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Fauna, Stratigraphy and Depositional Environment of the Hettangian-Sinemurian (Early Jurassic) of Adnet (Salzburg, Austria)

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53 Text-Figures, 4 Tables and 30 Plates

Dedicated to the Memory of Edith Kristan-Tollmann (1934–1995)

Northern Calcareous Alps
Adnet
Liassic
Stratotype
Biostratigraphy
Facies
Foraminifera
Ammonites
Brachiopods
Ferromanganese Crust
Stable Isotopes

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Fauna, Biostratigraphie und Sedimentologie des Hettang und Sinemur (Unterlias) von Adnet, Salzburg, Österreich

Zusammenfassung

In dieser Studie präsentieren wir eine detaillierte Beschreibung der in den Adneter Steinbrüchen aufgeschlossenen frühliassischen Kalke. Diese bildeten sich während und kurz nach dem Ertrinken der kalkalpinen Obertrias-Riffe. Diese hatten in der Trias die Kontinentalränder des Tethysozeans beherrscht, verschwanden jedoch vollständig zu Beginn des Jura. Wir beschreiben eine spezielle Lias-Fazies der Adneter Steinbrüche, die sich im Übergangsbereich vom vormaligen Riff zum Becken kurz nach dem Obertrias-Riffsterben bildete. Diese Fazies besteht aus bunten massigen bis bankigen Kalken mit reichen Faunen von Kieselschwämmen, Crinoiden, Foraminiferen, Brachiopoden und Ammoniten. Wir schlagen die Bezeichnung "Schnöll-Formation" für diese lithologische Einheit vor, deren Typlokalität der Langmoosbruch bei Adnet ist. Die Schnöll-Formation umfaßt den Zeitraum von der oberen Planorbis-Zone bis zur Marmorea-Zone, also das Hettang. Sie kann in zwei Members unterteilt werden: Das untere Langmoos-Member mit Schwämmen und Schwammnadeln und das obere Guggen-Member, das von Crinoiden-Detritus geprägt ist.

Das Sinemur wird in den Adneter Steinbrüchen durch die Adnet-Formation repräsentiert. Dies sind rote, dünnbankige, oft knollige Kalke. Die Adnet-Formation beginnt mit einem kondensierten Intervall, der "Basal Unit", roten Kalken, die zwischen zwei Eisen-Mangankrusten eingeschaltet sind. Die untere Kruste ist die "Marmorea-Kruste" ("Brandschicht") des Hettang (und Sinemur?), die obere ist die "Basale Sinemur-Kruste", die sich im höheren Sinemur bildete. Letztere ist oft mit Tiefwasserstromatolithen verknüpft. Wir unterscheiden im Sinemuranteil der Adnet-Formation drei lithologisch unterschiedliche Einheiten: Das dünnbankige, knollig-mergelige Schmiedwirt-Member, das Dezimeter-bankige, Mergel-arme Lienbacher-Member, und die Crinoidenkalke des Motzen-Members.

Das Relief zur Ablagerungszeit im Sinemur wurde aus Geopetalgefügen rekonstruiert. Im Bereich nahe am Rhätischen Riffkern finden wir einen nordostfallenden Paläohang mit einem Hangwinkel von 10 bis 15 Grad. Das vertikale Relief betrug ca. 50–80 m. Eine nordwestwärts progradierende Einheit im oberen Hangbereich ist am besten als eine durch Konturströmungen transportierte submarine Sedimentdüne, bestehend aus Crinoiden-Kalkschlamm zu interpretieren. Die großräumigen Geometrien der lithostratigraphischen Einheiten deuten ein komplexes Onlap-Geschehen bei der Anlagerung der Hettang-Sinemur-Sequenzen an das ertrunkene steile Rhätriff-Relief an. Wir halten relative Meeresspiegelschwankungen und die dadurch verursachten Verlagerungen der Ablagerungszentren und der Karbonatbildungsräume für die Hauptfaktoren bei der Bildung der Sedimentkeile. Dagegen finden wir in den Adneter Steinbrüchen keine Hinweise auf großskalige tektonische Verkippungen während dem frühen Lias. Strömungserosion und gravitativer Sedimenttransport am Hang waren die wesentlichen Faktoren bei der Bildung der Litho-Einheiten der Schnöll- und der unteren Adnet-Formation. Weder Mikrofazies noch stabile Isotope geben Hinweise auf meteorische Diagenese am unteren Hang im Zeitraum Hettang-Sinemur. Während der obere Hangbereich möglicherweise im unteren Hettang aufgetaucht war, reichte der Meeresspiegelabfall zu dieser Zeit nicht aus, um die Beckenregionen trockenzulegen. Allerdings führte der Meeresspiegel-Tiefstand zu starker submariner Erosion und Bildung einer Sequenzgrenze am unteren Hang.

Die Ergebnisse der Kohlenstoff- und Sauerstoff-Isotopenanalysen deuten auf eine spätdiagenetische Überprägung der grauen Intervalle, die in die roten Kalke der Schnöll-Formation eingeschaltet sind. In den roten Intervallen sind kaum Änderungen der Kohlenstoff-Isotopenwerte vom Hettang bis ins Unterdomer zu verzeichnen. Dies unterstreicht die Bedeutung des anschließenden Kohlenstoffisotopenmaximums im Toarc, das mit dem Posidonienschiefer-Event im Zusammenhang steht. Die hohen Sauerstoffisotopenwerte der Schnöll- und Adnet-Formation passen gut zu dem aus der Mikrofazies ersichtlichen Ablagerungsmilieu in kaltem Tiefenwasser unterhalb einer Pycnokline. Eine sehr auffällige Sauerstoffisotopen-Exkursion an der Basis der Marmorea-Kruste im Schnöll-Bruch läßt sich nur schwer durch meteorischen Einfluß erklären. Sie deutet eher auf spätdiagenetische Rekristallisation und Überprägung im Bereich der Kruste hin. Die Kruste selbst ist in diesem Steinbruch sekundär pyritisiert.

Weitere geochemische Untersuchungen zeigen deutliche Unterschiede zwischen der Marmorea-Kruste und der basalen Sinemurkruste. Die Marmorea-Kruste weist eine besondere chemische Zusammensetzung auf. Sie hat einen extrem hohen Eisengehalt und sehr niedrige Spurenmetall-Gehalte. Zwei mögliche Interpretationen werden diskutiert: Bildung aus hydrothermalen Fluiden oder fluviatiler Einfluß in einem eingeschränkten Epikontinentalmeer.

Die Foraminiferenfauna der Schnöll- und unteren Adnet-Formation wird von Involutiniden dominiert. Die große morphologische Variabilität zahlreicher Arten wird dokumentiert. Einzelne Taxa, wie z.B. *Semiinvoluta clari* Kristan, konnten erstmals im kalkalpinen Lias nachgewiesen werden.

Im Schnöll-Bruch sind drei Ammonitenzonen vorhanden. Die Planorbis Zone des frühen Hettang ist durch *Psiloceras calliphyllum* (Neum.) belegt, die im Steinbruch XXXI unmittelbar unter dem ersten Spongien-Horizont des Langmoos-Mb. der Schnöll-Formation auftritt. Der Spongien-Horizont repräsentiert die Liasicus Zone des Mittel-Hettang, während in der "Brandschicht" ("Marmorea Crust") eine reiche Ammoniten-Vergesellschaftung der Liasicus und "Marmorea" Zone sensu Wähner nachgewiesen werden kann. Im Langmoos-Bruch weist der liegende Hartgrund eine Ammoniten-Vergesellschaftung des Mittel-Hettang auf.

Die Arten- und Individuen-reichsten Brachiopoden-Vergesellschaftungen wurden in der Schnöll-Formation (insbesondere in der Liasicus Zone) der Steinbrüche XVII und XXXI nachgewiesen. Rhynchonelliden dominieren im Langmoos-Bruch, wie z.B. *Prionorhynchia fraasi* (Oppel), *"Rhynchonella"* ex gr. *belemnitica* (Quenst.) und *Cirpa* aff. *latifrons* (Geyer). Das Brachiopoden-Faunenspektrum der Schnöll-Formation ist jenem des Sinemur der klassischen Lokalität Hierlatz bei Hallstatt sehr ähnlich, das von Oppel (1861) und Geyer (1889) beschrieben wurde. Lediglich *Dispiriferina* aff. *segregata* (Di-Stefano), die von unweit nördlich des Bruches XXXI stammt, stellt ein Fremdelement dieses Faunenspektrums dar und zeigt stärkere Beziehungen zu den südeuropäischen Brachiopoden-Assoziationen. Die Brachiopoden-Vergesellschaftungen der roten kondensierten Adneter Kalke mit Fe/Mn-Krusten in den Brüchen XII, XVII, XXX und XXXI entsprechen den Assoziationen der "Marmorea" Zone der Steinplatte (Siblík, 1993a).

Abstract

In this paper we give detailled descriptions of the Early Liassic variegated limestones outcropping in the quarries of Adnet. These limestones formed during and shortly after the drowning of the Late Triassic reefs, which had flourished along the Tethyan continental margins for most of the Triassic but vanished completely at the beginning of the Jurassic. We describe a peculiar facies from the Adnet quarries that formed at the transition from the former reef to the basin shortly after the end-Triassic reef drowning. This facies consists of variegated massive to bedded limestones with rich faunas of siliceous sponges, crinoids, foraminifera, brachiopods and ammonites. The term "Schnöll-Formation" is introduced for this lithologic unit with the type section at the Langmoos Quarry, Adnet. The Schnöll-Formation comprises the period from the upper Planorbis Zone until the Marmorea Zone, i.e. it is of Hettangian age. It can be subdivided in two members, the lower Langmoos-Mb. with abundant sponges and sponge spicules and the upper Guggen-Mb., dominated by crinoidal debris.

The Sinemurian of the Adnet area is made up by the lower Adnet-Formation, red, thin-bedded, often nodular limestones. It starts with the condensed Basal Unit, red limestones intercalated between two ferromanganese crusts, the lower "Marmorea Crust" of Hettangian (-Sinemurian?) age and the upper "Basal Sinemurian Crust" that formed during the higher Sinemurian. The latter crust is often connected with deepwater stromatolites. Three lithostratigraphic members of the Sinemurian Adnet-Formation are recognized in the Adnet quarries: The thin-bedded, nodular-marly Schmiedwirt-Mb., the decimetre-bedded, marl-poor Lienbacher-Mb., and the crinoidal limestones of the Motzen-Mb.

The depositional relief during the Sinemurian is reconstructed from the attitude of geopetal fabrics. We find a northeast dipping palaeoslope with an angle of 10 to 15 degrees in the area close to the Rhaetian reef. The vertical relief was probably on the order of 50–80 m. A unit prograding towards the northwest is found in the upper part of the slope. It most likely represents a contour current driven sediment wedge of crinoidal carbonate mud. The large-scale geometries of the lithostratigraphic units point to a complex onlap history of the Hettangian-Sinemurian post-drowning sequences on the steep constructional topography of the Rhaetian reef. The geometries are interpreted as controlled by relative sea-level fluctuations with the resulting shifts of depocenters and "carbonate factories". We find no evidence for large-scale tectonic tilting during the early Liassic in the Adnet area. Current erosion and downslope sediment transport played a major role for the formation of the lithologic units of the Schnöll- and lower Adnet-Formations. Neither microfacies nor stable isotopes indicate meteoric diagenesis at the lower slope during the Hettangian or Sinemurian. So, while the upper slope may have been subaerially exposed during the early Hettangian, the sea-level drop was not sufficient to expose the basinal area. Nevertheless, it caused strong submarine erosion at the lower slope.

The stable isotope results point to a late diagenetic overprinting of the grey intervals intercalated with red limestones in the Schnöll-Formation. For the red layers there is very little variation in the carbon isotopic composition from the Hettangian until the lower Domerian. This is in contrast to the subsequent Toarcian carbon isotope excursion of the *Posidonia* shale event. The high oxygen isotope values of the Schnöll- and Adnet-Fm. are compatible with the environmental setting in cool deeper-water, below a pycnocline, as deduced from microfacies analysis. A very pronounced negative oxygen isotope excursion at the base of the "Marmorea Crust" in the Schnöll Quarry can hardly be explained by meteoric diagenesis. It rather points to late diagenetic overprinting and recrystallization connected with the crust, which itself is strongly pyritized in this quarry.

Further geochemical investigations of the "Marmorea Crust" and the Basal Sinemurian Crust show a clear distinction of the two crusts. The "Marmorea Crust" displays a unique chemical composition with a very high iron content, but low trace metal contents. Two possible explanations are discussed: formation from hydrothermal fluids or continental influx in a semi-enclosed basin.

The foraminifera assemblages of the Schnöll- and lower Adnet-Formation are dominated by Involutinids. The enormous morphologic variability of several species is documented. Some taxa, e.g. *Semiinvoluta clari* KRISTAN, are recorded for the first time in the Alpine Liassic.

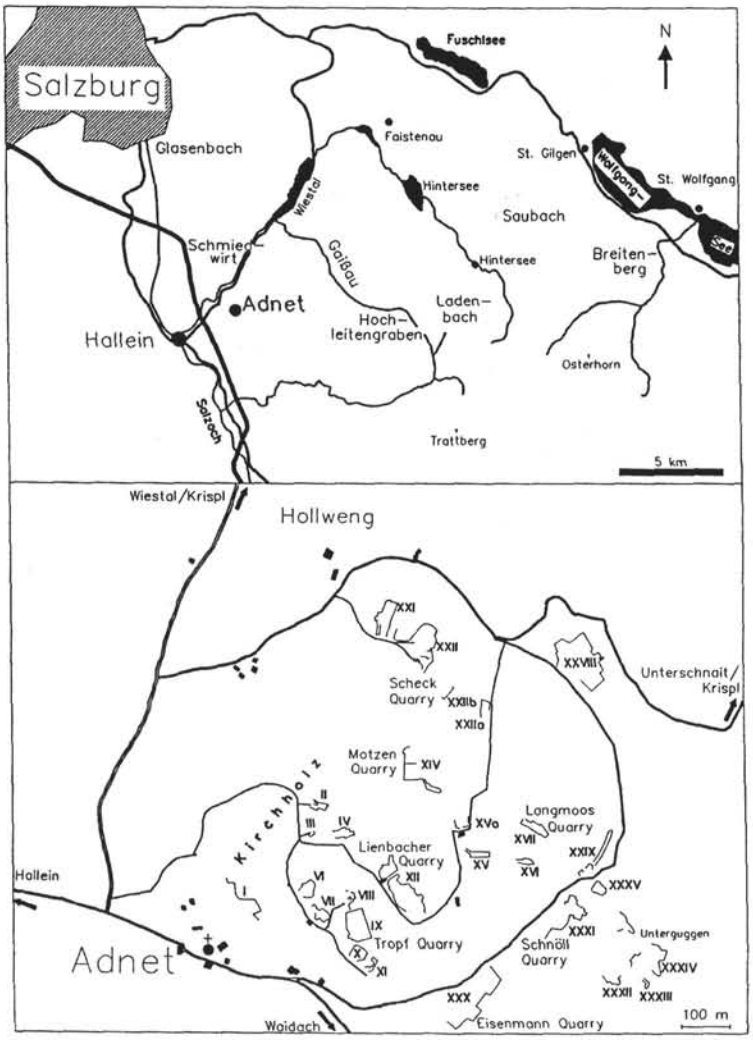
In the Schnöll Quarry ammonites prove the presence of 3 ammonite zones in the Schnöll-Formation. The Early Hettangian Planorbis Zone is confirmed by *Psiloceras calliphyllum* (NEUM.) just below the first sponge horizon. The sponge horizon represents the Middle Hettangian Liasicus Zone and the "Brandschicht" shows a rich ammonite assemblage of the Liasicus and "Marmorea" Zones sensu WÄHNER. In the Langmoos Quarry the lower hardground also yields a Middle Hettangian ammonite assemblage.

The most varied and numerous brachiopod fauna in the Adnet quarries was found in the Schnöll-Formation (mostly Liasicus Zone) of the quarries XVII and XXXI. In the brachiopod fauna of the Langmoos Quarry rhynchonellids prevail, e.g. *Prionorhynchia fraasi* (OPPEL), *"Rhynchonella"* ex gr. *belemnitica* (QUENST.) and *Cirpa* aff. *latifrons* (GEYER). However, the total specific composition of the brachiopod fauna of the Schnöll-Formation reminds one of the Sinemurian brachiopod assemblage of the Hierlatz locality near Hallstatt, described by OPPEL (1861) and GEYER (1889). Only *Dispiriferina* aff. *segregata* (DI-STEFANO) from N of the quarry XXXI is an alien element in the total fauna, and has more affinities to the South European brachiopod assemblages. Brachiopod assemblage of the red condensed limestone with Fe/Mn crusts ascertained in the quarries XII, XVII, XXX and XXXI is characteristic and corresponds to the "Marmorea" Zone assemblage at Steinplatte (SIBLÍK, 1993a).

1. Introduction

This paper summarizes the results of various research activities obtained during the last years on the lower part of the Liassic Adnet Limestone Group. Based on previous studies (BÖHM, 1992; DOMMERGUES et al., 1995; BÖHM et al., 1995) the first author of this paper in cooperation with Leopold KRYSTYN updated and completed his research on the various Liassic rock units in the quarries of Adnet locus classicus. At the same time a "Liassic working group" was established in the framework of the bilateral cooperation programme between the Austrian Geological Survey and the Slovak Geological Survey, respectively, the Czech Academy of Sciences, the Hungarian Museum of Natural History and the University of Budapest, Palaeontological Department and the University of München, Palaeontological Department. This Liassic working group performs part of the Austrian Geological Survey's working programme named "Stratotypes of the Northern Calcareous Alps". The study of ammonites is in the hands of Miloš RAKÚS, Miloš SIBLÍK studies the brachiopods, Oskar EBLI is responsible for the micropalaeontology and part of the microfacies interpretation, while Harry LOBITZER assists in fieldwork and facies interpretation. So far field work of this working group was focused on the locus classicus of Hierlatz and on Adnet; also the Liassic of Steinplatte/Kammerköhralm was studied and several papers were published (e.g. HLADIKOVÁ et al., 1994; BÖHM et al., 1997b; LOBITZER et al., 1994; RAKÚS, 1999a, b; RAKÚS & LOBITZER, 1993; RAKÚS et al., 1993; SIBLÍK, 1993, 1993a; WAGREICH et al., 1996). The study of gastropods in the Hierlatz papers was performed by János SZABO, while István SZENTE (both Budapest) studied the bivalve assemblages (SZENTE, 1996). In a basic paper Attila VÖRÖS (1991) reflects the change of meaning of Hierlatzkalk, which was originally described as brachiopod-bearing limestone. Later its meaning was synonymous with Liassic crinoidal limestones. The question, how to deal with the various rock types of Hierlatz Limestone-Group versus Adnet Limestone-Group from the nomenclature point of view remains to be solved in the future.

The dedication of this paper to the late colleague Mrs. Edith KRISTAN-TOLLMANN results from the fact, that Mrs. KRISTAN-TOLLMANN before her early death cooperated intensively with our working group. We will never forget her.



Text–Fig. 1.
Location maps of the Osterhorn block (top) and Adnet area (bottom). Quarry numbers according to KIESLINGER (1964).

1.1. Regional Setting

The quarries of Adnet are located to the northeast and east of the village of Adnet (Pl. 2, Fig. 1), which is situated about 10 km southeast of the city of Salzburg (Text-Fig. 1). The Adnet area is part of the Osterhorn block, a tectonic unit in the northern portion of the Tyrolic nappe system of the Northern Calcareous Alps (PLÖCHINGER, 1989). Upper Triassic coral reef limestones and Liassic red hemipelagic limestones are exploited in the Adnet quarries. The quarries were described, catalogued and numbered by KIESLINGER (1964).

The limestones of the Rhaetian Adnet Reef (SCHÄFER, 1979; BERNECKER et al., 1999) interfinger to the north with basinal limestones and marls of the Kössen-Formation (KUSS, 1983). Reef growth stopped at the end of the Triassic (SCHÄFER, 1979; ZAPFE, 1963) and was followed by a Liassic series of hemipelagic limestones and marls (BÖHM, 1992). A facies differentiation due to the inherited Rhaetian relief is clearly visible until the middle Liassic: The former reef and upper slope are covered by red condensed limestones of the Adnet-Formation after a pronounced hiatus (WENDT, 1971), while the basinal Kössen beds continuously pass into grey marls of the Kendlbach-Formation (GOLEBIOWSKI, 1990; HALLAM & GOODFELLOW, 1990; HALLAM, 1994; BLAU & GRÜN, 1994), and further on into the grey cherty limestones of the Scheibelberg-Formation (BERNOULLI & JENKYNS, 1970; BÖHM, 1992).

At the transition between former reef and basin a peculiar Hettangian facies occurs with partly massive variegated limestones rich in siliceous sponges, crinoids, brachiopods and ammonites. Facies, fauna and sedimentology of this so-called Schnöll limestone (KIESLINGER, 1964; WENDT, 1971; BÖHM, 1992) are the major topic of this paper.

In Plate 1 some of the very decorative types of polished stone of the Schnöll- and Lower Adnet-Formations are demonstrated. For more details on this issue the reader should refer to the books by KIESLINGER (1964) and KRETSCHMER (1986).

1.2. Previous Research

Red ammonite-bearing limestones ("marbles" of the stone cutters) of the Adnet region are mentioned in many early publications (e.g. PARTSCH, 1826). Already since Roman time and in particular from the Gothic period onward till the Present the Adnet limestones (including also Rhaetian "Oberrhätkalk" besides the Liassic types) are used extensively as decoration stone in particular in sacral art.

BOUÉ (1829) states, that ammonites together with a few small nautiloids seem to be frequent in certain beds of reddish limestones ("marbles"), e.g. in Adnet. In addition he mentions the presence of ichthyolites.

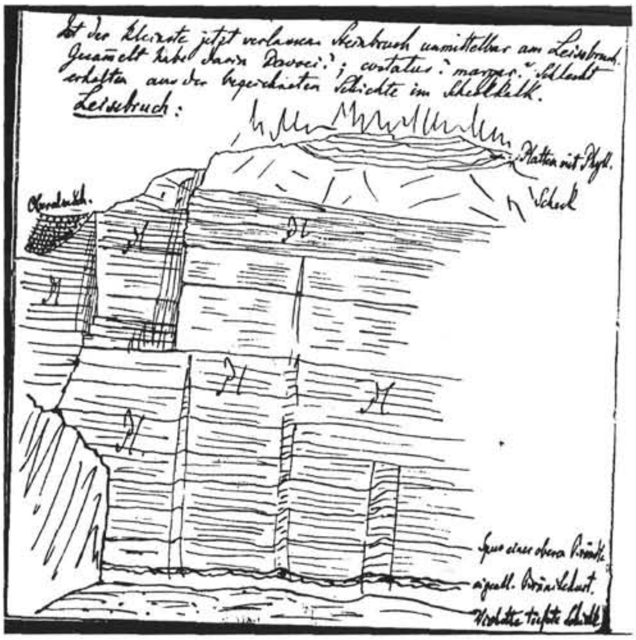
In their famous paper "A Sketch of the Structure of the Eastern Alps,..." SEDGWICK & MURCHISON (1831) mention "deep red-coloured limestone, distinguished by a multitude of broken stems of Encrinites, together with some Ammonites, Belemnites, casts of bivalves, &c. This limestone is largely developed in the great valley of the Salza, on the west side of which it ranges beneath the salt deposit of Hallein, and on the east side it is extensively quarried at Wiesthal as well as some other places."

Already in 1833 LILL von LILIENBACH assignes these red limestones of Wiesthal (Schmiedwirt-Member of this paper) to the Liassic, however, he still merges also the red Triassic limestones of Aussee, Ischl and Hallstatt to the Liassic "Lower Group of Alpenkalk".

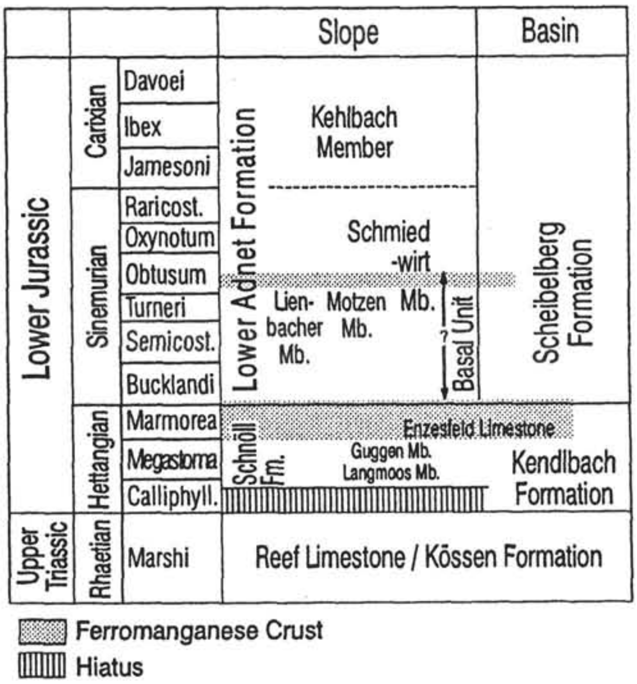
MORLOT (1847) argues, that the ammonite-rich red and yellow limestones in the quarries nearby Adnet probably can be assigned to the middle part of the Alpenkalk. Further he concludes that these "Adneter Schichten" represent rocks different from the red Hallstatt limestones, because also HAUER could not identify a single ammonite taxon in these red limestones which resemble those found in Hallstatt or Aussee.

In his monographic treatise QUENSTEDT (1849) deals already with the systematic and stratigraphic position of the Adnet ammonites, which he considers as absolutely different from the Hallstatt ones. According to his opinion, many taxa closely resemble Liassic ones, however, nothing definitely proves this age assignment.

In a short note KUDERNATSCH (1851) states, that corresponding to the opinion by LIPOLD (1851) all so far identified ammonite taxa from Adnet are exclusively of Liassic age.



Text–Fig. 2.
Drawing of Wimberg- or Platten- (former Leiss-) Quarry by STUR (1875). On top of the Scheck-Formation limestone beds with *Phylloceras* cf. *capitanei* were cropping out.



Text–Fig. 3.
Stratigraphic framework for the Adnet area. The precise chronostratigraphic position of the Basal Sinemurian Crust, which forms the top of the Basal Unit, is uncertain. The Marmorea Crust may extend to the Megastoma and Bucklandi Zones. "Slope" and "basin" refer to the inherited Rhaetian morphology.

Already in 1851 CŽJŽEK mentioned the variegated "Adneth marbles" as well-known, for their widespread usage as decoration stone throughout the Austrian-Hungarian monarchy and in Bavaria. Further on he states, that "these limestones belong to the red ammonite marbles of the Alps, which belong to the Liassic". LIPOLD (1851b) refers to chemical analyses of various limestones from occurrences south of Salzburg, e.g. from Hochleitengraben.

The Adnet "marbles" of Hochleitengraben near Gaissau and of the classical quarries nearby Adnet are described in two profile sections by LIPOLD (1851).

In one of his key papers HAUER (1853) states, that based on the field results and extensive palaeontological studies the main part of the Alpenkalk of the northeastern Alps is of Liassic age. The Kössen-Formation, Dachstein Limestone and Gresten-Formation according to HAUER (l.c.) belongs to the Lower Liassic, while the Adnet Limestones, Fleckenmergel and Hierlatz-Formation are part of the Upper Liassic. In a basic paper on the stratigraphy of the Mesozoic of the Northern Calcareous Alps, HAUER (1853) distinguishes in the calcareous developments of the Late Liassic (see discussion before) two facies developments, namely the cephalopod-rich Adnet Group and the brachiopod-crinoid-rich Hierlatz Limestone. The cephalopod assemblage HAUER's (l.c.) contains taxa comprising a stratigraphic range from the Early Sinemurian to the Middle Toarcian (WENDT, 1971).

In his excellent monographic synthesis on the geology of the Bavarian Alps GÜMBEL (1861) concludes, that the lumping and mixing-up of various very similar looking red limestone types (e.g. Hallstatt- and Adnet-Limestones) contributed to a fatal confusion in respect to a better understanding of Alpine stratigraphy. In addition the Austrian geologists (e.g. HAUER, 1853) erroneously ranked the underlying rock units of the Adnet Limestone, as the Dachstein Limestone, the Kössen-Formation and the Hauptdolomit, into the Early Liassic. It is the merit of GÜMBEL (1862), who convinced his distinguished Viennese colleagues (in particular HAUER), that the latter rock units are part of the Upper Triassic sequence.

In his unrivaled textbook on the "Geology of Styria" STUR (1871) compares the ammonite fauna of Adnet with other Liassic rock units and states, that the ammonites prove an age comprising the Lower, Middle and Upper Liassic (Lias Beta to Zeta, while Lias Alpha is missing). It should be mentioned here, that STUR started very detailed field investigations in the Adnet quarries, as documented in his field note books (STUR, 1875, see Text-Fig. 2). Already before the classic papers by WÄHNER (l.c.) he recognized, that the various Adnet facies show different stratigraphic ages.

The monographic studies on Liassic ammonites by WÄHNER (1882–1898, especially 1903) laid the foundation for the stratigraphy of the Alpine Liassic, in particular also for the Adnet sequence.

From the palaebiogeographical point of view the poor gastropod fauna of the Adnet Limestone Group belongs to the Alpine Subprovince of the "Mediterranean" faunal province (NEUMAYR, 1872; SZABO, 1994). However, as SZABO states (oral comm.) for the Liassic gastropod faunas of the Northern Calcareous Alps (e.g. Hierlatz and Adnet) modern studies are still missing. The gastropod assemblage described from the Early Liassic by AMMON (1893) according to his description of the mother rock, however, most probably seems to be part of the Late Triassic Oberrhätkalk assemblage and not of the Liassic one. Also the bivalve fauna of the Adnet-Group is very poor and a modern study is completely missing. The bivalve assemblages of the Hierlatzkalk were studied recently by SZENTE (1996).

A real milestone in the literature on Adnet is the concise paper by WÄHNER (1903), who described several of the most important Adnet quarries, their facies, fossil content and biostratigraphy. This paper was of course based on his previous extensive biostratigraphic research on the Adnet Liassic ammonites (WÄHNER, 1882–1898). WÄHNER already recognized that the onset of Liassic sedimentation took place at varying Liassic stages in the different outcrops.

In a number of exellent working reports published between 1957 and 1968 SCHLAGER provided the first detailed description of the geology and all the lithologic units encountered in the Adnet region. The results of his studies are also documented in a coloured geological map 1:10.000 (SCHLAGER, M., with contribution by SCHLAGER, W., 1960). The outstanding book by KIESLINGER (1964) documents the state of research on all the Adnet Quarries. All operating and important historic quarries are numbered, described and assessed in respect of their quality and reserves. A main focus of this book is laid on the various rock types with a view to their potential usage as polished stones. KIESLINGER's unique book is also highly estimated by art historians, because the author summarizes the artistic applications of the variegated Adnet rock types by sculptors and stone cutters through the centuries.

Modern sedimentological research on the various limestone types of Adnet-Group was started by HALLAM (1967), followed by several important papers by British sedimentologists and geochemists (e.g. HUDSON & JENKYNS, 1969; HUDSON & COLEMAN, 1978; JENKYNS, 1974). The most important modern paper on ammonite biostratigraphy of Adnet locus classicus was published by WENDT (1971); he also performed a concise sedimentological analysis. In correspondence with WÄHNER (1882–1898; 1903), WENDT was able to confirm a stratigraphic range of the Adnet sequence from the Hettangian till the earliest Toarcian. Nearby Adnet, in the Mörtlbach section, WENDT's (l.c.) ammonite findings also confirmed the presence of Late Toarcian-Aalenian ammonites in red limestones of Adnet-type, which are at present not exposed in the Adnet Quarries. However, it must be mentioned, that the Adnet Limestone above the Scheck-Formation yielded ammonites of latest Liassic/Early Dogger age during the collecting in the last century (RAKÚS, 1999a). An interesting paper by VÖRÖS (1991) compares the litho- and biofacies of Austrian and Hungarian Hierlatz Limestones.

MEIXNER (1976), MEIXNER (in BECKER et al., 1977) and STRASSER (1975) report about mineralisations in the Adnet Limestone of Wimberg, Schnöll and Lienbacher Quarries. In the Wimberg Quarry MEIXNER (1976) identified native copper and the yellow Cu-V-mineral tangeite. STRASSER (1975) reports about native sulfur in the Schnöll-Formation. MEIXNER (in BECKER et al., 1977) describes coatings of malachite, azurite, yellow tangeite, bornite, pyrite, barite and chalcocite, which in part is altered to covelline.

In the future an attempt will be made to dissolve various types of Adnet Limestone in concentrated acetic acid in order to recover planktonic foraminifers. GÖRÖG (1994) successfully dissolved samples of Pisznice Limestone of ?Hettangian age from the Gerecse Mountains in northern Hungary and recovered well preserved planktonic foraminifers for SEM studies.

Additional informations concerning previous research on Adnet Limestone Group can be found in chapters 3.1., 3.2. and 3.3.

2. Stratigraphy and Sedimentology

2.1. Lithostratigraphic Units (Text-Fig. 3)

2.1.1. Kendlbach-Formation (Hettangian)

In basinal settings the marly limestone series of the Kössen-Formation are overlain by grey marls and limestones of the Kendlbach-Formation (PLÖCHINGER, 1982). GOLEBIOWSKI (1990) differentiated a lower member with peloidal wackestones, poor in bioclasts (Tiefengraben Mb.), and an upper member characterized by the occurrence of bioclastic limestones, partly rich in glauconite (Breitenberg-Mb.). BLAU & GRÜN (1994) contrary to the original definition used the strongly decreasing marl content in the upper part of the Kendlbach-Fm. for discriminating the Breitenberg-Member. With that, they placed the base of the Breitenberg-Mb. several metres too high in their section.

At Adnet only the upper part of the Breitenberg-Mb. is exposed in quarry XXII (Scheck Quarry; Text-Fig. 5): nearly 3 m of thin-bedded limestones with thin marl layers. A nearly complete section of the Kendlbach-Fm. is exposed at the Hochleitengraben, about 5 km east of Adnet (Text-Figs. 4, 5). At quarry XXII as well as at the Hochleitengraben 1.3 m of reddish crinoidal limestones overlie ca. 1.5 m of grey spiculitic limestones (Text-Fig. 5). A similar succession is found in the concurrent Schnöll-Fm. as described below (spiculitic Langmoos overlain by crinoidal Guggen-Mb.). Descriptions of the microfacies of the Kendlbach limestones can be found in BLAU & GRÜN (1994) and BÖHM (1992).

2.1.2. Adnet-Group (Hettangian-Toarcian)

In the Adnet area the Adnet-Group (mostly red limestones and marls of Liassic age) shows a subdivision into two formations: The variegated limestones of the Schnöll-Formation underly the red limestones of the Adnet-Formation (Text-Fig. 3).

2.1.2.1. Schnöll-Formation (Hettangian)

We propose the term "Schnöll-Formation" for a unit of thick to thin bedded grey, yellow, violet and red biomicritic limestones exposed in several Adnet quarries (Pl. 1, Figs. 1-3; Pl. 2, Fig. 3; Pl. 3, Figs. 3, 4; Pl. 4, Figs. 1-2). The name "Schnöll" is derived from the quarrymen's term for this facies (KIESLINGER, 1964). GALLET et al. (1993) informally used the term "Unnamed Formation" for this unit. The Schnöll-Fm. can be divided in a lower part of sponge-rich limestones, partly with stromatactis (Langmoos-Member), and an upper part with crinoidal limestones (Guggen-Member). The best outcrops are found in Quarry XXXI (Schnöll Quarry, Text-Fig. 15) and XVII (Langmoos Quarry, Text-Figs. 5, 12).

Type section: Adnet (Salzburg, Austria), Quarry XVII (Langmoos Quarry, Text-Figs. 5, 12). Exposed thickness 12 m.

Distribution: The Schnöll-Fm. rests on Rhaetian limestones of the lower slope facies of the drowned Adnet reef. It is found in Quarries XV, XVI, XVII, XXIX and XXXI, as well as in small outcrops between Quarries XII and XVI and at small cliffs southeast of Quarries XVI and XVII.

Boundaries: The Schnöll-Fm. is bounded by disconformities at the base and at the top. The lower boundary is a disconformity with more or less obvious indications of an erosive phase. It shows an abrupt facies change from the grey grain- and packstones of the underlying "Oberrhätkalk" to varicoloured spicule-rich wacke- and mudstones of the Schnöll-Fm. The base of the Schnöll-Fm. is not exposed in the type section and only badly exposed at a cliff immediately to the southeast of Quarry XVI. As exposed in the cliff, the "Oberrhätkalk" is capped by a roughly 30 cm thick yellow limestone layer (Kendlbach facies) followed by cream and violet-grey spiculitic wackestones of the Schnöll-Fm. Southeast of Quarry XII red stromatactis-spicula wackestones of the Schnöll-Fm. rest immediately on grey Rhaetian limestones. In Quarry XXXI (Schnöll Quarry) the Schnöll-Fm. starts with a sponge-rich layer above an erosional surface capping grey packstones (Pl. 1, Fig. 1; Pl. 3, Figs. 1-3; Pl. 4, Fig. 1), which in their microfacies show affinities to the Hettangian Kendlbach-Fm. (BÖHM, 1992).

The upper boundary is clearly marked by a conspicous ferromanganese crust (Pl. 2, Fig. 3) with a very rich ammonite fauna, dominated by *Schlotheimia marmorea* (e.g. DOMMERGUES et al., 1995). We introduce the term "Marmorea Crust" for this important stratigraphic marker (e.g. WENDT, 1971; BÖHM, 1992). It is overlain by red well bedded mud- and wackestones of the Adnet-Fm.

Stratigraphy: From the thin yellow layer intercalated between Oberrhätkalk and Schnöll-Fm. a *Parapsiloceras naumanni* pointing to the upper Planorbis Zone was described by GALLET et al. (1993). The ferromanganese crust at the top of the Schnöll-Fm. yields a rich ammonite fauna of the ?Liasicus and Marmorea Zones (Text-Figs. 12, 15; chapter 3.2; WENDT, 1971; GALLET et al., 1993; DOMMERGUES et al., 1995).

Subdivision: Two members can be differentiated based on micro- and macrofacies. The lower member (Langmoos-Mb.) is characterized by an abundance of siliceous sponge spicules (mainly MF9 of BÖHM, 1992) and occasional enrichments of brachiopods (Pl. 1, Fig. 3; chapter 3.3.). Sponge skeletons (Pl. 1, Fig. 2) and stromatactis may occur. This member is well exposed at the Langmoos, that is in Quarries XV to XVII. It is also present at the very base in the northern part of Quarry XXXI (Text-Fig. 15).

The upper member (Guggen-Mb., Pl. 3, Fig. 4) shows a predominance of crinoidal debris. Sponge skeletons may still occur (Pl. 1, Fig. 1), but sponge spicules are rarer than in the underlying Langmoos-Member. The Guggen-Mb. is present in all quarries exposing the Schnöll-Fm. and can best be studied in Quarry XXXI (Text-Fig. 20), situated on the western slope of the Unterguggen.

Enzesfeld Limestone (Middle-Late Hettangian)

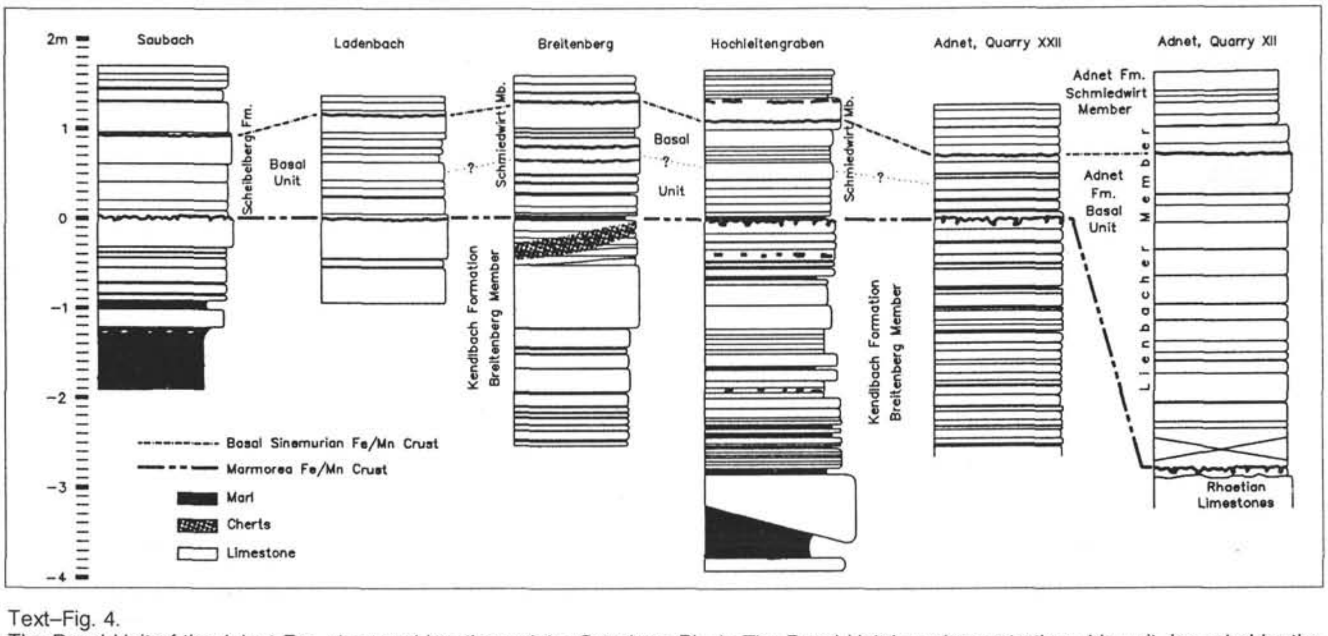
We use this term for a special yellow-red facies marking the top of the Hettangian in many sections at Adnet. It is characterized by a special bioclastic microfacies, very rich in foraminifera (mainly Involutinids and Nodosariids) and ostracodes (MF10 of BÖHM, 1992; TOLLMANN, 1976: Fig. 188; Biofaziesbereich 3 of BLAU & GRÜN, 1994). Throughout the Adnet area this facies is constrained to a thin (<40 cm, Text-Fig. 5) condensed limestone bed capped by the conspicuous ferromanganese crust of the Marmorea zone ("Marmorea Crust").

The same microfacies occurs at the top of the Breitenberg-Mb. in the basinal settings (Kendlbach-Fm., e.g. at Gaißau, Breitenberg, Saubach; BÖHM, 1992). The major difference is that the limestones in most basinal settings are grey. This can be explained by lower bottom water oxygenation or higher sedimentation rates in the basin, allowing reduction of Fe^{3+} during early burial (BURDIGE, 1993). But, also in some of the basinal settings coloured "Enzesfeld limestones" occur at the very top of the Breitenberg-Mb. This points to local high oxygenation rates at the end of the Hettangian in some basinal settings (e.g. Hochleitengraben, Breitenberg, BÖHM, 1992).

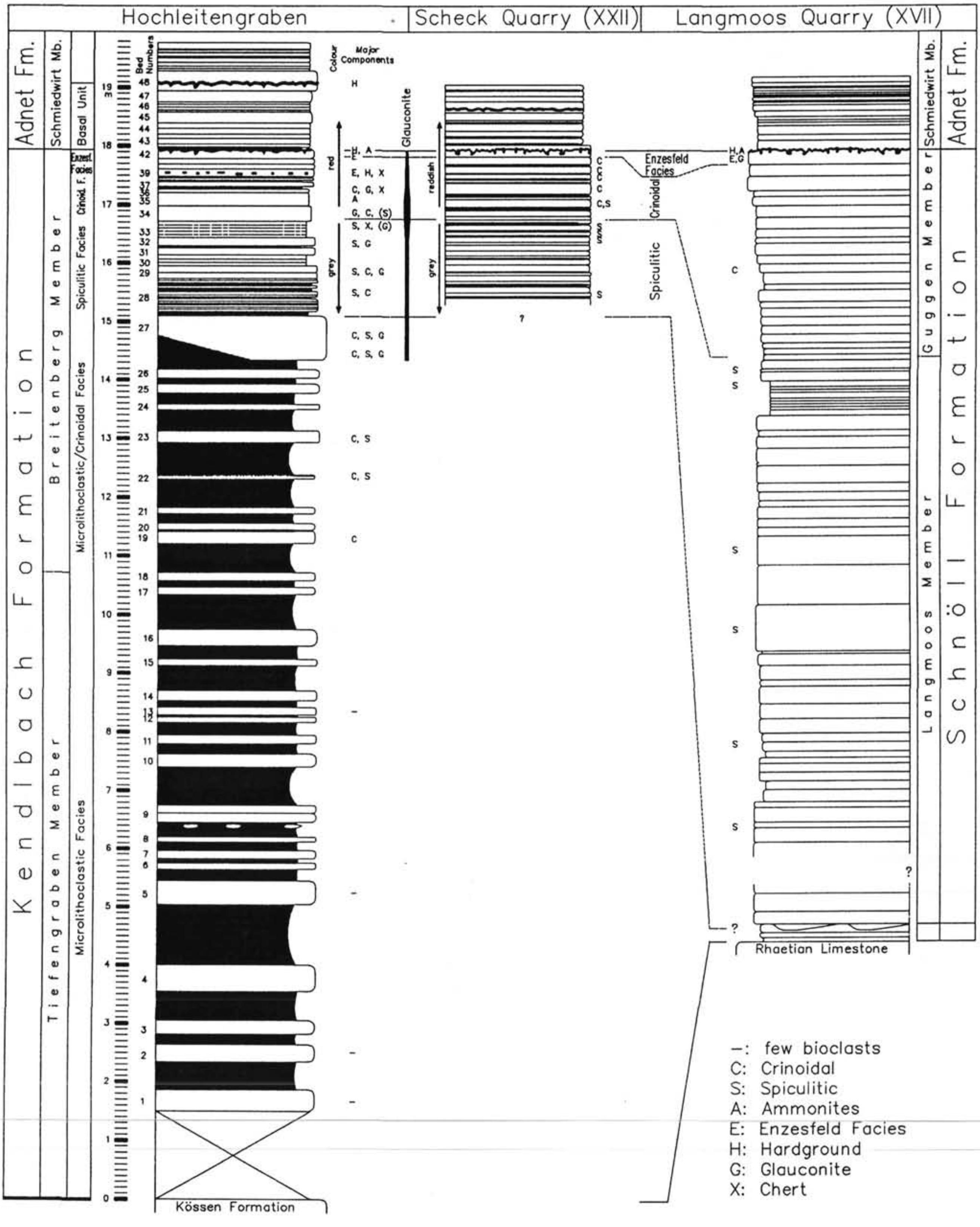
We do not use "Enzesfeld Limestone" as a lithostratigraphic term in the rank of a formation or member in the Adnet area, but for describing a coloured bioclastic facies occurring in a thin layer forming either the top of the Schnöll-Fm. or the top of the Kendlbach-Fm. (Breitenberg-Mb.).

2.1.2.2. Lower Adnet-Formation (Sinemurian-Carixian)

The Sinemurian in the Adnet area is represented by the red limestones of the Adnet-Fm. According to BÖHM et al. (1995) the **Lower Adnet-Fm.** (Text-Fig. 3) mainly consists of



Text–Fig. 4.
The Basal Unit of the Adnet-Fm. at several locations of the Osterhorn Block. The Basal Unit is a chronostratigraphic unit, bounded by the Marmorea Crust and the Basal Sinemurian Crust. It can be recognized in different facies at the base of the Adnet-Fm. (Lienbacher- and Schmiedwirt-Mb.) and at the base of the Scheibelberg Fm. (at Ladenbach and Saubach). A twofold division with a thicker bed near the middle of the unit is visible in some sections. Except for quarry XII, the base of the sections is formed by the Kendlbach-Fm. At Breitenberg the Marmorea Horizon is not marked by a ferromanganese crust, but ammonites of this level show ferromanganese coatings. The Basal Unit starts with a pronounced marl layer in this section and at Hochleitengraben. For further informations on the Breitenberg, Ladenbach and Saubach sections see BÖHM (1992).



Text–Fig. 5.
Kendlbach-Fm. at Hochleitengraben and Scheck Quarry (XXII) compared to Schnöll-Fm. at quarry XVII. Spiculitic, crinoidal and Enzesfeld facies occur on top of the Kendlbach-Fm. (upper Breitenberg Mb.) as well as in the Schnöll-Fm. (Langmoos- and Guggen-Mb.). A fourth microlithoclastic/crinoidal facies forms the lower part of the Breitenberg-Mb. at Hochleitengraben. At quarry XXII the lower part of the Breitenberg-Mb. is not exposed. The microlithoclastic facies is lacking in the Schnöll-Fm. of quarry XVII. It may be represented by thin lenses of peloidal packstone, exposed at the base of the Schnöll at a cliff east of quarry XVII (drawn at the base of the Langmoos section). Glaucony-rich limestones at the top of the Kendlbach-Fm. start with bed 27 at Hochleitengraben, which is a lensoid bed of lithoclastic packstone.

thin-bedded, partly nodular limestones of the Sinemurian Schmiedwirt-Mb. and the Carixian Kehlbach-Member. So far, no Kehlbach Mb. is known from the Adnet quarries. The **Upper Adnet-Fm.** starts with the breccias of the Scheck Mb. and continues throughout the Toarcian with marls and limestones of the Saubach-Mb. Small remains of marls of the Saubach-Mb. can be found on top of the Scheck breccia at the Scheck Quarry (XXII) and in small outcrops at Hollweng (BÖHM et al., 1995).

Basal Unit (Sinemurian)

The Basal Unit is a group of slightly condensed limestone beds intercalated between two prominent ferromanganese crusts present in most sections of the Osterhorn Mountains (Text-Fig. 4). With the plausible assumption that each crust is approximately synchronous in different locations, the Basal Unit represents a chronostratigraphic unit. The facies of the Basal Unit changes with distance from the Rhaetian reef. In sections distal to the Rhaetian reef the Basal Unit is less than 1 m thick (Quarries XXII, XXXI, Hochleitengraben; Saubach, Ladenbach, BÖHM, 1992: 124, 130), while in the near-reef sections of Quarries XII and XIV it locally attains a thickness of more than 4 m.

The two ferromanganese crusts bounding the Basal Unit are: at the base the top-Hettangian "Marmorea Crust" (Pl. 2, Fig. 3); at the top a crust, which is characterized by a lack of ammonoids (Pl. 2, Fig. 4). We use the term "Basal Sinemurian Crust" for the latter. A stromatolitic layer occurs immediately above and below the Basal Sinemurian Crust in Quarries XII, XIV and XXXI (Pl. 4, Fig. 3) (BÖHM & BRACHERT, 1993). Conspicuous onlap can be seen above the second crust in Quarries XII and XIV (see below).

In some of the basinal sections the Basal Unit shows two sequences of upward thickening beds (Text-Fig. 4). In the Breitenberg section even two mineralized hardgrounds occur in the thick bed capping the first sequence. The ferromanganese crust that marks the top of the Basal Unit often is situated near the center of the thick capping bed of the second sequence.

The age of the Basal Unit is only roughly constrained by biostratigraphic data to post-Marmorea/syn-Obtusum zone. The underlying "Marmorea Crust" can be dated as late Hettangian or earliest Sinemurian, but no precise zonal range can be assigned (chapter 3.2., DOMMERGUES et al., 1995; BLOOS, 1996). Ammonite findings from the Basal Unit are rare. A cross section of an Arietitid (BÖHM & BRACHERT, 1993, Pl. 33/3) and a specimen of *Angulaticeras* sp. juv. (chapter 3.2.) both from Quarry XII do not provide any further constraints on the age range.

Arnioceras sp. and/or *Adnethiceras adnethicus* occur about 1 m above the Basal Sinemurian Crust in Quarries XII, XXVIII and XXXI (chapter 3.2., DOMMERGUES et al., 1995; BÖHM et al., 1995). Again these findings are not age diagnostic.

A specimen of *Coroniceras* aff. *lyrae* found in the screes in quarry XXVIII (DOMMERGUES et al., 1995) points to the presence of the lower Semicostatum zone. Ammonites of the middle Obtusum zone are found 7 m above the Basal Sinemurian Crust in the Schmiedwirt Quarry and at Breitenberg (MEISTER & BÖHM, 1993; BÖHM et al., 1995). At the Lienbacher Quarry a level with ammonites of the Oxynotum or Raricostatum zone occurs 3 m above this crust (DOMMERGUES et al., 1995). The recent finding of an Obtusum zone ammonite fauna within the Basal Unit in Quarry XII proves its continuation until the Obtusum Zone (unpubl. data L. KRYSTYN). Therefore, the Basal Unit probably comprises the time from the Semicostatum until the (?early) Obtusum chron.

Schmiedwirt-Member (Sinemurian)

This is the most widespread member of the Lower Adnet-Fm. It is characterized by medium- to thin-bedded, often nodular red limestones (Pl. 1, Fig. 4), intraclastic wackestones with ostracodes, sponge spicules and crinoidal debris (BÖHM et al., 1995). This is the typical nodular Adnet Limestone sensu strictu. The Basal Unit is only about 1 m thick at the base of the Schmiedwirt-Mb. (Text-Fig. 4).

Lienbacher-Member (Sinemurian)

The sediments of the Lienbacher-Member are found in Quarries XII and IV (Lienbacher Quarry, Pl. 1, Fig. 6; Pl. 2, Fig. 2; Text-Figs. 4, 6). That is near the top of the drowned Rhaetian Adnet Reef. They are characterized by decimetre-bedded, marl-poor, blotchy red micritic limestones without nodular fabrics (Pl. 1, Fig. 6). Millimetre to centimetre sized intraclasts with ferromanganese coatings are very frequent.

The Basal Unit is <0.2 m (Text-Fig. 6) to >4 m (Text-Fig. 4) thick in this facies, wedging out on a ridge of Rhaetian limestones. The facies of the Lienbacher-Mb. continues above the Basal Unit, but the differences to the Schmiedwirt-Mb. are becoming less pronounced upsection. DOMMERGUES et al. (1995) reported ammonites of the Oxynotum or Raricostatum zone from there.

Motzen-Member (Sinemurian)

To the north of Quarry XII the micrites of the Lienbacher-Mb. pass into pink-red crinoidal limestones (Pl. 1, Fig. 5), well exposed in Quarry XIV (Motzen Quarry, Text-Figs. 1, 10). Like the Lienbacher-Mb. they are rather thick-bedded. The Motzen-Mb. occurs in a narrow belt on the northern slope of the drowned Adnet Reef, between the areas of the Lienbacher- and Schmiedwirt-Members.

As with the Lienbacher-Mb. it is most characteristic in the Basal Unit, which is currently exposed with up to 2.5 m thickness in Quarry XIV. Again the facies continues above the Basal Unit, but becomes more similar to the Schmiedwirt-Mb. further upsection.

2.2. Description of the Outcrops

Hochleitengraben

Only the topmost beds of the basinal Hettangian (Kendlbach-Fm.) are exposed in the Adnet quarries (Quarry XXII). We therefore present for comparison a section situated about 6 km to the east of Adnet (Hochleitengraben section, Blatt 94 Hallein, $R^4$4150 $H^2$8368) in a small tributary of the Mörtlbach. It is located in a gorge, accessible from the forest road during dry weather. Along the forest road only the higher parts of the Liassic (Adnet-Formation) are exposed (BÖHM, 1992), overlain by radiolarites of the Late Jurassic.

The section (Text-Figs. 4, 5) starts with more than 3 m of massive dark grey bioturbate micritic limestones, causing a small waterfall. It is the well known top bed of the Rhaetian Kössen-Formation (PLÖCHINGER, 1982). The Rhaetian is overlain by 15 m of dark grey marl layers (<1 m) interbedded with limestone beds (<45 cm), assigned to the Kendlbach-Formation (Tiefengraben-Mb. and lower Breitenberg-Mb., early Hettangian). The limestones are bioturbate micrites, partly dark grey, marly in the lower part becoming more calcareous and rich in echinodermal remains, sponge spicules and peloids in the higher parts. Echinodermal packstones occur about

10 m above the base. Trace fossils (mainly *Chondrites*) are very frequent in the limestones of the lower part of the section. In bed 22 (Text-Fig. 5) a conspicuous dark (?bituminous) seam in echinodermal spiculitic packstone overlying a wackestone might represent organic matter trapped in a turbidite or tempestite. The packstone is penetrated by dewatering pipes, pointing to its quick emplacement. The marl-rich part of the section ends with a thick wavy bed (35–75 cm) of glauconitic crinoidal packstone with centimetre-sized micritic intraclasts (bed 27). This bed laterally thins to 15 cm over a distance of a few metres. Most of this relief is cut into the underlying marl layer (channel-like structure), but the upper surface of the bed is wavy as well. This bed probably represents a mass flow deposit.

The following 2.7 m are thin-bedded, grey, violet-grey and finally red, partly nodular, glauconitic, first spiculitic, finally crinoidal, limestones. Big yellow chert nodules occur in bed 39. Less obvious cherts are dispersed in the underlying beds as well. Typical Enzesfeld facies rich in foraminifera and other bioclasts occurs in the uppermost four beds (39 to 42). The last bed is capped by a ferromanganese crust with ammonites. We found a specimen of *Paracaloceras* cf. *coregonensis* SOWERBY, which is typical for the "Marmorea Crust". Another ammonite-rich layer occurs in bed 35.

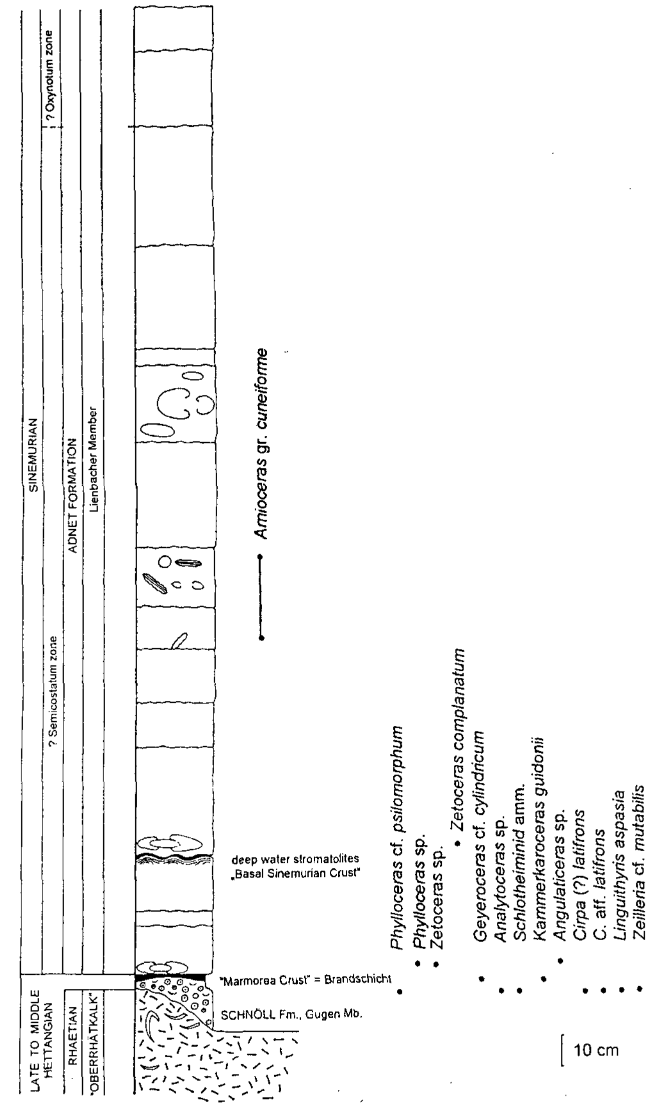
From field observations and polished sections four different microfacies can be distinguished in the Kendlbach-Fm. at Hochleitengraben: The lower part (Tiefengraben-Mb.) is dominated by peloidal and microlithoclastic wacke- and packstones (biofacies I of BLAU & GRÜN, 1994). The basal part of the Breitenberg-Mb. is rich in crinoidal remains (microlithoclastic/crinoidal facies, biofacies II of BLAU & GRÜN, 1994). The middle part of the Breitenberg-Mb. is very rich in sponge spicules (spiculitic facies). This facies is lacking in the section described by BLAU & GRÜN (1994) as well as in other sections of the eastern Osterhorn Block (e.g. the type section at Kendlbachgraben). However, it is well developed in quarry XXII at Adnet (Text-Fig. 5). In the uppermost part of the Breitenberg-Mb. the typical bioclastic wacke- and packstones of the Enzesfeld facies occur (MF10 of BÖHM, 1992; biofacies III of BLAU & GRÜN, 1994). It persists up to the Marmorea hardground. Intercalated between spiculitic and Enzesfeld facies five beds (34-38) of predominantly crinoidal facies might represent an equivalent of the crinoid-rich Guggen-Mb. of the Schnöll-Fm. (Text-Fig. 5). This crinoidal facies is very well developed at quarry XXII, too.

According to GOLEBIOWSKI (1990) the Breitenberg-Mb. of the Kendlbach-Fm. differs from the underlying Tiefengraben-Mb. by the frequent occurrence of bioclasts. With that we place the lower boundary of the Breitenberg-Mb. between beds 15 and 19, where the facies changes from bioclast-poor to bioclast-rich. This is contrary to BLAU & GRÜN (1994), who used the marl content for discrimination. With their definition the boundary would be placed at bed 28.

The Adnet-Formation starts above the Marmorea hardground with a conspicuous marl layer followed by thin-bedded red mud/wackestones of the **Schmiedwirt-Mb**. The **Basal Unit** (beds 43 to 48) is 1.3 m thick, capped by the thick bed 48 with a ferromanganese hardground. The section continues with several metres of red nodular limestones (Adnet-Fm., Schmiedwirt-Mb.).

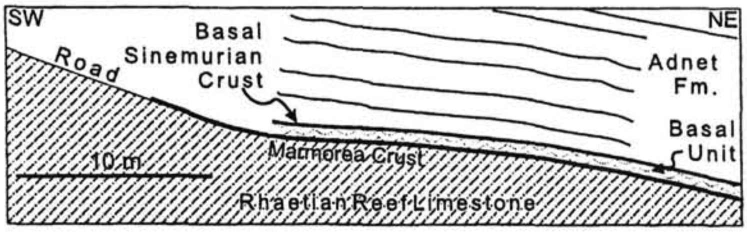
Quarry XII (Lienbacher Quarry)

This is one of the largest quarries at Adnet, situated near the Rhaetian reef core (Quarry IX, Text-Fig. 1; Pl. 2, Fig. 2). It mainly exposes red limestones of the Lienbacher-Member, overlain by a breccia in the middle part of the quarry (BÖHM et al. 1995, 1997a). The northwestern corner exposes the transition from underlying Rhaetian light grey massive packstones and boundstones to the red Liassic limestones (Text-Fig. 6). The Rhaetian reveals a near-reef position by the presence of decimetre-sized fragments of coral colonies (mainly massive colonies of *"Astraeomorpha"*-type). The ferromanganese "Marmorea Crust" rests on 0–10 cm of red crinoidal limestones, rich in brachiopods (chapter 3.3., Enzesfeld Limestone, Hettangian), overlying the Rhaetian limestones. The following Basal Unit of the Adnet-Fm. (Obtusum Zone; unpubl. data by L. KRYSTYN), usually several metres thick in Quarry XII, thins to only 0.15 m thickness in this part of the quarry. It can be seen to wedge out on a small ridge of Rhaetian limestones and thickens towards the southeast to more than 4 m (Text-Fig. 4). The Rhaetian ridge can be traced to the SW towards the forest road. It probably trends SW–NE (i.e. downslope) and may be connected to a similar structure in the Motzen Quarry (XIV) to the NNE (20°) from the Lienbacher Quarry. At the southeastern edge of Quarry XII the Basal Unit is 4.0 m thick.



Text–Fig. 6.
Simplified lithostratigraphic profile of Lienbacher Quarry, northwestern part, with locations of selective ammonite- and brachiopod findings. At the top of the shown section Late Sinemurian (Oxynotum Zone) was proven by DOMMERGUES et al. (1995).

The Rhaetian top surface displays a small-scale relief along the NW side of the quarry (Text-Fig. 7), modifying the medium-scale morphology of the ridge and the large-scale



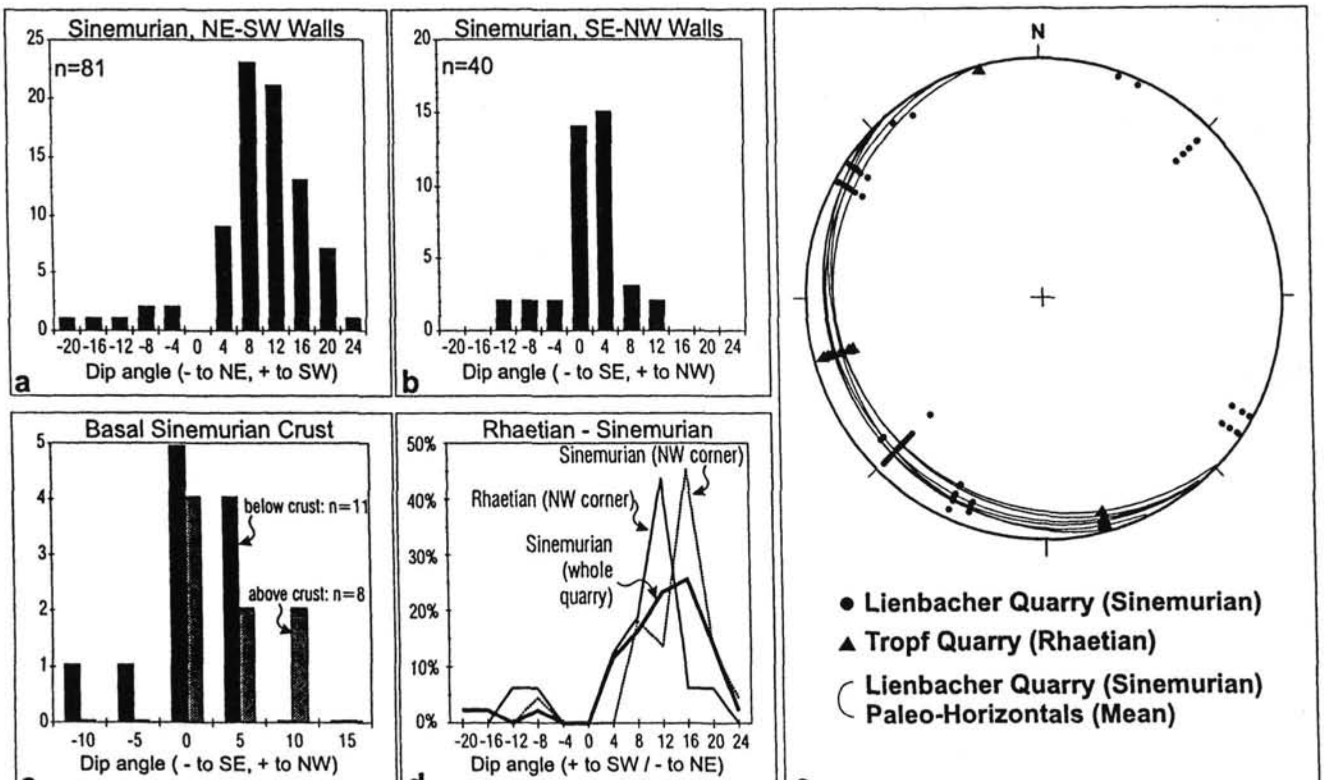
Text–Fig. 7.
Slightly exaggerated sketch of the depositional small-scale relief as exposed in the NW part of quarry XII. The "Marmorea Crust" covering the underlying massive Rhaetian reefal limestone is shown as a thick line. It forms the pavement of the road at left. It is overlain by the Adnet-Formation (Lienbacher-Mb.) with only 20 cm of stromatolites of the Basal Unit and the Basal Sinemurian Crust, followed by medium-bedded limestones. The original relief was restored by tilting the section 10° to the right, according to the mean inclination of geopetal infills.

morphology of the NE-dipping slope. A small terrace is formed by a mound-like structure in the NW corner. It could be caused by a small Rhaetian coral patch reef, as coral colonies become more frequent towards the mound.

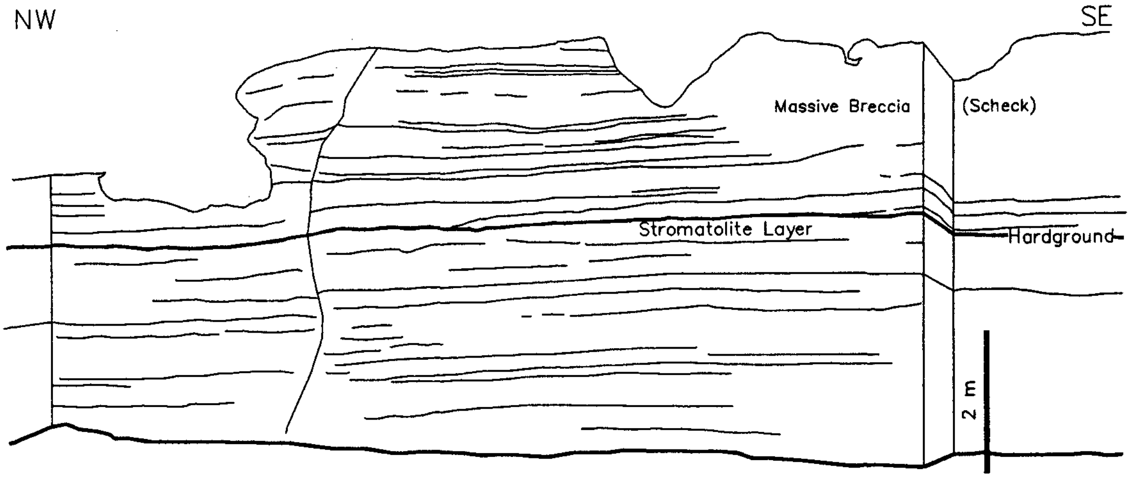
Inclinations of geopetal infills and bedding planes of the Basal Unit point to a large-scale palaeoslope dipping to the NE with an inclination of 10–15° (see chapter 2.3.). Average dip of geopetal infills is 230°/12° in quarry XII and stratification varies from 280°/7° in the NW to 250°/3° in the central part and 310°/5° in the SE corner.

At the SW–NE trending wall in the NW part of the quarry, cut in July 1996, we observed a slight difference in the dip of Rhaetian and Sinemurian geopetal infills (Text-Fig. 8 d). In the Rhaetian the mean dip angle is 9° (to the SW, mode 12°, median 12°, n=16), while it is 15° in the Sinemurian (mode 18°, median 16°, n=22). However, if measurements of Sinemurian from the other SW–NE trending walls are included, the difference is reduced to a negligible value (Sinemurian mean 12°, mode 12°, median 13°, n=43, difference insignificant in t-test: p=0.19). Therefore, with the currently available strongly varying data it is not possible to decide, if there actually was a northeastward tilt of ca. 5° of the Rhaetian block in the NW part of quarry XII during the Hettangian or early Sinemurian.

The Basal Unit is overlain by the basal Sinemurian ferromanganese crust, a stromatolite layer (Böhm & Brachert, 1993) and at least five more metres of red Adnet Limestones. Ammonites of the Oxynotum- or Raricostatum zone were reported from the upper part of this section by Dommergues et al. (1995). As clearly visible at the large NW–SE trending quarry wall, these strata prograde towards the NW above the Basal Sinemurian Crust with an inclination of ca. 3° (Text-Fig. 9). The progradation is most pronounced at the NW–SE trending, but minor at the SW–NE trending walls. Only a very slight thinning towards the NE can be observed in the northwestern part of the quarry.



Text–Fig. 8.
Attitudes of geopetal infills in the Rhaetian and Liassic of the Tropf Quarry (IX) and Lienbacher Quarry (XII). (**a, b**): Histograms of dip angles measured at two perpendicular walls of quarry XII in Sinemurian limestones of the Lienbacher Mb. (Adnet-Fm.). Geopetal infills are almost horizontal in the SE–NW wall but clearly show an inclination on the NE–SW walls, indicating a tectonic tilt. Note clear maxima but high variability of the dip angles! (c, d): Comparison of dip angles below and above the Basal Sinemurian Crust (c) and of Rhaetian versus Sinemurian (d) in Quarry XII. The differences are not significant. If there was tectonic activity during these intervalls, the resulting tilt was minor. (e): Today's attitudes of paleo-horizontal planes reconstructed from geopetal infills, indicating a tectonic tilt of both Quarries XII and IX of about 10° to the southwest.



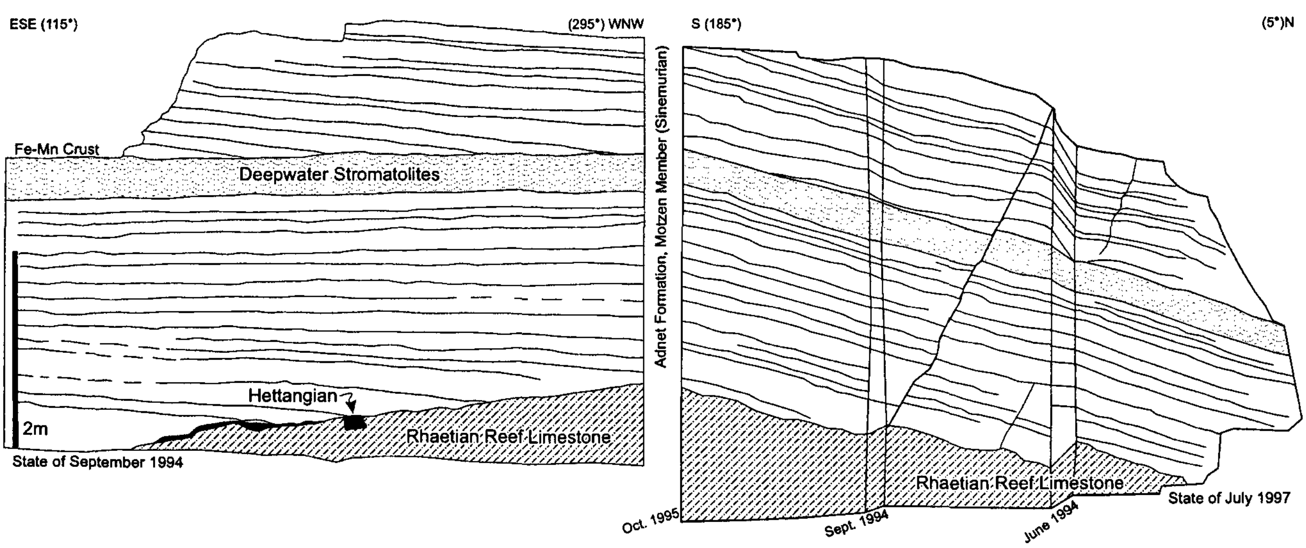
Text–Fig. 9.
View of a quarry wall, exposed in the northwestern part of Lienbacher Quarry (XII) in 1991, showing the rather thick-bedded facies of the Lienbacher-Member (Adnet-Fm.). The lower half of the section is formed by the Basal Unit, capped by the stromatolite layer and the Basal Sinemurian Crust ("hardground"). The beds above the hardground show an onlap with an angle of about 3–5°. At the top of the section a massive breccia layer (Scheck breccia) is visible on the right.

As the layer above the Basal Sinemurian Crust is hardly accessible in most parts of the quarry, we have only limited data (n=18) of geopetal infills to detect a possible tectonic tilt during formation of the crust. In the SW–NE trending walls we observed no significant difference below and above the crust (means are 16° below and 15° above in the NW part of the quarry). A slight change can be observed in the NW–SE trending walls with means of 2° below and 6° above the crust (both to the NW, Text-Fig. 8 c). The difference is significant only at a 90% level (t-test), but is conform with the relative change in dipping angle between the beds below and above the crust (ca. 3°). However, the medians of the measured values are similar below (4°) and above (5°) the crust. It is, therefore, likely that this difference is rather an artifact of the limited data set.

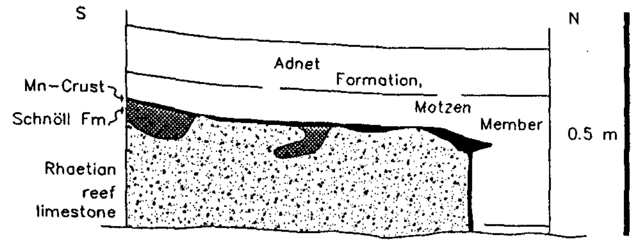
Neptunian dykes are very frequent in quarry XII. They are usually 5 to 10 cm wide and filled with Liassic sediments, mainly red biomicrites. Most dykes trend E–W and NNE–SSW. Ferromanganese incrustations and marls are common. Many dykes end above the ferromanganese crusts, but below the Scheck breccia. However, most appear to be polyphase, with opening phases contemporary with formation of the crusts. This is evident from ferromanganese incrustations entering the dykes where they cross a crust.

Outcrops Between Quarry XII and Quarry IX (Tropf Quarry)

Small outcrops south of Quarry XII expose bedded red limestones of the Lienbacher-Mb. overlying massive Rhaetian reef limestones. The Rhaetian reef core is well exposed in



Text–Fig. 10.
Views of the quarry walls of Quarry XIV (Motzen Quarry), exposed from 1994 to 1997. Perpendicularly E–W (left) and N–S (right) striking quarry walls displaying the almost undisturbed depositional relief. The base of the section is formed by massive Rhaetian limestones of reef slope facies (packstones). Locally, mainly in small pockets, limestones of the Schnöll-Fm. (Hettangian, sponge spicule-rich biomicrites) are present (cross-hatched). They are covered by a ferromanganese crust (?"Marmorea Crust"). Crinoidal, bedded limestones of the Motzen-Mb. onlap this basal succession mainly from east to west. A second onlap from E to W is found above the Basal Sinemurian Crust on top of the stromatolite layer.



Text–Fig. 11.
Detail from the base of the Motzen section. The underlying Rhaetian packstones are abruptly cut off towards the north. This points to an erosional phase prior to deposition of the Schnöll-Fm., similar as observed in Quarry XXXI (compare Fig. 15). The relief is overlain by relics of the Schnöll-Fm., found in small pockets, and covered by a ferromanganese crust. Crinoidal limestones of the Motzen-Mb. fill up the remaining relief.

Quarry IX (SCHÄFER, 1979; WAGREICH et al., 1996; BERNECKER et al., 1999). The tectonic tilt of Quarry IX, deduced from measurements of geopetal infills, is almost identical to that of Quarry XII. Geopetal infills (n=19) show a dip towards the SW with a mean angle of 10° (median 8°, Text-Fig. 8 e). Mean inclination is 245°/10°. Both quarries are thus probably situated on the same tectonic block. The top Rhaetian surface shows nearly the same dip, pointing to a horizontal relief.

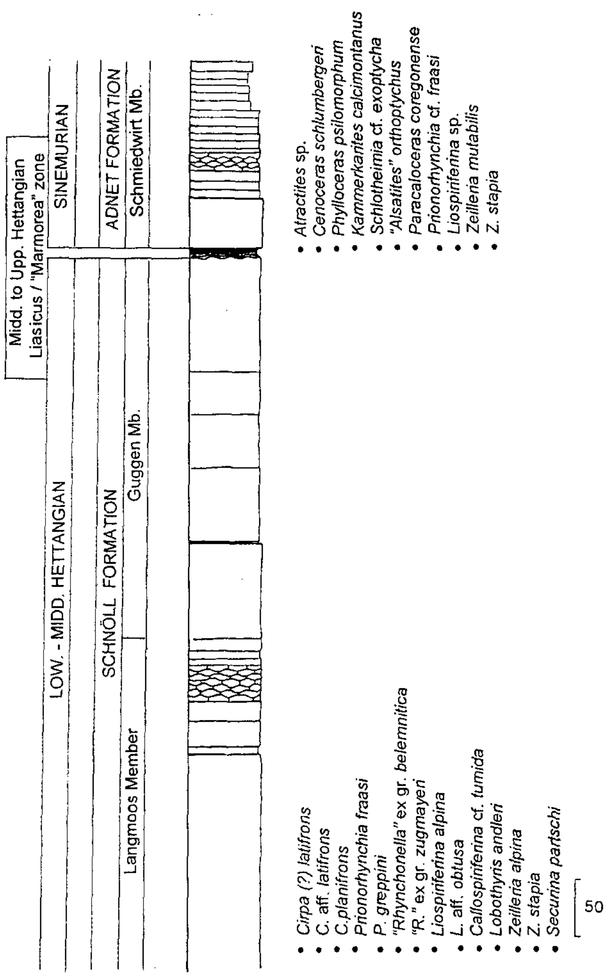
Quarry XIV (Motzen Quarry)

The Motzen Quarry is situated about halfway between the Adnet reef (Quarry IX) and the rim of the Kössen Basin (Quarry XXII), which points to a mid-slope position. It shows a similar succession as the Lienbacher Quarry. The base is formed by massive, medium-grey, fine-grained packstones, most likely of Rhaetian age. It is capped by a very thin pyritized ferromanganese crust, overlain by 0–10 cm of pinkish-greenish grey biomicrites with sponges and sponge spicules, representing the Schnöll-Formation. The latter are mainly found in small pockets of the underlying Rhaetian limestones (Text-Fig. 11). They are rich in pyrite, strongly stylolitized. The green colour results from glauconite, mainly present in biomoulds (e.g. sponge spicules). A second ferromanganese, partly pyritized crust of up to 2 cm thickness caps the Schnöll and Rhaetian limestones.

Like in the Lienbacher Quarry the Rhaetian ridge structure is onlapped by Sinemurian limestones (Text-Fig. 10). The facies is slightly different with pink-grey to red medium-bedded crinoidal biomicrites of the Motzen-Member (Adnet-Fm.). The stromatolite horizon and basal Sinemurian ferromanganese crust are present as well, appearing up to 4 m above the base of the quarry. Again, the overlying limestones have a different dip angle and direction (Text-Fig. 10). As visible in the three-dimensional section of the quarry, the strata wedge out towards the W (275°). This is a similar direction as for the progradation in the Lienbacher Quarry. The prograding bedding planes often bend down to slightly steeper inclinations near the contact surface.

Average dip of geopetal infills is horizontal. Tectonic tilting, therefore, is negligible for quarry XIV. With that, bedding attitudes are still in their original depositional position. They are about 50°/20° for the Rhaetian top surface, 5°/10° for the Basal Unit and 330°/12° for the upper unit. The palaeoslope of the Basal Unit therefore faced more northward than in Quarry XII, but had the same inclination (10–15°). The overlying unit, like in Quarry XII, prograded along the slope.

Like in Quarry XII, reconstruction of the palaeoslope angle is further supported by the asymmetric growth of stromatolite domes, well visible on the west-facing wall. Stromatolite domes on the north-facing wall are symmetric.



Text–Fig. 12.
Lithostratigraphic profile of Langmoos Quarry with locations of selective ammonite- and brachiopod findings.

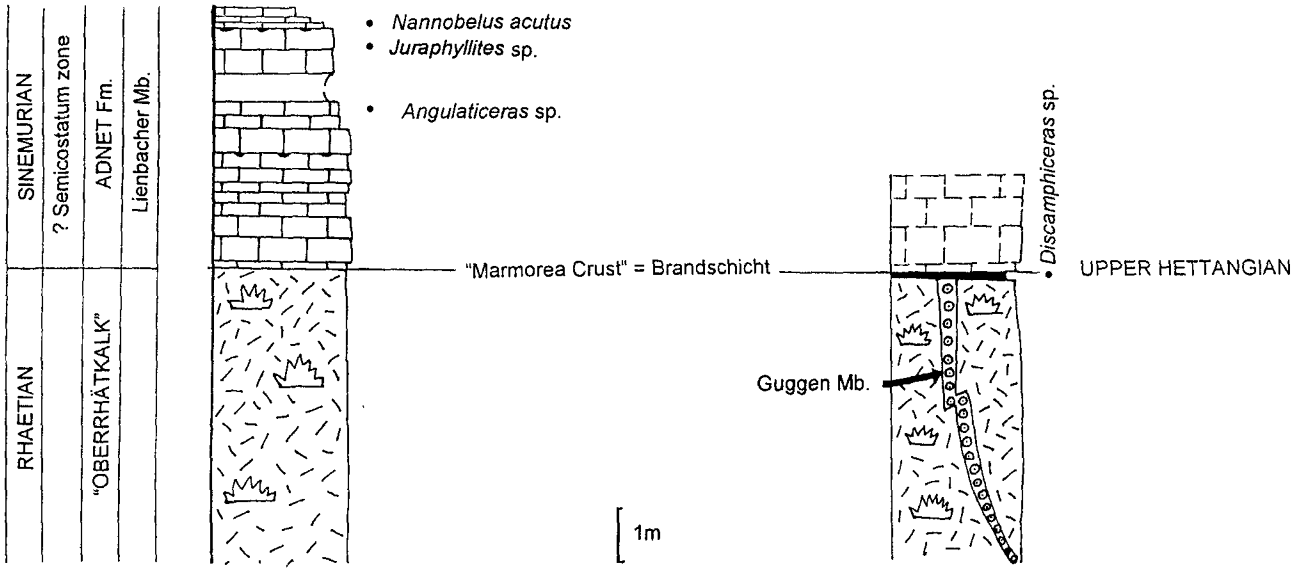
Cliffs east of Quarries XVI and XVII

The base of the Schnöll-Formation is exposed in small cliffs east and south of Quarry XVI. A yellowish biomicrite of probable Rhaetian age is overlain by about 30 cm of partly marly wackestones and peloidal packstones (?Kendlbach-Fm.). Lensoid bedding points to channel infills within this layer. The top of the layer is stained yellow. GALLET et al. (1993) found an ammonite of the late Planorbis zone in this position.

This layer is overlain by some metres of well-bedded (10–20 cm), creme-coloured wackestones with sponge spicules, forming the base of the Schnöll-Fm. (Langmoos-Mb.). The latter can be traced to the near-by Quarries XVI and XVII.

Quarry XVII (Langmoos Quarry)

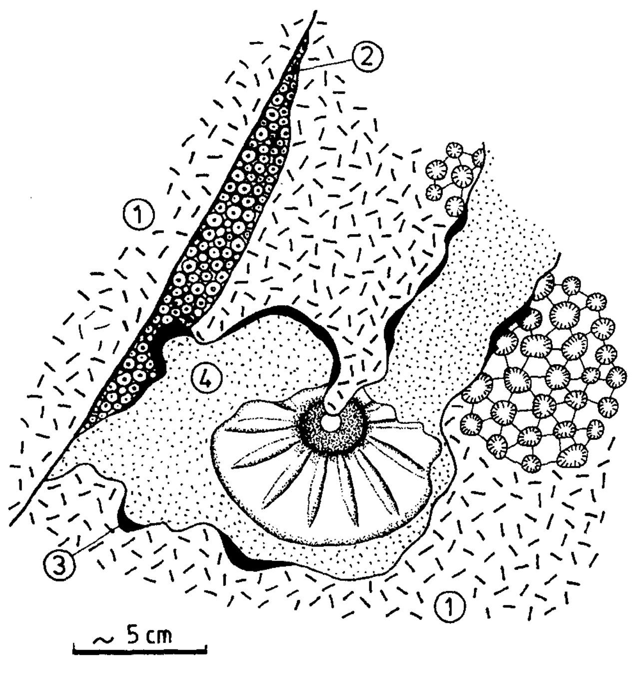
This quarry is abandoned and strongly covered by vegetation. Nevertheless it exposes the most complete section of the Schnöll-Fm. at Adnet (Text-Figs. 5, 12). It was therefore chosen for the type locality. A short description and geomagnetic data of this quarry were presented by GALLET et al.



Text–Fig. 13.
Simplified lithostratigraphic profile of Eisenmann Quarry with locations of selective ammonite findings.

(1993). Unfortunately the contact between the Rhaetian and the Schnöll-Fm. are not exposed in the quarry, but from the local situation it is clear that no more than 2 or 3 metres are hidden between the quarry floor and small outcrops of the Rhaetian at the small cliffs southeast of the quarry.

The section starts with creme-coloured wackestones similar to those overlying the Rhaetian/Kendlbach-Fm. at the cliffs described above. Sponge spicules are very common.



Text–Fig. 14.
Contact between Late Rhaetian reef limestones and red Liassic limestones in Eisenmann Quarry (n° XXX). 1 – light-coloured reef limestones with hermatypic colonial corals, 2 – pink, partly crinoidal limestones filling up neptunian dykes, 3 – Fe/Mn crusts, 4 – red biomicritic limestones with *Discamphiceras* sp., "Marmorea" Zone (3 and 4 = "Brandschicht").

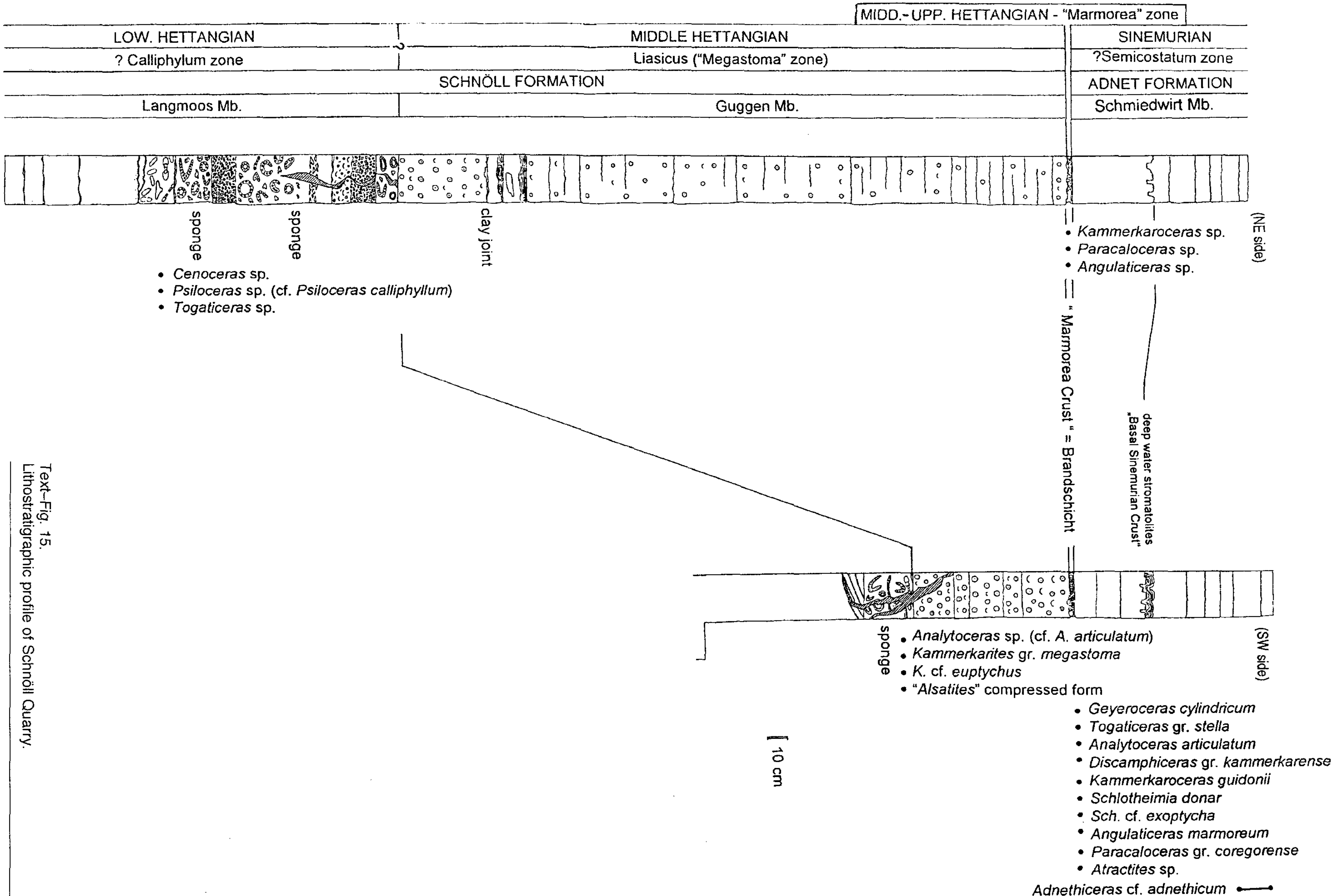
Other frequent bioclastic components are foraminifera, shell debris and echinoderms. The rather vague bedding is caused by very thin marl partings. Dipping directions vary in the basal beds. A thin grey layer of crinoidal packstone with some small gastropods and lithoclasts is intercalated near the base of the section.

Small stromatactis are common in the basal beds. Thin slightly meandering and bifurcating, mainly horizontal fissures are common about 1.5 m above the quarry floor in the southeastern corner of the quarry. They are filled by lithoclastic micrite, fibrous cement, some second internal sediment and finally blocky cement. Most fissures are less than one centimetre wide and can be traced for several decimetres laterally.

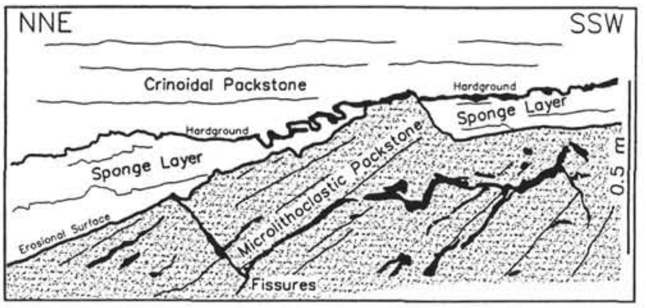
These creme-coloured to grey limestones are exposed with a thickness of roughly 3 m. The are overlain by about 4 m of thick-bedded red to violet and grey bioclastic wackestones rich in sponge spicules and siliceous sponges (Pl. 1, Fig. 2). Small stromatactis are common (MF9 of BÖHM, 1992). Networks of bleached blotches and pipes, some tracing spicules and other components are very characteristic in the deep-red lower part of this sequence.

A conspicuous layer of thin-bedded, nodular violet-red limestones of about half a metre thickness caps the thick-bedded sequence near the top of the Langmoos-Member. The microfacies of the nodular layer is still the same as in the underlying beds. Microfacies starts to change in the overlying grey and reddish, again marl-poor limestones. The echinoderm content increases, while sponge spicules become rarer. The resulting crinoidal limestones of the Guggen-Member have a thickness of roughly 3 m in Quarry XVII. They form the top of the Schnöll-Fm. and are capped by glauconitic condensed Enzesfeld facies and the Marmorea Crust. Red nodular limestones of the Adnet-Formation (Schmiedwirt-Mb.) overly the Marmorea Crust. We did not find any traces of the Basal Sinemurian Crust in this quarry. Accordingly, the presence of the Basal Unit is questionable there.

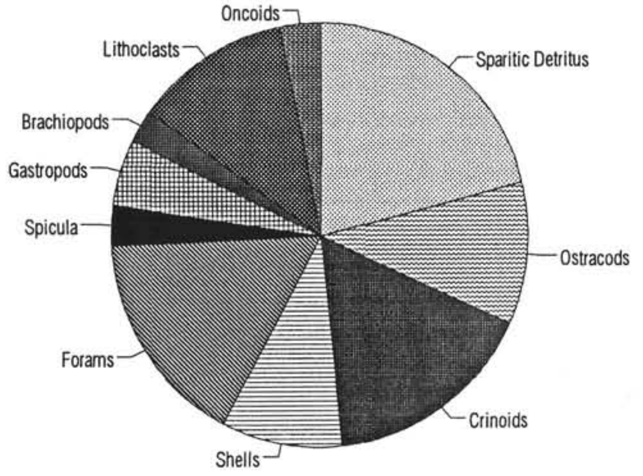
Brachiopods are very common in the Schnöll-Fm. of Quarry XVII. They are described in detail in chapter 3.3.



Text–Fig. 15.
Lithostratigraphic profile of Schnöll Quarry.



Text–Fig. 16.
Detail of the erosional surface at the base of the Schnöll-Fm. in Quarry XXXI (Pl. 3, Figs. 1-3) The crossbedded grey microlithoclastic packstones of the ?Kendlbach-Fm. are truncated at the top and overlain by the Schnöll-Fm. starting with the sponge layer. The position of the isotope sampling transect (Text-Fig. 24) is near the left rim of the depicted area. (Interpretation F. BÖHM).



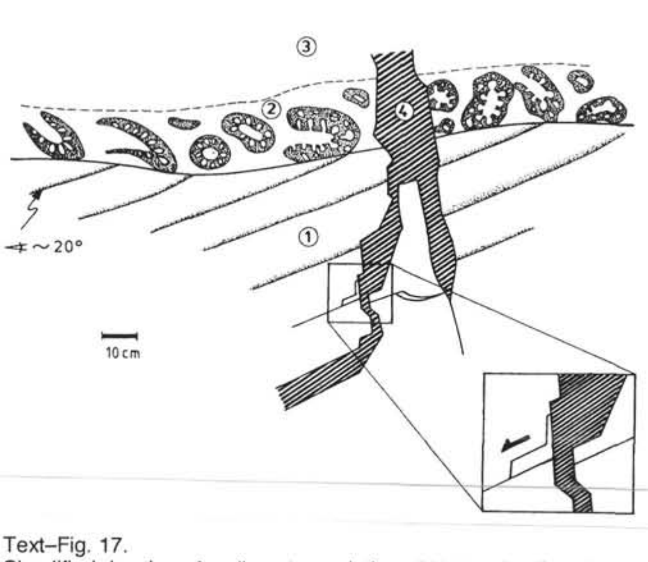
Text–Fig. 18.
Composition of the sponge layer in Quarry XXXI as determined by point counting of two thin sections (864 counts; MF 2.2, chapter 2.4.2.1). Micritic and microsparitic matrix making up 40% of the counts is not shown. "Shells" are recrystallized bioclasts, most likely of broken bivalves and ammonites. The microfacies is dominated by crinoids and foraminifers.

Quarry XXII (Scheck Quarry)

The Scheck Quarry is situated in a basinal position near the base of the Rhaetian reef slope (Text- Fig. 22). Sections in the northwestern part of the quarry expose the base of the Schmiedwirt-Mb. and the top of the underlying Kendlbach-Fm. (Text-Figs. 4, 5) as previously described by SCHLAGER (1970). Only the topmost 2.5 metres of the Kendlbach-Fm. are exposed. The succession is very similar to the Hochleiten section.

The lower part of the succession is exposed behind the shed, the higher portions in the recently uncovered northwestern part of the quarry. It starts with >1.4 m of thin-bedded (<10 cm) grey sponge spicule wackestones with distinct dark-grey marl layers. A crinoidal packstone layer and a bivalve wackestone are intercalated near the bottom of the section. The following 1.3 m are thicker bedded with violet- to greenish-grey crinoidal limestones. The reddish massive top-bed of the series is capped by the ferromanganese "Marmorea Crust". Some centimetres of limestone below the crust show a yellow stain. All of the exposed limestones of the Kendlbach-Fm. have a high glauconite content.

The "Marmorea Crust" is overlain by a conspicous marl layer, followed by thin-bedded red, nodular limestones of the Schmiedwirt-Mb. The basal Sinemurian ferromanganese crust is well exposed about 60 cm above the "Marmorea Crust". The Schmiedwirt-Mb. is about 9 m thick in the Scheck Quarry, with the uppermost beds probably belonging to the Obtusum zone. It is erosively overlain by the Scheck-Breccia (BÖHM et al., 1995).



Text–Fig. 17.
Simplified drawing of sedimentary relation of Hettangian limestones in the Schnöll Quarry (XXXI; Pl. 3, Figs. 1-3). Light-grey laminated limestones are tilted at about 20°. The sponge horizon is lying on the tilted limestones with low-angle intraformational disconformity and sharp delimited basis. Both lithological members of pre-"Marmorea" age were still fractured by sub vertical extension faults and parallel dilatations. Thus open faults were filled with red micritic limestones. 1 – light-grey to beige-coloured biomicritic limestones with parallel lamination, 2 – grey biomicritic limestones with imbricated siliceous sponges, 3 – grey to reddish-coloured, more or less crinoidal limestones, 4 – red micritic limestones filling neptunian dyke. (Interpretation M. RAKÚS).

Quarry XXX (Eisenmann Quarry)

The Eisenmann Quarry is located to the east of Adnet. It mainly exposes massive Rhaetian limestones with corals and megalodonts (reef slope facies, SCHÄFER, 1979). Recent descriptions are given by RAKÚS et al. (1993), LOBITZER et al. (1994) and HLADIKOVA et al. (1994).

The Rhaetian limestones are overlain by the ferromanganese Marmorea Crust. A thin layer of red Enzesfeld limestones with ?Middle/Late Hettangian ammonites and brachiopods (chapter 3.3.) is found locally (Text-Figs. 13, 14). The succession continues with bedded red limestones of the Lienbacher-Mb., Adnet-Fm. (?early Sinemurian, RAKÚS et al., 1993). They are exposed in the northeastern part of the quarry with a thickness of more than 5 m. Some layers are very rich in crinoidal debris. The succession is capped by a ferromanganese crust. The crust covers an irregular, wavy surface and is overlain by green-grey radiolarites with a thin basal red layer. Ammonites of the Obtusum zone were reported from the upper part of these limestones by KRYSTYN (1971). Therefore, they probably comprise the Basal Unit.

Quarry XXXI (Schnöll Quarry)

The Schnöll Quarry, situated roughly 200 m northeast of the Eisenmann Quarry, exposes a spectacular section of the

Schnöll-Fm. (Text-Figs. 15-21), wedging out from a thickness of more than 5 m in the northeastern part of the quarry to little more than 1 m in the southwest (Text-Figs. 15, 20). Using local hardgrounds as timelines, one finds an onlap of the varicoloured Schnöll upon a body of cross-bedded grey peloidal packstones. In the southern part of the quarry the base of the Schnöll is formed by a decimetre-thick layer of wackestone with siliceous sponges (Text-Figs. 15-17). This basal sponge layer shows a remarkably constant thickness compared to the overlying Schnöll (Text-Fig. 20). Sedimentary structures and facies of the quarry were recently decribed and discussed by BLAU & GRÜN (1996), WAGREICH et al. (1996) and BÖHM et al. (1997b).

The oldest limestones exposed in the quarry are grey cross-bedded microlithoclastic/peloidal packstones with foresets dipping steeply to the northeast (Pl. 3, Figs. 1-2). After restoring for a local tectonic tilt in the Schnöll Quarry of about 10° to the WNW we find a dip of up to 20° to the NE (ca. 40°) for the foresets and of 5° to the NE (ca. 50°) for the slightly hummocky, erosional top surface of the grey packstones. This latter relief is onlapped by the Schnöll-Fm. (Text-Fig. 20).

The age of the grey packstones is not well known. They either are part of the Rhaetian lower reef slope facies or more likely of the Hettangian Kendlbach-Formation. The grey packstones are dissected by a dense network of vertical and horizontal neptunian dykes, filled by red Liassic biomicrites (Text-Figs. 16, 17; Pl. 3, Figs. 1, 2). The vertical fissures trend NW–SE, which is approximately perpendicular to the dipping direction of the foresets and the top surface.

The lower member of the Schnöll-Fm. (Langmoos-Mb.) is only present in the left (northeastern) part of the quarry, where it is seen in the basal 1.5 m of the section with red-yellow-grey spiculitic biomicrites (Text-Fig. 15). Siliceous sponges are common. A layer with small stromatactis structures is present near the top of the Langmoos-Mb.

In the southwestern part of the quarry the basal sponge layer might represent a condensed equivalent of the Langmoos-Mb. (Pl. 3, Fig. 3; Pl. 1, Fig. 1). It is a grey, partly reddish, pyritic bioclastic packstone. Major micro-components are crinoids and forams, while sponge spicules are surprisingly scarce (Text-Fig. 18). Crinoids become even more important upsection, leading to the crinoidal packstones of the Guggen-Member. Lithoclasts and oncoids are rather common in the basal sponge layer (chapter 2.4.2.1.; Pl. 6, Fig. 4; BÖHM, 1992: Plate 1).

The major part of the Schnöll-Fm. in the Schnöll Quarry is assigned to the Guggen-Member: thick- to medium-bedded, reddish- and yellowish-grey crinoidal limestones (Pl. 3, Fig. 4). Scattered sponge layers occur in the Guggen-Mb. as well, but crinoidal debris is the major component. A faint lensoidal lamination occurs in some layers, mainly caused by grain-size variations. Near the top of the Guggen-Mb. an interbedding of ca. 10 cm thick internally brecciated layers and normal beds is observed in the middle part of the quarry. Neptunian dykes are frequent. There are several thin ferromanganese crusts within the Guggen-Mb., BLAU & GRÜN (1996) observed at least 5 crusts, but none can be traced throughout the quarry. The situation is different for the "Marmorea Crust" at the top of the Schnöll-Fm. which provides a very good marker horizon throughout the quarry. It caps a thin layer of Enzesfeld facies forming the top of the Schnöll.

The succession continues with half a metre of red Adnet limestone capped by the Basal Sinemurian Crust. The crust covers a relief of up to 10 cm with thin protrusions of the underlying limestone forming small pillars, only a centimetre wide and up to 10 cm high (Pl. 4, Fig. 4). These may partly be stylolites, but upward widening of some pillars and mushroom-shaped ferromanganese caps contradict this explanation. Small bowl-like depressions, half a metre wide and some centimetres deep, point to some erosion before formation of the crust. The crust is overlain by a roughly 15 cm thick bed of stromatolites (Pl. 4, Fig. 3), interpreted as deep-water stromatolites by BÖHM & BRACHERT (1993). They form the base of thin-bedded typical red nodular limestones of the Adnet-Formation (Schmiedwirt-Mb.).

During continued quarrying in the spring of 1992 two collapse structures were exposed in the Schnöll Quarry (Text-Figs. 20, 21). The structures are 4 to 5 m wide and symmetrical. From both sides the beds bend down towards a central axis. It is not clear if the center of symmetry is circular or linear, as the structures are only exposed in two-dimensional sections of the quarry walls. Beds near the center of the structure are partly broken. The resulting neptunian dykes are filled with red marls. This points to tensional forces, breaking the beds. A massive bed at the base of the section is partly brecciated with a red marly matrix like the one filling the fractures above. The bases of the collapse structures are not exposed. The lowermost exposed beds are still bent down, pointing to a continuation of the structures below the quarry floor.

Towards the top of the structures angles of bending and intensity of fracturing decrease. The overlying bed (bed immediately below the "Marmorea Crust") becomes thicker towards the center of the structure, levelling out the underlying trough. It shows some small marl-filled fractures at its base, pointing to slight movements after its deposition.

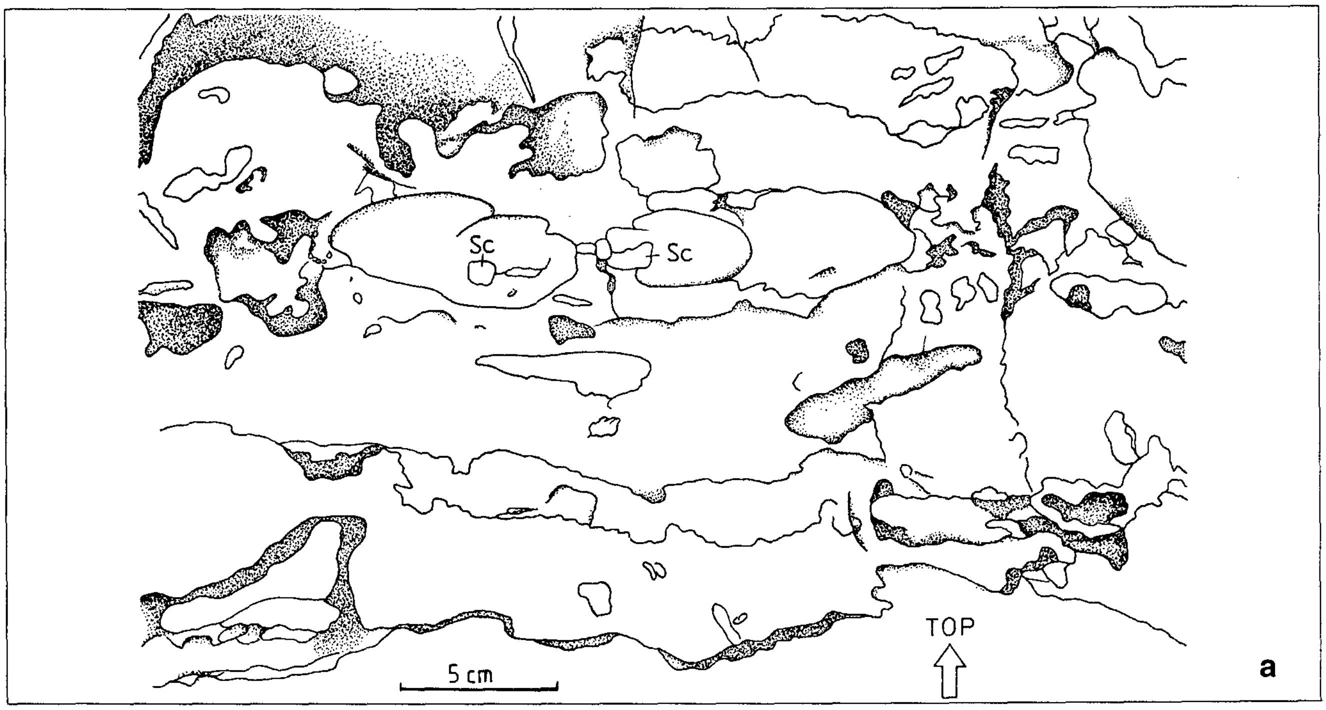
The northern structure, which is a little larger than the southern one, is distorted by a later fault. A younger Liassic neptunian dyke is visible near the southern structure. Young spar-filled veins can be seen in all parts of the quarry. They show no correlation to the collapse structures.

2.3. Interpretation of the Field Observations

Depositional Relief

The Rhaetian relief between the Adnet reef and the adjacent Kössen basin most likely was constructional. That is, it resulted from the higher sedimentation rates of the reef limestones. No Triassic fault between reef and basin is known. The end-Rhaetian relief can thus be reconstructed from the thickness difference between reef and coeval basinal sediments. The Rhaetian reef limestones have a vertical thickness of about 150 m. The entire thickness is not exposed at Adnet, but is visible at the coeval Feichtenstein reef (PLÖCHINGER, 1990), the Rötelwand reef (SCHÄFER, 1979), as well as at a drill site near Adnet (KRAMER & KRÖLL, 1979). The contemporary basinal Kössen-Beds of the Eiberg-Member (GOLEBIOWSKI, 1991) have a thickness of about 50 m at Gaißau, 4 km northeast of Adnet (KUSS, 1983). Considering a post-Rhaetian compaction of the marly basinal sediments of less than 50%, the relief was about 50 to 80 m at the end of the Rhaetian. For the well comparable situation of the Steinplatte a relief of about 100 m was calculated by STANTON & FLÜGEL (1995). The average slope angle of the Adnet reef can be assumed from the vertical distance (50–80 m) and the width of the slope (c. 400 m) as roughly 10°.

Analogous to other reef slopes (e.g. Steinplatte) we expect a concave shape for the Adnet reef slope with a steep upper and a less inclined lower portion (KENTER, 1990). SCHÄFER (1979) suggested that the oncolitic facies surrounding the reef core area was deposited on the steep upper slope, while the detrital mud and arenitic facies covered the gradual lower slope (Text-Fig. 22).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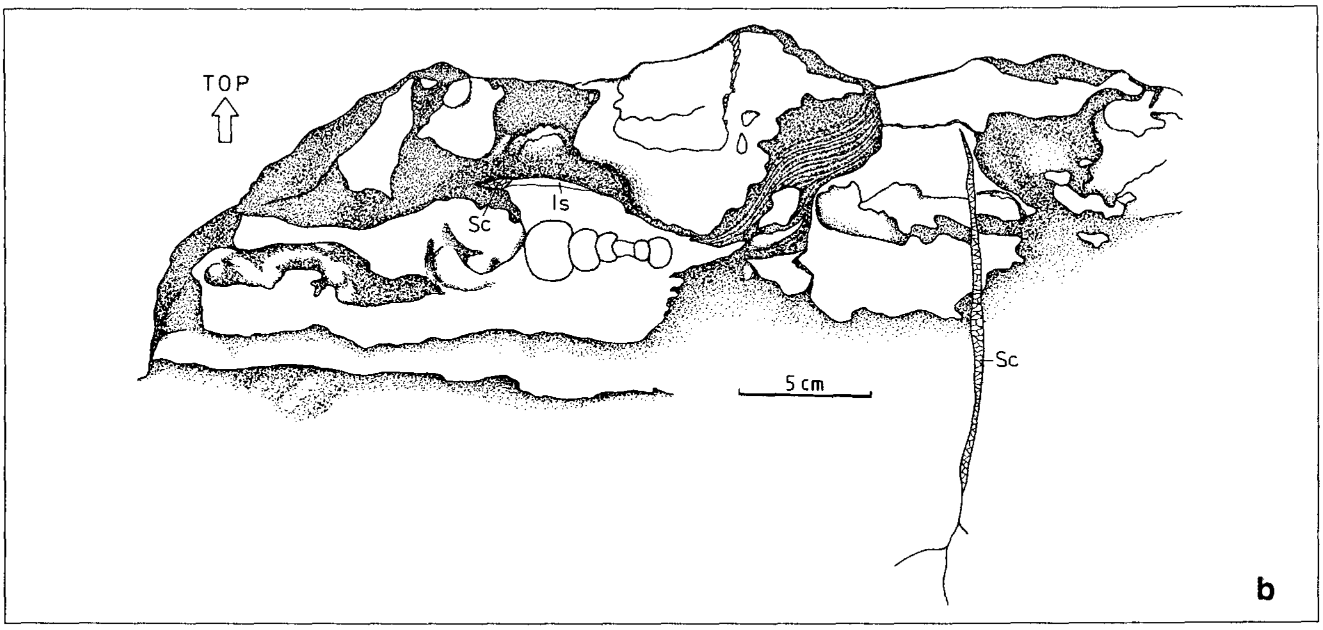
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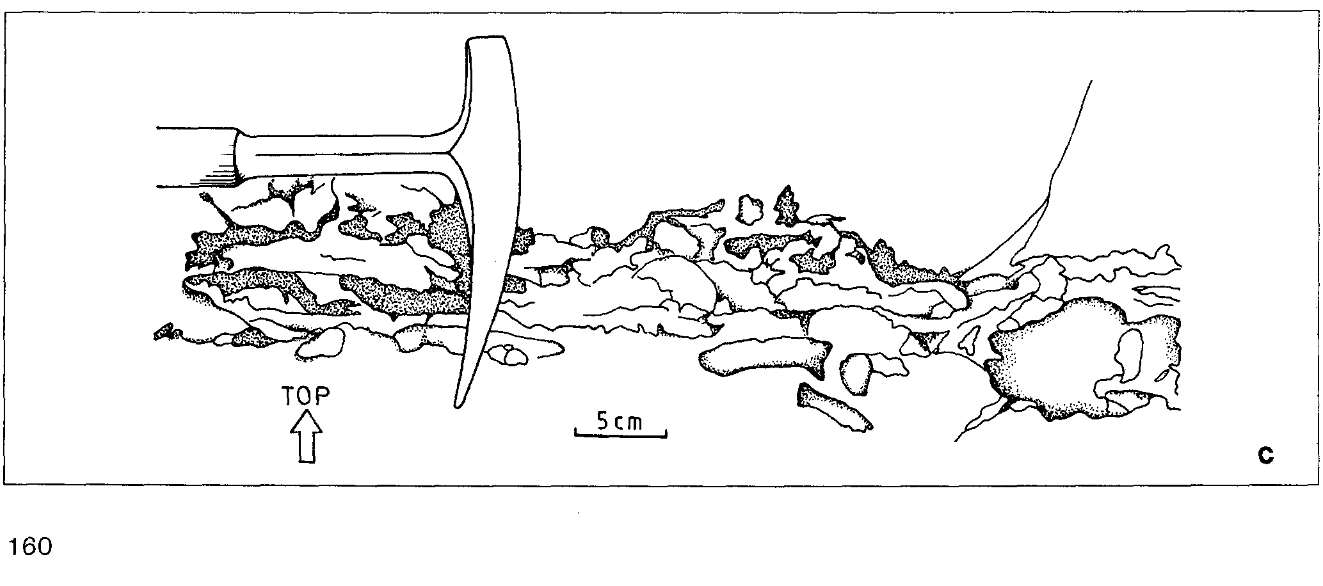
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◀ Text–Figs. 19a, b, c.
Hardgrounds represented by complex sedimentary discontinuities with irregular and multiple alternation of Fe/Mn crusts. The crusts consist of thin layers forming planar but irregular multilayered coatings. Occasional stromatolithic structures may be seen too (middle of figure b). Dissolution is frequent and mostly affecting the shells of ammonites. The relicts of ammonite shells are coated with multilayered crusts, which could be produced by cyanobacteria. Although the underlying and surrounding limestones are rich in organic relics (foraminiferal wackestone) the proper crusts are without benthic or sessile foraminifera. Epifauna is also missing on the ammonite shells (e.g. serpulids). Inside the ammonite shells internal sediments (Is) are present too. They are accompanied by sparite calcite (Sc).
The hardground polarity is well expressed by gradual outward growth of pigmentation. The colour of hardgrounds is generally reddish-brown to ochre. In the non-altered parts the colour of hardgrounds is sometimes dark to black or greyish-green. Minerals composition is: pyrite, gypsum, calcite, rosenite, manganite and glauconite (maybe chlorite). This association of mineral and colour of non altered Fe/Mn crusts evoke anoxic environment. The brownish colour maybe is the result of alteration. Schnöll Quarry, "Marmorea Crust" Late Hettangian. (Interpretation M. Rakús).

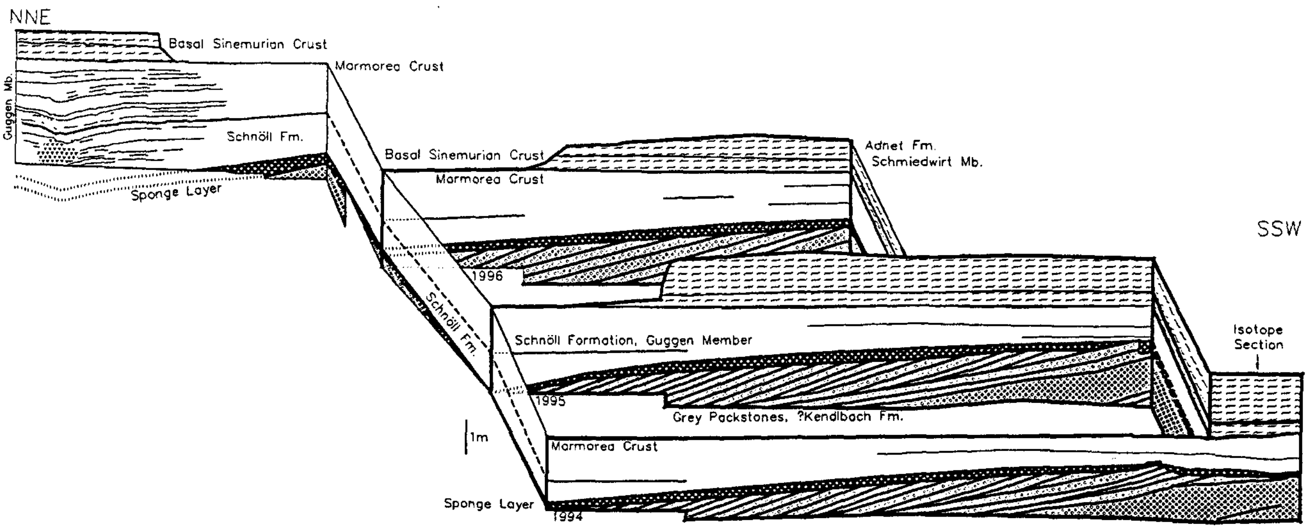
A more detailed analysis of the end-Rhaetian to early Liassic relief of the Adnet reef area was carried out by studying thicknesses of sedimentary units and bedding attitudes in the quarries (Böhm & Krystyn, 1998). For the back-rotation of later tectonic tilt we used geopetal structures. Geopetal infills in the Sinemurian (n=121) and Rhaetian (n=16) of quarry XII show a wide range of varying inclinations (Text-Fig. 8 a, b). This variation can be explained by reworking and downhill movements on the palaeoslope. An injection of sediments into small cavities by currents provides a further explanation: we observed inclinations varying by as much as 20° in one cavity.

Nevertheless, a clear pattern emerges from the statistical analysis of all geopetal infills in Quarry XII (Text-Fig. 8), pointing to a tectonic SW tilting (ca. 10°) of the block. The mean inclination of traces of geopetal infills on the NW–SE trending walls is 3°, dipping to the NW (mode 0°, median 3°). The inclination of traces of bedding planes (strata below the Basal Sinemurian Crust) on these walls varies from 0° to 5°. Dip is towards the NW. In contrast, mean inclination of infills on the SW–NE trending walls is to the SW at 11° (mode and median 12°). Traces of stratal planes of these walls dip to the SW with 0° to 4°.

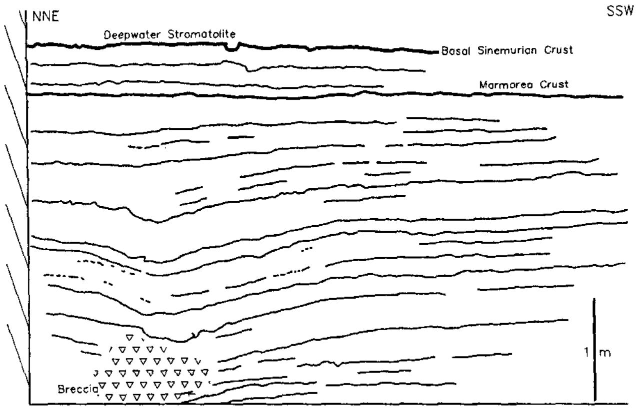
From this pattern we obtain a palaeoslope for the whole Quarry XII towards the NE with a slope angle of 10° to 15°. This is in close agreement with the slope reconstruction of Böhm & Brachert (1993), which covered only the southeastern part of the quarry. Our palaeoslope reconstruction is supported by the asymmetric growth of stromatolite domes, as first documented by Böhm & Brachert (1993). It is visible on the SW–NE trending, but lacking on the NW–SE trending walls. A NE dipping slope is also compatible with the facies distribution in the Adnet area, which shows a NW–SE trending boundary between basinal Kössen facies and the more calcareous reef and slope facies (Schlager & Schlager, 1960; Schäfer, 1979; Böhm et al., 1995).

A similar slope angle as in Quarry XII can be reconstructed for Quarry XIV. Geopetal infills show no significant tectonic tilt, thus, except for compaction effects, the bedding attitude represents the primary slope (Text-Fig. 10). This was 20° to the NE for the top of the Rhaetian and 10° to the N for the overlying Sinemurian. Again asymmetric stromatolite domes on the NS trending quarry walls confirm this result. The steeper Rhaetian slope partly represents a local small scale relief of a reef spur or channel that probably can be traced from Quarry XIV to Quarry XII (see outcrop description of Quarry XII). The Rhaetian reef slope was not a simple plane but rather a hummocky surface with small mounds or terraces (Text-Fig. 7).

In Quarry XII as well as in Quarry XIV a prograding unit occurs above the Basal Sinemurian Crust (Text-Figs. 9, 10). It most likely represents a contour current driven sediment wedge prograding along the slope towards the west (Quarry XIV) or northwest (Quarry XII) above the mineralized hardground of the Basal Sinemurian Crust (Böhm et al., 1997b).



Text–Fig. 20.
Three-dimensional view of Quarry XXXI (Rotgrauschnöll Quarry) constructed from different stages of quarrying between 1994 and 1996. Distances between successive walls (roughly 2 m) are expanded for better view. Total west-east distances between the walls of 1994 and 1996 and the collapse structure (left) are 14 m and 10 m respectively. The view has been corrected for tectonic tilt and small faults under the assumption of a roughly horizontal attitude of the "Marmorea Crust" during Hettangian, which is corroborated by the presence of geopetal structures parallel to the crust. Cross bedding of the basal grey packstones (?Kendlbach-Fm.) is shown schematically. Their slightly wavy surface dips to the NE and is onlapped by the Schnöll-Fm. (Guggen-Mb.). The latter is only 1.2 m thick in the southern corner (compare Text-Fig. 15), but thickens to 3 m near the collapse structure (left).



Text–Fig. 21.
The collapse structure in the left part of the figure is shown as exposed in Quarry XXXI in 1993. Most of the section is represented by medium-bedded crinoidal limestones the Guggen Mb. (Schnöll-Fm.), capped by the "Marmorea Crust". Above the latter, the Basal Unit with the overlying Basal Sinemurian Crust forms the top of the section (Adnet-Fm.). Only the beds of the Guggen-Mb. are deformed in the collapse structure. Overlying beds are undeformed. An intraformational breccia is positioned at the centre of the structure, at the base of the outcrop.

Bedding planes and geopetal structures are parallel in Quarry XXXI, which is situated close to the toe of the slope, and in Quarry XXVIII, positioned in the Kössen basin. A horizontal palaeo-relief was also detected in small outcrops between Quarries IX and XII, that is at the top of the Adnet reef. In contrast to the multitude of onlap and progradation sequences exposed in the quarries positioned on the palaeoslope, bedding is always parallel in the basinal settings. It is even possible to correlate single beds with a constant thickness along the toe of the slope for a distance of at least 1 km (Böhm & Krystyn, 1998).

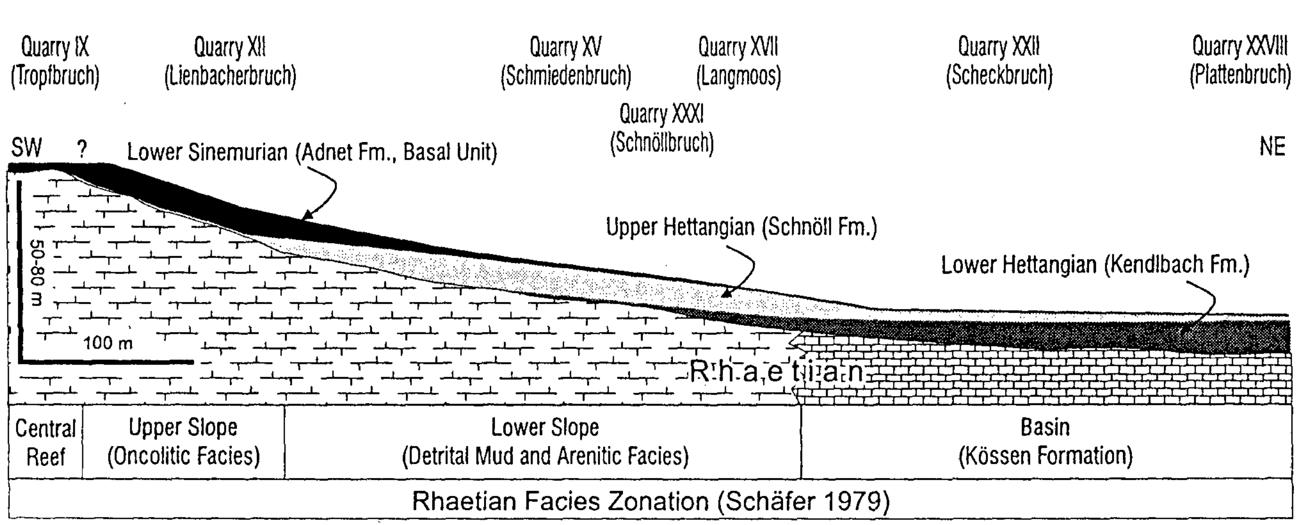
In conclusion, the Adnet reef displays a constructional end-Rhaetian palaeorelief with a horizontal palaeo-seafloor at top and base and a north to northeast dipping slope with a slope angle of about 10–15° in between. This large-scale relief of about 50–80 m vertical height was structured by small scale terraces or patch reefs and possibly spurs or channels.

Large-scale Geometries of the Sedimentary Units

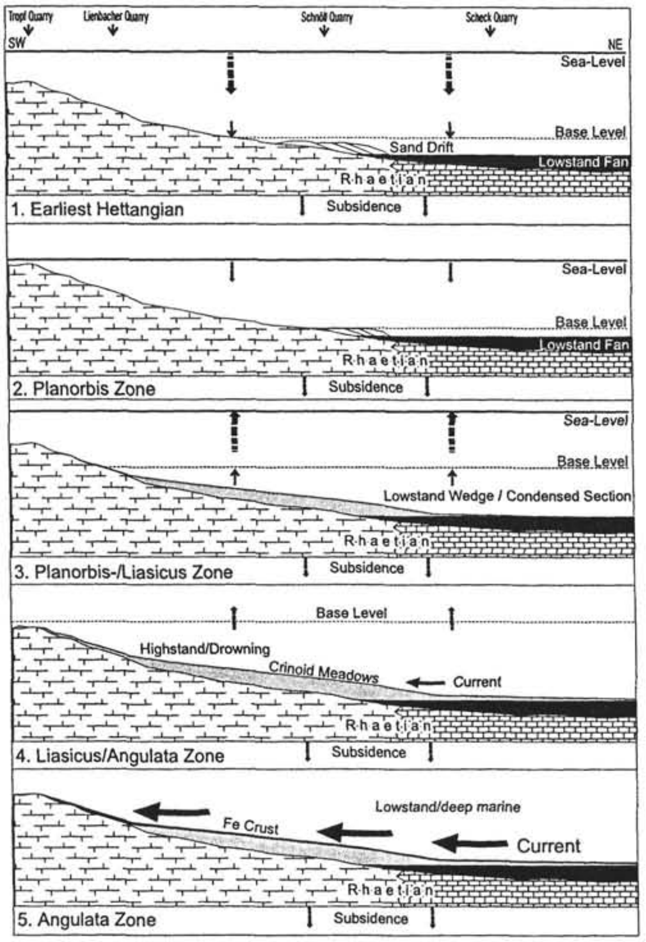
The large scale distribution of sedimentary thicknesses of the lithostratigraphic units points to a complex onlap of the Liassic on the end-Rhaetian topography (Böhm & Krystyn, 1998; Text-Fig. 23). During the early Hettangian sediments were deposited only in the basin (lower Kendlbach-Fm.). This period is interpreted as a time of sea-level lowstand (e. g. Hallam & Goodfellow, 1990; Böhm, 1992).

During the middle Hettangian the depocenter moved to the toe of slope (Schnöll-Fm.). Sedimentation also started to encroach on the higher slope. In the basin a phase of sediment starvation started (upper Kendlbach-Fm.). This interval probably represents a transgressive phase. Flooding of shelf areas reduced the siliciclastic input to the basin. Therefore, the upper Kendlbach-Fm. lacks the thick clay intervals (Text-Fig. 5). Microlithoclasts, major components of the lower Kendlbach-Fm. and probably derived from erosion of the platform, decreased in abundance. A sponge-dominated community settled on the lower slope (Langmoos-Mb.). Later, the community on the former reef slope changed to crinoid-dominated (Guggen-Mb.). This may be due to a better ventilation and decreased nutrient content of the deeper waters during the subsequent highstand phase. During this highstand the base level moved above the former platform and allowed sedimentation to start on the higher slope.

The late Hettangian is a period of strong condensation in the basin as well as on the slope and platform. However, for the first time in the Jurassic there was deposition, although very condensed, on the upper slope and reef top. Probably at this time the Adnet area was drowned deep enough that both platform and basin were affected in the same way. The reason for the strong sediment starvation may have been current activity combined with strongly reduced input of carbonate mud due to the widespread platform drowning (Böhm, 1992). The expansion of sediments rich in open-marine faunas (ammonites, brachiopods, crinoids; Enzesfeld Limestone and "Marmorea Crust") from the lower slope to the reef top at this time is not compatible with a subaerial emer-



Text–Fig. 22.
Schematic reconstruction of the end-Rhaetian to early Sinemurian morphology of the Adnet area. Reconstruction based on thicknesses and facies distribution of the shown formations. Liassic formations onlap the former reef relief with continuous sedimentation in basinal areas and a hiatus comprising most of the Hettangian at the upper slope.



Text–Fig. 23.
Speculative sequence stratigraphic interpretation of the geometries and facies of the Hettangian sediments at Adnet. 1 – Earliest Hettangian, Pre-planorbis/Planorbis zone. Falling sea-level, late highstand/early lowstand systems tract (LST). Basal Kendlbach beds form as a lowstand fan by turbidites shed from the platform margins. Higher parts of the platform emerge. At the base of slope a carbonate sand fan develops (Schnöll Quarry, cross-bedded packstones). Higher up the slope wave action erodes or prevents sedimentation. 2 – Planorbis zone. Sea-level at lowest point. Even the sand fan at the base of the slope is eroded by wave action. Only in the basin sedimentation continues (lower Breitenberg-Mb. lowstand fan). 3 – Late Planorbis/Liasicus zone. Rising sea-level, late LST and transgressive systems tract. Rising base level allows onlap of the lower Schnöll-Fm. at the slope as a lowstand wedge. Poorly oxygenated, nutrient-rich bottom waters foster dense sponge populations. Drowning of the platform. Reduced input of siliciclastic sediments leads to condensed sedimentation of glauconite-rich limestones in the basin. 4 – Liasicus/Angulata zone. Highstand systems tract. Change to sedimentation of crinoidal limestones in Schnöll- and Kendlbach-Fms. caused by better oxygenation and reduced nutrient levels. Progressive platform drowning. 5 – Angulata zone. Sea-level falls again, but has no immediate influence as drowning has already increased waterdepth substantially. Indirect influence through enhanced current activity. Strong condensation and finally formation of ferromanganese crust ("Marmorea Crust").

gence in the late Hettangian, proposed for the nearby Steinplatte by MAZZULLO et al. (1990).

Onlap Structures and Small Scale Relief

A prominent erosional unconformity is present at the Schnöll Quarry (XXXI) between the grey cross-bedded packstones and the overlying Schnöll (Pl. 3, Figs. 1-2; Text-Figs. 16, 17, 20). BLAU & GRÜN (1996) interpreted the dip of this unconformity as a result of tectonic eastward tilting. However, the concurrent dip direction of the fore-sets below the unconformity point to a depositional origin, rather than tectonic tilt. The quarry is positioned at the lower palaeoslope of the Rhaetian reef (SCHÄFER 1979) and dip direction as well as dip angle of the unconformity agree well with the supposed Rhaetian palaeo-relief (Text-Fig. 22). Further, the basal cross-bedded packstones probably represent a submarine dune or fan (BÖHM et al., 1997b), which may have formed a bar-like structure with positive relief. Therefore, the observed dip of the unconformity can be interpreted as a primary depositional slope. We suggest that the unconformity formed during a sea-level lowstand and was subsequently onlaped by the Schnöll during a sea-level rise (Text-Fig. 23). With that, the unconformity would represent a sequence boundary, formed during a sea-level lowstand in the Planorbis zone. Of course, this interpretation does not exclude regional tectonic *uplift* as a cause for the early Hettangian sea-level lowstand. But we see no evidence for early Hettangian tectonic *tilt* in any Adnet quarry. All observed onlap sequences (Quarries XII, XIV, XXXI) occur in slope settings and on a relief with a plausible sedimentary origin, connected to the Rhaetian reef topography.

The inclinations of geopetal infills measured in Quarry XII (Text-Fig. 8 d) exclude large scale tectonic tilting of the reef core during the Hettangian/Sinemurian. However, they provide no conclusive evidence for or against minor tilt. The data allow for a local 5° northeastward tilt during the Hettangian or early Sinemurian in the NW part of Quarry XII. Even if real, such local small scale tilt could as well be due to differential compaction and cannot be taken as evidence for a tectonic event.

Very likely the onlaping sediments were impinged by bottom currents following the contours of the drowning reef mound. For instance the prograding beds above the Basal Sinemurian Crust in Quarries XII and XIV (Text-Figs. 9, 10) are most easily explained by the current-driven progradation of a submarine dune along the former reef slope (BÖHM et al., 1997b; BÖHM & KRYSTYN, 1998). Indications for current controlled sedimentation are also seen in Quarry XXXI. There the sponge layer at the base of the onlaping Guggen-Mb. was formed by sessile suspension feeders (sponges, crinoids) and displays a remarkably constant thickness throughout the quarry (Text-Fig. 20). The overlying muddy sediments, however, were first deposited in the depression beside the crossbedded unit, only slowly encroaching on the inclined hard substrate of the hardground covered sponge layer (Text-Fig. 16). At Quarry XIV Hettangian sediments were only deposited in small pockets and depressions of the Rhaetian limestone, which obviously was well lithified at this time and formed a hard, inclined substrate (Text-Fig. 10, 11). Such inclined hard substrates could easily be kept free of the muddy Liassic sediments even by weak bottom currents.

Neptunian Dykes - Hettangian Tectonics?

BLAU & GRÜN (1996) stressed the high frequency and importance of neptunian dykes in the Hettangian of the Schnöll Quarry. They pointed out that two generations of dykes can be observed, one confined to the grey basal packstones and a second reaching up into the Guggen-Member as far as one bed below the "Marmorea Crust". They also mention the good fit of corresponding dyke walls as evidence against a karst origin. Extensional stress leading to the dyke formation and their proposed synsedimentary tectonic eastward tilt of the basal grey packstones are called upon as evidence for an early Hettangian period of tectonic activity (BLAU & GRÜN, 1996).

We observed some brecciated layers near the top of the Guggen-Mb. in Quarry XXXI that could be interpreted as seismites. The top-bed of the microlithoclastic facies at Hochleitengraben (bed 27, Text-Fig. 5), which we tentatively correlate with the base of the Schnöll-Fm., probably is a mass flow deposit. Both observations could be taken as further evidence for early Hettangian tectonic activities. However, none of the features listed above is unequivocal evidence.

We already stated that we prefer an interpretation of sedimentation on a depositional reef slope (Text-Fig. 23), possibly connected with minor local tectonic or compactional tilting (e. g. as observed at the Steinplatte, EBLI, 1997: 52), for the observed sedimentary geometries. Sedimentation in the early Hettangian was probably influenced by sea-level fluctuations and reworking on the higher slope (Text-Fig. 23; EBLI, 1997; SATTERLEY et al., 1994; BÖHM, 1992; HALLAM & GOODFELLOW, 1990). With that, gravity flow deposits like bed 27 at Hochleitengraben or the grey cross-bedded packstones of the Schnöll Quarry are expected features of a lower slope or basinal setting. Further lowering of the base level would lead to erosion and could explain the unconformity on top of the grey packstones (Text-Fig. 23). The mud-rich Kössen Beds interfinger with the Rhaetian reef limestones very close to Quarry XXXI. Compaction of the Kössen beds after cessation of the high Rhaetian sediment input from the reef probably led to an increase of the slope inclination. This could have caused tensional stresses that led to gravity sliding and the formation of fissures. Neptunian dykes were previously ascribed to gravity sliding by WINTERER et al. (1991). An additional mechanism for the generation of fissures, especially for the grey cross-bedded packstones, could be a synsedimentary sea-floor cementation (SHINN, 1969).

Puzzling features of the Schnöll Quarry are the collapse structures (Text-Fig. 21). These structures are clearly tensional and point to the presences of collapsed cavities below the quarry floor. Possible causes include the break-down of a Rhaetian karst cavity and tensional fracturing through compactional or tectonic movements. The processes that caused the formation of these structures are likely also responsible for the formation of the brecciated layers near the top of the Guggen-Mb. as well as for the fissures cutting into the Guggen-Mb. An increase in the frequency of these fissures towards the center of the quarry, i. e. towards the collapse structures, was also observed by BLAU & GRÜN (1996). These processes apparently took place shortly before the formation of the Marmorea crust as shown by the levelling of the resulting depression by the bed immediatley below the crust (Text-Fig. 21).

In conclusion, we cannot exclude tectonic activities during the Hettangian or Sinemurian in the Adnet area, however, at the most these were of minor and only local importance. Most observed structures can as well or even better be explained by depositional or erosional processes acting on a sedimentary slope built up by reef organisms during the Rhaetian. In the Early Hettangian a change took place from a high-productivity carbonate platform with long-term sedimentation rates on the order of 100 m/Ma in shallow water and 50 m/Ma in the Kössen basin to the very slow Liassic sedimentation with rates <10m/Ma. The sediment type changed from grain-dominated to mud-dominated. These changes certainly had consequences for the maintenance of the steep depositional relief built up during the Late Triassic. Redeposition and compactional oversteepening may have played a role during the early phase of drowning. Current activities gained a major control on sedimentation on the drowning reef, especially on the slopes. Such processes must be taken into account for the interpretation of syndepositional structures and geometries of the early Liassic of Adnet.

2.4. Microfacies

Work on microfacis focused mainly on the Schnöll-Quarry, and here especially on the lower parts. Therefore only sparse descriptions of the Adnet-Fm. and the Lower Schnöll-Fm. are possible. For further information – also for the Kendlbach-Fm. – see BÖHM (1992) and EBLI (1997).

2.4.1. Kendlbach-Formation

As stated in chapters 2.1.2.1. and 2.2. the basal limestones outcropping in the Schnöll-Quarry (quarry XXXI) could be assigned to the Kendlbach-Fm. This lithology is represented here by one layer of thick, grey, cross-bedded limestone.

Microfacies 1: Microlithoclastic pelbiomicrite to -sparite with echinoderms (pack- to grainstone; Pl. 5, Figs. 1-5).

The main components of this lithology are microlithoclasts and peloids, varying in abundance between 20–50%. The microlithoclasts are mostly well to moderately rounded and have diameters of up to 1,1 mm. Mostly they can be interpreted as intraclasts, whereas also some clasts represent strongly micritized bioclasts, especially echinodermal remains. Sometimes the peloids are very densly packed, and then have stylolitic contacts.

The biogenic components are mainly represented by echinoderms (-30%) and debris of often thick-shelled bivalves and brachiopods (-10%). Foraminifera are rather rare (4-12 individuals/cm^2). Miliolids dominate, followed by arenaceous foraminifera and the rare lagenids. Sometimes the echinodermal remains and tiny fragments of bivalves are encrusted by cyanobacteria.

The micritic matrix is often recrystallized to microspar. Sometimes it has a yellowish colour. In this case the components are often surrounded with fibrous A-cement, dog-tooth cements (length of single crystals up 56 μm, width of 24 μm) or bladed calcite (length 120 μm, width 80 μm). Pyrite is finely dispersed in the sediment, or enriched in small patches.

The matrix can also be primarily washed out. This is the case in the cross-bedded layers where micritic and sparitic foresets change. This sedimentological characteristics are mostly obscured by post-depositional phenomena, especially by diagenetically induced growth of calcite (Pl. 5, Figs. 1-2, 4-5). Elongated bioclasts as bivalves are well orientated.

At the top of a redeposited sequence a very finegrained, cross-bedded sediment (diameters between 8-40 μm) is relictly preserved. It is interpreted as the finest part of a calciturbidite.

The sequence starts with a parallel-laminated finegrained sediment (plane-bed, more proximal calciturbidite) followed by a mostly non-erosive inverse graded biomicrite, that exhibits in its upper parts a coarse-tail-grading. One lithoclast has the extraordinary diameter of 4,5 mm! Due to these sedimentary features this sediment is interpreted as a debris-flow.

2.4.2. Adnet-Group

2.4.2.1. Schnöll-Formation Guggen-Mb. (Hettangian)

The contact of the Schnöll-Fm. to the underlying Kendlbach-Fm. in Quarry XXXI is a sedimentary discontinuity, therefore erosive and sharp.

The surface of the Kendlbach-Fm. is strongly bioeroded, with borings that penetrate several mm down into the rock (compare also WENDT, 1970). The partly dichothomous borings (Plate 5, Fig. 3: B) are filled by a yellow-brown phosphatic, or a dark Fe/Mn-rich sediment, indicating a time of very slow or non-sedimentation after their construction. The same sediments are preserved only in pockets of this relief and sealed by a very thin sparitic crust with a thickness between 8–20 μm (Plate 5, Fig. 3: arrows) that can also lie directly upon the rocks of the Kendlbach-Fm. Therefore sedimentation was only possible in depressions.

Also the microfacies and the biota change abruptly. Noteworthy are neptunian dykes cutting deep into the rocks of the Schnöll-Fm. and ending at the contact to the Kendlbach-Fm.

The dykes (Plate 8) are filled either by a densely packed echinodermal-biosparite to -micrite, having sometimes a high lithoclast content, or by a fine siltitic sediment. Filling was polyphase, as indicated by laminations.

The contact to the normal sediment is mostly very sharp, sometimes pronounced by stylolites, generated by pressure-solution. Only rarely the dykes grade continuously into the sediment, indicating fracturing of the rocks in a semi-lithified state. In thin-sections 2 generations of dykes can be identified.

The sediments of the Schnöll-Fm. in Quarry XXXI mostly correspond to MF-type 2.2. The MF-types 2.1. and 2.3. to 2.5. represent end members that are linked with this microfacies by a continuous spectrum of mixing of the distinctive biogens and allochems.

Cyano-Oncoids are very characteristic components of the Schnöll-Fm. They consist of massive, only rarely layered micrite and reach maximal diameters up to several millimeters. JENKYNS (1972) termed such components as "pelagic ooliths" or "micro-oncoids". For their genesis the sediment-binding activity of cyanobacteria was responsible (op. cit.).

Microfacies 2.1.: Bivalve-gastropod biomicrite (wackestone)
Plate 5, Fig. 3

Shell fragments of bivalves, gastropods and echinodermal remains (together 15-20%) constitute this sediment type. The foraminiferal fauna includes most forms characteristic for the Schnöll-Fm., but reveals low densities. Bioclasts can be impregnated by Fe/Mn-oxides or by yellowish-brown phosphatic precipitates. Cyano-oncoids are missing!

Microfacies 2.2: Echinoderm-foram-biomicrite with cyano-oncoids (wackestone to packstone)
Plate 6, Figs. 1, 3

The sediment mainly consists of echinoderms (10–25%), spicula (3–10%), thick-shelled ostracods (3–15%) and bivalve debris (5–15%). Further components are gastropods (ca. 2,5%), and the omnipresent cyano-oncoids. Angular intraclasts with diameters up to 2 mm (Plate 6, Fig. 1: arrows) reveal the synsedimentary reworking of the sediment. The characteristic foraminifera reach abundances of 15–34 individuals/cm^2. Involutinids dominate over Lagenids, Miliolids and the rare arenaceous forms. Sclerites of Holothurians (*Theelia* sp.: Plate 7, Fig. 5) occur in one sample. Serpulids and *Globochaete alpina* are rare.

The matrix of the sediment is a reddish-yellowish to grey micrite to microsparite, often exhibiting stromatactis-structures, filled by a coarse spar. In some samples the foraminifera, other biogens or the meshwork-structures of echinoderms are filled with glauconite. This mineral can also be enriched around sponges. Pyrite is especially abundant in the basal parts of the Guggen-Member and occures in patches or is finely dispersed in the sediment. Bioturbation is common in some layers.

Microfacies 2.3.: Bivalve-ostracod biomicrite with cyano-oncoids (wacke- to packstone)
Plate 6, Fig. 2

The reddish-white mottled sediment consists mainly of the debris of thick-shelled bivalves (20–30%), ostracodes (-10%), spicula (10-15%) and gastropods. Cyano-oncoids and lithoclasts (together 5–7,5%) are reddish-brown in colour.

Microfacies 2.4.: Cyano-oncoidal biomicrite (packstone)
Plate 6, Fig. 4

In some layers the cyano-oncoid content is enriched up to 50%. The components are surrounded by a grey micritic to microsparitic sediment. Echinoderms reach up to 10%, and are therefore rarer than in MF 2.1., as is also true for the other above mentioned biogens. Vagile foraminifera in the sediment reach abundances up to 13 individuals/cm^2. The faunal composition is the same as in MF 2.3.

Microfacies 2.5.: Spiculite with cyano-oncoids (wackestone)
Plate 7, Fig. 1

Spicula of mostly hexactinellid sponges (20–40%) are the main bioclasts. Echinoderms (5%), cyano-oncoids (1- max. 5%), rare foraminifera and accessoric remains of gastropods and bivalves complete the spectrum. The matrix is often a bioturbated, silicified dark-grey peloidal to pure micrite. Sometimes the spicula are fully replaced by pyrite, or only the axial-channels are impregnated (Plate 7, Fig. 4).

In contrast to the sponge-fragments (Plate 7, Figs. 2-3) that are characterized by a cubic meshwork of spicula, the spicula are more randomly orientated in this MF-type. They also have a layered occurence due to disintegration and redistribution by current-activity, whereas the sponge-fragments have a patchy distribution.

Enzesfeld Limestone

The Enzesfeld Limestone is represented in Adnet by a thin condensed layer (hardground), the "Marmorea-Crust" ("Brandschicht").

Microfacies 4: Echinoderm-foram-biomicrite with gastropodes (wacke- to packstone)
Plate 9, Figs. 1-6

This lithology is characterized by a high content of foraminifera (up to 60 Individuals/cm^2; especially Involutinids) that occur with echinoderms (-25%), ostracodes, gastropodes and debris of bivalves, brachiopods and ammonites. *Globochaete alpina* is common. Pelagic crinoids (Plate 9, Fig. 3) occur. Intercalated hardgrounds may consist of brownish-yellow phosphatic sediment or of dark Fe/Mn-oxides, the latter being massive (Plate 10, Fig. 1) or laminated (Plate 10, Fig. 2). In one case a radiolaria (Plate 9, Fig. 4) survived diagenetic dissolution due to the fact, that it was incorporated in a massive crust!

Spicula are mostly rare, only in some samples they have a greater abundance (up to 5%). Moreover, in other samples (e.g. Brand 7) more or less intact sponges occur. The matrix can bear a very high content of calcareous nannoplankton (Plate 9, Figs. 3, 5, 6).

Intraclasts occur locally. Noteworthy is a platy lithoclast (max. diameter: 2,5 mm) in the sample Lien HG I (Plate 9,

Fig. 2), that was eroded from the underlying Rhaetian neritic limestones.

This MF-Type corresponds to MF 10 of BÖHM *(1992).*

2.4.2.2. Lower Adnet-Formation (Sinemurian-Carixian)

In the investigated section only the Basal Unit of the Adnet-Formation was sampled. It exhibits a rather uniform microfacial appearance.

Microfacies 5: Bioturbated ostracod-echinoderm-mollusc-biomicrite (wackestone)
Plate 10, Figs. 3-4

As the most important group of biogens, ostracodes, delicate mollusc-shells ("filaments") and echinodermal remains reach up to 20%. Of special interest are very tiny remains of pelagic crinoids (Plate 10, Fig. 3). Additional spicula, very fine grained and therefore no more determinable biogenic detritus, *Globochaete alpina,* and forams appear. In several patches the bioclasts are strongly recrystallized, and the ghosts are filled by a mosaic of relatively dark microsparite. The darker matrix of the sediment is bioturbated and contains several irregular nodules, that are only sometimes surrounded by Fe/Mn-coatings.

2.5. Nannofacies

The main share of Adnet-Group sediments are variegated coloured, mostly red, micritic to microsparitic limestones. This is also demonstrated by the SEM-photomicrographs shown on Plates 12 and 13.

For study of ultrafacies we used chips of crushed samples, which were neither polished nor etched, but only gold-sputted. Maybe polished/etched samples would have allowed a better identification of coccolithophorids and *Schizosphaerella* sp., however, our method of sample preparation displays clearly the state of grain preservation and the microfabric. In addition we used EDAX for checking eventual silicification and for identification of non-carbonate grains.

Diagenetic alteration of originally micritic limestone is abundant, evidenced by recrystallization of micrites into microsparites and by grain corrosion, the latter explains the scarce presence of identifiable biota. In general coccolithophorids and *Schizosphaerella* sp. are scarce and always strongly corroded. In addition also calcispheres, tests of foraminifera, sponge spicules and mollusc shell debris can be identified in the SEM preparations (see also chapter 3.1.1. for more details on *Schizosphaerella punctulata*). In part also silicification can be observed, in particular in the samples from the sponge bearing Schnöll-Formation (Langmoos-Mb.). Enrichments of clay minerals, mica flakes and other non-carbonate grains are characteristic for zones of pressure solution, as e.g. stylolites.

2.6. Stable Isotopes

2.6.1. Material and Methods

Stable carbon and oxygen isotopes of limestones from a short section in the southwestern part of Quarry XXXI (Schnöll Quarry) were analyzed (Text-Fig. 24). The section measures ca. 4 m. It starts in the basal grey crossbedded packstones (?Kendlbach-Fm.) and continues up to the lower Schmiedwirt-Mb. (Adnet-Fm.). Five additional samples of red and grey spiculitic wackestones of the Langmoos-Mb. were collected in the northeastern part of Quarry XXXI (thin nodular beds near the quarry floor), in Quarry XV (massive bed at base of quarry) and Quarry XVII (basal section in southeastern part and thin-bedded nodular layer in northwestern part). We further measured stable isotopes of 21 samples of nodular limestones of the Adnet-Fm. (Schmiedwirt-Mb.) of the Schmiedwirt section near Adnet (BÖHM, 1992; MEISTER & BÖHM, 1993). All measured values are shown in Tabs. 1, 2.

Carbonate powders were drilled with a dental drill from micritic parts of cut limestone samples, avoiding fossil debris and fractures. Carbonate powder samples were reacted with 100% H_3PO_4 at 75 °C in an online, automated carbonate reaction device (Kiel Device) connected to a Finnigan Mat 252 mass spectrometer. Isotopic ratios are reported in standard notation relative to the PDB standard. External precision based on multiple analyses of the NBS 19 standard is better than ±0.1‰ for $\delta^{13}C$ and $\delta^{18}O$.

2.6.2. Results

The basal grey packstones (?Kendlbach-Fm.) show homogenous $\delta^{13}C$ values of +2.4±0.1‰ and $\delta^{18}O$ values of -1.1±0.2‰ (Text-Figs. 24, 25). No trend towards the erosional surface was found. The samples of the Langmoos-Member show different ranges for grey and red samples with

Tab. 1

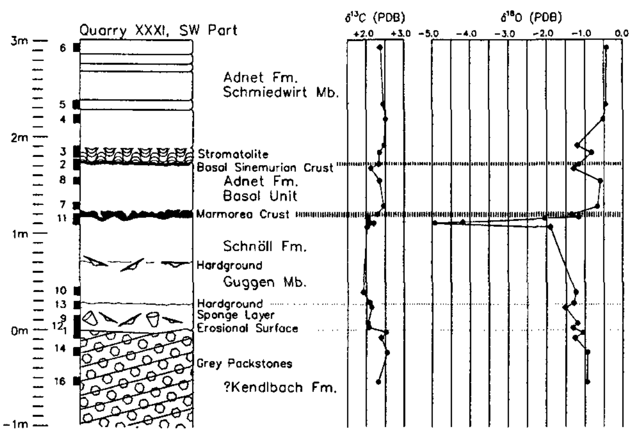
Stable isotope results. All isotope values in ‰ PDB. External precission (±2σ) is better than ±0.1‰ for $\delta^{13}C$ and $\delta^{18}O$. Short section in the SW part of quarry XXXI (Text-Figs. 15, 24). Samples are arranged in stratigraphic order. Sample position is given in cm relative to the erosional surface on top of the basal grey packstones of the ?Kendlbach-Fm. Additional sample SCH16 from base of quarry wall in NE part of Quarry XXXI. Langmoos Mb. samples from Quarries XV and XVII, arranged in stratigraphic order.

Sample	Position [cm]	Lithology, Stratigraphy	$\delta^{13}C$ (PDB)	$\delta^{18}O$ (PDB)
Quarry XXXI				
AD16	-50	grey packstones, ?Kendlbach Fm.	2.32	-0.94
SCH14	-20	grey packstones, ?Kendlbach Fm.	2.55	-0.93
SCH1bott.	-4	grey packstones, ?Kendlbach Fm.	2.39	-1.26
SCH1mid.	-1	grey packstones, ?Kendlbach Fm.	2.52	-1.05
SCH1top	0.5	*sponge layer, Schnöll Fm., Guggen Mb.*	2.07	-1.32
SCH12	3	sponge layer, Schnöll Fm., Guggen Mb.	2.04	-1.19
SCH13bott.	24	sponge layer, hardground, Schnöll Fm., Guggen Mb.	2.14	-1.52
SCH13top	25	sponge layer, Schnöll Fm., Guggen Mb.	2.09	-1.30
SCH10	50	crinoidal lst., Schnöll Fm., Guggen Mb.	1.91	-1.25
SCH11-4	97	Enzesfeld lst., Schnöll Fm. Guggen Mb.	2.02	-1.90
SCH11-10	100	Enzesfeld lst., Schnöll Fm. Guggen Mb.	2.17	-4.92
SCH11-5	101	Enzesfeld lst., Schnöll Fm. Guggen Mb.	2.06	-4.19
SCH11-8	106	Enzesfeld lst., Schnöll Fm. Guggen Mb.	2.02	-2.06
SCH11-7	108	Enzesfeld lst., Schnöll Fm. Guggen Mb.	2.02	-1.17
SCH11-6	110	base of Marmorea Crust	2.30	-1.35
SCH7	125	brown biomicrite, Adnet Fm., Basal Unit	2.45	-0.67
SCH8	150	grey biomicrite, Adnet Fm., Basal Unit	2.34	-0.60
SCH2bott.	167	red biomicrite, Adnet Fm., Basal Unit	2.12	-1.30
SCH2top	170	red biomicrite, ferrom. crust, Adnet Fm., Basal Unit	2.32	-1.17
SCH3bott.	185	red biomicrite, stromatolite, Adnet Fm., Basal Unit	2.34	-0.84
SCH3top	190	red biomicrite, Adnet Fm., Schmiedwirt Mb.	2.46	-1.21
SCH4	220	red nodular biomicrite, Adnet Fm., Schmiedwirt Mb.	2.50	-0.54
SCH5	230	red biomicrite, Adnet Fm., Schmiedwirt Mb.	2.45	-0.45
SCH6	300	red biomicrite, Adnet Fm., Schmiedwirt Mb.	2.37	-0.42
SCH16	NE wall	reddish biomicrite, Schnöll Fm., Langmoos Mb.	2.48	-0.52
Quarries XV and XVII (in stratigraphic order, top to bottom)				
La-1	qu. XVII	grey-red biomicrite Schnöll Fm., top Langmoos Mb.	1.86	-0.66
La-5	qu. XV	red biomicrite, Schnöll Fm., Langmoos Mb.	2.30	-0.20
AD96-3	qu. XVII	red biomicrite, Schnöll Fm., Langmoos Mb.	2.32	-0.32
AD96-1	qu. XVII	creme biomicrite, Schnöll Fm., base Langmoos Mb.	2.16	-0.83

Tab. 2

Stable isotope results. All isotope values in ‰ PDB. External precission ($\pm 2\sigma$) is better than ± 0.1‰ for $\delta^{13}C$ and $\delta^{18}O$. Nodular limestones of the Adnet-Fm., Schmiedwirt and Kehlbach Mb., of the Schmiedwirt section. Samples in stratigraphic order, position in metres above base of section (layer 1 in MEISTER & BÖHM, 1993). Layer numbers refer to MEISTER & BÖHM (1993).

Sample	Position [m], Layer	Lithology, Stratigraphy	$\delta^{13}C$ (PDB)	$\delta^{18}O$ (PDB)
Schmiedwirt Quarry				
SW36	0.0, L1	matrix, red biomicrite, Adnet Fm., Schmiedwirt Mb.	1.92	-0.26
SW35	0.7, L1	matrix, reddish biomicrite, Adnet Fm., Schmiedwirt Mb.	2.10	-0.28
SW32-m	1.4, L2	matrix, red biomicrite, Adnet Fm., Schmiedwirt Mb.	2.10	-0.15
SW32-c	1.4, L2	clast, red biomicrite, Adnet Fm., Schmiedwirt Mb.	2.11	-0.22
SW31	2.2, L2	matrix, red biomicrite, Adnet Fm., Schmiedwirt Mb.	2.14	-0.17
SW29	5.0, L4	matrix, red biomicrite, Adnet Fm., Schmiedwirt Mb.	2.45	-0.07
SW30	6.2, L4	matrix, red biomicrite, Adnet Fm., Schmiedwirt Mb.	2.28	-0.45
SW28	8.1, L6	nodule, red biomicrite, Adnet Fm., Schmiedwirt Mb.	2.17	-0.16
SW27	9.4, L6	matrix, red biomicrite, Adnet Fm., Schmiedwirt Mb.	2.18	-0.33
SW26-n	10.4, L7	nodule, red biomicrite, Adnet Fm., Schmiedwirt Mb.	2.22	0.10
SW26-m	10.4,L7	matrix, red biomicrite, Adnet Fm., Schmiedwirt Mb.	2.20	0.06
SW24	10.9, L7	nodule, red biomicrite, Adnet Fm., Schmiedwirt Mb.	2.08	-0.08
SW22	11.9, L7	matrix, red biomicrite, Adnet Fm., Schmiedwirt Mb.	1.98	-0.32
SW21	12.6, L7	nodule, red biomicrite, Adnet Fm., Schmiedwirt Mb.	1.94	-0.27
SW20	13.2, L8	nodule, red biomicrite, Adnet Fm., Schmiedwirt Mb.	1.96	-0.18
SW12	14.3, L8	matrix, red biomicrite, Adnet Fm., Kehlbach Mb.	2.01	-0.05
SW10	14.8, L8	nodule, red biomicrite, Adnet Fm., Kehlbach Mb.	2.08	-0.27
SW9	15.4, L9	nodule, red biomicrite, Adnet Fm., Kehlbach Mb.	2.10	-0.22
SW7	16.2, L10	nodule, red biomicrite, Adnet Fm., Kehlbach Mb.	2.10	-0.21
SW8	16.7, L10	nodule, red biomicrite, Adnet Fm., Kehlbach Mb.	2.28	-0.19
SW5	17.4, L12	nodule, red biomicrite, Adnet Fm., Kehlbach Mb.	2.29	-0.16



Text-Fig. 24.
Section in the SW part of Quarry XXXI (Schnöll Quarry), covering sediments from ?lower Hettangian to Sinemurian. Stable isotope values (‰ PDB) are shown on the right. Sample numbers shown on the left for reference to Tab. 1. Carbon isotopes vary very little throughout the section. Above the basal erosion surface $\delta^{13}C$ shifts by -0.5‰, opposite to what would be expected for an emersion horizon. The most prominent feature in the $\delta^{18}O$ curve is a negative shift about 10cm below the "Marmorea Crust". $\delta^{18}O$ values of the Adnet-Fm. are close to -0.5‰, except for the stromatolite horizon with values close to -1.0‰.

the grey samples depleted in both ^{13}C and ^{18}O: red samples $\delta^{13}C = +2.4\pm0.1$‰, $\delta^{18}O = -0.3\pm0.2$‰; grey samples $\delta^{13}C = +2.0\pm0.2$‰, $\delta^{18}O = -0.7\pm0.1$‰. All analyzed samples from the Guggen-Mb. are grey and have similarly depleted values as the grey samples of the Langmoos-Mb.: $\delta^{13}C = +2.1\pm0.1$‰, $\delta^{18}O = -1.3\pm0.1$‰.

3 to 20 cm below the "Marmorea Crust" carbon isotopes from the Enzesfeld Limestone show usual values of the Guggen-Mb. ($\delta^{13}C = +2.1\pm0.1$‰), but oxygen isotope values display a strong negative excursion with extreme values as low as -4.9‰ 10 cm below the crust. Micrite within the crust again has oxygen isotope values like in the Guggen-Mb.

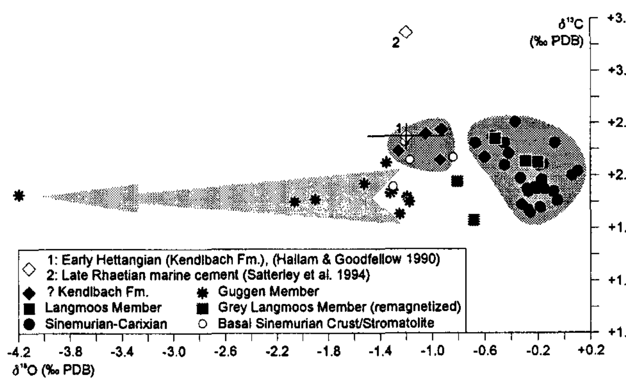
The overlying Schmiedwirt-Mb. shows a slight positive shift in both carbon and oxygen isotopes: $\delta^{13}C = +2.4\pm0.1$‰, $\delta^{18}O = -0.7\pm0.3$‰. Most oxygen isotope values are close to -0.5‰, only samples from the vicinity of the Basal Sinemurian Crust have lighter values around -1.0‰. The isotope values of the Schmiedwirt-Mb. at the Schmiedwirt Quarry have slightly lower $\delta^{13}C$ values of +2.1±0.1‰ and a slightly higher mean $\delta^{18}O$ of -0.2±0.1‰.

2.6.3. Discussion

Carbon isotopes

All $\delta^{13}C$ values are compatible with formation and diagenesis of the micrite in normal marine waters. $\delta^{13}C$ values are very close to +2.4‰ throughout the section except for the slight negative excursions of the grey Schnöll samples with $\delta^{13}C \approx +2.0$‰. The lower value also predominates in the section of the Schmiedwirt Quarry. The latter may be due to slightly ^{13}C-depleted bottom and/or pore waters in this more basinal, less well oxygenated setting. Sea-floor cementation probably played an important role in the formation of the red nodular limestones (JENKYNS, 1974; BÖHM, 1992; CLARI & MARTIRE, 1996). Therefore, carbon and oxygen isotopes are supposed to be significantly influenced by isotopic composition and temperature of local bottom waters (MARSHALL, 1981).

The lighter $\delta^{13}C$ values of the grey Schnöll samples may be explained by late diagenetic overprinting of the primarily homogenous carbon isotopic composition. This is corroborated by a concurrent depletion in ^{18}O in the grey Schnöll compared to red Schnöll. Additionally, GALLET et al. (1993) provided evidence for a secondary (post-Paleocene) remagneti-

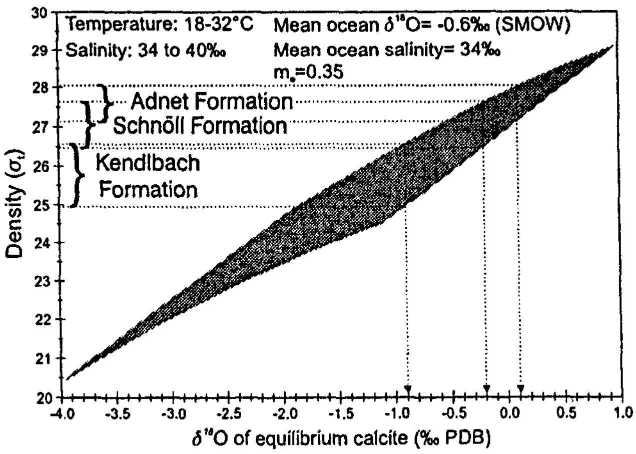


Text-Fig. 25.
Stable isotope values of Hettangian to Carixian matrix samples from quarries at Adnet and Schmiedwirt (compare Tab. 1, 2 and Text-Fig. 24). Also shown are average values ($\pm 1\sigma$) of Early Hettangian (Kendlbach-Fm.) matrix samples from Kendlbach section (HALLAM & GOODFELLOW, 1990) and a Late Rhaetian marine cement value (SATTERLEY et al., 1994). Carbon isotopes are rather invariable, except for the higher Rhaetian value. Oxygen isotopes, however, show a very wide range with the highest values found in the red Adnet and Schnöll limestones (Langmoos-Mb.). Early Hettangian limestones (Kendlbach-Fm.) have lower $\delta^{18}O$ values. The reason for the strong depletion of the Guggen-Mb. at Quarry XXXI is not clear. Carbon and oxygen isotopic depletion of grey remagnetized Schnöll limestones probably occurred during late diagenesis.

zation of the grey intervals of the Schnöll at Quarry XVII. The *red intervals retained their primary Liassic magnetization.* The diagenetic (?thermal) processes responsible for remagnetization may have affected the isotopic composition of the grey Schnöll as well.

In conclusion, the carbon isotope values of early Hettangian to early Carixian deeper water limestones of the Adnet area show very little variations ($\delta^{13}C \approx +2.2 \pm 0.2‰$). This is in contrast to the positive $\delta^{13}C$ excursions observed in the Domerian and early Toarcian (Domerian: Southern Alps: $\delta^{13}C \approx +3.0‰$, JENKYNS & CLAYTON, 1986; Adnet Scheck: $\delta^{13}C \approx +3.0‰$ to +3.5‰, HUDSON & COLEMAN, 1978; WAGREICH et al., 1996; Toarcian: $\delta^{13}C \approx 4.5‰$, JENKYNS & CLAYTON, 1986).

Carbon and oxygen isotope values of bulk limestone samples of the early Hettangian Kendlbach-Fm. (Tiefengraben-Mb., Praeplanorbis-Beds, $\delta^{13}C \approx +2.5 \pm 0.1‰$, $\delta^{18}O \approx -1.2 \pm 0.3‰$, HALLAM & GOODFELLOW, 1990) do not differ significantly from our Hettangian values (Text-Fig. 25). This may point to a continuation of the invariant carbon isotope curve down to the base of the Hettangian. On the other hand, basinal limestones of the latest Rhaetian Kössen-Fm. analyzed by HALLAM & GOODFELLOW (1990) are slightly enriched in ^{13}C ($\delta^{13}C \approx +2.7 \pm 0.2‰$) compared to the lower Liassic average.



Text–Fig. 26.
Bottom water densities during formation of the Kendlbach, Schnöll and Adnet, calculated from measured $\delta^{18}O$ using the most enriched values of each formation. Water densities increased from Kendlbach- to Adnet-Fm., which is explained by transition into a pycnocline starting in the middle Hettangian (Schnöll-Fm.). Densities are given as σ_t-values (density [g/l] - 1000), calculated from temperature (T) and salinity (S) according to DIETRICH et al. (1975). T/S pairs for plausible temperature (18–32 °C) and salinity (34–40‰) ranges were calculated for $\delta^{18}O_{calcite}$ according to RAILSBACK (1990). Grey area comprises all possible T/S pairs within the given bounds with a corresponding $\delta^{18}O$ range of -4.0‰ to +1.0‰. Mean ocean $\delta^{18}O$ (-0.6‰, SMOW) and salinity (34‰) are for a non-glacial Mesozoic world. Factor m_e (0.35) describes the relation between salinity and $\delta^{18}O_{water}$ in an evaporative setting (RAILSBACK, 1990).

Oxygen isotopes

The oxygen isotopic composition of limestones reflects temperatures and compositions of the fluids from which the carbonate was precipitated during sedimentation and diagenesis. Most later diagenetic processes tend to deplete oxygen isotopes (MARSHALL, 1992). Therefore, the most enriched $\delta^{18}O$ values measured on a limestone sample are usually thought to be closest to the primary isotopic composition, obtained during sedimentation and early diagenesis in contact with marine water.

Micrites of (hemi-)pelagic sediments like the Adnet Limestone originally include a considerable fraction of carbonate mud precipitated in warm surface water, carrying a correspondingly low $\delta^{18}O$ signal. However, cementation or *recrystallization at the sea-floor quickly leads to isotopic* equilibration with ambient deepwater (e.g. SCHLAGER & JAMES, 1978; MCKENZIE & BERNOULLI, 1982; DIX & MULLINS, 1988). Therefore, if not significantly altered during later diagenesis, oxygen isotope values from the Schnöll- and Adnet-Fms. will reflect temperature and salinity at the Early Liassic sea-floor.

The measured $\delta^{18}O$ values of the Schnöll- and Adnet-Formations are very high ranging up to -0.2‰ and +0.1‰ respectively. MARSHALL (1981) found this to be a common feature among red Jurassic nodular limestones. He assumed that part of the ^{18}O-enrichment is caused by cementation of high-Mg calcite (HMC), which later lost Mg but retained its isotopic signature by recrystallization in an isotopically closed system. HMC is enriched in $\delta^{18}O$ compared to low-Mg calcite by +0.06‰ per mole $MgCO_3$ (TARUTANI et al., 1969), resulting in an enrichment of about +0.9‰ for an average HMC cement (15 mole-% $MgCO_3$). By contrast, HUDSON & COLEMAN (1978) assumed ^{18}O-enriched marine water in an arid setting as an alternative explanation for high $\delta^{18}O$ values of Adnet Limestones and Scheck cements from Adnet. They calculated water temperatures of 17 °C and 24 °C for a non-glacial and a glacial model respectively.

Palaeoclimatic and palaeoceanographic models developed during the last few years support the increased salinity model proposed by HUDSON & COLEMAN (1978). During the Late Triassic and Early Jurassic the Tethys Ocean formed a sheltered embayment of Pangea, centered at the equator (CHANDLER et al., 1992). The Northern Calcareous Alps were positioned at the northwestern continental margin of the Tethys Ocean (e.g. HAAS et al., 1995). With its northern margin at about 30°N and its southern margin at about 40°S Tethys was sheltered from the cold high-latitude (boreal/austral) seas. Paleoclimatic models suggest that the Tethyan sea-surface temperatures were warmer than 20 °C throughout the year except for very narrow zones near the northern and southern coasts. Moreover, for large areas of Tethys the models suggest a negative moisture balance, i.e. arid conditions (CHANDLER et al., 1992; ROSS et al., 1992). Due to these conditions, Tethys most likely had slightly hypersaline surface-waters and an anti-estuarine circulation (BARRON & MOORE, 1994). Accordingly, Tethyan deeper waters had high salinities and were warm, nutrient-poor and oxygen-rich, similar to the present day Mediterranean Sea (HAY, 1995). These conditions may have favoured the formation of red nodular limestones (MÜLLER & FABRICIUS, 1974). At the Tethyan pycnocline both salinity and temperature may have shifted. But, water temperatures significantly colder than 20 °C probably did not occur even in the Tethyan deep waters (PARRISH, 1992).

With these constraints from palaeoclimatic models we can try to estimate the salinities required to explain the measured oxygen isotope values. Following the actualistic approach of RAILSBACK (1990), we assume a global average salinity of 34‰ and a mean ocean-water $\delta^{18}O$ of -0.6‰ (SMOW) for the non-glacial Jurassic, a linear correlation of salinity and $\delta^{18}O$ of marine waters due to evaporation with a slope m_e of 0.35 and a water temperature of 20±2 °C for the Schnöll- and Adnet-Formations. The value for the $\delta^{18}O$/salinity relation (m_e) of 0.35 may represent an upper limit for a subtropical ocean. In the modern Red Sea and Mediterranean this factor is 0.3 and 0.2 to 0.4 respectively (ANATI & GAT, 1989; PIERRE et al., 1988; RAILSBACK, 1990) in the tropical Atlantic and Pacific it varies from 0.1 to 0.3 and locally can be as high as 0.5 (FAIRBANKS et al., 1992; FERRONSKY & BREZGUNOV, 1989). A lower value for m_e would result in a less tight isotope/salinity relation and increase the error bars of the salinity and density estimates presented below.

For the measured $\delta^{18}O$ of the Hettangian Schnöll of -0.2‰ we then calculate a salinity range of 38±1.5‰. With the assumption of a preserved high-Mg calcite isotopic signal according to MARSHALL (1981, 1992) the calculated salinity is reduced to 36±1‰. For comparison, average salinities of the modern North Atlantic subtropical surface waters (25°N) are 36.6‰ to 36.8‰ (LEVITUS, 1982), i.e. about 2‰ above the modern global average. Salinities of intermediate waters in the modern Mediterranean Sea even range up to 39‰ (MÜLLER & FABRICIUS, 1974; PIERRE et al., 1988). Hence, both values calculated for the Schnöll-Fm. are reasonable. The slightly heavier oxygen isotope values of the Adnet-Fm. correspond to either a salinity increase of about 1‰ or a temperature decrease of 1.5 °C. As burial diagenesis may have depleted the $\delta^{18}O$ values, salinities may have been higher than calculated from maximum measured $\delta^{18}O$ values.

Late Rhaetian non-luminescent marine cements (SATTERLEY et al., 1994) from a reef mound in the NCA show $\delta^{18}O$ values as high as -1.2‰. This value fits very well with the early Hettangian oxygen isotope data from Adnet (this paper) and Kendlbach (HALLAM & GOODFELLOW, 1990). In contrast, the $\delta^{18}O$ values of the Schnöll- and Adnet-Fm. range up to -0.2‰ and +0.1‰ respectively. The limited data sets do not allow us to completely exclude a diagenetic cause for this difference. However, the observed shift in $\delta^{18}O$ of roughly +1‰ from Rhaetian/early Hettangian to middle Hettangian/Sinemurian times is synchronous with considerable microfacial changes pointing to a changing depositional environment. With that, a likely explanation for the increase in $\delta^{18}O$ is the passage of the sea-floor into a pycnocline by the middle Hettangian. The top of the pycnocline of modern subtropical oceans is typically situated between 50 and 100 m (e.g. HAY, 1995). For both Kössen and lower Kendlbach sedimentation likely took place within the mixed layer above the pycnocline. Passage into the pycnocline then happened when sedimentation of the Schnöll-Fm. started.

The isotope shift of +1‰ corresponds to a shift in water density of about 1 σ_t-unit (Text-Fig. 26). In the modern subtropical Atlantic Ocean thermocline an increase of 1 σ_t-unit corresponds to an increase in water depth on the order of 100 m (LEVITUS, 1982). Thus, the observed oxygen isotope shift can easily be explained by the drowning of the Rhaetian shallow water platform.

In conclusion, the oxygen isotope values agree well with the progressive deepening of the Adnet area that can be deduced from microfacies and subsidence analysis (e.g. BÖHM, 1992). They do not imply climatic deterioration from Rhaetian to Hettangian times as also demonstrated by HALLAM & GOODFELLOW (1990). Climatic cooling was proposed by FABRICIUS et al. (1970) as a cause for the end-Rhaetian reef drowning.

We currently have no explanation for the very pronounced neagtive $\delta^{18}O$ excursion immediately below the "Marmorea Crust" and less marked below the Basal Sinemurian Crust (Text-Fig. 24). A connection with the ferromanganese crusts is obvious. Also, the peak excursion is confined to a layer less than 20 cm thick, with the minimum value about 10 cm below the "Marmorea Crust". It is not accompanied by a comparable shift in $\delta^{13}C$, which shows only little variation in the studied section.

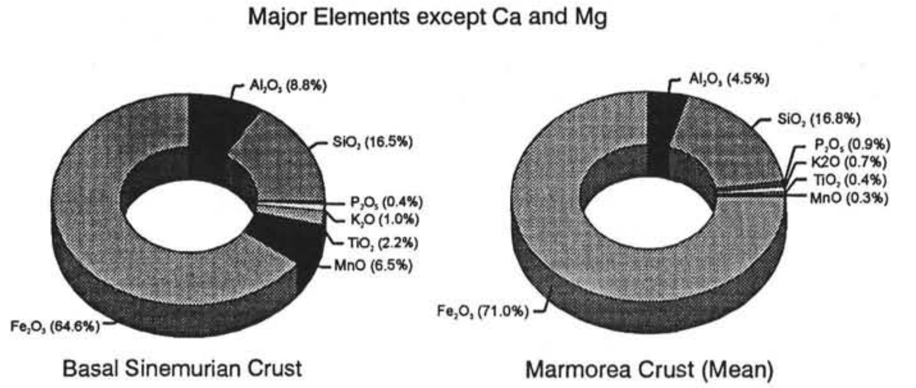
Meteoric diagenesis linked to the discontinuity surfaces of the crusts might provide an explanation, even though a negative $\delta^{13}C$ trend towards the crust would be expected in this case (JOACHIMSKI, 1994). However, we found no indications of meteoric diagenesis in microfacies. In fact, the Enzesfeld limestone underlying the "Marmorea Crust" is very rich in well preserved Involutinids (Pl. 6, Fig. 1; Pl. 10, Fig. 1), a group of aragonitic foraminifera (PILLER, 1978). Their very high frequency and good preservation is very difficult to explain in connection with an emersion surface. We therefore think that emersion does not provide a satisfying explanation for the observed situation.

GALLET et al. (1993) called on burial diagenesis, connected

Tab. 3

Chemical compositions of the analyzed samples of the "Marmorea Crust" and the Basal Sinemurian Crust. Sample "Saubach" collected from an outcrop south of Lake Wolfgang (BÖHM, 1992: 129, compare Text-Fig. 4). Dashes denote content below detection limit. Ranges are ±2σ.

	Marmorea Crust								Sinemurian Crust	
	Quarry XXXI		Quarry XXIX		Quarry XXII		Saubach		Quarry XXXI	
	Weight %	±2σ	Weight %	±2σ	Weight %	±2σ	Weight %	±2σ	Weight %	±2σ
MgO	0.9	0.1	1.0	0.2	1.2	0.1	1.2	0.1	1.2	0.2
Al_2O_3	0.89	0.03	1.19	0.04	1.16	0.03	1.14	0.03	5.2	0.1
SiO_2	2.16	0.02	2.19	0.04	6.05	0.03	3.43	0.03	9.9	0.1
P_2O_5	0.28	0.01	0.75	0.02	0.07	0.01	0.14	0.01	0.26	0.01
SO_3	3.26	0.01	--	--	--	--	--	--	--	--
K_2O	0.15	0.01	0.07	0.01	0.24	0.01	0.16	0.01	0.59	0.01
CaO	48.2	0.1	27.5	0.1	41.7	0.1	41.0	0.1	17.09	0.04
TiO_2	0.103	0.003	0.078	0.002	0.088	0.002	0.134	0.003	1.30	0.01
MnO	0.144	0.002	0.254	0.001	0.044	0.001	0.055	0.001	3.89	0.01
Fe_2O_3	4.30	0.01	41.5	0.1	10.98	0.01	14.81	0.02	38.60	0.04
Loss	37.3		25.1		36.7		36.2		21.3	
	ppm	±2σ	*ppm*	±2σ	*ppm*	±2σ	*ppm*	±2σ	*ppm*	±2σ
Cl	124	5	158	8	122	5	110	5	115	6
V	107	8	1211	12	261	9	583	12	1075	20
Cr	--	--	70	5	24	3	91	5	--	--
Ni	85	2	254	8	56	2	58	3	1179	16
Cu	13	1	73	4	129	2	4	1	450	9
Co	20	5	--	--	--	--	--	--	231	40
Zn	35	1	480	8	77	2	85	2	446	7
Ga	1.6	0.4	--	--	2	0.5	2	1	--	--
Ge	1.1	0.3	--	--	--	--	--	--	--	--
As	24	1	545	5	52	1	102	1	251	5
Se	--	--	--	--	--	--	--	--	--	--
Br	1.5	0.3	4	2	1.4	0.4	2	0.5	--	--
Rb	4.7	0.3	--	--	9.9	0.4	6.2	0.4	15	1
Sr	165	1	154	2	199	1	201	1	154	2
Y	29.1	0.4	18	1	10.2	0.4	23	1	25	1
Zr	24	0.5	67	1	31	1	58	1	334	2
Nb	10.2	0.4	12	1	7	0.5	14	1	155	2
Mo	2	1	37	2	5	1	--	--	41	2
Ag	--	--	--	--	--	--	--	--	--	--
Cd	1.0	0.2	--	--	1.3	0.3	2.4	0.3	7	3
In	--	--	--	--	--	--	--	--	--	--
Sn	6.0	0.3	--	--	1.4	0.2	1.8	0.2	11.4	0.3
Sb	2.0	0.2	28	1	5.2	0.3	1.9	0.3	35	1
Te	2.3	0.1	3.4	0.2	5.9	0.2	6.4	0.2	68	1
I	16	1	12	1	9	1	10	1	--	--
Cs	--	--	--	--	--	--	--	--	--	--
Ba	37	1	18	1	24	1	23	1	287	1
La	31	2	21	2	11	2	26	2	40	3
Ce	85	2	43	3	7	2	36	2	1638	3
Pr	--	--	--	--	--	--	--	--	--	--
Nd	22	4	27	6	--	--	14	4	--	--
Ta	--	--	--	--	--	--	--	--	--	--
W	--	--	--	--	--	--	--	--	--	--
Hg	--	--	--	--	--	--	--	--	--	--
Tl	--	--	--	--	--	--	--	--	--	--
Pb	18	1	--	--	13	2	14	3	220	8
Bi	--	--	--	--	--	--	--	--	16	3
Th	5	1	--	--	--	--	4	1	73	4
U	--	--	--	--	--	--	--	--	--	--



Text–Fig. 27.
Major element weight ratios of the "Marmorea Crust" (average of three samples) and the Basal Sinemurian Crust. Ca and Mg are not shown, so the pies approximately represent carbonate-free samples. Note the low Al and Mn contents of the "Marmorea Crust". Fe+Mn is about 70% in both crusts for carbonate-free samples.

with a thermal event during the Tertiary, to explain the remagnetization of parts of the Schnöll-Formation. Recrystallization at elevated temperatures could cause a strong depletion in ^{18}O. However, it is very difficult to explain how recrystallization can be confined to a very thin layer beneath a thin ferromanganese crust.

2.7. Ferromanganese Crusts

2.7.1. Material and Methods

We analyzed the chemical composition of four bulk samples of the "Marmorea Crust" and one bulk sample of the Basal Sinemurian Crust. All samples are mixtures of crust material and limestone matrix. Chemical analyses were carried out by the Central Analytical Laboratory of Technical University at Ostrava (Czech Republic) with a SPECTRO X-LAB x-ray fluorescence spectrometer. Due to the calibration for determinations of trace elements the analytical precision for Ca and Na is poor. Sodium is present in traces (<2%) only and is not shown in Tab. 3. From one sample of the Marmorea Crust from Hochleitengraben and from various facies of the Adnet-Fm. and the Scheibelberg-Fm. major elements were analyzed by EDX. External precission for EDX is about ±0.2%.

The "Marmorea Crust" samples are from the Adnet Quarries XXII, XXIX and XXXI, that is from the lower slope of the drowned reef. The "Marmorea Crust" caps crinoidal limestones of the Kendlbach- and the Schnöll-Formation. An additional sample of the "Marmorea Crust" from a basinal section of the eastern Osterhorn block (Saubach, BÖHM, 1992) was analyzed for comparison. It shows no significant differences from the Adnet samples. The sample from Quarry XXXI is strongly pyritized and shows a slightly different chemical composition (Tab. 3). The sample of the Basal Sinemurian Crust was collected in Quarry XXXI.

2.7.2. Results

After subtracting CaO and MgO, which mainly represent the carbonate fraction of the samples, the mean major element compositions of Marmorea and Sinemurian crusts are similar (Text-Fig. 27): The mean Fe_2O_3+MnO content is 71% in both crusts. Mean SiO_2 (17%) is almost identical as well. The major difference is the scarcity of aluminium and of manganese in the "Marmorea Crust".

The trace element compositions show some clear differences between the two crusts (Text-Fig. 28). Ni, Cu and Co as well as Ce and Th are much more enriched in the Sinemurian crust. These elements are typically found in pelagic hydrogenous ferromanganese crusts (BONATTI et al., 1972; PFEIFER et al., 1988; DE CARLO & EXON, 1992). A plot of chondrite-normalized rare earth elements shows a positive Ce anomaly for the Sinemurian crust but no anomaly for the "Marmorea Crust" samples (Text-Fig. 29). The most important trace element of the "Marmorea Crust" is vanadium followed by arsenic, zinc and chlorine. Strontium is present in all samples with values (175±25 ppm) well within the range found for Adnet limestones (240±70 ppm, KINDLE, 1990). No significant correlation between Sr and Ca was found in our samples (r=0.6, n=5). The Sr/Ca mole ratio is lowest in the pyritized sample ($2.2x10^{-4}$) and highest in the Sinemurian crust ($5.8x10^{-4}$). The other samples with values of $3.1x10^{-4}$ to $3.6x10^{-4}$ fit very well with the Adnet Limestones ($3.4x10^{-4}±1x10^{-4}$, KINDLE, 1990).

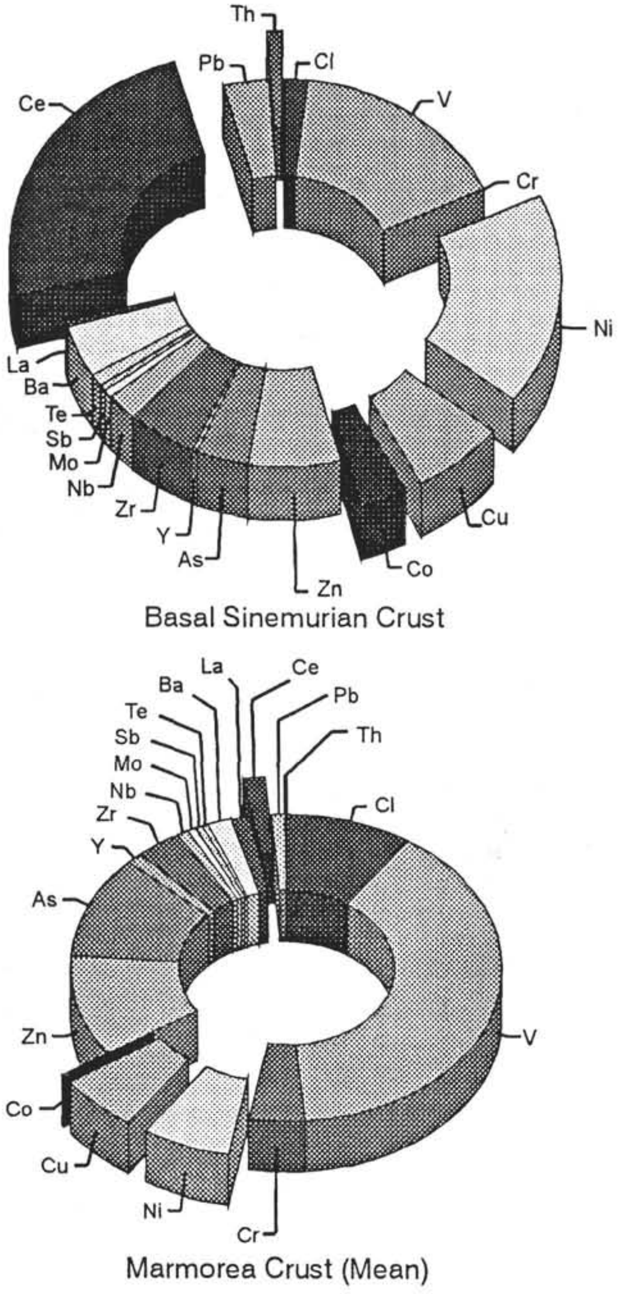
In a cluster analysis of all analyzed elements (Text-Fig. 30) the samples of the "Marmorea Crust", except for the pyritic sample, show very high correlations, forming a clear cluster. They are clearly distinct from the basal Sinemurian crust. The pyritic sample differs slightly from the other samples of the "Marmorea Crust". It is the only sample with detectable amounts of sulfur. It also has a higher Mn content. In the cluster analysis its composition is intermediate between the two crusts.

Tab. 4
Comparison of some ratios (weight ratios and weight %). "Marmorea Crust" values are average of the three non-pyritic samples. "Adnet Fm, NCA West" are averages of 6 analyses of reddish Adnet Limestones from the western part of the NCA as given by KINDLE (1990). "Adnet Fm, Salzburg" are averages of EDX analyses of 5 samples of red Adnet limestone from the Osterhorn Block (locations Tauglbach, Gaißau, Saubach, Adnet, Breitenberg; BÖHM, 1992). "Scheibelberg Lst." is an EDX analysis of grey spiculitic cherty limestone from Gaißau (BÖHM, 1992). Ti and Mn are below detection limits (<0.2%) in the EDX analyses. Ranges are ±1σ.

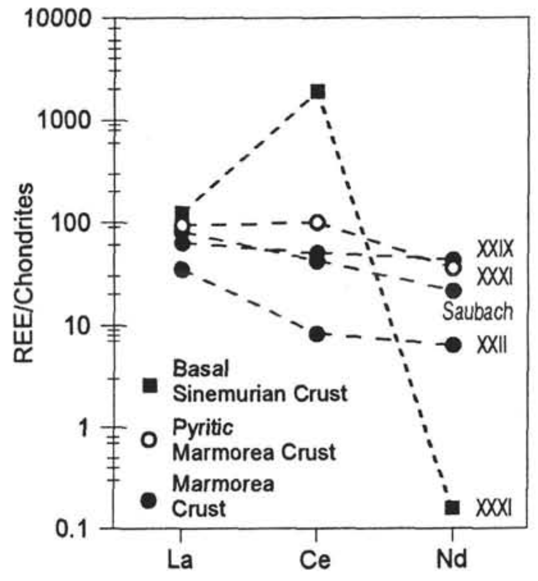
	Marmorea Crust	Sinemurian Crust	Adnet Fm. NCA West	Adnet Fm. Salzburg	Scheibelberg Lst.
$Al_2O_3+SiO_2$	5±2%	15%	7±5%	10±3%	16%
Al_2O_3/SiO_2	0.4±0.1	0.6	0.5±0.2	0.3±0.2	0.1
Al/Ti	10±3	4	15±4	--	--
Al/Fe	0.05±0.03	0.1	1.6±0.3	1±0.3	1
Fe/Ti	130 to 620	35	9±1	--	--
Fe/Mn	204±50	9	34±21	--	--
Fe	<29%	<27%	0.7±0.2%	1±0.2%	1%

The mean SiO_2+Al_2O_3 content of the "Marmorea Crust" (Tab. 4) is not significantly different from contents reported from Adnet Limestones (KINDLE, 1990). The measured SiO_2+Al_2O_3 content of the basal Sinemurian crust on the other hand is about twice as high. The Al_2O_3/SiO_2 ratios are very constant (0.5±0.2) for Adnet Limestones (KINDLE, 1990), "Marmorea Crust" and the Basal Sinemurian Crust (Tab. 4). On the other hand, variations of the Al_2O_3/SiO_2 ratios and a correlation between SiO_2 content and the frequency of formerly siliceous fossils (sponge spicules, radiolarians) can be observed in different facies of the Adnet- and Scheibelberg-Formations. Al_2O_3/SiO_2 ratios vary from 0.6 in facies poor in such fossils to 0.1 in chert rich Scheibelberg limestones. Al/Fe ratio and total iron content show no significant differences between red Adnet limestones and grey Scheibelberg limestone (Tab. 4). Al/Ti ratios are highest in Adnet Limestone (KINDLE, 1990) and lowest in the Sinemurian crust. According to the Al/Ti ratios, both crusts are slightly enriched in Ti. The very low Al/Fe ratios compared to the Adnet limestone (Tab. 4) show that both crusts are strongly enriched in iron relative to their Al content.

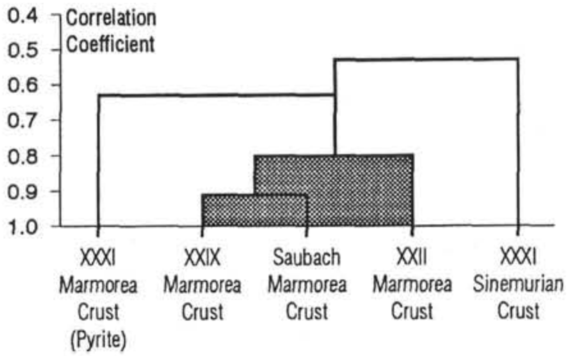
The most striking feature of the "Marmorea Crust" is its very high Fe/Mn ratio (up to 240), which is several times higher than in the Adnet limestones (Tab. 4). The basal Sinemurian crust, on the other hand, is slightly enriched in Mn compared to the Adnet limestones. It lies well within the



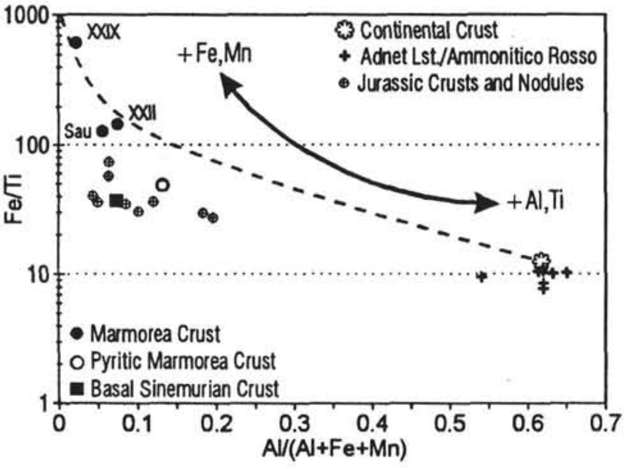
Text-Fig. 28.
Weight ratios of trace elements of the ferromanganese crusts. Only elements with proportions of more than 20 ppm are shown. Note high percentages of Ni+Co+Cu as well as Ce in the Sinemurian Crust compared to the Marmorea Crust, where Cl, V, Zn and As predominate.



Text-Fig. 29.
Some chondrite-normalized (NAKAMURA, 1974) rare earth elements of the ferromanganese crusts. A strong positive Ce anomaly as seen in the Basal Sinemurian Crust is characteristic for hydrogenous crusts, while hydrothermal deposits have negative Ce anomalies. The "Marmorea Crust" samples show intermediate proportions. Roman numbers refer to quarries.



Text-Fig. 30.
Cluster analysis with all analyzed elements (pair-group method, Pearson correlation coefficient). The samples from the "Marmorea Crust" form a highly correlated cluster (shaded), clearly distinct from the pyritic sample and the Basal Sinemurian Crust.



Text–Fig. 31.
"Boström diagram" of the crust samples, Tethyan Jurassic crusts and nodules (DRITTENBASS, 1979, CRONAN et al., 1991), Adnet limestones and Ammonitico Rosso marls (KINDLE, 1990, HALLAM, 1967). Adnet limestones plot closely to average continental crust material (BOSTRÖM, 1970), while crusts and nodules are strongly enriched in iron. Dashed line is a mixing curve between Al- and Ti-rich continental crust and an Fe- and Mn-rich source (e.g. volcaniclastic sediments, BOSTRÖM, 1970). "Marmorea Crust" samples plot close to this mixing line, pointing to a non-terrigenous (Al- and Ti-poor) iron-source for this crust. The other crusts and nodules are enriched in Ti. This may be due to scavenging of Ti during formation of hydrogenous crusts and nodules (SUGISAKI et al., 1987).

range of other Jurassic ferromanganese crusts and nodules of the Tethyan realm (Text-Fig. 33).

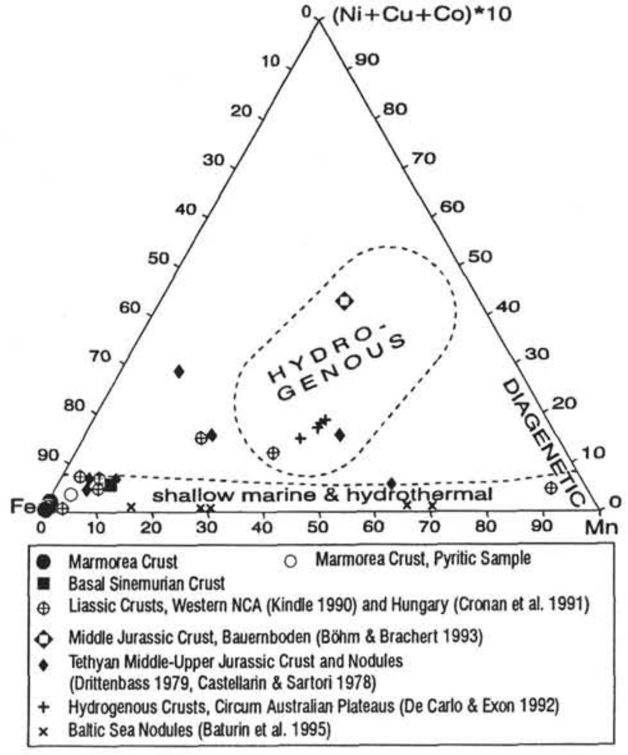
2.7.3. Discussion

Red Adnet Limestones

The source of red oxidized iron in the Adnet-Formation and other ammonitico rosso type sediments has been a matter of debate for decades (e.g. LEUCHS & UDLUFT, 1926; KIESLINGER, 1964; HALLAM, 1967; FLÜGEL & TIETZ, 1971). Early papers assumed the input of red lateritic material from adjacent subaerial areas. HALLAM (1967) and FLÜGEL & TIETZ (1971) questioned this assumption because of their finding of low Al/Fe ratios and the lack of kaolinite and allitic minerals.

From a geochemical point of view it is clear that condensed pelagic mud retains a red colour if all organic matter is oxidized before passing into the zone of iron reduction (BURDIGE, 1993). This is facilitated by an extremely low sedimentation rate. For the Schmiedwirt Mb. an average sedimentation rate of roughly 2 mm/ka can be estimated from the thickness of 13 m at Adnet Quarry XXVIII, representing the Semicostatum to lower Raricostatum Zones (DOMMERGUES et al., 1995) with a duration of about 6–7 Ma (WESTERMANN, 1984). This is the same order of magnitude as found for oceanic red clay (ENOS, 1991).

FLÜGEL & TIETZ (1971) stressed that iron in marine environments is often transported with detrital clay minerals. The Al/Fe ratio (1.6±0.3), Al/Ti ratio (15±4) and Fe/Ti ratio (9±1) of Adnet Limestones measured recently by KINDLE (1990) are compatible with a terrigenous, continental source of iron-bearing clay and silt (Text-Fig. 31). Values for average continental rocks are Al/Fe≈1.5 (BONATTI et al., 1979), Al/Ti≈20 and Fe/Ti≈13 (BOSTRÖM, 1970). On the other hand, as demonstrated by EXON & CRONAN (1983) some volcaniclastic sediments may show similar values (Al/Fe≈1, Al/Ti≈20,



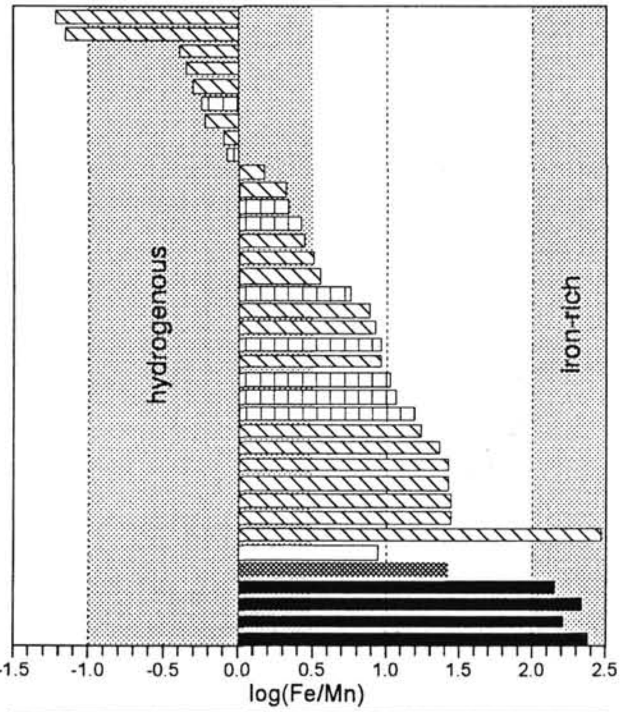
Text–Fig. 32.
"Bonatti diagram" showing the 10*(Ni+Co+Cu)/Fe/Mn weight ratios of the crust samples and other Jurassic crusts and nodules. Some typical hydrogenous oceanic crusts from a continent-near setting and nodules from the epicontinental Baltic Sea are shown for comparison. This diagram is used to discriminate hydrogenous from hydrothermal and diagenetic ferromanganese deposits (BONATTI et al., 1972). The "Marmorea Crust" samples clearly plot in the hydrothermal/shallow marine field. The Basal Sinemurian Crust lies close to a mixing line between the iron corner and the hydrogenous field. The very high trace metal content of the Bathonian Bauernboden crust could be explained by microbial scavenging as this crust displays a stromatolitic fabric and contains *Frutexites arboriformis* (BÖHM & BRACHERT, 1993).

Fe/Ti≈20, SW Pacific). Therefore, these ratios do not allow to unequivocally exclude a volcaniclastic source.

Clay and quartz silt are a frequently observed component of Adnet Limestones (BÖHM, 1992). Probably, they carried the red-staining iron to the Adnet Limestones. As this material can be transported for thousands of kilometres by wind and ocean currents, it is not necessary to postulate a nearby land area. This also implies that iron is not significantly enriched in the Adnet-Fm. and that there is no need to assume an extra iron-source for these red limestones.

Basal Sinemurian Crust

In contrast to the Adnet Limestones, iron is strongly enriched in the analyzed crusts compared to terrigenous mud. Consequently, measured Al/Fe ratios (<0.1) are much lower. The SiO_2+Al_2O_3 percentage did not change significantly during formation of the crusts despite strongly reduced carbonate sedimentation rates (BÖHM, 1992: 160ff). This points to reduced supply of terrigenous mud during crust formation, probably due to enhanced current activities. Very likely the terrigenous background sedimentation continued with an unchanged composition, as implied by the constant Al_2O_3/SiO_2 ratios of limestone and crusts, while iron for the crust formation was supplied by an independent source.



Text–Fig. 33.
Logarithmic plot of Fe/Mn ratios of Tethyan Jurassic crusts and nodules. Except for one single value from GERMANN (1971) all ratios are significantly lower than the measured ratios of the "Marmorea Crust". Some 40% of the shown values are compatible with a hydrogenous origin, while the rest shows a moderate to strong iron enrichment. Values from BÖHM (1992 and unpublished data), CASTELLARIN & SARTORI (1978), DRITTENBASS (1979), GERMANN (1971), KINDLE (1990), KRAINER et al. (1994). Additional sample of Marmorea Crust from Hochleitengraben, EDX analysis.

CRONAN et al. (1991), in comparing Middle/Late Liassic crusts and nodules from Hungary to modern counterparts, favoured seawater as the most important source of iron and manganese. During long periods of non-sedimentation ferromanganese nodules and crusts may precipitate very slowly from seawater. These hydrogenous precipitates usually show Fe/Mn≈1 and due to scavenging effects have relatively high Ni+Cu+Co concentrations (BONATTI et al., 1972). The Basal Sinemurian crust shows these features, even so the proportions are not exactly comparable to modern examples of hydrogenous crusts (Text-Fig. 32). The trace metal content is mainly controlled by the growth rate of the crust, as scavenging is a very slow process (BOLTON et al., 1988). Fast growing crusts, e.g. near hydrothermal vents, have low trace metal contents and plot near the baseline of the Bonatti-Diagram (Text-Fig. 32). The Fe/Mn ratio on the other hand is mainly controlled by proximity to an iron or manganese source. As iron is more easily oxidized than manganese, it quickly precipitates from aerobic solutions. For instance, iron-rich crusts and nodules are found near hydrothermal vents with iron-rich fluids (BONATTI et al., 1972, 1979). In oxygen poor settings like the Baltic Sea, Fe/Mn ratios can also be controlled by the oxygen content of the ambient water (pers. comm. S. HLAWATSCH, Kiel). In this case Mn may remain dissolved while Fe is oxydized and precipitates.

The Basal Sinemurian Crust like many other Jurassic crusts and nodules shows a high Fe/Mn ratio but at the same time has a relatively high trace metal (Ni, Cu, Co) content (Text-Fig. 32). As Ce and Th are enriched aŝ well, we suppose that despite the high Fe/Mn ratio this crust is a marine hydrogenous precipitate. This means that the crust grew very slowly during a long period of non-sedimentation. In this interpretation we follow CRONAN et al. (1991), whose samples of Liassic crusts and nodules from Hungary compare well to our Basal Sinemurian Crust.

The high iron content may be due to late diagenetic mobilization of manganese (GERMANN, 1971) or, more likely, to minor contributions of an additional iron source. CRONAN et al. (1991) called on the proximity of land in the continental margin setting of the Alpine Liassic for providing iron-rich seawater. The distance between the NCA and the European shelf probably was on the order of a few hundred kilometres during the Liassic (DERCOURT et al., 1993). With that, continental input may have influenced the NCA sufficiently to explain the Fe/Mn ratios between 3 and 10 of the Late Liassic crusts of Hungary (CRONAN et al., 1991) and of the Basal Sinemurian Crust of Adnet.

"Marmorea Crust": A Hydrothermal Precipitate?

The Fe/Mn ratio of the "Marmorea Crust" is exceptional among Tethyan Jurassic crusts and nodules (Text-Fig. 33). The trace metal contents are much smaller than in the Sinemurian crust (Text-Fig. 28). This strongly suggests a different mode of formation in the proximity of a substantial iron source different from normal seawater.

It was previously suggested that mobilization of iron from organic-rich sediments in an anoxic environment may provide a source for iron enrichments in marine sediments (e.g. BORCHERT, 1953). However, there are no widespread anoxia during the Hettangian. Moreover, mineralizations from such diagenetically mobilized solutions are enriched in manganese (PFEIFER et al., 1988; DYMOND et al., 1984; BONATTI et al., 1972).

We further exclude diagenetic alterations as an explanation of the dissimilar chemical compositions of the two crusts. Significant remobilization of Mn or Fe during early diagenesis is unlikely in an oxidizing setting of red condensed limestones (ALONGI et al., 1993). Also, late diagenetic influences cannot be responsible for the marked differences. They whould similarly have acted on both crusts, which are less than 1 m apart. Thus, the observed Fe/Mn ratios reflect a primary signal.

Late Liassic iron pisolites with a chemical composition similar to the "Marmorea Crust" were reported from Sicily by JENKYNS (1970) and related to volcanism. However, no indications for volcanic activities during the Hettangian/Sinemurian in the central part of the NCA have been reported. We therefore see no evidence for a volcanic origin of the "Marmorea Crust".

It was recently proposed by KINDLE (1990) that hydrothermal fluids circulating in fractures and neptunian dykes may have provided metal rich solutions for the formation of Jurassic ferromanganese crusts. Ferriferous fluids originating from circulation of seawater through a sedimentary pile are a common source for iron formations according to KIMBERLEY (1989). He proposed a silicate weathering mechanism in deep burial for the generation of iron-rich fluids. We think that the model of KINDLE (1990) can provide one possible explanation for the iron-dominated chemical composition of the "Marmorea Crust". Fractures opening by the late Hettangian could have allowed the migration of iron-rich fluids to the sea-floor. Ammonite dated neptunian dykes of late Hettangian age were described from Adnet Quarry XXX by WENDT (1971) and from the Steinernes Meer by SCHÖLL & WENDT (1971). We found a neptunian dyke near the base of the Kirchenbruch (Adnet, Quarry I) filled by late Hettangian Enzesfeld Limestone.

So, deep-reaching fractures may have allowed iron-rich fluids to spread on the Hettangian seafloor of the NCA. Strong bottom currents at the end of the Hettangian (BÖHM, 1992) could have promoted the spreading of these fluids. During a period of non-sedimentation the "Marmorea Crust" formed as an iron-rich mineralization. The more "hydrogenous" composition of the Basal Sinemurian Crust could then be explained by a reduced influence of the iron-rich fluids, e.g. by reduced tectonic activities or gradual sealing of the neptunian dykes by sediments and cement (KINDLE, 1990).

This endogenous iron source may provide a possible explanation for the observed chemical composition of the "Marmorea Crust". However, conclusive evidence is still lacking: The depth of penetration of Hettangian neptunian dykes is unknown. No dated ferromanganese fissure fill of Hettangian age is known. Ferromanganese infills in neptunian dykes do occur in Adnet, but all known examples crosscut (upper) Sinemurian strata.

The chemical composition of the "Marmorea Crust" with very low Co, Ni, Cu and Ce contents is very similar to compositions of crusts from shallow epicontinental seas (eg. the Baltic Sea, BATURIN et al., 1995), except for the lack of phosphate in the "Marmorea Crust". So, based on chemistry we cannot exclude an epicontinental mode of formation for the "Marmorea Crust".

Near-shore mud and fluviatile detritus commonly show Fe/Mn ratios of about 50 to 100 (CHESTER, 1990). A ferric hydroxide crust in the epicontinental Baltic Sea with a Fe/Mn ratio of 40 was reported by WINTERHALTER (1980). INGRI (1985) found ferromanganese concretions with Fe/Mn ratios of 18 in the continental margin setting of the Barents Sea. On the other hand, ferromanganese crusts in various settings of the Mediterranean Sea have Fe/Mn ratios between 0.3 and 1.4 (ALLOUC, 1988). Only crusts of likely hydrothermal origin dredged from submarine volcanoes near Sicily show Fe/Mn ratios between 1.0 and 220 (MORTEN et al., 1980). Ferromanganese nodules deposited on the Blake Plateau only about 500 km from land show a Fe/Mn $\approx$ 1.1 and the highest measured Fe/Mn ratio of nodules and crusts from the near continent zones of the Pacific is 4.5 (MERO, 1965; DE CARLO & EXON, 1992). From these examples it can be seen that ferromanganese deposits with very high Fe/Mn ratios can form in confined continental margin settings with estuarine circulation, humid climate and high riverine input, but are unlikely to form in anti-estuarine or open ocean continental margin settings as long as hydrothermal/volcanic iron sources are excluded.

As discussed above (chapter 2.6.), arid climate and anti-estuarine circulation probably dominated the Tethys ocean during the Jurassic. The modern examples suggest that such conditions are not in favour of crusts forming with very high Fe/Mn ratios. Oxygen isotope signatures of the Schnöll limestones suggest that such conditions prevailed already during the middle Hettangian. On the other hand, we have no reliable isotope data for the late Hettangian to exclude a late Hettangian period of different environmental conditions.

During the early Hettangian terrigenous silt and sand impinged on the Adnet area (GOLEBIOWSKI, 1990). Terrigenous input continued in the northeastern parts of the NCA (Frankenfels nappe) probably until the earliest Sinemurian as visible from terrigenous sand and silt in the Kalksburg beds (TOLLMANN, 1976). Moreover, during the Hettangian the drowning Dachstein carbonate platform may have formed a barrier sheltering the Kendlbach basin (northern Osterhorn block) from the open Tethys ocean. The Fe/Mn ratios >100 found in the "Marmorea Crust", may thus be related to the special situation of the marginal confined Kendlbach sea before the final drowning of the Dachstein platform, perhaps in connection with a sea-level lowstand at the Hettangian/Sinemurian boundary (HAQ et al., 1988).

As yet, available data are unsufficient to decide whether the chemical composition of the "Marmorea Crust" was caused by a hydrothermal or a continental iron source. Nevertheless, its particular composition points to peculiar environmental conditions by the late Hettangian that had given way to more oceanic surroundings by the time the Basal Sinemurian Crust was formed.

3. Fauna and Flora

3.1. Micropalaeontology

Although palaeontologists and sedimentologists (see chapter 1.2.), already very early in geological science drew attention to the Adnet Quarries, micropaleontology of the famous Liassic lithologies was long neglected. In a publication concerning Involutinid foraminifera from the Lienzer Dolomiten and several localities in the Northern Calcareous Alps – amongst them also one quarry in Adnet – BLAU (1987b) figured several specimens of *Involutina liassica* and *Coronipora austriaca* from the Eisenmann-Quarry.

Detailed sedimentological and microfacial investigations especially of the Osterhorn-Tyrolicum – the tectonic unit the Adnet quarries belong to - and an analysis of the biogenic components was done more recently by BÖHM (1992). In a further paper BLAU & GRÜN (1997) described several new foraminifera from the Schnöll-Quarry. They will be discussed in detail in chapter 3.1.4.

Because the examined Lower Liassic strata consist exclusively of limestones, without any washable marl-layers, the following chapter deals only with fossils in thin-sections. All in all 126 thin-sections were examined.

The main aim of this chapter is to document the tremendous variability of several groups of foraminifera, especially of the Involutinids and some Miliolids.

3.1.1. Calcareous Nannoplankton

Some samples of the Schnöll-Quarry were examined by using the technique described by STRADNER (1963: brushing finest parts of limestone from hardrocks and preparing smear-slides), but no Coccolithophorids could be detected, although this group is also present in the lowermost Liassic (compare BOWN, 1987; EBLI, 1997). The only discovered representatives of calcareous nannoplankton is the Dinophyceen-genus *Schizosphaerella*.

Division Pyrophyta PASCHER, 1914
Class Dinophyceae FRITSCH, 1929
Order Thoracosphaerales TANGEN et al., 1982
Family Schizosphaerellaceae DEFLANDRE, 1959

Genus *Schizosphaerella* DEFLANDRE & DANGEARD, 1938
emend. AUBRY, DEPÊCHE & DUTOUR, 1988

Type species: *Schizosphaerella punctulata* DEFLANDRE & DANGEARD, 1938.

Diagnosis: The nearly globular test of the genus *Schizosphaerella* is built up of two interlocking sub-hemispherical valves. The complex wall structure is constructed of variously intergrown parallelogram shaped tiny calcitic lamellae.

***Schizosphaerella punctulata* DEFLANDRE & DANGEARD, 1938**
(Plate 9, Figs. 5, 6; Plate 13, Figs. 1-4)

1938 *Schizosphaerella punctulata* n. sp. – DEFLANDRE & DANGEARD, p. 115, Figs. 1-6.
1980 *Schizosphaerella punctulata* DEFLANDRE & DANGEARD, 1938. – GRÜN & ZWEILI, p. 298-299, Pl. 16, Figs. 10-12 (cum syn.).
1970 Problematika (kalzitische Halbringe). – WENDT, p. 442, Fig. 12.
1987 Schizosphaerella punctulata DEFLANDRE & DANGEARD, 1938. – BOWN, p. 76, 78, 80, Pl. 11, Figs. 7-9; Pl. 15, Figs. 25-26.
1988 *Schizosphaerella punctulata* DEFLANDRE & DANGEARD, 1938 emend. – AUBRY, DEPÊCHE & DUTOUR, p. 715-716, Pl. 1, Figs. 11-20.
1992 *Schizosphaerella punctulata* DEFLANDRE & DANGEARD, 1938. – BÖHM, p. 96, Pl. 2, Fig. 3; Pl. 3, Fig. 4; Pl. 9, Fig. 4; Pl. 11, Fig. 6.
1997 *Schizosphaerella punctulata* DEFLANDRE & DANGEARD, 1938 emend. AUBRY, DEPÊCHE & DUTOUR. – EBLI, p. 83, Pl. 22, Figs. 19-21; Pl. 23, Fig. 20.

Remarks: *S. punctulata* is one of the best described nannofossils. It consists of two valves, linked together by a hinge in the aequator. For detailed descriptions of the ultrastructure see AUBRY & DEPÊCHE (1974), KÄLIN (1980) and KÄLIN & BERNOULLI (1984). The latter authors also discuss the biological affinity of the genus and state, that it would be best classified as a separate family of the Order Thoracosphaerales.

In our material *S. punctulata* can be best observed with the light microscope, where the species can be identified by its bell-shaped outline, the often recognizable cross-bar-structure and its small size, up to 30 µm.

Noteworthy is the fact, that the species was only observed as isolated valves, somehow orientated. This is because of relative high hydrodynamic energy, especially in hardground formation, where *S. punctulata* is often incorporated in high quantities (locally up to 60-70 Vol.-%) in Fe/Mn-crusts.

In SEM-samples (chapter 2.5.) *S. punctulata* is often obscured by secondary calcite overgrowth. The characteristic cross-bar-structure is only relicticly preserved due to strong diagenetic processes (Plate 13, Figs. 1-4).

Occurrence: Common in red limestones, in condensed layers in rock-forming quantities.

3.1.2. Algae

Division Chlorophyta PASCHER, 1914
Class Codiolophyceae KORNMANN, 1973
Order Chaetophorales WEST, 1904
Family Chlorosphaeraceae (GREVILLE) HARVEY, 1841

Genus *Globochaete* LOMBARD, 1945

Type species: *Globochaete alpina* LOMBARD, 1945

Synonyms: See detailed discussion in SKOMPSKI (1982)

Diagnosis: Single, or linear to ring-like arranged associations of hemispherical to spherical cells, that are epiphytic to free, and are in different stages of division. They are filled with radially arranged calcite crystals, therefore they show a black cross under crossed nicols.

***Globochaete alpina* LOMBARD, 1945**
(Plate 14, Figs. 1, 2)

1945 *Globochaete alpina* n. sp. – LOMBARD, p. 165, Figs. 1-3.
1972 *Globochaete alpina* LOMBARD, 1945. – FLÜGEL, p. 964-965, without figuration.
1982 *Globochaete alpina* LOMBARD, 1945. – SKOMPSKI, p. 47-53, Figs. 1-3; Pl. 1, Figs. 1-2; Pl. 2, Figs. 1-2; Pl. 3, Figs. 1-7 (cum syn.).
1997 *Globochaete alpina* LOMBARD, 1945. – EBLI, p. 119-120, Pl. 37, Figs. 7-10.

Description: *G. alpina* shows a high morphological variability. Most abundant are long aggregates consisting of one or two rows of cellules, or clotted aggregates. The cellules have a spherical to ovoid outline and a diameter between 40–80 µm. The micritic nucleus varies in diameter between 6–24 µm and is followed by a 6–20 µm thick sparitic "wall" that also can be enveloped by an up to 30 µm thick micritic sheet.

Remarks: Ring-shaped aggregates as figured by WEYNSCHENK (1950, Pl. 2, Fig. 11) or EBLI (1997, Pl. 37, Fig. 7) could not be detected in the examined material.

In the literature *G. alpina* is often regarded as a microproblematicum, whereas LOMBARD (1945) interpretated this species as zoospores and transfered it to the green algae (Chaetophorales; Protococcaceae). Within a detailed study SKOMPSKI (1982) was able to detect vegetative forms of *Globochaete alpina,* which he put in the family Chlorosphaeraceae of the green algae. His view is followed in this work.

Despite of this TAPPAN (1980: 843) sees no context between the species and green algae. She discusses *G. alpina* in the context of *Saccocoma,* that is of echinodermal remains.

Occurrence: The species is nearly omnipresent in differing quantities with a maximum in the strongly condensed Enzesfeld facies.

3.1.3. Microproblematica

Fossils with a problematic systematic position are regarded in general as microproblematica. These incertae-sedis organisms are especially described from Triassic shallow-water-limestones (e.g.: Northern Calcareous Alps: FLÜGEL, 1964, 1972; Western Carpathians: BORZA, 1975; Sicily: SENOWBARI-DARYAN, 1984). In these reef-complexes the microproblematica are often excellent facial-fossils, due to preference of distinct biotopes.

incertae sedis

***Muranella sphaerica* BORZA, 1975**
(Plate 14, Fig. 4)

1975 *Muranella sphaerica* n. gen. n. sp. – BORZA, p. 228, Pl. 7, Figs. 8, 10; Pl. 8, Figs. 1-4.
1984 *Muranella sphaerica* BORZA 1975. – SENOWBARI-DARYAN, p. 28-29, Pl. 11, Figs. 4-6 (cum syn.).
1989 *Muranella sphaerica* BORZA 1975. – EBLI & SCHLAGINTWEIT, p. 54-55, Pl. 1, Figs. 2-3; Pl. 2, Figs. 1-4.
1997 *Muranella sphaerica* BORZA 1975. – EBLI, p. 120, Pl. 19, Fig. 8.

Description: Isolated sphaeroids with a micritic nucleus varying in diameter between 8–20 µm, and an outer cortex (thickness up to 16 µm) consisting of radialfibrous calcite.

Remarks: *Muranella sphaerica* was described in detail by EBLI & SCHLAGINTWEIT (1989), who figured this species in LM and SEM. Because of the lack of any fine-structures typical for calcareous nannoplancton, the authors concluded, that this microproblematicum represents a (biogenic induced) calcite precipitate. For the genesis a repeated nucleation (MACINTYRE, 1985; CHAFETZ, 1986) seemed to be probable. This mechanism is induced by bacteria, creating a microenvironment favourable for calcite precipitation. Because of this carbonate, the organisms die and the physico-chemical microenvironment changes therefore. In a second stage carbonate precipitates due to abiogenic controlled factors in the form of radialfibrous cements around the micritic nucleus. The sparitic envelopes are often diagenetically altered due to recrystallisation.

Occurrence: The species was only found rarely and was restricted to burrows or the inner whorls of ammonite-phragmocons, both representing a confined environment, preferable for calcite precipation.

Microproblematicum 1
(Plate 14, Fig. 3)

? 1968 *Thurammina* sp. – OESTERLE, Text-Fig. 5.
1972 Incertae sedis ("Pseudoostracoden"). – SAMUEL et al., Pl. 110, Figs. 4-6; Pl. 111, Figs. 1-5.
? 1980 *Tentilenticulina latens* n. gen., n. sp., HITCHINGS, p. 216-217, Text-Figs. 1-3; Pl. 1, Figs. 1-7.
1991 Sessile Foraminiferen (?), gen. et sp. indet. – SCHLAGINTWEIT, p. 31, Pl. 8, Figs. 18-19 (cum syn.).

Description: The microproblematicum consists of several linear arranged chambers, that are separated by irregular distributed constrictions. The wall is calcitic-hyalin, monolamellar, sometimes bearing small spines.

Remarks: As SCHLAGINTWEIT (1991) pointed out, the organism under discussion was up to now reported from reef-cores, where it occures in the intraseptal-space of corals or within porifers. He discusses the taxonomic status of the microproblematicum and concludes that there exist strong affinities to the foraminifera genus *Tentilenticulina,* but also to *Bullopora* and *Thurammina,* the latter one being recorded by OESTERLE (1968) in a sponge-rich facies, as in our material.

In contrast to the above mentioned neritic distribution of the organism, it occurs in our material in hemipelagic limestones.

In the Northern Calcareous Alps it was observed by the author also in middle-Jurassic hemipelagic sediments (Klausschichten) where the microproblematicum inhabits the phragmocones of ammonites.

Occurrence: Very rare in the sample Spong 7a (grey limestones of the Schnöll-Fm.) where it is associated with a facies rich in sponge-detritus.

Microproblematicum 2 SENOWBARI-DARYAN, 1980
(Plate 14, Figs. 5, 6)

1980 Problematicum 2. – SENOWBARI-DARYAN, p. 98, Pl. 21, Fig. 6; Pl.23, Figs. 5, 6.
1992 Bryozoa. – BÖHM, p. 94, Pl. 5, Fig. 6; Pl. 10, Fig. 3.

Remarks: The remnants of these multicameral organisms fit well with the descriptions given by SENOWBARI-DARYAN (1980) and BÖHM (1992). These probable Bryozoan organisms are differentiated from the above mentioned Microproblematicum 1 by its wall-structure with a dark inner layer and the arrangement of chambers. SENOWBARI-DARYAN (op. cit.) found this microproblematicum in Upper Triassic and Lower Liassic sediments.

Occurrence: Very rare in rocks of the Schnöll-Fm. and the Adnet-Fm.

3.1.4. Foraminifera

As mentioned above – due to the lithology of the examined units –, foraminifera could only be investigated in thin-sections. This makes it in most cases impossible to determine especially the members of the important Lagenina, because here classification is based on combination of several features, not visible altogether in the same section.

For example the Family Vaginulinidae: Regarding an aequatorial longitudinal section one can observe the mode of coiling, but the additional informations necessary for reliable determination even on a generic level, as morphologies of flanks (e.g. *Planularia, Astacolus*) or ornamentation (specific level), are then not visible.

Other problems arise concerning the Involutinina. Due to their original aragonitic test-material, members of this suborder are more or less recrystallized, so that internal structures as lamination can be obscured or are more often lost. Only in rare cases this lamellae are impregnated by Ferroan-coatings (compare PILLER, 1978).

The classification follows LOEBLICH & TAPPAN (1988). In the succeeding work the generic diagnosis and synonyms of some important foraminifera are briefly given, for other cases see LOEBLICH & TAPPAN (1988).

Subclassis Foraminifera EICHWALD, 1830
Suborder Textulariina DELAGE & HEROUARD, 1896
Superfamily Ammodiscacea REUSS, 1862
Family Ammodiscidae REUSS, 1862
Subfamiliy Ammodiscinae REUSS, 1862

Genus *Ammodiscus* REUSS, 1862

Type species: *Ammodiscus infimus* BORNEMANN, 1874

Synonyms:
Arammodiscum RHUMBLER, 1913 (non: STRICKLAND, 1846)
Bifurcammina IRELAND, 1939

Diagnosis: Test free, discoidal. The spherical proloculus is followed by an tubular second chamber, being planispiral enrolled; aperture at the end of this chamber. Wall agglutinated.

***Ammodiscus incertus* (D'ORBIGNY, 1839)**
(Plate 14, Fig. 7)

1839 *Operculina incerta* D'ORB. – D'ORBIGNY, p. 49, Pl. 6, Figs. 16-17.
1964 *Ammodiscus incertus* (D'ORBIGNY, 1839). – KRISTAN-TOLLMANN, p. 32, Pl. 3, Figs. 1-2.
1985 *Ammodiscus siliceus* (TERQUEM, 1862). – RIEGRAF, p. 94, Pl. 5, Figs. 21-23 (cum syn.).
1997 *Ammodiscus incertus* (D'ORBIGNY, 1839). – EBLI, p. 93-94, Pl. 27, Figs. 3-5.

Remarks: In our material A. incertus possesses always a fine agglutinated wall.

Occurrence: The very rare species occurs in all investigated environments.

Subfamily Ammovertellinae SAIDOVA, 1981

Genus *Glomospira* RZEHAK, 1885

Type species: *Trochammina squamata* JONES & PARKER, var. *gordialis* JONES & PARKER, 1860

***Glomospira* sp.**
(Plate 14, Fig. 9)

Remarks: In our material members of this genus are always irregular coiled.
Occurrence: Rare in the red limestones of the Lienbacher-Quarry.

Genus *Glomospirella* PLUMMER, 1945

Type species: *Glomospira umbilicata* CUSHMAN & WATERS, 1927

***Glomospirella* sp.**
(Plate 14, Fig. 8)

Remarks: The early stage of irregular coiling is followed by a planispiral one. The figured representative of this species is slightly deformed. This phenomenon affects also other foraminifera as *A. incertus* (compare Pl. 14, Fig. 7)
Occurrence: Rare in the condensed sediments of the "Marmorea Crust" (Brandschicht) of Schnöll Quarry.

Superfamily Hormosinacea HAECKEL, 1894
Family Hormosinidae HAECKEL, 1894
Subfamily Reophacinae CUSHMAN, 1910

Genus *Reophax* MONFORT, 1808

Type species: *Reophax scorpiurus* MONFORT, 1808

Remarks: The author follows the species concept of RIEGRAF (1985). BRÖNNIMANN & WHITTAKER (1980) described a neotype for the genus. Due to RIEGRAF (1985) the changed diagnosis of these authors is too specific, so that most of the typical representatives of Reophax had to be transfered to the genus *Hormosina* BRADY, 1879.

Because most of the species of *Reophax* were described on the base of isolated material, external morphology is well described, but no information of internal morphology of chambers is available. Therefore the following determinations were only possible on a cf.-stage.

***Reophax* cf. *agglutinans* (TERQUEM, 1866a)**
(Plate 14, Fig. 12)

cf. 1866 *Marginulina agglutinans,* TERQ. – TERQUEM, p. 433, Pl. 17, Figs. 14 a-c.
cf. 1985 *Reophax agglutinans* (TERQUEM, 1866). – RIEGRAF, p. 96; Pl. 5, Figs. 33-35; Text-Fig. 20 g-i (cum syn.).

Description: The nearly straight to arcuate tests consist of 6–8 slightly globular chambers, increasing only slowly in size. Sutures are very shallow, therefore the outline of this species is nearly cylindrical.
Occurrence: The rare species occurs only in the peloidal packstones of the Kendlbach-Formation of Quarry XXXI.

***Reophax* cf. *crispata* (TERQUEM, 1866b)**
(Plate 15, Figs. 1-3)

cf. 1866 *Nodosaria crispata,* TERQ. – TERQUEM, p. 433, Pl. 19, Figs. 9, 10 a-c, 11 a, b.
cf. 1985 *Reophax crispata* (TERQUEM, 1866). – RIEGRAF, p. 96, Pl. 6, Fig. 1 (cum syn.).

Description: Large, coarsly agglutinating tests consisting of 3 rapidly increasing (microspheric forms) or 4–5 chambers of nearly the same diameter (megalospheric forms). Chambers overlap the foregoing ones in their uppermost part (mostly the fourth to fifth of diameter). Sutures are always distinct.
Occurrence: Samples Lien 4, 6 and 1995-11; Lienbacher Quarry.

***Reophax* cf. *densa* TAPPAN, 1955**
(Plate 14, Fig. 13)

cf. 1955 Reophax densa TAPPAN, n. sp. – TAPPAN, p. 35-36, Pl. 8, Figs. 1-6.

Remarks: The species under consideration fits well with the original description given by TAPPAN (op. cit.).
Occurrence: Very rare in sample AD 12/4a.

***Reophax* cf. *metensis* FRANKE, 1936**
(Plate 15, Fig. 4)

cf. 1936 *Reophax metensis* n. sp. – FRANKE, p. 19, Pl. 1, Fig. 17 a, b.
cf. 1985 *Reophax metensis* FRANKE, 1936. – RIEGRAF, p. 96, Pl. 5, Figs. 27-32; Text-Fig. 20 a-f, j-n (cum syn.).

Remarks: This species is discriminated from the above ones by its deep constrictions.
Occurrence: Rare in condensed sediments (e.g. Sample HG III.1; Schnöll Quarry).

Superfamily Lituolacea DE BLAINVILLE, 1827
Family Lituolidae DE BLAINVILLE, 1827
Subfamily Ammomarginulininae PODOBINA,1978

Genus *Ammobaculites* CUSHMAN, 1910

Type species: *Spirolina agglutinans* D'ORBIGNY, 1846

***Ammobaculites alaskensis* TAPPAN, 1955**
(Plate 15, Fig. 6)

1955 *Ammobaculites alaskensis* TAPPAN, n. sp. – TAPPAN, S. 43-44, Pl. 12, Figs. 1-10 (cum syn.).
1990 *Ammobaculites agglutinans* (D'ORBIGNY, 1846). – BOUTAKIOUT, p. 98, Pl. 5, Figs. 1-3.
1990 *Ammobaculites alaskensis* TAPPAN, 1955. – KRISTAN-TOLLMANN, Pl. 1, Figs. 14, 16.

1997 *Ammobaculites alaskensis* TAPPAN, 1955. – EBLI, p. 95, Pl. 27, Fig. 11.

Description: The planispiral part of the test consists of 6-7 chambers and is followed by 3 to 6 chambers of the rectilinear part. The sutures are often deeply incised.

Remarks: In this highly variable species TAPPAN (1955) lumped all forms that were described in the older literature as *Ammobaculites agglutinans*.

A. alskensis is discriminated from *A. zlambachensis* by ist smaller spira being up to 1/3 of total heigh.

Occurrence: Kendlbach-Formation, Quarry XXXI.

Ammobaculites zlambachensis KRISTAN-TOLLMANN, 1964

(Plate 15, Fig. 5)

1964 *Ammobaculites zlambachensis* n. sp. – KRISTAN-TOLLMANN, p. 36, Pl. 4, Figs. 5-7.
1990 *Ammobaculites zlambachensis* KRISTAN-TOLLMANN, 1964. – KRISTAN-TOLLMANN, Text-Fig. 8: 11-16, Pl. 1, Figs. 11-13, 17-18.
1993 *Ammobaculites zlambachensis* KRISTAN-TOLLMANN, 1964. – EBLI, p. 158, Pl. 1, Fig. 5.
1997 *Ammobaculites zlambachensis* KRISTAN-TOLLMANN, 1964. – EBLI, p. 95, Pl. 27, Figs. 12-13.

Description: The chambers of the coarse to finely agglutinating species are broader than high, the spiral part being high up to 60% of the test. The rectilinear part of the test consists of 3–4 chambers.

Remarks: The representatives of this genus are mostly badly preserved.

Occurrence: The rare species was found in the Kendlbach-Formation of Quarry XXXI and in the condensed sediments of the "Marmorea Crust" (Brandschicht).

Family Placopsilinidae RHUMBLER, 1913
Subfamily Placopsilininae RHUMBLER, 1913

Genus *Placopsilina* D'ORBIGNY, 1850

Type species: *Placopsilina cenomana* CUSHMAN, 1920

?*Placopsilina* sp.

(Plate 15, Fig. 7)

1969 *Placopsilina* (?) sp. – WENDT, p. 190-191, Fig. 7 a-n.

Remarks: The foraminifera under consideration fit well with those described and figured by WENDT (op. cit.). Small specimen with a homogenous test-structure dominate. Bigger ones (Pl. 15, Fig. 7) show rarely incorporated calcite grains, revealing the agglutinating wall-character.

Occurrence: Representatives of this genus are almost exclusively associated with hardground-sedimentation, that is with Fe/Mn-crusts.

Superfamily Trochamminacea SCHWAGER, 1877
Family Trochamminidae SCHWAGER, 1877
Subfamily Trochammininae SCHWAGER, 1877

Genus *Trochammina* PARKER & JONES, 1859

Type species: *Nautilus inflatus* MONTAGU, 1808.

Trochammina alpina KRISTAN-TOLLMANN, 1964

(Plate 15, Figs. 8-11)

1964 *Trochammina alpina* n. sp. – KRISTAN-TOLLMANN, p. 7, Figs. 2-3
1976 *Trochammina alpina* KRISTAN-TOLLMANN, 1964. – ZANINETTI, p. 114-115, Pl. 14, Fig. 10 (cum syn.).
1983 *Trochammina alpina* KRISTAN-TOLLMANN, 1964. – SALAJ, BORZA & SAMUEL, p. 19, Figs. 9-10; Pl. 21, Figs. 4-12.

Remarks: In our material *T. alpina* occures nearly exclusively with megalospheric forms, whereas the microspheric generation was only detectable in one specimen (Plate 15, Fig. 8).

Up to now the stratigraphic distribution of *T. alpina* was given as ?Ladinian to Upper Triassic (ZANINETTI, 1976) and Anisian to Rhaetian (SALAJ et al., 1983).

Occurrence: Kendlbach-Fm. of Quarry XXXI and condensed red limestones.

Superfamily Textulariacea EHRENBERG, 1839
Family Textulariidae EHRENBERG, 1839
Subfamily Textulariinae EHRENBERG, 1839

Genus *Textularia* DEFRANCE in DE BLAINVILLE, 1824

Type species: *T. sagitulla* DEFRANCE in DE BLAINVILLE, 1824

Textularia sp. 1

(Plate 14, Fig. 10)

Remarks: Members of this coarsly agglutinating "species" exhibit a compact morphology.

Occurrence: Rare in the condensed "Marmorea Crust" (Brandschicht).

Textularia sp. 2

(Plate 14, Fig. 11)

Remarks: Differs from the above stated ones by having a more elongated test and by agglutinating finer particles.

Occurrence: In hardground sediments.

Suborder Involutinina HOHENEGGER & PILLER, 1977
Familiy Involutinidae BÜTSCHLI, 1880
Subfamily Involutininae BÜTSCHLI, 1880

Genus *Coronipora* KRISTAN, 1958

Type species: *Coronella austriaca* KRISTAN, 1957

Synonyms:
Coronella KRISTAN, 1957
Paalzowella CUSHMAN, 1933, pars: LOEBLICH & TAPPAN, 1964
Lasiodiscus REICHEL, 1945, pars: PIRINI, 1966; BOCCALETTI et al., 1966; PAPP & TURNOVSKY, 1970; HOHENEGGER & LOBITZER, 1971.

Diagnosis: Test free, slightly to high conical. The two chambers consist of a spherical proloculus and a tubular, undivided deuteroloculus. Coiling is nearly planispiral to trochospiral. Lower part of test covered by more or less thick lamellae, therefore whorls are not visible on this side, unlike the upper part of the test, that also shows more or less long ridge-like prolongations that follow the spira.

Coronipora austriaca (KRISTAN, 1957)

(Plate 19, Figs. 1-16, Plate 20, Fig. 1)

1957 *Coronella austriaca* nov. gen. nov. spec. – KRISTAN, p. 19, Pl. 23, Figs. 10 a-c, 11-13.
1978 *Semiinvoluta* ? sp. – PILLER, p. 88, Pl. 21, Figs. 6-8.
1987b *Coronipora* sp. 1 cf. *austriaca* (KRISTAN, 1957). – BLAU, p. 10, Pl. 4, Figs. 8-11; Text-Fig. 1e.
1987b *Coronipora gusici* n. sp. – BLAU, p. 9-10, Pl. 3, Figs. 10-13.
1990 *Coronipora austriaca* (KRISTAN, 1957). – KRISTAN-TOLLMANN, p. 242, Figs. 13, 19, 20, Pl. 13, Figs. 2, 8-11.
1991 *Coronipora* sp. 1 cf. austriaca (KRISTAN, 1957). – BLAU & HAAS, p. 18, Figs. 7 A-E.
1993 *Coronipora austriaca* (KRISTAN, 1957). – EBLI, p. 158, Pl. 2, Figs. 1-2.
1997 *Coronipora austriaca* (KRISTAN, 1957). – EBLI, p. 96, Pl. 35, Figs. 1-2 (cum syn.).
1997 *Coronipora austriaca* (KRISTAN, 1957). – BLAU & GRÜN, p. 256, Fig. 5 J.
1997 *Coronipora kristantollmannae* n. sp. – BLAU & GRÜN, p. 250-254, Fig. 5 A-H.

Description: Nearly planispiral to trochospiral tests, with 6–8 deuteroloculus-whorls. The proloculus and the first 2-3 deuteroloculus-whorls are mostly arranged planispiral, whereas the next following whorls show a shallow to high trochospiral coiling. Especially in the juvenile stage they can be very small, so that in the area of the initial whorls a more or less deep depression can be observed (e.g. Pl. 19, Figs. 11-13, 15). The cross-section of the deuteroloculus-tube is halfmoon-shaped to crescent. The upper side of the test shows pores and characteristic ridges of variable thickness and length.

Well preserved specimens exhibit one lamella per deuteroloculus-whorl. With regard to one specimen each lamella is often of constant thickness, but can also thin towards the center of the test(Pl. 19, Figs. 9, 11). Within one population the thickness of the lamellae is highly variable. So, at the same degree of coiling the umbilicus can be filled totally and then shows a flat base, the test is plano-convex, whereas in other cases thin lamellae are arranged parallel to the upper side of the test, that is then concavo-convex.

Remarks: *Coronipora gusici* was described by BLAU (1987b) mainly with respect to the outer morphology of the test. An other differential feature he noted, is that the last whorl is not covered by lamellae, but this is not thought to be a species-relevant criterium but only a growth stage. BLAU (1987b) also figured specimen of *C. austriaca* with a free last whorl (op. cit. Pl. 4, Fig. 10). Therefore, and due to high variability of *Coronipora austriaca,* the forms that are described as *Coronipora gusici* by BLAU (1987b) are regarded as a synonym of the first one.

Coronipora kristantollmannae BLAU & GRÜN (1997) is thought to represent only very high conical specimen of *C. austriaca.* PILLER (op. cit) figured 3 specimen of *Semiinvoluta* ? sp., to document the different morphologies of these doubtful species, one of them being highly conical (PILLER's Plate 21, Fig. 8). BLAU (1987b) identified all these foraminifera to represent *C. austriaca.* Also BLAU & GRÜN (1997) transfered these foraminifera in the synonymie of *C. austriaca.* But in their Fig. 3 the measurments of PILLER's conical specimen would lie within, but very near the frontier of their *C. kristantollmannae*-field.

Also our material suggests that there is a continuous spectrum in the height versus widths plot between both "species". The specimen documented on Plate 20, Fig. 1 also approaches the *"kristantollmannae"*-field and therefore indicates that variability of *C. austriaca* is by far higher than plotted by BLAU & GRÜN (1997).

Therefore and having in mind the immense variability of *C. austriaca* (Plates 19 and 20) there exists no reason to establish a new species.

Occurrence: *Coronipora austriaca* is a common foraminifer in the red Adnet limestones and is very abundant in condensed parts of the Schnöll-Formation, especially in the Enzesfeld facies.

aff. *Coronipora etrusca* (PIRINI, 1966)

(Plate 20, Fig. 2)

aff. 1966 *Lasiodiscus* (?) *etruscus* n. sp. – PIRINI, p. 91, Text-Figs. 1d-e, Pl. 1, Figs. 1-3.
aff. 1987a *Coronipora etrusca* (PIRINI, 1966). – BLAU, p. 503, Pl. 4, Figs. 2-6.
aff. 1987b *Coronipora etrusca* (PIRINI, 1966). – BLAU, p. 9, Pl. 5, Figs. 1-9.
aff. 1991 *Coronipora etrusca* (PIRINI, 1966). – BLAU & HAAS, p. 16, 18, Text-Fig. 6, Figs. 5 A-K (cum syn.).

Remarks: The only specimen probably related to this species is poorly preserved. It is very strongly recrystallized, so that no internal structures are visible. The main criteria for the determination are the well developed spines, that are thought to represent prolongations of the deuteroloculus. Also the size and the overall morphology fits well with specimen figured by BLAU (1987a, b).

Occurrence: As noted above aff. *C. etrusca* is extremly rare in our material (sample RGS HG III.2; Quarry XXXI).

Genus *Involutina* TERQUEM, 1862

Type species: *Nummulites liassicus* JONES in BRODIE, 1853.

Synonyms:
See PILLER (1978: 65)

Diagnosis: Test free, bilocular consisting of a spherical proloculus and a tube-like, not divided deuteroloculus-tube or semi-tube. Mode of coiling planispiral to oscillating.

Involutina liassica (JONES, 1853)

(Plate 15, Fig. 17, Plate 16, Figs. 1-16)

1853 *Nummulites liassicus* n. sp. – JONES in BRODIE, p. 275.
1978 *Involutina liassica* (JONES, 1853). – PILLER, p. 65-68, Pl. 13, Figs. 1-9 (cum syn.).
1987b *Involutina liassica* (JONES, 1853). – BLAU, p. 6-7, Pl. 1, Figs. 1, 4, 6.
1991 *Involutina liassica* (JONES, 1853). – SCHLAGINTWEIT & PILLER, p. 147, Figs. 1-2; Pl. 2, Figs. 1-13. (cum syn.).
1993 *Involutina liassica* (JONES, 1853). – EBLI, p. 158, Text-Fig. 3; Pl. 2, Figs. 1-2.
1997 *Involutina liassica* (JONES, 1853). – EBLI, p. 96-97, Text-Fig. 36c; Pl.28, Figs. 7-8; Pl. 35, Figs. 3-10 (cum syn.).

Remarks: The species was described in detail by PILLER (1978). To his diagnosis it has to be added, that the mode of coiling is not always strictly planispiral. As shown on Plate 16, Fig. 2, there exist also specimens, that exhibit oscillating whorls.

The morphology of the species is highly variable. Lens-shaped specimen dominate, whereas globular forms are rare. In the latter ones the umbilical-mass is very well developed (e.g. Plate 16, Figs. 15, 16), whereas it can also be nearly absent (Plate 16, Fig. 1). Of great importance is the fact that the umbilicus always shows nodes that are especially well developed in the lens-shaped morphotypes.

The section of deuterolocutus-semitube is ranging from heart-shaped to elliptical. The last 1–3 whorls can be evolute (e. g. Pl. 16, Figs. 3, 6, 7, 8).

Involutina liassica is characterised in contrast to the morphologically similar species *Involutina turgida* by the presence of a deuterolocutus semi-tube, whereas the latter species builds a complete tube. Different to the globular *Aulotortus sinuosus* the species possesses nodes on the umbilicus and the lamellae pass this area without interruptions, whereas they wedge out there in *A. sinuosus*.

Occurrence: In our material *I. liassica* is by far the most abundant involutinid foraminifer. It occures with big morphotypes and in a high variability in the red limestones, whereas it is rarer, smaller and not so variable in the grey ones.

Genus *Licispirella* Blau & Grün, 1997

Type species: *Semiinvoluta violae* Blau, 1987 b

Diagnosis: Test free, planispiral to low trochospiral. The spherical proloculus is followed by an undivided deuteroloculos semitube, the lower side of which can be covered with more or less thick test material. Lamellae are lacking. The spiral side exhibits small ridges in the area of the sutures.

Licispirella violae (Blau, 1987b)

(Plate 17, Figs. 9-14)

1987b *Semiinvoluta violae* n. sp. – Blau, p. 10, Pl. 2, Figs. 1-8.
1987a gen. et sp. indet 1. – Blau, p.507, Pl. 7, Figs. 4-8.
1987a gen. et sp. indet 2. – Blau, p.507, Pl. 7, Figs. 12-13.
1991 *Semiinvoluta violae* Blau, 1987 b. – Blau & Haas, p. 18-19, Figs. 3 M, 7 F-G (cum syn.).
1993 *Semiinvoluta violae* Blau, 1987 b. – Ebli, p. 158, Pl. 2, Fig. 3.
1997 *Semiinvoluta violae* Blau, 1987 b. – Ebli, p. 97, Pl. 35, Figs. 11-12.
1997 *Licispirella* n. gen. *violae* (Blau, 1987 b). – Blau & Grün, p. 257-258, Fig. 4 a.
1997 *Licispirella marmorensis* n. gen. n. sp. – Blau & Grün, p. 258, Fig. 5 L.
1997 Licispirella tricarinata n. gen. n. sp. – Blau & Grün, p. 258-259, without figuration.

Description: The planispiral to slightly trochospiral enrolled proloculus has an ovoid to halfmoon shaped cross-section. The diameter of the whorls mostly increases continuously. Periphery of the test is curved or straight.

The upper side of the foraminifera show more or less triangular ridges in the area of the sutures. The lower side is covered by more or less thick test material, exhibiting also triangular thickenings that are situated at each chamber in a direction towards the prolocolus.

Remarks: In the original diagnosis Blau (1987 b) stated the importance of the covering of the ventral side with a thick layer of test material in *Semiinvoluta violae* (=*Licispirella violae*). This distinctive marking is lacking in *Licispirella bicarinata,* the former *Semiinvoluta* (?) *bicarinata* Blau, 1987b. For this species in the original diagnosis a straight periphery that shows keel-like thickenings on the upper and lower side of the test is mentioned. These thickenings are also present in *L. violae,* but in this species they overlay the foregoing chamber on the umbilical side of the test in different extent (e.g. Plate 17, Figs. 9-14), giving rise to different thick umbilical-masses. This "keels" show a great variability in their dimensions. They may be nearly absent (Pl. 17, Fig. 9,) or well developed (e.g. Pl. 17, Fig. 11). Also the thickenings on the upper side of the test exhibit a wide range of morphology from those resembling a *Coronipora*-like type (Plate 17, Fig. 9) to tri- and rectangular (e.g. Plate 17, Fig. 11) forms. Because of this variability *Licispirella marmorensis* Blau & Grün (1997) is thought to represent a synonym of *L. violae.*

Due to variability of the test-periphery (curved: e.g. Plate 17, Figs. 9, 10) to straight (e.g. Plate 17, Fig. 11) also *Licispirella tricarinata* Blau & Grün (1997) that was based on 2 specimen, is thought to represent a synonym of *L. violae.*

In *L. bicarinata* the umbilical thickenings are situated mostly at the periphery of each coil, but in some specimens they have the tendency to approach the foregoing chamber (e.g. Plate 17, Fig. 6, right side). This indicates a very close relationship between these two "species". Therefore it could be possible that *L. violae* and *L. bicarinata* only represent morphotypes of one species. A further hint for this assumption could be a specimen of *L. bicarinata* reported by Blau & Haas (1991) that "seem to be thickened" at the non-perforate side of the test (op. cit.: p. 19, Fig. 7 H).

Occurrence: This species was also in the red and grey limestones of the Schnöll-Formation, with greatest abundance in condensed layers.

Licispirella bicarinata (Blau, 1987b)

(Plate 17, Figs. 1-8)

1987b *Semiinvoluta* (?) *bicarinata* n. sp. – Blau, p. 11, Pl. 4, Figs. 1-7.
1991 *Semiinvoluta* (?) *bicarinata* Blau, 1987 b. – Blau & Haas, p. 19, Figs. 7 H-I.
1993 *Semiinvoluta* (?) *bicarinata* Blau, 1987b. – Ebli, p. 160, Pl. 2, Fig. 4.
1997 *Semiinvoluta* (?) *bicarinata* Blau, 1987b. – Ebli, p. 97, Pl. 35, Figs. 13-14.
1997 *Licispirella* n. gen. *bicarinata* (Blau, 1987 b). – Blau & Grün, p. 258, Fig. 4b.

Remarks: See L. violae.

Occurrence: See above.

Genus *Piriniella* Blau, 1987a

Type species: *Piriniella blindi* Blau, 1987a

Diagnosis: Conical test free, with sperical proloculus followed by trochospiral enrolled deuteroloculus semi-tube. Initial part covered on the upper and lower side by test-material, the latter being even or nodose. Umbilicus hollow.

Piriniella blindi Blau, 1987a

(Plate 20, Fig. 3)

1987a *Piriniella blindi* n. gen. n. sp. – Blau, p. 502-503, Pl. 3, Figs. 1-4.

Remarks: The only specimen put into this species is strongly recrystallized. The covering with test material is confined on both sides of the foraminifera to the initial growth-stage. The umbilicus is hollow. Towards the youngest whorls, coiling becomes steeper.

Occurrence: Sample AD 92/2; Eisenmann Quarry; white micritic limestone, 180 cm above Oberrhätkalk.

Genus *Semiinvoluta* KRISTAN, 1957

Type species: *Semiinvoluta clari* KRISTAN, 1957.
Diagnosis: See KRISTAN (1957) and PILLER (1978).
Remarks: The diagnosis should incorporate the highly variable morphology of the pillars.

Semiinvoluta clari KRISTAN, 1957
(Plate 20, Figs. 4-10; Plate 21, Figs. 1-4)

1957 *Semiinvoluta clari* nov. gen. nov. spec. – KRISTAN, p. 276, Pl. 22, Figs. 11-17.
1978 *Semiinvoluta clari* KRISTAN, 1957. – PILLER, p. 87-88, Pl. 21, Fig. 5 (cum syn.).
1990 *Semiinvoluta clari* KRISTAN, 1957. – KRISTAN-TOLLMANN, p. 242, Text-Fig. 13, Figs. 12-18; Pl. 13, Figs. 3-7, 12-14.

Description: Nearly planispiral to trochospiral foraminifera with a kidney-shaped to ovoid deuterolocolus cross section. The upper side of the test always bears a more or less thick calcitic mass that can show a central depression (eg.Plate 20, Fig. 4) or can be rounded (e.g. Plate 21, Fig. 2).

The lower side of the deuteroculus can exhibit pillars, that are very variable in their thickness and length. If they are restricted to the initial parts of the test (e.g. Plate 20, Figs. 4, 9, 10), the chambers not exhibiting these pillars are mostly sharpened towards the lower side.

Remarks: As KRISTAN-TOLLMANN (1990) pointed out, the known stratigraphic range of S. clari is the Norian to Rhaetian stage of the Upper Triassic. During that time the species under consideration was a typical inhabitant of the reef and near fore-reef environments, as it was also *Coronipora austriaca.*

Occurrence: With exception of the Kendlbach-Fm. in all investigated sedimentary environments.

cf. *Semiinvoluta clari* KRISTAN, 1957
(Plate 21, Figs. 5, 6)

cf. 1957 *Semiinvoluta clari* nov. gen. nov. spec. – KRISTAN, p. 276, Pl. 22, Figs. 11-17.
? 1987b *Planispirillina trochoidea* n. sp. – BLAU, p. 504-505, Pl. 7, Figs. 1-3a, b.

Remarks: Also some specimen without pillars could probable be incorporated in *S. clari,* because also this morphological feature is highly variable.

Occurrence: See above.

Genus *Trocholina* PAALZOW, 1922 emend. PILLER, 1978

Type species: *Involutina conica* SCHLUMBERGER, 1898

Synonyms:
Involutina TERQUEM, 1862, pars: SCHLUMBERGER, 1898
Coscinoconus LEUPOLD, 1936
? *Neotrocholina* REICHEL, 1955
Trocholina (Trochonella) KRISTAN, 1957
Lamelliconus PILLER, 1978, pars: SALAJ et al., 1983.

Diagnosis: Bilocular, rounded or sharp conical free test, consisting of a spherical proloculus and a not divided deuteroloculus. Mode of coiling trochospiral. Simple aperture at the end of the tube. Umbilicus and the exterior of the test filled or covered by lamellae. Per whorl one lamella with pillars is built, but the youngest whorls can lack this feature.

Trocholina turris FRENTZEN, 1941
(Plate 18, Figs. 1-3)

1941 *Trocholina turris* n. sp. – FRENTZEN, p. 306, Pl. 1, Figs. 13 a-c.
1978 *Trocholina turris* FRENTZEN, 1941. – PILLER, p. 83-84, Pl. 20, Figs. 12, 15, 18 (cum syn.).
1987b *Trocholina turris* FRENTZEN, 1941. – BLAU, p. 8, Pl. 2, Figs. 9-13
1991 *Trocholina turris* FRENTZEN, 1941. – BLAU & HAAS, p. 10, Figs. 3 E, G.
1993 *Trocholina turris* FRENTZEN, 1941. – EBLI, p. 160, Pl. 2, Fig. 10.
1997 *Trocholina turris* FRENTZEN, 1941. – EBLI, p. 98, Pl. 28, Figs. 13-15; Pl. 35, Fig. 16.

Remarks: The species was described in detail by PILLER (1978). It is distinguished from *T. umbo* by its high-conical shape and the mode of coiling, being high trochospiral from the beginning.

Occurrence: *Trocholina turris* is confined to the red limestone facies.

Trocholina umbo FRENTZEN, 1941
(Plate 18, Figs. 4-12)

1941 *Trocholina umbo* n. sp. – FRENTZEN, p. 306, Pl. 1, Figs. 12 a-c.
1991 *Trocholina umbo* FRENTZEN, 1941. – BLAU & HAAS, p. 14, 16, Figs. 3 D, F.
1993 *Trocholina umbo* FRENTZEN, 1941. – EBLI, p. 160, Pl. 2, Fig. 7.
1997 *Trocholina umbo* FRENTZEN, 1941. – EBLI, p. 98, Pl. 28, Figs. 10-12; Pl. 36, Figs. 1-2 (cum syn.).

Description: The species is characterized by a nearly planispiral to low trochospiral juvenile stage, and a therefore resulting rounded periphery. The coiling changes then and the deuteroloculus semitube is mostly high trochospiral enrolled. The number of whorls varies between 5–10, the cross-section is ovoid to crescent. The last, rarely the two last whorls can be free, the thick umbilicus bearing more or less well developed nodes. It can be impressed or domed.

Remarks: The species is highly variable. As WICHER (1952: 262-263) has shown, *Trocholina granosa* described by FRENTZEN (1941) is only a preservation stage of *T. umbo* and therefore a junior synonym. The proposed unification of *T. turris* and *T. umbo* is not followed here, because of the clearly different coiling mode of the deuteroloculus in the initial stage (see above).

BLAU & GRÜN (1997) thought the strongly recrystallized specimen published by EBLI (1993) to be a representative of their new described species *Coronipora kristantollmannae.* This view must be rejected, because the foraminifer in question exhibits weak nodes, although they are difficult to recognize, because they are obscured by secondary calcite. Furthermore also in some specimen of *T. umbo* published by BLAU (1987a) small pores can be detected (op. cit. Pl. 1, Figs. 1, 10, 11).

Occurrence: See *Trocholina turris.*

Suborder Miliolina DELAGE & HEROUARD, 1896
Superfamily Cornuspiracea SCHULTE, 1854
Familiy Cornuspiridae SCHULTE, 1854
Subfamiliy Calcivertellinae LOEBLICH & TAPPAN, 1961

Genus *Planiinvoluta* LEISCHNER, 1961

Type species: *Planiinvoluta carinata* LEISCHNER, 1961

Diagnosis: Test attached, consisting of a globular proloculus and a not further divided second chamber, at the end of which the simple aperture is situated. Wall imperforate. Mode of coiling is planispiral to irregular in the adult-stage; therefore the test is discoidal to columnar. Whorls are evolute against the substratum, involute towards the upper side.

Remarks: Although in the original diagnosis LEISCHNER (1961) stated a calcareous, perforate test (op. cit.: 11), the wall is imperforate (e.g. WERNLI, 1971: 224). Due to the latter author it exhibits also a micropeloidal structure ("Elle est souvent pigmentée de petits granules noirs." op. cit.: 224).

Planiinvoluta carinata LEISCHNER, 1961

(Plate 5, Fig. 5, Plate 22, Figs. 1-15)

1961 *Planiinvoluta carinata* n. sp. – LEISCHNER, p. 11-12, Pl. 10, Figs. 1-14; Pl. 12, Figs. 6, 7a, 8a

1961 *Planiinvoluta deflexa* n. gen. n. sp. – LEISCHNER, p. 12, Pl. 10, Figs. 15-22; Pl. 12, Figs. 7b, 8b

1971 *Planiinvoluta carinata* LEISCHNER, 1961. – WERNLI, p. 222-225, Pl. 1, Figs. 1-7; Pl. 2, Figs. 1-6; Pl. 3, Figs. 1-8.

1976 *Planiinvoluta carinata* LEISCHNER, 1961. – ZANINETTI, p. 130-140, Pl. 7, Figs. 32-33 (cum syn.).

1977 *Planiinvoluta carinata* LEISCHNER, 1961. – SEPTFONTAINE, p. 70-71, Pl. 1, Figs. 11-15.

1983 *Planiinvoluta carinata* LEISCHNER, 1961. – SALAJ, BORZA & SAMUEL, p. 105, Pl. 61, Figs. 5-17; Pl. 62, Figs. 1-2; Pl. 63, Figs. 8-10.

1983 *Planiinvoluta deflexa* LEISCHNER, 1961. – SALAJ, BORZA & SAMUEL, p. 105-106, Pl. 62, Figs. 3-10.

1983 *Planiinvoluta irregularis* n. ssp. (sic!) – SALAJ, BORZA & SAMUEL, p. 106, Pl. 62, Figs. 11-13; Pl. 53, Figs. 1-7.

1983 *Planiinvoluta regularis* n. sp. – SALAJ, BORZA & SAMUEL, p. 106, Pl. 64, Figs. 1, 3.

1990 *Planiinvoluta deflexa* LEISCHNER, 1961. – KRISTAN-TOLLMANN, p. 231-232, Text-Fig. 11-1; Pl. 8, Fig. 5.

1990 *Planiinvoluta multitabulata* n. sp. – KRISTAN-TOLLMANN, p. 232, Text-Fig. 11-4; Pl. 4, Figs. 3-6.

1993 *Planiinvoluta carinata* LEISCHNER, 1961. – EBLI, p. 160-162, Pl. 2, Figs. 12-13.

1994 *Planiinvoluta carinata* LEISCHNER, 1961. – BLAU & GRÜN, Pl. 3, Figs. 1-17.

1994? *Planiinvoluta carinata* LEISCHNER, 1961. – BLAU & GRÜN, Pl. 4, Fig. 3.

1997 *Planiinvoluta carinata* LEISCHNER, 1961. – EBLI, p.99, Pl. 36, Figs. 6-7.

Description: The globular proloculus is followed by a second tubular chamber. In a first stage the deuteroloculus is more or less regular (planispiral) enrolled, whereas a – not always realized – second stage being planispiral as well, or totaly irregular coiled, can follow these initial whorls.

The diameter of the second tube increases gradually or can be also nearly constant during growth. In marginal sections it can be seen, that this species is able to build "bridges", that means, that it has not alway contact to the substratum (e.g. Plate 22, Fig. 5).

Remarks: Due to the form of the evolute part of the test, LEISCHNER (1961) differentiated 2 "species": *P. carinata* (even to slightly concave) and *P. deflexa,* with a more or less convex evolute part. Both "species" are sessile foraminifera, therefore this distinction is by no means valuable, because it only reflects the form of the substratum. As WERNLI (1971) pointed out, *P. deflexa* was not figured by axial sections by LEISCHNER (1961), but by oblique, not centered ones.

Planiinvoluta irregularis SALAJ, BORZA & SAMUEL (1983) is differentiated by definition from *P. carinata* by the thicker wall and an irregular coiling mode. As is true for *P. deflexa,* also *P. irregularis* was not figured by axial sections, therefore the wall appears in tangential sections much thicker than it is in reality. As also documented by the mentioned authors (e.g. Pl. 61, Figs. 5 and 6; Pl. 62, Figs. 5 and 7) *Planiinvoluta carinata* and *P. "deflexa"* have a wide range of wall thickness, with maximal values comparable or even identical (Pl. 61, Fig. 5) with those of *P. irregularis.* This is in agreement with the observed specimen of *P. carinata* and also with the results of other workers (e.g. WERNLI, 1971).

Additionally the holotype of *P. irregularis* documented by SALAJ, BORZA & SAMUEL (1983: Pl. 63, Fig. 1) consists of two succeeding generations of settling foraminifera. The basal foraminifer represents a rather regular, not centered section of *Planiinvoluta* followed by a second "coiling stage" that is differentiated by the first settling stage by its brighter micritic wall.

Therefore *P. irregularis* is thought to be a junior synonym of P. carinata. The same is thought about *P. regularis* SALAJ, BORZA & SAMUEL (1983).

Planiinvoluta multitabulata KRISTAN-TOLLMANN, 1990 was defined by a planispiral initial part, followed by the youngest, elongated part of the test in one or two layers oblique to the base. Also this species was not documented in axial sections. Because of the reasons pointed out above and because of the immense variability of *P. carinata* this species is invalid.

Occurrence: *P. carinata* is very frequent in the grey limestones under investigation, whereas it is extremely rare in the red ones.

Family Nubeculariidae JONES, 1875
Subfamily Nodophthalmidiinae CUSHMAN, 1940

Genus *Nodophthalmidium* MACFADYAN, 1939

Type species: *Nodobacularia compressa* RHUMBLER, 1906

? *Nodophthalmidium* sp.

(Plate 22, Fig. 16)

1975 *Nodobacularia* sp. – GUSIC, p. 37-38, Pl. 14, Figs. 9-11.

1991 *Nodophthalmidium* sp. – SCHLAGINTWEIT, p. 42, Pl. 15, Fig. 24.

Description: Free foraminifera, with uniserial arranged, pyriform to bottle-shaped chambers and an imperforate wall.

Remarks: Though the initial part of the foraminifera is not preserved, it can not be decided, if this form belongs to the genus or not. In *Nodophthalmidium* this juvenile stage is spirally wound.

Foraminifera designed to the genus *Nodophthalmidium* are often covered by a multiple layered micritic envelope and are then known as *Tubiphytes morronensis* CRESCENTI, 1969 (see detailed discussion in SCHMID, 1995). Because the genus *Nodobacularia* is sessile, the foraminifera published by GUŠIĆ, are thought to belong to the genus under discussion.

Occurrence: The only appearing representative of this genus was found in grey limestones of the Schnöll-Formation (Sample RGS Spong 4b; Quarry XXXI, sponge horizon).

Nubeculariidae gen. et sp. indet.
(Plate 21, Fig. 11)

Description: The only specimen of this unidentified foraminifera is broken and shows a very thick, porcelaneous, imperforate wall with a micropeloidal structure. The lumen of the chambers is pyriform. The mushroom-like appearance shows that the foraminifera is pluriloculin, the chambers changing rapidly their direction.

Remarks: The author thinks that this foraminifer could be attributed to two species, belonging to different genera: The first (and in the author's opinion more probable) is *Nubecularia reicheli* RAT, 1966, occurring in the Middle Jurassic of the Northern Calcareous Alps (Vils Limestone; EBLI, 1997), where it can build – as in its type-locality – monospecific foraminiferal-oncoids. The second one is *"Tubiphytes" morronensis* CRESCENTI,1969, recently revised by SCHMID (1995), who showed it to be a nubeculariid foraminifer, occurring from the Middle Jurassic to the Middle Cretaceous. Because only a small bioclast of this foraminifer is available, no determination is possible. For both species this would be the first occurrence in the Liassic of the Northern Calcareous Alps.

Occurrence: Extremely rare in the Kendlbach-Formation of Quarry XXXI.

Family Ophthalmidiidae WIESNER, 1920
Genus *Ophthalmidium* KÜBLER & ZWINGLI, 1866

Type species: *Oculina liasica* KÜBLER & ZWINGLI, 1870

Synonyms:
Neoangulodiscus KRISTAN-TOLLMANN, 1962

Diagnosis: Test free, wall calcareous, porcellaneous. Aperture terminal, simple, circular at the end of a neck, may have a phialine lip. The globular proloculus is followed by a tubular, planispiral enrolled flexostyle with a length nearly half a whorl, whereas the next chambers can have up to one coil in length, are broader at their base and are narrowing towards the aperture.

***Ophthalmidium carinatum* (KÜBLER & ZWINGLI, 1866)**
(Plate 21, Fig. 7)

1866 *Oculina carinata* n. sp. – KÜBLER & ZWINGLI, p. 14, Pl. 2, Fig. 19.
1961 *Involutina carinata* n. sp. – LEISCHNER, p. 10, Pl. 2, Figs. 15-18; Pl. 12, Fig. 5.
1993 *Ophthalmidium carinatum* (KÜBLER & ZWINGLI, 1866). – EBLI, p. 162 , Pl. 2, Fig. 15.
1997 *Ophthalmidium carinatum* (KÜBLER & ZWINGLI, 1866). – EBLI, p. 100 , Pl. 29, Fig. 1; Pl. 36, Figs. 8-9 (cum syn.).

Remarks: The species differs from *O. leischneri* (see below) in having a more or less sharp, keel-like periphery, and by having a deep depression in the area of juvenile growth stage. This is due to a changing of the coiling-mode from involute (juvenile) to semiinvolute (adult). Because of the test material *Involutina carinata* LEISCHNER (1961: Pl. 12, Fig. 5) is a miliolid foraminifer that is attributed to the genus *Ophthalmidium,* therefore homonym to *Ophthalmidium carinatum* (KÜBLER & ZWINGLI, 1866) and because of this invalid. Therefore the "species" of LEISCHNER can be synonymized with the latter one.

GUŠIĆ (1975) assumed that the species *"Vidalina" carinata* and *leischneri* could "represent only differently situated axial sections of one and the same form." That means that a section through the junction of the ophthalmiid chambers would produce the keeled carinata-outline, whereas axial sections perpendicular to the first would represent the *leischneri*-type.

The mentioned asymmetry of the median edge that would support this assumption, was also observed in our material. The only difference between the two species would be then the much deeper umbilical depression in *O. carinatum,* a feature that could not be explained by different situated sections, because it represents different coiling modes. The question, if both species are valid, could only be solved if orientated thinsections were available from isolated material.

Occurrence: The species is rarer as *O. leischneri,* but also present in all investigated sedimentary environments.

***Ophthalmidium leischneri* (KRISTAN-TOLLMANN, 1962)**
(Plate 21, Figs. 8, 9)

1962 *Neoangulodiscus leischneri* n. gen. n. sp. – KRISTAN-TOLLMANN, p. 5, 8, Pl. 2, Figs. 25-34.
1976 *Ophthalmidium leischneri* (KRISTAN-TOLLMANN, 1962). – ZANINETTI, p. 144-145, Pl. 7, Figs. 14-16.
1993 *Ophthalmidium leischneri* (KRISTAN-TOLLMANN, 1962). – EBLI, p. 162, Pl. 2, Fig. 14.
1997 *Ophthalmidium leischneri* (KRISTAN-TOLLMANN, 1962). – EBLI, p. 100-101, Pl. 36, Fig. 10 (cum syn.).

Remarks: For a detailed description see KRISTAN-TOLLMANN (1962). The main differences to *O. carinatum* are the rounded periphery and the slighter developed umbilical depression in *O. leischneri.* In some cases the flanks of the foraminifera are nearly parallel. In contrast to this species *O. martanum* is defined by a biconvex outline, with its greatest diameter in the umbilical area.

Occurrence: The species occures in nearly all investigated samples.

***Ophthalmidium martanum* (FARINACCI, 1959)**
(Plate 22, Fig. 10)

1959 *Vidalina martana* nov. sp. – FARINACCI, p. 12-13, Text-Fig. 2 (partim), Pl. 9, Fig. 3; Pl. 10, Fig. 1?, Fig. 2.

Remarks: For differentiation to the other species of *Ophthalmidium* see above. Noteworthy is the fact that FARINACCI (1959) has not designated a holotype for this species! The documented specimen of *O. martanum* are either broken (her Pl. 9, Fig. 3; Pl. 10, Fig. 2), questionable (her Pl. 10, Fig. 1) or do not belong to the genus *Ophthalmidium* (her Text-Fig. 2, aequatorial-section). The only valuable figured specimen of *O. martanum* is therefore only a line-drawing (her Text-Fig. 2, left side).

Occurrence: The species is very rare and is restricted to the red limestone facies.

Suborder Lagenina DELAGE & HEROUARD, 1896
Superfamily Nodosariacea EHRENBERG, 1838
Familiy Nodosariidae EHRENBERG, 1838
Subfamily Lingulininae LOEBLICH & TAPPAN, 1961

Genus *Lingulina* D'ORBIGNY, 1826

Type species: *Lingulina carinata* D'ORBIGNY, 1826.

Lingulina sp.
(Plate 15, Figs. 12, 13)

Description: In thin sections the genus is only determinable in sections perpendicular to the longitudinal axis. In this orientation the tests are strongly compressed, flanks parallel to slightly biconcave, the sides being biconvex. At the edges of the test 4–6 ribs are visible.
Remarks: Sections parallel to the longitudinal axis could be misidentified with those of the genera *Pseudonodosaria, Frondicularia* and *Ichthyolaria*.
Occurrence: Red and grey limestones of the Adnet quarries.

Family Lagenidae REUSS, 1862

Genus *Lagena* WALKER & JACOB, 1798

Type species: *Serpula (Lagena) sulcata* WALKER & JACOB, 1798

Lagena sp.
(Plate 15, Figs. 14-16)

1992 *Lagena* sp. – BÖHM, Pl. 10, Fig. 6.

Description: Globular, unilocular tests with a calcareous hyaline wall. In some cases a short neck is visible, bearing the simple aperture.
Remarks: LEISCHNER (1961) described several species of this genus from the Lower Liassic, that he figured in schematic line-drawings. Bicamerate tests as published by him (op. cit.: p. 24-25, Pl. 4, Figs. 4-6, 10) as *Lagena bicamerata* JONES, 1874 do not belong to this genus that only includes unilocular test. Furthermore LEISCHNER (op. cit: p. 24, Pl. 4, Fig. 3) described *Lagena mucronata* TERQUEM & BERTHELIN, 1875, having a spine ("Stachelspitze") on its lower side, but his drawing exhibits, that this spine is a broken neck of a multilocular form. This would imply that this specimen would possess long necks between the globular chambers, and would then belong to the genus *Ramulina*. Concerning *Lagena bullaeformis* SCHWAGER, 1867 he noted (op. cit.: 24) transitional forms to *L. hispida,* that – in the opinion of the author – could represent *Nodosaria apheilocula,* because this species also possesses a basal "spine".
Occurrence: Rare in red limestones.

Family Polymorphinidae D'ORBIGNY, 1839
Subfamily Webbinellinae RHUMBLER, 1904

Genus *Bullopora* QUENSTEDT, 1856

Type species: *Bullopora rostrata* QUENSTEDT, 1857

Synonyms:
Arperneorum RHUMBLER, 1913
Arplacopsum RHUMBLER, 1913
Placopsum RHUMBLER, 1913

Diagnosis: Test attached, composed of ovate to circular, hemispherical chambers, that may increase rapidly in diameter (microspheric forms), or are of nearly equal size (megalospheric forms). Initial chambers closely spaced, whereas later ones may be connected by stoloniferous necks, at the open end of which the simple aperture is situated. The wall is calcareous perforate.

Bullopora tuberculata (SOLLAS, 1877)
(Plate 21, Figs. 12, 13)

1877 *Webbina tuberculata*. – SOLLAS, p. 104, Pl. 6, Fig. 4-9.
1977 *Bullopora tuberculata* (SOLLAS, 1877). – SEPTFONTAINE, p. 67-68, Pl. 1, Figs. 1-4.
1993 *Bullopora tuberculata* (SOLLAS, 1877). – EBLI, p. 163, Pl. 2, Fig. 16.
1997 *Bullopora tuberculata* (SOLLAS, 1877). – EBLI, p. 119, Pl. 37, Fig. 6.

Description: The irregular, hemispherical to elongated-ovoid chambers are arranged more or less rectilinear. The wall of the sessile foraminifera is calcitic-hyaline and radial fibrous. It is bearing small, double-cone-shaped spines, integrated to the half into the wall.
Remarks: Because of the characteristic spines *Bullopora tuberculata* is easy to determine.
Occurrence: The species is often involved into the microbial crusts of the Enzesfeld Limestone, but is also found in the sponge-rich lithologies.

Bullopora sp.
(Plate 23, Figs. 1, 2)

Remarks: These foraminifera are differentiated from *Bullopora tuberculata* by the lack of spines.
Occurrence: See *Bullopora tuberculata.*

3.2. Ammonites and Biostratigraphy

3.2.1. Introduction

With some exaggeration we can say that from the scientific view the glory of the Adnet locality has a double origin: in the fact that in the Adnet quarries there are excellent outcrops of the Adnet limestones and rich cephalopod fauna, especially Ammonites. It is reflected in many famous monographs like HAUER (1856), WÄHNER (1882–1898) and PIA (1914). With some admiration we must state more than one century there is nothing really significant to add, for example to the number of Ammonite taxa.

Perhaps a "shortcoming" of modern Ammonite biochronology is an insufficient precision of the location of single taxa affecting phyllogeny. It was partly corrected by WENDT (1971) and DOMMERGUES et al. (1995), especially for the Adnet facies. Still some stratigraphic troubles have continued henceforth, mainly in the biostratigraphy of Hettangian stage, especially in the so called "Brandschicht" ("Marmorea Crust"). We focused our attention just at this problem.

The Ammonite assemblage described has a double origin:
1. The major part (more than one hundred specimens) comes from STUR's collection at GBA in Vienna. This collection is dated from 1875. Obviously, it is not horizoned and accompanied by precise location of single specimens (e.g. *names of quarries or number of beds either*). For the major part of specimens, especially for those from the Adnet limestones it is very difficult to establish their exact position in the profile. Only a minor part of the material can be located

exactly owing a particular mode of their preservation in the condensed horizon (Brandschicht).

2. the smaller part of the material was collected by us (1992–1995) bed by bed. The new collections are poorer and their precise biostratigraphy is prevented by limited collecting possibilities.

Material: mainly from condensed horizons of the Eisenmann, Schnöll, Langmoos and Lienbacher Quarries (see Text-Figs. 6, 12, 13, 15). The preservation of ammonites is in most cases good and some specimens have also preserved their body chamber. In the systematic part we prefer a short description. When possible, we present a photo, whorl section or suture line of the specimen. All specimens described here are deposited at the GBA collection.

3.2.2. Systematic Descriptions

Nautilidae de BLAINVILLE, 1825

***Cenoceras* HYATT, 1883**

***Cenoceras schlumbergeri* (TERQUEM, 1855)**
(Pl. 24, Fig. 3)

1855 *Nautilus Schlumbergeri*, TQM. – TERQUEM: 242, Pl. 12, Fig.4
1984 *Cenoceras (Cenoceras) schlumbergeri* (TERQ.) – TINTANT: 39, Fig. 6

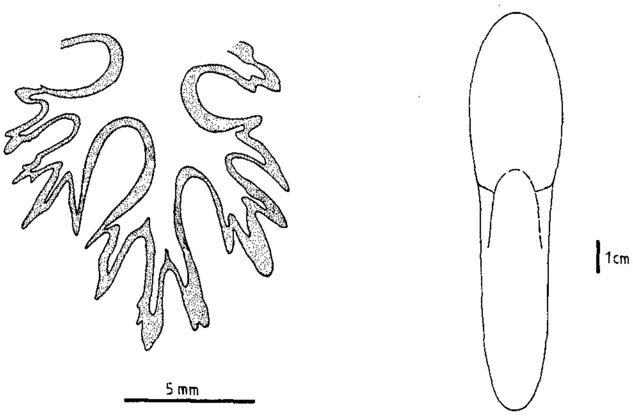
Material: one incomplete specimen

Dimensions:

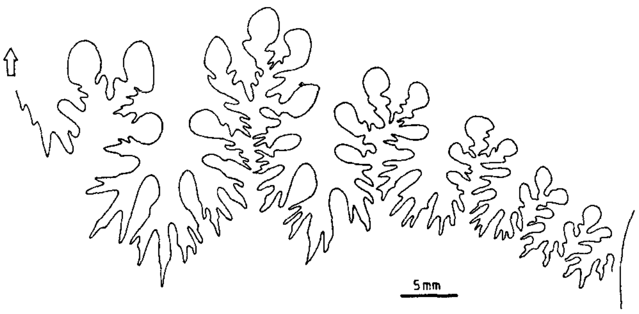
D	H	W	O
50,0	25,0	–	8,2

Remark: Our specimen from Langmoos quarry is in good accordance with the original description. Cross-section of last preserved whorl and suture line are very similar to those figured by TINTANT (1984, Fig. 6).

Occurrence: Langmoos Quarry "Marmorea Crust" ("Brandschicht"), Middle to Late Hettangian, "Marmorea" Zone, probably also Lienbacher Quarry.



Text–Fig. 34.
Togaticeras stella (SOWERBY). Cross-section of an adult specimen and mural part of suture line. Schnöll Quarry, "Marmorea Crust".



Text–Fig. 35.
Togaticeras stella (SOWERBY). Suture line of an adult specimen. Schnöll Quarry, "Marmorea Crust".

Juraphyllitidae ARKELL, 1950

***Togaticeras* RAKÚS, 1993**

***Togaticeras stella* (SOWERBY, 1883)**
(Text-Figs. 34, 35; Pl. 24, Fig. 1)

1883 *Ammonites stella* SOWERBY in de la BÉCHE: 333, Fig. 63
1993 ? *Paradasyceras stella* (SOWERBY, 1883) – RAKÚS & LOBITZER: 923, Text-Fig. 9; Pl.1, Fig. 3; Pl. 2, Figs. 1-5 (cum syn.)
1993 *Togaticeras stella* (SOW.) – RAKÚS: 946

Material: One relatively well preserved specimen (= phragmocone only) from STUR's collection.

Dimensions:

	D	H	W	O
GBA 404	126,0	52,6	31,2	32,5

Remark: The long ranged species is quite frequent in a Lower Liassic condensed horizon in the Northern Calcareous Alps. Our specimen is a large form only representing a phragmocone. In its size it is very close to the specimens deposited in the Bavarian Museum (Bayerische Staatssamlung für Paläontologie, München – WÄHNER's collection). Here some individuals have a diameter between 200–250 mm. There are also minute specimens with the same morphology. The size difference may correspond to macro- and microconchs (sexual dimorphism).

Occurrence: Schnöll Quarry, "Marmorea Crust" ("Brandschicht"), Middle Hettangian to Lotharingian (Oxynotus Zone).

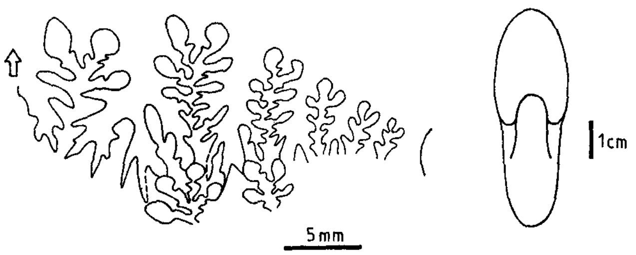
Phylloceratidae ZITTEL, 1884

Phylloceratinae ZITTEL, 1884

***Phylloceras* SUESS, 1865**

***Phylloceras psilomorphum* NEUMAYR, 1879**
(Text-Fig. 36; Pl. 24, Fig. 4)

1879 *Phylloceras psilomorphum* n.f. – NEUMAYR: 21, Pl. 2, Fig. 4
1952 *Phylloceras psilomorphum* NEUMAYR – LANGE: 82, Text-Fig. 1; Pl. 11, Fig.1



Text-Fig. 36.
Phylloceras psilomorphum (NEUMAYR). Cross-section and suture line. Schnöll Quarry, "Marmorea Crust".

?1995 *Phylloceras* sp. – DOMMERGUES et al.: 169, Pl. 1, Fig. 3

Material: four partly preserved specimens (phragmocons).

Dimensions:

	D	H	W	O
	48,6	–	17,6	5,8
GBA 402	59,0	32,2	22,3	6,4
	69,5	36,7	24,5	8,8

Remark: Our specimens are in good accordance with original description by NEUMAYR (1879) and LANGE (1952). Particularly the suture line (Text-Fig. 36) shows characteristic spatulation of follioles and markedly strangled saddles. Cross section of our specimens is somewhat larger in comparison with the lectotype of species (cf. NEUMAYR, 1879, Pl. 2, Fig. 4b).
Occurrence: Langmoos, Schnöll (STUR's collection) and Lienbacher Quarries, "Marmorea Crust" ("Brandschicht"), Early/Middle Hettangian.

Phylloceras sp.

Remark: In the Lienbacher quarry we have found an ammonite whose cross section proves that it is a *Phylloceras*. It was found above the "Marmorea Crust" ("Brandschicht"). Stratigraphically we range the layer as Lower Sinemurian.

Zetoceras KOVÁCS, 1939

Zetoceras complanatum (VADÁSZ, 1908)
(Pl. 24, Fig. 2)

1908 *Phylloceras oenotrium,* FUC. var. *complanata,* nov. var. – VADÁSZ: 318, Pl. 8, Fig.6; Text-Fig. 20
1936 *Phylloceras oenotrium* FUCINI var. *complanata* VAD. – GUGENBERGER: 147, Pl. 1, Fig. 6-8

Material: Three incomplete specimens and one large section (about 190 mm in diameter).
Remark: The initial whorls have flat flanks, convergent to the venter. The venter is narrow and rounded. The adult specimen is characterised by subtriangular whorl section. The shell is practically smooth, with very fine growth lines. By the subtriangular whorl section our specimen is well distinguished from the group of *Zetoceras oenotrium* (FUCINI) or *Z. pseudozetes* (FUCINI).
Occurrence: Lienbacher Quarry,? "Marmorea Crust" and the next bed over the Basal Sinemurian Crust, ? "Marmorea Zone" and Sinemurian, ?Semicostatum Zone.

Geyeroceras HYATT, 1900

Geyeroceras cylindricum (SOWERBY, 1831)
(Pl. 25, Fig. 6)

1831 *Ammonites cylindricus* SOWERBY – SOWERBY in de la BÉCHE: 318, Fig. 54
1993 *Geyeroceras cylindricum* (SOWERBY, 1831) – RAKÚS & LOBITZER: 923, Text-Fig. 8; Pl. 1, Figs. 1, 2; Pl. 2, Fig. 1 (cum syn.).
non 1995 *Phylloceras cylindricum* (SOWERBY, 1833) – DOMMERGUES et al.: 169, Pl. 1, Fig. 3

Material: Many fragments of phragmocons.
Remark: This specimen is very common in condensed horizon in the Adnet area. We described this species recently (RAKÚS & LOBITZER, 1993).
Occurrence: Schnöll and Lienbacher Quarries, "Marmorea Crust" ("Brandschicht"), Hettangian to Sinemurian (Oxynotum Zone).

Pleuroacanthidae HYATT, 1900

Analytoceratinae SPATH, 1927

Analytoceras HYATT, 1900

Analytoceras articulatum (SOWERBY, 1831)
(Pl. 24, Fig. 6)

1831 *Ammonites articulatus* SOWERBY – SOWERBY in de la BÉCHE: 333, Fig. 70
1993 *Analytoceras articulatum* (SOWERBY, 1831) – RAKÚS & LOBITZER: 924, Text-Fig. 11, (cum syn.)

Material: One medium-sized incomplete specimen.

Dimensions:

	D	H	W	O
GBA 400	90,0	27,5	27,8	37,4

Remark: The specimen from STUR's collection is in good accordance with WÄHNER's description and figuration. Its subadult stage is characterised by distinct, slightly prorsiradiate constrictions. No constrictions are visible on the last preserved whorl of STUR's specimen.
Occurrence: Schnöll Quarry, "Marmorea Crust" ("Brandschicht"), Middle-Late Hettangian, "Megastoma" – "Marmorea" Zone.

Ectocentrites CANAVARI, 1888

Ectocentrites petersi (HAUER, 1856)
(Pl. 28, Fig. 2)

1856 *Ammonites petersi* HAU. – HAUER: 65, Pl. 21, Fig. 1-3
1993 *Ectocentrites petersi* (HAUER, 1856) – RAKÚS & LOBITZER: 924, Pl. 2, Fig. 6 (cum syn.).

Material: One incomplete specimen with partly preserved body chamber and large fragment of body chamber.

Dimensions:

D	H	W	O
137,0	51,6	36,5	63,6

Remark: The specimen from STUR's collection is incomplete but relatively well preserved. It represents a typical juvenile stage characterised by distinct radial constrictions. Subadult and adult stages are characterised by regular, prominent radiate slightly rursiradiate ribs with moderate ventrolateral tubercules.

The collection comprises a large fragment of body chambers characterised by strong and spaced ribs without ventrolateral tubercles. We can deduce that the adult specimen of *Ectocentrites petersi* was a large form with a diameter of about 300 mm.

Occurrence: Schnöll Quarry, "Marmorea Crust" ("Brandschicht"), Middle – Late Hettangian, "Megastoma" – "Marmorea" Zone.

Adnethiceras WIEDMANN, 1970

Adnethiceras adnethicum (HAUER, 1854)

(Pl. 28, Fig. 4)

1854 *Ammonites Adnethicus* HAUER – HAUER: 101, Pl. 1, Fig. 1-3
1970 *Adnethiceras adnethicum* (HAUER) – WIEDMANN: 998, Text-Figs. 25, 27b, 30K, 30L; Pl. 8, Fig. 1 (cum syn.)
1995 *Adnethiceras adnethicum* (HAUER, 1854) – DOMMERGUES et al.: 171, Pl. 2, Figs. 1, 6

Material: One medium sized stone cast with partly preserved body chamber and two whorl fragments.

Dimensions:

D	H	W	O
87,0	25,0	25,4	44,0

Remark: This species was examined in detail by WIEDMANN (1970) so we need not give any detailed description. The representatives of this species are relatively frequent near the base of the Adnet-Fm., about 40 cm above the Basal Sinemurian Crust.

Stratigraphically our species was ranged to the Upper Sinemurian (WIEDMANN, 1970: 999). In our opinion the species *adnethicum*'s first appearance is in the Lower Sinemurian, Semicostatum Zone.

Occurrence: Schnöll Quarry, Sinemurian, ?Semicostatum Zone.

Psiloceratidae HYATT, 1867

Psiloceras HYATT, 1867

Psiloceras sp. [(cf. *P. calliphyllum* (NEUM.)]

Remark: In the NE side of Schnöll quarry (at the base of the lower sponge horizon (Text-Fig. 15) we have found one section about 10 cm in diameter of an ammonite, which reminds of *Psiloceras calliphyllum* (NEUM.). The evolute and polygyrate form as well as the elliptical whorl section seem to confirm our assumption.

Occurrence: Schnöll Quarry (NE side), Lower Hettangian, Planorbis Zone.

Discamphiceratinae GUEX & RAKÚS, 1991

Kammerkaroceras LANGE, 1941

Kammerkaroceras guidonii (SOWERBY, 1833)

(Pl. 28, Fig. 5)

1833 *Ammonites guidonii* SOWERBY – SOWERBY in de la BÉCHE: 33, Fig. 69
1993 *Kammerkaroceras guidonii* (SOWERBY, 1833) – RAKÚS & LOBITZER: 925, Text-Figs. 13, 14; Pl. 1, Figs. 6-9 (cum syn.)

Material: One more or less complete specimen and numerous incomplete specimens.

Dimensions:

	D	H	W	O
GBA 409	64,0	30,2	15,0	9,2

Remark: Our specimen is an adult stage and it is very similar to WÄHNER's figuration (WÄHNER, 1886, Pl. 26, Fig. 4). The species is relatively frequent in the Lower Liassic sections in the Northern Calcareous Alps.

Occurrence: Schnöll and Lienbacher Quarries, "Marmorea Crust" ("Brandschicht"), Late Hettangian, "Marmorea" Zone.

Schlotheimiidae SPATH, 1923

Schlotheimia BAYLE, 1878

Schlotheimia cf. *exoptycha* (WÄHNER, 1884)

(Pl. 26, Fig. 4)

Material: One incomplete specimen from Langmoos quarry and several whorl fragments.

Remark: Our specimens are poorly preserved but the type of their strong ribs enables a comparison with WÄHNER's depiction (1884, Pl. 20, Fig. 2).

Occurrence: Langmoos and Schnöll Quarries, "Marmorea Crust" ("Brandschicht"), Late Hettangian, "Marmorea" Zone.

Schlotheimia donar (WÄHNER, 1884)

(Pl. 26, Fig. 2,3)

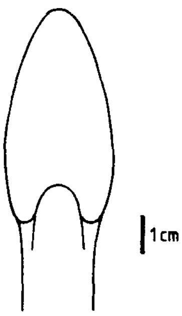
1884 *Aegoceras* Donar n.f. – WÄHNER: 172, Pl. 19, Fig. 4; Pl. 21, Figs. 1, 2

Material: One phragmocone from STUR's collection and one whorl fragment.

Dimensions:

D	H	W	O
65,6	27,5	18,0	18,0

Remark: One specimen is in type and course of ribs and flat ventrum very close to WÄHNER's figuration (1884, Pl.19, Fig. 4). Our specimen is more involute.



Text–Fig. 37.
Angulaticeras marmoreum (OPPEL). Cross-section of whorl. Schnöll Quarry, "Marmorea Crust".

Occurrence: Schnöll Quarry, "Marmorea Crust" ("Brandschicht"), Late Hettangian, "Marmorea" Zone.

Angulaticeras QUENSTEDT, 1883

Angulaticeras marmoreum (OPPEL, 1862)

(Text-Fig. 37, Pl. 26, Fig. 1)

1856 *Ammonites Charmassei* d'ORBIGNY – HAUER: 49, Pl.11, Fig. 1-3
1988 *Angulaticeras marmoreum* (OPPEL) – BLOOS: 6, Pl. 1, 2; Pl. 4, Fig. 7-8; Pl. 5, Fig. 8; Pl. 9, Fig. 1; Text-Fig. 3-11 (cum syn.)
1993 *Angulaticeras marmoreum* (OPPEL, 1862) – RAKÚS & LOBITZER: 926, Text-Fig. 16; Pl. 2, Fig. 2
1995 *Schlotheimia marmorea* (OPPEL, 1862) – DOMMERGUES et al.: 172, Pl. 2, Figs. 4, 7-9; Pl. 3, Figs. 1, 2

Material: Several whorl fragments and a phragmocone with partly preserved body chamber from STUR's collection.

Dimensions:

	D	H	W	O
	72,0	53,4	25,0	67,8
GBA 385	64,0	26,0	–	23,8

Remark: The whorl section, course of ribs and general shape of our specimen are in good accordance with WÄHNER's (1886) and BLOOS's (1988) species depiction.
Occurrence: Schnöll Quarry, condensed horizon – "Brandschicht", Upper Hettangian, "Marmorea" Zone.

Angulaticeras sp. juv.

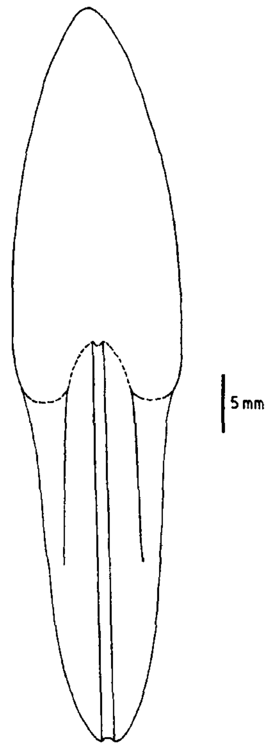
(Pl. 27, Fig. 2)

Remark: Scarce juvenile specimens found in the first bed above the "Marmorea Crust" ("Brandschicht") in the Lienbacher Quarry (Text-Fig. 6) and in Eisenmann Quarry are assigned to the genus *Angulaticeras*. The laterally compressed whorl section, narrow venter with longitudinal ventral grove as well as the course of fine ribs proved that the specimens are close to species *Angulaticeras lacunatum* (BUCKMAN).
Occurrence: Eisenmann and Lienbacher Quarries, Sinemurian, ?Semicostatum Zone.

Angulaticeras aff. *angustisulcatum* (GEYER, 1886)

(Text-Fig. 38; Pl. 25, Fig. 5)

Material: One well preserved stone cast (phragmocone).



Text–Fig. 38.
Angulaticeras aff. *angustisulcatum* (GEYER). Cross-section of a subadult specimen. Adnet, Quarry unknown.

Dimensions:

	D	H	W	O
GBA 567	62,3	34,6	14,0	8,8

Remark: Our specimen is characterised by oxycone form with keeled whorl section. The subadult stage has a narrow furrow on the venter (Text-Fig. 38). It disappears at 40–45 mm of total diameter. Ornamentation consists of fine sigmoidal ribs.
Occurrence: Red biomicritic limestone from Adnet (location of finding is unknown), Sinemurian, probably Oxynotum Zone.

Kammerkarites SPATH, 1924

Kammerkarites calcimontanus (WÄHNER, 1883)

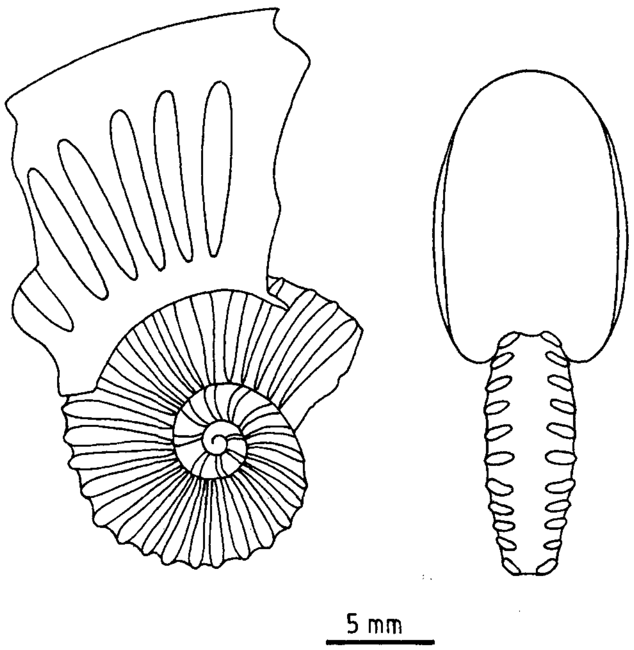
(Text-Figs. 39, 40; Pl. 25, Figs. 2, 3, 4)

1883 *Aegoceras calcimontanus* n.f. – WÄHNER: 112, Pl. 26, Fig. 1, 2

Material: Two incomplete specimens which are only phragmocons.
Dimensions:

	D	H	W	O
	58,0	22,0	–	20,5
GBA 408	111,4	43,0	22,7	34,3

Remark: The species is medium sized, lateral compressed and convolute. Juvenile stage is characterised by scarce but strong radiate ribs (Text-Fig. 39; Pl. 25, Fig. 3). From the third whorl their number increases and subadult stage (diameter 15–20 mm) have about 29 ribs. The ribs are radiate and interrupted on the ventral side. Subadult stage has distinct massive ribs only on side. The cross-section of

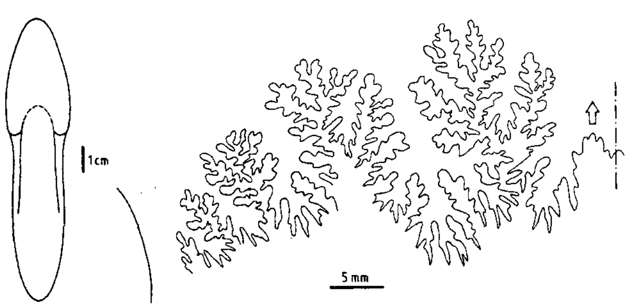


Text–Fig. 39.
Kammerkarites calcimontanus (WÄHNER). Lateral view and cross-section of a subadult specimen. Langmoos Quarry, "Marmorea Crust", Middle Hettangian.

the whorl is elliptical. Suture line (Text-Fig. 40) is asymmetric, with large follioles. Saddles S1 and S2 are deeply dissected.

Our species resembles the species *K. kammerkarensis* (GÜMB.) from which it differs in more involute shell and more prominent ribs.

Occurrence: Schnöll, Eisenmann and Langmoos Quarries, "Marmorea Crust" ("Brandschicht"), Middle Hettangian, Liasicus Zone, ? "Marmorea" Zone.



Text–Fig. 40.
Kammerkarites calcimontanus (WÄHNER). Cross-section and suture line. Schnöll Quarry.

Kammerkarites kammerkarensis (GÜMBEL, 1861)
(Text-Fig. 41; Pl. 25, Fig. 1)

1861 *Ammonites kammerkarensis* GÜMB. – GÜMBEL: 474
1883 *Aegoceras kammerkarense* GÜMB. – WÄHNER: 112, Pl. 24, Figs. 3, 4; Pl. 25, Figs. 1, 2
1952 *Storthoceras (Discamphiceras) kammerkarense* (GÜMBEL) – LANGE: 141

Material: One medium sized specimen (only phragmocone).

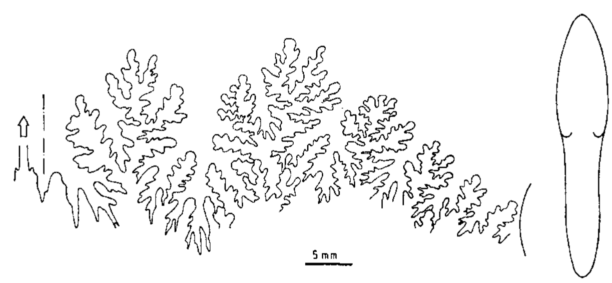
Dimensions:

	D	H	W	O
GBA 406	116,0	53,5 ·	23,0	24,6

Remark: Our specimen is in a good accordance with WÄHNER's description and figuration. GÜMBEL's original figured by WÄHNER (1883, Pl. 25, Fig. 1), deposited in Bayerische Staatssamlung Museum n°AS XXII is a large discoidal form. Its juvenile stage (WÄHNER, 1883, Pl. 24, Fig. 4) has a very clear "Knötchen" or tuberculate stage. Subadult stage is characterised by slightly sigmoidal main ribs. The secondary intercalated ribs have a relatively great periventral projection. About the diameter 30 mm, secondary ribs are missing. The main ribs are prominent only on the sides. Subadult and adult stages have large ribs only on flanks.

Suture line (Text-Fig. 41) is asymmetric, with large external lobe (E). The saddles S1 and S2 are large and deeply dissected.

Occurrence: Schnöll Quarry, "Marmorea Crust" ("Brandschicht"), Middle Hettangian, Liasicus Zone.



Text–Fig. 41.
Kammerkarites kammerkarensis (GÜMBEL). Cross-section and suture line. Schnöll Quarry, "Marmorea Crust".

Kammerkarites* cf. *megastoma (GÜMBEL, 1861)

Material: One medium sized (approx. 130 mm of diameter) impression.

Remark: In the Schnöll Quarry we have found one relatively well preserved impression in the sponge horizon. The general shape, degree of involution as well as the character of ribs prove that our specimen is close to *K. megastoma* (GÜMBEL).

Occurrence: Schnöll Quarry, right side, sponge horizon, Middle Hettangian, Liasicus Zone.

Kammerkarites* cf. *euptychus (WÄHNER, 1882)
(Pl. 24, Fig. 5)

Material: One incomplete impression of a whorl.

Remark: Although we only have an incomplete impression of the whorl, the character of slightly sigmoidal ribs indicates that our specimen is close to *K. euptychus* (WÄH.).

Occurrence: Schnöll Quarry, right side, sponge horizon, Middle Hettangian, Liasicus Zone.

Arietitidae HYATT, 1875

Alsatitinae SPATH, 1924

Alsatites HAUG, 1894

"Alsatites" orthoptychus (WÄHNER, 1884)
(Pl. 27, Fig. 6)

1884 *Arietites orthoptychus* n.f. – WÄHNER: 208, Pl. 27, Fig. 2; Pl. 30, Fig. 2

Material: One partly preserved stone cast.

Dimensions:

D	H	W	O
40,5	12,5	–	19,0

Remark: Degree of coiling, type of ribs as well as the whorl section are very close to the original figuration by WÄHNER (1884, Pl. 27, Fig. 2). Concerning the generic assignation, actual classification of laterally compressed *Alsatites*-like species is rather uncertain and it needs new studies of horizoned material. Our specimen is associated with a Schlotheiminid similar to *Schlotheimia* gr. *donar* (WÄH.).
Occurrence: Langmoos Quarry, "Marmorea Crust" ("Brandschicht"), Middle – ? Late Hettangian.

"Alsatites" liasicus (sensu WÄHNER, 1887)
(Text-Fig. 42; Pl. 28, Fig. 1)

1887 *Arietites liasicus* ORB. – WÄHNER: 293, Pl. 20, Fig. 3 only
non 1994 *Alsatites liasicus* (d'ORB.) sensu WÄHNER, 1887 – RAKÚS: 28, Text-Figs. 21-26; Pl. 1, Figs. 3, 4, 7; Pl. 7, Figs. 1, 3, 4, 5 and Pl. 8, Fig. 7

Material: One incomplete specimen (phragmocone).

Dimensions:

	D	H	W	O
GBA 1856/01/9 =WÄHNER, 1887, Pl. 20, Fig. 3	47,0	9,8	7,2	28,8

Remark: The specimen was originally examined by WÄHNER who ranged it to *liasicus* species. Our specimen is a relatively small, polygyrate, laterally compressed form with roof shaped venter and blunt keel (Text-Fig. 42). First 3-4 whorls show rectiradiate strong ribs (the *Caloceras* type). Last preserved whorl has arched ribs of the *Alsatites* type. Although from lateral view this type of ribs is similar to *Alsatites liasicus* (d'ORB.), but our specimen differs from it in a laterally compressed whorl section. As we mentioned above, systematic position of this group of *"Alsatites"* is uncertain.

Text–Fig. 42.
Alsatites liasicus sensu WÄHNER. Cross-section and suture line (cf. WÄHNER, 1882, Pl. 20, Fig. 3). Probably from Schnöll Quarry.

Suture line (Text-Fig. 42) is characterised by narrow S1 with deep incisions. The saddle S2 is a large only at its basis.
Besides this morphotype, we have found in Schnöll Quarry (sponge horizon) a fragment of compressed *Alsatites* with more dense ribbing on the first whorls.
Occurrence: Probably Schnöll Quarry, GBA collection, Middle Hettangian, Liasicus Zone.

Arietitinae HYATT, 1875

Paracaloceras SPATH, 1923

Paracaloceras gr. *coregorense* (SOWERBY, 1833)
(Pl. 27, Fig. 3)

Material: One medium seized stone cast.

Dimensions:

D	H	W	O
52,0	15,4	16,7	27,8

Remark: In type of ribbing and depressed whorl section our specimen its most similar to *P. coregorense* (SOW.).

Occurrence: Schnöll Quarry, "Marmorea Crust" ("Brandschicht"), Upper Hettangian, "Marmorea" Zone.

Paracaloceras subsalinarium (WÄHNER, 1891)

1891 *Arietites subsalinarius* n.f. – WÄHNER: 241, Pl. 16, Fig. 1, 2
1891 *Arietites anastreptoptychus* n.f. - WÄHNER: 243, Pl. 16, Fig. 3-5
1990 *Paracaloceras subsalinarium* (WÄHNER) – TAYLOR: 215, Pl. 2, Fig. 2-4

Material: One incomplete specimen (fragment of whorls) from STUR's collection.

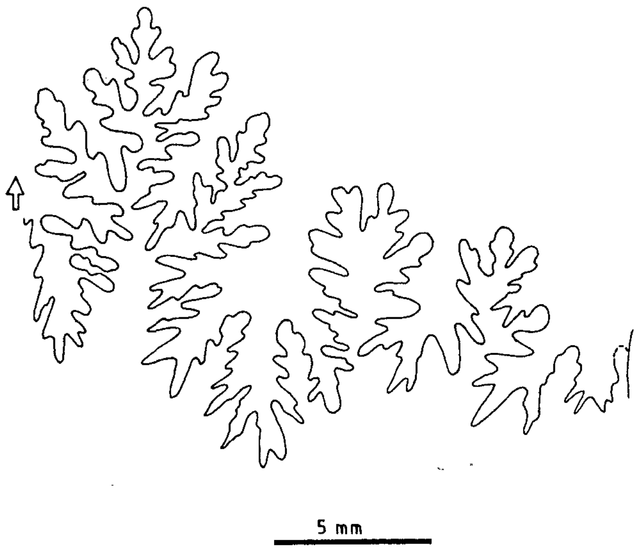
Remark: Although our specimen is rather incomplete we have no doubt about its relation to the subsalinarium species. Depressed whorl section with tricarinate broad ventrum and ventro-lateral shoulders prove it. Ribbing on the flanks of the whorls is simple, nearly straight to markedly concave and rursiradiate.

Occurrence: Schnöll Quarry, "Marmorea Crust" ("Brandschicht"), Late Hettangian, "Marmorea" Zone.

Paracaloceras grunowi (HAUER, 1856)
(Text-Fig. 43; Pl. 27, Fig. 5)

1856 *Ammonites grunowi* HAU. – HAUER: 27, Pl. 8, Figs. 4-6
1882 *Arietites grunowi* HAU. – WÄHNER: 320, Pl. 25, Figs. 2-3
1990 *Paracaloceras* cf. *grunowi* (HAUER) – TAYLOR: 215, Pl. 1, Fig. 1; Pl. 2, Fig. 1
1994 *Paracaloceras grunowi* (HAU.) – BLOOS: 15, Fig.10a, Pl. 16
1995 *Paracaloceras* aff. *grunowi* (HAUER, 1856) – DOMMERGUES et al.: 172, Pl. 3, Fig. 5

Material: One incomplete specimen (phragmocone), slightly deformed from HAUER's collection.



Text–Fig. 43.
Paracaloceras grunowi (HAUER). Suture line of lectotype (cf. WÄHNER, 1882, Pl. 25, Fig. 2). Schnöll Quarry.

Dimensions:

	D	H	W	O
GBA 1856/01/12 = Holotype cf. HAUER, 1856, Pl. 8, Figs. 4-6 and WAHNER, 1882, Pl. 25, Fig. 2	59,8	15,0	19,0	30,6

Remark: Holotype refigured here is an incomplete specimen without body chamber. Description and figuration of the species by WÄHNER (1882, p. 318, Pl. 25, Fig. 2) is good. We complete WÄHNER's description as follows: cross-section of first whorls is depressed and "cadicone" with funnel-like umbilicus. The venter on intermediate whorls is large with a very blunt keel. In this growing stage the keel is without sulci. Ribbing is simple, recti or slightly rursiradiate.

The suture line is poorly observable on the HAUER's (1856, Pl. 8, Fig. 6) and WÄHNER's (1882, Pl. 25, Fig. 2d) figuration are rather inexact, especially concerning first lateral saddle. Our redrawing of external suture (Text-Fig. 43) shows that the first external lobe E is deep and narrow. The first lateral saddle is high and triple-branched.

Occurrence: Schnöll Quarry, "Marmorea Crust" ("Brandschicht"), Late Hettangian, "Marmorea" Zone.

Paracaloceras haueri (GÜMBEL, 1861)

(Pl. 27, Fig. 1)

1861 *Ammonites Haueri* GÜMB. – GÜMBEL: 51
1879 *Arietites Haueri* GÜMBEL. – NEUMAYR: 39, Pl. 4, Fig. 1-3
1887 *Arietites Haueri* GÜMB. – WÄHNER: 38, Pl. 16, Fig. 3; Pl. 19, Fig. 1; Pl. 20, Fig.2; Pl. 23, Figs. 8, 9

Material: One medium-sized stone cast (phragmocone) from STUR's collection.

Dimensions:

D	H	W	O
84,0	19,4	16,7	54,0

Remark: This species was in detail described by NEUMAYR (1879) and WÄHNER (1887). It differs from other species of *Paracaloceras* in dense and arcuate ribs as well as in relatively compressed whorl section.

Occurrence: Schnöll Quarry, "Marmorea Crust" ("Brandschicht"), Late Hettangian, "Marmorea" Zone.

Vermiceras HYATT, 1889

Subgenus *Gyrophioceras* SPATH, 1924

Vermiceras (Gyrophioceras) perspiratum (WÄHNER, 1887)

(Pl. 27, Fig. 4)

1887 *Arietites perspiratus* n.f. – WÄHNER: 297, Pl. 20, Fig. 10

Material: One incomplete stone cast from grey-reddish biomicritic limestone.

Dimensions:

D	H	W	O
70,0	13,3	–	47,5

Remark: This polygyrate, highly evolute form is characterised by subrectangular whorl section with bisulcate venter, well developed median keel and dense slightly prorsiradiate and arched ribs. Our specimen is from a grey-reddish biomicritic slightly crinoidal limestone with *Angulaticeras marmoreum*. This type of limestone occurs just on the top of the "Marmorea Crust" ("Brandschicht") in Schnöll Quarry.

Occurrence: probably from Schnöll Quarry, Late Hettangian, "Marmorea" Zone.

Tmaegoceras HYATT, 1889

Tmaegoceras latesulcatum (HAUER, 1856)

(Text-Fig. 44, Pl. 28, Fig. 3)

1856 *Ammonites latesulcatus* HAU. – HAUER: 44, Pl. 9, Figs. 1-3
1901 *Tmaegoceras latesulcatum* v. HAU. sp. – POMPECKJ: 165
1977 *Tmaegoceras latesulcatum* (HAUER, 1856) – GEBHARD & SCHLATTER: 3

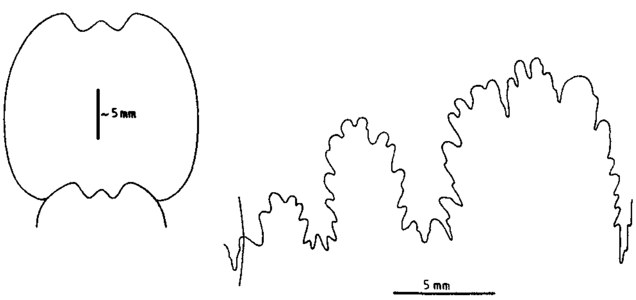
Material: Two relatively well preserved specimens, one of them (= Holotype) has the body chamber preserved.

Dimensions:

	D	H	W	O
	59,0	14,0	–	31,6
GBA 1856/01/27 =Holotype, HAUER, 1856, Pl. 9, Figs. 1-3	73,5	21,0	–	40,0

Remark: This particular group of ammonites is characterised by more or less involute shell with large and deep furrow on the venter. The furrow is divided by median keel to two folds (bisulcate venter). The median keel is always lower than the borders of furrow. In comparison with the other species of *Tmaegoceras* our species are clearly more involute.

The suture line (Text-Fig. 44) is characterised by narrow



Text–Fig. 44.
Tmaegoceras latesulcatum (HAUER). Cross-section and suture line. Adnet, quarry unknown.

and deep external lobe (E), large saddle S1 and little S2. Both lateral saddles are slightly dissected.

The systematic position of *Tmaegoceras* is vague. ARKELL (1957) ranged it to the subfamily Alsatitinae. On the other hand, DONOVAN et al. (1981) consider this genus as a member of subfamily Arietitinae. The character of the suture line seems more favourable for DONOVAN's proposal.

Occurrence: Adnet locality, name of quarry is unknown, Sinemurian, Semicostatum Zone.

3.2.3. Ammonite Biochronology

The base of the biochronological division of the Alpine Lower Liassic had been laid by WÄHNER (1882–1898 and 1886), who divided it into the following ammonites zones: Psiloceras calliphyllum, Psiloceras megastoma and Schlotheimia marmorea. This zonal division was lately adopted by LANGE (1952) in his excellent revision of the Fonsjoch locality.

Although DEAN et al. (1961: 438) emphasise that zonation of the Liassic from NW Europe cannot be used in the Alpine realm, we should admit a great progress concerning the zonal correlation between both domains (GUEX, 1980, 1987 and BLOOS, 1988).

Whereas correlation of the two first WÄHNER's zones does not cause serious difficulties, a correlation of the Marmorea Zone with Angulata Zone provokes a living discussion (GUEX and TAYLOR, 1976; BLOOS, 1983 and TAYLOR, 1986).

Our little, but horizoned collection of ammonites permitted us to divide it into three, so called classic zones (see above). Regarding the needs of inter-regional correlation we prefer the application of the classic zones designation. As to the Angulata Zone, the situation seems quite different. As we mentioned above, the position of this zone, especially its chronostratigraphic range can be very controversial. For this reason, we prefer using the old WÄHNER's name Marmorea being aware of a mistake.

We should emphasize that most ammonites come from a condensed horizon, designated in the past as "Brandschicht". It is generally known that exact biostratigraphy of this type of sedimentation is always very difficult and risky. In spite of this handicap, due to detailed study as well as our experience from other region we propose to arrange our ammonite collection in the following biochronological zones:

Planorbis Zone (= Calliphyllum Zone of WÄHNER)

At the beginning of our studies we did not confirm the presence of this zone in the Adnet area. During our last detailed study (spring 1995) in the NE part of Schnöll Quarry we found a section of Psiloceratid ammonite from the group *Psiloceras calliphyllum* in the bed n°2 just below the lowest observable sponge horizon. This species should indicate the presence of the Planorbis Zone here. We also found there *Cenoceras* sp. and *Togaticeras* sp.

The presence of the zone in this region was mentioned by KRYSTYN in GALET et al., 1993: 577), who found *Parapsiloceras naumanni* (NEUM.) in the neighbourhood of the Langmoos Quarry (see chapter 2.2.).

Liasicus Zone (= Megastoma Zone of WÄHNER)

The first level where we found the ammonites of this zone is the so called sponge horizon at the Schnöll Quarry (Text-Figs. 15, 20, 24). Beside numerous section of sponges we collected:

Togaticeras sp.
Analytoceras sp. juv.
Kammerkarites cf. *megastoma*
K. cf. *euptychus*
K. sp.
"Alsatites" sp. (compressed form)

We place here also some species from the condensed horizon ("Marmorea Crust", "Brandschicht") from the Langmoos Quarry:

Cenoceras schlumbergeri
Phylloceras psilomorphum
Kammerkarites calcimontanus
"Alsatites" orthoptychus

Further we are joining here the following species from STUR's collection:

Phylloceras psilomorphum
Analytoceras articulatum
Kammerkarites kammerkarensis
K. kalcimontanus
"Alsatites" liasicus sensu WÄHNER

"Marmorea" Zone of WÄHNER

This zone can be characterised by the following species:

Togaticeras stella (up to the Lower Sinemurian)
Geyeroceras cylindricum (up to the Lower Sinemurian)
Ectocentrites petersi
Kammerkaroceras guidonii
Schlotheimia cf. *exoptycha*
S. donar
Angulaticeras marmoreum
Paracaloceras gr. *coregorense*
P. subsalinarium
P. grunowi
P. haueri
? Vermiceras (Gyrophioceras) perspiratum

The entire assemblage is located in the "Marmorea Crust" ("Brandschicht"), characterised by particular type of fossilisation – hematitic or limonitic crust and for this quality it is easily discernible.

I would like to emphasize that the species *Kammerkaroceras guidonii* seems to be a good index fossil for this zone. It has a wide geographic range and its occurrence is frequent !

?Semicostatum Zone

After an hiatus corresponding to the first two zones of Sinemurian (Rotiforme and Bucklandi Zones), the Semicostatum Zone may be present at the base of the Adnet Formation. It is characterised by

Adnethiceras adnethicum
Angulaticeras aff. *angustisulcatum*
Angulaticeras sp.
Tmaegoceras latesulcatum

Unlike the Enzesfeld locality, which does not show any outcrops at present, but from where a rich fauna of *Arietites* and *Coroniceras* was described by STUR (1851), HAUER (1856) and WÄHNER (1894), in the Adnet area we did not find any specimens of the mentioned genera, which are so characteristic for the lowermost Sinemurian !

On the basis of the stratigraphic range of the ammonites we can conclude that the age of the sequence between the top of the Upper Rhaetian reef limestones and the basis of the Adnet Formation is Lower – Upper Hettangian to lowermost Sinemurian.

3.3. Brachiopods

3.3.1. Introduction

The finds of Liassic brachiopods from Adnet have been mentioned only exceptionally in the literature, even if they seem locally to be frequent. Already in 1855 a peculiar rare terebratulid was named by SUESS after the locality – *Terebratula Adnetensis.* It became later the type-species of *Securithyris* VÖRÖS, 1983. This Pliensbachian species is more frequently reported from the Southern Alps (often under its synonymic name *Terebratula erbaensis* SUESS). In 1886 ROTHPLETZ (Pl. 11, Fig. 24) figured a well-preserved specimen of *Rhynchonella plicatissima* coming from "Adneth", without exact localization. A new species – *Amphiclinodonta adnethica* – was described by BITTNER (1894) from the white limestone at the boundary between the Triassic and Liassic (locality "Brunnauer Tropfbruch"). Its Liassic age is taken for granted by PEARSON (1977). During the study of the fauna coming from the Upper Rhaetian Reef Limestone from Adnet, ZAPFE (1963) determined in the museum material collected by WÄHNER at the end of the last century following brachiopods: *Rhynchonella* ex aff. *cartieri* OPPEL, *Rhynchonella* sp. I, *Rhynchonella* sp. II, *Amphiclinodonta adnethica* BITTNER and *Waldheimia mutabilis* OPPEL. Brachiopods of Liassic character were regarded by ZAPFE as Rhaetian forerunners of the Liassic species. Their revision was made by PEARSON (1977) who determined the following species: *"Rhynchonella" cartieri* OPPEL, *Cirpa briseis* (GEMMELLARO), *Fissirhynchia fissicostata* (SUESS), *Amphiclinodonta adnethica* BITTNER and *"Zeilleria" mutabilis* (OPPEL). According to PEARSON that fauna came from the Liassic fissures.

Owing to the limited number of suitable specimens, it was not possible to section many to study internal structures. Many specimens coming from Quarry XVII were damaged and much recrystallized.

As can be seen in Text-Fig. 45 the brachiopod assemblages vary considerably in different lithologies of the Schnöll-Formation.

3.3.2. Localities

Locality 1: Lienbacher Quarry (XII) – red condensed limestone with Fe/Mn crust: *Cirpa (?) latifrons* (GEYER), *Cirpa* aff. *latifrons* (GEYER), *Linguithyris aspasia* (ZITTEL), *Zeilleria* cf. *mutabilis* (OPPEL).

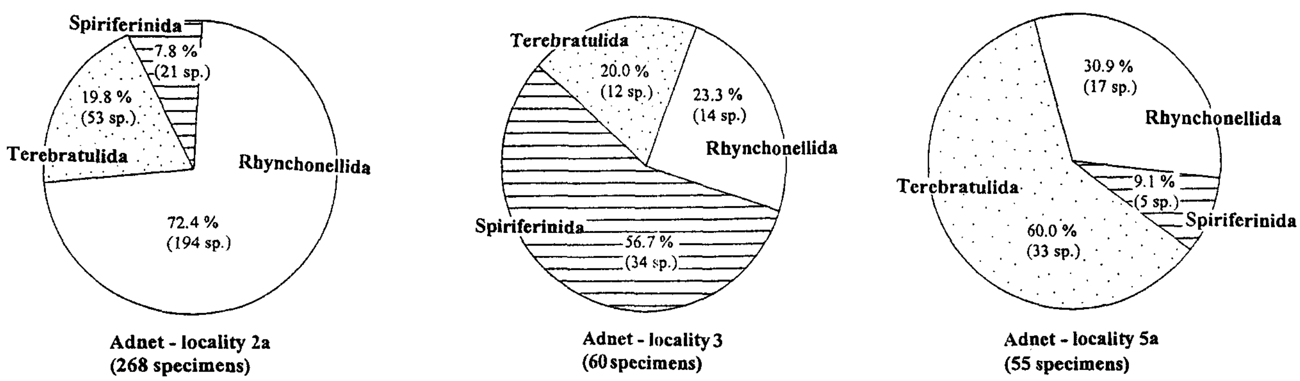
Locality 2: Großer Langmoos Quarry (XVII)

2a: variegated grey, mostly reddish and greenish, mottled marly limestone (Schnöll Limestone): *Calcirhynchia (?) plicatissima* (QUENSTEDT), *Cirpa (?) latifrons* (GEYER), *Cirpa* aff. *latifrons* (GEYER), *Cirpa planifrons* (ORMÓS), *Prionorhynchia fraasi* (OPPEL), *Prionorhynchia greppini* (OPPEL), *"Rhynchonella"* ex gr. *belemnitica* (QUENSTEDT), *"Rhynchonella"* ex gr. *zugmayeri* GEMMELLARO, *Liospiriferina alpina* (OPPEL), *Liospiriferina* aff. *obtusa* (OPPEL), *Callospiriferina* cf. *tumida* (BUCH), *Lobothyris andleri* (OPPEL), ? *Securithyris* sp., *Zeilleria alpina* (GEYER), *Zeilleria choffati* HAAS, *Bakonyithyris (?) engelhardti* (OPPEL), *Securina partschi* (OPPEL).

2b: condensed horizon with Fe/Mn crust: *Prionorhynchia* cf. *fraasi* (OPPEL), *Liospiriferina* sp., *Zeilleria mutabilis* (OPPEL), *Zeilleria stapia* (OPPEL).

Locality 3: Rocks in forest W of Quarry XXIX (N of Quarry XXXI) – red and greyish, partly crinoidal limestones obviously corresponding to Schnöll Limestone of the near-by Quarry XXXI: *Cirpa (?) latifrons* (GEYER), *Cirpa* aff. *latifrons* (GEYER), *Prionorhynchia greppini* (OPPEL), *Liospiriferina* aff. *obtusa* (OPPEL), *Dispiriferina* aff. *segregata* (DI-STEFANO).

Locality 4: Eisenmann Quarry (XXX) – red condensed lime-



Text–Fig. 45.
Brachiopod communities of the Schnöll-Fm. in 3 Adnet localities (including specifically undeterminable specimens as considerable part of the whole material).

stone with Fe/Mn crust, directly overlying Upper Rhaetian Reef Limestone: *Calcirhynchia (?) plicatissima* (QUENSTEDT), *Prionorhynchia fraasi* (OPPEL), *"Rhynchonella"* ex gr. *belemnitica* (QUENSTEDT), *Zeilleria mutabilis* (OPPEL), *Zeilleria perforata* (PIETTE), *Zeilleria stapia* (OPPEL).

Locality 5: Schnöll Quarry (XXXI).

5a: red, grey and greenish Schnöll Limestone: *Calcirhynchia* (?) aff. *plicatissima* (QUENSTEDT), *Cirpa* aff. *latifrons* (GEYER), *Cirpa planifrons* (ORMÓS), *Prionorhynchia fraasi* (OPPEL), *Prionorhynchia greppini* (OPPEL), *"Rhynchonella"* ex gr. *zugmayeri* GEMMELLARO, *Liospiriferina* cf. *obtusa* (OPPEL), *"Terebratula" juvavica* GEYER, *Linguithyris aspasia* (ZITTEL), *Linguithyris beyrichi* (OPPEL), *Zeilleria choffati* HAAS, *Zeilleria mutabilis* (OPPEL), *Zeilleria stapia* (OPPEL).

$5a_1$: horizon with sponges: *Cirpa* aff. *latifrons* (GEYER), *Cirpa planifrons* (ORMÓS), *Prionorhynchia greppini* (OPPEL), *"Rhynchonella"* ex gr. *belemnitica* (QUENSTEDT), *Callospiriferina* cf. *tumida* (BUCH).

5b: red condensed horizon with Fe/Mn crust: *Calcirhynchia (?) plicatissima* (QUENSTEDT), *Cirpa planifrons* (ORMÓS), *Cuneirhynchia retusifrons* (OPPEL), *Linguithyris aspasia* (ZITTEL), *Zeilleria mutabilis* (OPPEL).

3.3.3. Systematic Descriptions

Order: **Rhynchonellida KUHN, 1949**
Superfamily: **Rhynchonellacea GRAY, 1848**
Family: **Wellerellidae LIKHAREV in RZHONSNITSKAYA, 1956**
Genus: ***Calcirhynchia* BUCKMAN, 1917**

Calcirhynchia (?) plicatissima (QUENSTEDT, 1852)

(Pl. 29, Fig. 4)

1852 *Terebratula plicatissima* – QUENSTEDT, p. 451, Pl. 36, Fig. 3.
1992 *Calcirhynchia ? plicatissima* (QUENSTEDT) – DULAI, p. 44, Pl. 1, Fig. 3; Text-Figs. 4-5 (cum syn.).
1993a *Calcirhynchia (?) plicatissima* (QUENSTEDT) – SIBLÍK, p. 966, Pl. 1, Fig. 4; Text-Fig. 2 (cum syn.).

Material: 3 specimens. The figured one measures 12.6 x 12.9 x 8.2 mm.

Remarks: Our specimens belong to the variants of *"plicatissima"* with coarse ribs (sensu GEYER, 1889, p. 59, see his Pl. 6, Figs. 33 and 35). The serial sections reproduced by DULAI (1992) are practically the same as those ascertained in the material from Steinplatte (SIBLÍK, 1993a). However, the definitive generic attribution of *"plicatissima"* still remains unclear.

Occurrence: Adnet – locality 2a (1 specimen), locality 4 (1 specimen) and locality 5b (1 specimen); locality 5a yielded 1 specimen determinable as "aff. *plicatissima*". Hettangian – Sinemurian.

Genus: *Cirpa* Di GREGORIO, 1930

Cirpa (?) latifrons (GEYER, 1889)

(Pl. 29, Fig. 5)

1889 *Rhynchonella latifrons* STUR.m.s. – GEYER, p. 54, Pl. 6, Figs. 25-31.
1967 *Prionorhynchia latifrons* (STUR) – SACCHI VIALLI & CANTALUPPI, p. 77, Pl. 11, Figs. 7-8; Text-Fig. 4.
1992 *Cirpa ? latifrons* (STUR in GEYER) – DULAI, p. 43, Pl. 1, Fig. 2; Text-Fig. 3 (cum syn.).

Material: 7 specimens. The figured specimen measures 13.5 x 16.1 x 8.2 mm.

Remarks: The figured specimen agrees very well with that figured by GEYER (1889) in Pl. 6, Fig. 29 though the umbones cannot be compared since they have been damaged in the Adnet specimen. Some variants of the species are not easily separable from *Calcirhynchia (?) plicatissima* (QUENSTEDT). The "average" shells are, however, relatively thicker and the beaks less prominent in the QUENSTEDT's species.

The generic affiliation of *Rhynchonella latifrons* GEYER has not been definitely solved yet. SACCHI VIALLI & CANTALUPPI (1967) assigned *"latifrons"* from Gozzano to *Prionorhynchia,* whereas DULAI (1992) described somewhat different material from the Bakony Mts. as *Cirpa latifrons* (STUR in GEYER), without having sectioned his material.

Occurrence: Adnet – locality 1 (2 specimens), locality 2a (4 specimens) and locality 3 (1 specimen).

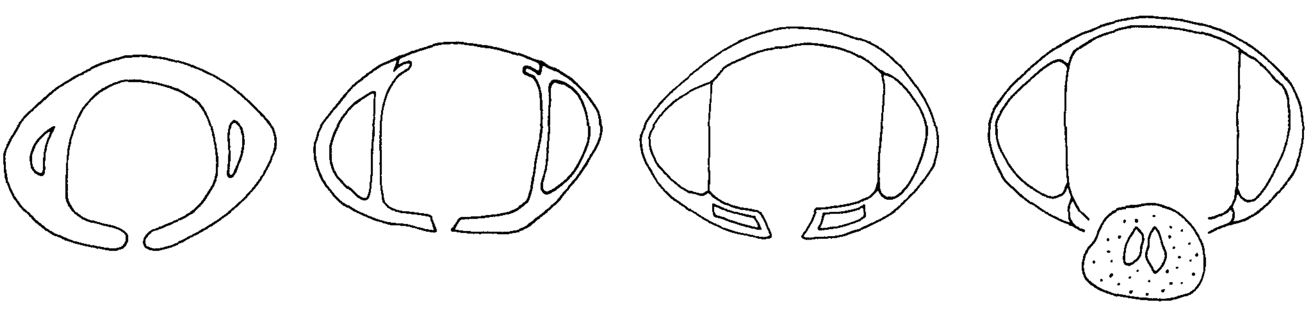
According to ALMÉRAS (1964) the distribution of *"latifrons"* is Hettangian – Upper Sinemurian. The specimens described by SACCHI VIALLI & CANTALUPPI (1967) come from the Middle Liassic.

Cirpa aff. *latifrons* (GEYER, 1889)

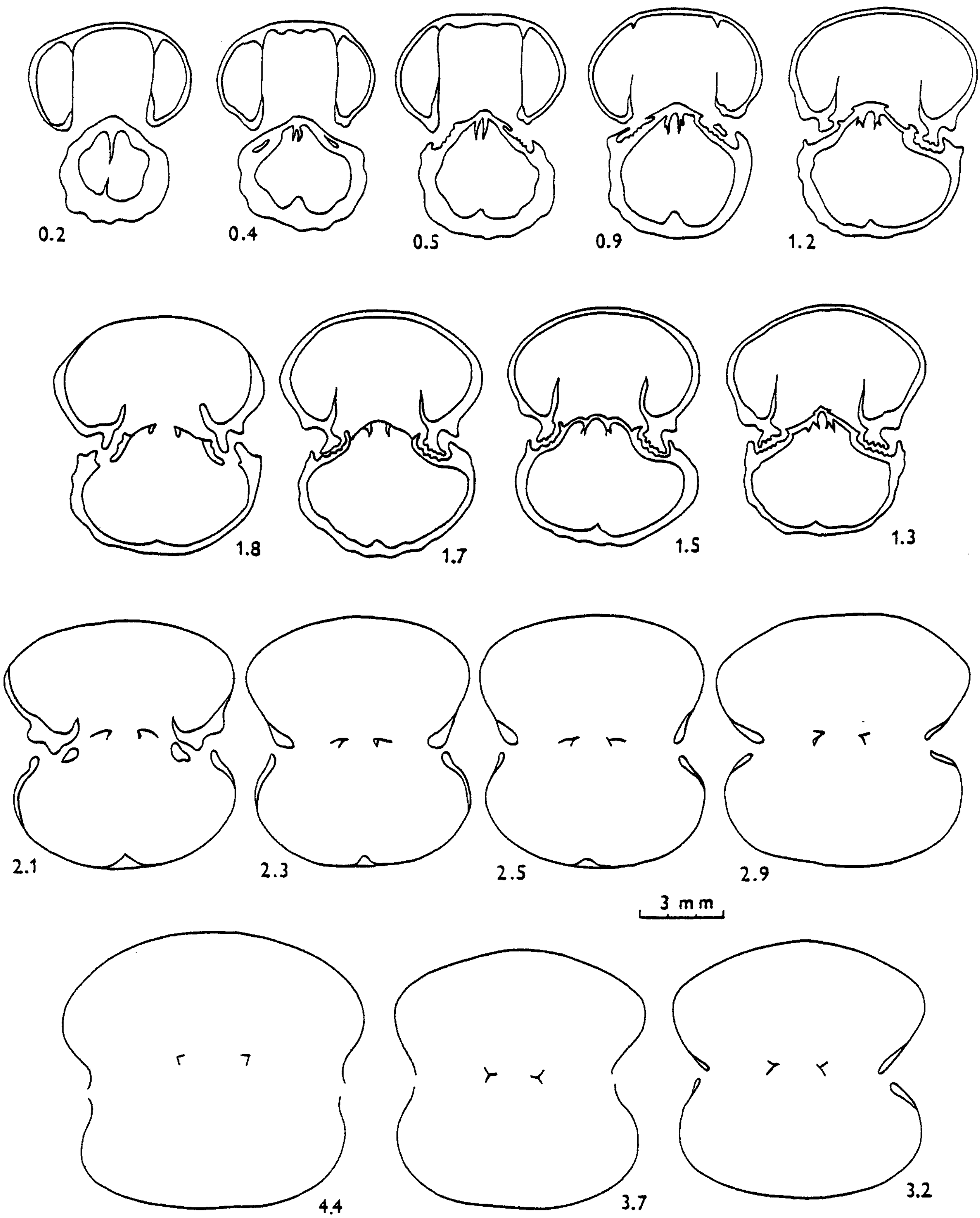
(Pl. 29, Figs. 1, 3; Text-Figs. 46, 47)

aff. 1889 *Rhynchonella latifrons* STUR m.s. – GEYER, p. 54, Pl. 6, Figs. 25-31.
1993 *"Rhynchonella"* aff. *fissicostata* SUESS – SIBLÍK, p. 129, Pl. 2, Fig. 2.

Material: 39 mostly fragmentary specimens. The dimensions



Text–Fig. 46.
Cirpa aff. *latifrons* (GEYER). Sections through the posterior part of shell showing well-developed double deltidial plates and very short septum. Locality 2a. (Quarry XVII). Magnified.



Text–Fig. 47.
Cirpa aff. *latifrons* (GEYER). Serial transverse sections through another specimen. Measured from dorsal umbo. Termination of crura unclear. Original length of specimen 19.0 mm. Locality 2a (Quarry XVII). Magnified.

of the figured ones: 18.5 x 19.8 x 12.4 mm (Pl. 29, Fig. 1) and ? x 17.8 x 13.5 mm (Pl. 29, Fig. 3).

Internal characters: Delthyrial cavity subquadrate, lateral umbonal cavities semicircular in cross-section. Dental lamellae subparallel and short. Double deltidial plates well developed. Hinge teeth laterally expanded and in all 6 specimens sectioned strongly crenulated. Traces of pedicle collar ascertained in 1 specimen. Hinge plates fused, later subhorizontally orientated or ventrally slightly converging. Socket ridges strongly developed, sockets large and crenulated. Neither septalium nor true median septum present. Crura seemingly raduliform, extending slightly into pedicle valve, their terminations unclear (damaged?).

Remarks: A specimen of this markedly uniplicate, multicostate rhynchonellid with strongly elevated fold was already figured by the author (Siblík, 1993) under *"Rhynchonella"* aff. *fissicostata* because of its external resemblance to *Fissirhynchia fissicostata*. Thanks to the subsequent collection, a better comparison was made possible. Larger material shows relatively great variability which makes determination rather difficult. Our specimens have between 11–17 moderately sharp costae on each valve (4–8 on the fold), traceable right to the umbones. Posterolateral parts of shell are flattened; in 4 specimens very shallow, not sharply limited planareas have been ascertained. There is a series of species in literature (incl. also some species of *Tetrarhynchia* and *Squamirhynchia*) externally well resembling Adnet material. In this connection two names should be especially mentioned: *Rhynchonella peristera* Uhlig, 1879 from Sospirolo near Belluno, differing from our material by its unusually massive posterior part of pedicle valve, and *Rhynchonella* cf. *fissicostata* Suess, figured by Geyer (1889, Pl. 6, Fig. 32) from Hierlatz and differing by its sharper costae. This latter specimen was synonymized later – according to my opinion improperly – by Ager with *Quadratirhynchia crassimedia* Buckman (Ager, 1956, p.16). One broader specimen from Adnet agrees well with *Rhynchonella latifrons* as figured by Vigh, 1943 on Plate 26, Fig. 24. The specimens from Adnet can be best compared with *Rhynchonella latifrons* Geyer. They are distinguished, however, from it – in average – by their larger size, narrower outline and higher plication and folding. The folding as shown in the specimens figured on Plate 29, Figs.1 and 3 is more elevated than average. The attribution to *Cirpa* is based on the internal characters ascertained in the material under consideration, viz. well-developed double deltidial plates, fused hinge plates and absent septalium and septum. These characters differ from those of externally similar *Fissirhynchia, Quadratirhynchia, Tetrarhynchia* or *Prionorhynchia*.

Occurrence: Adnet – locality 1 (1specimen), locality 2a (34 specimens), locality 3 (2 specimens), localities 5a (1 specimen) and $5a_1$ (1 specimen).

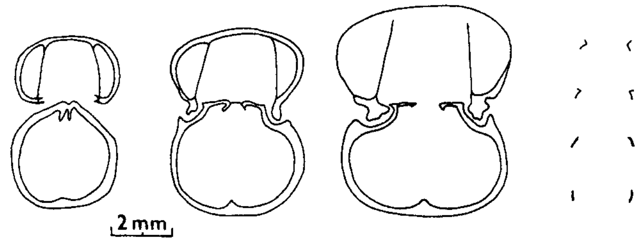
Cirpa planifrons (Ormós, 1937)

(Pl. 29, Figs. 7, 9; Text-Fig. 48)

1937 *Rhynchonella planifrons* nov. sp. – Ormós, p. 35, 41, Pl. 1, Fig. 19.
1993a *Cirpa planifrons* (Ormós) – Siblík, p. 967, Pl. 1, Figs. 1-3; Text-Fig. 3.

Material: 13 partly damaged specimens. Dimensions of the figured ones: ?12.5 x 12.4 x 9.3 mm (Pl. 29, Fig. 7) and 12.2 x 11.6 x 8.9 mm (Pl. 29, Fig. 9).

Internal characters: Due to bad preservation, only double deltidial plates, subhorizontal hinge plates, absent median septum and prefalciform crura could be ascertained, all proving affiliation to *Cirpa*.



Text–Fig. 48.
Cirpa planifrons (Ormós). Due to bad preservation only discontinuous series of transverse sections has been made. Double deltidial plates and fused subhorizontal hinge plates. Length of specimen 12.5 mm. Locality 5a (Quarry XXXI). Magnified.

Remarks: The rectangular anterior view and flattening of the anterior part of shell are essential features of the species and are fully developed in 13 specimens. In addition to these, some 15 very similar specimens from locality 2a lacking these characters could also belong to the species under consideration. However, their internal characters could not be studied and their attribution to *"planifrons"* is thus doubtful.

Occurrence: Adnet – locality 2a (10 specimens), locality 5a (1 specimen), locality $5a_1$ (1 specimen) and 5b (1 specimen). The species was described from the Lower Liassic (*Oxynotum* Zone), and reported also from the *Marmorea* Zone of Steinplatte (Siblík, 1993a).

Genus: *Prionorhynchia* Buckman, 1917

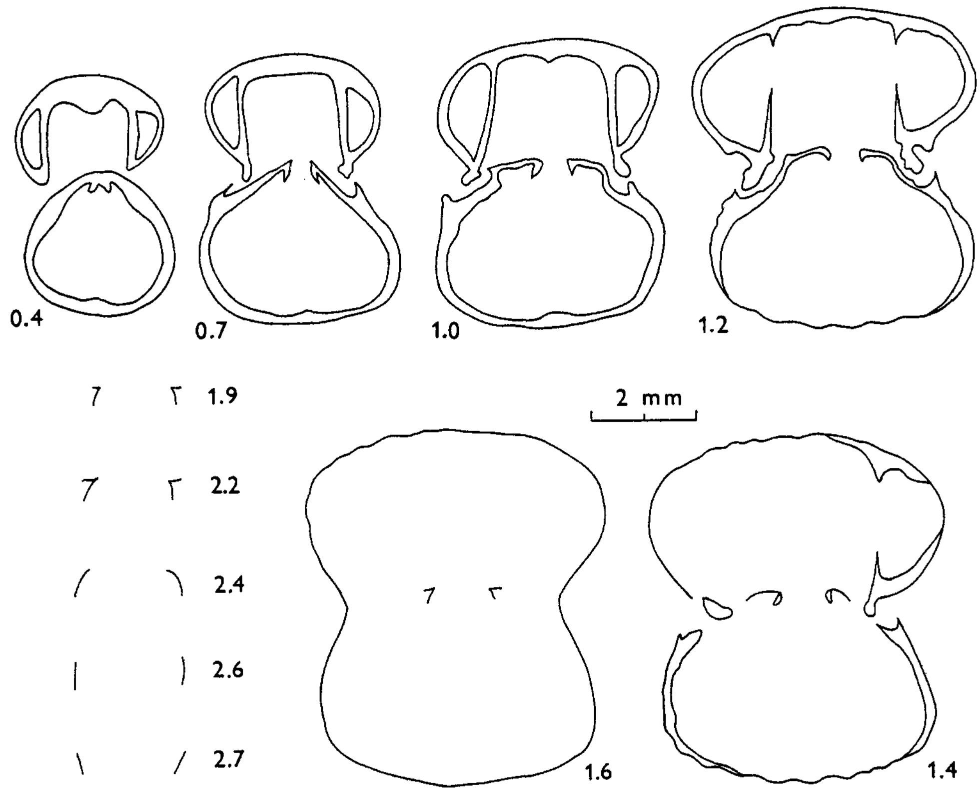
Prionorhynchia fraasi (Oppel, 1861)

(Pl. 30, Figs. 1-5; Text-Fig. 49)

1861 *Rhynchonella Fraasi* Opp. – Oppel, p. 543, Pl. 12, Fig. 3.
1861 *Rhynchonella polyptycha* Opp. – Oppel, p. 544, Pl.12, Fig. 4.
1889 *Rhynchonella polyptycha* Opp. – Geyer, p. 51, Pl. 6, Figs. 15-17.
1889 *Rhynchonella Fraasi* Opp. – Geyer, p. 52, Pl. 6, Figs. 18-24.
1992 *Prionorhynchia polyptycha* (Oppel) – Dulai, p. 48, Pl. 1, Fig. 5; Text-Figs. 7-8.
1993 *"Rhynchonella" fraasi* Oppel – Siblík, Pl. 2, Fig. 7.
1993a *Prionorhynchia (?) polyptycha* (Oppel) – Siblík, p. 968.
1993a *"Rhynchonella" fraasi* Oppel – Siblík, p. 969, Pl. 1, Figs. 7-?8 (cum syn.).
1994 *"Rhynchonella" fraasi* Oppel – Siblík in Lobitzer et al., Pl. 1, Fig. 5.

Material: 38 partly damaged specimens. The figured ones measure: 15.6 x 15.6 x 9.8 mm (Pl. 30, Fig. 5), 15.3 x 17.9.x 10.0 mm (Pl. 30, Fig. 3), 14.0 x 16.6 x 9.3 mm (Pl. 30, Fig. 1), 13.6 x 15.4 x 8.7 mm (Pl. 30, Fig. 4), 13.2 x 14.0 x 9.8 mm (Pl. 30, Fig. 2).

Internal characters: Serial sections showed following characters: Subparallel or ventrally converging dental lamellae, poorly crenulated strong teeth, short denticula, subhorizontal hinge plates, vestigial median septum, mostly no septalium, dorsally situated crural bases, and prefalciform crura. The main characters prove the attribution to *Prionorhynchia*. The sections of *"polyptycha"* figured in Dulai (1992) differ from those of the Adnet specimens in longer median septum and in absent denticula. Only very short median septum was also shown in the type species



Text–Fig. 49.
Prionorhynchia fraasi (OPPEL). Measured from dorsal umbo. Crura persisted to 3.0 mm. Original length of specimen 17.5 mm. Locality 2a (Quarry XVII). Magnified.

of *Prionorhynchia, Prionorhynchia serrata* (SOWERBY) by AGER (1956, Text-Fig. 26), and in *Prionorhynchia quinqueplicata* (ZIETEN) and *Prionorhynchia regia* (ROTHPLETZ) by ALMÉRAS, AMEUR & ELMI (1993, Text-Figs. 4-6).

Remarks: OPPEL's species *"fraasi"* and *"polyptycha"* both described from Hierlatz are considered synonymous in the present paper. Already GEYER (1889, p. 53) mentioned passages from *Rhynchonella Fraasi* into *Rhynchonella polyptycha* which was distinguished above all on the grounds of its more numerous ribs. It seems that the relatively thicker specimens of subpentagonal outline and of higher plication have been determined in literature as *"fraasi"*, whereas the specimens of subtrigonal or semicircular outline, with numerous ribs have been placed under *"polyptycha"*. Basing on our material, there do not appear to be sufficient grounds for separating both these species externally. In the list of the Jurassic brachiopods from the Bakony Mts. made by VÖRÖS (1993), *"polyptycha"* is attributed to *Prionorhynchia*, whereas *"fraasi"* is mentioned as *Cuneirhynchia ? fraasi.*

Occurrence: Adnet – locality 2a (36 specimens), locality 4 (1 specimen) and locality 5a (1 specimen). Locality 2b yielded 1 specimen determined here as *Prionorhynchia* cf. *fraasi.*

According to ALMÉRAS (1964) Sinemurian – Domerian age is reported for *Rhynchonella fraasi* and Hettangian - Upper Sinemurian for *Rhynchonella polyptycha.*

Prionorhynchia greppini (OPPEL, 1861)

(Pl. 29, Figs. 2, 8)

1861 *Rhynchonella Greppini* OPP. – OPPEL, p. 545, Pl. 13, Fig. 1 only.

1900 *Rhynchonella Greppini* OPPEL – BÖSE & SCHLOSSER, p. 194, Pl. 18, Fig. 14 only.

1960 *Rhynchonella Greppini* OPP. – FÜLÖP et al., Pl. 1, Fig. 4.

non 1989 *Prionorhynchia greppini* (OPPEL) – TCHOUMATCHENCO, p. 10, Pl. 3, Figs. 10-12; Pl. 4, Figs. 1-3; Text-Fig. 6.

1992 *Prionorhynchia greppini* (OPPEL) – DULAI, p. 47, Pl. 1, Fig. 4; Text-Fig. 6 (cum syn.).

Material: 6 specimens. The figured ones measure: 16.5 x 17.7 x 9.7 mm (Pl. 29, Fig. 8) and 16.4 x 15.0 x 9.3 mm (Pl. 29, Fig. 2).

Remarks: It is sometimes difficult to separate this species from *Prionorhynchia fraasi.* With "average" specimens, *Prionorhynchia greppini* may be recognized by its less numerous but mostly stronger ribs and by lesser convexity of its valves. Other features are very variable both in *"greppini"* and *"fraasi"*. Our figured specimens differ by their narrower outline and by shallower, or only flattened planareas from the most specimens figured by GEYER (1889, Pl. 6, Figs. 1-9). Our specimen on Pl. 29, Fig. 8 with slightly rounded ribs corresponds well to the specimen figured by GEYER, 1889 on Pl. 6, Fig. 10 as *Rhynchonella Greppini* var. *humilis* STUR m.s. TCHOUMATCHENCO's specimens (1989) differ from *"greppini"* in having robust, thick shells, different anterior views and fewer costae.

Occurrence: Adnet – locality 2a (2 specimens), locality 3 (1 specimen), locality 5a (2 specimens) and locality $5a_1$ (1 specimen).

Age: According to ALMÉRAS (1964) Hettangian – Sinemurian, ? Pliensbachian.

Family: Rhynchonellidae GRAY, 1848
Genus: *Cuneirhynchia* BUCKMAN, 1917

Cuneirhynchia retusifrons (OPPEL, 1961)

1861 *Rhynchonella retusifrons* OPP. – OPPEL, p. 544, Pl. 12, Fig. 5.
1993a *Cuneirhynchia retusifrons* (OPPEL) – SIBLÍK, p. 968, Pl. 1, Fig. 10 (cum syn.).

Material: 1 fragmentary specimen with both valves (length ? 7.5 mm).
Remarks: The semicostate specimen corresponding well to the description and figure given by OPPEL (1861) and to the figured specimen from Steinplatte which is, however, more inflated (SIBLÍK, 1993a).
Occurrence: Adnet – locality 5b.
Hettangian to Upper Sinemurian – ? Pliensbachian.

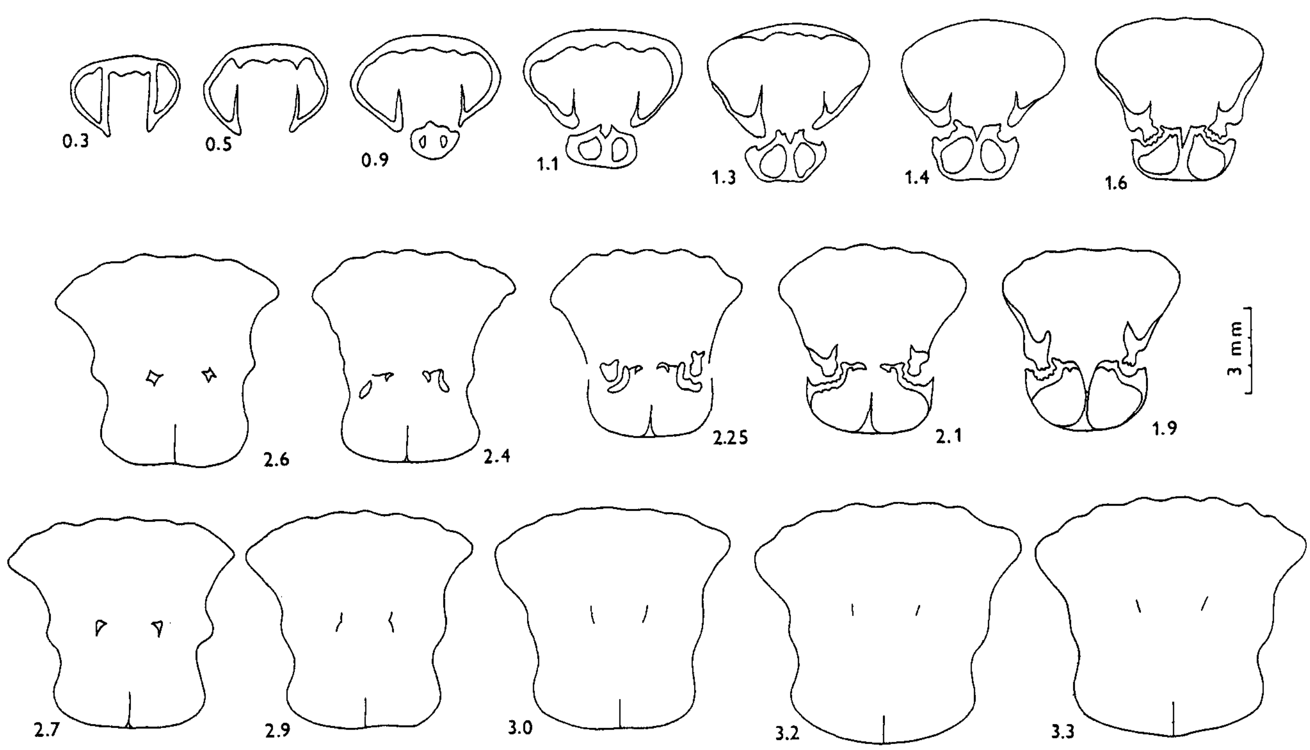
Genus: *Rhynchonella* FISCHER, 1809 ; s.l.

"Rhynchonella" ex gr. *belemnitica* (QUENSTEDT, 1856)

(Pl. 30, Fig. 6; Text-Fig. 50)

ex gr. 1856 *Terebratula belemnitica* – QUENSTEDT, p. 73, Pl. 8, Fig. 15.
1893 *Rhynchonella belemnitica* QUENSTEDT – BÖSE, p. 639, Pl. 15, Figs. 5-6 (cum syn.).

Material: 26 more or less fragmentary specimens. The figured one measures 15.0 x 14.7 x 10.4 mm (Pl. 30, Fig. 6).
Internal characters: Serial sections showed a fairly "normal" rhynchonellid type. Short subparallel dental lamellae, umbonal cavities subtrigonal in cross-section. Teeth strong, dorsally expanded and crenulated. Squat denticula developed laterally. V-shaped septalium between subhorizontal, narrow hinge plates. Hinge plates clearly separated from inner socket ridges. Median septum thick, persisting anteriorly as a long ridge. Strong crural bases situated dorsally on distal ends of hinge plates. Crura prefalciform. Pedicle collar not observed.
Remarks: It is rather difficult to characterize and determine this variable material of the ordinarily looking ribbed rhynchonellids because a whole series of existing specific names could be well applicable, basing on external characters only. Our specimens show large variation in anterior view, plication and costation. They have 4–9 more or less strong ribs in the fold, and most of them develop flat planareas. They are best comparable to *Rhynchonella belemnitica* (QUENSTEDT) as interpreted by BÖSE (1893). He discussed the variability of the species and tried to distinguish it from very similar *Rhynchonella variabilis* (SCHLOTHEIM, 1813). This SCHLOTHEIM's species was usually used as a "catch-all species" to house varied rhynchonellids with few strong ribs, and was rejected later as a "nomen dubium" by AGER (1958, p. 56). Some of our specimens with few strong costae (Pl. 30, Fig. 6) correspond well to *"belemnitica"* as figured by BÖSE, 1893 in Pl. 15, Fig. 5, some others with more numerous costae to his Fig. 6 in Pl. 15 (BÖSE's var. *"multicostata"*). AGER (1967, p. 145) followed BUCKMAN's doubtful attribution of *"belemnitica"* to *Squamirhynchia*. The serial sections of the type-species of this genus – *Squamirhynchia squamiplex* (QUENSTEDT) as shown by AGER (1967, Text-Fig. 90) documented a clear relation to *Cirpa* and *Calcirhynchia* (double deltidial plates, arching hinge plates, small septalium and very short septum). The inner details of Adnet specimens are different from these characters and some sections are suggestive of *Rudirhynchia* or *Grandirhynchia*. Further comparisons are for the present made difficult owing to the serious difficulties in determination of this highly variable material. Some years ago, SHI & GRANT (1993) associated *"belemnitica"* with *Prionorhynchia* BUCKMAN, 1918.



Text–Fig. 50.
"Rhynchonella" ex gr. *belemnitica* (QUENSTEDT). Length of specimen 15.6 mm. Locality 2a (Quarry XVII). Magnified.

Occurrence: Adnet – locality 2a (22 specimens), locality 4 (1 specimen) and locality $5a_1$ (3 specimens).

According to ALMÉRAS (1964) *Rhynchonella belemnitica* occurs in Sinemurian.

"Rhynchonella" ex gr. *zugmayeri* GEMMELLARO, 1878

(Pl. 29, Fig. 6; Text-Figs. 51, 52)

ex gr. 1878 *Rhynchonella Zugmayeri* GEMM. – GEMMELLARO, p. 420, Pl. 31, Figs. 50-60.

Material: 6 specimens. The figured one measures 13.0 x 14.8 x 8.1 mm.

Internal characters: The sections showed dorsally divergent dental lamellae, very short, dorsally expanded strong teeth, V-shaped septalium, low and short median septum, horizontally orientated hinge plates with dorsally situated crural bases, and prefalciform crura.

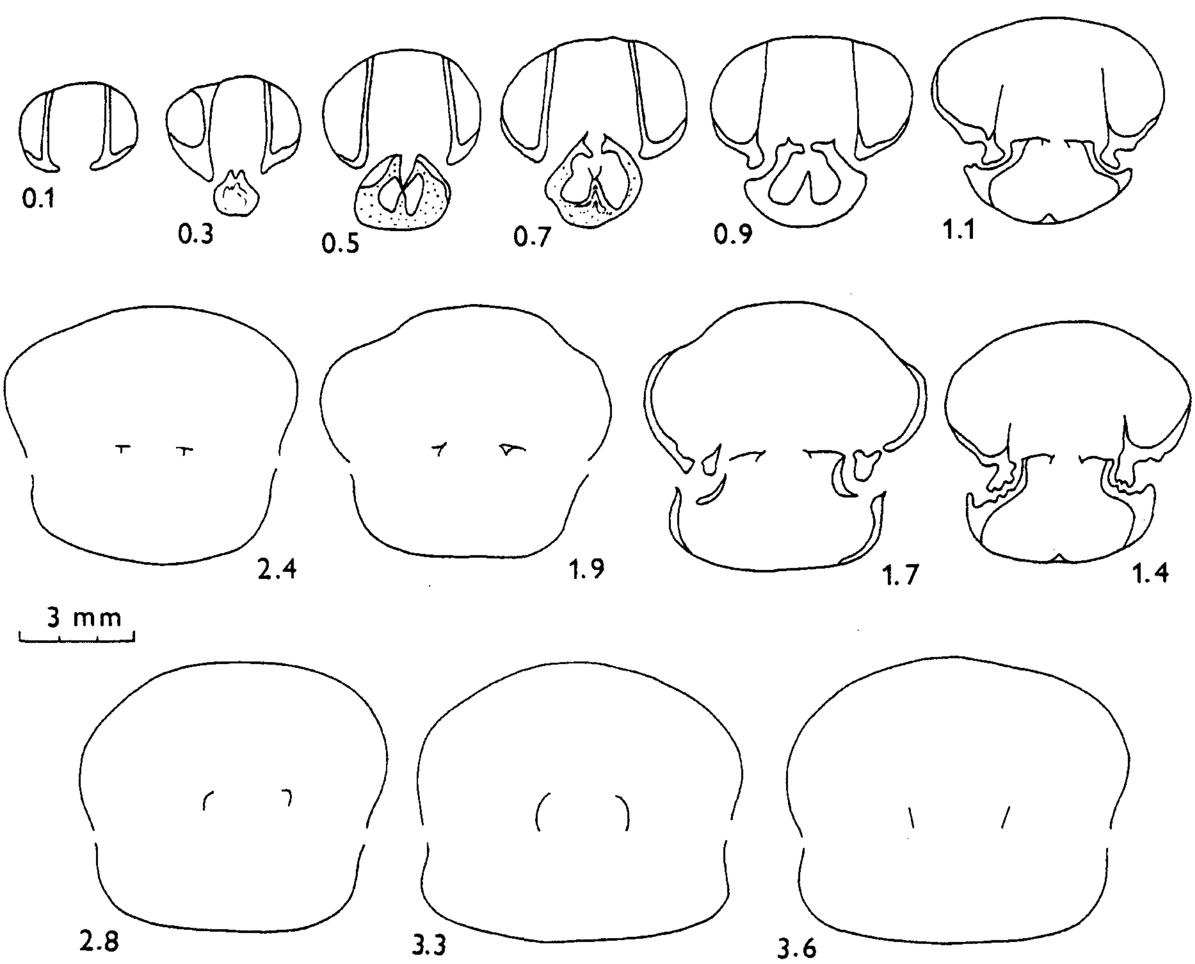
Remarks: Shells are medium-sized, dorsibiconvex, subpentagonal to circular in outline, with low but distinct uniplication. Beak prominent and erect, beak ridges delimiting flat planareas on both valves. Costae rounded, of the *dumbletonensis* type (sensu AGER, 1956, Text-Fig. 6) in the number 14–18 on each valve (6–9 of them confined to the fold), forming a wavy line in the anterior commissure (not well discernible in specimen figured). Certain asymmetry in outline or plication is according to BÖSE & SCHLOSSER (1900, p. 193) a characteristic feature.

Specimens from Adnet show a considerable resemblance to those figured by GEMMELLARO (1878) as *Rhynchonella Zugmayeri* (wavy anterior commissure, certain asymmetry in plication), and differ from them only in development of planareas. *Rhynchonella Böckhi, Rhynchonella subcostellata* and *Rhynchonella Caroli* described by GEMMELLARO at the same time are closely allied to *"zugmayeri"* by their shape, ribbing and character of anterior commissure, and could be well conspecific with it. Further comparisons are for the present impossible owing to the scarcity of material. Internally, the specimens of *"zugmayeri"* show certain similarity to the internal characters of some species of *Grandirhynchia, Tetrarhynchia* or *Gibbirhynchia*. The sections made, however, are not considered here to be sufficient for closer comparison.

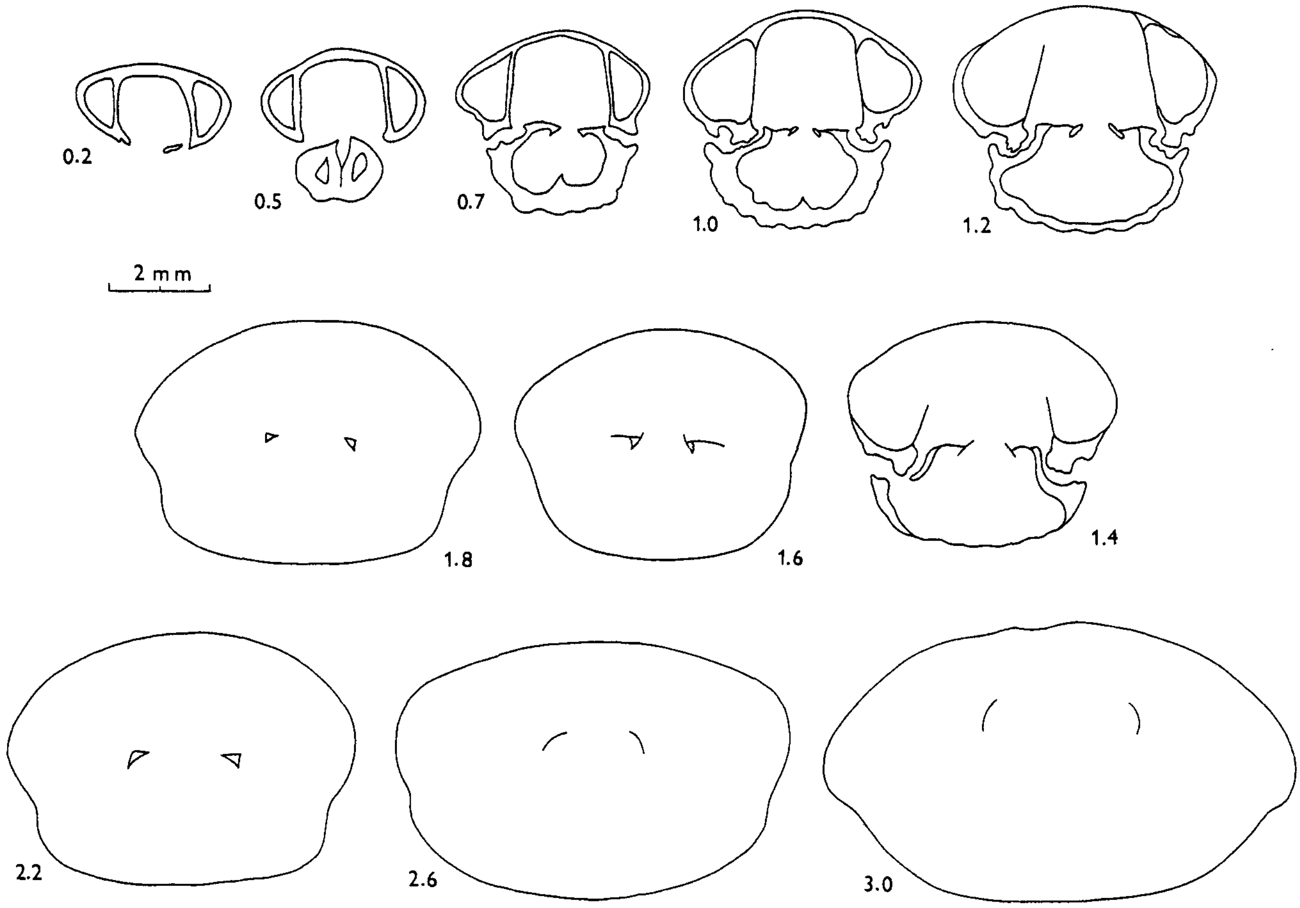
Occurrence: Adnet – locality 2a (4 specimens) and locality 5a (2 specimens).

Rhynchonella zugmayeri occurs according to ALMÉRAS (1964) in Sinemurian and questionably up to Pliensbachian.

Order: **Spiriferinida** IVANOVA, **1972**
Suborder: **Spiriferinidina** IVANOVA, **1972**
Superfamily: **Spiriferinoidea** DAVIDSON, **1884**
Family: **Spiriferinidae** DAVIDSON, **1884**
Subfamily: **Spiriferininae** DAVIDSON, **1884**
Genus: ***Liospiriferina*** ROUSSELLE, **1977**



Text–Fig. 51.
"Rhynchonella" ex gr. *zugmayeri* GEMMELLARO. Length of specimen 13.8 mm. Locality 2a (Quarry XVII). Magnified.



Text–Fig. 52.
"Rhynchonella" ex gr. *zugmayeri* GEMMELLARO. Crura persisted to 3.2 mm. Length of specimen 13.0 mm. Locality 2a (Quarry XVII). Magnified.

Liospiriferina alpina (OPPEL, 1861)

1861 *Spiriferina alpina* OPP. – OPPEL, p. 541, Pl. 11, Fig. 5.
1889 *Spiriferina alpina* OPP. – GEYER, p. 71, Pl. 8, Figs. 4-8 (cum syn.).
1992 *Liospiriferina alpina* (OPPEL) – DULAI, p. 55, Pl. 2, Fig. 4; Text-Fig. 13 (cum syn.).
1993 *Liospiriferina alpina* (OPPEL) – SIBLÍK, Pl. 1, Fig. 5.
1993a *Liospiriferina alpina* (OPPEL) – SIBLÍK, p. 970, Pl. 2, Fig. 7 (cum syn.).

Material: 1 incomplete specimen with both valves and 3 slightly damaged pedicle valves.
Remarks: Our specimens agree in all observed external features with the specimen of *"alpina"* as figured by GEYER (1889) on Pl. 8, Fig. 4. The only difference is that GEYER's specimen is about twice bigger. For the other affinities of the species see SIBLÍK, 1993a.
Occurrence: Adnet – locality 2a.
Sinemurian – Domerian (ALMÉRAS, 1964), *Marmorea* Zone on Steinplatte.

Liospiriferina aff. *obtusa* (OPPEL, 1861)
(Pl. 30, Fig. 10)

aff. 1861 *Spiriferina obtusa* OPP. – OPPEL, p. 542, Pl. 11, Fig. 8.

Material: 5 more or less fragmentary specimens with both valves, 1 brachial and 33 pedicle valves. The dimensions of the figured specimen: 14.2 (length of brachial valve) x 15.0 x 11.5 mm.
Remarks: Our specimens have short hinge lines, pedicle valves with curved beaks and low, badly delimited interareas. They differ from average specimens of *"obtusa"* by narrower outline and poor sulcation of pedicle valve (locality 2a) or by poor sulcation only (locality 3).
Occurrence: Adnet – locality 2a (8 specimens) and locality 3 (31 specimens). Two other pedicle valves determinable as *Liospiriferina* cf. *obtusa* were found at the locality 5a.
Liospiriferina obtusa occurs in Sinemurian – ?Domerian (according to ALMÉRAS, 1964), and is known from the *Marmorea* Zone on Steinplatte, too (SIBLÍK, 1993a).

Genus: *Callospiriferina* ROUSSELLE, 1977

Callospiriferina cf. *tumida* (BUCH, 1840)

cf. 1840 *Spirifer tumidus* – BUCH, p. 201, Pl. 10, Fig. 29.
1992 *Callospiriferina pinguis* (ZIETEN) – DULAI, p. 63, Pl. 4, Fig. 1; Text-Fig. 21.

Material: 4 fragmentary pedicle valves.
Remarks: Valves with curved, low beaks and with poorly

delimited interareas. Sulcation broad but shallow, faint ribbing observable laterally. Our best specimen is well comparable to that figured by DULAI (1992, Pl. 4, Fig. 1) under *Callospiriferina pinguis,* and coming from the Early Sinemurian of the Bakony Mts. Nevertheless, our material is not suitably preserved for definitive determination. The nomenclatural problem of *"tumida"* and *"pinguis"* was solved by ROUSSELLE, 1977 (*"pinguis"* being preoccupied); her solution is followed in this paper.

Occurrence: Adnet – locality 2a (3 specimens), locality 5a1 (1 specimen).
ALMÉRAS (1964) gives the distribution Upper Sinemurian – Domerian for *"tumida"* and Hettangian – Domerian for *"pinguis"*.

Superfamily: Pennospiriferinoidea DAGYS, 1972
Family: Lepismatinidae XU & LIU, 1983
Subfamily: Dispiriferininae CARTER, 1994
Genus: *Dispiriferina* SIBLÍK, 1965

Dispiriferina aff. *segregata* (DI-STEFANO, 1887)

aff. 1887 *Spiriferina segregata* DI-STEF. – DI-STEFANO, p. 44, Pl. 1, Fig. 18.

Material: 3 pedicle valves, the best preserved one is 16.0 mm long and 17.0 mm wide.

Remarks: The specimens remind one of *Spiriferina segregata* DI-STEFANO by their suberect beaks and completely ribbed surface (3 ribs within the sulcus). They differ, however, from DI-STEFANO's species in only very shallow sulcation and poorly developed, rounded ribs. *"Segregata"* was attributed to *Dispiriferina* by DULAI, 1992 on the external resemblances only.

Occurrence: Adnet – locality 3.
Dispiriferina segregata occurs according to ALMÉRAS (1964) in Sinemurian. It was described from Sicily and is reported also from the Lower and Upper Sinemurian of the Bakony Mts. (DULAI, 1992, VÖRÖS, 1993).

Order: Terebratulida WAAGEN, 1883
Superfamily: Terebratulacea GRAY, 1840
Family: Terebratulidae GRAY, 1840
Genus: *Lobothyris* BUCKMAN, 1918

Lobothyris andleri (OPPEL, 1861)
(Pl. 30, Fig. 7)

1861 *Terebratula Andleri* OPP. – OPPEL, p. 536, Pl. 10, Fig. 4.
1889 *Terebratula punctata* SOW. Var. *Andleri* OPP. – GEYER, p. 3, Pl. 1, Figs. 3-8, 11, 13, 15-16.
1993 *Lobothyris andleri* (OPPEL) – DULAI, p. 37, Pl. 2, Fig. 4; Text-Figs. 11-12 (cum syn.).

Material: 3 more or less damaged specimens of the dimensions: 18.7 x 15.4 x 9.3 mm (figured), 16.7 x 14.0 x 8.5 mm and ca.15.0 x 12.7 x 8.0 mm; moreover 2 small specimens most probably also belonging here.

Remarks: GEYER (1889) showed the great variability of this species and our specimens approach in their subrounded outline his specimen figured on Pl. 1, Fig. 3. They differ, however, not only from the other specimens figured by GEYER but also from OPPEL's original specimen (1861) and from the specimen figured by DULAI (1993). All these are of subpentagonal outline with straight anterior margin.

Occurrence: Adnet – locality 2a.
Hettangian – Sinemurian (according to ALMÉRAS, 1964).

Genus: *Terebratula* MÜLLER, 1776; s.l.

"Terebratula" juvavica GEYER, 1889

1889 *Terebratula juvavica* n.sp. – GEYER, p. 6, Pl. 1, Figs. 17-23.
1937 *Terebratula juvavica* GEYER – VIGH, p. 20.

Material: 1 slightly damaged specimen of the dimensions 11.0 x 9.5 x 5.0 mm.

Remarks: Subpentagonal outline and pointed beak accompanied with long, sharpened beak ridges seemed to testify a zeilleriid character of the specimen. However, the sections showed low but wide cardinal process and essential features of Terebratulidae (absence of dental lamellae and of any dorsal septum). The specimen is thus provisionally assigned to *"Terebratula"*. It is well comparable to *"juvavica"* as described by GEYER (1889) differing from it by its smaller size only.

Occurrence: Adnet – locality 5a.
Hettangian – Upper Sinemurian (according to ALMÉRAS, 1964).

Family: Pygopidae MUIR-WOOD, 1965
Genus: *Linguithyris* BUCKMAN, 1917

Linguithyris aspasia (ZITTEL, 1869)

1869 *Terebratula Aspasia* MENEGH. – ZITTEL, p. 126, Pl. 14, Figs. 1-4.
1975 *Propygope aspasia* (MENEGHINI) – AGER, p. 151, Text-Fig. 1.
1991 *Nucleata aspasia* (MENEGHINI) – AGER, p. 240, Pl. 1, Fig. 3.
1992 *Linguithyris aspasia* (MENEGHINI) – DULAI, p. 67,Pl. 4, Fig. 3; Text-Fig. 25 (cum syn.).
1993 *Linguithyris aspasia* (MENEGHINI) – MANCENIDO, p. 91 (cum syn.).
1993 *Linguithyris aspasia* (MENEGH.) – SIBLÍK, Pl. 2, Figs. 1, 4.
1993a *Linguithyris aspasia* (MENEGHINI) – SIBLÍK, p. 971, Pl. 2, Figs. 1, 8; Text- Fig. 6 (cum syn.).

Material: 1 damaged specimen with both valves and 3 single pedicle valves.

Remarks: The existing range of variation has been discused in the literature already several times (e.g. GEYER, 1889; VIGH, 1943; SACCHI VIALLI & CANTALUPPI, 1967; SIBLÍK, 1993a). According to DULAI (1992) *Linguithyris aspasia* and *Linguithyris nimbata* are synonymous; this opinion is not followed in the present paper. Usually, MENEGHINI (1853) has been mentioned as the author of the species. His name is, however, nomen nudum (see PROSOROVSKAYA & VÖRÖS, 1988).

Occurrence: Adnet – locality 1 (1 specimen) and locality 5a-5b (3 single valves).
Sinemurian – Domerian; ascertained also in the *Marmorea* Zone on Steinplatte (SIBLÍK, 1993a).

Linguithyris beyrichi (OPPEL, 1861)
(Pl. 30, Fig. 9)

1861 *Terebratula Beyrichi* OPP. (Waldheimia ?) – OPPEL, p. 539, Pl. 11, Fig. 3.

1889 *Terebratula Beyrichi* OPP. – GEYER, p. 12, Pl. 2, Figs. 4-8.
1960 *Glossothyris beyrichi* OPP. – FÜLÖP et al., Pl. 1, Fig. 2.

Material: 1 specimen with both valves, measuring ? 9.5 x 9.7 x 6.7 mm.

Remarks: Subpentagonal outline of shell and its width about equal to its length suggest the attribution of the specimen to *"beyrichi"* despite its smaller size in comparison to the OPPEL's and GEYER's material. The specimen was provisionally determined as *"Terebratula" nimbata* OPPEL in RAKÚS, SIBLÍK & LOBITZER (1993, p. 641). It is very similar to the variant figured by GEYER, 1889 on Pl. 30, Fig. 9 and representing the morphological passage between *Terebratula nimbata* and *Terebratula beyrichi*. The species under consideration was questionably referred to *Rhapidothyris* TULUWEIT, 1965 by VÖRÖS (1993). The generic attribution of *"beyrichi"* still remains unsatisfactory.

Occurrence: Adnet – locality 5.
According to ALMÉRAS (1964) Hettangian to Sinemurian.

Genus: *Securithyris* VÖRÖS, 1983

? *Securithyris* sp.

Material: 1 fragmentary specimen, with length slightly surpassing 20.0 mm.

Remarks: Rectimarginate (?) shell with slightly concave flanks posteriorly, with maximum-width forward of mid-length, and with equally convex punctate valves. Poorly delimited planareas present. Dental lamellae and dorsal septum absent. The specimen reminds one of young *Securithyris* without characteristic axiniform development (see e.g. ZITTEL, 1869, Pl.15 sub *Terebratula Erbaensis* SUESS). Further comparisons are made difficult owing to the scarcity of better preserved specimens.

Ocurrence: Adnet – locality 2a.

Superfamily: Zeilleriacea ALLAN, 1940
Family: Zeilleriidae ALLAN, 1940
Genus: *Zeilleria* BAYLE, 1878
***Zeilleria alpina* (GEYER, 1889)**

1889 *Waldheimia alpina* nov. sp. – GEYER, p. 29, Pl. 3, Figs. 33-38.
1943 *Waldheimia alpina* GEY. – VIGH, p. 324, Pl. 25, Fig. 4; Text-Fig. 5c.
1960 *Waldheimia* cfr. *alpina* GEY. – FÜLÖP et al., Pl. 1, Fig. 3.
1992 *Zeilleria alpina* (GEYER) – DULAI, p. 71, Pl. 5, Fig. 2; Text-Figs. 29-30.
1993a *Zeilleria alpina* (GEYER) – SIBLÍK, p. 975, Pl. 2, Fig. 10 (cum syn.).

Material: 2 specimens. The greater one measures 11.7 x ca.12.0 x 5.8 mm.

Remarks: The specimens correspond well externally to the detailed original description by GEYER (1889). From the internal characters only a median septum can be seen through the shell in the posterior half of the brachial valves. The specimens are, however, devoid of any sinuation in the anterior commissure, resp. of shallow sulcation on the brachial valve which was developed in the material from Steinplatte (SIBLÍK, 1993a). In this respect the specimens from Adnet agree with those described by DULAI from the Bakony Mts. (1992).

Occurrence: Adnet – locality 2a.
Hettangian – Upper Sinemurian (according to ALMÉRAS, 1964).

***Zeilleria choffati* HAAS, 1885**
(Pl. 30, Fig. 11)

1885 *Waldheimia (Zeilleria) Chofatti*, nov. spec., 1884 – HAAS, p. 61, Pl. 4, Figs. 20-24.
1889 *Waldheimia Choffati* HAAS – GEYER, p. 22, Pl. 3, Figs. 8-13.
1936 *Zeilleria Choffati* H. HAAS – JOLY, p. 155 (cum syn.).
1943 *Waldheimia choffati* HAAS – VIGH, p. 330, Pl. 25, Fig. 16; Text-Fig. 8d.
1964 *Zeilleria choffati* HAAS – SACCHI VIALLI, p. 17, Pl. 2, Figs. 9-10.
1992 *Zeilleria choffati* (HAAS) – DULAI, p. 73, Pl. 5, Fig. 3; Text-Figs. 31-32.
1993 *Zeilleria mutabilis* (OPPEL) – SIBLÍK, Pl. 1, Fig. 3.
1994 *Zeilleria mutabilis* (OPPEL) – SIBLÍK in LOBITZER et al., Pl. 1, Fig. 9.

Material: 3 internal moulds with the shell remains. The figured specimen measures 15.0 x 12.6 x 7.9 mm.

Remarks: After the study of the more numerous material of *Zeilleria mutabilis*, the specimen figured by SIBLÍK (1993 and 1994) was redetermined and placed here under *Zeilleria choffati* because of its general outline with the maximum-width situated in the mid-length, and of its slightly concave anterior margin. The specimen corresponds well to the Fig. 20 on Pl. 4 in HAAS (1885) and also to the Figs. 9 and 11 on Pl. 3 in GEYER (1889) who gave thorough description of the species under consideration. However, very thick specimen with remarkably concave anterior margin (e.g. Figs. 23 and 24 in HAAS, 1885) have been ascertained neither on Hierlatz nor in Hungary.

Occurrence: Adnet – locality 2a (1 specimen), locality 5a (2 specimens).
Sinemurian (according to ALMÉRAS, 1964).

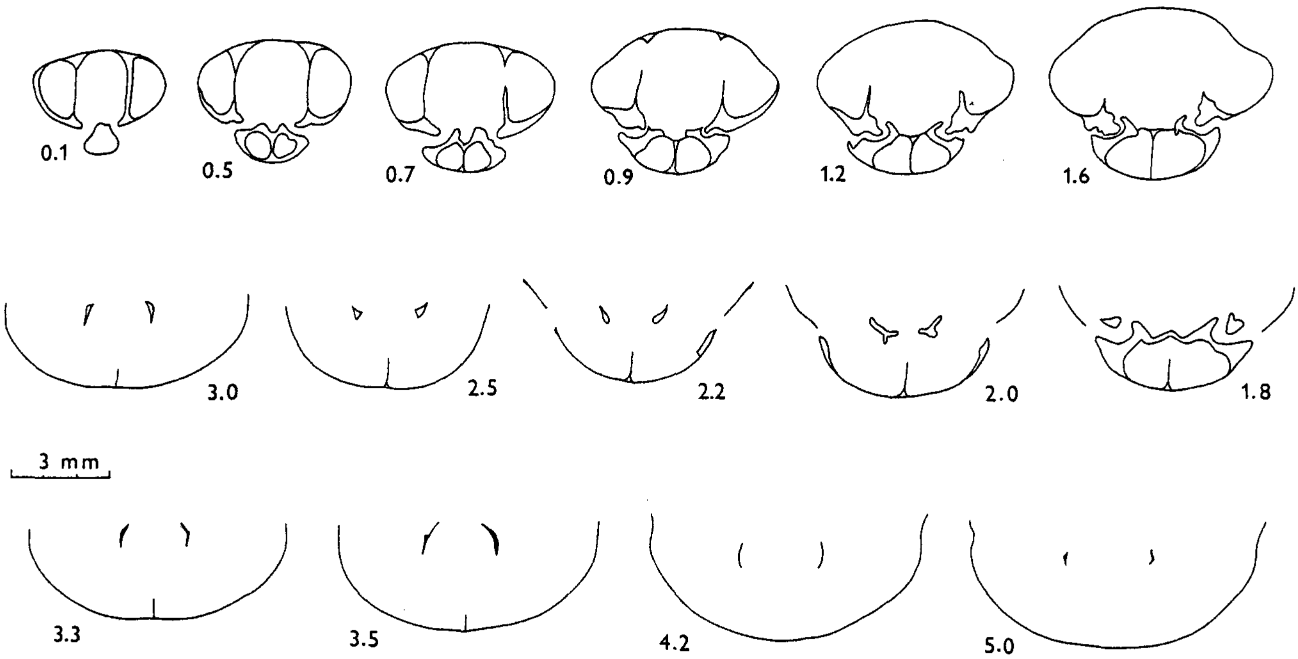
***Zeilleria mutabilis* (OPPEL, 1861)**
(Pl. 30, Fig. 8)

1861 *Terebratula mutabilis* OPP. *(Waldheimia)* – OPPEL, p. 538, Pl. 10, Fig. 7.
1992 *Zeilleria mutabilis* (OPPEL) – DULAI, p. 69, Pl. 4, Fig. 6; Pl. 5, Fig. 1; Text-Figs. 27-28 (cum syn.).
1993 *Zeilleria mutabilis* (OPPEL) – SIBLÍK, Pl. 1, Fig. 4, non Fig. 3 (=*Zeilleria choffati*).
1993a *Zeilleria mutabilis* (OPPEL) – SIBLÍK, p. 974, Pl. 2, Fig. 3; Text-Figs. 8-9 (cum syn.).
? 1993 *Zeilleria mutabilis* (OPPEL) – DULAI, p. 43, Pl. 2, Fig. 3; Text-Fig. 19.
non 1994 Zeilleria mutabilis (OPPEL) – SIBLÍK in LOBITZER et al., Pl. 1, Fig. 9 (=*Zeilleria choffati*).

Material: 19 mostly fragmentary internal moulds with shell remains. The dimensions of the better preserved specimens: ca.19.0 x 16.2 x 9.0 mm, 15.6 x 13.4 x 7.7 mm, 15.4 x 14.4 x 7.2 mm (figured), 14.5 x 13.1 x 6.5 mm, 13.8 x 12.4 x 6.7 mm. Moreover, about 25 damaged specimens most probably also belonging here (?).

Remarks: Nothing is to be added to the external characters of this highly variable species as were summarized by DULAI (1992), and to the remarks by SIBLÍK (1993a). Some specimens resemble by their greater convexity *Zeilleria choffati* or *Zeilleria stapia*.

Occurrence: Adnet – locality 2a (11 specimens), locality 2b (1 specimen), locality 4 (1 specimen), locality 5a (4 specimens), locality 5b (2 specimens).



Text-Fig. 53.
Zeilleria stapia (OPPEL). Measured from dorsal umbo. Loop incompletely preserved. Length of specimen 16.0 mm. Locality 5a. (Quarry XXXI). Magnified.

Zeilleria perforata (PIETTE, 1856)

1856 *Terebratula perforata* – PIETTE, p. 206, Pl. 10, Fig. 1.
1974 *Zeilleria (Zeilleria) perforata* (PIETTE) – DELANCE, p. 75, Pl. 1, Figs. 1-7;Text-Figs. 6-1 to 6-9 (cum syn.).
1993 *Zeilleria perforata* (PIETTE) – SIBLÍK, Pl. 1, Fig. 6.
1993a *Zeilleria perforata* (PIETTE) – SIBLÍK, p. 973, Pl. 2, Fig. 4; Text-Fig. 7 (cum syn.).

Material: 1 slightly damaged specimen of the dimensions 22.4 x 16.1 x 10.7 mm.
Remarks: The specimen resembles by its outline the elongated specimen from the Upper Hettangian of Auxois figured by DELANCE (1974), and particularly the specimen from the *Marmorea* Zone of Steinplatte figured by SIBLÍK (1993a).
Occurrence: Adnet – locality 4.
Hettangian to *Obtusum* Zone (according to DELANCE, 1974).

Zeilleria stapia (OPPEL, 1861)
(Text-Fig. 53)

1861 *Terebratula stapia* OPP. *(Waldheimia)* – OPPEL, p. 539, Pl. 11, Fig. 2.
1889 *Waldheimia stapia* OPP. – GEYER, p. 16, Pl. 2, Figs. 25-30.
1993a *Zeilleria stapia* (OPPEL) – SIBLÍK, p. 975, Pl. 2, Fig. 2; Text-Fig. 10 (cum syn.).

Material: 11 partly damaged specimens. The best preserved ones measure: 23,7 x ca.17.0 x 12.0 mm, 16.2 x 12.9 x 8.8 mm and 16.0 x 12.5 x 8.9 mm.
Internal characters: The sections are practically the same as those figured by SIBLÍK (1993a) from Steinplatte. Due to bad conditions, the loop was not preserved in 4 specimens sectioned from Adnet.
Remarks: Our specimens agree well with those figured in GEYER's monograph (1889) where also the variability of the species and its relations to *Zeilleria mutabilis* were treated with in detail.

Occurrence: Adnet – locality 2a (4 specimens), locality 2b (1 specimen), locality 5a (6 specimens).
Sinemurian. The species was also ascertained in the *Marmorea* Zone on Steinplatte.

Genus: *Bakonyithyris* VÖRÖS, 1983

Bakonyithyris (?) engelhardti (OPPEL, 1861)

1861 *Terebratula Engelhardti* OPP. *(Waldheimia)* – OPPEL, p. 537, Pl. 10, Fig. 5.
1889 *Waldheimia Engelhardti* OPP. – GEYER, p. 31, Pl. 3, ?Fig. 39; Pl. 4, Figs. 1-2.
non 1967 *Zeilleria engelhardti* (OPP.) – SACCHI VIALLI & CANTALUPPI, p. 105, Pl. 15, Fig. 12; Text-Fig. 27.

Material: 1 fragmentary specimen with length slightly surpassing 13.0 mm.
Remarks: The specimen agrees very well in all observed external features (outline, anterior view, slight sinuation of the anterior commissure) with the specimen figured by GEYER (1889) on Pl. 4, Fig. 2. Short dental lamellae and dorsal septum extending for about one fourth of length of brachial valve are visible externally on the mould of our specimen.
Zeilleriids with stronger sinuation of anterior commissure or even with starting sulcation in anterior half of brachial valve are usually referred to *Zeilleria* (resp. *Bakonyithyris*) *ewaldi* (OPPEL). The transitions between the two species were well-known already to GEYER (1889). A great variability within the zeilleriid group of *"alpina – engelhardti – ewaldi – mutabilis"* types could well be intraspecific (SIBLÍK, 1993a, p. 975). The scarcity of suitable material has precluded also to say something more to the generic affiliation of *"engelhardti"*.
Occurrence: Adnet - locality 2a.
Sinemurian.

Genus: *Securina* VÖRÖS, 1983

***Securina partschi* (OPPEL, 1861)**

1861 *Terebratula Partschi* OPP. *(Waldheimia)* – OPPEL, p. 538, Pl. 10, Fig. 6.
1889 *Waldheimia Partschi* OPP. – GEYER, p. 25, Pl. 3, Figs. 20-26.
1992 *Securina partschi* (OPPEL) – DULAI, p. 78, Pl. 6, Fig. 1; Text-Figs. 37-38 (cum syn.).
? 1993 *Securina partschi* (OPPEL) ? – MANCENIDO, p. 94, Pl. 2, Fig. 7.
1994 *Securina partschi* (OPPEL) – SIBLÍK in LOBITZER et al., Pl. 1, Fig. 7.

Material: 1 slightly damaged specimen of the dimensions 16.0 x ca.14.0 x 8.1 mm.

Remarks: The specimen with its subtrigonal outline, concave anterior margin and only poorly delimited lateral planareas is well comparable to those figured on Pl. 3, Fig. 22 by GEYER (1889) and in the Text-Fig. 37 by DULAI (1992). GEYER (1889, p. 27) observed already the passages from *Waldheimia partschi* towards *Waldheimia hierlatzica* which was distinguished by its slightly different outline and better developed planareas only. Both these species are regarded synonymous by DULAI (1992).

Occurrence: Adnet - locality 2a.

Sinemurian; *Securina hierlatzica* was reported by VÖRÖS (1993) also from the Carixian and Domerian of the Bakony Mts.

3.4. Trace-fossils

In the investigated sections ichnofossils occur solely in form of trails or burrows, and borings.

The first ones developed in not lithified, soft sediments, while the latter ones are restricted to hard substrates as mollusk-shells or rock surfaces.

Burrows and trails may be produced by polychaets, echinoderms, molluscs, sipunculids or other organisms (e.g. BROMLEY, 1996; FU, 1991). Also for the genesis of borings different taxa as algae, funghi, bryozoans, molluscs etc. are known (e.g. BROMLEY, 1970; GLAUB, 1994). Because we have only information about 2-dimensional aspects of these borings, they will be treated only morphologically.

3.4.1. Borings

Morphotype 1
(Plate 23, Fig. 3)

In thin-section circular to elliptical (cutting-effect) dark dots with a diameter about 0,32 mm.

It is not clear if they represent sections perpendicular to elongate boring-systems, or something like a „central cavity" from which borings of the same organism start with a smaller diameter (Plate 23, Fig. 3, top left). Of course these smaller borings with a diameter of about 0,06–0,08 mm could also have been generated by other organisms, and could be therefore of secondary origin.

Morphotype 2
(Plate 23, Figs. 4, 5)

Straight to slightly curved or even meandering , unbranched borings with a diameter of about 0,03 mm.

Morphotype 3
(Plate 23, Figs. 6-9)

This morphotype is represented by branched forms. Due to kind of branching we can further differentiate
- dichothom (Plate 23, Figs. 6, 7, diameter between 0,03 and 0,05 mm)
- rectangular (Plate 23, Fig. 8, diameter 0,06–0,08 mm)
- zig-zag (Plate 23, Fig. 9, diameter 0,016–0,025 mm) forms.

3.4.2. Burrows and trails

Typical aspects of bioturbation in the investigated rocks are shown in Plate 11, Fig. 1. Only rarely more or less isolated trace fossils can be observed (Plate 23, Figs. 10, 11).

Ichnogenus *Chondrites* STERNBERG, 1833

***Chondrites recurvus* (BRONGNIART, 1823) STERNBERG, 1833**
(Plate 23, Fig. 10)

1823 *Fucoides recurvus* n. sp. – BRONGNIART, p. 309, Pl. 19, Fig. 4.
1991 *Chondrites recurvus* (BRONGNIART, 1823) STERNBERG, 1833. – FU, p. 19-21, Figs. 12-13, Pl. 2, Figs. D-E (cum syn.).

Description: Curved, dichothomous structure with secondary branches on only one side of the burrow. In the figured case it is the right side. Diameter of the burrow about 0,08 mm.

Remarks: Because of its unique geometry of branching, this species is easily and acurately determinable. According to FU (1991) *Chondrites recurvus* is only known from alpine Flysch-type sediments of Upper Cretaceous to Tertiary age. Our finding is therefore the oldest one that additionally occures in a different facies.

Occurrence: Sample Lien HG I (Lienbacher Quarry).

Ichnogen. et Ichnosp. indet.
(Plate 23, Fig. 11)

Description: Irregular meandering tubes with a diameter of 1–1,2 mm. Different burrowing systems may overlap.

Remarks: Because of the dense packing of the tubes and the small and incomplete preservation of this trace-fossil, it is impossible to evaluate its complete geometrical pattern.

There are two ichnogenera that must be considered:

–*Helminthopsis* HEER emend. WETZEL & BROMLEY, 1996
Due to the emended diagnosis given by WETZEL & BROMLEY (1996) the ichnogenus consists of simple, unbranched, elongate, cylindrical tubes with curves, windings, or irregular open meanders; crossings have not been observed by them. Although our material shows straight segments (not shown on Plate 23, Fig. 11) that would give a hint to *H. hieroglyphica* WETZEL & BROMLEY, 1996 (compare also STANLEY & PICKERILL, 1998) a touching or "guiding" of tubes – as in our material – is also not known.

–*Gordia* EMMONS, 1844
According to PICKERING & PEEL (1991) these are unbranched trails or burrows that wind or loop, but do not regularly me-

ander, with a marked tendency to level crossing. In this ichnospecies the burrows "merge with, and apparently follow, the course of their own or pre-existing burrows. Additionally, individual burrows are commonly crossed by seperate burrow systems" (op. cit.: 20). This is also true for our material, but the most characteristic feature of this ichnospecies – the true level-crossing (of one individual burrow) – is missing!

Occurrence: "Marmorea Crust" (Brandschicht) of the Schnöll Quarry.

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Plate 1

Polished slabs showing lithotypes of the Schnöll- and Adnet-Fms. Sections ± parallel to bedding.

Fig. 1: Sponge layer at the base of the Guggen-Mb. (Schnöll-Fm.) at the Schnöll Quarry (XXXI). Entrance to main building of the Kiefer Company, Hallein: "Rot-Grau-Schnöll".

Fig. 2: Typical sponge facies from the red middle part of the Langmoos-Mb., Schnöll-Fm., Langmoos Quarry (XVII). Note various sections of hexactinellid sponges. Marmormuseum at Adnet: "Langmoos-Rot-Hell".

Fig. 3: Brachiopod-rich, yellow-grey facies of the basal part of the Langmoos-Mb., Schnöll-Fm., Kleiner Langmoos Quarry (XVII). Marmormuseum at Adnet: "Langmoos-Rot-Grau".

Fig. 4: Nodular limestone of the Schmiedwirt-Mb., Adnet-Fm. of Wimberg/Platten-Quarry (XXVIII): Light red nodules floating in a dark red marly matrix. Some of the nodules contain small, dark-rimmed intraclasts: "Wimberger".

Fig. 5: Crinoidal limestone of the Motzen-Mb., Adnet-Fm.: A mudstone-filled ammonite, cut obliquely is visible at the top. Note the lack of nodular fabrics contrasting with the limestones of the Schmiedwirt-Mb. (Fig. 4). Large segments of crinoid columnae are typical for the Motzen. Dark-rimmed intraclasts are common. Marmormuseum at Adnet: "Motzen". The crinoid particles are called "Engerlinge" (cock-chafer grubs) by the quarry workers.

Fig. 6: Blotchy red limestones of the Lienbacher-Mb., Adnet-Fm. of Lienbacher Quarry. Dark-rimmed intraclasts, encrusted by ferromanganese rims are very common in the Lienbacher Mb. Note the vaguely nodular appearance (?bioturbation) in contrast to the clearly developed nodules of the Schmiedwirt-Mb. (Text-Fig. 4). Entrance to main building of the Kiefer Company, Hallein: "Lienbacher" or "Adneter Rot".

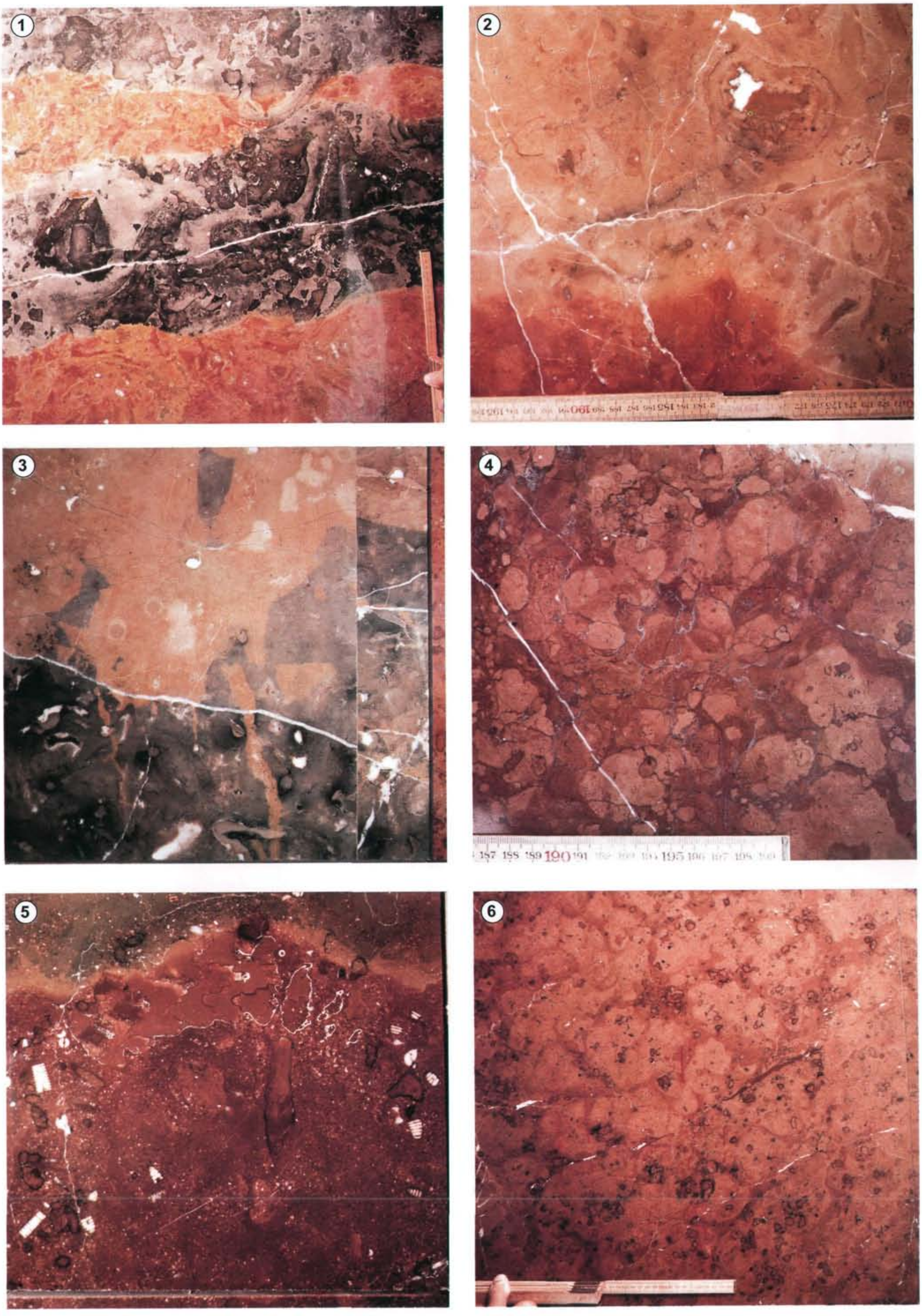
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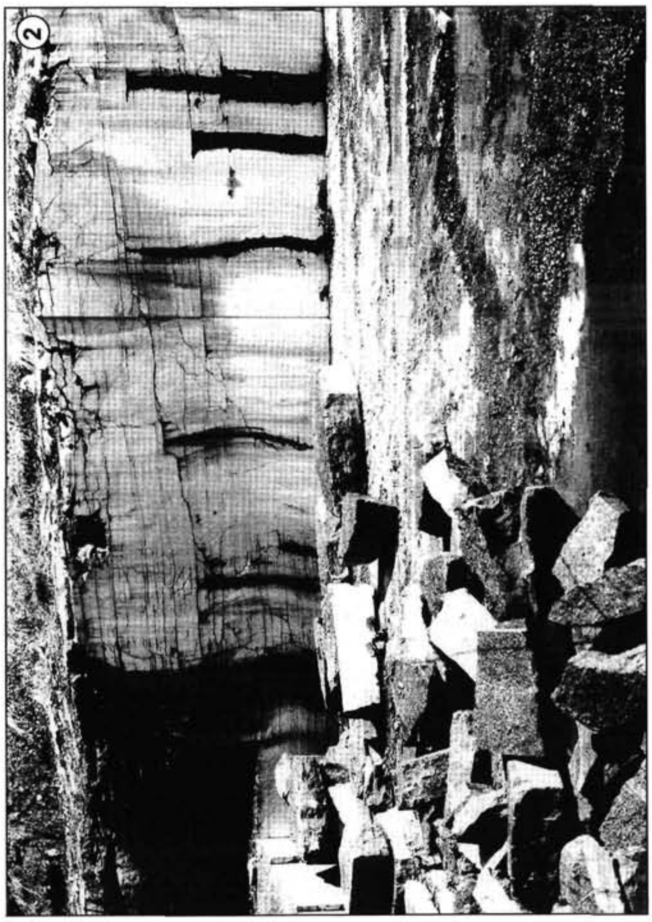
Plate 2

Fig. 1: The village of Adnet in front of the Kirchholz hill in spring 1995, view from the south-west. The Kirchenbruch (quarry I) is visible to the left of the church. It is cut into the Upper Rhaetian reef limestones forming the Kirchholz hill. The reef forms a pinnacular body sloping to the northeast, overlain by the Liassic beds. The Guggen hill, built up by the Rhaetian Guggen reef, is visible at the right rim of the picture.

Fig. 2: Lienbacher Quarry (XII) at the northern slope of the Kirchholz hill. Southwest facing wall in 1995, showing the weakly bedded red Sinemurian limestones of the Lienbacher-Mb. (Adnet-Fm.). Hemicircular cutting traces of the diamond cable saw are visible at the surface of the wall. This very efficient cutting technique is used in the Adnet quarries to recover various dimension stones with very low loss.

Fig. 3: Close view of the late Hettangian Marmorea Crust at the Schnöll Quarry (XXXI) with numerous ammonite casts (Schlotheimiids).

Fig. 4: The ferromanganese Basal Sinemurian Crust (late Sinemurian) at the Lienbacher Quarry (XII). In contrast to the "Marmorea Crust" the Basal Sinemurian Crust is completely devoid of fossils. Coin for scale.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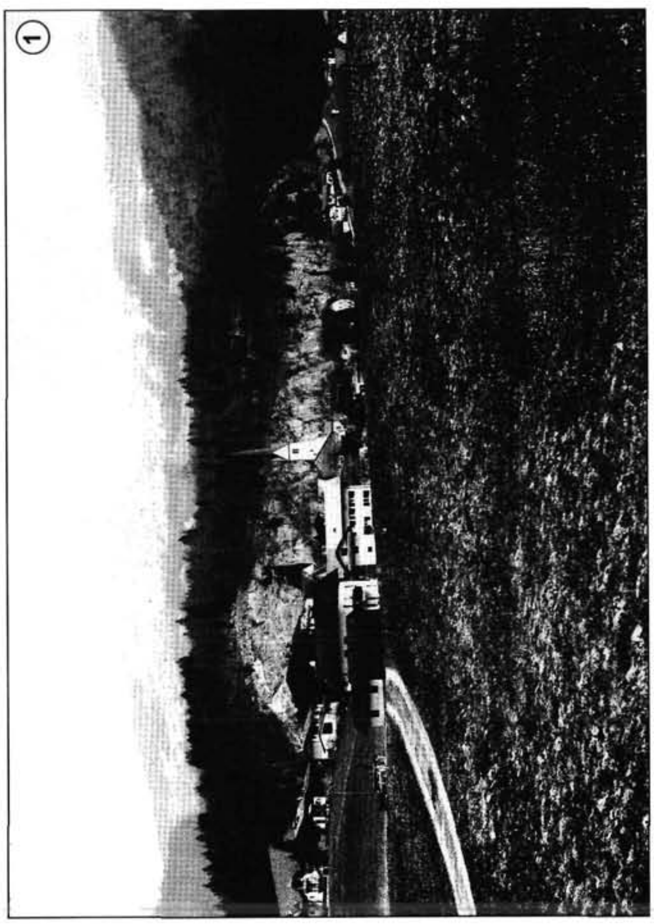
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Plate 3

Lithotypes of the Schnöll Quarry (XXXI)

Fig. 1: Basal grey crossbedded limestones (early Hettangian?), view in 1996. The crossbeds are clearly visible. They are overlain by the sponge layer of the Schnöll-Fm. with a clear-cut erosional unconformity. The crossbeds are cut by fissures perpendicular to bedding. A large cone-shaped fissure with reworked clasts is visible to the left of the hammer.

Fig. 2: Large fissure semiparallel to bedding in the crossbedded unit (arrow). Note massive bed at the base of the crossbedded unit. The Marmorea Crust is visible near the top of the picture. Height of picture is ca. 2 m. View of 1996.

Fig. 3: Sponge layer (Schnöll-Fm.) on top of the crossbedded unit, filling the erosional relief. Note spectacular protrusion of the crossbeded unit at the left, capped by a ferromanganese incrustation at the top and the concentration of large clasts in the sheltered pocket below. Several ferromanganese crusts occur around clasts and within the sediment near the top of the sponge layer. Arrows point to circular sections of sponges. Height of picture 0.5 m. View of 1996.

Fig. 4: Typical dotted texture of the Guggen-Mb. (Schnöll-Fm.). Note massive bedding. Some brachiopods (white cement-filled spots) are visible above and to the right of the hammer.

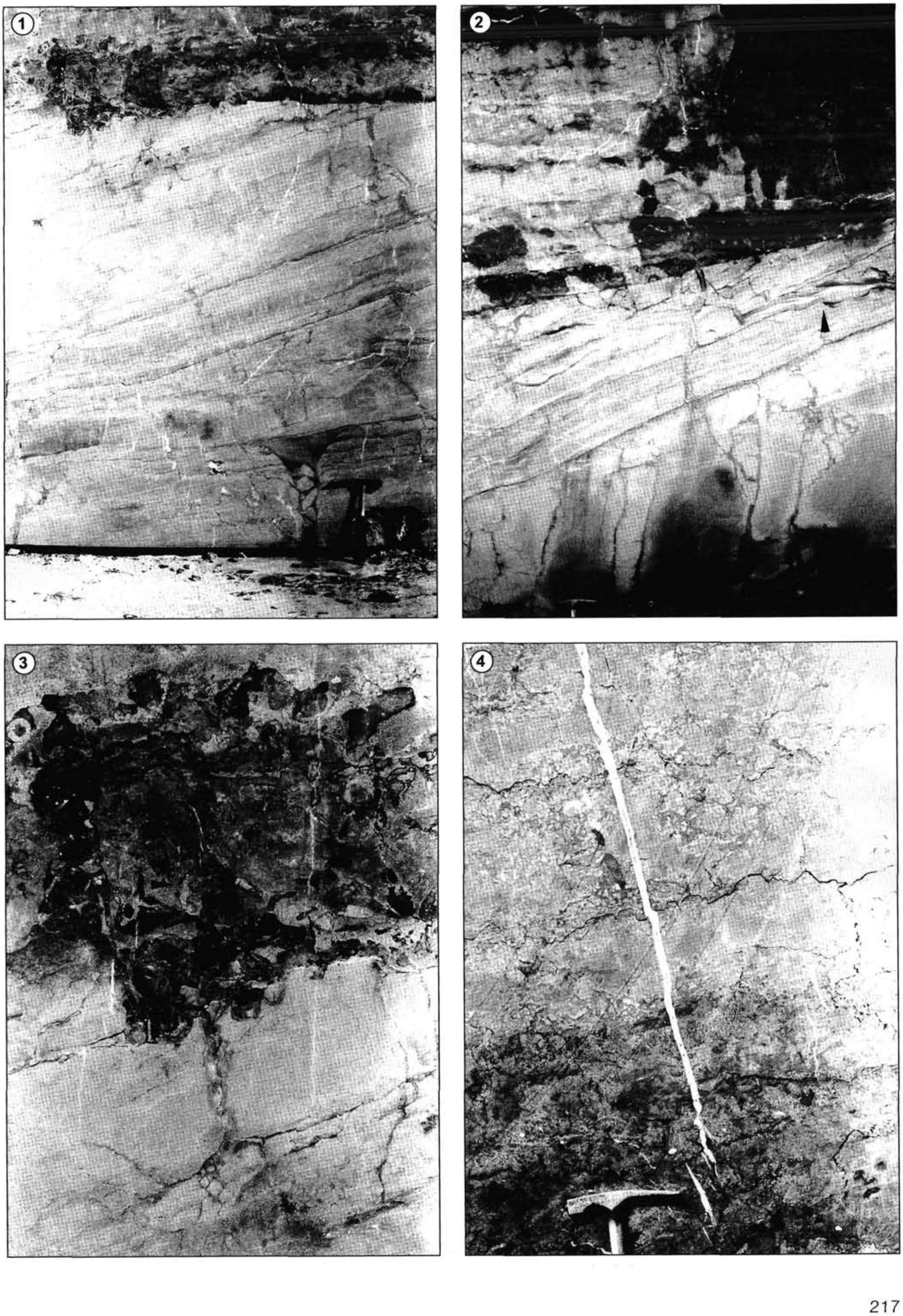
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Plate 4

Ferromanganese crusts of the Schnöll- and Adnet-Fms., Schnöll Quarry (XXXI).

Fig. 1: Sponge layer, overlying crossbedded unit with a smooth erosional surface (arrows). Note several circular sections of sponges and irregular ferromanganese incrustation on top. Height of picture 0.4 m.

Fig. 2: "Marmorea Crust" with encrusted ammonites. Note multiphase formation of irregular crusts. Height of the picture 0.1 m.

Fig. 3: Basal Sinemurian Crust (top of the hammer), overgrown by deepwater stromatolites. Note single phase formation of the crust and pronounced relief. Encrustations are thickest on top of pillar-like protrusions, pointing to a longer submarine omission of the elevated parts.

Fig. 4: Pronounced relief of the Basal Sinemurian Crust. Pillars of up to 10 cm height, capped by ferromanganese encrustations probably originated from bioerosion and preserved by overgrowth of stromatolites (coin for scale). The late Hettangian "Marmorea Crust" is visible near the bottom of the picture.

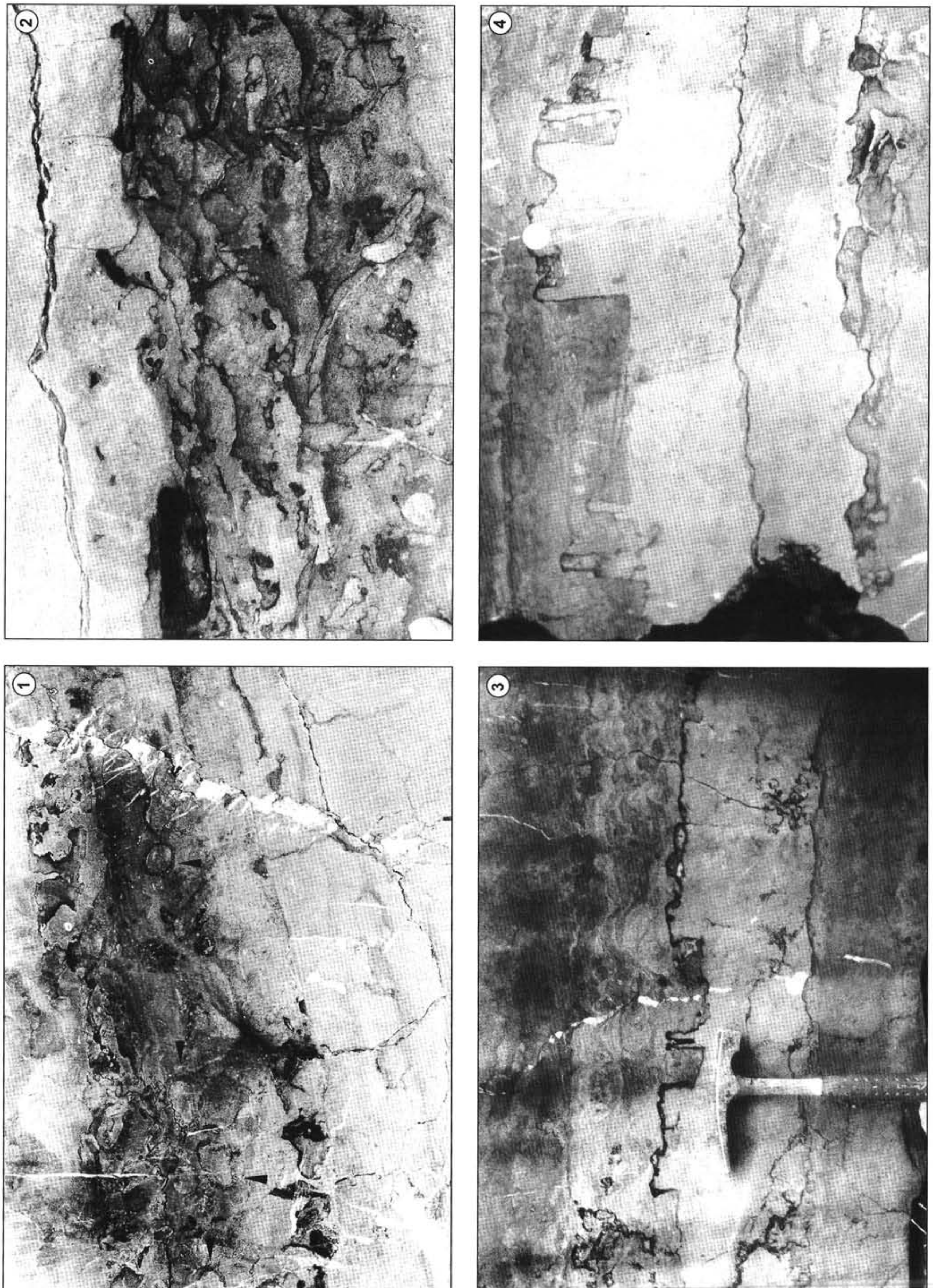
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Plate 5

Microfacies of the Kendlbach- and Schnöll-Formation, Schnöll Quarry. Sedimentary characteristics of the Kendlbach-Formation.

Figs. 1, 2, 4, 5: Resedimentation is a common feature of the Kendlbach-Formation. Fig. 1 illustrates in its lower part a mostly sparitic cemented layer rich in microlithoclasts and strongly micritizised bioclasts (mostly echinoderms; compare also Figs. 2, 4, 5). Sessile foraminifera (*Planiinvoluta carinata,* Fig. 5: P) and syntaxial rim cements growing around echinodermal remains are common (Fig. 5: arrow).
Only rarely micritic areas are preserved (Fig. 2). Due to their alternation with sparitic layers and their parallel orientation they are interpreted as relicts of a low-angle cross-bedding. Growth of secondary calcite into these layers is evident (e. g. Fig. 2: arrows).
The top of this layer in Fig. 1 exhibits a rippled surface, overprinted by secondary calcite, consisting mainly of a mosaic of blocky and rare fibrous calcite. This surface is followed by a fine grained graded sediment, interpreted as a distal calciturbidite. The base of the fine grained sediment is also only relictly preserved (Fig. 1: arrow). The next resedimented cycle starts with a finely laminated siltitic sediment that is also interpreted as a distal calciturbidite. At the base of the following micritic to microsparitic packstone a sharp increase in size of components is visible. The base of this resediment is mostly non-erosive. Only some components were pushed into the sediment due to loading. This is indicated by the deformation of under lying fine grained sediment (Figs. 1; 4). The lower part of this sediment exhibits inverse grading, whereas in the upper part a coarse-tail grading is developed. Due to these sedimentary features this resediment is interpreted as a debris flow (Sample Sch 14, grey packstones, see Text-Fig. 24 for sample positions; Figs. 1, 2: x 6; Figs. 4, 5: x 22).

Fig. 3: The contact Kendlbach-Fm./Schnöll-Fm. is clearly erosive. Delicate, partly dichothomous borings (B) penetrate the rocks of the Kendlbach-Fm. down to several mm depth. They are filled with Fe/Mn-rich sediment. Of interest is a very fine sparitic coating of the discontinuity surface (arrows 1) and a relictic preserved Fe/Mn-sediment (arrows 2). The Schnöll-Fm. is represented by the MF-Type 2.1., a bivalve-gastropod biomicrite (wackestone). (Sample Sch 1, grey packstones, see Text-Fig. 24 for sample positions; x 18).

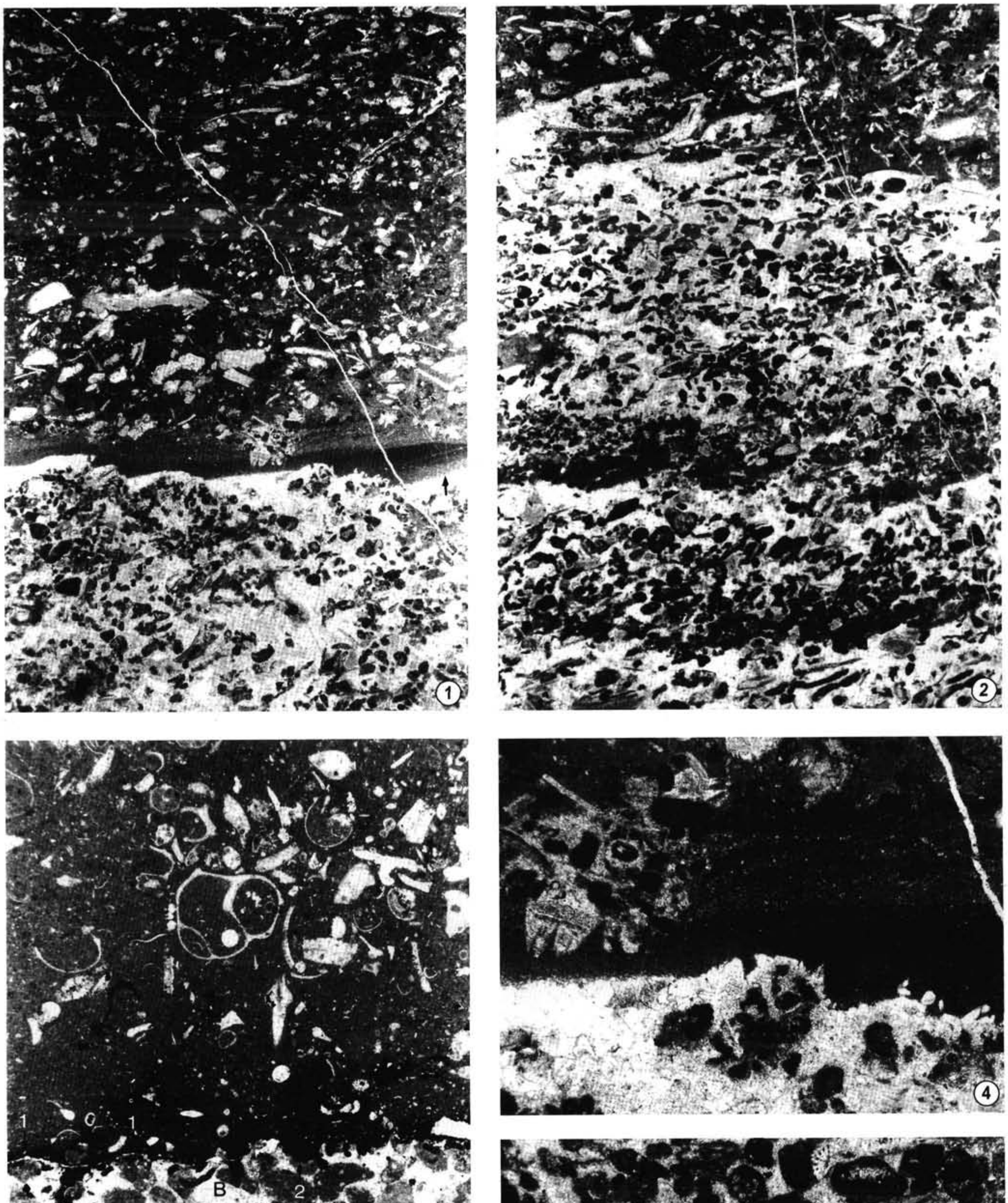
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Plate 6

Microfacies of the Schnöll-Formation (Guggen-Member)

Figs. 1, 3: MF-Type 2.2. Echinoderm-foram-biomicrite with cyano-oncoids (wackestone to packstone). The sediment is characterized by a high content in foraminifera (Involutinids: I; Lagenids: L), echinoderms and ostracodes. The overview (Fig. 3) exhibits also a high amount of cyano-oncoids. Some intraclasts (Fig. 1: arrows) occur. Fig. 1: Sample RGS Brand 5; x 18; Fig. 3: Sample RGS 8/1; Schnöll Quarry; x 13.

Fig. 2: MF-Type 2.3 .: Bivalve-ostracod biomicrite with cyano-oncoids (wacke- to packstone). The high contents of thick-shelled bivalve debris and ostracodes, together with cyano-oncoids are a distinctive feature of this sediment. Note the well expressed orientation of elongated bioclasts. Sample XVII A; Langmoos Quarry; x 10.

Fig. 4: Microfacies 2.4.: Cyano-oncoidal biomicrite (packstone). This sediment reveals a very high content of cyano-oncoids. Encrusted particles are shell debris, spicula, microproblematica (M: see also Plate 13), foraminifera, the serpulid worm *Spirorbis* (S) and gastropods. Note euhedral cubic pyrite (lower middle and right) and the geopetal fillings of bioturbation (arrow). Sample RGS Spong 6b; Schnöll Quarry; x 20.

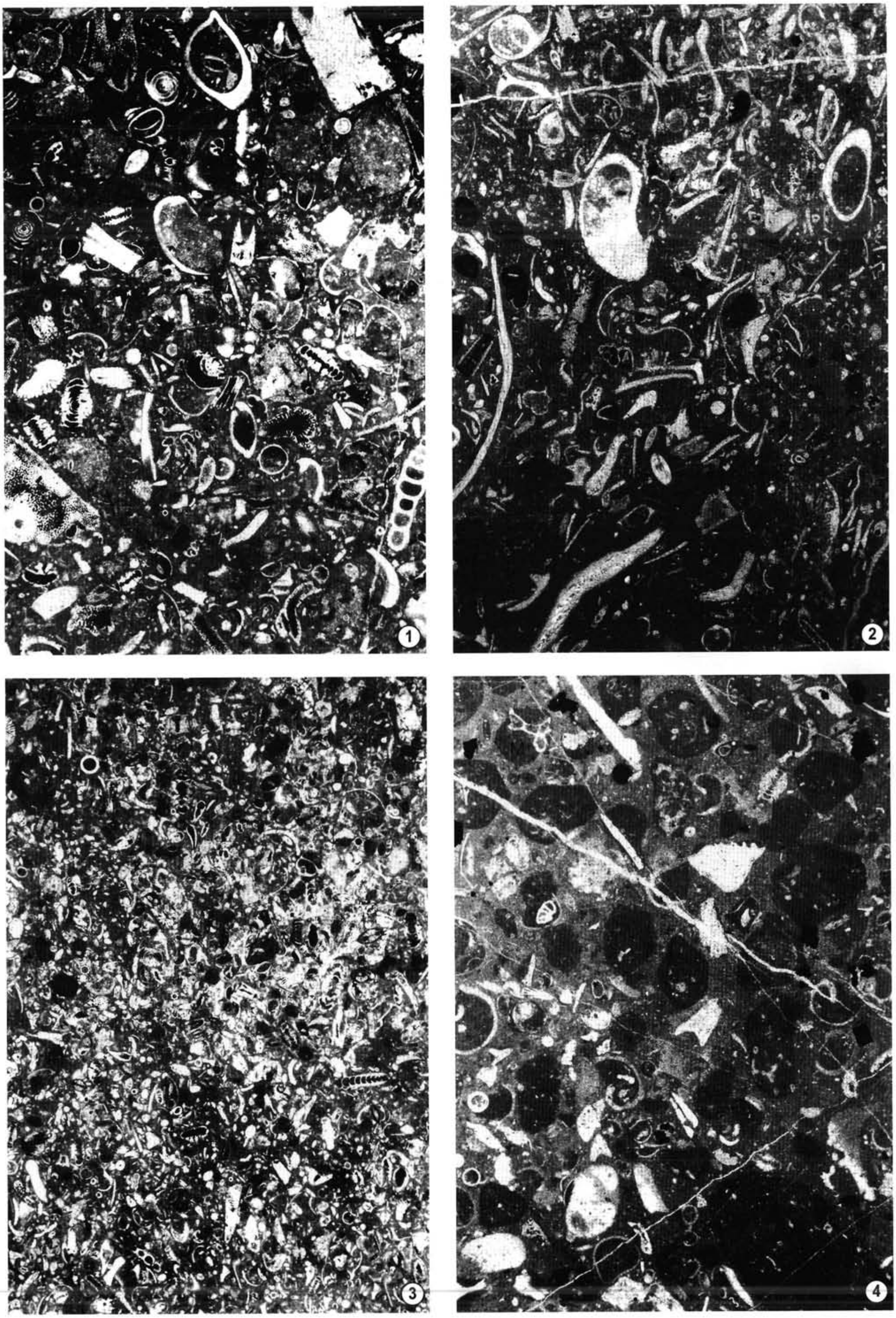
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Plate 7

Microfacies, sponges and holothurians of the Schnöll-Formation, Schnöll Quarry (XXXI).

Fig. 1: MF-Type 2.5.: Spiculite with cyano-oncoids (wackestone). Dominant spicula are arranged rather randomly. Note high degree of bioturbation. Sample RGS 4; x 14.

Figs. 2, 3: Sponges are characterized by original cubic arrangement of spicula. Both sponges exhibit characteristics of abrasion and are therefore transported and embedded in sediments of MF-Type 2.2. Note geopetal (stromatactis-like) fillings of irregular burrows in Fig. 2. Fig. 2: Sample RGS 2; x 7 ; Fig. 3: Sample RGS Brand 7; "Marmorea Crust"; x 10.

Fig. 4: The central channels of spicula can be filled by pyrite. In the course of ongoing diagenesis under the same physico-chemical conditions in a reducing milieu, the spicules are completely replaced by pyrite. Sample RGS Spong 2a; sponge layer; x 60.

Fig. 5: Poorly preserved holothurian sclerites (*Theelia* sp.) show a patchy distribution. Sample Spong 1b; sponge layer; x 55.

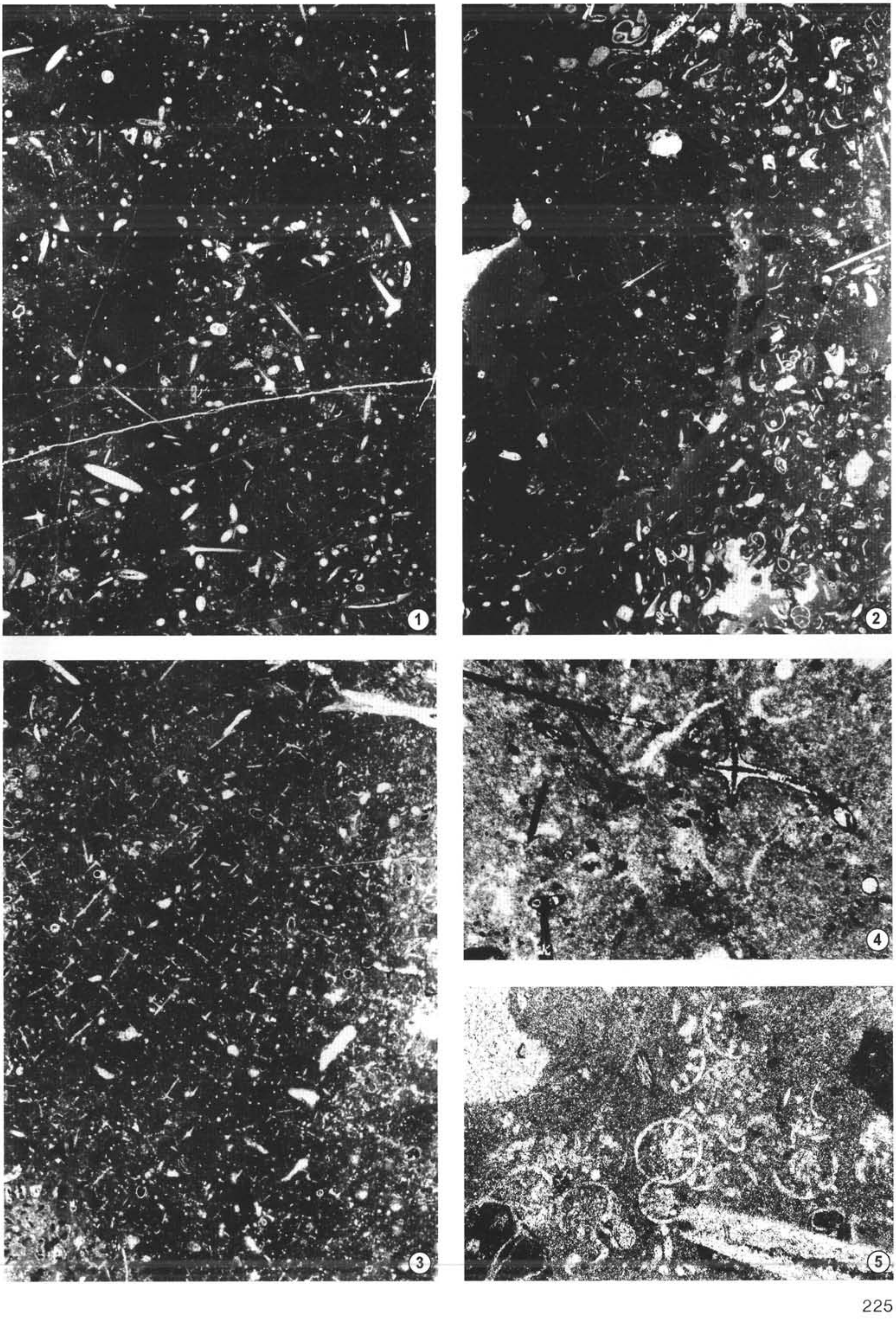
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Plate 8

Neptunian dykes of the Schnöll-Formation, Quarry XXXI.

Fig. 1: The degree of fracturing of the rocks by neptunian dykes is sometimes very high. 2 generations of dykes can be identified. Note the high amount of calcite, that seals the former cavities. This calcite is not always geopetally arranged on the roofs, but also covers the floors (see also Fig. 4). This means that the dykes were opened during several stages. Sediment infill is here mostly micritic. Sample RGS 3, x 5,5.

Fig. 2: Example of a one-phase filling of dykes by a densely packed echinodermal sediment. Sample RGS 3, x 7.

Fig. 3: Thicker dykes are filled by a sediment rich in lithoclasts, whereas apophyses – in this case a second generation of fracturing – are filled by a fine micritic sediment. The calcitic seam in the middle of this dyke reveals further stretching of the rock. Note enrichment of pyrite (dark dots) in the dykes. Sample RGS Spong 8b; sponge layer; x 5.

Figs. 4, 5: Examples of a well-layered, partly cross-bedded filling of dykes. Arrangement of cements in Fig. 4 reveals polyphase opening. Fig. 4: Sample RGS 4, x 10; Fig. 5: Sample RGS 1, x 11.

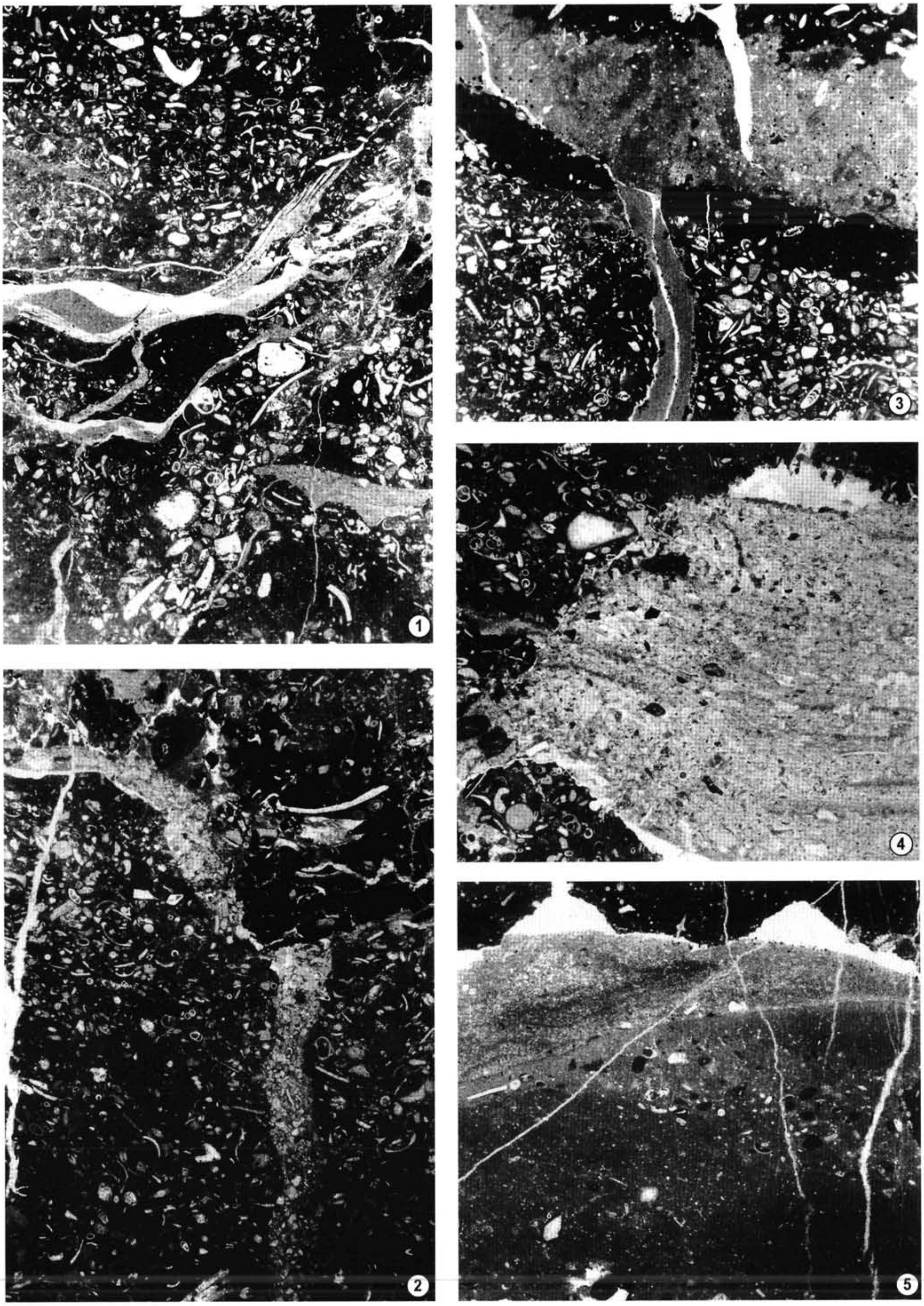
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Plate 9

Microfacies of the Enzesfeld Limestone ("Marmorea Crust")

Figs. 1, 2: MF-Type 4: Echinoderm-foram-biomicrite with gastropodes (wacke- to packstone). The Enzesfeld Limestone is characterized by a very high foram-content. In contrast to the omnipresent *Involutina liassica*, other species as *Licispirella violae, L. bicarinata, Ophthalmidium leischneri* and lagenids are clearly rarer. In Fig. 2 an angular clast of Oberrhätkalk reveals the erosion of the underlying formation. Fig. 1: Sample Lien HG I.4., x 30; Fig. 2: Sample Lien HG I.1.; Lienbacher Quarry; x 22.

Fig. 3: Relict of a pelagic crinoid. Bright semi-valves embedded in the dark, ferro-manganiferous matrix correspond to*Schizosphaerella punctulata*. Sample Lien HG I.2.; Lienbacher Quarry; x 240.

Fig. 4: Relict of a radiolaria, incorporated in a Fe/Mn-oxide crust. Sample RGS HG III.2.; Schnöll Quarry; x 175.

Figs. 5, 6: The calcareous Dinophyceen cyst *Schizosphaerella punctulata* (bright semi-valves) is a common constituent of the matrix of the Enzesfeld Limestone. At higher magnifications, characteristic pores (Fig. 6: arrows) are visible. Sample Lien HG I.2.; Fig. 5; Lienbacher Quarry; x 92; Fig. 6, x 460.

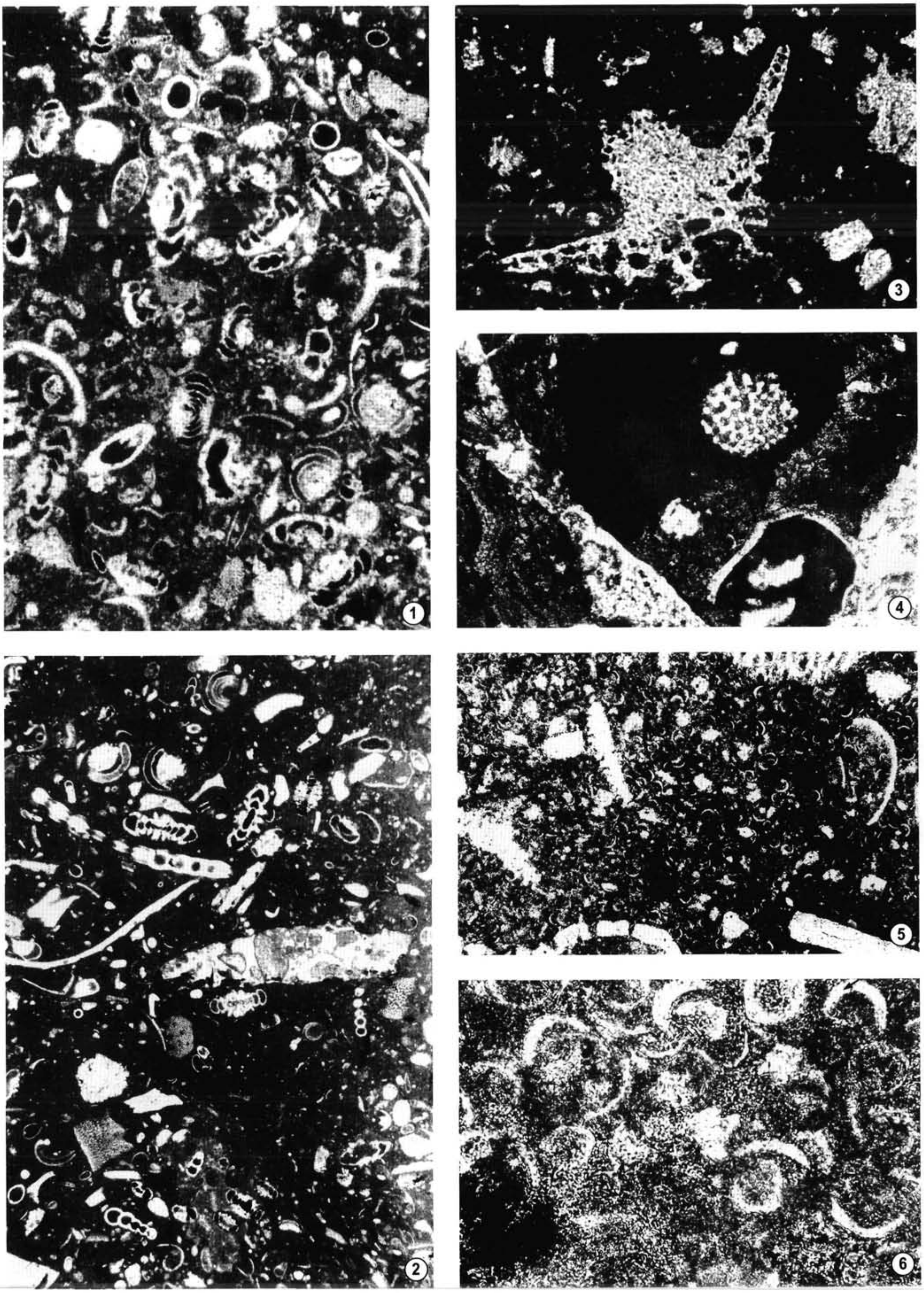
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Plate 10

Hardgrounds and crusts of the Enzesfeld Limestone and Microfacies of the Adnet-Formation, Schmiedwirt-Mb., Basal Unit.

Figs. 1, 2: "Marmorea Crust": Crusts of Fe/Mn-oxides indicate periods of very low or non-sedimentation. These crusts may be massive (Fig. 1) or finely laminated (Fig. 2). On these crusts growing of serpulid worms (Fig. 1: gen. et spec. indet., Fig. 2: ? *Spirorbis* sp.) is rather common. Borings penetrating down from these crusts into the underlying rocks, indicate hardground formation (Fig. 1: arrows). Fig. 1: Sample Lien HG I.5., Lienbacher Quarry, x 35; Fig. 2: Sample RGS Brand 13, Schnöll Quarry, "Marmorea Crust"; x 80.

Figs. 3, 4: MF-Type 5: Basal Unit, Adnet-Fm.: Bioturbated ostracod-echinoderm-mollusc-biomicrite (wackestone). The bioturbated sediment also contains relicts of pelagic crinoids (Fig. 3: C) and nodules, that can be assigned as hardground nodules (Fig. 4), if they are coated by Fe/Mn-oxides, bored or settled by organisms. Sample RGS HG III.3; Fig. 3, x 26; Fig. 4; Schnöll Quarry; x 24.

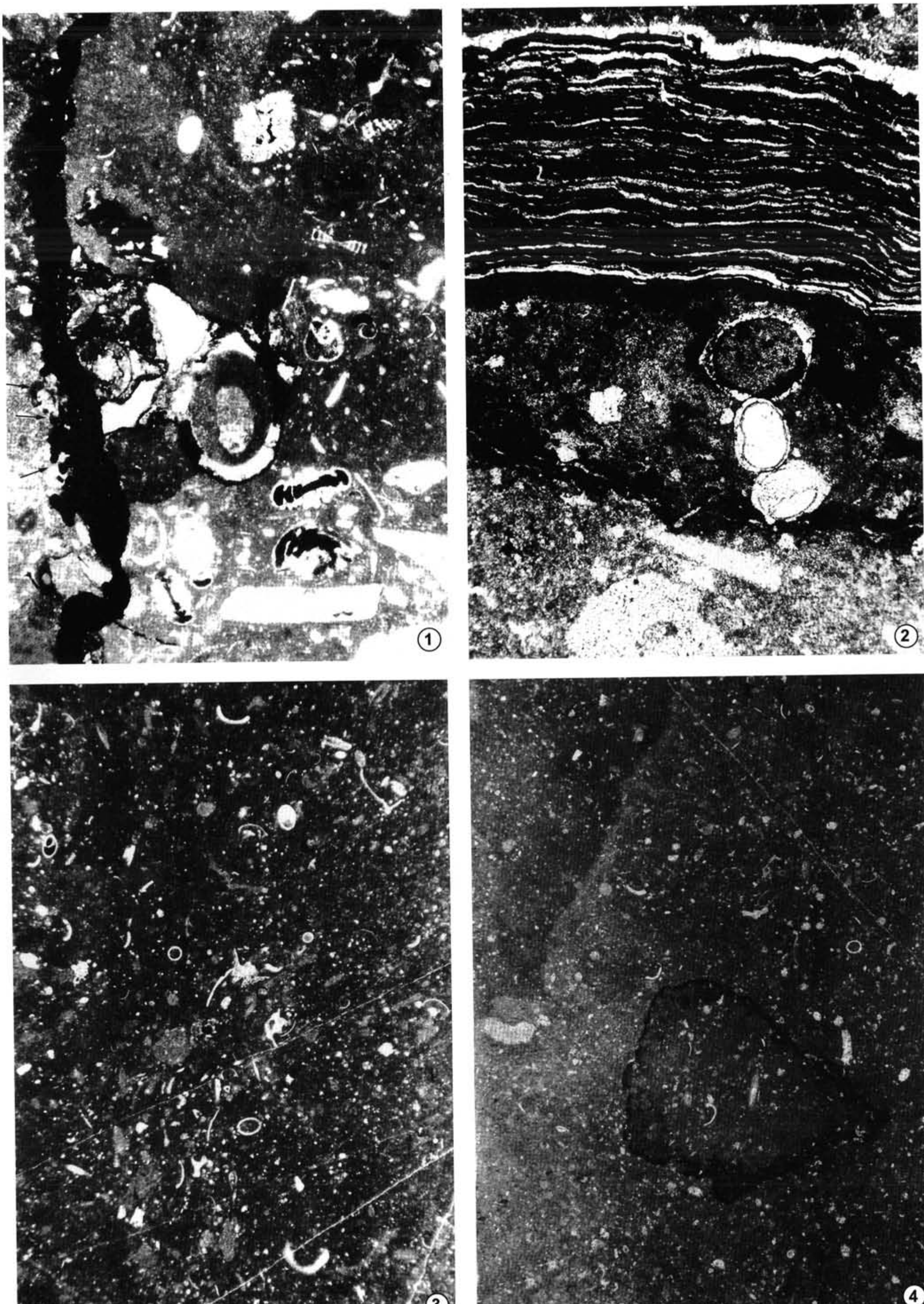
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Plate 11

Bioturbation structures

Fig. 1: The mottled bright-dark appearence of this type of the Schnöll-Fm., Guggen-Mb., is due to a high degree of bioturbation. By the bifurcating character of the burrows, they might be correlated to the ichnogenus *Chondrites*. Sample RGS 2; Schnöll Quarry; x 7.

Fig. 2: A different type of bioturbation structures is found in the Enzesfeld-Limestone. These burrows exhibit polyphase formation as shown by tiny Fe/Mn-coatings (arrow). From a main cavity 1 or 2 further burrows extend down into the sediment. Sample RGS Brand 14; "Marmorea Crust"; x 7.

Fig. 3: Two generations of burrows (1st generation: darker, big burrows, 2nd one smaller, bright ones) are to be indicated in this example of the Enzesfeld Limestone. Sample Lien HG I.1.; Lienbacher Quarry; x 7.

Fig. 4: Especially in the Schnöll-Fm. the burrows exhibit signs of rapid lithification, as indicated by stylolitization of their outlines. A nodular appearence of the rocks develops. Sample Spong 1b; Schnöll Quarry, sponge layer; x 10.

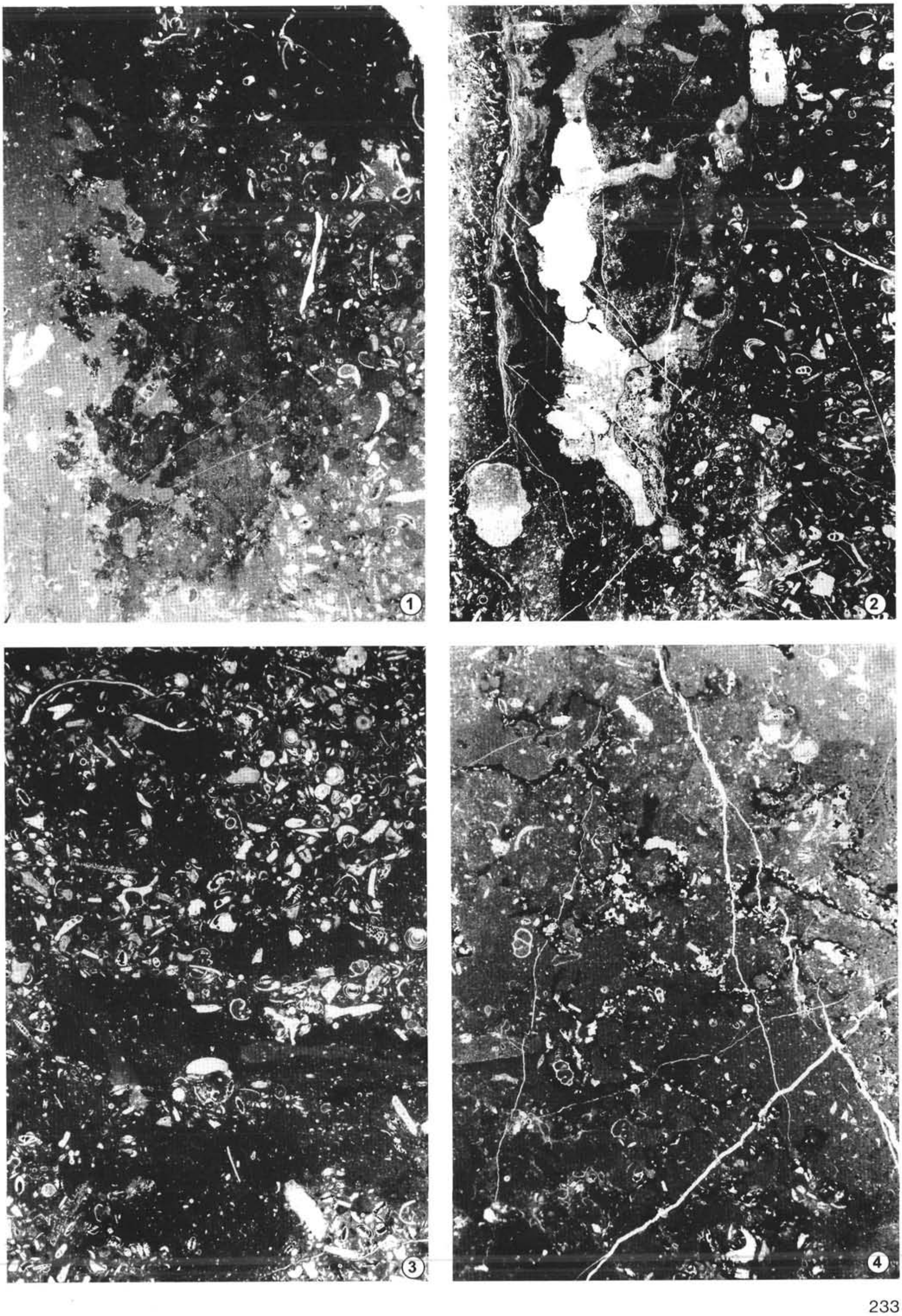
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Plate 12

SEM-photomicrographs

Fig. 1: Micrite, in part probably originating from disintegrated *Schizosphaerella* sp.; cf. Plate 13, Fig. 1, which shows likely grain sizes of *Schizosphaerella* as the finer grain fraction of this micrite. Sample AD 92/10A. Deisl Quarry (Quarry XLI), Scheck-Fm.

Fig. 2: Diagenetically recrystallized micrite to microsparite. Sample XVII-A. Großer Langmoos Quarry (Quarry XVII).

Fig. 3: Micrite with mica flake in the centre and sparry calcite void filling in the left side lower part. Sample AD 92/4B. Eisenmann Quarry (Quarry XXX); red basal Adnet Limestone.

Fig. 4: Micrite on left side of photomicrograph, on right side microsparitic blockly calcite fissure filling. Sample RGS 3/2. Schnöll Quarry (XXXI).

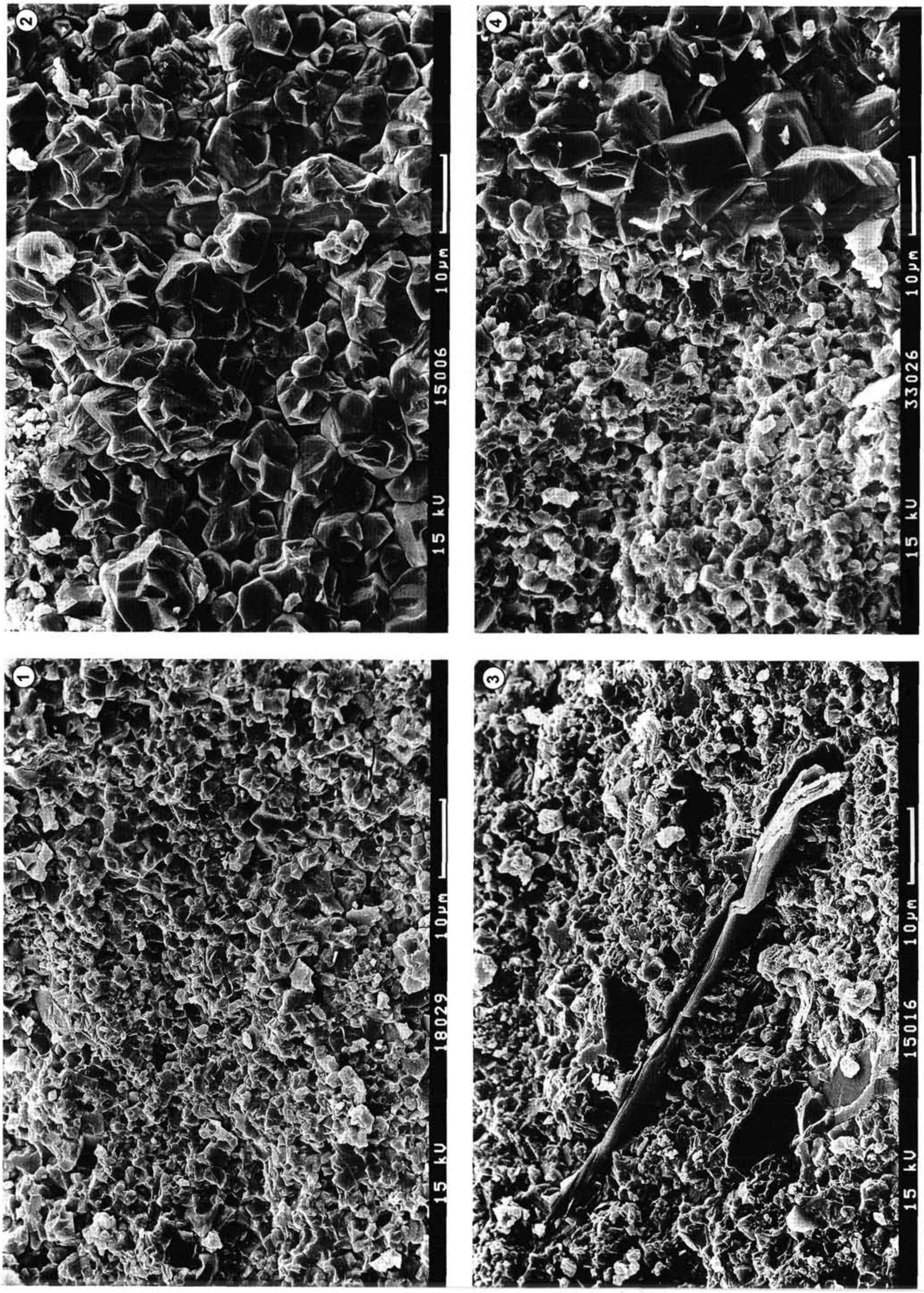
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Plate 13

SEM-photomicrographs

Fig. 1: Rock forming accumulation of *Schizosphaerella* sp. in otherwise micritic to microsparitic limestone. Sample AD/XII-A (Lienbacher Quarry).

Fig. 2: Micrite to microsparite with cast of *Schizosphaerella* sp. in the lower centre, above flake of phyllosilicate.

Fig. 3: Micrite to microsparite with internal cast of *Schizosphaerella* sp. Marmorea Crust in Schnöll Quarry; "Marmorea Crust". Sample AD 92/9c.

Fig. 4: Micrite/microsparite with remnants of *Schizosphaerella* sp., right side of photo, below flake of phyllosilicate and sparry calcite void filling. Sample AD 92/9D. Schnöll Quarry. "Marmorea Crust".

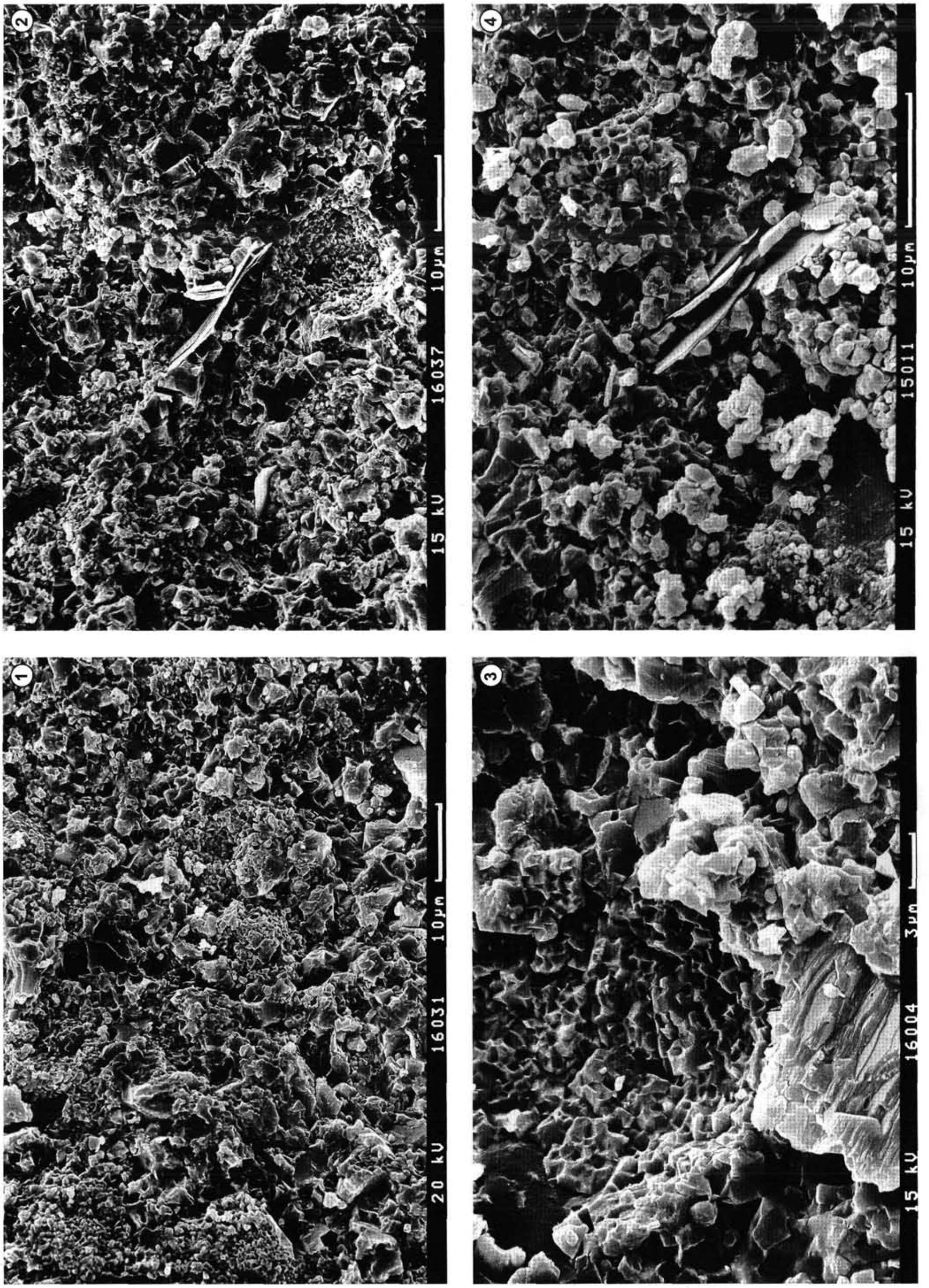

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Plate 14

Figs. 1, 2: *Globochaete alpina* LOMBARD, 1945. Sample XVII-A, Fig. 2 crossed polars; x 118.
Fig. 3: *Microproblematicum* 1. Sample RGS Spong 7a; x 88.
Fig. 4: *Muranella sphaerica* BORZA, 1975. Sample BGS; x 250.
Figs. 5, 6: *Microproblematicum* 2 SENOWBARI-DARYAN, 1980.
Fig. 5: Sample Sch Top; Scheck Quarry; "Scheck"; x 95;
Fig. 6: Sample RGS Spong 6b; Schnöll Quarry, sponge horizon; x 95.
Fig. 7: *Ammodiscus incertus* (D'ORBIGNY, 1839). Sample RGS HG III 3; Schnöll Quarry; x 270.
Fig. 8: *Glomospirella* sp. Sample Brand 3; Schnöll Quarry, "Marmorea Crust"; x 280.
Fig. 9: *Glomospira* sp. Sample Lien 4; Lienbacher Quarry; x 300.
Fig. 10: *Textularia* sp. 1 Sample RGS Brand 8; Schnöll Quarry, "Marmorea Crust"; x 100.
Fig. 11: *Textularia* sp. 2 Sample Lien HG I-5; Lienbacher Quarry; x 140.
Fig, 12: *Reophax* cf. *agglutinans* (TERQUEM, 1866a). Sample Sch 1; Quarry XXXI; see Text-Fig. 24 for sample position; x 80.
Fig. 13: *Reophax* cf. *densa* TAPPAN, 1955. Sample AD 12/4a; Lienbacher Quarry; x 135.

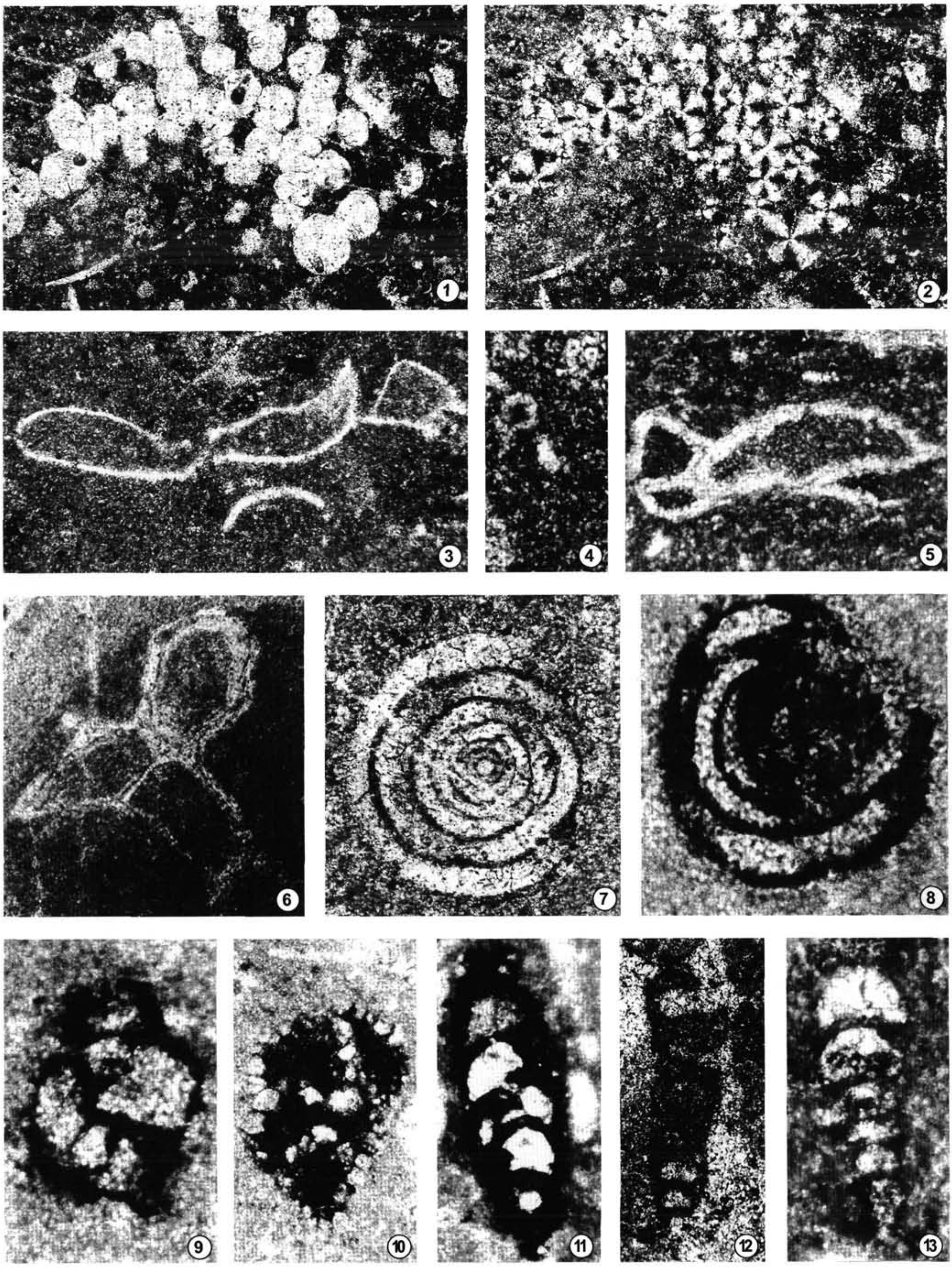
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Plate 15

Figs. 1–3: *Reophax* cf. *crispata* (TERQUEM, 1866b).
Figs. 1, 2 megalospheric Forms, Fig. 3 microspheric specimen.
Fig. 1: Sample RGS 1995-11; Schnöll Quarry; x 110;
Fig. 2: Sample Lien 6; Lienbacher Quarry; x 63;
Fig. 3: Sample Lien 4; Lienbacher Quarry; x 260.

Fig. 4: *Reophax* cf. *metensis* FRANKE, 1936. Sample HG III.1; Schnöll Quarry; x 205.

Fig. 5: *Ammobaculites zlambachensis* KRISTAN-TOLLMANN, 1964. Sample Brand 2; Schnöll Quarry, "Marmorea Crust" x 153.

Fig. 6: *Ammobaculites alaskensis* TAPPAN, 1955. Sample Sch 14; Quarry XXXI, grey packstones; see Text-Fig. 24 for sample position; x 170.

Fig. 7: ?*Placopsilina* sp. Sample RGS HG III.2; Schnöll Quarry; x 110.

Figs. 8–11: *Trochammina alpina* KRISTAN-TOLLMANN, 1957.
Fig. 8: Sample Lien HG I.5; tangential section; Lienbacher Quarry; x 470;
Fig. 9: Sample RGS HG III.1; section perpendicular to long axis; Schnöll Quarry; x 410;
Fig. 10: Sample Sch 1; longitudinal section; Quarry XXXI, grey packstones; see Text-Fig. 24 for sample position; x 110;
Fig. 11: Sample AD 16; longitudinal section; as Fig. 10; x 190.

Figs. 12–13: *Lingulina* sp. Fig. 12: Sample Spong 6a; x 185; Fig. 13: Sample RGS 7; Schnöll Quarry; x 210.

Figs. 14–16: *Lagena* sp.
Fig. 14: Sample RGS Brand 5; Schnöll Quarry, "Marmorea Crust"; x 190;
Fig. 15: Sample Brand 8; as Fig. 14; x 190;
Fig. 16: Sample Brand 14; as Fig. 14; x 215.

Fig. 17: *Involutina liassica* (JONES, 1853). The right specimen represents a strongly aberrant form. Sample Brand 8; as Fig. 14; x 56.

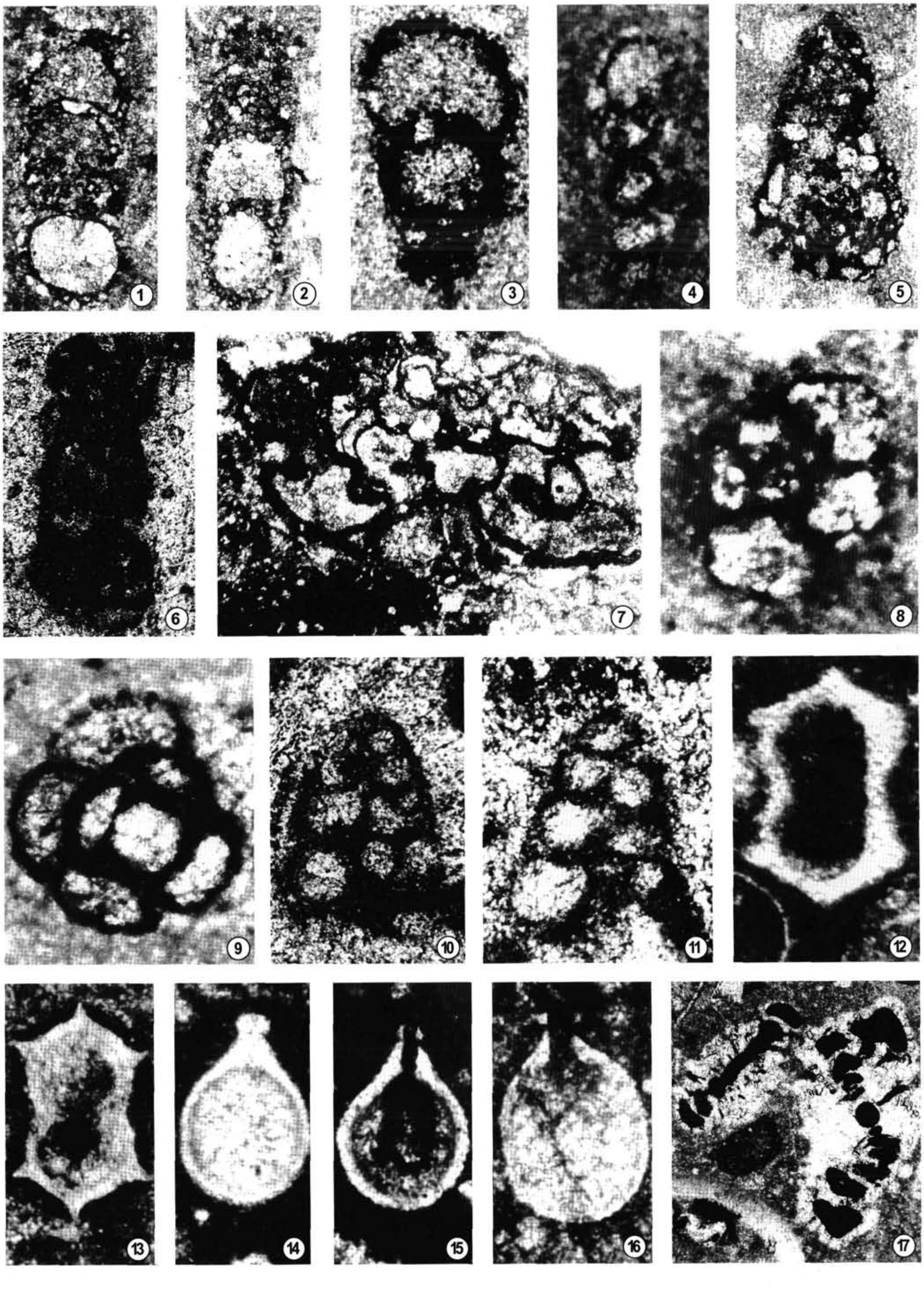
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Plate 16

Figs. 1–16: *Involutina liassica* (JONES, 1853)
Fig. 1: Sample RGS 7; Quarry XXXI; x 125.
Figs. 2, 3: Sample Lien HG I.3; Lienbacher Quarry; Fig. 2: x 170; Fig. 3: x 62.
Figs. 4, 11: Sample Lien HG I.2; Lienbacher Quarry; Fig. 4: x110; Fig. 11: x 100.
Figs. 5, 10: Sample RGS 8-2; Quarry XXXI; Fig. 5: x 135; Fig. 10: x 95.
Figs. 6, 7, 9: Sample Lien HG I.4; Lienbacher Quarry; Fig. 6: x 110; Fig. 7: x 100; Fig. 9: x 240.
Figs. 8, 16: Sample RGS Brand 3; Quarry XXXI, "Marmorea Crust"; x 110;
Fig. 12: Sample Lien HG I.1; Lienbacher Quarry; x 130.
Fig. 13: Sample Brand 11; Quarry XXXI, "Marmorea Crust"; x 130.
Fig. 14: Sample Brand 8; Quarry XXXI, "Marmorea Crust"; x 145.
Fig. 15: Sample XVII D; Langmoos Quarry; x 120.

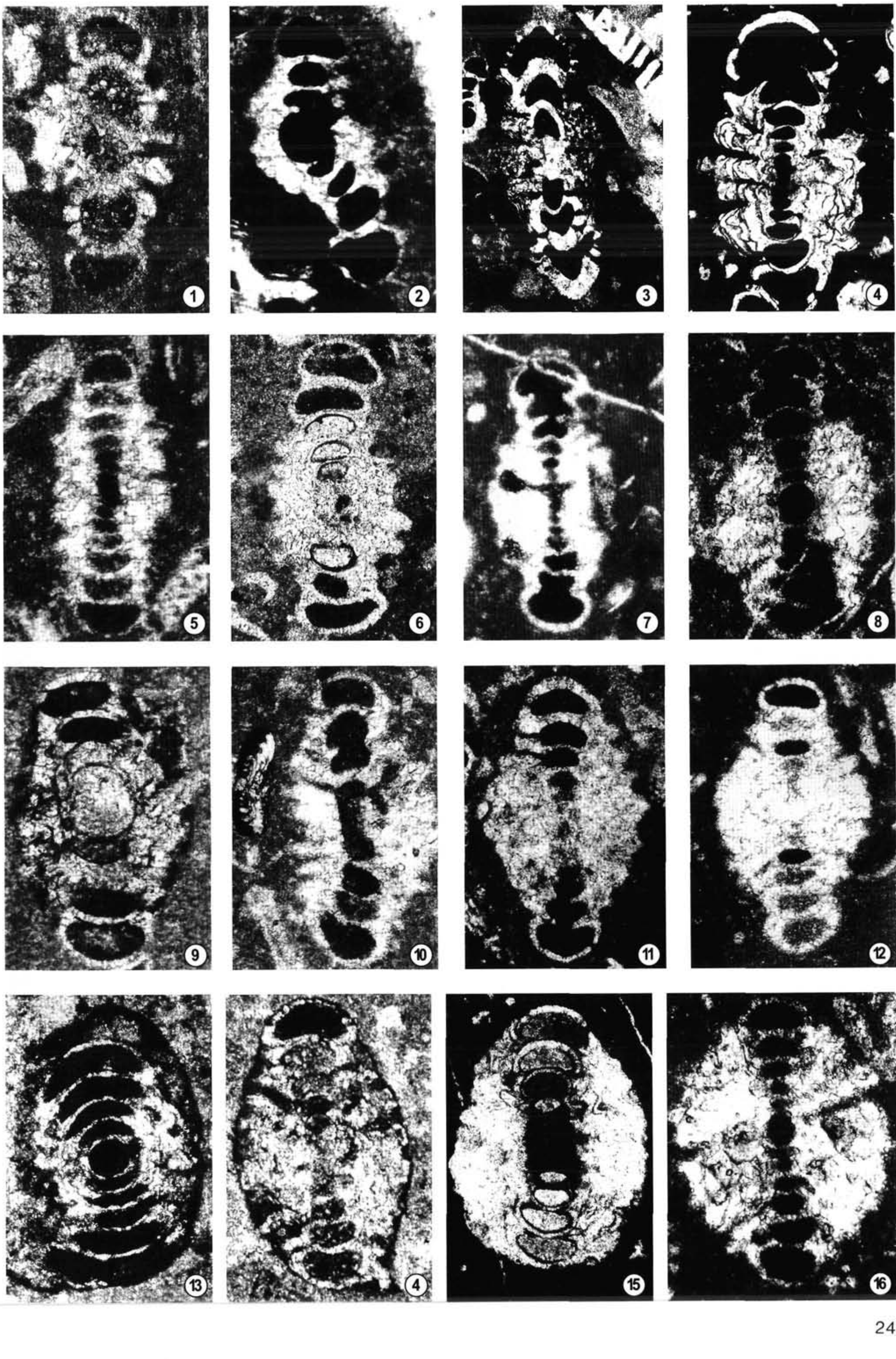
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Plate 17

Figs. 1–8: *Licispirella bicarinata* (BLAU, 1987 b)

Fig. 1: Sample RGS Spong 7; Quarry XXXI, sponge horizon; x 145.
Fig. 2: Sample Brand 2; Quarry XXXI, "Marmorea Crust"; x 117.
Fig. 3: Sample RGS Brand 14; x 145.
Figs. 4, 6: Sample Lien HG I.1; Lienbacher Quarry; Fig. 4: x 156; Fig. 6: x 116.
Fig. 5: Sample Lien HG I.2; Lienbacher Quarry; x 126.
Fig. 7: Sample Lien HG I.4; Lienbacher Quarry; x 23.
Fig. 8: Sample RGS Spong 5a; Quarry XXXI, sponge horizon; x 137.

Figs. 9–14: *Licispirella violae* (BLAU, 1987 b)

Fig. 9: Sample Lien HG I.4; Lienbacher Quarry; x 290.
Fig. 10: Sample Brand HG I.2; Quarry XXXI, "Marmorea Crust"; x 140.
Fig. 11: Sample Brand 7; Quarry XXXI, "Marmorea Crust"; x 158.
Figs. 12, 13: Sample Brand 3; Quarry XXXI, "Marmorea Crust"; Fig. 12: x 170; Fig. 13: x 150.
Fig. 14: Sample Brand 2; Quarry XXXI, "Marmorea Crust"; x 150.

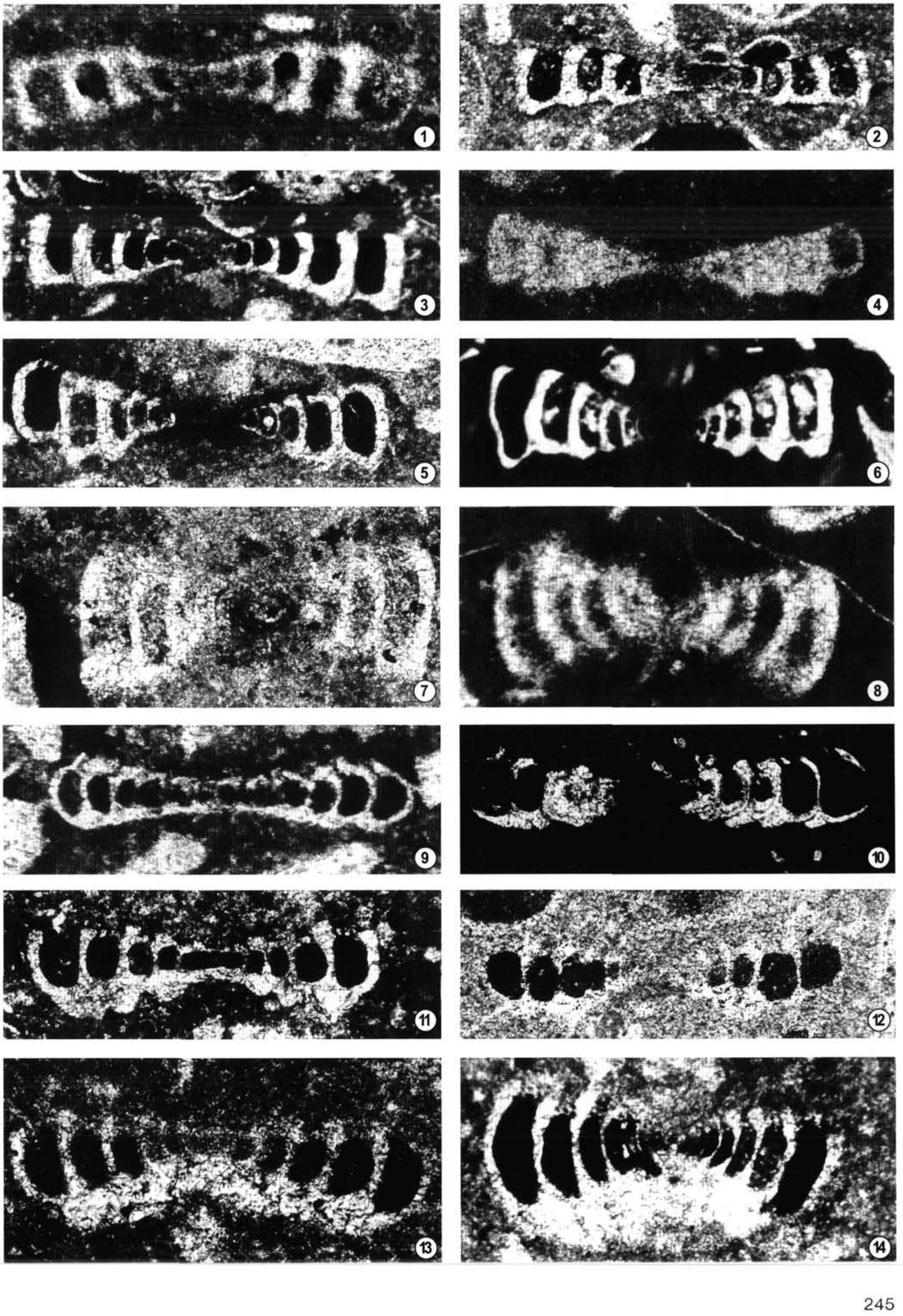
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Plate 18

Figs. 1–3: *Trocholina turris* FRENTZEN, 1941.
Fig. 1: Sample RGS HG III.2; Quarry XXXI; x 140;
Fig. 2: Sample RGS Brand 8; Quarry XXXI, "Marmorea Crust"; x 220;
Fig. 3: Sample RGS Brand 13; Quarry XXXI, "Marmorea Crust"; x 160.

Figs. 4–12: *Trocholina umbo* FRENTZEN, 1941
Figs. 4, 6, 11: Sample Lien HG I.1; Lienbacher Quarry; x 190.
Fig. 5: Sample Lien HG I.4; Lienbacher Quarry; x 150.
Fig. 7: Sample RGS HG III.2; Quarry XXXI, "Marmorea Crust"; x 150.
Figs. 8, 9, 10: Sample RGS Brand 4; Quarry XXXI, "Marmorea Crust"; Fig. 8: x 210; Fig. 9: x 175; Fig. 10: x 200
Fig. 12: Sample Lien HG I.2; Lienbacher Quarry; x 180.

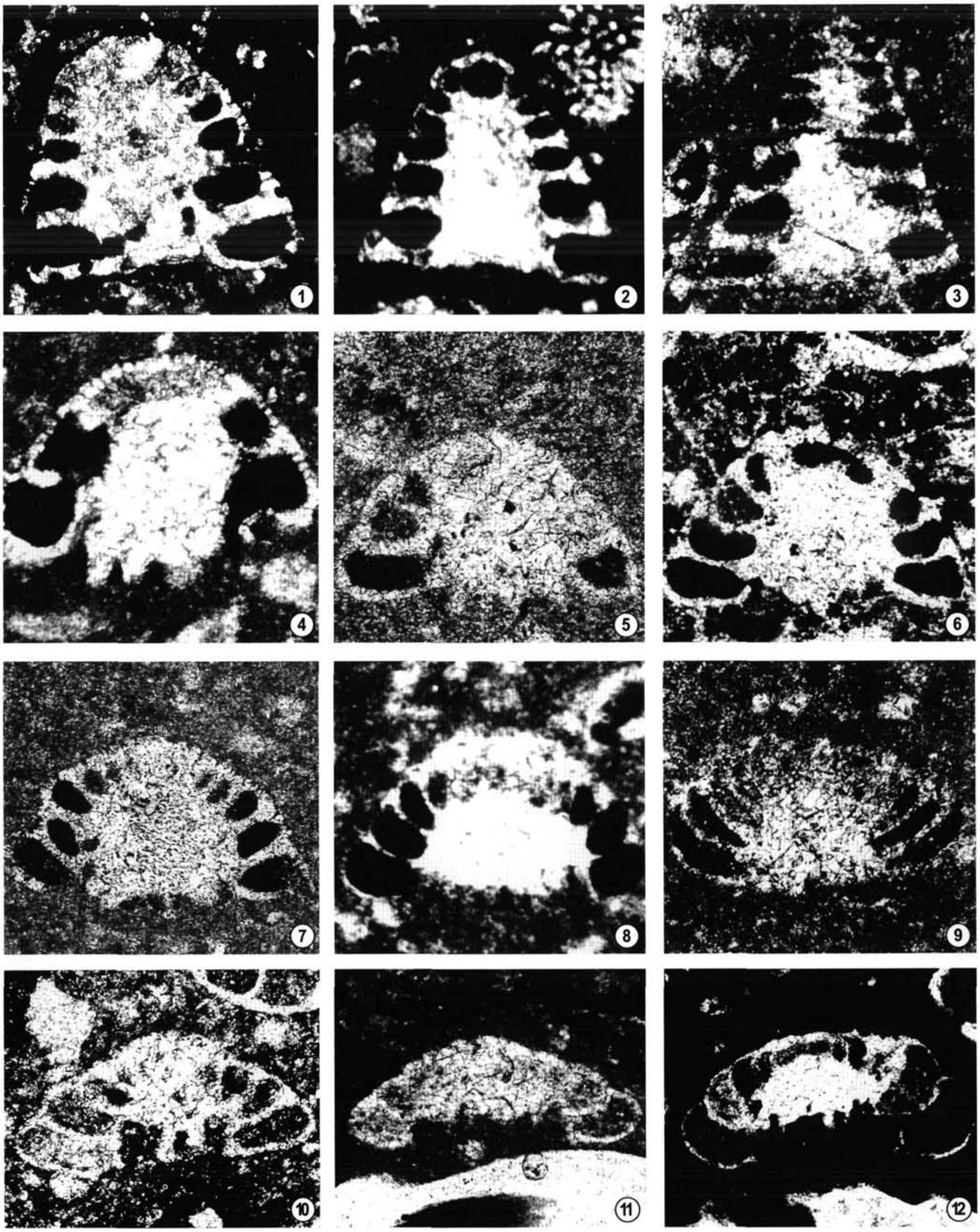
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Plate 19

Figs. 1–16: *Coronipora austriaca* (KRISTAN, 1957)
Figs. 1, 3, 8, 9, 12, 14: Sample XVII D; Langmoos Quarry;
Fig. 1: x 230;
Fig. 3: x 235;
Fig. 8: x 270;
Fig. 9: x 210;
Fig. 12: x 255;
Fig. 14: x 205.
Fig. 2: Sample Lien HG I. 2; Lienbacher Quarry; x 250.
Fig. 4: Sample RGS Brand 11; Quarry XXXI, "Marmorea Crust"; x 225.
Fig. 5: Sample Lien HG I.4; Quarry XXXI, "Marmorea Crust"; x 230.
Fig. 6: Sample Lien HG I.1; Lienbacher Quarry; x 205.
Figs. 7, 11: Sample RGS 8-2; Quarry XXXI; x 180.
Figs. 10, 13: Sample RGS Brand 12; Quarry XXXI, "Marmorea Crust"; Fig. 10: x 230; Fig. 13: x 315.
Fig. 15: Sample RGS Brand 14; Quarry XXXI, "Marmorea Crust"; x 295.
Fig. 16: Sample RGS Brand 8; Quarry XXXI, "Marmorea Crust"; x 180.

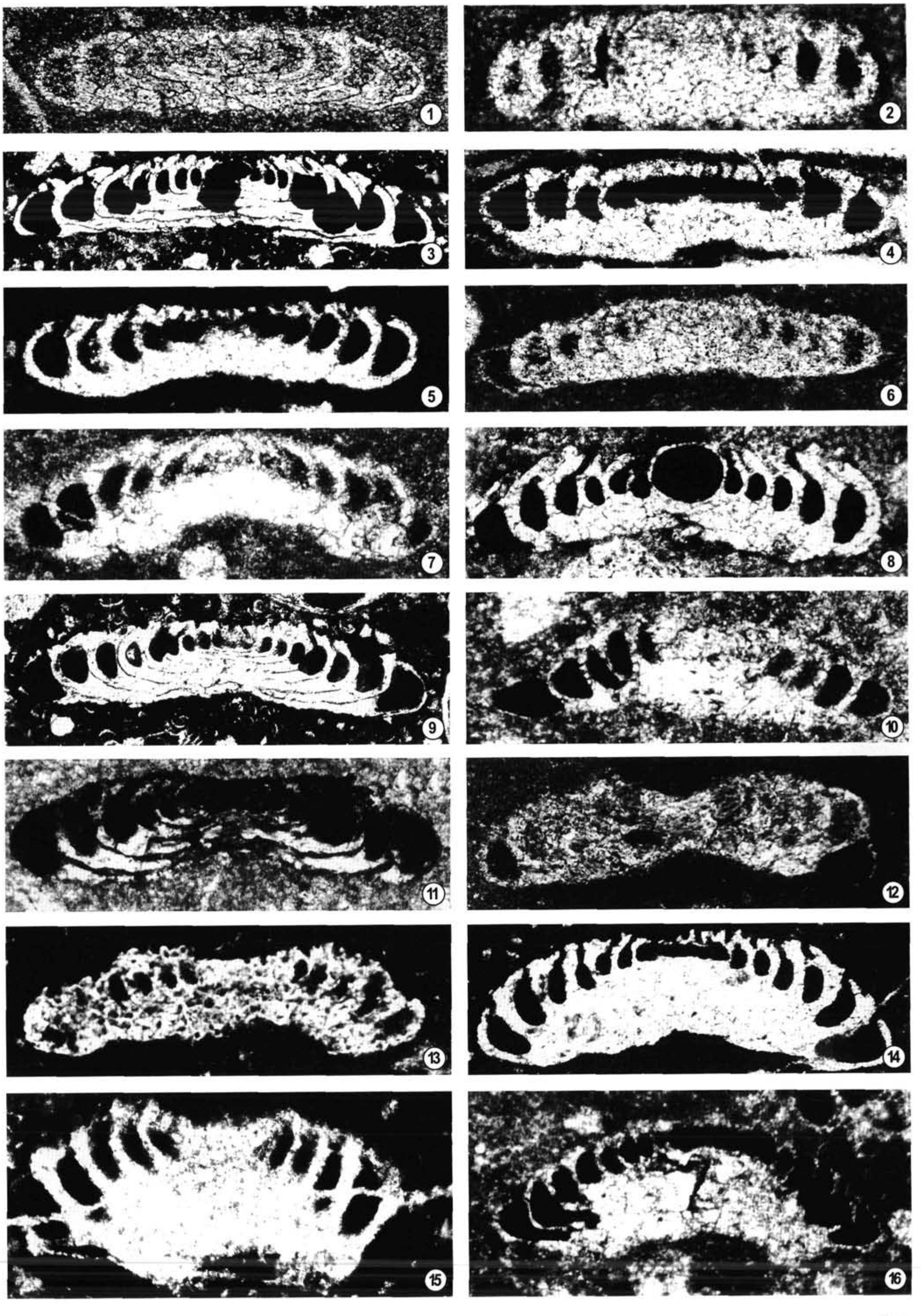
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Plate 20

Fig. 1: *Coronipora austriaca* (KRISTAN, 1957). Aberrant form. Sample Lien HG I.2; Lienbacher Quarry; x 220.
Fig. 2: aff. *Coronipora etrusca* (PIRINI, 1966). Sample RGS HG III.2; Quarry XXXI; x 230.
Fig. 3: *Piriniella blindi* BLAU, 1987a. Sample AD 92/2; Eisenmann Quarry (XXX), first (lowest) bed of Liassic sedimentation; x 150.
Figs. 4–10: *Semiinvoluta clari* KRISTAN, 1957.
Figs. 4, 5, 7: Sample RGS 4; Quarry XXXI;
Fig. 4: x 120;
Fig. 5: x 135;
Fig. 7: x 145.
Fig. 6: Sample RGS Spong 3b; Quarry XXXI, sponge horizon; x 135;
Fig. 8: Sample RGS 1; Quarry XXXI; x 150;
Fig. 9: Sample Spong 1; Quarry XXXI, sponge horizon; x 120;
Fig. 10: Sample RGS Brand 1; Quarry XXXI, "Marmorea Crust"; x 210.

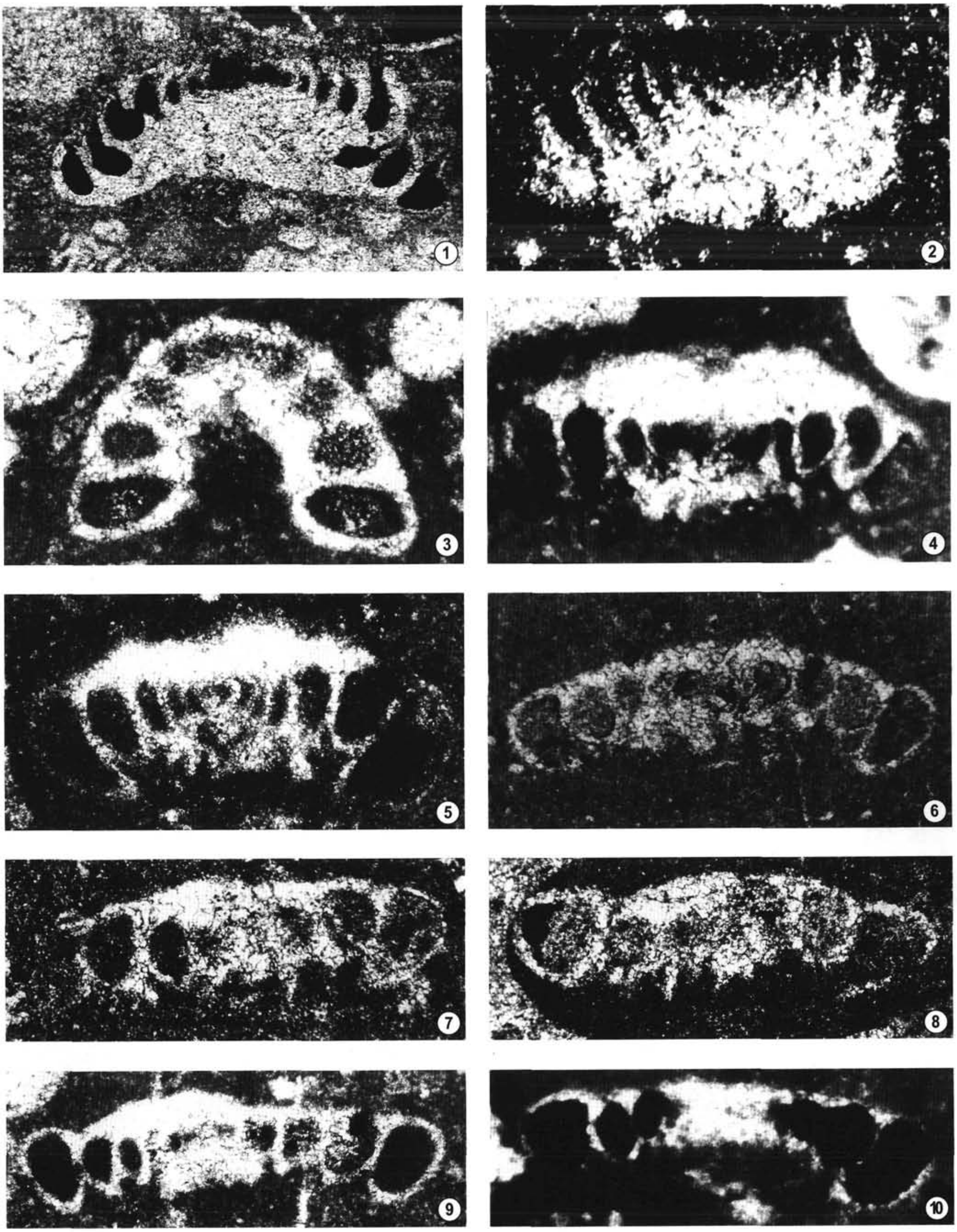
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Plate 21

Figs. 1–4: *Semiinvoluta clari* KRISTAN, 1957.
Fig. 1: Sample RGS Brand 3; Quarry XXXI, "Marmorea Crust"; x 135;
Fig. 2: Sample RGS HG III.2; Quarry XXXI; x 135;
Fig. 3: Sample RGS 1995-3; Quarry XXXI; x 120;
Fig. 4: Sample RGS Spong 2b; Quarry XXXI, sponge horizon; x 180.
Figs. 5–6: cf. *Semiinvoluta clari* KRISTAN, 1957.
Figs. 5, 6: Sample RGS 8/2; Quarry XXXI;
Fig. 5: x 250;
Fig. 6: x 220.
Fig. 7: *Ophthalmidium carinatum* (KÜBLER & ZWINGLI, 1866). Sample Lien HG I.1; Lienbacher Quarry; x 230.
Figs. 8–9: *Ophthalmidium leischneri* (KRISTAN-TOLLMANN, 1962).
Fig. 8: Sample Lien HG I.4; Lienbacher Quarry; x 290;
Fig. 9: Sample Lien HG I.1; Lienbacher Quarry; x 220.
Fig. 10: *Ophthalmidium martanum* (FARINACCI, 1959). Sample RGS Brand 5; Quarry XXXI, "Marmorea Crust"; x 220.
Fig. 11: Nubeculariidae gen. et sp. indet. Sample Sch 14; Quarry XXXI, grey packstones, see Text-Fig. 24 for sample position; x 135.
Figs. 12, 13: *Bullopora tuberculata* (SOLLAS, 1877).
Fig. 12: Sample RGS Spong 1; Quarry XXXI, sponge horizon; x 60;
Fig. 13: Sample RGS Brand 1; Quarry XXXI, "Marmorea Crust"; x 50.

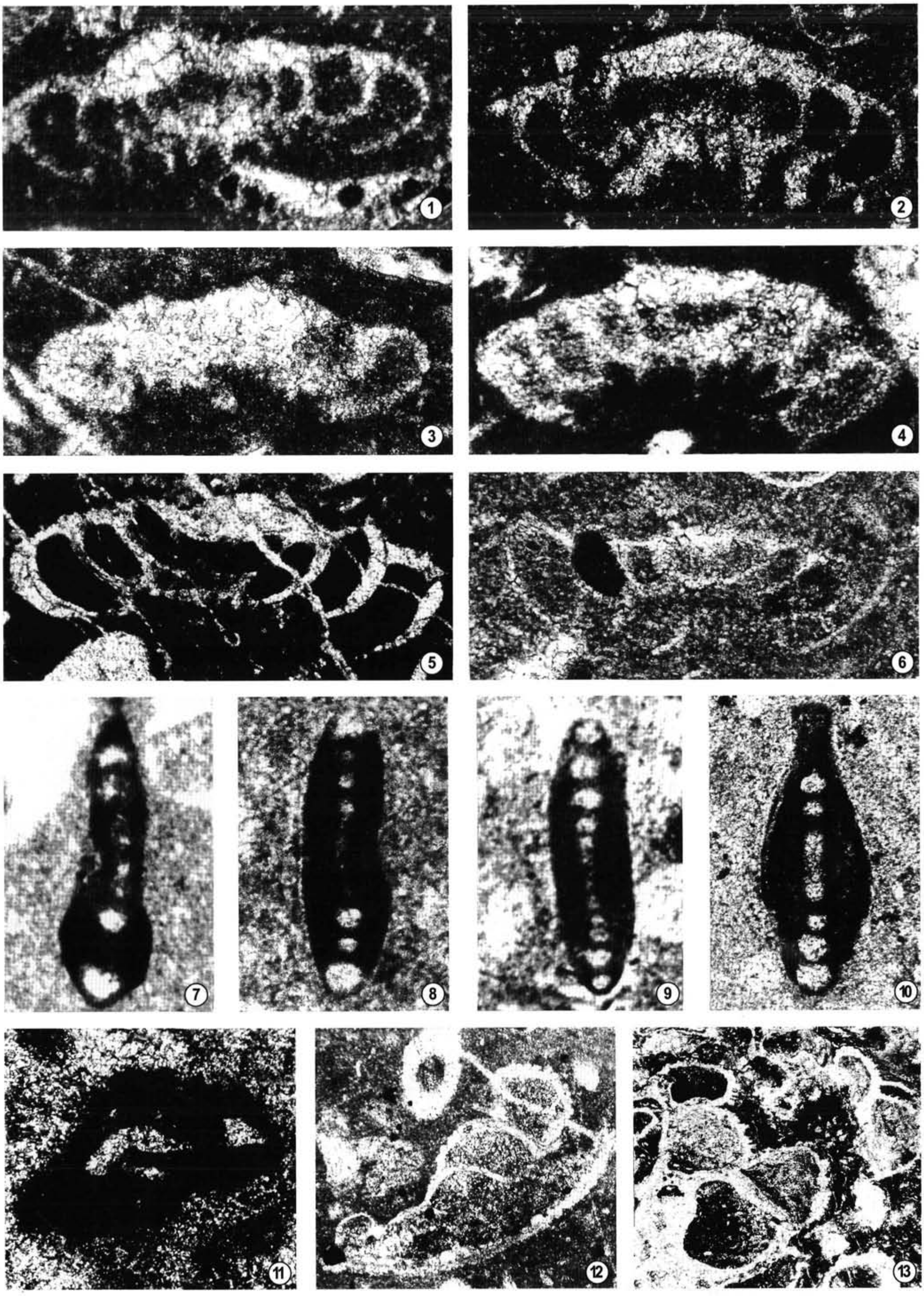
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Plate 22

Figs. 1–15: *Planiinvoluta carinata* LEISCHNER, 1961
Fig. 1: Sample RGS 7; Quarry XXXI; x 70
Fig. 2: Sample XVII A; Langmoos Quarry; x 96.
Fig. 3: Sample VXII B; Langmoos Quarry; x 110.
Figs. 4, 13: Sample RGS 8-3; Quarry XXXI; x 95.
Fig. 5: Sample Spong 9; Quarry XXXI, sponge horizon; x 130.
Fig. 6: Sample RGS 3; Quarry XXXI; x 100.
Fig. 7: Sample Spong 3a; Quarry XXXI, sponge horizon; x 85.
Fig. 8: Sample Spong 8; Quarry XXXI, sponge horizon; x 95.
Figs. 9, 10: Sample Spong 4a; Quarry XXXI, sponge horizon; x 95.
Figs. 11, 15:Sample Spong 5b; Quarry XXXI, sponge horizon; x 85.
Fig. 12: Sample RGS 4; Quarry XXXI; x 160.
Fig. 14: Sample RGS Spong 2b; Quarry XXXI, sponge horizon; x 125.

Fig. 16: *Nodophthalmidium* sp. Sample RGS Spong 4b; Quarry XXXI, sponge horizon; x 110.

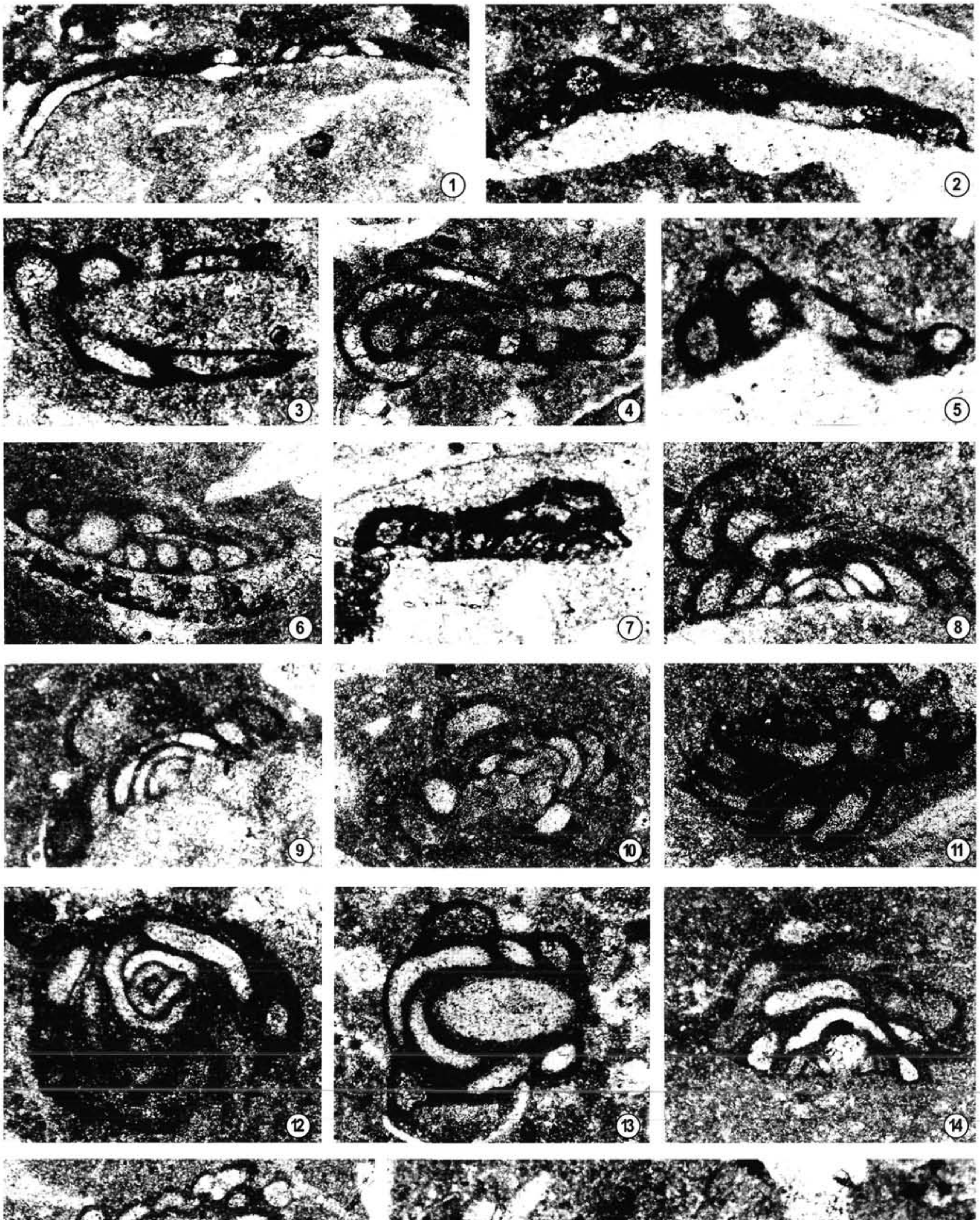
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Plate 23

Figs. 1, 2: *Bullopora* sp.
Fig. 1: Sample RGS Brand 1; x 135; Schnöll Quarry, "Marmorea Crust"; Fig. 2: Sample Lien HG I.4; x 66; Lienbacher Quarry.
Figs. 3–9: Borings
Fig. 3: Morphotype 1 ("spotted"). Sample RGS 1995-3; x 20; Schnöll Quarry.
Figs. 4–5: Morphotype 2 (unbranched, elongated).
Fig. 4: Sample RGS Brand 13; x 60;
Fig. 5: Sample Adnet XIV; x 60.
Figs. 6–9: Morphotype 3 (branched) – dichothom: Figs. 6-7: Fig. 6: Sample Lien HG I.1; x 60; Lienbacher Quarry.
Fig. 7: Sample RGS Brand 5; x 77; Schnöll Quarry, "Marmorea Crust".
– rectangular: Fig. 8: Sample Lien HG I.1; x 50; Lienbacher Quarry.
– zig-zag: Fig. 9: Sample RGS 7; x 60; Schnöll Quarry.
Figs. 10–11: Burrows and trails.
Fig. 10: *Chondrites recurvus* (BRONGNIART, 1823) STERNBERG, 1833. Sample Lien HG I; x 50; Lienbacher Quarry.
Fig. 11: Ichnogen. et ichnosp. indet. Sample Brand-Ichn.; x 4,2; Schnöll Quarry, "Marmorea Crust".

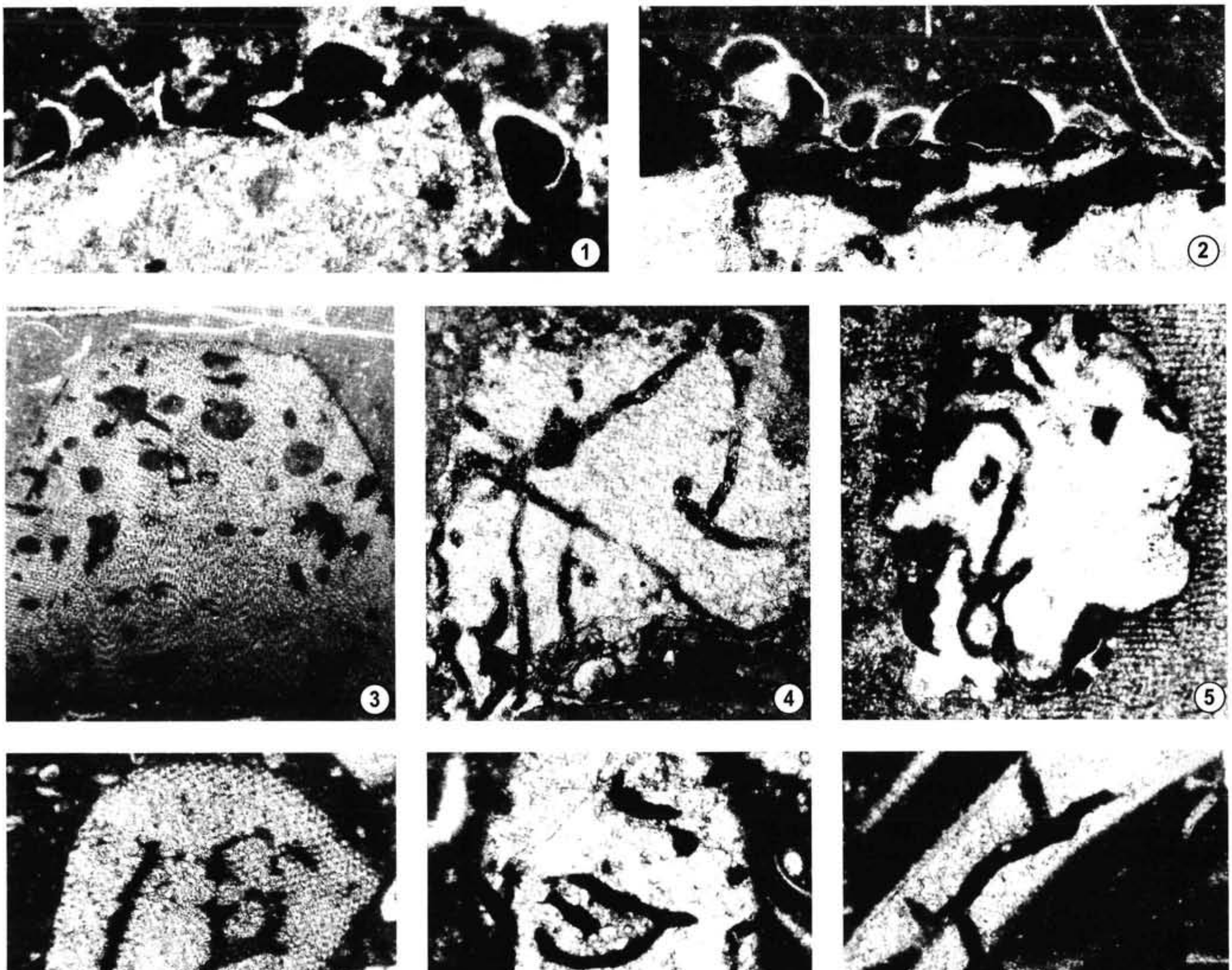
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Plate 24

Fig. 1: *Togaticeras stella* (Sow.), phragmocone with partly preserved body chamber. GBA, STUR's collection, Adnet locality, Schnöll Quarry, condensed horizon – "Marmorea Crust" ("Brandschicht"), Late Hettangian, "Marmorea" Zone, natural size.

Fig. 2: *Zetoceras complanatum* (VADÁSZ), phragmocone, GBA collection , Adnet locality, Lienbacher Quarry, bed n°5, Early Sinemurian, Semicostatum Zone, 1x.

Fig. 3: *Cenoceras schlumbergeri* (TERQ.), GBA collection , Adnet locality , Langmoos Quarry, "Marmorea Crust" ("Brandschicht"), Middle – Late Hettangian, Liasicus to "Marmorea" Zones, slightly enlarged.

Fig. 4: *Phylloceras psilomorphum* NEUM., GBA, STUR's collection , Adnet locality, Schnöll Quarry, "Marmorea Crust" ("Brandschicht"), Middle – Late Hettangian, Liasicus to "Marmorea" Zones, slightly enlarged.

Fig. 5: *Kammerkarites euptychus* (WÄHNER), author's collection, plaster cast, Adnet locality, Schnöll Quarry, sponge horizon, Middle Hettangian, Liasicus Zone, 0,5x.

Fig. 6: *Analytoceras articulatum* (Sow.), GBA, STUR's collection, Adnet locality, Schnöll Quarry, "Marmorea Crust" ("Brandschicht"), Middle – Late Hettangian, Liasicus to "Marmorea" Zones, slightly enlarged.


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Plate 25

Fig. 1: *Kammerkarites kammerkarensis* (GÜMBEL), phragmocone, GBA, STUR's collection n°406, Adnet locality, Schnöll Quarry, "Marmorea Crust" ("Brandschicht"), Middle Hettangian, Liasicus Zone, natural size.

Figs. 2, 3: *Kammerkarites calcimontanus* (WÄHNER), GBA collection, Adnet locality, Langmoos Quarry, "Marmorea Crust" ("Brandschicht"), Middle Hettangian, Liasicus Zone.
Fig. 2: natural size.
Fig. 3: is the same specimen with enlarged internal whorls, 2x.

Fig. 4: *Kammerkarites calcimontanus* (WÄHNER), GBA, STUR's collection n°408, Adnet locality, Schnöll Quarry, "Marmorea Crust" ("Brandschicht"), Middle Hettangian, Liasicus Zone, natural size.

Fig. 5: *Angulaticeras* aff. *angustisulcatum* (GEYER), GBA, STUR's collection n°567, Adnet locality, quarry unknown, Sinemurian, probably Oxynotum Zone, 0,5x.

Fig. 6: *Geyeroceras cylindricum* (SOW.), GBA collection, Adnet locality, Lienbacher Quarry, "Marmorea Crust" ("Brandschicht"), Late Hettangian "Marmorea" Zone, 0,5x.

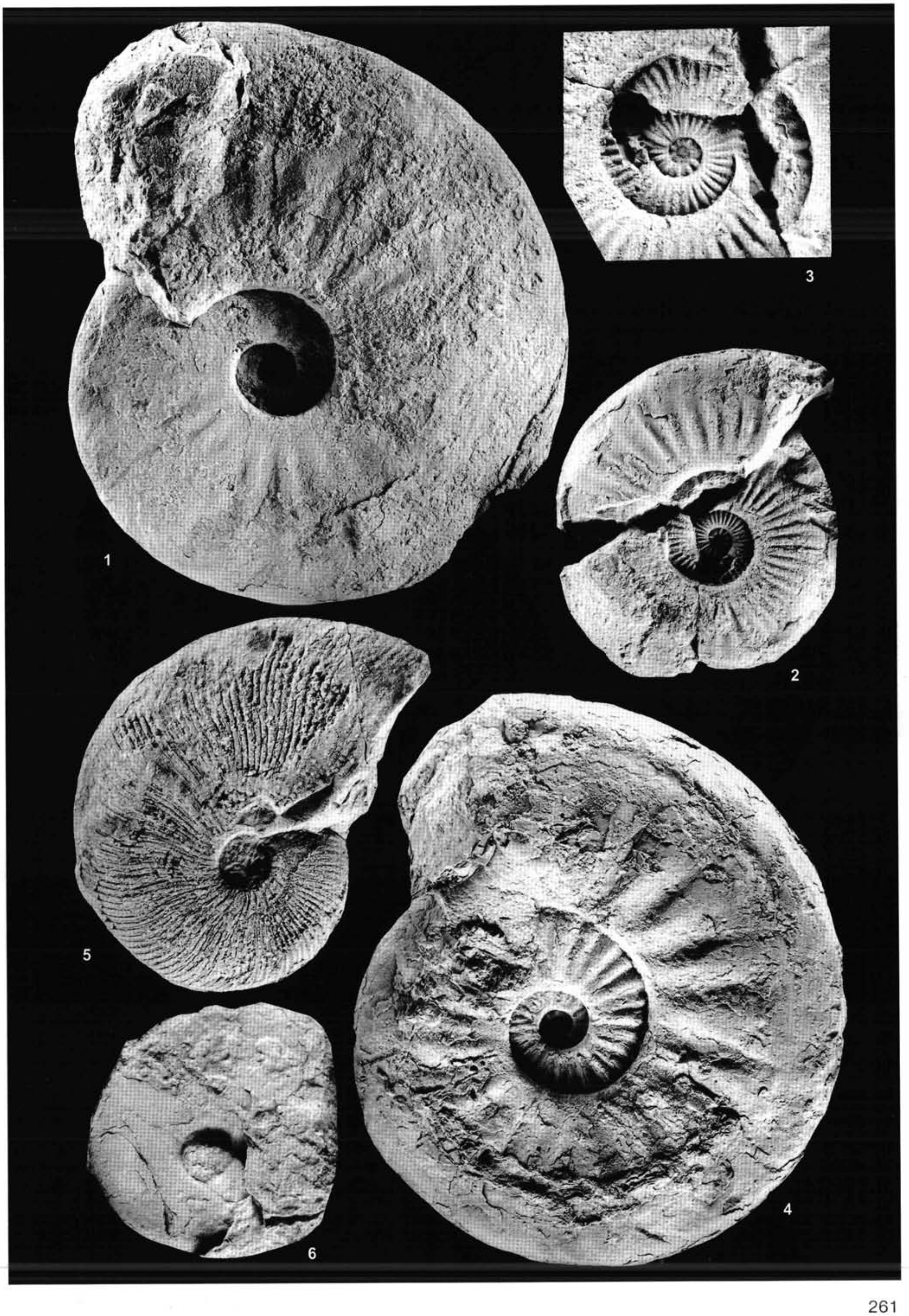
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Plate 26

Fig. 1: *Angulaticeras marmoreum* (OPPEL), phragmocone with body chamber partly preserved, GBA, STUR's collection n°385, Adnet locality, Schnöll Quarry, "Marmorea Crust" ("Brandschicht"), Late Hettangian, "Marmorea" Zone, slightly diminished.

Figs. 2, 3: *Schlotheimia donar* (WÄHNER), GBA, STUR's collection , Adnet locality, "Marmorea Crust" ("Brandschicht"), Late Hettangian, "Marmorea" Zone, 0,5x.

Fig. 4: *Schlotheimia* cf. *exoptycha* (WÄHNER), GBA collection, Adnet locality, Langmoos Quarry, "Marmorea Crust" ("Brandschicht"), ? Middle – Late Hettangian, Liasicus to "Marmorea" Zones, natural size.


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Plate 27

Fig. 1: *Paracaloceras haueri* (GÜMBEL), phragmocone, GBA, STUR's collection, Adnet locality, Schnöll Quarry, "Marmorea Crust" ("Brandschicht"), Late Hettangian, "Marmorea" Zone, 0,2x.

Fig. 2: *Angulaticeras* sp. juv., GBA collection, Adnet locality, Lienbacher Quarry, red limestones above "Marmorea Crust" Sinemurian, ?Semicostatum Zone, 3x.

Fig. 3: *Paracaloceras* gr. *coregorense* (SOW.), juvenile specimen, GBA collection , Adnet locality, Lienbacher Quarry, "Marmorea Crust" ("Brandschicht"), Late Hettangian, "Marmorea" Zone, slightly enlarged.

Fig. 4: *Vermiceras (Gyrophioceras) perspiratum* (WÄHNER), phragmocone, GBA, STUR's collection, Adnet locality, probably Schnöll Quarry in grey-reddish weakly crinoidal limestones above the "Marmorea Crust" ("Brandschicht"), ? Late Hettangian, "Marmorea" Zone, 0,3x.

Fig. 5: *Paracaloceras grunowi* (HAUER), GBA, HAUER's collection n°1856/01/12 = Lectotype (cf. HAUER, 1856, Pl. 8, Fig. 4-6 and WÄHNER, 1882, Pl. 25, Fig. 2a-d), Adnet locality, most probably Schnöll Quarry, "Marmorea Crust" ("Brandschicht"), Late Hettangian, "Marmorea" Zone.

Fig. 6: *"Alsatites" orthoptychus* (WÄHNER) and *Schlotheimia* gr. *donar* (WÄHNER), GBA collection, Adnet locality, Langmoos Quarry, "Marmorea Crust" ("Brandschicht"), ? Middle Hettangian, Liasicus Zone, natural size.

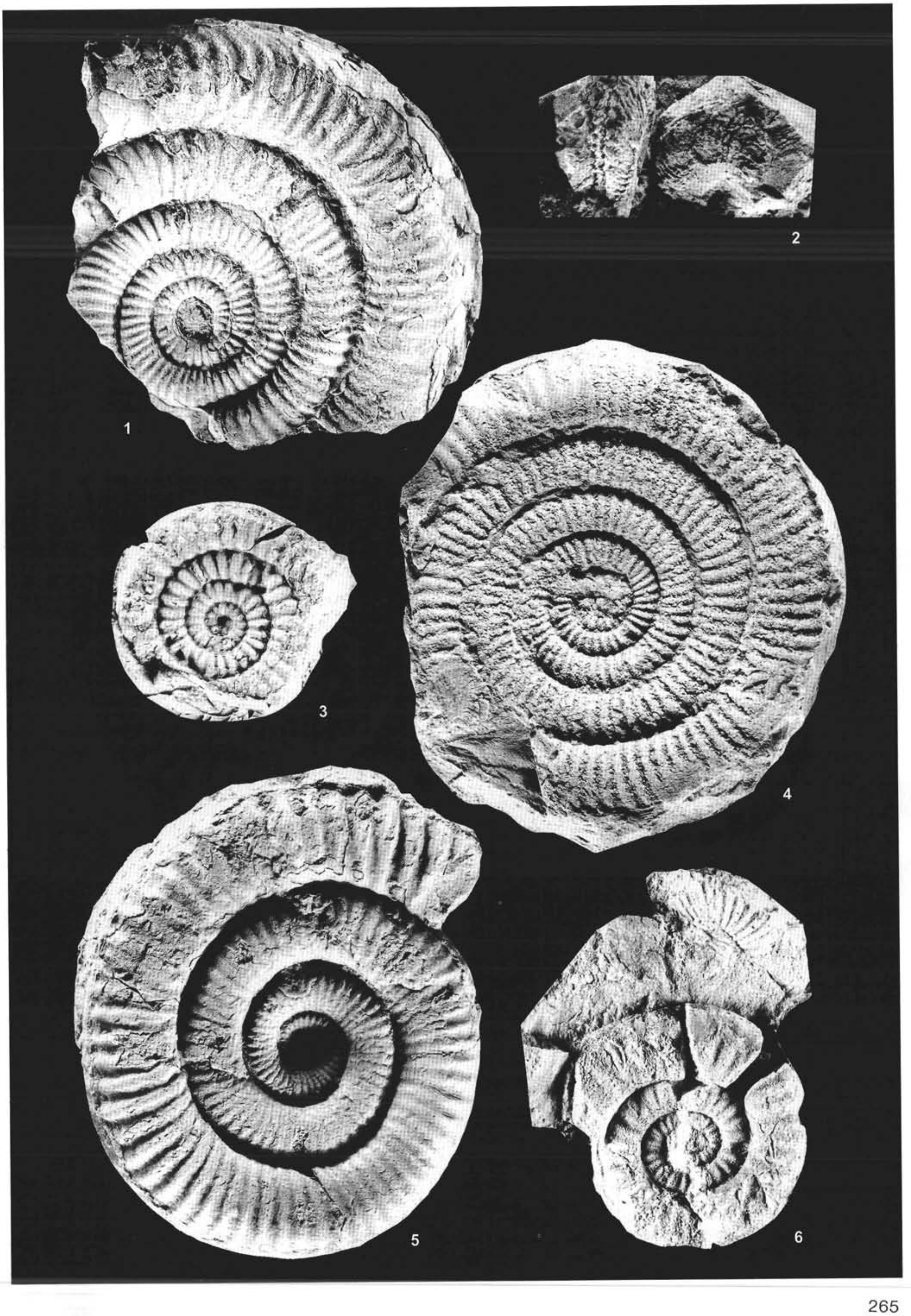
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Plate 28

Fig. 1: *Alsatites liasicus* (sensu WÄHNER), GBA collection n°1856/01/9 (= WÄHNER, 1887, Pl. 10, Fig. 3), Adnet locality, probably Schnöll Quarry, "Marmorea Crust" ("Brandschicht"), Middle Hettangian, Liasicus Zone, 0,4x.

Fig. 2: *Ectocentrites petersi* (HAUER), GBA, STUR's collection, Adnet locality, Schnöll Quarry, "Marmorea Crust" ("Brandschicht"), Late Hettangian, "Marmorea" Zone, natural size.

Fig. 3: *Tmaegoceras latesulcatum* (HAUER), GBA, HAUER's collection n°1856/01/27 = Lectotype (cf. HAUER, 1856, Pl. 9, Fig. 1-3), Adnet locality, quarry unknown, Lower Sinemurian, probably Semicostatum Zone, 0,2x.

Fig. 4: *Adnethiceras adnethicum* (HAUER), GBA, STUR's collection , Adnet locality, quarry unknown, Sinemurian, ?Semicostatum Zone, natural size.

Fig. 5: *Kammerkaroceras guidonii* (SOWERBY), GBA, STUR's collection , Adnet locality, Schnöll Quarry, "Marmorea Crust" ("Brandschicht"), Late Hettangian, "Marmorea" Zone, natural size.


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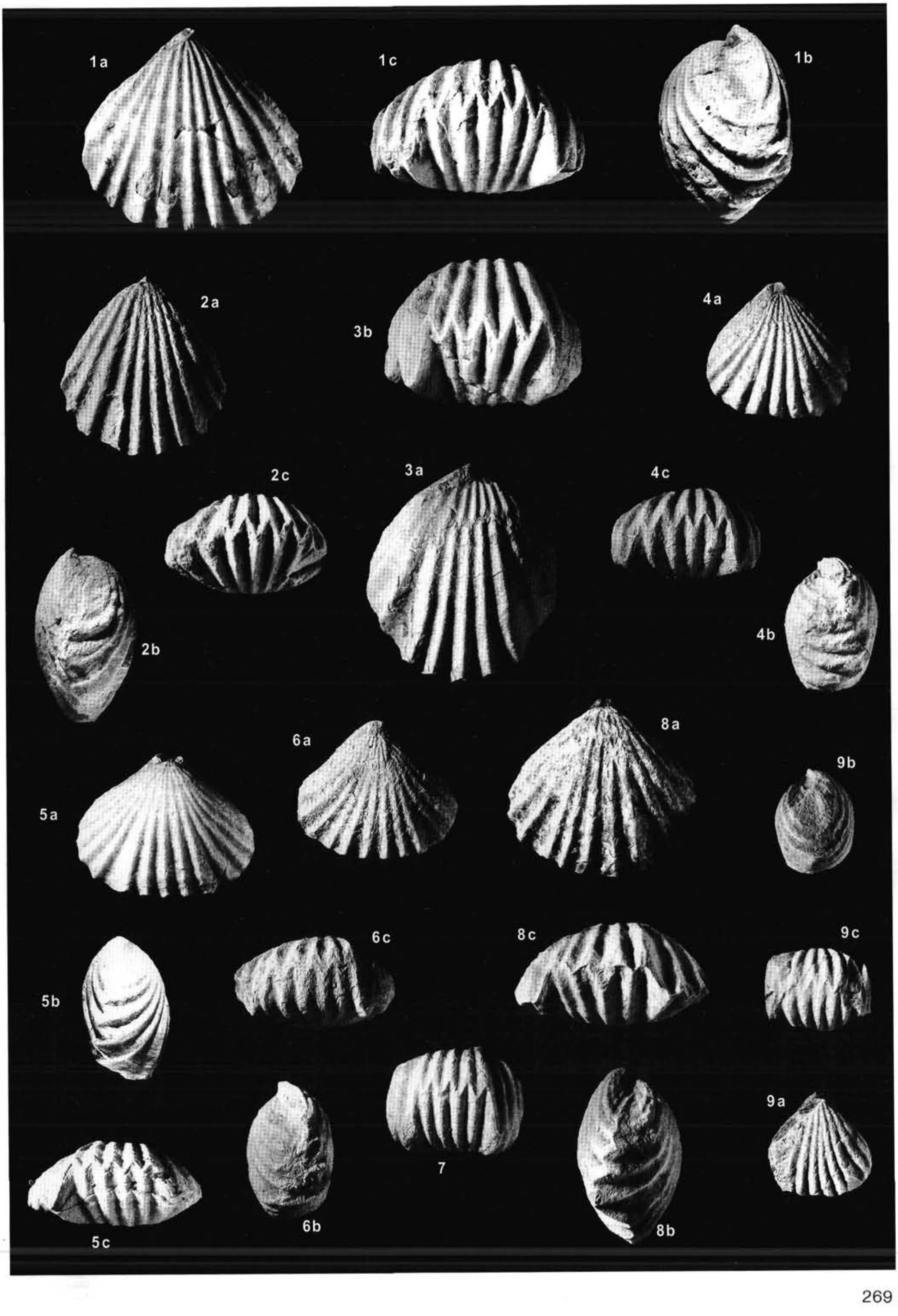
Plate 29

Fig. 1: *Cirpa* aff. *latifrons* (GEYER). Locality 2a. Collection of the Geologische Bundesanstalt Wien (Museum). GBA no.1995/3/1. Magnified, x 2.
Fig. 2: *Prionorhynchia greppini* (OPPEL). Locality 2a. GBA no.1995/3/2. x 2.
Fig. 3: *Cirpa* aff. *latifrons* (GEYER) Locality 2a. GBA no.1995/3/3. x 2.
Fig. 4: *Calcirhynchia (?) plicatissima* (QUENSTEDT). Locality 2a. GBA no.1995/3/4. x 2.
Fig. 5: *Cirpa (?) latifrons* (GEYER). Locality 2a. GBA no.1995/3/5. x 2.
Fig. 6: *"Rhynchonella"* ex gr. *zugmayeri* GEMMELLARO. Locality 2a. GBA no.1995/3/6. x 2.
Fig. 7: *Cirpa planifrons* (ORMÓS). Locality 2a. GBA no.1995/3/7. x 2.
Fig. 8: *Prionorhynchia greppini* (OPPEL). Locality 2a. GBA no.1995/3/8. x 2.
Fig. 9: *Cirpa planifrons* (ORMÓS). Locality $5a_1$. GBA no.1995/3/9. x 2.

All specimens were coated with ammonium chloride before photographing.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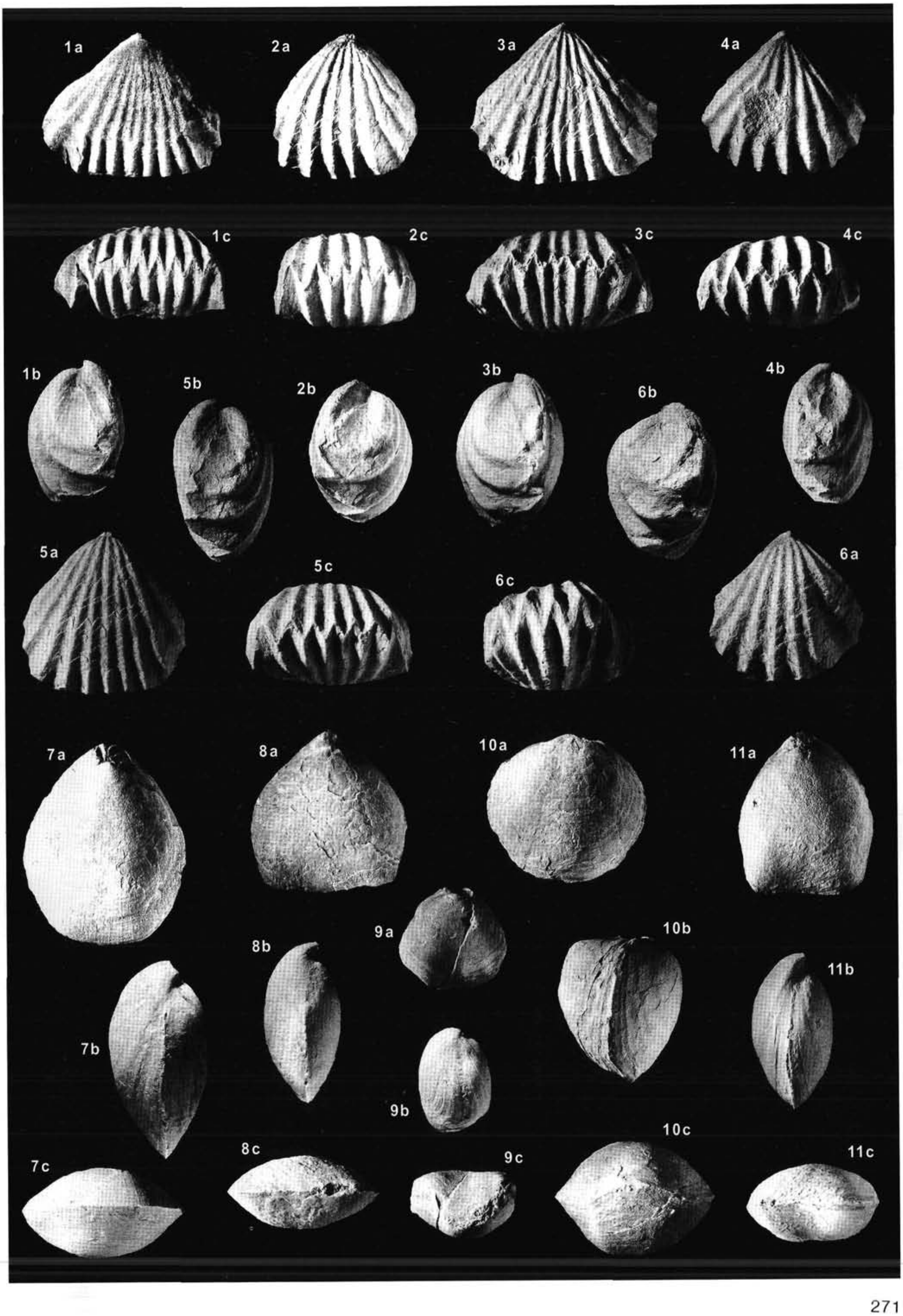
6b
8b

Plate 30

Fig. 1: *Prionorhynchia fraasi* (OPPEL). Locality 5a. GBA no.1995/3/10. Magnified, x 2.
Fig. 2: *Prionorhynchia fraasi* (OPPEL). Locality 2a. GBA no.1995/3/11. x 2.
Fig. 3: *Prionorhynchia fraasi* (OPPEL). Locality 2a. GBA no.1995/3/12. x 2.
Fig. 4: *Prionorhynchia fraasi* (OPPEL). Locality 2a. GBA no.1995/3/13. x 2.
Fig. 5: *Prionorhynchia fraasi* (OPPEL). Locality 2a. GBA no.1995/3/14. x 2.
Fig. 6: *"Rhynchonella"* ex gr. *belemnitica* (QUENSTEDT). Locality 5a. GBA no.1995/3/15. x 2.
Fig. 7: *Lobothyris andleri* (OPPEL). Locality 2a. GBA no.1995/3/16. x 2.
Fig. 8: *Zeilleria mutabilis* (OPPEL). Locality 2a. GBA no.1995/3/17. x 2.
Fig. 9: *Linguithyris beyrichi* (OPPEL). Locality 5a. GBA no.1995/3/18. x 2.
Fig. 10: *Liospiriferina* aff. *obtusa* (OPPEL). Locality 2a. GBA no.1995/3/19. x 2.
Fig. 11: *Zeilleria choffati* HAAS. Locality 5a. GBA no.1995/3/20. x 2.

All specimens were coated with ammonium chloride before photographing.


1a
2a
3a
4a
1c
2c
3c
4c
1b
5b
2b
3b
6b
4b
5a
5c
6c
6a
7a
8a
10a
11a
9a
10b
8b
11b
7b
9b
10c
7c
8c
9c
11c