, Stylosmilia* (immediately above coral head). In addition, there are also undetermined massive scleractinians.

Three metres to the left below a large massive coral head, there is a thicket of *Thamnasteria dendroidea* 2 m broad and 1 m high showing annual(?) thickening of branches, suggesting an approximate growth rate of 13 mm / year. Such well developed growth rings of *Thamnasteria dendroidea* are a common phenomenon in the Haudainville reefs (see fig.59).

20 m to the left a *Thamnasteria dendroidea* thicket, 5 m broad, terminates at an overlying brown marker horizon. On top of this *Thamnasteria* there is an *Aplosmilia* with clearly truncated top (brown marker bed) and overlain by biodetritic sediments (fig. 60).

Station 11F : Cut of highway NE of highway bridge (fig. 61)

Extensive interlocking framework of dense coral thickets dominated by *Thamnasteria dendroidea* within the lower part of the coral build-up. Disruptions and reinstallation of reef growth is indicated by at least 3 brown marker horizons. The probable yearly growth rate of *Thamnasteria dendroidea*, as suggested by rhythmic thickening of branches, is about 12 mm/year.

Most conspicuous corals in outcrop:
branching *Thamnasteria dendroidea, Aplosmilia , Calamophylliopsis,*
lamellar *Actinaraea, Meandraraea, Fungiastraea*
undetermined massive corals.

Further fossils:
Chlamys, gastropods, echinoid debris, *Solenopora*.

Fig. 54: Stop 11. Panoramic view of Stations 11C, 11D and 11E (marked C, D and E), Haudainville.

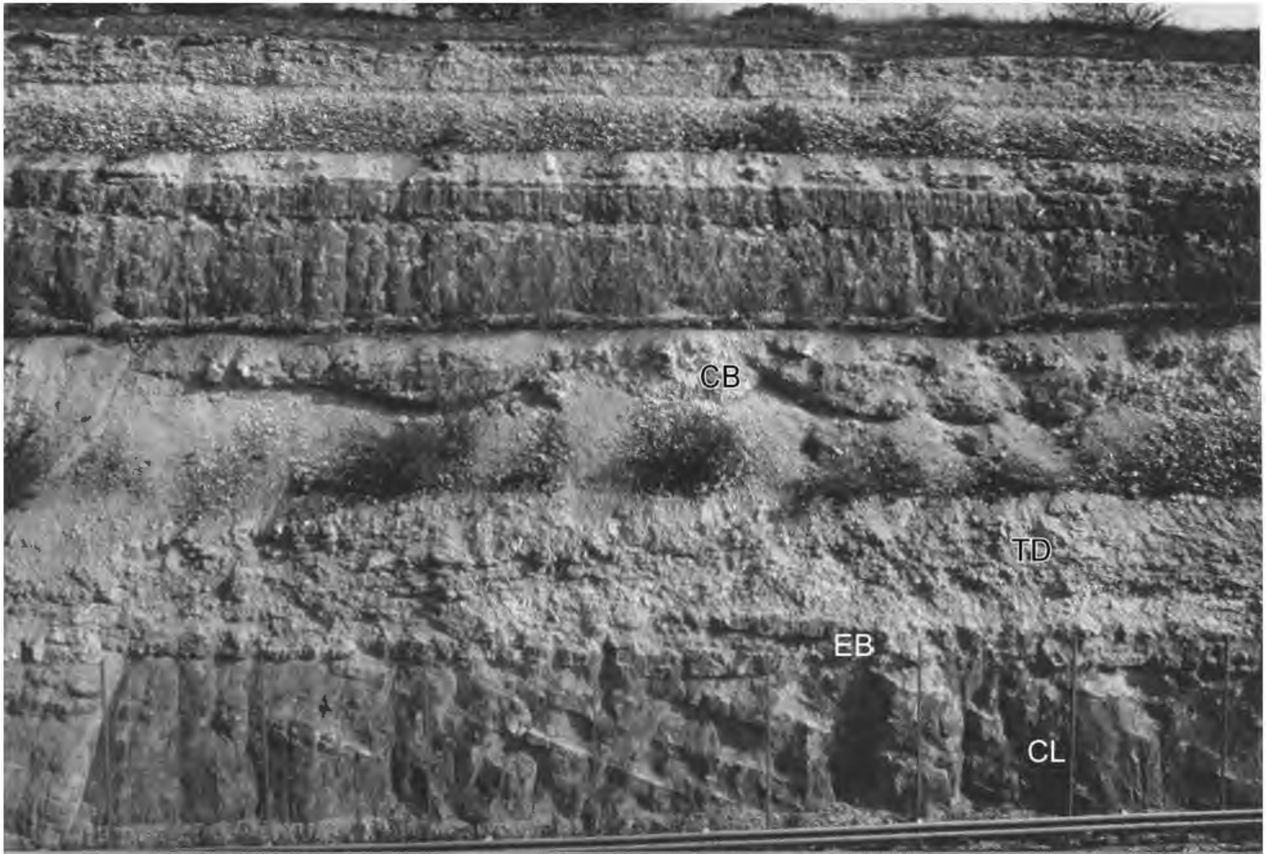


Fig. 55: Stop 11. Panorama of road cut at station 11D. CL = crinoidal limestone EB = en echelon beds of coral pavement TD = *Thamnasteria* thickets CB = coral build-ups SB = major storm bed (?) (see fig.56)

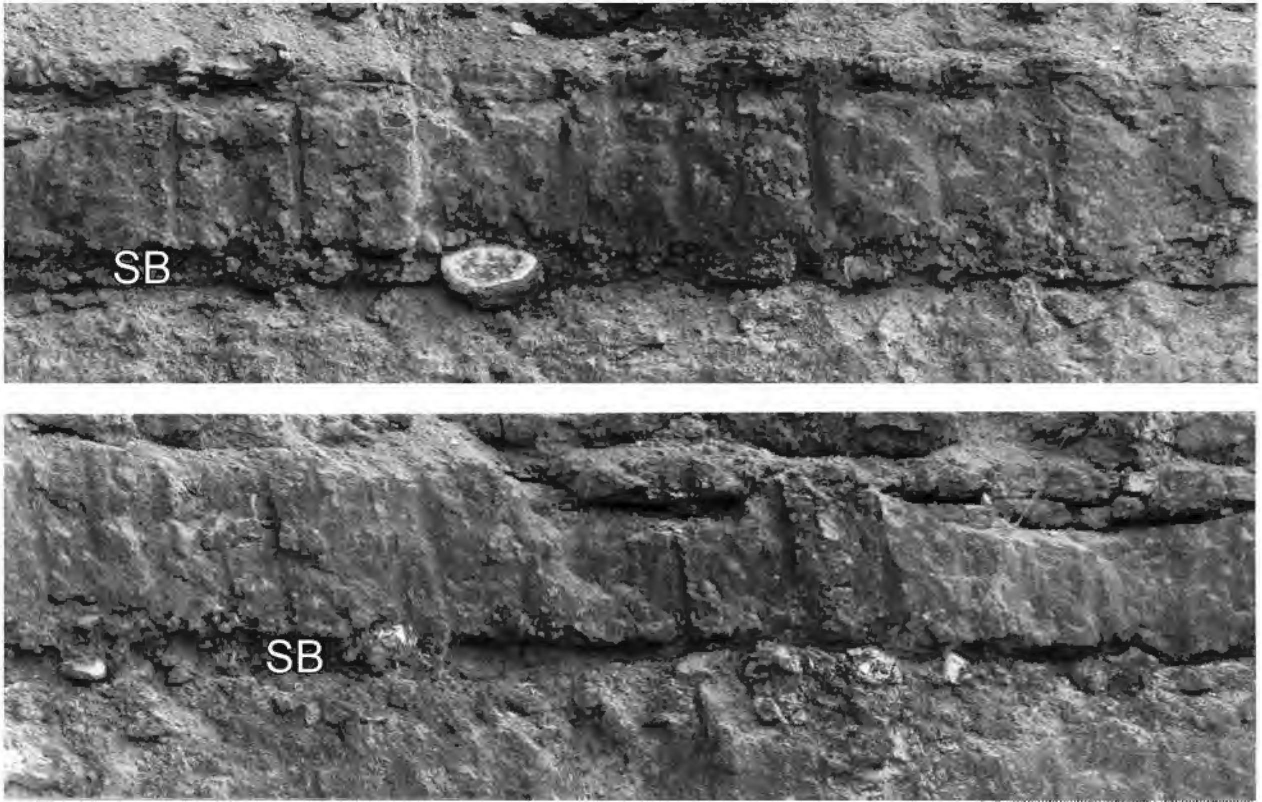


Fig. 56: Stop 11. Details from fig. 55 featuring major storm (?) bed (SB) with broken and overturned massive corals. Station 11D.

Fig. 57: Stop 11. Reef framework formed by large lamellar , unifacial colonies of *Actinaraea*. Station 11E.

Fig. [illegible]: Stop 11. Very large massive coral head formed by several different coral genera as well as by *Solenopora*. Branching corals include *De[illegible]araea, Calamophylliopsis* and *Stylosmilia* (the latter immediately above coral head). Station 11E. Photograph by Urs Klahr.

Fig. 59: Stop 11. External growth banding in a colony of *Thamnasteria dendroidea* from the Haudainville reefs. Regular annual (?) thickening of branches indicates the growth rate. Middle Oxfordian.

Fig. 60: Stop 11. *Thamnasteria dendroidea* thicket terminating at an overlying brown marker horizon . An *Aplosmilia* on top of *Thamnasteria* has a clearly truncated top overlain by another brown marker bed and by biodetritical sediments. Station 11E. Photograph by Urs Klahr.

Fig. 61: Stop 11. Interlocking framework of dense coral thickets dominated by *Thamnasteria dendroidea*. Station 11F. Hammer 32 cm.

Fig. 62: Stop 11. Panoramic view of highway cut NW of highway bridge. Stations 11G and 11H are marked G and H.

Fig. 63: Stop 11. *Thamnasteria dendroidea* growing on top of colony of *Dendraraea racemosa* separated from it by a brown marker horizon (M). Station 11G. Hammer 32 cm.

Station 11G : Cut of highway NW of highway bridge (figs. 62, 63)

Reef framework within coral build-up. The thicket of branching *Thamnasteria dendroidea*, 3 m broad and 1 m high shows growth rings indicating a yearly growth rate of about 14 mm. The *Thamnasteria* grew above a colony of *Dendraraea racemosa* (fig. 63) and is separated from it by a brown marker bed which may be followed laterally into the biodetrital reef sediments.

As indicated by this and additional marker beds the growth rate of the build-ups corresponds roughly to the growth rate of branching corals, i.e. 10 to 14 mm / year. This means that a coral build-up of 6 m height needed a maximum of 600 years for its formation. Five succeeding brown marker beds in inter-reefal sediments are distant 0.1 to 1 m suggesting that the related events which disturbed the reefs occurred in time lapses of the order of 10 to 100 years.

Note the lateral transition of the round *Thamnasteria* branches into an extremely platy growth form, especially at their periphery. In the literature, the branching part of this coral is commonly cited as *Thamnasteria dendroidea* (LAMOUROUX) and the platy part as *Thamnasteria* or *Stereocoenia concinna* (GOLDFUSS). The presence of 2 strongly diverging growth habits within a single coral colony is comparable to those observed in Recent colonies of *Synaraea convexa* , as described by JAUBERT (1977).

Further scleractinians observed: *Calamophylliopsis, Isastrea, Comoseris*

Other fossils: perisphinctid ammonite, echinoid spines, calcareous sponge(?)

Station 11H: Highway cut NW of highway bridge, 40 m W of Station 11G (figs.62, 64)

Reef framework within build-up. Dense thicket of *Thamnasteria dendroidea* (fig. 64) at the base of outcrop showing 3 brown marker horizons within 1.5 m of vertical distance. The thicket is overlain by 3-4 m of coral-bearing sediments within the bioherm. The upper wall of outcrop shows 2 to 3 m of dense thickets of *Thamnasteria dendroidea* and other branching corals with some platy and massive colonies.

Other scleractinians seen:
Calamophylliopsis, Aplosmilia, Isastrea, Actinaraea, Fungiastraea??, microsolenids

Further fossils:
terebratulid and rhynchonellid brachiopods, *Chlamys* and other pelecypods, nerineans and other gastropods, *Paracidaris florigemma* and other echinoid spines, serpulids, *Solenopora*.

Fig. 64: Stop 11. Thicket of *Thamnasteria dendroidea* overlain by coral-bearing sediments. Brown marker horizon (M). Station 11H.

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The Rhône-Poulenc Company provided access to their quarry ("Carrière du Revoi") at Pagny which is normally closed for visitors. Monsieur B. Aubertin of the Société des Autoroutes du Nord kindly allowed us to visit the outcrops of the highway interchange at Haudainville. The Institut Géographique National gave permission to reproduce their topographic maps 1:50,000 or 1:25,000 for our description of the outcrops. We are especially grateful to Mr. Guillaume Hoffmann, mayor of the town of Rumelange (Luxembourg) for putting an excavator at our disposal to clear one important outcrop in the "Carrière Blanche" from quarry debris and vegetation. Finally, we would like to thank Michel Guiraud (Nancy) and Steve Burns (Bern) for their helpful reviews of the English text and to Andy Werthemann (Bern) for most of the photographic work.

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References

BEAUVAIS, L. (1964): Etude stratigraphique et paléontologique des formations à madréporaires du Jurassique supérieur du Jura et de l'Est du Bassin de Paris. - Mém. Soc. géol. France (N.S.)*43*, Mém. *100*, 1-287.

BEAUVAIS, L. (1985): Les madréporaires jurassiques indicateurs de paléoenvironnements: quelques exemples. - Palaeogeogr. Palaeoclimatol. Palaeoecol. *49*, 207-215.

BEAUVAIS, L., HAGUENAUER, B. & HILLY, J. (1980): Etude d'une formation récifale rythmique dans le Jurassique supérieur de la région de Verdun (Meuse).- 8e Réunion ann. Sci. de la Terre (Marseille 1980), p.30, Soc. géol.France.

CONTINI, D. (1970): L'Aalénien et le Bajocien du Jura franc-comtois. Etude stratigraphique. - Ann. scient. Besançon 3, Géologie, fasc. *11*, 204 p.

DEBRAND-PASSARD, S. (1980): Oxfordien moyen. -*In:* MEGNIEN,C. et al.: Synthèse géologique du bassin de Paris. - Mém. BRGM *102*, pl.JS3.

DECHASEAUX, C. (1931): L'Oxfordien supérieur de la bordure Est du Bassin de Paris. - Bull. Soc. géol. France, Sér.5,*1*, 353-389.

DURAND, M., HANZO, M., LATHUILIERE, B., LE ROUX, J. & MANGOLD, Ch. (1989): DUGW Stratigraphische Kommission- Subkommission für Jura-Stratigraphie. Excursion en Lorraine. Nancy 3-5 Mai 1989.- 60 p.- Université de Nancy I, Laboratoire de Géologie des Ensembles sédimentaires.

ENAY, R. & BOULLIER, A. (1981): L'âge du complexe récifal des côtes de Meuse entre Verdun et Commercy et la stratigraphie de l'Oxfordien dans l'Est du Bassin de Paris. - Géobios *14*, 727-771.

GAILLARD, C. (1983): Les biohermes à spongiaires et leur environnement dans l'Oxfordien du Jura méridional. - Doc. Lab. géol. Lyon *90*, 514 p.

GARDET, G. (1929): Le Bajocien supérieur et le Bathonien de Villey St. Etienne (Meurthe et Moselle). - Bull. Soc. géol. France, Sér.4, *29*, 153-166.

GARDET, G. (1943): Faciès à polypiers du Bajocien supérieur (Dubisien) à l'Est de Toul (Meurthe et Moselle). - Bull. Soc. géol. France, Sér.5, *13*, 193-206.

GEISTER, J. (1977): The influence of wave exposure on the ecological zonation of Caribbean coral reefs. - Proc. 3rd int. Coral Reef Symp. (Miami 1977) *1*(Biology), 23-29.

GEISTER, J. (1980): Calm-water reefs and rough-water reefs of the Caribbean Pleistocene. - Acta palaeont. polon. *25*/3-4, 541-556.

GEISTER, J. (1982): Pleistocene reef terraces and coral environments at Sto. Domingo and near Boca Chica, southern coast of the Dominican Republic. - Trans. 9th caribb. geol. Conf. (Sto. Domingo 1980) *2*, 689-703.

GEISTER, J. 1983): Holozäne westindische Korallenriffe: Geomorphologie, Ökologie und Fazies. - Facies *9*, 173-284.

GEISTER, J. (1984a): Récifs à coraux du Bajocien du Grand-Duché de Luxembourg et de Malancourt en Lorraine. -*In*: Géologie et paléoécologie des récifs, GEISTER, J. & HERB, R. (eds.), pp.12.1-12.16, Institut de Géologie de l'Université de Berne.

GEISTER, J. (1984b): Bajocian coral reefs of the northeastern Paris Basin: paleoecological aspects. - Ann. Meeting int. Soc. Reef Studies, (Miami, Florida), abstract, 36-37.

GEISTER, J. (1986a): Taux de croissance et production de carbonates d'un récif corallien bajocien (Rumelange, Grand-Duché de Luxembourg). - Fossil Cnidaria *15*/2, 13-14.

GEISTER, J. (1986b): Reef formation during eustatic cycles - Bajocian and Quaternary reefs compared. - Ann. Meeting int. Soc. Reef Studies (Marburg, Lahn), abstract, 18-20.

GEISTER, J. (1989): Quantitative aspects of coral growth and carbonate production in a Middle Jurassic reef. - Mem. Ass. australas. Palaeontol. *8*, 425-432.

GILL, G. & COATES, A.G. (1977): Mobility, growth patterns and substrates in some fossil and Recent corals. - Lethaia *10*, 119-134.

GYGI, R. (1986): Eustatic sealevel changes of the Oxfordian (late Jurassic) and their effect documented in sediments and fossil assemblages of an epicontinental sea. - Eclogae geol. Helvet. 79/2, 455-491.

HALLAM, A. (1963): Eustatic control of major cyclic changes in Jurassic sedimentation. - Geol. Mag. *100*/5, 444-450.

HALLAM, A. (1975): Coral patch reefs in the Bajocian (Middle Jurassic) of Lorraine. - Geol. Mag. *112*/4, 383-392.

HALLAM, A. (1988): A reevaluation of Jurassic eustasy in the light of new data and the revised Exxon curve. - Spec. Publ. Soc. econ. Paleont. Miner. *42*, 261-274.

HANZO, M., LE ROUX, J. et al. (1982): Excursion en Lorraine. Groupe français d'étude du Jurassique. 22-28 Sept. 1982.- Livret-guide, Univ. Nancy I (unpubl.), 23+43 p.

HARY, A. (1970): Récifs de coraux du Bajocien moyen aux environs de Rumelange (Grand-Duché de Luxembourg). - Arch. Inst. grand-ducal Luxembourg, Sect. Sci. nat. phys. math. *34*(N.S. 1968-1969), 431-455.

HILLY, J. & HAGUENAUER, B. (1979): Lorraine - Champagne.- 216 p., Guides Géologiques Régionaux (ed. Ch. POMEROL), Masson, Paris.

HUMBERT, L. (1971): Recherche méthodologique pour la restitution de l'histoire bio-sédimentaire d'un bassin. L'ensemble carbonaté Oxfordien de la partie orientale du Bassin de Paris. - Thèse d'Etat Univ. Nancy, no.AO 5096, 364 p.

HUMBERT, L. (1976): Eléments de pétrologie dynamique des systèmes calcaires. - Technip ed., 213 p. and atlas.

JAUBERT, J. (1977): Light metabolism and growth forms of the hermatypic scleractinian coral *Synaraea convexa* Verrill in the lagoon of Moorea (French Polynesia). - Proc. 3rd int. Coral Reef Symp. (Miami 1977), *1*(Biology), 483-488.

KLÜPFEL, W. (1919): Über den Lothringer Jura. - Jb. k. preuss. geol. Landesanst. *38*, Teil 1, Heft 2(for 1917), 252-346.

LATHUILIERE, B. (1981): Paléoécologie des calcaires à polypiers et faciès associés du Bajocien dans le Jura du Sud. - Thèse Université Claude Bernard Lyon I., 199 p.

LATHUILIERE, B. (1982): Bioconstructions bajociennes à madréporaires et faciès associés dans l'Ile Crémieu (Jura du Sud, France). - Géobios *15*, 491-504.

LATHUILIERE, B. (1984): La plasticité du genre *Kobyastraea* (Hexacorallia): un bon marqueur paléoécologique. - Géobios *17*, 371-375.

LATHUILIERE, B. (1988): Analyse de populations d'Isastrées bajociennes (scléractiniaires jurassiques de France). Conséquences taxonomiques, stratigraphiques et paléoécologiques. - Géobios *21*, 269-305.

LATHUILIERE, B. (1989): *Isastrea*, polypier branchu! - C.R. Acad. Sci. (Paris) *308*, Sér.II, 889-892.

LATHUILIERE, B.(1990): *Periseris*, scléractiniaire colonial jurassique. Révision structurale et taxinomie de populations bajociennes de l'Est du Bassin de Paris. - Géobios *23*, 33-35.

LEDIT, D. (1985): Etude sédimentologique de l'Oolithe miliaire supérieure (Bajocien terminal) de Pierre-la-Treiche (Meurthe-et-Moselle): structures sédimentaires d'origine tidale et fracturation synsédimentaire. - Rapport stage DEA, Université Nancy I, 77 p. (unpubl.)

LEJEUNE, M.J. (1935): Les *Montlivaultia*. Contribution à l'étude biologique des hexacoralliaires fossiles. - Ann. Paléont. *24*, 99-135.

LUCIUS, M. (1945): Beiträge zur Geologie von Luxemburg. Die Luxemburger Minetteformation und die jüngeren Eisenerzbildungen unseres Landes. - Publ. Serv. Carte géol. Luxembourg IV, 1-347.

MANGOLD, C., POIROT, E., LATHUILIERE, B. & LE ROUX, J. (1991): Biochronologie du Bajocien supérieur et du Bathonien de Lorraine. - Third int. Symp. Jurassic Stratigraphy, Poitiers (France), Sept. 22-29, 1991 (in print.)

MARCHAND, D. & MENOT, J.C. (1980): Oxfordien - Ardenne et Lorraine. -*In*: MEGNIEN, C. et al.: Synthèse géologique du bassin de Paris. - Mém. BRGM *101*, 204-206.

MAUBEUGE, P. L. (1953a): Sur la présence de surfaces taraudées d'un type spécial dans le Jurassique de l'Est du Bassin de Paris. - C.R. Acad. Sci. (Paris) *236*, 1686-1688.

MAUBEUGE, P. L. (1953b): Les limites du Séquanien en Lorraine centrale. -C.R. Acad. Sci. (Paris) *236*, 1908-1910.

MAUBEUGE, P. L. (1955): Le Kimméridgien dans l'Est du Bassin de Paris. -C.R. Acad. Sci. (Paris) *240*, 545-547.

MAUBEUGE, P. L. (1968a): Le contact de l'Oxfordien (Ex Séquanien) et du Kimméridgien dans le département de la Meuse. - Bull. Acad. & Soc. lorraines Sci. (Nancy) *7*/1, 3-4.

MAUBEUGE, P. L. (1968b): Sur le contact de l'Oxfordien (ex Séquanien) et du Kimméridgien dans le département de la Meuse. - Bull. Acad. & Soc. lorraines Sci. (Nancy) *7*/3, 210-217.

MAUBEUGE, P. L. (1972): La carrière de Malancourt (Moselle): une contribution à la sédimentation récifale et à la stratigraphie du Bajocien moyen lorrain. - Bull. Acad. & Soc. lorraines Sci. (Nancy) *11*, 1-21.

MENOT, J. C. (1980): Lorraine (Formations récifales de).-*In*:MEGNIEN, C. et al.: Synthèse géologique du bassin de Paris. - Lexique des noms de Formation.- Mém. BRGM *103*, 217-218.

MEYER, G. (1888): Die Korallen des Doggers von Elsass-Lothringen. - Abh. geol. Spez.-Karte Els.-Lothr. *4*/5, 1-44.

MICHELIN, H. (1840-1847): Iconographie zoophytologique. Descriptions par localités et terrains des polypiers fossiles de France et pays environnants. - P. Bertrand Editeur, Paris. 348 p. + atlas 79 pls.

PERES,J.-M. & PICARD,J. (1964): Nouveau manuel de bionomie benthique de la Méditerranée. - Recl. Trav. Stn. marine Endoume, Bull. *31*/47, 1-137.

POIROT, E. (1986): Description géologique de quelques gisements paléontologiques en Lorraine centrale, région de Toul. - Minéraux & Fossiles *126*, 24-34.

POIROT, E. (1987): Le Terrain à Chailles (Oxfordien inf. et moyen) du Toulois (Lorraine). - Mémoire D.E.S. Université Nancy I, 120p.

PÜMPIN, V.F. (1965): Riffsedimentologische Untersuchungen im Rauracien von St. Ursanne (Zentraler Schweizer Jura). - Eclogae geol. Helvet. *58*/2, 799-876.

PURSER, B.H. (1969): Syn-sedimentary marine lithification of Middle Jurassic limestones in the Paris Basin. - Sedimentology *12*, 205-230.

RONIEWICZ, E. & RONIEWICZ, P. (1971): Upper Jurassic coral assemblages of the Central Polish Uplands. - Acta geol. polon. *8*/3, 399-422.

STAMM, R. (1976): Petrographisch-fazielle Untersuchungen in den Other Schichten (mittleres Bajocien) Süd-Luxemburgs. - Diplomarbeit, Geologisches Institut, Universität Bonn, 80 p.

TERQUEM, O. & PIETTE, E. (1865): Le Lias inférieur de l'Est de la France. - Mém. Soc. géol. France, 2ème Sér., *8*/1, 175 p.

VADET (1987): Les échinides fossiles de Foug. - Minéraux & Fossiles *147*, 27-35.

VAIL, P.R., COLIN, J.P., DU CHENE, R.J., KUCHLY, J., MEDIAVILLA, F. & TRIFILIEFF, V. (1987): La stratigraphie séquentielle et son application aux corrélations chronostratigraphiques dans le Jurassique du bassin de Paris. - Bull. Soc. géol. France *III*/7, 1301-1321.

WATERLOT, G., BEUGNIES, A., BONTE, A., CHARLET, J.-M., CORSIN, P., BINTZ, J., HARY, A. & MULLER, A. (1973): Ardenne - Luxembourg. - 206 p., Guides Géologiques Régionaux (ed. Ch. POMEROL), Masson, Paris.

ZLATARSKI, V. N. & MARTINEZ ESTALELLA, N. (1980): Skleraktinii Kuby s dannymi o soputstvuyushchikh organizmach. - 312 p., Izdatel'stvo Bolgarskoj Akademii Nauk, Sofija.

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Appendix :

TENTATIVE KEY TO DETERMINE

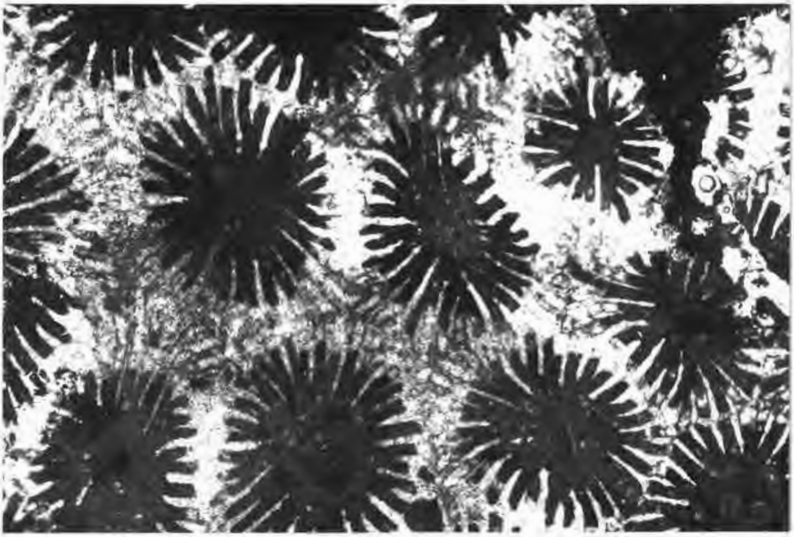
MAIN CORAL GENERA

IN THE FIELD

TENTATIVE KEY TO DETERMINE MAIN CORAL GENERA IN THE FIELD.

- Bajocian
  - massive form
    - cerioïd. average distance between corallite centres:
      - 7-8 mm.......................... *Isastrea* pl.1
      - nearly 20 mm.................... *Complexastrea*
    - thamnasterioïd. average septal density =
      - 12 septa /3mm.................................. *Kobyastraea* pl.2
      - 6,5 septa /3mm, clearly pennular.................. *Periseris* pl.3
  - branching form
    - phaceloïd. average diameter of corallites=
      - 3 mm .... *Stylosmilia* pl.4
      - 16 mm.. *Thecosmilia* pl.5
    - dendroïd perforated and pennular...................... *Dendraraea* pl.6
- Oxfordian
  - branching form
    - phaceloid diameter of corallites=
      - 3-4 mm styliform columella and auriculae.......... *Stylosmilia* pl.4
      - 5-6 mm, many thin septa .... *Calamophylliopsis* pl.7
      - >8 mm
        - -often elliptic, some very thick septa corresponding to thick costae visible in young parts. Strong contrast in thickness of major and minor septa .... *Aplosmilia* pl.8
        - -other characters (Oxfordian species are less circular than Bajocian ones)............... *Thecosmilia* pl.5
    - dendroïd
      - thamnasterioïd. septa :
        - compact and thin .... *Thamnasteria* pl.9
        - perforated, thick and pennular................ *Dendraraea* pl.6
      - plocoïd without columella........................ *Pseudocoenia* pl.10
  - massive form (lamellar, foliaceous or dome shaped). septa :
    - compact or subcompact
      - plocoïd
        - columella, auriculae and costulated peritheca........ *Stylina*
        - without columella, well developped septae .... *Pseudocoenia* pl.10
      - cerioïd. distance between corallite centres:
        - < 4mm, a styliform thick columella................ *Allocoenia*
        - > 5mm .... *Isastrea* pl.1
      - thamnasterioïd. average distance between corallites:
        - < 3mm, styliform columella, no series...... *Thamnasteria* pl.9
        - > 3mm, + spongious columella, series...... *Fungiastraea* pl.11
    - regularly perforated
      - clearly regular alternating pennular pattern, thamnasterioïd,
        - concentric series of corallites........... *Dimorpharaea* pl.12
        - no concentric series........................ *Microsolena* pl.13
      - irregular alternating pennular pattern, altered by tabuloïd dissepiments. Meandroïd.
        - -rather straight and tectiform collines, rather lamellar colony....................... *Meandraraea* pl.14
        - -rather sinuous and tholiform collines, rather dome-shaped colony......................... *Comoseris*
      - pennulae absent, regular tabuloïd dissepiments........................... *Actinaraea* pl.15

Isastrea - PLATE 1



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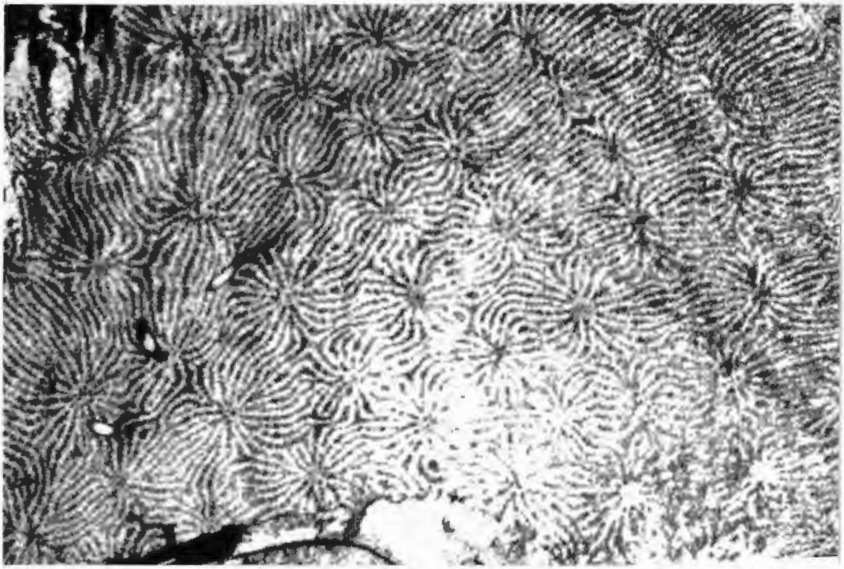
long.sect. 5mm

Kobyastraea - PLATE 2



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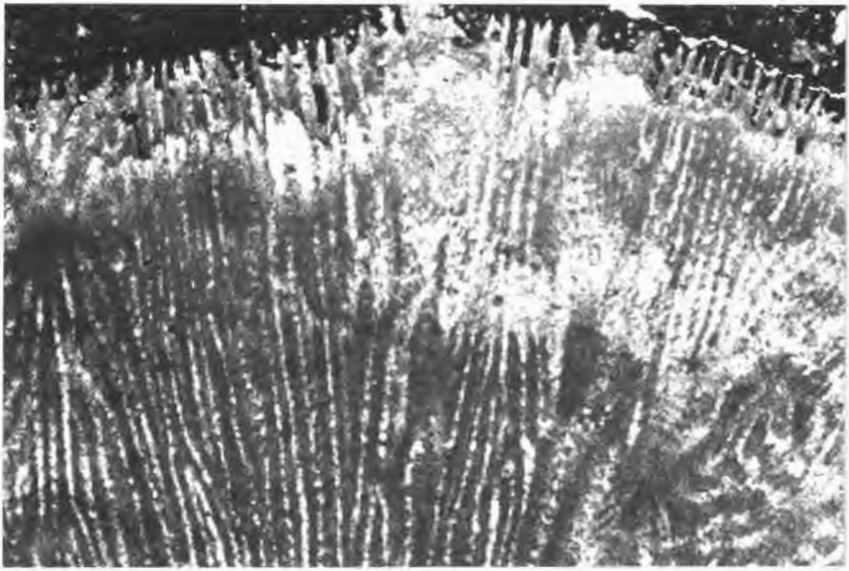

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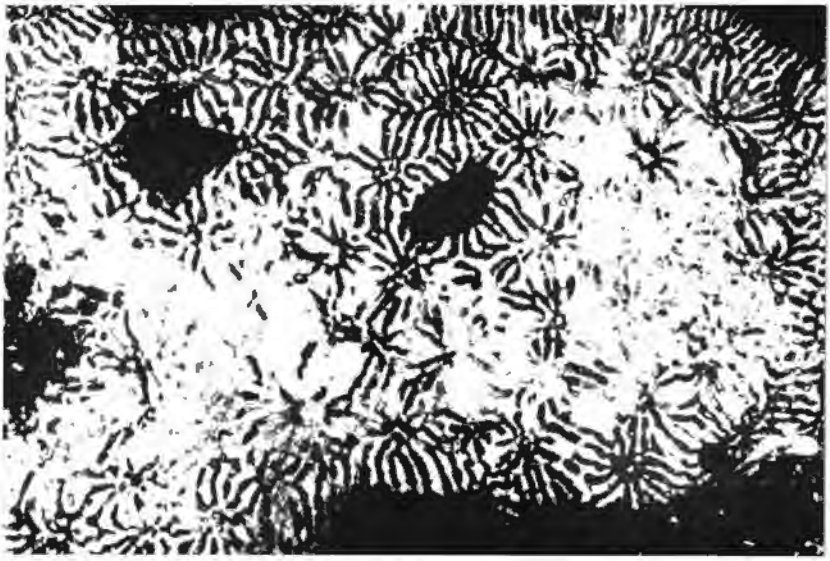
Periseris - PLATE 3



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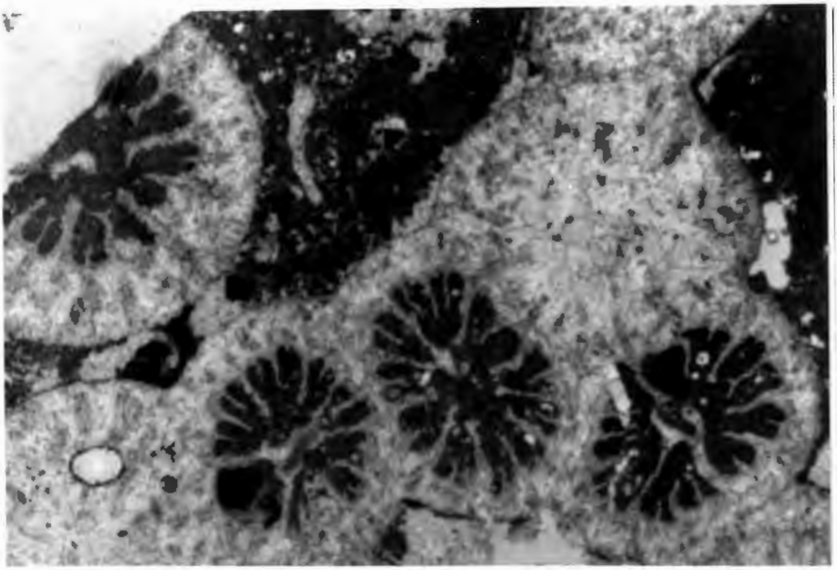
Stylosmilia - PLATE 4



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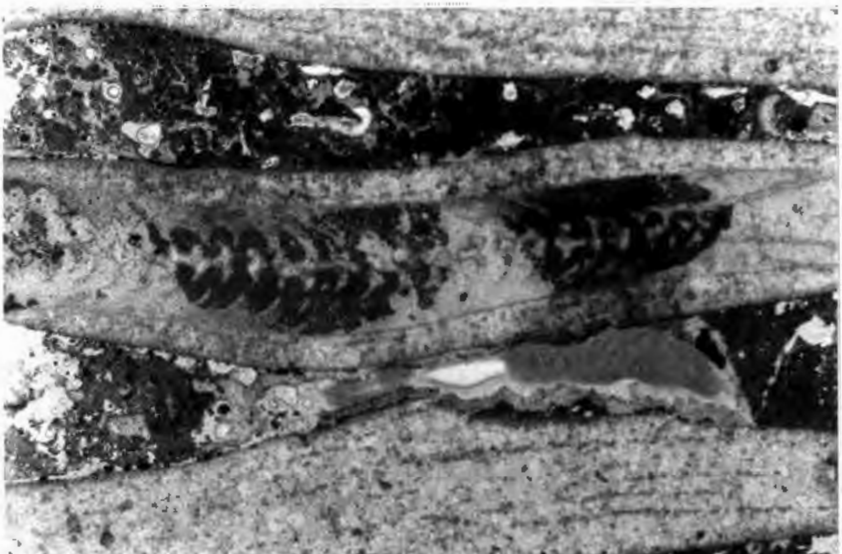

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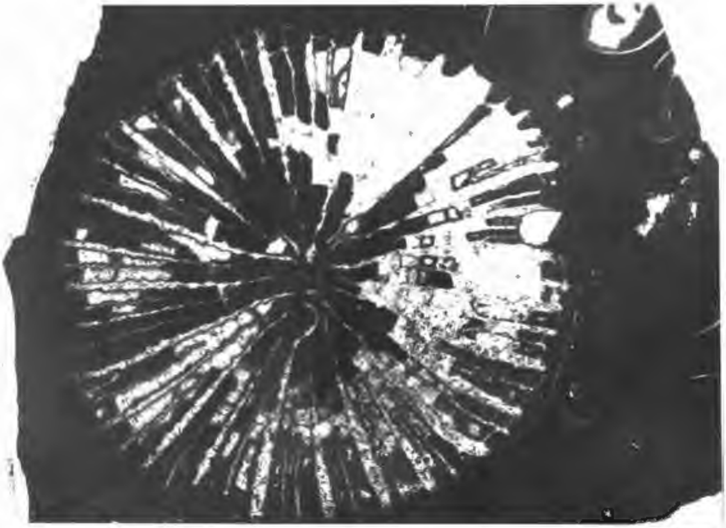
Thecosmilia - PLATE 5



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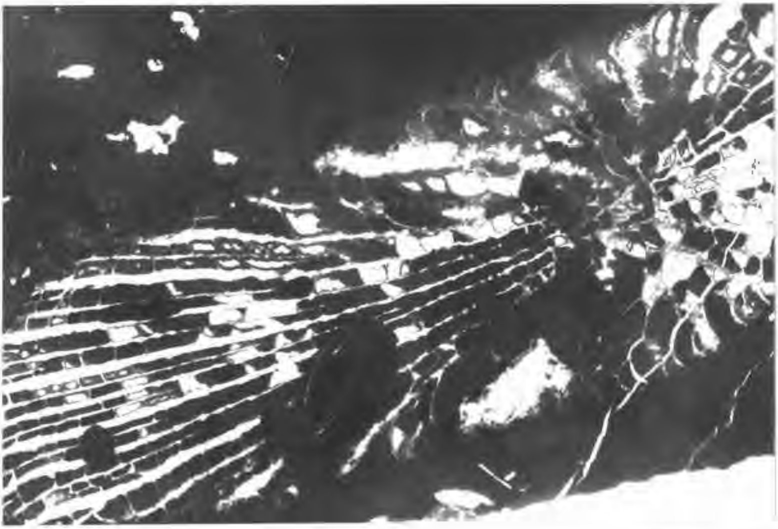
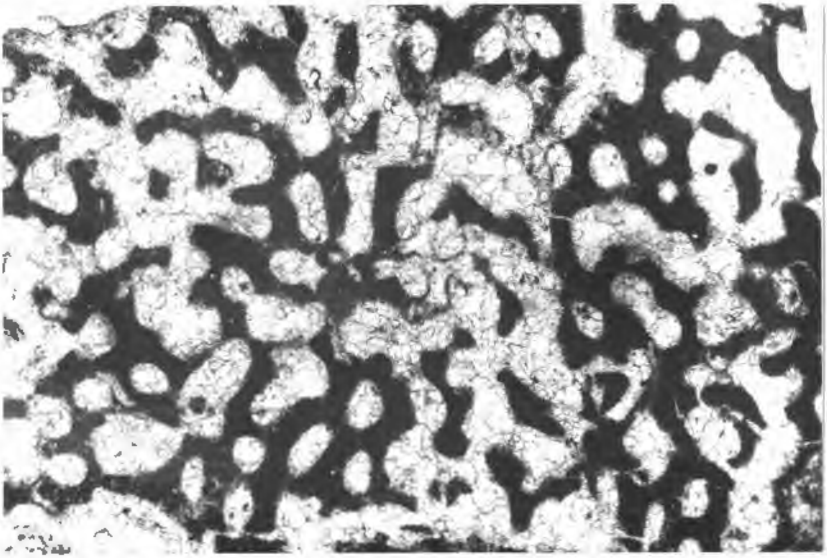


long. sect. 5mm

Dendraraea - PLATE 6



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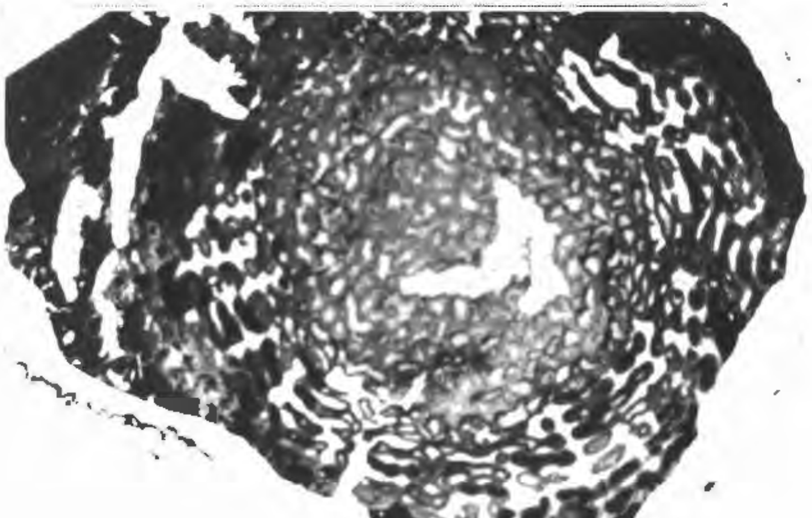

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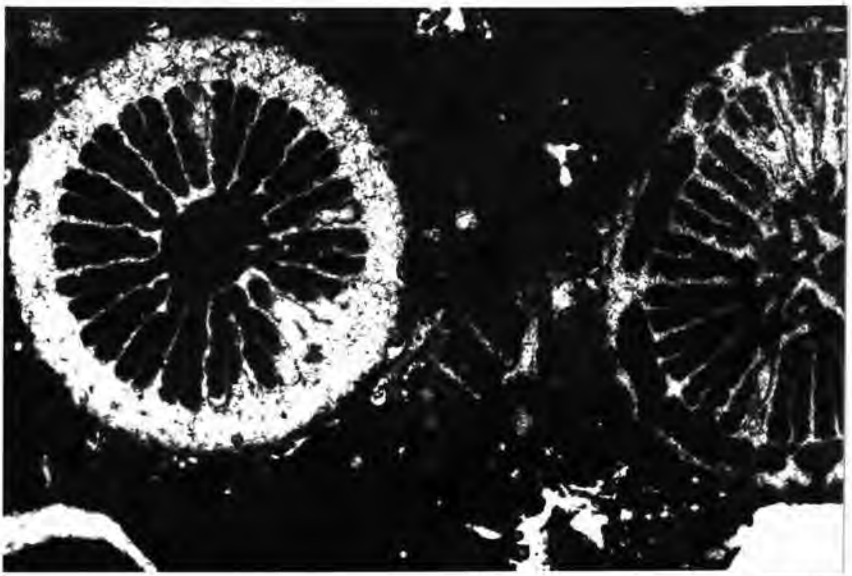
Calamophylliopsis - PLATE 7



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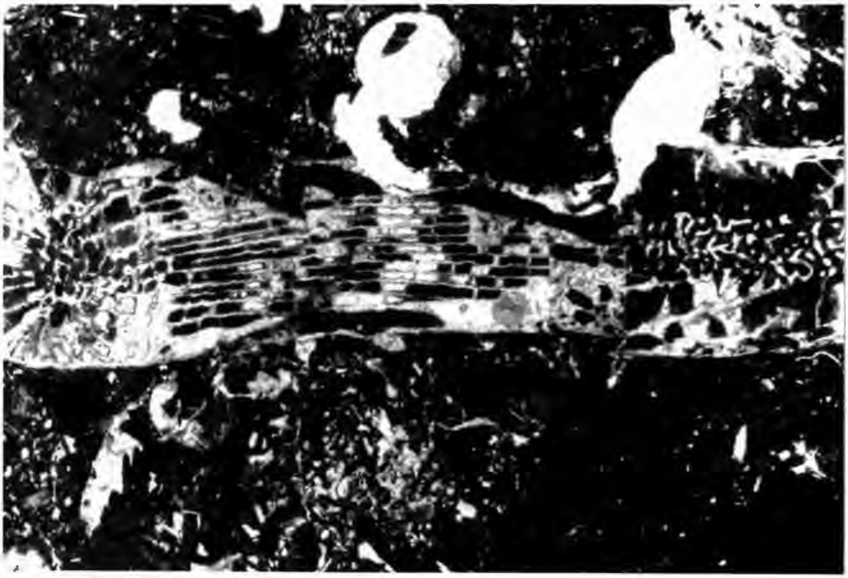

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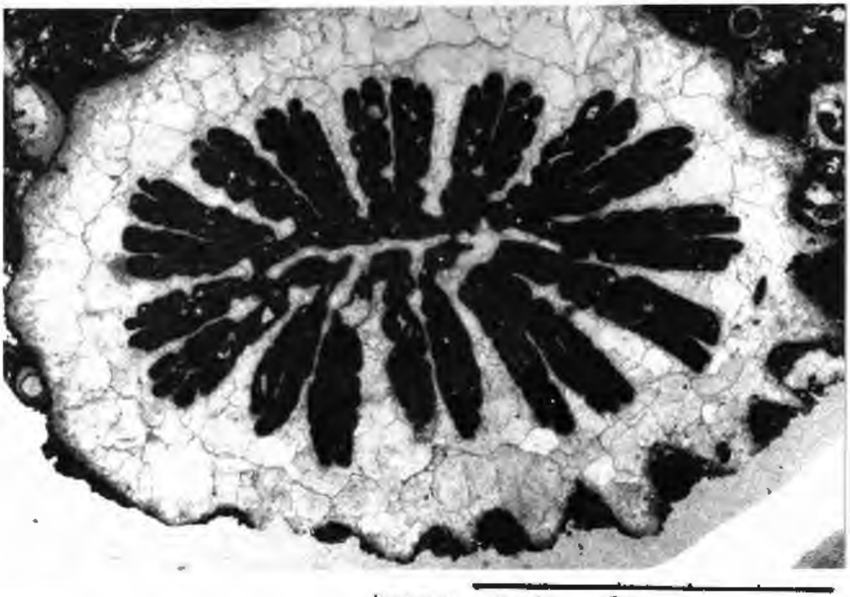
Aplosmilia - PLATE 8



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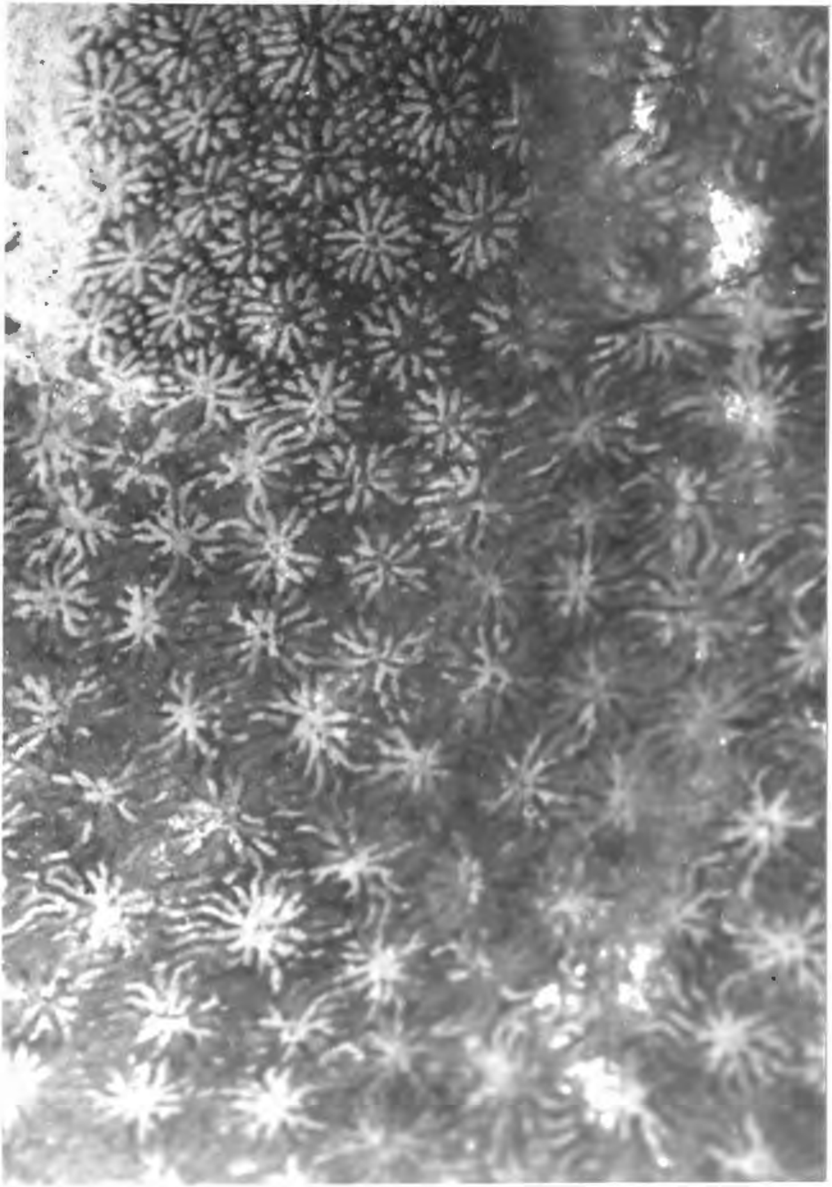
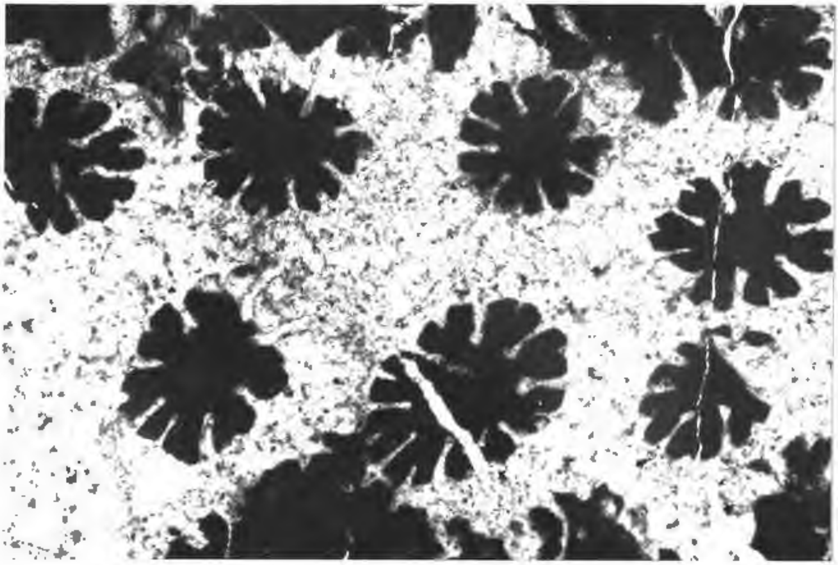
long. sect. 5mm

Thamnasteria - PLATE 9



calical view, skeleton in dark 1mm

Pseudocoenia - PLATE 10



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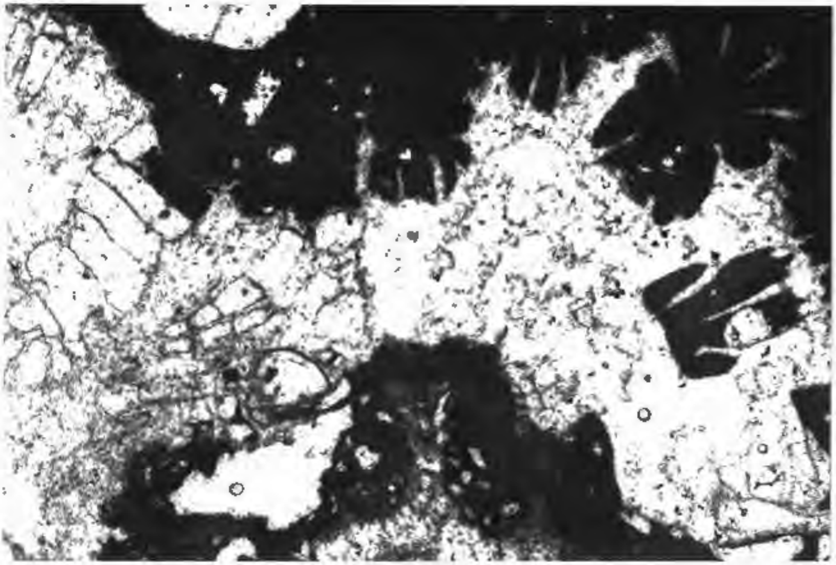

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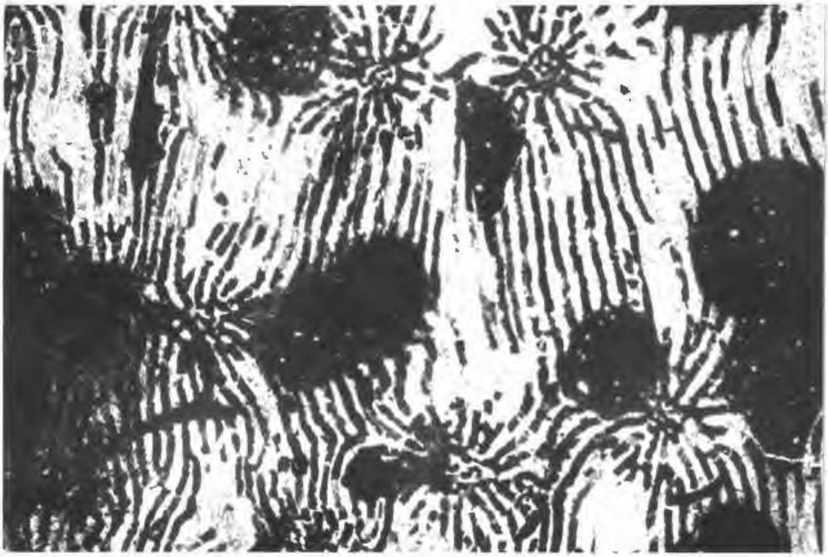
Fungiastraea - PLATE 11



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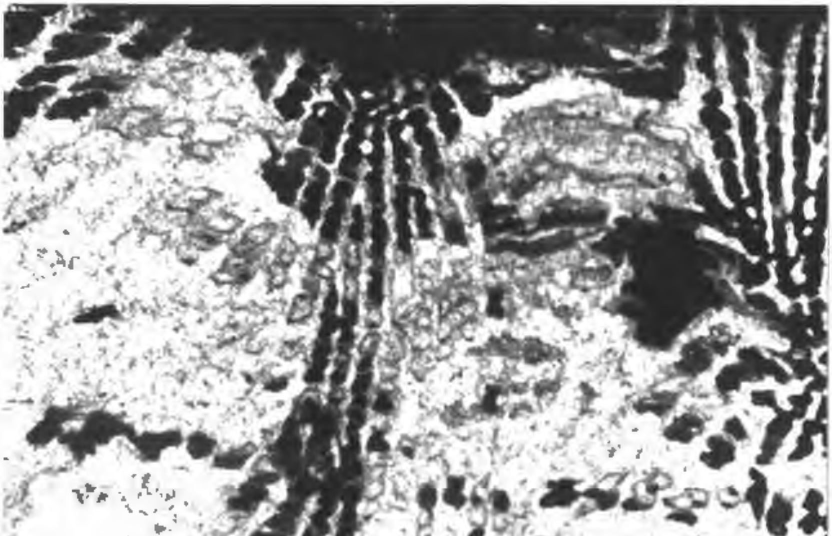

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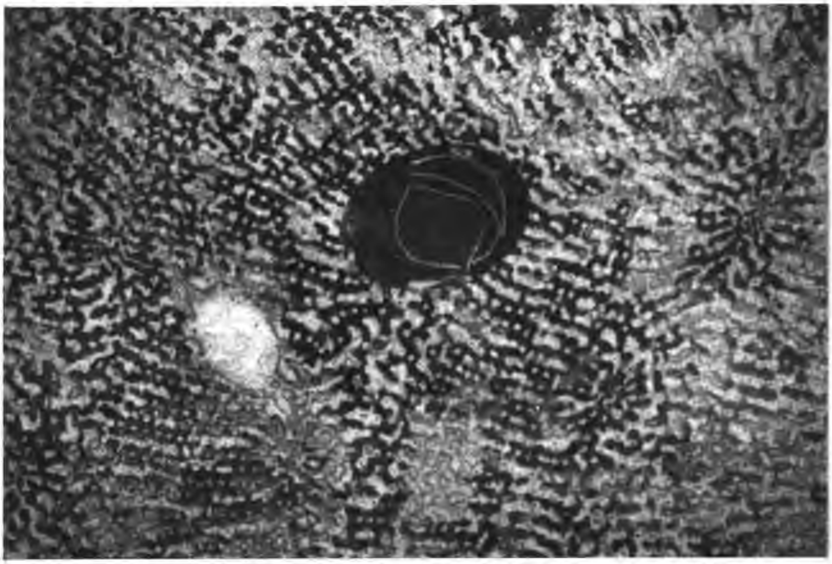
Dimorpharaea - PLATE 12



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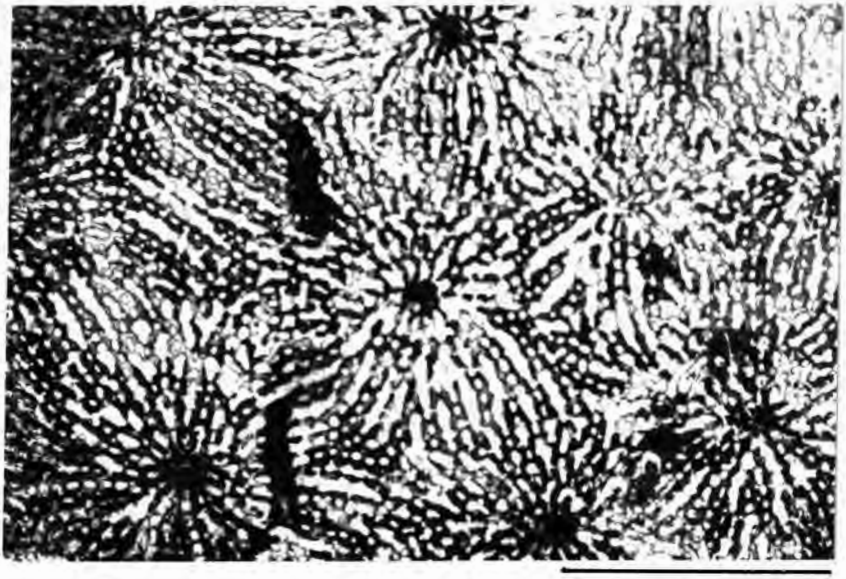
long. sect. 5mm

Microsolena - PLATE 13



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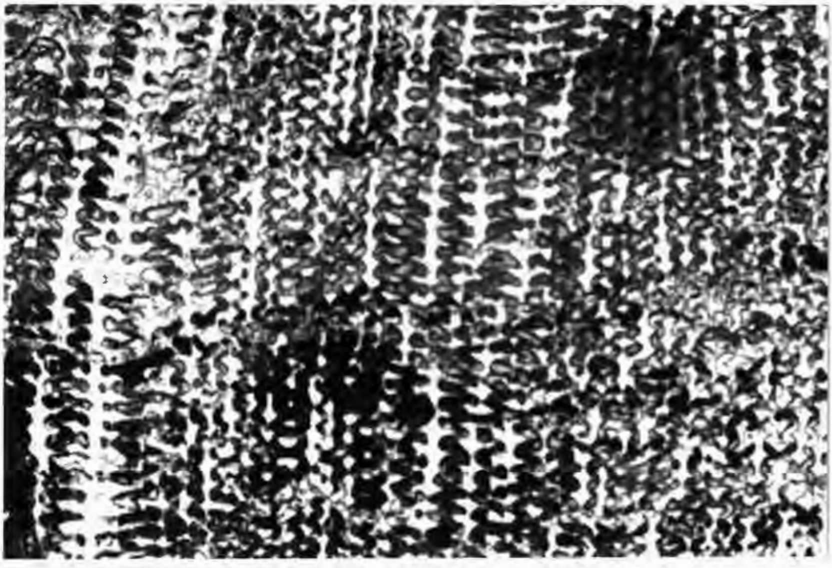

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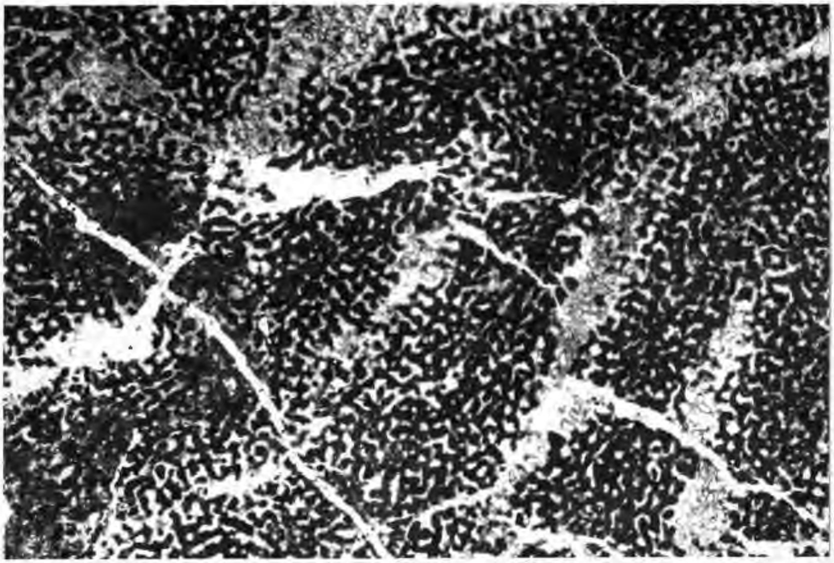
Meandraraea - PLATE 14



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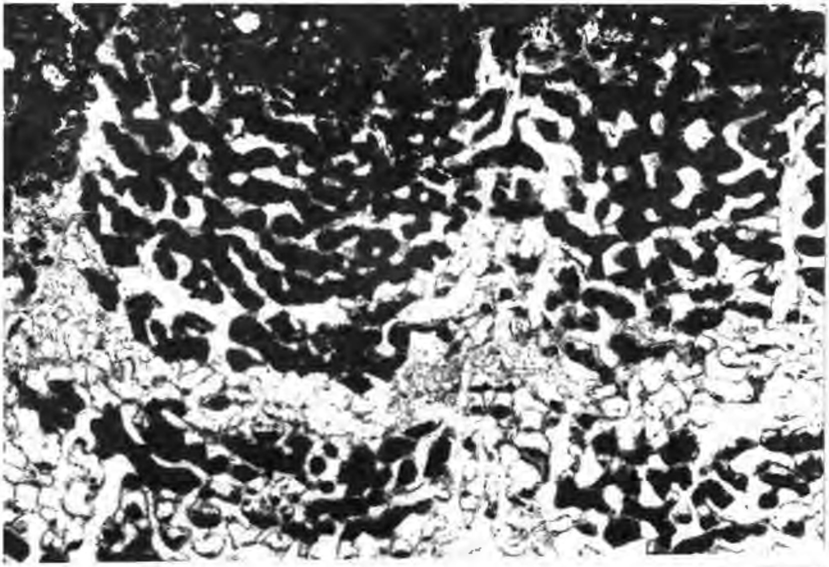
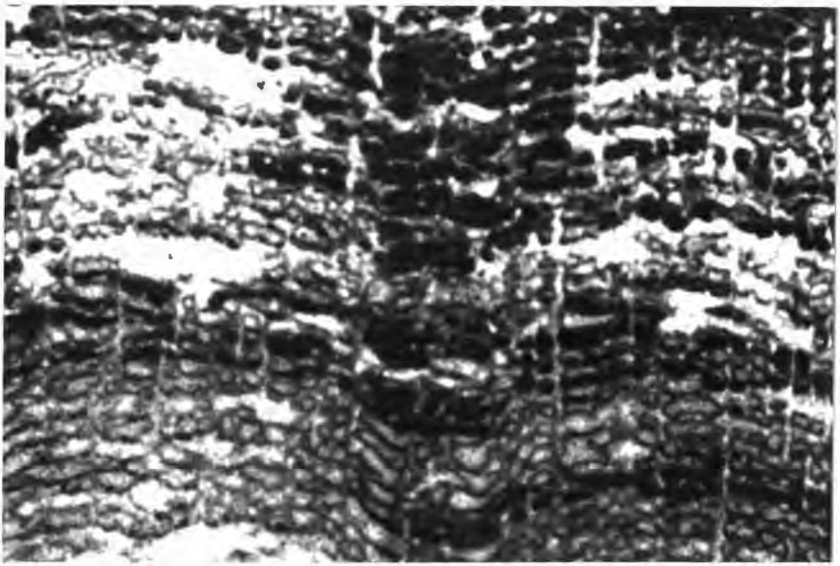


long. sect. 1mm

Actinaraea - PLATE 15

transv. sect. 5mm



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