Zeitschrift: Eclogae Geologicae Helvetiae
Herausgeber: Schweizerische Geologische Gesellschaft
Band: 71 (1978)
Heft: 1

Artikel: Aptian to Maastrichtian in the Swiss Jura Mountains
Autor: Renz, Otto / Jung, Peter
DOI: https://doi.org/10.5169/seals-164714

Eclogae geol. Helv.	Vol. 71/1	Pages 1-18	2 figures in the text and 2 plates	Basle, March 1978

Aptian to Maastrichtian in the Swiss Jura Mountains[1])

By Otto Renz and Peter Jung[2])

ABSTRACT

Our present knowledge on Mid-Cretaceous events in the Jura Mountains of Switzerland is reviewed and the sedimentation history of the Aptian to the Maastrichtian is described. Some paleogeographical conclusions are discussed.

ZUSAMMENFASSUNG

Der heutige Stand der Kenntnisse über die mittelkretazische Stratigraphie des schweizerischen Jura wird dargelegt, und die Sedimentationsgeschichte vom Aptien bis Maastrichtien wird beschrieben. Einige paläogeographische Schlüsse werden gezogen.

CONTENTS

1. Introduction

Towards the end of the Jurassic Epoch the sea retreated from the region covered today by the Swiss Jura Mountains and paralic to lagoonal conditions, characterized by the presence of *Chara*, prevailed during deposition of the Goldberg Formation of Purbeckian age (Häfeli 1966, p. 590). With the beginning of the Cretaceous Epoch the sea again invaded the region under review, apparently from the south-west, and an extended carbonate platform developed during Berriasian-Valanginian times. During the Lower Hauterivian an influx of fine-grained terrigenous material

[1]) This paper is a contribution to "Mid-Cretaceous Events".

[2]) Museum of Natural History, Augustinergasse 2, CH-4051 Basel.

occurred, and partly grey, glauconitic calcilutites, rich in ammonites, were deposited. This interval, marked by conspicuous morphological depressions, is followed with a sharp contact by a sheet of cross-bedded, yellow-brown oolite composed of medium-grained ooids cemented by clear calcite. Its age is assumed to be Upper Hauterivian and they are referred to as "Pierre jaune de Neuchâtel".

This formation is concordantly overlain by a massively bedded, cliff-forming body of limestone, consisting partly of micritic skeletal limestone with molluscan debris and benthonic Foraminifera, and partly of interbedded thick sheets of oolite. It is known under the facies term "Urgonien" introduced by D'ORBIGNY (1847, p. 269), and assumed to be of Barremian age. During Aptian-Albian times sediments of predominantly terrigenous origin, mostly characterized by the presence of detrital quartz, were deposited.

With the beginning of the Upper Cretaceous, depositional conditions changed fundamentally. The Tethyan Ocean submerged great parts of the territory of Switzerland as far north as the Jura Mountains. In the Alps the "Couches rouges" facies, corresponding in lithology and fauna to the "Scaglia" facies of Southern Switzerland and the Apennines has been deposited. This open-marine deposition is characterized by the presence of pelagic Foraminifera, mainly globotruncanids. A similar pelagic facies with *Praeglobotruncana* and *Rotalipora* has been deposited during the Cenomanian on the territory now covered by the western Jura Mountains. It differs, however, from the typical Scaglia facies further to the south by the presence of ammonite assemblages, abundant *Inoceramus* and some benthonic Foraminifera. It is possible that during the Turonian-Campanian the region emerged above sea level, but very little is known about the events of that time interval, because a great part of the younger Cretaceous deposits were eroded during the Tertiary terrestrial period.

In the Maastrichtian the sea again transgressed from the south-west and neritic limestones containing a rich fauna of typical larger Foraminifera have been deposited, apparently on sediments of Cenomanian age. In the course of the long continental period during the lower Tertiary these limestones were transported by rivers into caverns of karst origin present in the Valanginian limestone, where they are now found as boulders. During the Late Aquitanian - Burdigalian the region again submerged below sea level, and shallow water sediments such as coarse-grained sands and conglomerates have been deposited. Subsequently, in the Pliocene, a late Alpine orogenetic phase folded the sediments discussed into the well-known trunk-shaped anticlines and synclines. Mid-Cretaceous sediments are preserved in the cores of synclines only.

2. Historical remarks

The abundance of well preserved fossils occurring in the Cretaceous formations surrounding the Tertiary basin of L'Auberson (Canton of Vaud) attracted the attention of paleontologists as early as the middle of the last century. Between 1858 and 1864 PICTET & CAMPICHE published their excellent monographs on the Albian cephalopods and bivalves. Based on the rich faunas present in the topmost Albian in the vicinity of the village La Vraconne in the Canton of Vaud, RENEVIER (1868,

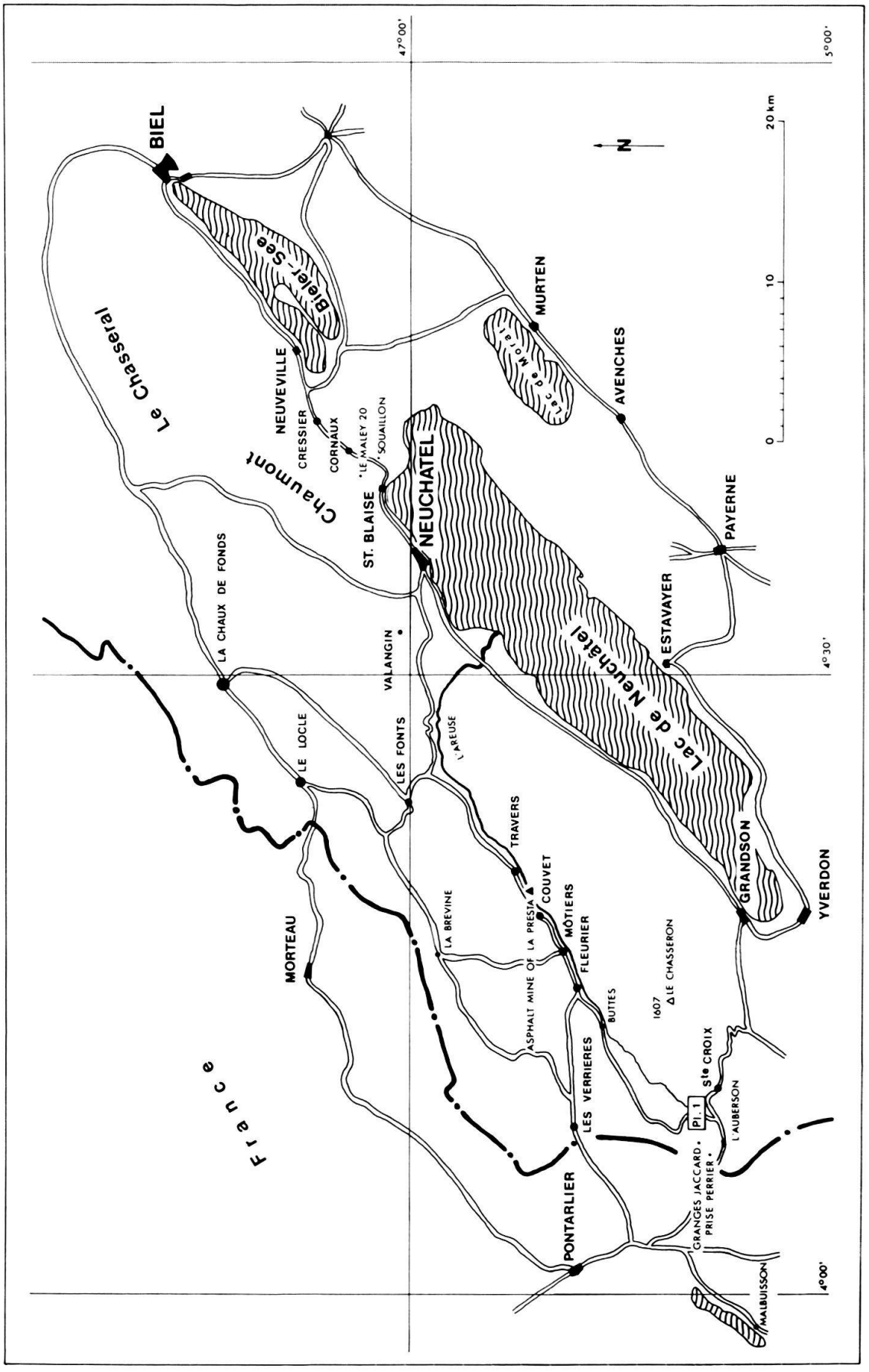


Fig. 1. Location map.

p. 201) introduced the stage term "Vraconnien". JACCARD (1869) published a first regional geological map at the scale of 1:100,000, covering the Jura Mountains of the Cantons of Vaud and Neuchâtel. The Albian has been subdivided by JACCARD (1869, p. 121-128) in:

— Albien supérieur ou Vraconnien
— Albien moyen ou Marnes à fossiles pyriteux
— Albien inférieur ou Sables à fossiles phosphatés

A detailed geological map (scale 1:25,000) of the Tertiary basin of L'Auberson and its surroundings has been prepared by RITTENER (1902). The mapping is based on a sound stratigraphic subdivision partly still in use at present. The following succession of lithological units is recognized (from top to bottom):

— Cénomanien (Rhotomagien, COQUAND 1857, p. 747)
— Albien gréseux = Vraconnien
— Albien argileux ou pyriteux
— Albien sableux
— Aptien, Grès vert quartzeux
— Rhodanien (RENEVIER 1854, p. 20, Perte du Rhône)
— Urgonien = Barrémien

JACOB (1907, p. 265-277) first recognized connections of the Albian faunas from the Jura Mountains with those of the Albian exposed near Besançon and in the Saône valley (Bresse Graben), and as far as the eastern border of the Paris basin and south-east England.

For the 9th European Micropaleontological Colloquium in Switzerland (1965), the stratotypes of the Valanginian, Hauterivian and Vraconnian have been revised and resampled. The Foraminifera of the Albian and Cenomanian have been provisionally investigated by LUTERBACHER (in RENZ & LUTERBACHER 1965), the ostracodes by OERTLI (1965) and the cephalopods by RENZ (1968). E.G. Kauffman (U.S. National Museum, Washington) identified the species of *Inoceramus* from the Middle Albian and Cenomanian. A detailled remapping of the region has been carried out by the authors (Pl. 1).

3. Aptian in the asphalt mine of La Presta (Val de Travers)

The Aptian and Albian deposits represent one sedimentary cycle. The asphalt mine of La Presta (Canton of Neuchâtel) (Fig. 1) is the only place where the Aptian yielded an age indicating ammonite fauna. For a better understanding of the Aptian/Albian boundary exposed in the Tertiary basin of L'Auberson it is useful to discuss the section of the Aptian in the asphalt mine (Fig. 2d).

The Aptian sediments in the mine have been investigated by FREY (1922). Since a long time the exposures are no more accessible. The asphalt impregnates porous limestones of the uppermost Barremian in "Urgonien" facies with *Caprina*. This sequence is followed by varicoloured, poorly consolidated, soft marly clays interspersed irregularly by accumulations of ferrugineous ooids. The average thickness of this interval reaches 6-7 m (FREY 1922, p. 9). Layers with *Orbitolina* are intercalated

within the lower half of the section (FREY 1922, Fig. 5). The rather uniform fauna of mollusks consists of several species, among which *Plicatula placunea* LAMARCK, *Pterocera pelagi* BRONGNIART, *Varigera rochati* PICTET & CAMPICHE, and *Cerithium heeri* PICTET & CAMPICHE are predominant.

Of special interest, however, are the cephalopods collected by FREY, which are deposited in the Natural History Museum of Basel. Only recently they have been investigated by RENZ. The following species permitting an age determination have been identified:

Cheloniceras (Cheloniceras) cornuelianum (D'ORBIGNY)
Cheloniceras (C.) crassum SPATH
Cheloniceras (C.) kiliani (VON KOENEN)
Deshayesites grandis SPATH
Deshayesites wiltshirei CASEY
Deshayesites involutus hysthensis CASEY
Dufrenoyia praedufrenoyi CASEY
Dufrenoyia cf. *furcata* (J. DE C. SOWERBY)
Epanocycloceras fractum CASEY
Tropaeum cf. *hillsi* (J. DE C. SOWERBY)
Anisoceras urbani NEUMAYR & UHLIG

The age of this assemblage is Early Aptian, and it might best be placed within the *Deshayesites deshayesi* and the *D. bowerbanki* Zone (Pl. 2).

The upper part of this section, consisting apparently of a more resistant, yellow brown, marly limestone, yielded a fragment of a *Parahoplites*, possibly indicating Late Aptian.

The soft and marly sequence of the Aptian is followed by a resistant glauconite bearing limestone containing abundant rounded and polished quartz grains. Its thickness attains about 5 m in section 5 of FREY (1922, p. 11). The following ammonite species are available: *Hypacanthoplites milletioides* CASEY, *Parahoplites* cf. *nutfieldiensis* (J. SOWERBY) (CASEY 1965, p. 404).

These species indicate the Late Aptian (*P. nutfieldiensis* Zone) and the lowermost Albian (*H. milletioides* Subzone). The interval might correspond to the "Grès vert quartzeux" and the "Albien sableux" present in the Tertiary basin of L'Auberson (Fig. 2).

In the old exploration well (Nr. 7) this Aptian-Albian sequence is overlain by about 20 m of grey marls (FREY 1922, p. 9) containing a pyritized fauna composed of small *Douvilleiceras* sp. This marly sequence is correlated with the "Albien pyriteux" exposed along the margin of the Tertiary basin of L'Auberson. It is disconformably followed by 12 m of Cenomanian limestones.

4. Aptian to Cenomanian bordering the Tertiary basin of L'Auberson (Plate 1)

A continuous section from the Lower Cretaceous to the Cenomanian is exposed in this region. To the south-east the Tertiary basin of L'Auberson is bordered by the dominating Chasseron anticline culminating in the Mont Chasseron (1611 m). In the north-west the margin of the basin is formed by the much lower Vraconne anticline (Mont de la Chèvre, 1142 m). This structure is crossed by one of the great transcurrent faults displacing the axis of the Jura anticlines, which have been described by HEIM (1919, p. 614, Fig. 103). This transcurrent faulting occurred after the last orogenic movements affecting the Jura chains as it has been overthrusted by the Chasseral anticline (Pl. 1).

The sediments intercalated between the massive limestone body of the Barremian and the limestones of the Cenomanian are affected by widespread submarine erosion and resedimentation apparently induced by strong bottom currents. An instructive example of such conditions can be observed along the top of the Barremian limestone: Along the western end of the L'Auberson Tertiary basin, 25 m of a rudist bioherm composed of *Caprina ammonia* (GOLDFUSS) forms the top of the Barremian limestone body. Eastwards, along the northern border of the basin, on the southern slope of the Mont de la Chèvre, there is a boulder bed containing components with *Caprina*, which here replaces the *Caprina* bioherm (Fig. 2a-b). Still further to the east, along the eastern end of the basin, around the small anticline north of Noirvaux called Scie Besse, a loosely packed fine breccious layer of about 1-2 m thickness composed of *Caprina* debris and well rounded, polished quartz grains (average grain size 1-2 mm) replaces the *Caprina* bioherm and the boulder bed. This thin zone may perhaps be correlated with the asphalt bearing interval forming the uppermost Barremian in La Presta (Fig. 2d). Along the southeastern border of the basin, near Entre-Roches east of La Chaux, the top layer of the "Urgonien" limestone consists of a medium-grained clastic limestone with abundant *Dictyoconus* in a crystalline calcite matrix. The Barremian/Aptian boundary thus is marked by a considerable stratigraphical gap.

4.1 *Aptian*

The Barremian is followed by about 4-5 m of fine-grained glauconitic, brownish, marly shale, which is not exposed at present. PICTET & RENEVIER (1858, p. 22) as well as PICTET & CAMPICHE (1860, p. 253) described a rich bivalve fauna and *Cheloniceras (Epicheloniceras) martini* (D'ORBIGNY) (Neotype: CASEY 1962, p. 241, Textfig. 84d, e) from this interval. In England this *Cheloniceras* occurs in the Late Aptian. We might conclude that the Early Aptian of La Presta is not present in this region. It might have been deposited, but if so, it has been removed again by the influence of bottom currents.

The upper lithological unit of the Aptian is a ridge-forming, hard, skeletal limestone composed of molluscan and bryozoan debris, rounded polished quartz grains, and glauconite cemented by transparent calcite. It is further characterized by large oysters. Apart from echinoderms (*Toxaster* sp.) and some indeterminable bivalves, no age indicating fossils are known from this interval, which has been referred to by RITTENER (1909, p. 54) and by us as "Grès verts quartzeux".

4.2 *Albian*

The most complete and best preserved succession of the Albian in the Jura Mountains of Switzerland is found along the north-eastern border of the Tertiary basin of L'Auberson in the vicinity of the village of La Vraconne. The poorly consolidated sediments indicate a significant environmental change; they are mostly covered by a screen of alluvions dating partly from the last glaciation period. In the course of the last century, at the time when Pictet and Campiche were collecting fossils, the shales of the Albian were exploited for tile production. These activities were given up at the beginning of this century.

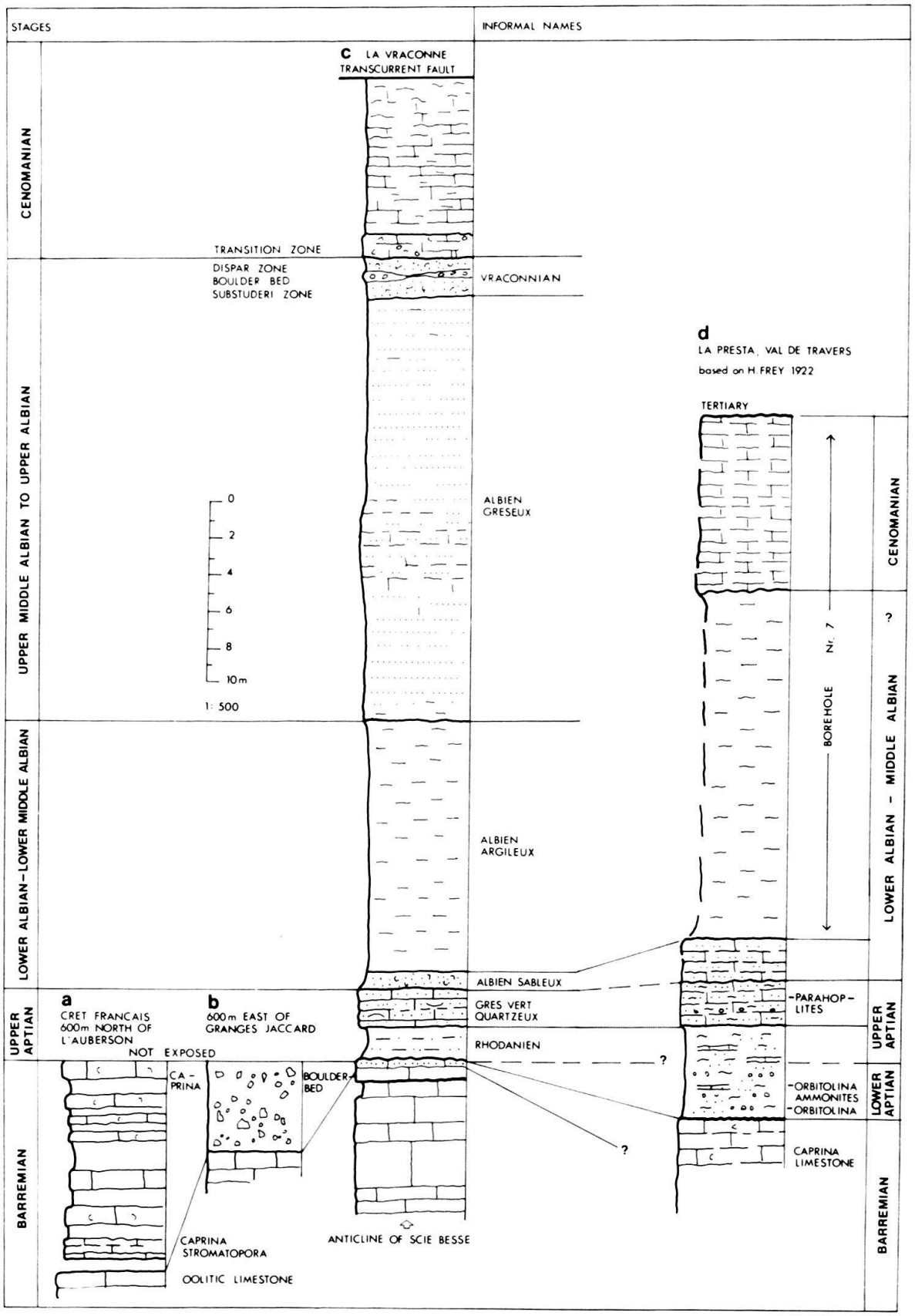


Fig. 2. Stratigraphical sections of the Aptian, Albian and Cenomanian in the Swiss Jura Mountains (Cantons of Vaud and Neuchâtel).

According to RITTENER (1902, p. 54) the Albian has been subdivided into three lithological units. From top to bottom they are:

— "Albien gréseux" (upper part with cephalopods = Vraconnian)
— "Albien argileux" (ou "pyriteux")
— "Albien sableux"

So far official formation names have not been introduced for these lithostratigraphical units because the stratotypes of the area are usually poorly exposed. In order to study them properly, artificial outcrops have to be made, which, however, will not last long due to erosion.

4.2.1 *"Albien sableux"*

This interval consists of loose, light brown quartz sands with glauconite grains overlying conformably the "Grès verts quartzeux" of Late Aptian age. The quartz grains are rounded and polished and closely resemble those from the Upper Aptian suggesting that both were supplied from the same source area. The average grain size varies between 0.5 and 1.5 mm; the grains are thus clearly smaller than those from the Upper Aptian. The thickness of this interval reaches about 1 m. Fossils are very abundant and consist of dark brown calcium phosphate. Predominant are casts of bivalves and cephalopods (ammonites and few nautilids). The more important ammonite species are:

Phylloceras (Hypophylloceras) sp.
Leymeriella tardefurcata (LEYMERIE)
Leymeriella regularis (BRUGUIÈRE)
Epileymeriella hitzeli (JACOB)
Hypacanthoplites cf. *corrugatus* CASEY
Hypacanthoplites milletianus (D'ORBIGNY)
Hypacanthoplites trivialis BREISTROFFER
Hypacanthoplites subelegans BREISTROFFER
Douvilleiceras pustulosum CASEY
Pictetia depressa (PICTET & CAMPICHE)
Protanisoceras blancheti (PICTET & CAMPICHE)

This assemblage represents the *L. tardefurcata* Zone of the Early Albian. Most species are typical for the *L. regularis* Subzone. The questionable *Hypacanthoplites ? corrugatus* might indicate the presence of the *F. farnhamensis* Subzone of the lowermost Albian (Pl. 2).

4.2.2 *"Albien argileux"*

The glauconitic quartz sands of the Lower Albian are overlain (apparently conformably) by a sequence of dark to lighter grey, very plastic and tough clays without glauconite or quartz grains. Due to their plastic nature the thickness of these clays is extremely variable and depends on the local tectonical conditions. Their true thickness in tectonically less disturbed sections might amount to not much more than 20 m. These clays can be followed around the Tertiary basin of L'Auberson. Their fauna consists mostly of ammonites. The lithology of the ammonites seems to depend on the amount of pyrite contained in the clays.

The lower part of the "Albien argileux" consists of dark, blue-grey, pyritic, sparsely fossiliferous clay. The ammonites are pyritized and desintegrate rapidly. They include the following species:

Douvilleiceras pustulosum CASEY
Douvilleiceras orbignyi HYATT
Oxytropidoceras roissianum (D'ORBIGNY)
Beudanticeras laevigatum (J. SOWERBY)

Bottom dwelling bivales are absent and samples washed for Foraminifera proved to be barren which indicates a reducing environment. The age of this small fauna is considered to correspond to the *D. mammillatum* Zone of the Early Albian (Pl. 2).

Towards the middle part of the section of the "Albien argileux" the clays gradually become less pyritic and their colour changes from dark grey into a lighter grey. A considerable change of the fauna is obvious. Apart from cephalopods small bottom dwelling bivalves and gastropods as well as benthonic Foraminifera occur abundantly. These assemblages suggest a less euxinic environment than in the lower part of the clays. Accordingly a conspicuous change in the lithology of the fossils from a pyritic towards a limonitic preservation can be observed. The fossils consist entirely of Fe_2O_3 and display a typically yellow-brown colour. The thickness of this middle part of the clay section could not be determined accurately. It certainly is very variable depending on the tectonic conditions. The ammonite fauna consists of the following species:

Douvilleiceras pustulosum CASEY
Douvilleiceras mammillatum (SCHLOTHEIM)
Douvilleiceras orbignyi HYATT
Cleoniceras quercifolium (D'ORBIGNY)
Cleoniceras cleon (D'ORBIGNY)
Tetragonites jurinianus (PICTET)
Beudanticeras dupinianum (D'ORBIGNY)
Beudanticeras albense BREISTROFFER

Among the Heteromorpha the following species may be mentioned:

Protanisoceras blancheti (PICTET & CAMPICHE)
Protanisoceras raulinianum (D'ORBIGNY)
Protanisoceras vaucherianum (PICTET)
Protanisoceras halleri (PICTET & CAMPICHE)
Protanisoceras nicoleti (PICTET & CAMPICHE)
Protanisoceras lardyi (PICTET & RENEVIER)

This assemblage represents the *D. mammillatum* Zone of the late Lower Albian. Cephalopods indicating the *H. dentatus* Zone of the early Middle Albian include:

Hoplites (Isohoplites) steinmanni CASEY
Hoplites (Hoplites) baylei SPATH
Hoplites (H.) devisensis SPATH
Hoplites (H.) pseudodeluci SPATH
Hoplites (H.) dentatus (J. SOWERBY)

The *A. intermedius* Subzone at the base of the *E. loricatus* Zone of the Middle Albian is indicated by:

Tetragonites jurinianus (PICTET)
Anahoplites intermedius SPATH
Anahoplites praecox SPATH
Anahoplites cf. *planus* (MANTELL)
Protanisoceras moreanum (BUVIGNIER)
Hamites (Hamites) attenuatus J. SOWERBY
Hamites (H.) compressus J. SOWERBY

The upper few meters of the "Albien argileux" and its contact with the overlying "Albien gréseux" were exposed when the road from L'Auberson to Fleurier was enlarged recently. The outcrop was situated 220 m east of the deviation of the road leading to La Vraconne (Pl. 1). This uppermost part of the clay sequence consists of a light-grey clay without traces of pyrite. Ammonites are rare: so far only an unidentified species of *Hamites (Hamites)* has been found. Species of *Inoceramus*, however, are abundant, but poorly preserved. E.G. Kauffman determined *Biostrina concentrica* (PARKINSON) suggesting an Upper Albian age.

Of special interest is an allochthonous ammonite assemblage composed of forms from the late Early Albian and the Middle Albian. These ammonites are preserved as fragments consisting of hard, dark brown to black calcium phosphate. These fragments usually have rounded edges and polished, sometimes also striated

surfaces which are often affected by boring organisms. Apart from the ammonites abundant small phosphatized fragments of crabs occur. In addition to the fossils irregularly shaped phosphorite nodules (diameters up to 20 mm) indicating non-depositional areas also form part of this allochthonous material. On the distribution chart the ammonites are plotted by squares, and they are shown where they actually occurred, i.e. before reworking. Our assumption that this phosphatized material derived from an older sediment, deposited in a different environment than that found in the described section, seems to be acceptable. The fossils were washed out from this older sediment, transported by strong bottom currents over long distances, and finally redeposited where we observe them at present. Lumps of shale (diameter up to 10 cm) with phosphorite nodules sticking on their surface indicate transportation along the sea floor. They seem to support our interpretations.

This reworked phosphatized fauna consists of the following species:

Douvilleiceras orbignyi HYATT
Douvilleiceras cf. *mammillatum* (SCHLOTHEIM)
Douvilleiceras cf. *monile* (J. SOWERBY)
Desmoceras (Desmoceras) latidorsatum (MICHELIN)
Beudanticeras laevigatum (J. SOWERBY)
Prothoplites (Prothoplites) michelinianus (D'ORBIGNY)
Otohoplites raulinianus (D'ORBIGNY)
Otohoplites cf. *waltoni* CASEY
Otohoplites cf. *simplex* CASEY
Hoplites (Isohoplites) eodentatus CASEY
Lyelliceras lyelli (D'ORBIGNY)
Lyelliceras seunesi (PICTET & CAMPICHE)
Lyelliceras huberianum (PICTET)
Lyelliceras hirsutum (PICTET & CAMPICHE)
Lyelliceras camatteanum (D'ORBIGNY)

Nucula (Pectinula) pectinata (SOWERBY) and *Grammatodon carinatus* (SOWERBY) are the only bivalves associated with this reworked ammonite assemblage.

The abundance of specimens of *Lyelliceras* in this phosphatic preservation is striking. So far this mode of preservation has not been observed in the autochthonous fauna. On the other hand species of *Protanisoceras*, which are represented by numerous specimens, are not found reworked. In this connection we might refer to an observation mentioned by OWEN (1971, p. 120) according to whom *Protanisoceras* is common in deposits of the *L. lyelli* Subzone containing benthonic forms, and no benthos is present, where heteromorph ammonites are absent. We may thus conclude that the ecological conditions in the region from where the *Lyelliceras* derived were hostile for the development of benthos.

A rich foraminiferal fauna has been recognized by LUTERBACHER (in RENZ & LUTERBACHER 1965, p. 89) from about the middle part of this clay formation. It consists of 16 genera and 43 species. The most abundant genera are *Haplophragmoides, Tritaxia, Arenobulimina, Nodosaria, Frondicularia, Lenticulina, Hedbergella, Ticinella* and *Anomalina.*

OERTLI (1965, p. 89) identified the following ostracod species:

Protocythere albae DAMOTTE & GROSDIDIER
Cythereis cf. *cornueli* DEROO
Cythereis reticulata JONES & HINDE
Dolocytheridea bosquetiana (JONES & HINDE)
Cytherella cf. *ovata* (ROEMER)
Schuleridea jonesiana (BOSQUET)
Centrocythere denticulata MERTENS
Meenia ? *harrisiana* (JONES)

4.2.3 *"Albien gréseux"*

We do not know whether there is a depositional gap between the "Albien argileux", the top of which falls within the *A. intermedius* Subzone (Middle Albian), and the "Albien gréseux", because no ammonites are known from the lower part of

the "Albien gréseux". If there is no depositional gap, this sandy interval would represent the late Middle Albian and the Upper Albian. Lithologically it consists of partly consolidated, glauconitic, medium-grained, unbedded sands, which often show cross-bedding, especially in the upper part of the section. The quartz grains are mostly semirounded displaying distinct percussion marks.

The preservation, distribution and number of species of Foraminifera within the "Albien gréseux" are variable. According to LUTERBACHER (1965, p. 92), 34 species belonging to the following genera are determinable: *Psammosphaera, Saccammina, Reophax, Haplophragmium, Ammobaculites, Textularia, Trochammina, Tritaxia, Arenobulimina, Dorothia, Eggerellina, Valvulammina, Nodosaria, Lenticulina, Vaginulina, Globigerinelloides, Hedbergella, Anomalina, Cibicides.*

According to OERTLI (1965, p. 93), Ostracoda are rare.

Vraconnian s. str.

About 4 m below the contact of the "Albien gréseux" and the Cenomanian, the lower boundary of the stratotype of the Vraconnian is indicated by the appearance of valves of small oysters within the dark green glauconitic sands of the "Albien gréseux". Their shells are desintegrated to a powdery calcite. The quartz grains in this upper part of the section are predominantly well rounded and polished. No ammonites have been found in this lower part of the section. The Foraminifera are poorly preserved and represented by only 6 genera: *Spiroplectammina, Tritaxia, Arenobulimina, Dorothia, Gyroidinoides, Anomalina.*

The upper 2 m of the glauconitic sands contain the rich macrofauna described by PICTET & CAMPICHE (1858–1864) and revised by RENZ (1968). Where this interval is fully developed it can be divided into 3 parts.

The lower part contains 56 species of ammonites which indicate the *A. substuderi* Zone. The most important forms are:

Phylloceras (Hypophylloceras) seresitense (PERVINQUIÈRE)
Tetragonites jurinianus (PICTET)
Zelandites dozei (FALLOT)
Desmoceras latidorsatum (MICHELIN)
Discohoplites subfalcatus (SEMENOW)
Arrhaphoceras substuderi SPATH
Callihoplites pulcher SPATH
Stoliozkaia (Faraudiella) gardonica (HÉBERT & MUNIER-CHALMAS)
Mortoniceras (Cantabrigites) cantabrigiense SPATH
Mortoniceras (C.) subsimplex SPATH
Mortoniceras (C.) minor SPATH
Mortoniceras (C.) picteti RENZ

Among the Heteromorpha the following species might be noted:

Hamites (Stomohamites) virgulatus BRONGNIART
Hamites (S.) venetzianus PICTET
Idiohamites desorianus (PICTET)
Anisoceras perarmatum PICTET & CAMPICHE
Lechites gaudini (PICTET & CAMPICHE)
Turrilitoides (Turrilitoides) hugardianus (D'ORBIGNY)
Mariella (Mariella) gresslyi (PICTET & CAMPICHE)
Mariella (M.) nobilis (JUKES-BROWNE)
Pseudohelicoceras elegans (D'ORBIGNY)
Scaphites (Scaphites) hugardianus D'ORBIGNY

The accompanying small oysters (*Ostrea arduennensis* D'ORBIGNY) as well as the ammonites are preserved as internal moulds.

Of special interest is the middle part of the Vraconnian, which represents a boulder bed with angular boulders, which are composed of a hard brown limestone with quartz grains. The only fossil is *Ostrea vesiculosa* (SOWERBY), the shell of which is always well preserved. The size of the boulders ranges from individual oysters to

fragments reaching diameters up to 20 cm. These boulders reflect considerable erosion activities and transportation of material by submarine currents due to which the thickness of the 3 parts changes within short distances. The stratigraphic origin of these boulders and their age are not known. We assume that they are of Late Albian age. A somewhat older age than Vraconnian, however, cannot be excluded. They might have been brought into their present position in a similar way as described for the phosphatized ammonite fragments present in the upper "Albien pyriteux".

The upper part of the Vraconnian is characterized by a very rich fauna composed of about 88 species of ammonites and one nautilid. Moreover, bivalves, gastropods, brachiopods, echinoderms, teeth of sharks, sponges, and abundant Foraminifera are present. The occurrence of *Stoliczkaia dispar* indicates the *S. dispar* Zone. Some of the more important ammonites include:

Phylloceras (Hypophylloceras) seresitense PERVINQUIÈRE
Tetragonites jurinianus (PICTET)
Desmoceras latidorsatum (MICHELIN)
Puzosia sharpei SPATH
Discohoplites subfalcatus (SEMENOW)
Hyphoplites campichei SPATH
Arrhaphoceras studeri (PICTET & CAMPICHE)
Lepthoplites falcoides SPATH
Lepthoplites cantabrigiensis SPATH
Callihoplites seeleyi SPATH
Callihoplites tetragonus dorsetensis SPATH
Pleurohoplites aff. *renauxianus* (D'ORBIGNY)
Stoliczkaia (Stoliczkaia) dispar (D'ORBIGNY)
Stoliczkaia (S.) dorsetensis SPATH
Stoliczkaia (S.) africana PERVINQUIÈRE
Stoliczkaia (S.) notha (SEELEY)
Mortoniceras (Durnovarites) perinflatum (SPATH)
Mortoniceras (D.) postinflatum (SPATH)
Mortoniceras (D.) rostratum (SOWERBY)
Mortoniceras (D.) subquadratum (SPATH)
Mortoniceras (Cantabrigites?) helveticum RENZ

Among the Heteromorpha the following species occur frequently:

Hamites (Stomohamites) virgulatus BRONGNIART
Hamites (S.) duplicatus (PICTET & CAMPICHE)
Idiohamites dorsetensis SPATH
Anisoceras perarmatum PICTET & CAMPICHE
Anisoceras armatum (J. SOWERBY)
Anisoceras picteti SPATH
Anisoceras saussureanum (PICTET)
Anisoceras campichei SPATH
Lechites gaudini (PICTET & CAMPICHE)
Lechites moreti BREISTROFFER
Mariella (Mariella) bergeri (BRONGNIART)
Mariella (M.) crassituberculata SPATH
Mariella (M.) miliaris (PICTET & CAMPICHE)
Ostlingoceras (Ostlingoceras) puzosianum (D'ORBIGNY)
Scaphites (Scaphites) meriani (PICTET & CAMPICHE)

In England, where less disturbed sections (without resedimented material) of the Upper Albian are available, a subdivision of the *Stoliczkaia dispar* Zone into 3 subzones is possible. They are from top to bottom the *S. dispar*, the *M. perinflatum* and the *A. substuderi* Subzones (OWEN 1969, p. 466; 1972, p. 288; KENNEDY 1970, p. 615).

The following species of mollusks have been identified by D. Petitbois-Mongin:

Ostrea arduennensis D'ORBIGNY
Nerinea gaultina PICTET & CAMPICHE
Lopha milletiana (D'ORBIGNY)
Plicatula radiola LAMARCK
Spondylus gibbosus D'ORBIGNY
Neacrea sanctaecrucis PICTET & CAMPICHE
Cyprina quadrata PICTET & CAMPICHE
Acmea inflexa PICTET & ROUX
Idonearca fibrosa D'ORBIGNY
Neithea syriaca (CONRAD)

Among the gastropods we might quote:

Pleurotomaria cf. *gaultina* D'ORBIGNY
Pleurotomaria cf. *rutimeyeri* PICTET & CAMPICHE
Numocalcar cf. *dentatum* D'ORBIGNY
Numocalcar rochatianum (PICTET & ROUX)
Avellana incrassata SOWERBY
Ringinella lacryma D'ORBIGNY

LUTERBACHER (in RENZ & LUTERBACHER 1965, p. 98) recognized the following genera of Foraminifera in sample GG 251: *Trochammina, Tritaxia, Dorothia, Pernerina, Pseudotextulariella, Lenticulina, Hedbergella, Gyroidinoides, Anomalina, Rotalipora.*

4.3 *Cenomanian*

A transition zone of 1 to 2 m thickness separates the glauconitic sands of the uppermost Albian from the pelagic Cenomanian limestones containing *Pithonella, Inoceramus* and ammonites. In this zone there is material reworked from the Albian such as glauconite grains, phosphatized casts of bivalves, and ammonites. It cannot be excluded that currents are responsible for this reworking. Part of the Cenomanian already deposited has been displaced, and mixed with the underlying Albian glauconitic sands. A *Mantelliceras (Submantelliceras) marrei* THOMEL (1972, p. 23, Pl. 8, Fig. 1-6) has been found overlying this transition zone. In the «Chaînes subalpines» in south-eastern France this species occurs at the base of zone 2 of THOMEL (1972, p. 10). This indicates that in our section zone 1 of THOMEL, characterized by *Mantelliceras (Submantelliceras) saxbii*, has not been deposited, or has been removed by currents. So far no *M. (S.) saxbii* has been recorded from this section, a circumstance which would confirm the above interpretation.

In the Isle of Wight the "*M. saxbii* assemblage-horizon", according to KENNEDY & HANCOCK (1971, p. 451), is underlain by about 5 m of chalk and glauconitic marls. The latter contain the *Hypoturrilites carcitanensis* assemblage, which so far is not known from the Swiss Jura Mountains.

The Cenomanian in this region is a predominantly whitish, partly chalky, argillaceous, irregularly thin bedded, partly slightly nodular limestone. Reddish colours, which are typical for the sections farther south along the foothills of the Jura Mountains, were not seen. In thin sections it displays a skeletal micritic appearance. Its exposed thickness reaches about 8 m. The upper part of the section is disturbed by faulting, bringing the limestone in contact with Upper Albian sands (Pl. 1).

Most ammonites are poorly preserved. Predominant are *Mantelliceras (M.)* cf. *mantelli* (J. SOWERBY) and *M. (M.)* ? *tenue* (SPATH). Among the bivalves *Inoceramus* is represented by various species. In addition a single species of an echinoid (*Heteraster* sp.) is fairly common.

The *Inoceramus* have been determined by E.G. Kauffman, who identified *Inoceramus (Inoceramus) etheridgei* n.ssp., with small, closely and evenly spaced rugae, transition to *I. cuneiformis* D'ORBIGNY, and *Inoceramus (I.) conicus* GUERANGER.

The foraminiferal fauna is composed of pelagic as well as benthonic forms. In the transition zone pelagic forms predominate. LUTERBACHER (in RENZ & LUTERBACHER 1965, p. 99) reported *Rotalipora* sp. aff. *cushmani* (MORROW), *Rotalipora gandolfii* PREMOLI SILVA & LUTERBACHER, *Rotalipora* sp. aff. *micheli* SIGAL & DEBOURLE, and *Praeglobotruncana* cf. *stephani* (GANDOLFI).

Higher up in the section abundant benthonic genera are associated with the pelagic forms. They include:

Spiroplectammina longa LALICKER
Tritaxia pyramidata REUSS
Arenobulimina chapmani CUSHMAN
Dorothia bulleta (CARSEY)
Dentalina siliqua REUSS
Lenticulina macrodisca REUSS
Tristix excavata REUSS
Rotalipora montsalvensis MORNOD

5. Cenomanian along the foothills of the Jura Mountains between Neuchâtel and Bienne

Between Neuchâtel and Bienne (Fig. 1) four important occurrences of Cenomanian rocks are known since a long time. They are:

1. Lower Cenomanian in the borehole "Le Maley 20" (Fig. 1) near the houses of Le Maley, 1.2 km NNW of the village Cornaux (SCHNEIDER in RENZ, LUTERBACHER & SCHNEIDER 1963, Fig. 2-3, p. 1076).
2. Lower Cenomanian in the Ravin Le Mortruz near the Château Jeanjaquet, 900 m WSW of the village Cressier (SCHARDT 1899, Fig. 4, p. 246).
3. Middle Cenomanian near the village of Alfermée (ANDEREGG in VONDERSCHMITT 1941, p. 199, Pl. 11).
4. Upper Cenomanian, 250 m N of the houses of Souaillon (RENZ in RENZ, LUTERBACHER & SCHNEIDER 1963).

5.1 *Lower Cenomanian in the borehole "Le Maley 20"*

Along the south-eastern flank of the Chaumont-Chasseral anticline a small secondary structure develops near St. Blaise. In the centre of the respective narrow syncline near the houses of Le Maley the hole "Le Maley 20" has been drilled by the Jura-Cementwerke (SCHNEIDER in RENZ, LUTERBACHER & SCHNEIDER 1963, Fig. 2-3, p. 1076). In this borehole Barremian (in "Urgonien" facies) is overlain disconformably by 11 m of green-grey to bluish, marly clays with quartz and glauconite grains. The fauna consists of pelagic Foraminifera such as *Hedbergella*, *Praeglobotruncana*, and poorly preserved *Rotalipora*. This marl sequence approximately corresponds to the "Albien gréseux" in the section of the Vraconne region. This means that there is a sedimentary gap representing the interval from the Aptian to the Lower and Middle Albian ("Albien pyriteux" in the Tertiary basin of L'Auberson). This section therefore indicates a thinning and wedging out of the Aptian-Albian from north to south.

5.2 *Lower Cenomanian in the Ravin Le Mortruz near Cressier*

This is the largest outcrop of Cenomanian in the Jura Mountains. It has been studied by SCHARDT (1899, Fig. 4, p. 246). Here we find pelagic and benthonic Foraminifera associated with ammonites and *Inoceramus*. The contact of the Cenomanian with the underlying deposits (presumably Upper Albian as present in "Le Maley 20") is not exposed. The lithology of the Cenomanian highly resembles the Upper Cretaceous Scaglia facies of the southern foothills of the Alps. Within the 12 m thick sequence light yellowish-brown, hard, dense limestones predominate.

They are bedded in layers of varying thickness, and intercalated with lenticular, partly argillaceous, reddish limestones. In thin sections the limestone appears micritic and densely filled with *Phytonella*, fragments of *Inoceramus* and pelagic Foraminifera, which were investigated by LUTERBACHER (RENZ, LUTERBACHER & SCHNEIDER 1963, p. 1080, Pl. 7–9). The following species have been described:

Rotalipora cushmani (MORROW)
Rotalipora montsalvensis minor MORNOD
Rotalipora cf. *appenninica evoluta* SIGAL
Rotalipora cf. *turonica* BROTZEN
Rotalipora cf. *turonica* BROTZEN
Rotalipora appenninica gandolfii PREMOLI SILVA & LUTERBACHER
Praeglobotruncana stephani (GANDOLFI)

In addition to the planktonic Foraminifera some benthonic forms occur: *Vaginulina, Verneuilina, Gaudryina, Lenticulina* and *Tritaxia.*

Inoceramus is abundant, and E. G. Kauffman recognized the following species:

Inoceramus (Inoceramus) etheridgei s.l. WOODS
Inoceramus (I.) cuneiformis D'ORBIGNY
Inoceramus (I.) flavus SORNAY
"Inoceramus" reachensis ETHERIDGE
Inoceramus conicus GUERANGER
"Inoceramus" (Mytiloides?) crippsi crippsi MANTELL
"Inoceramus" (Mytiloides?) hoppenstedtensis TRÖGER

Based on Inoceramidae the interval exposed in the Ravin Le Mortruz is Middle Cenomanian, thus of a somewhat younger age than indicated by the cephalopods.

The only echinoid present is *Heteraster laevis* AGASSIZ.

Of special interest is the cephalopod assemblage described by RENZ, LUTERBACHER & SCHNEIDER (1963, p. 1089, Pl. 1–6). The most common species belong to the genera *Mantelliceras* and *Schloenbachia.*

KENNEDY & HANCOCK (1971) and THOMEL (1972) have revised the genus *Mantelliceras* and discussed the biostratigraphy of its species. So far the following species have been found in the Ravin Le Mortruz:

Mantelliceras (Submantelliceras) saxbii (SHARPE). – THOMEL: zone 1; KENNEDY: *M. saxbii* assemblage, middle Lower Cretaceous.
Mantelliceras (Submantelliceras) ventnorense DIENER. – KENNEDY & HANCOCK: closely related to *M. saxbii.*
Mantelliceras (Submantelliceras) hyatti SPATH. – THOMEL: zone 1 and 2.
Mantelliceras (Coulonniceras) cressierense RENZ. – THOMEL: p. 27.
Mantelliceras (Promantelliceras) picteti HYATT. – THOMEL: base of zone 2.
Mantelliceras (Promantelliceras) tenue SPATH. – THOMEL: zone 2.
Mantelliceras (Mantelliceras) mantelli (SOWERBY). – THOMEL: zone 2.
Mantelliceras (Mantelliceras) batheri SPATH. – THOMEL: zone 2.

According to the above list the exposed sequence of the Cenomanian in the Ravin Le Mortruz corresponds to zone 1 and 2, equivalent to the *M. saxbii* and *M. mantelli* Zones in south-eastern France, and partly at least to the *M. saxbii* assemblage of the Isle of Wight.

Recently a large specimen of *Pachydesmoceras* aff. *denisonianum* (STOLICZKA) has been found in the Ravin Le Mortruz together with *Mantelliceras (Submantelliceras) saxbii* (SHARPE) (RENZ 1976).

In the Flysch filling the syncline of Amden, *P. denisonianum* has also been collected by HERB (1960, p. 148), together with *Rotalipora appenninica,* indicating a Cenomanian age for this Flysch.

5.3 *Middle Cenomanian near the village of Alfermée*

During excavations in 1941 at Alfermée a large fragment of an *Acanthoceras* aff. *rhotomagense* (BRUGUIÈRE) was found. It suggests a Middle Cenomanian age (zone 4 of THOMEL, from south-eastern France).

5.4 *Upper Cenomanian, north of Souaillon*

The small outcrops of Cenomanian 250 m N of the houses of Souaillon, 3 km SW of Cressier, represent the early Upper Cenomanian. Characteristic ammonites from these exposures include *Mantelliceras (Neomantelliceras) tuberculatum* (MANTELL), *Calycoceras (Gentoniceras) gentoni* (BRONGNIART), and *Calycoceras (Gentoniceras) souaillonense* RENZ. According to THOMEL (1972) this assemblage points to early Upper Cenomanian.

It is important to mention that E.G. Kauffman determined a *Mytiloides opalensis elongata* (SEITZ) from Souaillon indicating the earliest Lower Turonian.

6. Turonian–Campanian

North of the line Bienne–Besançon no Cretaceous sediments have been found exposed in the Jura Mountains. How far eastward from this line marine conditions actually persisted during the Cenomanian and possibly also during the Turonian–Senonian is not known. The presence of abundant pelagic Foraminifera and a well developed ammonite fauna in the Cenomanian suggest that open marine conditions prevailed and that direct connections must have existed with the Cenomanian in a very similar facies known from the northern Alps. The absence of detrital quartz and the reduced amount of terrigenous material in the Cenomanian limestones (about 15%) also supports the assumption that the coast of the Cenomanian sea reached far eastward, perhaps as far as the present Oberrheingraben. The reworked *Globotruncana* in the Oligocene («Blauer Letten» of the Basel area) considered to be reworked from the Alps might also derive from Cretaceous sediments eroded during the Oligocene (see FISCHER 1965, p. 70, Pl. 3).

7. Maastrichtian

Marine Maastrichtian limestones are known from the surroundings of Bienne (RENZ 1936, p. 545; HÄFELI 1966, p. 595). They occur as boulders together with fragments of limestones of Cenomanian age in karst cavernes within limestones of Valanginian age, where they have been transported by rivers during the Paleocene to Eocene continental period. The fauna of these limestones consists predominantly of larger Foraminifera such as *Orbitoides media* (D'ARCHIAC), *Orbitoides apiculata* SCHLUMBERGER, *Simplorbites gensacicus* (LEYMERIE), *Lepidorbitoides socialis* (LEYMERIE), *Omphalocyclus macropora* (LAMARCK), *Siderolites calcitrapoides* LAMARCK, and *Meandropsina vidali* SCHLUMBERGER.

Because no older reworked sediments are found in these Maastrichtian limestones, we do not know whether marine conditions prevailed during the time

interval from Cenomanian to Maastrichtian in this area or whether a terrestrial period interrupted the marine sedimentation.

Acknowledgements

We are greatly indebted to R. Panchaud, who collaborated during field work as well as during the preparation of this report. We also would like to thank Dr. H.G. Kugler for many good advices during excursions in the field.

REFERENCES

CASEY, R. (1961): *The stratigraphical palaeontology of the Lower Greensand.* - Palaeontology (London) *3*, 487-621.

— (1960-1966): *A Monograph of the Ammonoidea of the Lower Greensand* (Parts 1-7). - Palaeontogr. Soc. (London).

COQUAND, H. (1857): *Position des Ostrea columba et biauriculata dans le groupe de la craie inférieure.* - Bull. Soc. géol. France *14*, 747.

DESTOMBES, P. (1970): *Biostratigraphie des ammonites dans l'Albien inférieur et moyen argileux du Bassin de Paris.* - C.R. Acad. Sci. Paris. *270*, 2061-2064.

FISCHER, H. (1965): *Geologie des Gebietes zwischen Blauen und Pfirter Jura (SW Basel).* - Beitr. geol. Karte Schweiz [N.F.] *122*.

FREY, M. (1922): *Die Asphaltlagerstätten im schweizerischen Juragebirge mit besonderer Berücksichtigung des Val de Travers.* - Beitr. Geol. Schweiz, geotech. Ser. *9*.

HÄFELI, CH. (1966): *Die Jura/Kreide-Grenzschichten im Bielerseegebiet (Kt. Bern).* - Eclogae geol. Helv. *59/2*, 565-695.

HEIM, ALB. (1919): *Geologie der Schweiz.* Bd. 1: *Molasseland und Juragebirge.* - Tauchnitz, Leipzig.

HERB, R. (1960): *Die Flyschfüllung der Fliegenspitzmulde bei Amden.* - Eclogae geol. Helv. *53/1*, 147-154.

JACCARD, A. (1869): *Description géologique du Jura vaudois et neuchâtelois.* - Matér. Carte géol. Suisse *6*.

JACOB, CH. (1907): *Études paléontologiques et stratigraphiques sur la partie moyenne des terrains crétacés dans les Alpes Françaises et les régions voisines.* - Trav. Lab. Géol. Grenoble *8*, 280-590.

KENNEDY, W.J. (1970): *A correlation of the uppermost Albian and the Cenomanian of South-West England.* - Proc. Geologists' Assoc. (London) *81*, 613-677.

KENNEDY, W.J. & HANCOCK, J.M. (1971): *Mantelliceras saxbii and the horizon of the martimpreyi Zone in the Cenomanian of England.* - Palaeontology *14*, 437-454.

LUTERBACHER, H., in RENZ, O. et al. (1965): *Die Mittlere Kreide von La Vraconne bei Ste-Croix (Kt. Waadt).* - Bull. Ver. schweiz. Petroleum-Geol. u. -Ing. *31*, 76-101.

OERTLI, H.J., in RENZ, O. & LUTERBACHER, H. (1965): *Die Mittlere Kreide von La Vraconne bei Ste-Croix (Kt. Waadt).* - Bull. Ver. schweiz. Petroleum-Geol. u. -Ing. *31*, 76-101.

ORBIGNY, A. D' (1847): *Paléontologie Française. Terrains crétacés. 4. Brachiopodes; stratotype Urgonien* (p. 269). - Paris.

OWEN, H.G. (1969): *The correlation of the Lower Chalk of South-East England.* - Proc. Geologists' Assoc. (London) *80*, 459-560.

— (1971): *Middle Albian stratigraphy in the Anglo-Paris Basin.* - Bull. brit. Mus. (Geol.), Suppl. *8*, London.

— (1972): *The Gault and its junction with the Woburn Sands in the Leighton Buzzard area, Bedfordshire and Buckinghamshire.* - Proc. Geologists' Assoc. (London) *83*, 287-312.

PICTET, F.J., & CAMPICHE, G. (1858-1864): *Description des fossiles du terrain crétacé des environs de Sainte-Croix.* - Matér. Paléont. suisse 1858-1860; 1861-1864.

PICTET, F.J., & RENEVIER, E. (1854-1858): *Description des fossiles du terrain Aptien de la Perte-du-Rhône et des environs de Ste-Croix.* - Matér. Paléont. suisse.

RENEVIER, E. (1854): *Mémoire géologique sur la Perte-du-Rhône et ses environs.* - Nouv. Mém. Soc. helv. Sci. nat. *14*.

— (1868): *Notices géologiques et paléontologiques sur les Alpes vaudoise et les régions environnantes. - V. Complément de la faune de Cheville.* - Bull. Soc. vaud. Sci. nat. *9*, 389-479.

RENZ, O. (1936): *Über ein Maestrichtien-Cénomanien-Vorkommen bei Alfermée am Bielersee.* - Eclogae geol. Helv. *29/2*, 545-566.

— (1968): *Die Ammonoidea im Stratotyp des Vraconnien bei Ste-Croix (Kt. Waadt).* - Schweiz. paläont. Abh. *87*.

— (1976): *Ein grosser Pachydesmoceras (Ammonoidea) aus dem Unteren Cénomanien des Schweizer Juras.* - Eclogae geol. Helv. *69/3*, 753-763.

RENZ, O., LUTERBACHER, H., & SCHNEIDER, A. (1963): *Stratigraphisch-paläontologische Untersuchungen im Albien und Cénomanien des Neuenburger Jura.* - Eclogae geol. Helv. *56/2*, 1073-1116.

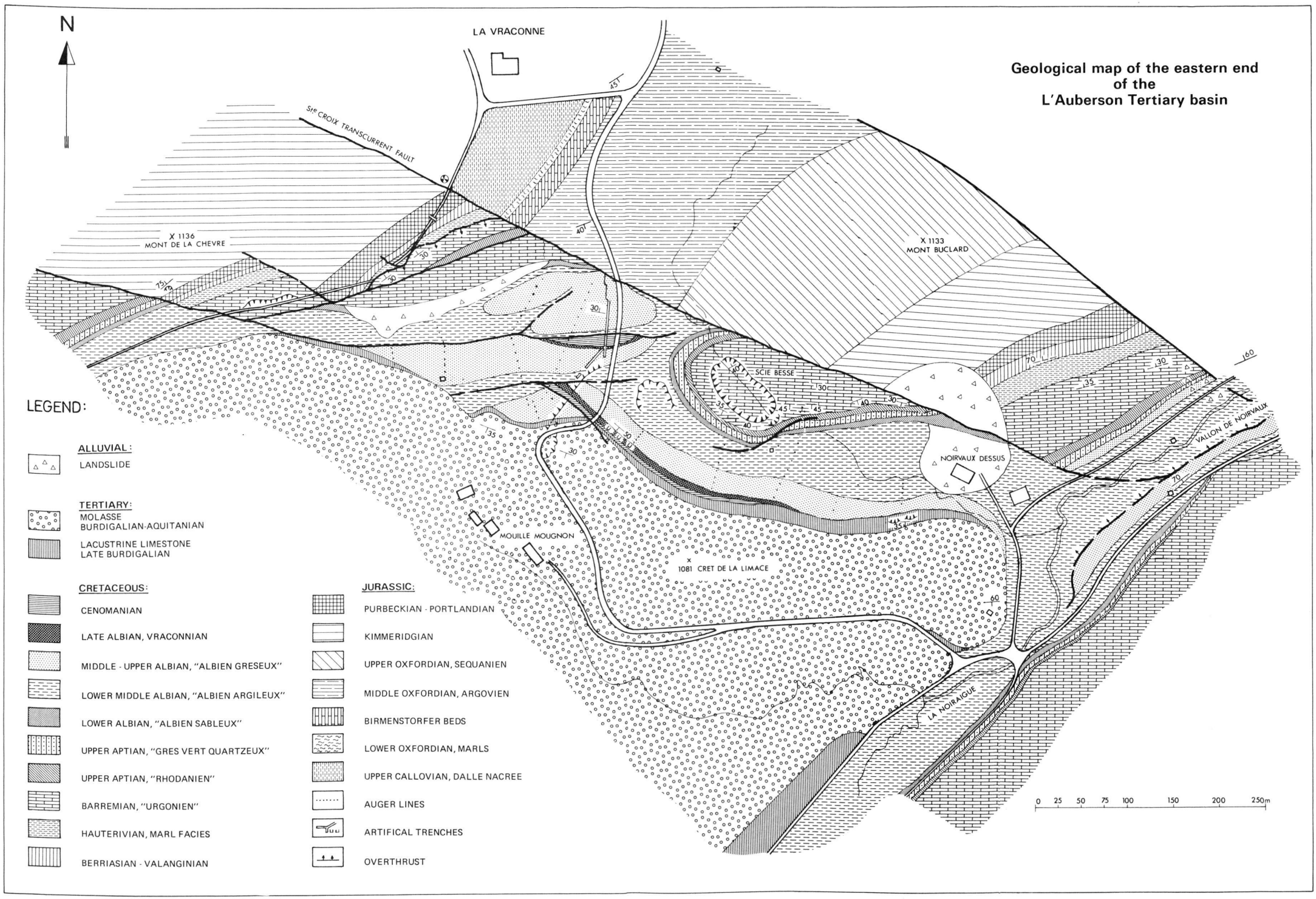
RENZ, O., & LUTERBACHER, H. (1965): *Die Mittlere Kreide von La Vraconne bei Ste-Croix (Kt. Waadt).* - Bull. Ver. schweiz. Petroleum-Geol. u. -Ing. *31*, 76-101.

RITTENER, TH. (1902): *Étude géologique de la Côte aux Fées et des environs de Ste-Croix et de Baulmes.* - Matér. Carte géol. Suisse [n.s.] *13*.

SCHARDT, H. (1899): *Sur un lambeau de calcaire cénomanien dans le Néocomien à Cressier.* - Bull. Soc. Sci. nat. Neuchâtel *26*, 239-250.

THOMEL, G. (1972): *Les Acanthoceratidae cénomaniens des chaînes subalpines méridionales.* - Mém. Soc. géol. France [n.s.] *51*, 116.

VONDERSCHMITT, L. (1941): *Bericht über die Exkursionen der Schweizerischen Geologischen Gesellschaft im nordschweizerischen Jura* [mit einer Tafel von H. ANDEREGG]. - Eclogae geol. Helv. *34/2*, 199-208.



Geological map of the eastern end of the L'Auberson Tertiary basin

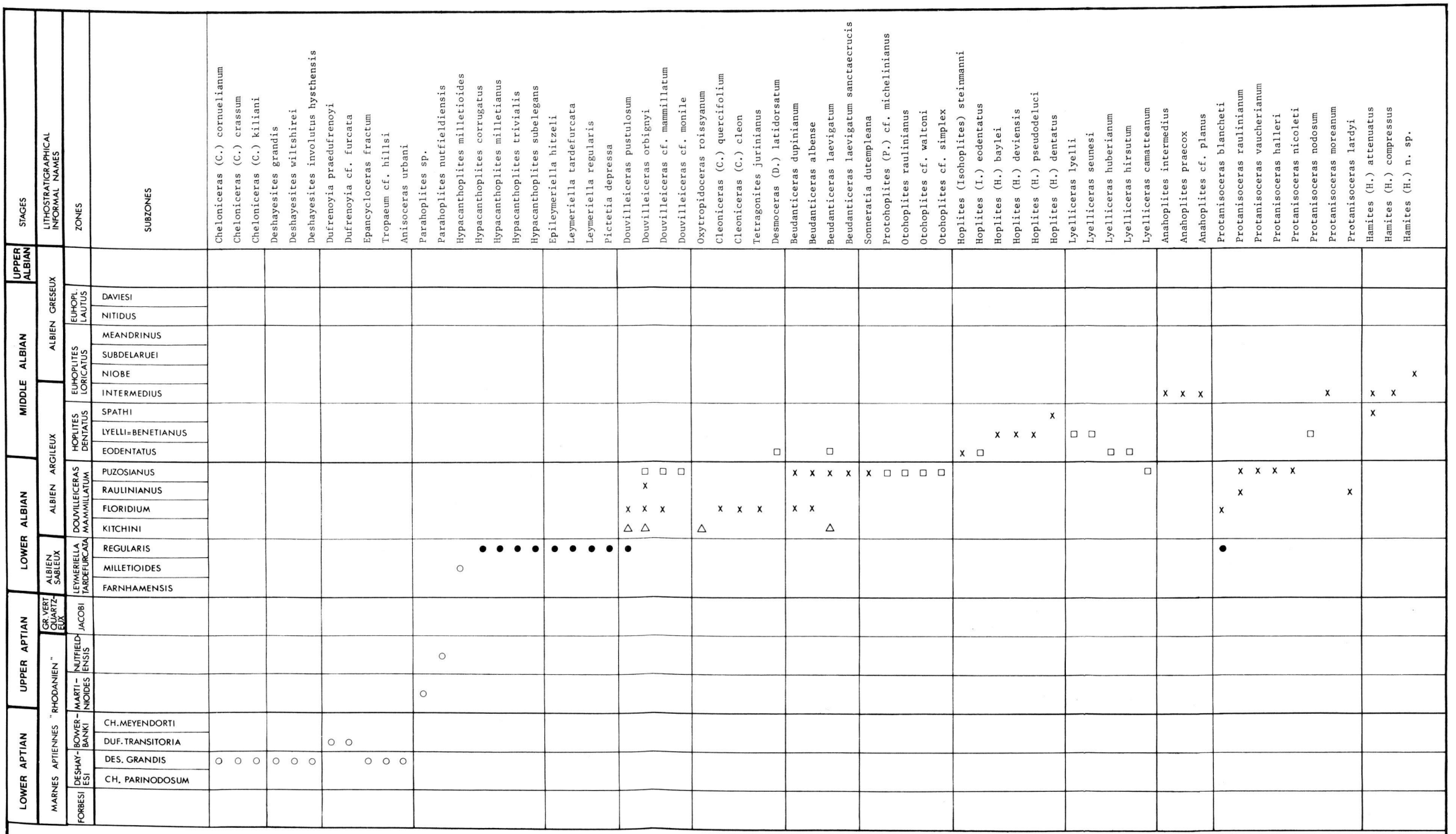
LEGEND:

ALLUVIAL:
- LANDSLIDE

TERTIARY:
- MOLASSE BURDIGALIAN-AQUITANIAN
- LACUSTRINE LIMESTONE LATE BURDIGALIAN

CRETACEOUS:
- CENOMANIAN
- LATE ALBIAN, VRACONNIAN
- MIDDLE - UPPER ALBIAN, "ALBIEN GRESEUX"
- LOWER MIDDLE ALBIAN, "ALBIEN ARGILEUX"
- LOWER ALBIAN, "ALBIEN SABLEUX"
- UPPER APTIAN, "GRES VERT QUARTZEUX"
- UPPER APTIAN, "RHODANIEN"
- BARREMIAN, "URGONIEN"
- HAUTERIVIAN, MARL FACIES
- BERRIASIAN - VALANGINIAN

JURASSIC:
- PURBECKIAN - PORTLANDIAN
- KIMMERIDGIAN
- UPPER OXFORDIAN, SEQUANIEN
- MIDDLE OXFORDIAN, ARGOVIEN
- BIRMENSTORFER BEDS
- LOWER OXFORDIAN, MARLS
- UPPER CALLOVIAN, DALLE NACREE
- AUGER LINES
- ARTIFICAL TRENCHES
- OVERTHRUST



Distribution chart of Aptian ammonites from La Presta (asphalt mine), and of Albian ammonites from the Tertiary basin of L'Auberson

Lithology of the ammonites:

- □ reworked phosphatized ammonites in their original stratigraphical position
- X limonitized ammonites
- △ pyritized ammonites
- ● phosphatized fossils in a quartz arenite
- O Aptian and Lower Albian ammonites from the La Presta asphalt mine