Lithostratigraphy of the Adnet Group (Lower to Middle Jurassic, Salzburg, Austria)

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Abstract: The Adnet Group as exposed at the Adnet quarries and the Osterhorn Mts. southeast of Salzburg is described and formally defined. Two formations are distinguished. The Schnöll Formation (Hettangian) at the base of the Adnet Group formed as a wedge at the slope of the drowned Rhaetian Adnet reef. The Adnet Formation is much more widespread in the type area and persisted with only slight facies variations from the Sinemurian until the early Middle Jurassic. The Schnöll Formation is subdivided into two members. The Langmoos Member is characterized by siliceous sponges, while crinoidal debris is the major component of the overlying Guggen Member. A similar facies succession is also found in the contemporaneous Kendlbach Formation and points to a regional change of environmental conditions, like oxygenation, current activities and nutrient levels in the wake of the platform drowning event of the Triassic-Jurassic boundary.

Six members make up the Adnet Formation. Three members formed simultaneously during the Sinemurian in different positions on the drowned Rhaetian reef slope and in the adjacent basin (Lienbacher, Motzen and Schmiedwirt Member). Three more members (Kehlbach, Scheck, Saubach) formed as a sequence of increasingly pelagic sedimentation during the middle and late Liassic. The Saubach Member continued into the early Middle Jurassic. Intercalated breccias, especially the breccia layers forming the Scheck Member, are evidence for tectonic activities culminating during the late Pliensbachian and early Toarcian. The trend to more pelagic conditions continued during the Middle Jurassic with the plankton dominated limestones of the Klaus Formation and the radiolarites of the Ruhpolding Group.

Zusammenfassung: Die lithostratigraphische Einheit der Adnet-Gruppe, aufgeschlossen in den Adneter Steinbrüchen und der Osterhorn-Scholle südöstlich von Salzburg, wird beschrieben und formal definiert. Die Adnet-Gruppe besteht aus zwei Formationen. Die Schnöll-Formation (Hettangium) bildet den liegenden Anteil der Adnet-Gruppe. Sie entstand als keilförmige Anlagerung am Hang des ertrunkenen rhätischen Adnet-Riffes. Die hangend folgende Adnet-Formation ist in der Typusregion wesentlich weiter verbreitet und wurde mit nur geringen Faziesvariationen vom Sinemurium bis in den unteren Mitteljura abgelagert. Die Schnöll-Formation wird in zwei Subformationen untergliedert. Die Langmoos-Subformation bildet den liegenden Anteil der Schnöll-Formation und wird von Kieselschwämmen geprägt. Die darüber folgende Guggen-Subformation zeichnet sich durch Crinoiden-Detritus als Hauptkomponente aus. Eine ähnliche Faziesabfolge findet man auch in der zeitgleichen Kendlbach-Formation. Sie deutet auf langfristige, weiträumig

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wirksame Veränderungen im Ablagerungsmilieu (Sauerstoffsättigung, Nährstoffgehalt, Strömungsaktivität) als Folge des Ertrinkens der Karbonatplattformen an der Trias-Jura-Grenze.

Die Adnet-Formation besteht aus sechs Subformationen. Drei davon bildeten sich gleichzeitig im Sinemurium in verschiedenen Positionen am Hang des ertrunkenen Rhätriffes und im angrenzenden Becken (Lienbacher-, Motzen- und Schmiedwirt-SbFm.). Drei weitere Subformationen (Kehlbach-, Scheck- und Saubach-SbFm.) bildeten sich als Sequenz zunehmend pelagischer Sedimentationsbedingungen im Mittel- und Oberlias. Die Saubach-SbFm. ertstreckt sich bis in den unteren Mitteljura. Eingeschaltete Breccien, vor allem die Breccienlagen der Scheck-SbFm., deuten auf tektonische Aktivität, die im oberen Pliensbachium und unteren Toarcium ihren Höhepunkt erfuhr. Der Trend zu vermehrt pelagischen Ablagerungsbedingungen setzte sich im Mitteljura mit der Ablagerung der plankton-dominierten Klaus-Formation und den Radiolariten der Ruhpolding-Gruppe fort.

Keywords: Lithostratigraphy, Adnet Group, Schnöll Formation, Adnet Formation, Jurassic, Osterhorn Mountains

Contents

1. INTRODUCTION

The red Lower Jurassic limestones of the Adnet area south of Salzburg have been used as decoration stone since medieval times (Kieslinger, 1964). Due to their rich ammonite fauna a major palaeontological interest arose already during the early days of palaeontology (e.g., Quenstedt, 1845–1849; Hauer, 1853, 1854, 1856; Stur, 1871). The conspicuous red limestones overlying grey Triassic facies catched the eyes of the pioneers of alpine geology (e.g,. Sedgewick & Murchison, 1831; Gümbel, 1861; Suess & Mojsisovics, 1868; Wähner, 1882–1898, 1903; Leuchs & Udluft, 1926) and were a welcome marker horizon for the geological mapping of the Northern Calcareous Alps in the following times (e.g., Vortisch, 1931, 1955; Plöchinger, 1953, 1972).

When during the 1960s and 1970s facies models and environmental interpretations became a mainstream in sedimentology, the Adnet limestones, heralded as an example of deep-water deposition and contrasted to their basement of shallow water platform carbonates (Garrison & Fischer, 1969), became a classic example for platform drowning (Schlager & Schöllnberger, 1974; Schlager, 1974, 1981). The breccias of the Adnet Formation were found to represent submarine debris flows, set in motion by rifting activities that were breaking up the former Triassic platform (Hudson & Jenkyns, 1969; Jurgan, 1969; Hudson & Coleman, 1978). Comparison with the less tectonically disturbed Southern Alps led to the basin and seamount facies model for the alpine Jurassic seafloor, with its thick grey and thin red sedimentary sequences (Bernoulli & Jenkyns, 1970, 1974).

The question whether the Triassic platform and reefs were killed by emergence during the early Liassic or drowned for some other reason is still under discussion today and soon was connected to the Adnet limestones (Fabricius, 1961; Hallam, 1967; Jurgan, 1969; Schöll & Wendt, 1971; Senowbari-Daryan, 1980; Wächter, 1987; Mazzullo et al., 1990; Böhm, 1992; Satterley et al., 1994; Blau & Grün, 1996; Ebli, 1997; Bernecker et al., 1999; Böhm et al., 1999; Gawlick et al. 1999). Most of this discussion dealt with the red sediment color, the formation of nodular fabrics, the ferromanganese crusts, the fauna and scarce flora of the Adnet facies, the neptunian dykes and fissures, meteoric versus deep marine dissolution and diagenesis, and the relief and possible karst features on top of the Upper Triassic.

The usage of the terms "Adneter Kalk" and "Adneter Schichten" dates back to the middle of the 19th century. The term "Adneter Schichten" was formally introduced by Hauer (1853). Quenstedt (1845–1849) among several others used the term (Gümbel, 1861). An early description of the type locality of the Adneter Schichten, the Adnet quarries, was given by Wähner (1903) in a guide book. A geological map of the Adnet area was provided by Schlager (1960) in more recent times. It was preceded and followed by several reports on the Adnet area (Schlager, 1957–1961, 1964–1971). At the same time a monograph on building and decoration stone types of the Salzburg area was published by Kieslinger (1964), including a map, detailed descriptions and a complete catalogue of the Adnet quarries. Another monograph on the Adnet limestones and their use as decoration stone was published later by Kretschmer (1986).

Wendt (1971) presented the first modern geological description of the Adnet Formation type locality including a biostratigraphic framework based on a review of the "classic" publications (Quenstedt, 1845–49; Hauer, 1854, 1856; Wähner, 1886, 1882–98, 1903; Pia, 1914) complemented by his own ammonite findings. At the same time Krystyn (1971) revised the Middle Jurassic Klaus Formation and included some biostratigraphic data from the Adnet Formation at Adnet. Krystyn (1971) also discussed the problem that because of the continuation of red limestone facies from the Lower into the Middle Jurassic in the Adnet area, Adnet Formation and Klaus Formation are hardly distinguishable. He suggested to use the term "Adneter/Klaus-Schichten" for the entire succession of red limestones. Tollmann (1976), in his description of the Mesozoic of the Northern Calcareous Alps, presented an overview of the Adnet Formation and related facies.

The last decade of the 20th century saw increased activities of geological research in the Adnet quarries. Rakus et al. (1993) and Hladikova et al. (1994) started studies on biostratigraphy, sedimentology and stable isotopes of the Rhaetian and Liassic of Adnet. An attempt to adopt magnetostratigraphy in the basal parts of the Adnet limestones failed due to a strong, multiphase, partly pre-Cretaceous remagnetization (GALLET et al., 1993). In this study the special character of the basal Adnet limestones was pointed out and it was suggested to consider them as a separate formation, intercalated between the Kössen Formation and the Adnet Formation. BLAU & GRÜN (1996, 1997) investigated foraminifera and microfacies of this basal formation (the Schnöll Limestones) emphasizing the widespread synsedimentary fracturing of the rocks. SCHWEIGL & NEUBAUER (1997) reinterpreted structures in the nodular fabric of the Adnet limestones in terms of postdepositional semiductile shear deformation during overthrusting of the Juvavic nappes. KAPPLER & ZEEH (2000) found indications of early Liassic hydrothermal activities in the Adnet limestones. Finally, a series of papers on the Adnet limestones and the type locality, was published by the author and his collaborators during the last decade, including biostratigraphy, lithostratigraphy, microfacies, and taxonomical studies of ammonites, foraminifera and brachiopods (BÖHM, 1992; BÖHM & BRACHERT, 1993; MEISTER & BÖHM, 1993; DOMMERGUES et al., 1995; WAGREICH et al., 1996; BÖHM et al. 1995, 1997a, b, 1999).

In the present paper, I will present the formal lithostratigraphic definition of the Schnöll Formation and the Adnet Formation, which together make up the Adnet Group. The lithostratigraphic concept is based on own data and data collected during the last 150 years in the studies mentioned above.

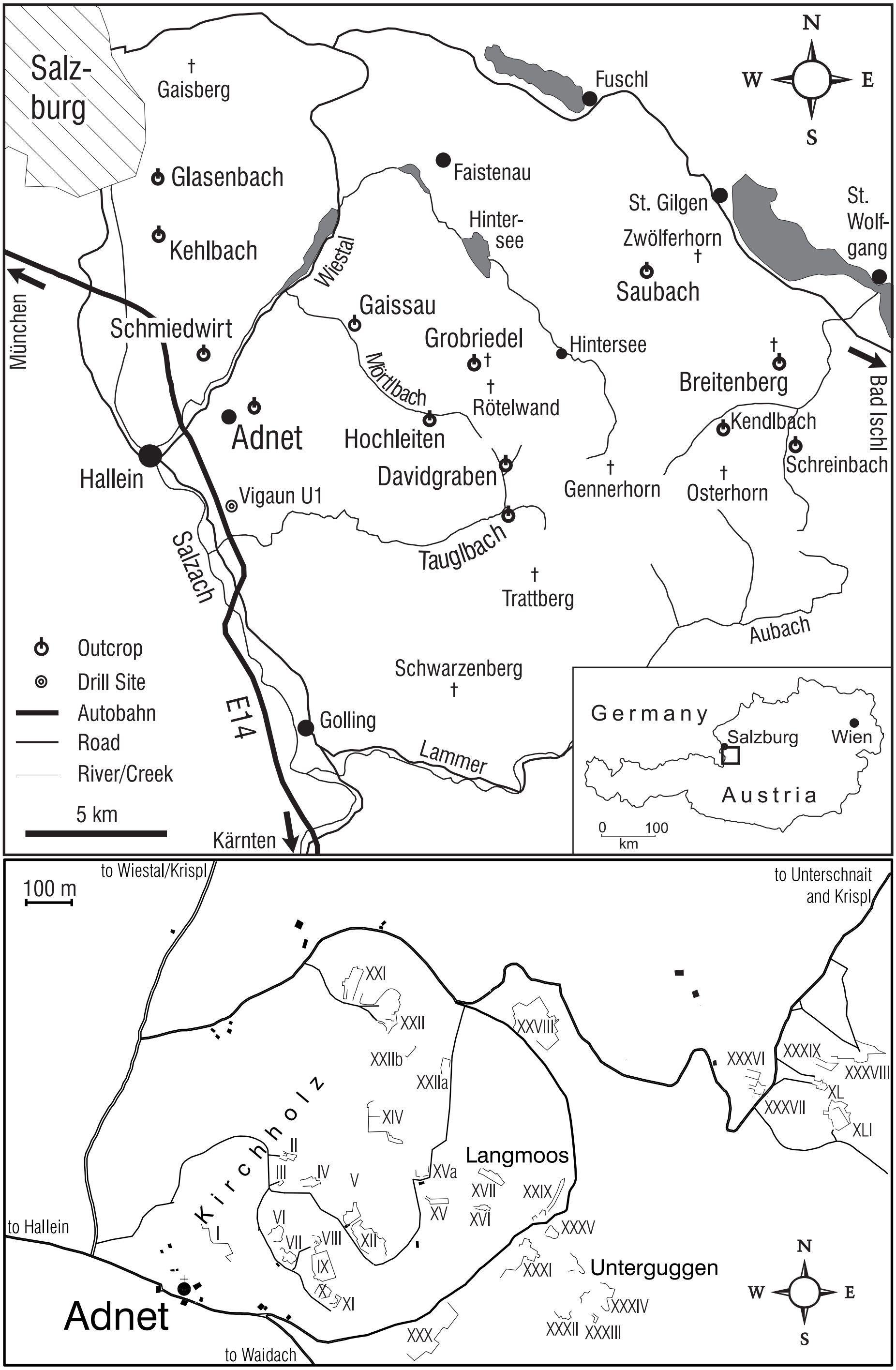
2. SETTING

The type area of the Adnet Group includes the Adnet quarries, located east and northeast of the village of Adnet, as well as some locations in the northern Osterhorn Mountains, e.g., the Schmiedwirt quarry and the Kehlbach gorge, between Adnet and the city of Salzburg. Location maps of the Osterhorn Mts. and of the Adnet quarries based on KIESLINGER (1964) are shown in Fig. 1. A detailed geological map of the area was published by SCHLAGER (1960). Recent descriptions of the Liassic in the Salzburg area can be found in PLÖCHINGER (1982, 1990), BÖHM (1992) and BÖHM et al. (1995, 1999).

The area is situated in the northwestern Osterhorn block, a tectonic unit in the northern part of the Tyrolic nappes (PLÖCHINGER, 1990; FRISCH & GAWLICK, in press). The Osterhorn block shows a relatively mild tectonic deformation compared to other units of the Northern Calcareous Alps. Large parts of the Adnet quarry area are only slightly tilted or still in the original position and show the original clinoform inclination of the Liassic seafloor on the inherited Rhaetian relief (SCHLAGER, 1960; BÖHM et al., 1999).

The Liassic Adnet Group (Fig. 2) overlies Rhaetian reef limestones and Kössen Marls (SCHÄFER, 1979; KUSS, 1983; BERNECKER et al., 1999) and the lower Liassic Kendlbach Formation (GOLEBIOWSKI, 1990; BÖHM et al., 1999). It interfingers with the Liassic Scheibelberg Formation, grey, often cherty limestones that were deposited more distally from the former Rhaetian reef than the Adnet Group, in a more basinal setting (BERNOULLI & JENKYNS, 1970; BÖHM, 1992; BÖHM et al., 1995, 1999; KRAINER & MOSTLER, 1997; EBLI,

Fig. 1: Location map of the Adnet Group type area. Upper panel: Osterhorn Mountains and locations mentioned in the text. Lower panel: Adnet quarry area. Quarries are numbered according to KIESLINGER (1964). ➔



Salz-
burg
Gaisberg
Glasenbach
Kehlbach
Schmiedwirt
München
Hallein
Adnet
Vigaun U1
Salzach
Wiestal
Gaissau
Mörtlbach
Hochleiten
Grobriedel
Rötelwand
Davidgraben
Tauglbach
Trattberg
Faistenau
Fuschl
Hinter-
see
Hintersee
St. Gilgen
Zwölferhorn
Saubach
St.
Wolf-
gang
Breitenberg
Kendlbach
Schreinbach
Bad Ischl
Gennerhorn
Osterhorn
Aubach
Schwarzenberg
Golling
Lammer
E14
Kärnten
N
W
E
S
Outcrop
Drill Site
Autobahn
Road
River/Creek
5 km
Germany
Salzburg
Wien
Austria
0
100
km
to Wiestal/Krispl
to Unterschnait
and Krispl
100 m
Kirchholz
Langmoos
Unterguggen
Adnet
to Hallein
to Waidach
I
II
III
IV
V
VI
VII
VIII
IX
X
XI
XII
XIV
XV
XVa
XVI
XVII
XXI
XXII
XXIIa
XXIIb
XXVIII
XXIX
XXX
XXXI
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XXXIII
XXXIV
XXXV
XXXVI
XXXVII
XXXVIII
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1997). There is no obvious break in the lithologic succession between the Lower Jurassic Adnet limestones and the Middle Jurassic Klaus Formation in the Adnet area (Krystyn, 1971; Wendt, 1971; Böhm, 1992). The Klaus Formation in the Adnet area is represented by very condensed (0–3 m) red limestones and overlain by radiolarites of Callovian to Oxfordian age (Huckriede, 1971; Böhm, 1992; Wagreich et al., 1996; Gawlick, 2000).

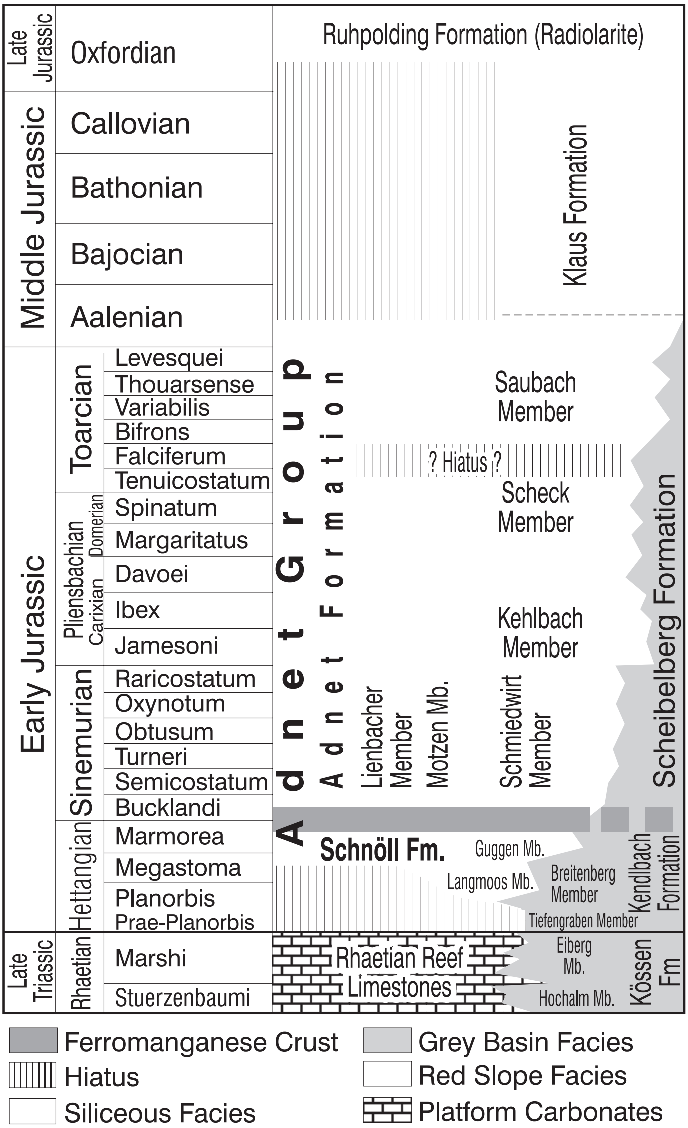

Fig. 2:
Schematic stratigraphic framework of the Adnet Group in the Osterhorn Mountains. Middle and Upper Jurassic ammonite zones are omitted. Kendlbach and Kössen Fm. according to Golebiowski (1990, 1991). The onset of the radiolarite facies (Ruhpolding Group) is currently under revision (Gawlick, 2000) and shown only schematically. The exact stratigraphic range of the Klaus Fm. in the Osterhorn Mts. is not known.

3. LITHOSTRATIGRAPHY OF THE ADNET GROUP

1971: Adneter Schichten, WENDT
1999: Adnet Group, BÖHM et al.

Type area: Adnet quarries and Osterhorn Mts. (ÖK50/Blatt 94 Hallein).
Type sections: For the base of the Adnet Group Adnet quarry XII (Adnet Fm. overlying Rhaetian reefal limestones), quarry XXII (Adnet Fm. overlying Kendlbach Fm., Fig. 3) and XXXI (Schnöll Fm. overlying Kendlbach Fm.) are proposed. A type section for the top of the Adnet Group is exposed at the Hochleitengraben (Adnet Fm. overlain by Klaus Fm., Fig. 4) and Gaissau (Adnet Fm. overlain by Ruhpolding Fm.).
Coordinates: Adnet quarry XII, $R^4 35\ 425$, $H^2 84\ 240$; Adnet quarry XXII, $R^4 35\ 475$, $H^2 84\ 775$; Adnet quarry XXXI, $R^4 35\ 775$, $H^2 84\ 275$; Hochleitengraben, $R^4 41\ 820$, $H^2 83\ 830$; Gaissau, $R^4 39\ 030$, $H^2 87\ 200$.
Name: From the village of Adnet.
Lithology: Limestones and marls with intercalated breccias. Predominantly of red color or varicolored. Mainly thin to medium bedded, rarely thick bedded. Nodular fabrics are common. Microfacies is dominated by mudstones and wackestones. Packstones occur less frequently. Hemipelagic faunas and reworked intraclasts are the major components. In the type area, the breccia components are intraclasts derived from immediately underlying Liassic strata.
Fossil content: Rich benthic and pelagic micro- and macrofaunas. Brachiopods, siliceous sponges and foraminifera are especially frequent in the Schnöll Fm., ammonites are found throughout the Adnet Group. Ostracods and echinoderms are very common, belemnites and vertebrate teeth occur more sporadically. Nannofossils are mainly represented by the problematic *Schizosphaerella*, coccoliths are increasingly common in the upper Adnet Formation. The pelagic bivalve *Bositra* forms shell-beds in the Saubach Member. No benthic flora has been found so far, except for rare stromatolite layers in the lower parts of the Adnet Formation, that probably represent aphotic microbialites (BÖHM & BRACHERT, 1993).
Lithostratigraphic subdivison: Schnöll Formation, Adnet Formation (see below).
Chronostratigraphy: Hettangian to Aalenian.
Biostratigraphy: Most ammonite zones between the Upper Planorbis zone and the Opalinum or Murchisonae zone are repesented by sediments in the Adnet Group. For details see descriptions of the subunits below.
Thickness: Variable thickness caused by shifting depocenters, onlap on pre-existing Rhaetian topography, syndepositional erosion and tectonic block tilting. Maximum thickness is estimated as 40–50 m. In a borehole south of Adnet the total thickness of the Adnet Group was only 5 m (KRAMER & KRÖLL, 1979).
Underlying unit: Upper Rhaetian reef limestones and Hettangian Kendlbach Formation.
Lower boundary: Abrupt facies change from underlying grey neritic carbonates dominated by boundstones, rudstones, packstones and grainstones to hemipelagic varicolored series of predominantly wackestones and mudstones.
Overlying unit: Klaus Formation (Middle Jurassic), Ruhpolding Group (Callovian to Tithonian).
Upper boundary: The boundary to the Klaus Fm. is problematic, based on subtle facies

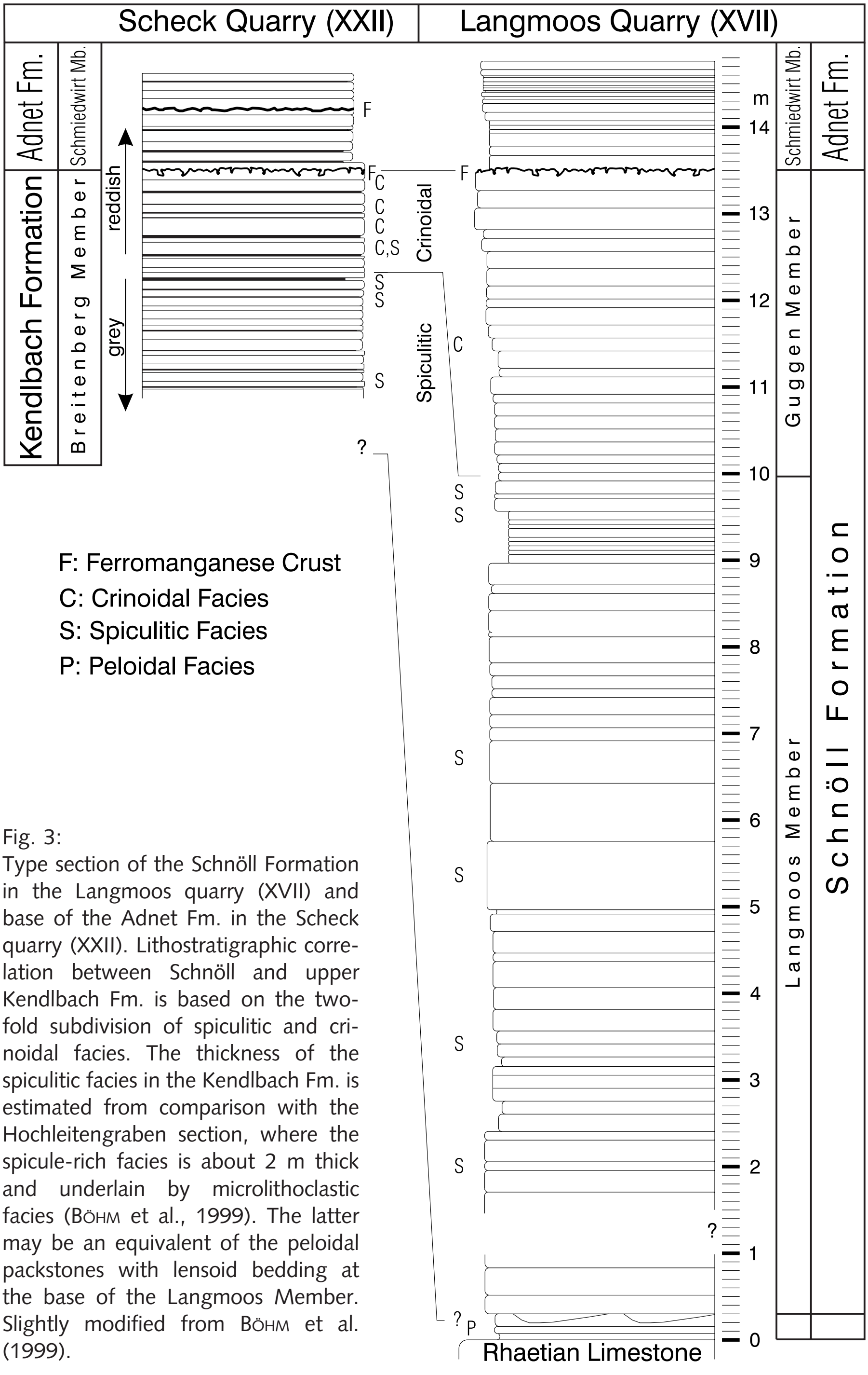

Fig. 3:
Type section of the Schnöll Formation in the Langmoos quarry (XVII) and base of the Adnet Fm. in the Scheck quarry (XXII). Lithostratigraphic correlation between Schnöll and upper Kendlbach Fm. is based on the twofold subdivision of spiculitic and crinoidal facies. The thickness of the spiculitic facies in the Kendlbach Fm. is estimated from comparison with the Hochleitengraben section, where the spicule-rich facies is about 2 m thick and underlain by microlithoclastic facies (Böhm et al., 1999). The latter may be an equivalent of the peloidal packstones with lensoid bedding at the base of the Langmoos Member. Slightly modified from Böhm et al. (1999).

changes discussed in more detail in section 3.2.6. The boundary to the radiolarites is a very distinct facies change from limestone/marl to siliceous radiolarites (Fig. 15), sometimes with an intercalated ferromanganese layer.
Regional distribution: Very widespread in the Osterhorn Mts. except for the northernmost and southernmost regions (BÖHM, 1992). Rocks of the Adnet Group occur in many parts of the Northern Calcareous Alps (e.g., GARRISON & FISCHER, 1969; TOLLMANN, 1976; BÖHM, 1992; EBLI, 1997).
Laterally bordering units: Scheibelberg Fm. in the northern Osterhorn Mts., ?Allgäu Fm. in the south (GAWLICK et al., 1999).

3.1. Schnöll Formation

1903: Graue, blaßrötliche, bunte und rote Kalke, WÄHNER, p.3
1970: Rotkalk- und Rot-Grau-Kalk-Bänke, SCHLAGER
1971: Fazies massiger bis grob gebankter Kalke lebhaft bunter Färbung, WENDT
1990: grau-bunt gemischter Kalk, "Schnöllmarmor", PLÖCHINGER, p. 19
1992: Adneter Schnöll, BÖHM, p.117
1993: Unnamed Formation, "Rot-Grau-Schnöll-Marmor", GALLET et al.
1996: "Enzesfelder Kalk", BLAU & GRÜN
1999: Schnöll Formation, BÖHM et al.

Type area: Adnet quarries, Adnet, Kirchholz, Langmoos and Unterguggen (ÖK50/Blatt 94 Hallein), see Fig. 1.
Type section: Adnet quarry XVII, Langmoos quarry (Figs. 1, 3). The Langmoos quarry exposes the most complete section of the Schnöll Formation. GALLET et al. (1993) proposed the section of this quarry as the type section of their "Unnamed Formation", a synonym of the Schnöll Formation. The base of the Schnöll is currently not well exposed in any of the Adnet sections. A small outcrop in a cliff immediately to the southeast of quarry XVI, close to quarry XVII is proposed as reference section for the formation base. The southern part of quarry XXXI exposes the base of the Schnöll Fm. very well, but the lower member of the Schnöll Fm. (Langmoos Mb.) is very condensed in this section and mainly represented by an erosional surface.
Coordinates: Quarry XVII: $R^4$35 700, $H^2$84 575; quarry XXXI: $R^4$35 775, $H^2$84 275; cliff: $R^4$35 725, $H^2$84 325
Name: "Schnöll" is the quarrymen's traditional name for the massive varicolored limestones that are a dominant facies of this formation (KIESLINGER, 1964; WENDT, 1971; GALLET et al., 1993). This name derives from the Schnöll quarry (XXXI), which, like most Adnet quarries, was originally named after its owner. Schnöll is a common family name in the Salzburg region.
Lithology: Thick to thin bedded grey, yellow, violet, and red biomicritic limestones.
Remark: The usage of the term "Enzesfeld limestone" is controversial in the Adnet area. BLAU & GRÜN (1996) applied it to the entire Schnöll Formation exposed in quarry XXXI (mainly the Guggen Mb.). They use a definition largely based on yellow to red and pink colors and the stratigraphic position at the base of the Adnet Fm. (BLAU & GRÜN, 1994). GALLET et al. (1993), on the other hand, use the term only for a 3–5 cm thick hardground layer on top of the Schnöll ("Marmorea Crust", "Brandschichte"). BÖHM (1992) applied

the term to a special microfacies (MF10, bioclastic packstones and wackestones rich in foraminifera and ostracods) occurring in many sections of the Osterhorn Mts. at the base of the Adnet Fm., often in connection with a ferromanganese crust or a condensed layer. This microfacies is typical for the Enzesfeld limestones of the type locality (Tollmann, 1976), but is different from the microfacies typical for the Schnöll Formation. The latter are wackestones or mudstones, rich in sponge spicules. Only the condensed upper part of the Schnöll shows affinities to the Enzesfeld facies (Böhm, 1992; Böhm et al., 1999). The Enzesfeld facies forms a very widespread marker horizon in the Osterhorn Mts. (Böhm, 1992; Blau & Grün, 1994), independent of the underlying facies (Kendlbach Fm., Schnöll Fm., hiatus above the Rhaetian reef limestones). Therefore, it should not be associated with the Schnöll Formation. However, this horizon in many cases is less than a metre thick and does not represent a mapable lithostratigraphic unit. Thus, it is suggested to include this horizon in the respective underlying lithostratigraphic unit, either the Kendlbach or Schnöll Formation.

Fossil content: Echinoderms, siliceous sponges, stromatactis, foraminifera, ostracods, ammonites, brachiopods, bivalves, gastropods (Wendt, 1971; Böhm, 1992; Gallet et al., 1993; Dommergues et al., 1995; Blau & Grün, 1997; Böhm et al., 1999).

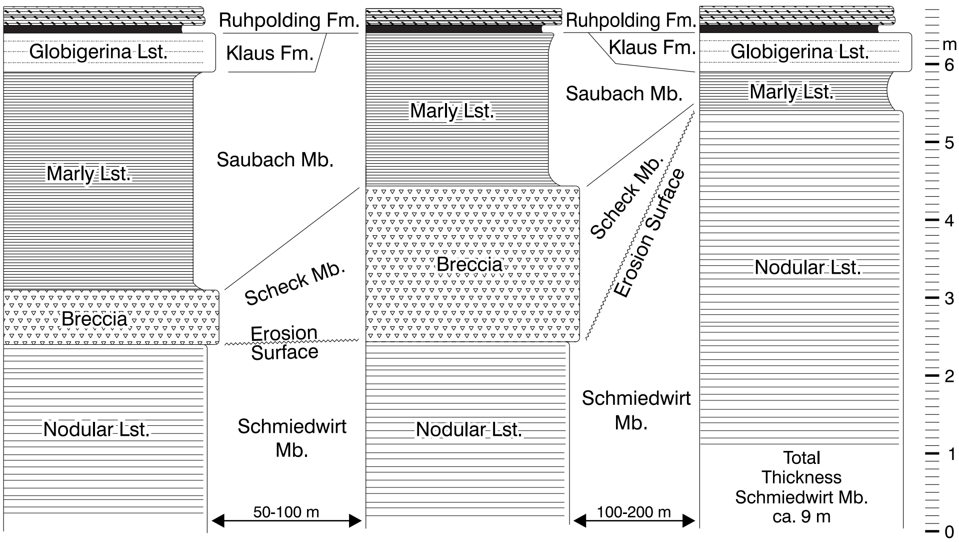

Fig. 4: Upper part of the Adnet Fm. at three outcrops at Hochleitengraben including the reference section for the upper boundary of the Adnet Formation (left column, section at the western side of the Hochleitengraben at 900 m). Nodular limestones of the Schmiedwirt Mb. (Sinemurian) are overlain by the breccia of the Scheck Member (Domerian/Toarcian). The Kehlbach Mb. (Carixian) and the upper portions of the Schmiedwirt Mb. were eroded during deposition of the Scheck Member. The breccia is overlain by marly limestones of the Saubach Mb. (Toarcian). The Klaus Fm. (Middle Jurassic) is represented by discontinuous lenses of red limestones with globigerinoids and filaments. The Ruhpolding Group (Upper Jurassic) starts above the Klaus or Adnet Fm. (Saubach Mb.) with a basal green-red marl layer followed by radiolarites.

Lithostratigraphic superunit: Adnet Group.
Lithostratigraphic subdivison: Langmoos Member, Guggen Member (see below).
Chronostratigraphy: Hettangian (BÖHM et al., 1999).
Biostratigraphy: Upper Planorbis zone (GALLET et al., 1993) to Marmorea zone (BÖHM et al., 1999).
Thickness: Very variable; maximum exposed thickness 12 m; estimated maximum thickness 14 m. Locally filling pockets and fissures in the surface of Rhaetian reef limestones (BÖHM et al., 1999: Figs. 11, 13).
Underlying unit: Rhaetian reef limestones and Kendlbach Formation, upper Rhaetian to lower Hettangian (SCHÄFER, 1979; PLÖCHINGER, 1982; GOLEBIOWSKI, 1990; BÖHM et al., 1999).
Lower boundary: Disconformity with indications of an erosive phase. Abrupt facies change from underlying gray grainstones and packstones to varicoloured, spicule-rich wackestones and mudstones of the Schnöll Formation. The base of the Schnöll Formation is not exposed in the type section, but visible in a cliff immediately to the southeast of quarry XVI, in small outcrops southeast of quarry XII, and in quarry XXXI (BÖHM et al., 1999).
Overlying unit: Adnet Formation, Sinemurian.
Upper boundary: Disconformity of the "Marmorea Crust", a ferromanganese crust with a rich ammonite fauna dominated by *Schlotheimia marmorea* (WENDT, 1971; DOMMERGUES et al., 1995; BÖHM et al., 1999).
Regional distribution: Adnet quarries XV, XVI, XVII, XXIX, XXXI, small outcrops between quarries XII and XVI, small cliffs southeast of quarries XVI and XVII. Restricted to the lower slope of the drowned Rhaetian reef.
Laterally bordering units: To the north and east (basinal area, quarry XXII) the upper Breitenberg Member of the Kendlbach Formation is likely a lateral equivalent. To the southwest (upper reef slope, quarries XII, XXX) this time interval is represented either by extremely condensed limestones or by a hiatus (BÖHM et al., 1999: Figs. 5, 6, 7, 11, 13).

3.1.1. Langmoos Member

1999: Langmoos Member, BÖHM et al.

Type area: Adnet quarries, Adnet, Kirchholz, Langmoos and Unterguggen (ÖK50/Blatt 94 Hallein), see Fig. 1.
Type section: Adnet quarry XVII, Langmoos quarry (Figs. 1, 3).
Coordinates: $R^4 35\ 700$, $H^2 84\ 575$
Name: Langmoos is the local name of the area between Kirchholz and Guggen. Langmoos quarry is the type locality of this member.
Lithology: Thin- to thick-bedded micritic limestones rich in siliceous sponge spicules. Stromatactis, siliceous sponges and accumulations of brachiopods occur locally. Grey and creme colours near the base are replaced by red, violet and grey colours higher up in the succession. Networks of grey bleached blotches and pipes, some following sponge spicules and other bioclasts, are characteristic for the deep-red middle part of the Langmoos Member. A thin-bedded, nodular intercalation of violet-red marly limestones

occurs near the top (Fig. 5). A detailed description of the succession is given in BÖHM et al. (1999).
Lithostratigraphic superunit: Schnöll Formation.
Chronostratigraphy: Lower to Middle Hettangian.
Biostratigraphy: *Parapsiloceras naumanni* (upper Planorbis zone) was described from the base of the Langmoos Member by GALLET et al. (1993). *Psiloceras* sp. also occurs in the upper parts of the Langmoos Mb. (quarry XXXI, BÖHM et al., 1999). An ammonite fauna from the Middle Hettangian (Megastoma zone) occurs at the base of the overlying Guggen Mb. in quarry XXXI (WÄHNER, 1886, 1903; BÖHM et al., 1999).
Thickness: 0 to 10 m.
Underlying unit: Rhaetian reef limestones and Kendlbach Formation; upper Rhaetian to lower Hettangian (BÖHM et al., 1999).
Lower boundary: The base of the Langmoos Mb. is identical with the base of the Schnöll Fm. (see description above).
Overlying unit: Guggen Member of the Schnöll Fm.
Upper boundary: The upper boundary of the Langmoos Mb. is defined by a transition to a crinoidal facies (Guggen Mb.).
Regional distribution: Adnet quarries XV, XVI, XVII, XXIX, XXXI, small outcrops between quarries XII and XVI, small cliffs southeast of quarries XVI and XVII. Restricted to the lower slope of the drowned Rhaetian reef.
Laterally bordering units: see Schnöll Fm.

Fig. 5: Top of the Langmoos Mb. (Schnöll Fm.) at quarry XXXI. The thin nodular beds at the base of the outcrop are overlain by a thicker bed with centimetre-sized siliceous sponge skeletons (S), visible as light blotches in the dark matrix. The next two beds, still rich in sponges, are capped by dark ferromanganese crusts (arrows). Length of scale is 1 metre.

3.1.2. Guggen Member

1996: Massiger rotgrauer Kalk, gebankter Schwammnadelkalk und Crinoidenkalk, Blau & Grün
1999: Guggen Member, Böhm et al.

Type area: Adnet quarries, Adnet, Kirchholz, Langmoos and Unterguggen (ÖK50/Blatt 94 Hallein), see Fig. 1.
Type section: Adnet quarry XXXI, Schnöll quarry (Fig. 1).
Coordinates: $R^4$35 775, $H^2$84 275
Name: Guggen is the local name of the hill east of quarry XXXI, which is the type locality of the Guggen Member.
Lithology: Thick- to medium-bedded, reddish to yellowish-grey crinoidal limestones (wackestones and packstones), typically showing a texture of light dotted, blotchy coloration. Sponges are present, but less important than in the Langmoos Member. A conspicuous sponge-rich layer at the base of the Guggen Mb. in quarry XXXI (Blau & Grün, 1996: Fig. 4; Böhm et al., 1999: Pl. 1, Fig. 1) represents a transitional facies between the Guggen and the Langmoos Member. Detailed descriptions of the litho-facies and microfacies are given by Böhm (1992), Blau & Grün (1996) and Böhm et al. (1999).
Lithostratigraphic superunit: Schnöll Formation (Fig. 3).
Chronostratigraphy: Middle to upper Hettangian.
Biostratigraphy: An ammonite fauna from the sponge-rich basal layer shows a middle Hettangian age (Megastoma zone) (Wähner, 1886, 1903; Böhm et al., 1999). An ammonite-rich ferromanganese crust at the top of the Guggen Member ("Marmorea Crust", "Brandschichte") contains a fauna from the Marmorea zone (late Hettangian to possibly early Sinemurian) and possibly some elements from the Megastoma zone (Wendt, 1971; Gallet et al., 1993; Dommergues et al., 1995; Böhm et al., 1999).
Thickness: Thickness varies from 1 m in the SSW corner to 3 m in the NNE parts of quarry XXXI; 3.5 m in quarry XVII.
Underlying units: The Guggen Mb. overlies either the Langmoos Member, grey pack-stones of the ?Kendlbach Fm. (S part of quarry XXXI), or may rest directly on Rhaetian reef limestones as a strongly condensed layer representing mainly the "Marmorea Crust" (e.g., quarries XII and XXX).
Lower boundary: Facies change to crinoidal facies from either grey massive limestones of Rhaetian or early Hettangian age, or from the sponge-rich Langmoos Member. Often developed as a hardground, erosional surface or discontinuity surface.
Overlying unit: Red wackestones of the Adnet Formation.
Upper boundary: Well defined by the omnipresent and conspicous "Marmorea Crust".
Regional distribution: Adnet quarries XVII, XXIX, XXXI. Restricted to the slope of the drowned Rhaetian reef. Represented by a thin condensed layer in quarries XII and XXX.
Laterally bordering units: See Schnöll Formation. Crinoidal limestones of the upper Kendlbach Formation probably are a lateral equivalent of the Guggen Member in more basinal settings (Böhm et al., 1999).

3.2. Adnet Formation

1853: Adnethen-Schichten, Hauer
1861: Adnether-Schichten, Gümbel, pp. 428, 436
1903: Adneter Schichten, Wähner, p. 5
1958: Roter Lias in Adneter Fazies, Schlager
1969: Adnet Beds, Garrison & Fischer
1971: Adneter Schichten s. str., Wendt
1976: Adneter Kalke s.l., Tollmann
1992: Adneter Schichten, Böhm
1995: Adnet Formation, Böhm et al.
1999: Adnet-Formation, Böhm et al.

Type area: Osterhorn Mountains southeast of Salzburg with Kehlbach Gorge south of Salzburg, Adnet quarries, and Schmiedwirt quarry at Wiestal; Saubach northeast of Hintersee (ÖK50/Blatt 94 Hallein), see Fig. 1.
Type section: Due to small-scale facies differentiations there is no single type section comprising all members of the Adnet Formation. The lower boundary is well exposed in several quarries at Adnet and will be discussed for each member in the sections below. Quarry XXII exposing the typical transition from the Kendlbach to the Adnet Formation (Fig. 3) is designated as type section for the base of the Adnet Formation. The upper boundary of the Adnet Fm. is currently not well exposed in any of the Adnet quarries. Therefore, the outcrop at the western side of the Hochleitengraben at 900 m is proposed as reference section for the upper boundary (Fig. 4, left column). Additional sections exposing the top of the Adnet Formation are found at the Tauglboden (Tauglbach and Davidgraben sections, Böhm, 1992).
Coordinates: Quarry XXII, $R^4$35 475 , $H^2$84 775; Hochleitengraben, $R^4$41 820 , $H^2$83 830
Name: Named after the village of Adnet.
Lithology: Thin to medium bedded, red micritic limestones and marls, mostly mudstones and wackestones, rarely packstones. Includes centimetres to metres thick breccia layers, mostly made up of intraformational clasts with marly, micritic or sparitic matrix. The latter variety is known as "Scheckbreccia". Nodular fabric is common.
Lithostratigraphic superunit: Adnet Group.
Lithostratigraphic subdivison: Schmiedwirt, Lienbacher and Motzen Member are laterally equivalent facies units in the lower part of the Adnet Formation. They are overlain by the Scheck and Saubach Member.
Chronostratigraphy: Sinemurian to Aalenian.
Biostratigraphy: Age diagnostic ammonites are very rare in the basal layers of the Adnet Formation ("Basal Unit", Böhm et al., 1999). Therefore the exact onset of the Adnet Fm. is not known. The basal Sinemurian may be contained in the condensed horizon at the base of the Adnet Formation ("Marmorea Crust"). Characteristic ammonite species of the Semicostatum zone are rare. Horizonted collections are not known at all. A level in the lower Semicostatum zone is indicated by *Coroniceras* cf. *lyra* found in the screes at quarry XXVIII and the Turneri zone is indicated by *Caenisites* sp. (Dommergues et al., 1995). The oldest level providing a rich ammonite fauna is the Paucicostum level of Dommergues et al. (1995), which includes, however, no age diagnostic species and can

only be placed somewhere between the lower Semicostatum and the lower Obtusum zones. The middle Obtusum, upper Oxynotum and Raricostatum zones are well documented in the Adnet Fm. (Krystyn, 1971; Dommergues et al., 1995). The Carixian is evident from rich faunas of the Jamesoni and Ibex zones. Davoei and Margaritus zone faunas are again rare. A condensed fauna of that age was described from a horizon below a breccia bed at Breitenberg by Meister & Böhm (1993). Late Domerian and early Toarcian faunas are mostly missing in the Adnet area. However, rich faunas of this age are present in the Adnet Fm. of the Unken Syncline, 40 km west of the Adnet area (Fischer, 1966). The record continues with the rich faunas of the Bifrons zone. All late Toarcian zones are present (e.g., Wendt, 1971; Krystyn, 1971; Huckriede, 1971; see compilation in Böhm, 1992). The youngest ammonite faunas of the Adnet Fm. prove its continuation into the Aalenian (Opalinum or Murchisonae zone; Wendt, 1971; Krystyn, 1971).

Thickness: In the type area the thickness varies between <1 m and 20 m for the Sinemurian-Carixian part and between <1 and 30 m for the Domerian-Toarcian part. However, there is no known section, where both time periods are represented with maximum thickness (Böhm, 1992). Therefore, the maximum total thickness is only about 30 m. Thicknesses are very variable, especially where breccia layers are present, which both eroded the underlying strata and may pinch out laterally over short distances (Böhm et al., 1995).

Underlying unit: The Adnet Fm. overlies the Schnöll Fm. in several quarries at Adnet, where the Triassic basement is formed by Rhaetian reef or reef slope facies. The Schnöll Fm. may be represented by a layer of only a few centimetres thickness where it overlies reefal limestones (Adnet quarries XII, XXX). At some distance from the Rhaetian reefs, the Adnet Formation overlies the Hettangian Kendlbach Formation (e.g., quarry XXII, Hochleitengraben, Schlager, 1969; Böhm et al., 1999; Breitenberg, Böhm, 1992; Schreinbachgraben, Blau & Grün, 1994; Kendlbach, Hallam & Goodfellow, 1990). More distal settings show a continuation of the grey facies of the Kendlbach Fm. into the Sinemurian chert-rich limestones of the Scheibelberg Formation. In these cases Adnet Fm. overlies the latter (e.g., Gaissau, Kehlbach, Grobriedel, Fig. 15; Böhm, 1992).

Lower boundary: The basal boundary is defined by the onset of red, bedded wackestones or mudstones (MF 5, 6 and 8 of Böhm, 1992). In the Adnet area the basal boundary is marked by the ferromanganese, ammonite-rich "Marmorea Crust" on top of the Schnöll or Kendlbach Formation (e.g., Adnet quarry XXII). In this case the underlying rocks are usually red, violet, yellowish or grey packstones, rarely grainstones, rich in bioclasts (mainly crinoidal debris, foraminifera, ostracods, MF10 of Böhm, 1992). In some cases (e.g., at Breitenberg) the "Marmorea Crust" is not well developed, but the transition from bioclastic packstones to wackestones still indicates the basal boundary. Where the Adnet Fm. develops from grey limestones of the Scheibelberg Fm. the basal boundary is defined by the onset of red sediment colours. Often the latter transition is gradational with chert nodules occuring in red limestones and alternations of red, pink and grey beds (e.g., at Gaissau, "Adneter Knollenkalk s.l." of Böhm, 1992).

Overlying unit: Often, the Adnet Fm. is overlain by the radiolarite of the Ruhpolding Formation (Gawlick et al. 1999; Gawlick, 2000) with only a very thin intercalation of marls, cherty marls or a ferromanganese crust (e.g., at Gaissau, Grobriedel, Adnet quarry XXX; Wendt, 1971; Krystyn, 1971; Böhm, 1992). In other sections up to 3 m of red

bedded limestones occur between the marls of the upper Adnet Fm. (Saubach Mb.) and the overlying radiolarite. These limestones show a facies with more pelagic components, most characteristically with globigerinoids, radiolarians and filaments (thin bivalve shells). Good examples can be found at Hochleitengraben (Fig. 4), Davidgraben or Tauglbach (HUCKRIEDE, 1971; BÖHM, 1992; WAGREICH et al., 1996). These limestones are of Middle Jurassic age and can be assigned to the Klaus Formation. As filaments are also very common in the upper Adnet Fm., it is often not possible to clearly differentiate between the two formations, especially where the Klaus Fm. is not well developed. In such cases the questionable red limestones should be included in the Adnet Fm./Saubach Member (see also KRYSTYN, 1971).
Upper boundary: Facies shift to globigerinoid-bearing, filamentous limestones, radiolarian limestones or radiolarites. The upper boundary is often represented by a hiatus, an erosional surface or a ferromanganese crust. In these cases the Adnet Fm. is overlain by the radiolarites of the Ruhpolding Group.
Regional distribution: The Adnet Fm. is very widspread in the Northern Calcareous Alps and especially common in their western and easternmost parts. It is mostly found overlying the Triassic Kössen Fm. in the vicinity of Rhaetian reefs.
Laterally bordering units: Lateral equivalents of the Adnet Fm. are the basinal facies of the Scheibelberg and the Allgäu Formation (GARRISON, 1964; JACOBSHAGEN, 1965; KRAINER & MOSTLER, 1997). The latter are found in the northwestern (and possibly southeastern) parts of the Osterhorn Mts. (BÖHM, 1992). In those tectonic units, where the Triassic is represented by Dachstein limestones (e.g., Tennengebirge, Totes Gebirge, Dachstein), the Hierlatz limestones (VÖRÖS, 1991; Sinemurian-Pliensbachian) replace the Adnet Formation.

3.2.1. Lienbacher Member

1992: Adneter Rotmikrit, BÖHM, p. 117
1993: Condensed red Adnet limestone, BÖHM & BRACHERT
1995: Thick bedded facies of the Adnet Fm. with few nodular layers, DOMMERGUES et al.
1996: Lienbacher Member, WAGREICH et al.
1999: Lienbacher Member, BÖHM et al.

Type area: Adnet quarries, Adnet (ÖK50/Blatt 94 Hallein), see Fig. 1.
Type section: Lienbacher quarry (Adnet quarry XII).
Coordinates: $R^4$35 425 , $H^2$84 240
Name: After the Lienbacher quarry, local name of the type locality.
Lithology: Decimetre-bedded, marl-poor, blotchy red micritic limestones. Rich in millimetre- to centimetre-sized intraclasts with ferromanganese coatings. Nodular fabrics are rare.
Lithostratigraphic superunit: Adnet Formation.
Lithostratigraphic subdivison: The Lienbach Mb. is subdivided in a lower and an upper unit by a discontinuity including a ferromanganese crust, stromatolites and onlap of the overlying beds (BÖHM & BRACHERT, 1993; BÖHM et al., 1999). The lower unit was termed "Basal Unit" by BÖHM et al. (1999).
Chronostratigraphy: ?Lower to upper Sinemurian.

Biostratigraphy: The underlying "Marmorea Crust" has a late Hettangian age. GALLET et al. (1993) report late Sinemurian ammonites from 2–3 m above the base of the Lienbacher Member in quarry XII. An ammonite horizon in the middle part of this section, immediately above the stromatolite layer has yielded only *Zetoceras complanatum*, but no age diagnostic species (BÖHM et al., 1999). DOMMERGUES et al. (1995) found late Sinemurian ammonites (Oxynotum-Raricostatum zone) a few metres higher in the same section. At quarry XXX KRYSTYN (1971) collected a fauna from the Obtusum zone in the Lienbacher Member.
Thickness: In the lower unit (section below the stromatolite layer) thickness varies in quarry XII through onlap on a ridge of Rhaetian reef limestones. It increases from 0.2 m in the NW to about 4 m in the SE. Above the stromatolite layer the section continues for at least 5 m, where it is overlain with an erosional contact by the "Scheck breccia" (BÖHM et al., 1995, 1999). In quarry XXX the maximum observed thickness of the Lienbacher Mb. is >5 m.
Underlying unit: The Lienbacher Member overlies Rhaetian reef limestones with a very thin intercalation of the "Marmorea Crust" including a few centimetres to decimetres of red crinoidal limestones of the Schnöll Formation (Guggen Mb.).
Lower boundary: The base is well defined by the "Marmorea Crust".
Overlying unit: In quarry XII the Scheck Member overlies the Lienbacher Member with an erosional contact (BÖHM et al., 1995; WAGREICH et al., 1996). At quarry XXX radiolarites of the Ruhpolding Fm. conformably overlie the Lienbacher Mb., partly with an intercalated thin ferromanganese crust.
Upper boundary: In the currently available outcrops the upper boundary is most likely an erosional contact which is overlain either by the "Scheck breccia" or by radiolarites. In both cases the overlying units are significantly younger than the Lienbacher Member, indicating either erosion or a depositional gap.
Regional distribution: Upper slope of the drowned Rhaetian Adnet reef forming a NW-SE striking facies belt, exposed in Adnet quarries II–IV, XII and XXX and in small outcrops between quarry XII and IX.
Laterally bordering units: Towards the north and northeast the Lienbacher Member interfingers with the Motzen and Schmiedwirt Members.

3.2.2. Motzen Member

1992: Crinoidenmikrit, BÖHM, Fig. 70
1996: Motzen Member, WAGREICH et al.
1999: Motzen Member, BÖHM et al.

Type area: Adnet quarries, Adnet (ÖK50/Blatt 94 Hallein), see Fig. 1.
Type section: Adnet quarry XIV, Motzen quarry (Fig. 6).
Coordinates: $R^4$35 450 , $H^2$84 500
Name: From the local name of the type locality. Motzen is the quarrymen's term for the crinoidal limestones exploited in this quarry.
Lithology: Decimetre-bedded, pink-red to red crinoidal limestones (wackestones and packstones). Characteristically with white crinoidal columnals and millimetre- to centimetre-sized intraclasts with ferromanganese coatings. Similar to Lienbacher Member, but with more crinoidal debris.

Lithostratigraphic superunit: Adnet Formation.
Lithostratigraphic subdivison: Like the Lienbacher Mb., the Motzen Mb. is subdivided in a lower and upper unit by a discontinuity consisting of a stromatolite layer and a ferromanganese crust (Fig. 6). Again the overlying beds onlap the discontinuity surface (Böhm et al., 1999).
Chronostratigraphy: Sinemurian.
Biostratigraphy: No biostratigraphic data are available for the Motzen Member. The chronostratigraphic age is estimated from lithostratigraphic correlation with quarry XII of the ferromanganese crust at the base of the section (Hettangian "Marmorea Crust") and the stromatolite layer/discontinuity surface (?upper Sinemurian).
Thickness: The lower unit shows a variable thickness in quarry XIV through onlap on the underlying Rhaetian relief (Fig. 6). Maximum observed thickness of the lower unit is 4 m. The upper unit is exposed with a thickness of about 1.5 m.
Underlying unit: Rhaetian reef limestones, locally with small pockets filled with limestones of the Schnöll Formation.
Lower boundary: Ferromanganese crust covering the surface of the underlying massive Rhaetian limestones. The contact is an erosional surface (Böhm et al., 1999).

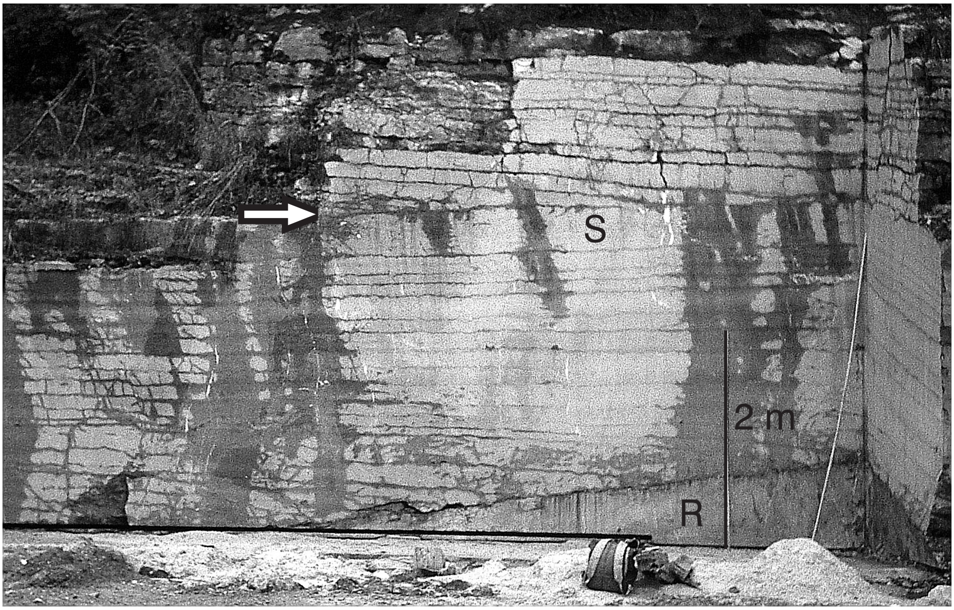

Fig. 6: Motzen Member (Adnet Formation) at quarry XIV. Rhaetian grey massive limestones (R) in the lower right corner of the quarry are overlain by the crinoidal limestones of the Motzen Member. A massive bed in the upper part of the section (S) is a deepwater stromatolite similar to the one described from the Lienbacher Mb. by Böhm & Brachert (1993). It is capped by a ferromanganese crust (arrow). The overlying beds of the Motzen Mb. onlap the unconformity on top of "S", prograding to the right (WNW). The beds in this quarry still have their original depositional attitude as shown by horizontal geopetal infillings and vertical growth axes of the stromatolite domes (Böhm et al., 1999).

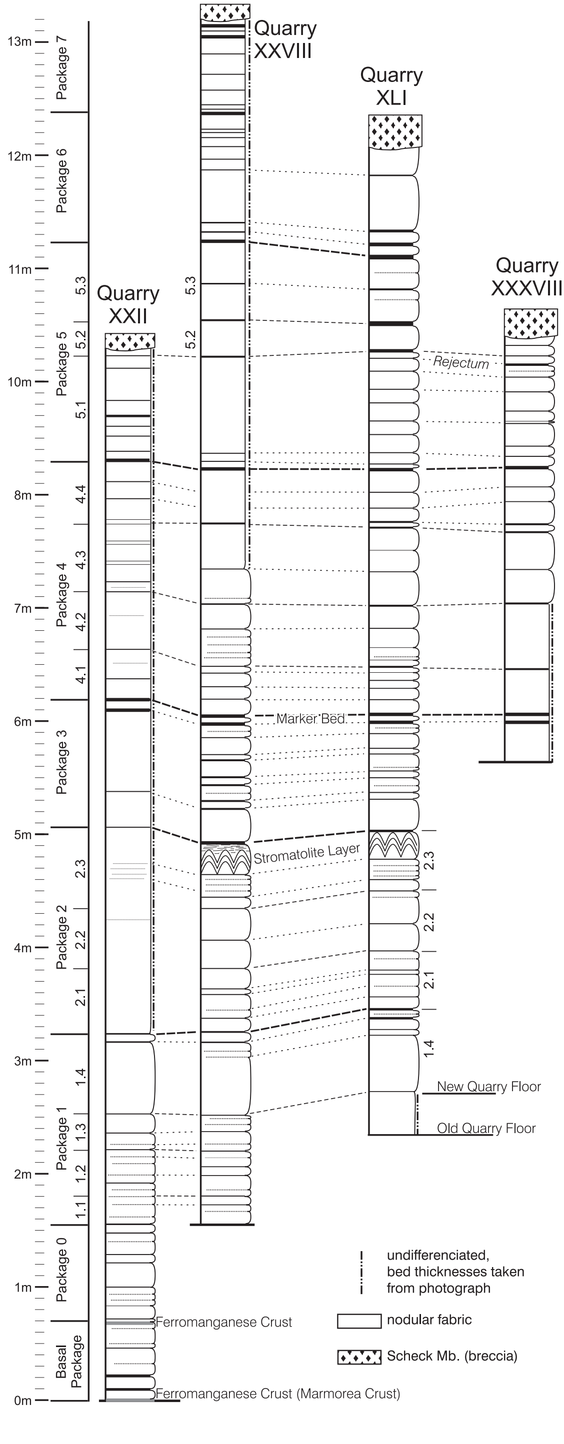

Fig. 7:
Detailed sections of the Schmiedwirt Mb. in several Adnet quarries showing packages, bed bundles and bed by bed correlations. In all sections the Schmiedwirt Mb. is directly overlain by the Scheck Mb. breccia. In quarry XLI the erosion by this breccia cuts down as deep as Package 4.3. See text for a description for the packages. The position of the Rejectum Horizon (Sinemurian, Obtusum zone) in quarry XXXVIII (Dommergues et al., 1995) is indicated.

Overlying unit: Unknown. The top of the Motzen Mb. is currently not exposed.
Upper boundary: Unknown.
Regional distribution: Only found in Adnet quarries V and XIV and small outcrops in between.
Laterally bordering units: To the south the Lienbacher Mb., to the north and east the Schmiedwirt Mb. are lateral equivalents of the Motzen Member

3.2.3. Schmiedwirt Member

1903: Adneter Schichten, Fazies der Cephalopoden-Knollenkalke, WÄHNER
1967: Adneterkalk, HALLAM
1969: Adnet Limestone, HUDSON & JENKYNS
1969: dünnschichtige Knollenkalke, SCHLAGER
1971: Adneter Schichten s. str., WENDT
1976: Adneter Kalke s. str., TOLLMANN
1983: roter, knollig-flaseriger, plattiger Adneter Kalk, PLÖCHINGER
1992: Adneter Knollenkalke, BÖHM
1995: Schmiedwirt Member, BÖHM et al.
1996: Schmiedwirt Member, WAGREICH et al.
1999: Schmiedwirt Member, BÖHM et al.

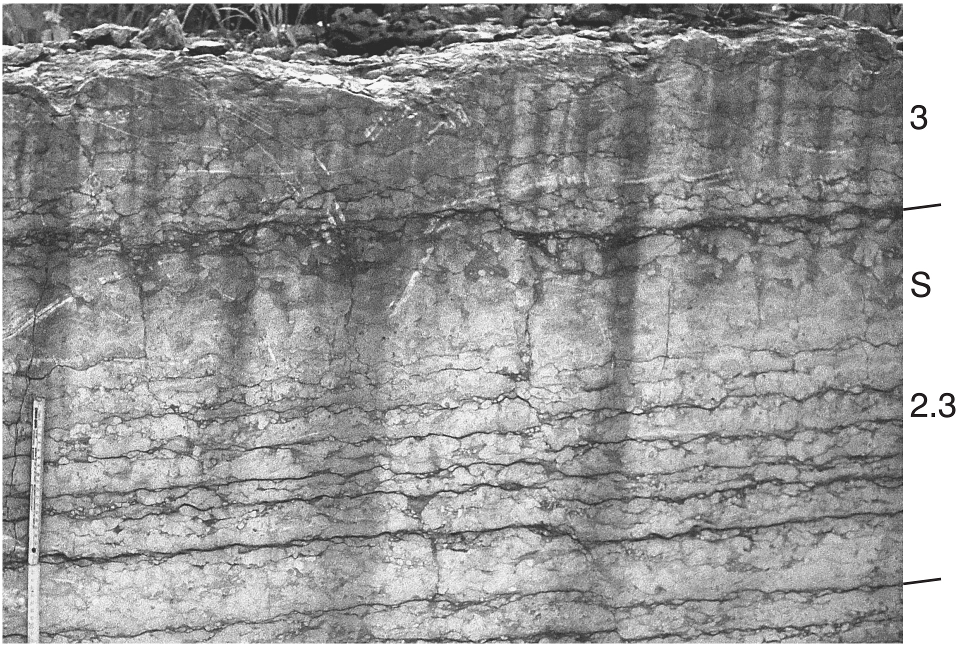

Fig. 8: Stromatolitic layer (S) on top of Package 2 (Schmiedwirt Mb.) at quarry XLI. The stromatolite structures develop from the thin nodular beds of Bundle 2.3 and make up a distinct massive layer. Stromatolitic lamination is very faint and hardly visible in the photograph. The top of the stromatolite is covered by marl (dark), followed by the thick unbedded nodular layer forming the base of Package 3. Scale at left is 30 cm.

Type area: Adnet quarries, Wiestal (ÖK50/Blatt 94 Hallein), see Fig. 1.
Type section: Schmiedwirt quarry, 2.5 km NNW of Adnet, at the old Wiestal road between Gasthof Bischoff and Schmiedwirt. The base of the Schmiedwirt Mb. is not well exposed at the type section. For the base of the Member the section of the Adnet quarry XXII provides the best outcrops and is proposed as reference section for the lower boundary (Figs. 3, 7).
Coordinates: Schmiedwirt quarry, $R^4$34 370 , $H^2$86 620; quarry XXII, $R^4$35 475 , $H^2$84 775.
Name: From the local name of the type locality.
Lithology: Medium to thin bedded, mostly nodular, red limestones (intraclastic wackestones; Fig. 8).
Lithostratigraphic superunit: Adnet Formation.
Lithostratigraphic subdivison: The Schmiedwirt Mb. is subdivided in at least 9 packages (Fig. 7). Each package is bounded by thicker than average marl layers (Fig. 9). Some packages consist of several bundles of beds. In the Adnet area it is possible to correlate most bundles and even single beds between individual quarries (Fig. 7). From bottom to top the packages are: ***Basal Package***, thin package of several decimetre-thick beds. Bounded on bottom and top by ferromanganese crusts. The lower one is the "Marmorea Crust" capping marls and limestones of the Kendlbach Fm. (Böhm et al., 1999). It is overlain by a prominent red marl layer, a thin limestone bed, and a second prominent marl layer. ***Package 0***, slightly thinner bedded than the basal package. The top is defined by a thin bed capped by a 1 cm thick marl layer. At present these two lowermost packages are only exposed in quarry XXII. Package 0 was occasinally exposed in quarry XXVIII. ***Package 1***, subdivided into 4 bundles with upward increasing nodular fabric. The topmost bundle shows a characteristic succession with a thick indistinctly bedded layer followed by three thin distinct limestone beds, the uppermost of which is bounded by prominent marl layers. ***Package 2*** (Fig. 10) starts with three relatively massive beds (2.1) followed by two thick beds, each with upward increase of nodular fabrics (2.2). The top of the package (2.3) is formed by a distinct thin bed, a characteristic bundle of four indistinct beds and finally a stromatolitic layer (Fig. 8). The latter is a conspicuous marker horizon of the Schmiedwirt Member. ***Package 3*** (Fig. 10) starts with a thick nodular bed, which is followed by an alternation of thin and thick beds. The package top is defined by a very distinct thin limestone bed bounded by thick marl layers (Figs. 9, 10). This is again a very conspicuous marker bed. ***Package 4*** consists of four bundles (Figs. 10, 11). The lowermost bundle (4.1) has relatively thin, distinct beds. The middle two bundles show less distinct bedding, except for clear marl partings, roughly in the middle of both 4.2 and 4.3. Like Package 3 Bundle 4.3 shows an alternation of thin and thick beds (Fig. 7 left column, Fig. 10). Bundle thickness increases from 4.1 to 4.3. The top bundle (4.4) is characterized by its thin-bedded, nodular center (Fig. 10). ***Package 5*** starts with a thick well bedded bundle (5.1) with relatively thin beds. It is overlain by a thin marly intercalation (5.2, Fig. 11). Dommergues et al. (1995) found a rich ammonite fauna of the Obtusum zone (Rejectum Horizon) at this level in quarry XXXVIII. Bundle 5.3 is again well bedded, similar to 5.1. ***Package 6*** is completely exposed only in the inaccessible upper walls of quarry XXVIII (Fig. 9). Therefore no detailed information is available. Its basal part is visible in some older, weathered parts of quarry XLI, where it starts with a thick marly layer, followed by a thick, indistinctly layered limestone bed. ***Package 7*** is

exposed only at the inaccessible top of quarry XXVIII. It is overlain by the Scheck Mb. breccia (Fig. 9). Ammonites of the Raricostatum zone reported by Dommergues et al. (1995) from immediately below the "Scheck breccia" are probably from the upper part of Package 7.

Chronostratigraphy: Sinemurian, ?Carixian.

Biostratigraphy: The lower part of the Schmiedwirt Mb. is poor in age diagnostic ammonites. A level in the early Semicostatum zone is indicated by *Coroniceras* cf. *lyra* found in the screes at quarry XXVIII (Dommergues et al., 1995). The lowermost level with *Arnioceras* sp., proving a Sinemurian age, is found at about 3 m above the base of the type section. The Paucicostum level of Dommergues et al. (1995) is the oldest ammonite rich level in the type section. It has also been found in the Adnet quarries XXXVIII and XLI and at Breitenberg (Meister & Böhm, 1993). Though its exact age is unknown, it may be placed somewhere between the lower Semicostatum and the lower Obtusum zones. The middle Obtusum and Raricostatum zones are well documented in the Schmiedwirt

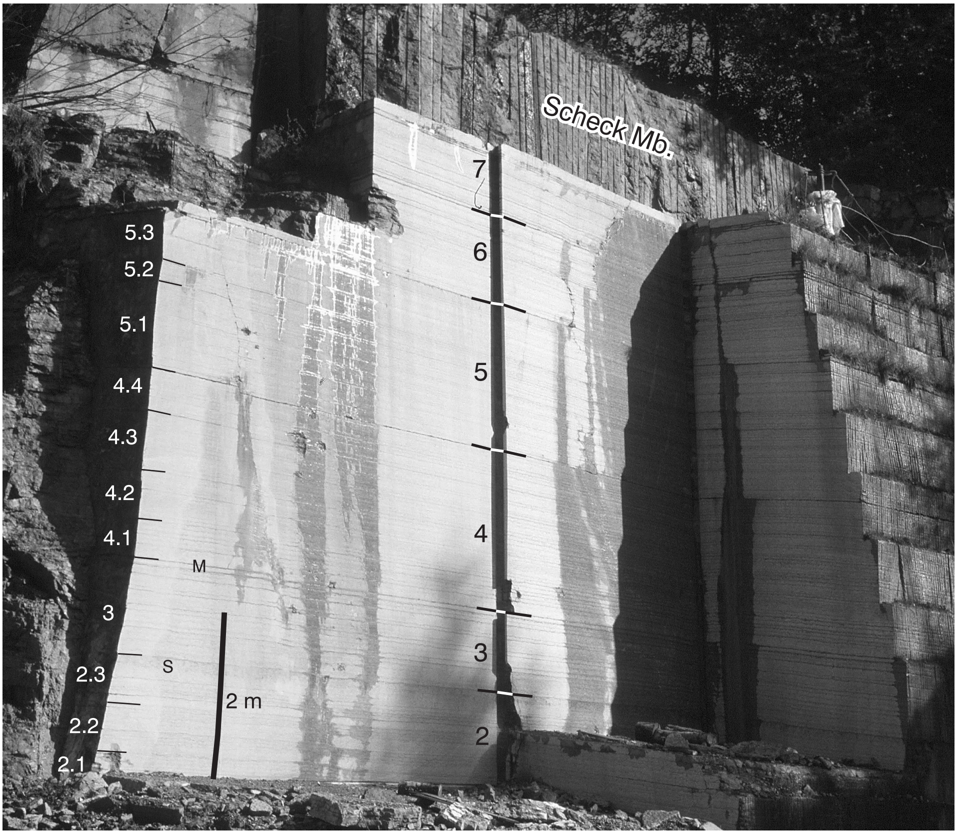

Fig. 9: Subdivision of the Schmiedwirt Mb. at quarry XXVIII by major marl layers. The Schmiedwirt Mb. is directly overlain by the Scheck Mb. breccia with an erosional contact. M: marker bed. S: stromatolite.

Member (Meister & Böhm, 1993; Dommergues et al., 1995). So far, the uppermost 3.5 m of the Schmiedwirt Mb. have not yielded characteristic ammonite faunas. The oldest ammonites from the overlying Kehlbach Mb. already indicate the middle Jamesoni zone. Thus it is possible that the top of the Schmiedwirt Mb. includes the earliest Carixian (Fig. 12).
Thickness: At the type locality the base of the Schmiedwirt Mb. is not well exposed. The exposed thickness is 14 m in the quarry. Böhm et al. (1995) estimated a total thickness

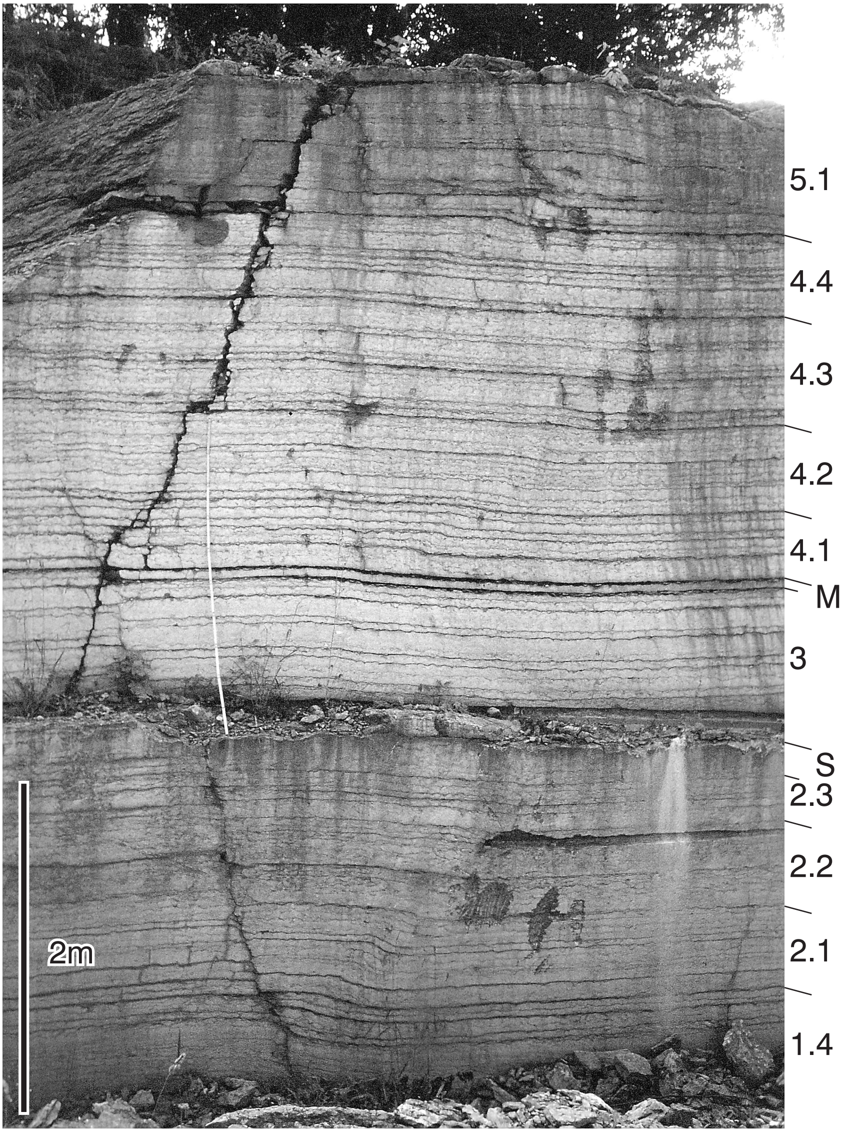

Fig. 10: Subdivision of Packages 2 to 4 of the Schmiedwirt Mb. at Adnet quarry XLI. M: marker bed at the top of Package 3. S: stromatolite horizon at the top of Package 2.

of 16 m. At Adnet the top of the Schmiedwirt Mb. is an erosional surface overlain by the "Scheck Breccia". The maximum measured thickness is 13 m in quarry XXVIII.

Underlying unit: Kendlbach Formation (e.g., quarry XXII), Schnöll Formation (e.g., quarry XXXI), or Scheibelberg Formation (e.g., Schmiedwirt quarry).

Lower boundary: At the Schmiedwirt quarry the Schmiedwirt Mb. develops from grey limestones of the Scheibelberg Formation. In this case the lower boundary is defined by the change from grey to red color, including a transitional interval. At Adnet quarry XXII the base is well defined by the ferromanganese "Marmorea Crust" and the facies shift from violet to greenish-grey crinoidal limestones of the Kendlbach Fm. to the red, thin-bedded, nodular limestones of the Schmiedwirt Mb./Adnet Formation (Fig. 3).

Overlying units: Kehlbach, Scheck or Saubach Member/Scheibelberg Formation.

Upper boundary: The transition to the Kehlbach Mb. is defined by the onset of crinoidal limestone beds in the Schmiedwirt section (middle of unit 8 of Meister & Böhm, 1993). Besides the increase in crinoidal debris, increasing marl contents mark the onset of the Kehlbach Member. When overlain by the Scheibelberg Fm. the boundary is defined by the color change from red to grey. Boundaries to the Scheck and Saubach Mbs. are defined by facies changes (see descriptions below).

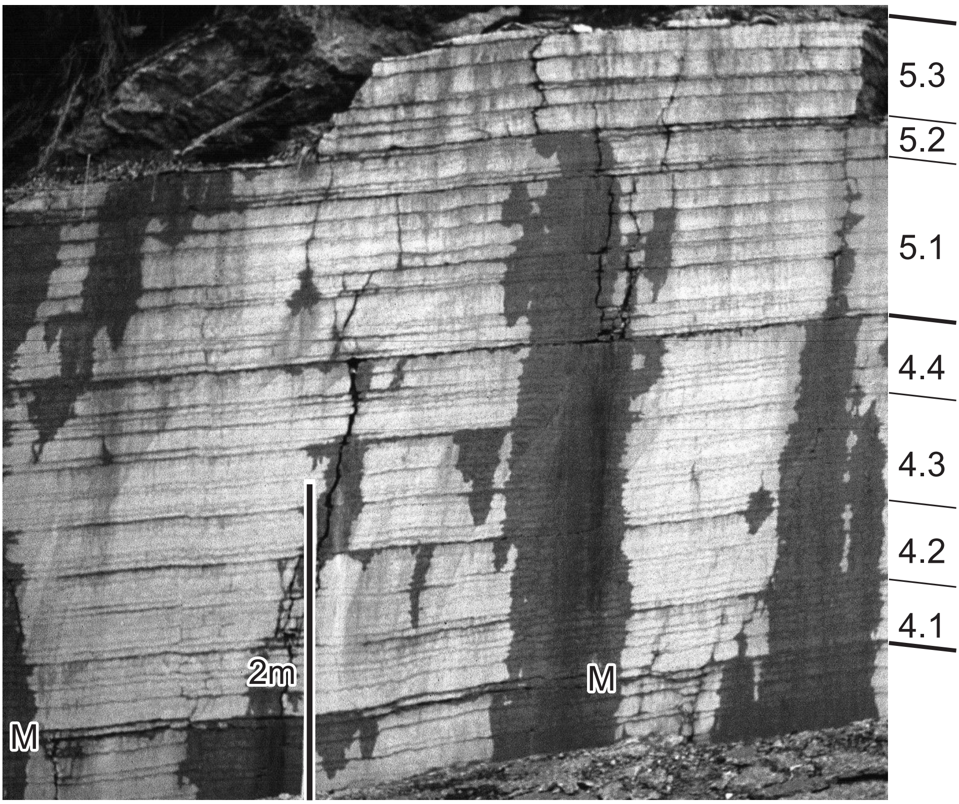

Fig. 11: Subdivision of Packages 4 and 5 of the Schmiedwirt Mb. at Adnet quarry XLI. M: marker bed at the top of Package 3.

Regional distribution: The Schmiedwirt Mb. is very widespread in the Osterhorn Mts. The typical nodular facies forms a W-E striking belt, probably tracing the margin of the former Rhaetian Kössen basin (Böhm, 1992). The northern part of this belt is characterized by a facies, transitional into the Scheibelberg Fm., with less well developed nodular fabric.
Laterally bordering units: In the Adnet quarry area the Schmiedwirt Mb. interfingers to the south with the Motzen and Lienbacher Members. On a larger scale, it passes northward into the Scheibelberg Formation of the northern Osterhorn Block.

3.2.4. Kehlbach Member

1968: Roter Knollenkalk des Mittellias, Vortisch
1970: r Kn mls (Roter Knollenkalk des Mittellias), Vortisch
1970: Red nodular limestones and marls, Unit 2A, Bernoulli & Jenkyns
1979: Adneter Knollenkalke, Pliensbach, Del-Negro, Fig. 2
1992: Rote, dünnplattige, crinoidenreiche Mergelkalke, Böhm, p. 112
1995: Kehlbach Member, Böhm et al.

Type area: Osterhorn Mts. (ÖK50/Blatt 94 Hallein), see Fig. 1.
Type section: Kehlbach, upstream from the roadbridge between Zieglau (Elsbethen) and Reinberg, south of the city of Salzburg.
Coordinates: $R^4$32 380 , $H^2$90 000
Name: The Kehlbach is a small tributary flowing into the Salzach river about 1 km south of Salzburg/Glasenbach.
Lithology: Thin bedded, nodular, marly, red limestones and marls (Fig. 13). The facies is similar to the Schmiedwirt Mb., characteristically it is richer in marls, echinoderms and belemnites. Thin, lens-like, intercalated breccia beds occur locally (Meister & Böhm, 1993; Böhm, 1992; Böhm et al., 1995).
Lithostratigraphic superunit: Adnet Formation.
Chronostratigraphy: Lower Pliensbachian (Carixian).
Biostratigraphy: The Kehlbach Mb. has a rich ammonite fauna. Meister & Böhm (1993) report 4 ammonite levels indicating the presence of the Jamesoni and Ibex zones at Schmiedwirt quarry (Fig. 12). At the type locality the Jamesoni zone is evident (Vortisch, 1968).
Thickness: 15 m at the type locality. Very variable. At Adnet and Breitenberg the Kehlbach Mb. is lacking in most sections, probably due to erosion by the mass flows of the Scheck Mb. At Schmiedwirt the thickness is 2.5 to 3.5 m (Fig. 12), the lower value reflecting channel erosion by a breccia (Böhm et al., 1995: Fig. 3).
Underlying unit: Schmiedwirt Member/Adnet Formation; Scheibelberg Formation.
Lower boundary: The boundary to the Schmiedwirt Mb. is defined by the gradational facies change to more marly, crinoidal limestones. The boundary to the Scheibelberg Fm. is well defined by the sharp change from grey to red color (e.g., at Kehlbach, Glasenbach).
Overlying units: Scheck or Saubach Mb./Adnet Fm., Scheibelberg Formation.
Upper boundary: Where overlain by the Scheibelberg Fm. the color change from red to grey indicates the well defined upper boundary. The Scheck Mb. consists of a few

massive breccia layers with an erosional base defining the boundary. In contrast, the breccias in the Kehlbach Mb. are non-erosive and form thin lense-like bodies (Fig. 13). In the rare cases lacking an intercalated Scheck Mb. breccia bed, the boundary to the Saubach Mb. is defined by the change to a distinct, brick-red marly facies and the occurrence of filament limestones (Böhm, 1992).
Regional distribution: Similar to the Schmiedwirt Member, however also present in the northwestern parts of the Osterhorn block (e.g., Kehlbach and Glasenbach). Often eroded by late Pliensbachian/Toarcian mass flows (i.e., Scheck Mb., e.g., at most Adnet quarries).
Laterally bordering units: Scheibelberg Formation.

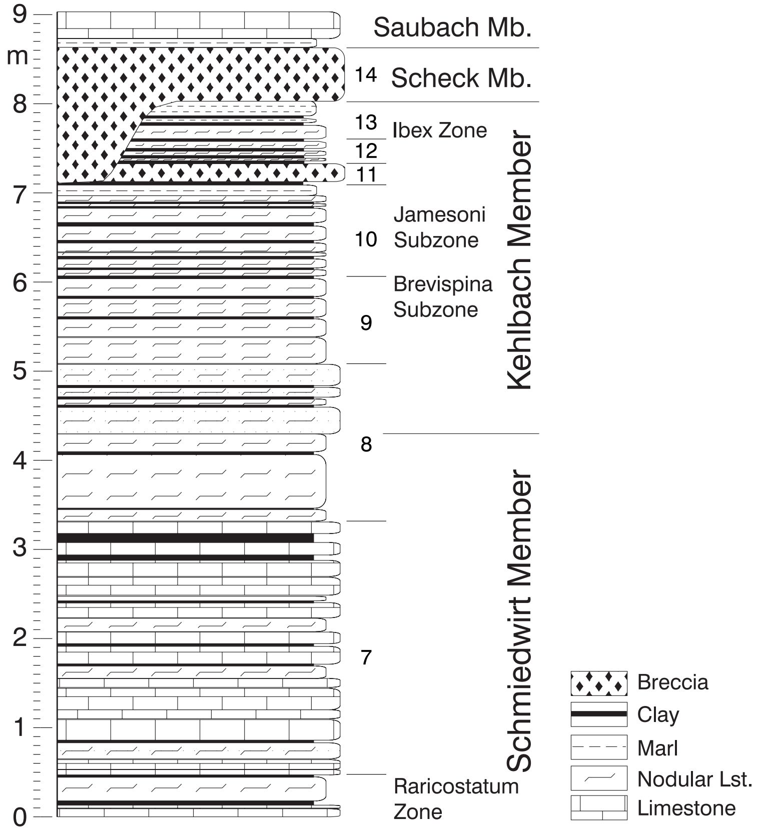

Fig. 12: Kehlbach Mb. at the Schmiedwirt quarry. The Kehlbach Mb. is characterized by higher marl contents compared to the Schmiedwirt Member. Crinoidal debris is more common as well, especially large columnals. Thin locally restricted breccia layers may occur. The thick breccia layer of the Scheck Mb. erodes the upper parts of the Kehlbach Mb. and is overlain by marls and limestones of the Saubach Member. Layer numbers and biostratigraphy are from Meister & Böhm (1993).

Fig. 13: Marly red limestones and marls of the Kehlbach Mb. at Schmiedwirt quarry (compare Fig. 12). Note the thin breccia layer in the Kehlbach Mb. pinching out to the left and the thick breccia layer of the Scheck Mb. at the top.

3.2.5. Scheck Member

1903: Scheck, Wähner
1964: Scheck, Kieslinger
1967: Scheck, Hallam
1969: Scheck, Jurgan
1969: Limestone conglomerate, Scheck, Hudson & Jenkyns
1970: Knollenbreccie, Scheck, Schlager
1970: Hauptknollenbreccie, Vortisch
1971: Scheck, rote Knollenbreccie, Wendt
1978: Scheck, Hudson & Coleman
1990: Adneter Rotscheck, oberliassische Knollenbreccie, Plöchinger, p. 19
1995: Scheck Member, Böhm et al.

Type area: Adnet quarries, Adnet (ÖK50/Blatt 94 Hallein), see Fig. 1.
Type section: Scheck quarry, Adnet quarry XXII.
Coordinates: $R^4$35 475 , $H^2$84 775
Name: "Scheck" (meaning spotty) is the quarrymen's term for breccias of micritic Adnet limestone clasts embedded in a white sparry matrix.
Lithology: Red to grey breccia with clast sizes ranging from millimeters to more than one

Fig. 14: Type section of the Scheck Mb. at Adnet quarry XXII. Thin bedded, nodular limestones (Nod) of the Schmiedwirt Mb. are overlain by the breccia of the Scheck Mb. with an erosional contact (traced by the black line). The basal part of the breccia is matrix-poor with marly and micritic matrix (Br1). It is overlain by matrix-rich breccia with sparitic and micritic matrix (Br2). Clasts (c) of up to 0.5 m in size are common. Length of scale is 2 m.

metre (Fig. 14); one massive layer of amalgamated breccia beds. Two different lithologies occur: (1) matrix-poor micritic, marly "Knollenbreccie"; (2) matrix-rich, sparry "Scheck", with partly cemented interparticle pores. Clasts are mainly Adnet limestones. A detailed description is given in Böhm et al. (1995). In the type section the matrix-poor variety forms the basal part of the Scheck Mb. and is oberlain by the sparry matrix-rich variety with increasingly larger clasts upsection (Fig. 14).
Lithostratigraphic superunit: Adnet Formation.
Chronostratigraphy: Pliensbachian (upper Carixian) to lower Toarcian
Biostratigraphy: No reliable biostratigraphic information is available from the Scheck Mb., as most fauna found within the breccia is reworked. This is evident from mixed Sinemurian-Domerian ammonite faunas described by Bernoulli & Jenkyns (1970), Vortisch (1970) and Wähner (1903). The oldest faunas found in the overlying strata are of early Toarcian age (Bifrons zone). The faunas from underlying strata are of different ages ranging from Sinemurian (Obtusum zone) in some Adnet quarries to Carixian (Ibex zone) at Schmiedwirt quarry and Domerian (Margaritatus zone) at Breitenberg (compilation in Böhm et al., 1995).
Thickness: Very variable. Breccias often fill channels and may pinch out within very short distances (Fig. 4). The maximum observed thickness is 40 m at Kehlbach.
Underlying unit: Adnet or Scheibelberg Formation. Because of its erosional lower boundary the Scheck Mb. may overlie Sinemurian limestones of the Schmiedwirt and Lienbacher Mb. in several Adnet quarries, e.g., in the type section (Fig. 14; Böhm et al., 1995).
Lower boundary: Often erosional. Sharp facies transition from mostly thin-bedded underlying limestones to the massive breccia (Figs. 9, 13).
Overlying unit: Marls of the Saubach Member (Figs. 4, 12, 15). In some cases a crinoidal turbidite layer occurs at the transition from the Scheck to the Saubach Member. If the overlying Saubach Mb. is very condensed, the Scheck Mb. may be overlain by the Klaus Fm. (red limestones) or Ruhpolding Formation (radiolarites). In the northwestern Osterhorn Mts. red-grey marls, transitional between Adnet and Allgäu Fm., overlie the Scheck Member.
Upper boundary: Facies change from massive breccia to marls and bedded limestones.
Regional distribution: Very widespread in the Osterhorn Mts., the sparry lithology is restricted to the Adnet quarries.
Laterally bordering units: Probably the Saubach Mb. rarely forms a lateral equivalent. However, in dated sections lacking the Scheck Mb., the time interval is represented by a hiatus.

3.2.6. Saubach Member

1976: Adneter Mergel, Tollmann
1982: Saubachschichten, Plöchinger
1990: ziegelroter Sandmergel, Saubachschichten, Plöchinger
1992: Saubachschichten, Böhm
1995: Saubach Member, Böhm et al.

Type area: Osterhorn Mts. (ÖK50/Blatt 94 Hallein), see Fig. 1.
Type section: The original type section at the Saubachgraben (Plöchinger, 1975) is largely destroyed and buried. The forest road section at the western side of the Gro-

briedel at 1290 m (Böhm, 1992) is designated as the new type section (Fig. 15). Additional sections are found in the Tauglboden area (Davidgrabenklamm, Tauglbach), at Gaissau and Hochleitengraben (Böhm, 1992).

Coordinates: Saubach, R[4]49 330, H[2]89 000, Grobriedel, R[4]43 450 , H[2]85 700, Davidgraben, R[4]44 680 , H[2]81 250, Tauglbach, R[4]44 570, H[2]81 000, Gaissau, R[4]39 030 , H[2]87 200, Hochleitengraben, R[4]41 820, H[2]83 830

Name: From the type locality, Saubach, a little creek southeast of the Schafbachalm near Hintersee.

Lithology: Brick red marls with intercalated limestone beds (Fig. 15; bioclastic wackestones and packstones, often with filaments and crinoidal debris). No nodular fabrics. Breccia layers occur occasionally.

Remark: In contrast to the "Adneter Mergel" as defined by Tollmann (1976), the Saubach Mb. does not include grey marls. In the type area, the Saubach Mb. consists of predominantly red sequences. In some cases (e.g., Gaissau) the Saubach Mb. is dominated by red condensed limestones with only minor marl intercalations. Red-grey marls of Toarcian age overlying the Scheck Mb. at Glasenbach Gorge are not included in the Saubach Mb. by this definition, but should rather be interpreted as a transitional facies between the red Adnet and grey Allgäu Formation. This is also indicated by the increased thickness of the Glasenbach sequence compared to the usually very condensed Saubach Mb. sections of the Osterhorn area. Krainer & Mostler (1997) suggested the name Saubach Formation for greenish grey Upper Liassic marls in the Unken Syncline. Their microfacies was described as identical to the Saubach Member as defined here. The grey

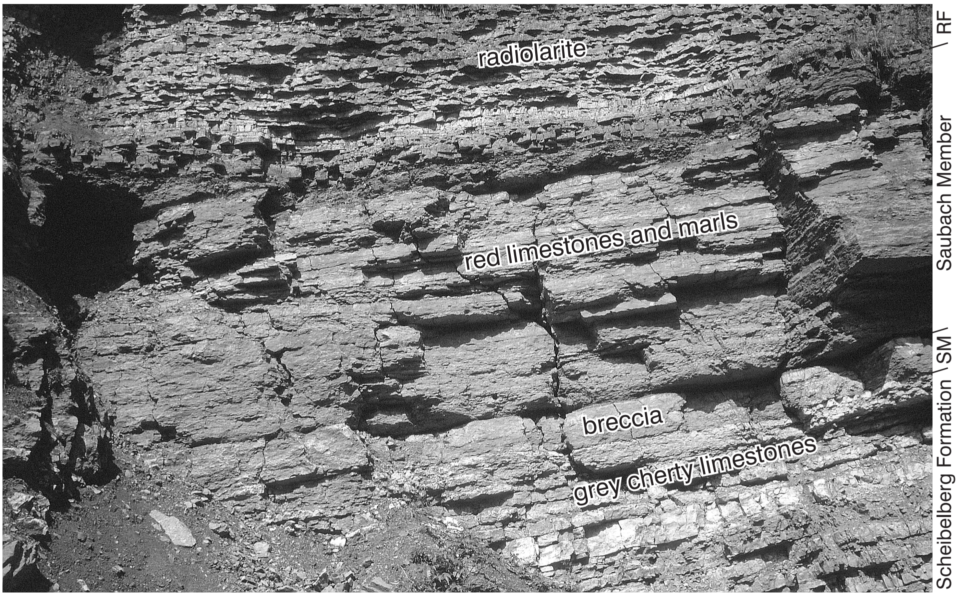

Fig. 15: Saubach Mb. intercalated between a thin breccia bed ("Knollenbreccie") of the Scheck Member and the radiolarites of the Ruhpolding Fm. at Grobriedel. The two members of the Adnet Fm. overlie grey cherty limestones of the Scheibelberg Formation. The thickness of the Saubach Mb. is 3.8 m. SM: Scheck Member, RF: Ruhpolding Formation.

color and the intercalated bituminous marls show that this unit has a transitional position between the red marls of the Saubach Mb. and the black shales of the Sachrang Formation (Ebli, 1997). The "Adneter Mergel" described by Ebli (1997) are lower Liassic red, grey and greenish marls, locally occuring at the transition between Adnet and Scheibelberg Formation. These are both of different age and different facies than the marls of the Saubach Member.

Lithostratigraphic superunit: Adnet Formation.

Chronostratigraphy: Toarcian to Aalenian.

Biostratigraphy: Despite the rich ammonite faunas found in the Saubach Mb., there is no detailed biostratigraphic description available for the Osterhorn Mts. The Bifrons zone and all zones of the late Toarcian are present in the Saubach Mb. (see compilation in Böhm, 1992). The youngest ammonite faunas prove its continuation to the Aalenian (Opalinum or Murchisonae zone; Wendt, 1971; Krystyn, 1971).

Thickness: Varies from <1 m to an observed maximum of about 15 m. Greater thicknesses are locally indicated by geological mapping. However, due to the marly nature of this member there are no outcrops known to the author where these could be verified (Böhm, 1992).

Underlying unit: Scheibelberg or Adnet Formation. Often a breccia (Scheck Mb.) forms the base of the Saubach Member (Figs. 4, 12, 15). Due to syndepositional erosion, the underlying strata may be as old as Sinemurian.

Lower boundary: The facies transition to red marls and limestones rich in filaments (bivalves) marks the onset of the Saubach Mb. Often the base of the Saubach Mb. is indicated by the onset of marls above a breccia layer (Scheck Mb.).

Overlying unit: Klaus or Ruhpolding Formation.

Upper boundary: The discrimination between the Saubach Mb. and the Klaus Fm. is often difficult. The latter is characterized by reduced marl contents, a red color with a violet or brown hue and a microfacies with more pelagic components including globigerinoids (Böhm, 1992). If directly overlain by radiolarites of the Ruhpolding Fm. the upper boundary of the Saubach Mb. is well recognizable by the facies change.

Regional distribution: Almost ubiquitous in the Osterhorn Mountains.

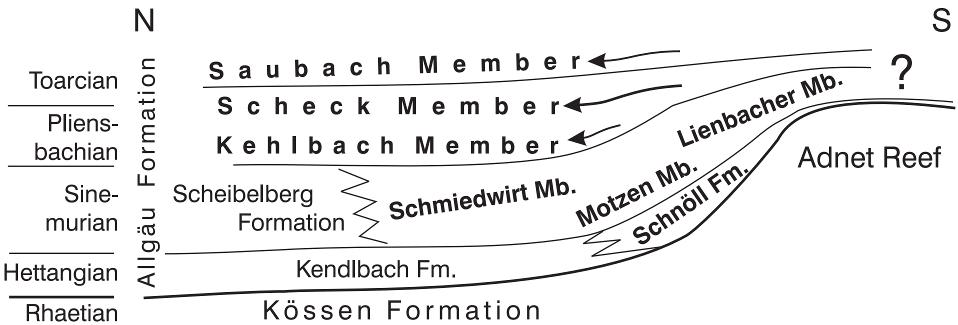

Fig. 16: Sketch showing the temporal and spatial distribution of the members of the Adnet Group and their relationship to the Rhaetian topography and surrounding Liassic formations. Arrows indicate gravitational transport, probably induced by tectonic activity. Not to scale.

Laterally bordering units: Toarcian Scheibelberg Fm. and a transitional facies between Saubach Mb. and the Allgäu and possibly Sachrang Formations are found in the northwestern parts of the Osterhorn block (Glasenbach Gorge).

4. DISCUSSION AND CONCLUSIONS

Despite 150 years of palaeontological, stratigraphical and sedimentological work in the Adnet region there are still considerable unknowns in the sedimentary history of the Adnet Group, e.g., in the knowledge of biostratigraphic details, synsedimentary tectonics, or the causes of the end-Triassic/early Liassic reef drowning. The continuing quarrying activities expose new sedimentary structures, but also destroy older outcrops. This requires a constant monitoring of the existing outcrops to document and preserve sedimentary structures and stratigraphic information before they are lost to quarrying (e.g., BERNECKER et al., 1999).

The Early Jurassic succession of facies reflected in the members of the Adnet Group has previously been interpreted in terms of environmental changes, the drowning history of the Late Triassic carbonate reefs and platforms and the tectonic break-up of the continental margin exposed in the Northern Calcareous Alps (BÖHM, 1992; BÖHM et al., 1995, 1999; GAWLICK et al., 1999). A short summary is presented here (Fig. 16).

***Schnöll Fm.*:** The sedimentation was restricted to lower slope and basinal settings during the early and middle Hettangian, when the Langmoos Mb. (Schnöll Fm.) was deposited. With its erosional basal surface and the successive onlap on the slope, the Langmoos Mb. can be interpreted as a late lowstand/transgressive systems tract (BÖHM et al., 1999). Environmental conditions with poorly oxygenated and nutrient rich waters may have fostered the predominance of siliceous sponges and the color variations between red and yellow-grey. The presumably contemporary sediments of the Kendlbach Fm., condensed glauconitic limestones with siliceous sponge spicules, are in accordance with this interpretation. With the stalling sea-level during the subsequent highstand phase, oxygenation of the bottom waters improved and the siliceous sponge associations were replaced by crinoidal meadows. The deposition of the Schnöll Mb. came to an end when the continued drowning, an increase in current strength and possible hydrothermal activities led to the formation of a ferromanganese crust during a prolonged period of repeated submarine erosion and non-sedimentation ("Marmorea Crust"). Current activities at this time may have increased through a climate shift and/or a sealevel lowstand (BÖHM, 1992).

***Lower Adnet Fm.*:** Deposition of the Adnet Formation began after conditions returned to "normal", probably when the sea floor had subsided to a water depth below base level or overall current activities were reduced by some external factors. Three different facies formed in different positions on the drowned Rhaetian relief, from upper to lower slope: Lienbacher, Motzen and Schmiedwirt Member. Besides this differentiation on the former reef slope, sedimentation was uniform over wide areas as reflected in the Schmiedwirt Member. While the nodular fabric can be explained by early diagenetic redistribution of carbonate (BÖHM, 1992), the successions of limestone and marl layers must have been controlled by external influences (e.g., climate or sea level variations). This is evident from the uniform, correlatable beds that can be traced between different quarries over distances of several hundreds of meters (Fig. 7; Böhm et al., 2000, 2003). Reworking and erosion during this time is evident from the occurrence of encrusted and bored intraclasts (Böhm, 1992), especially in the slope facies (Lienbacher Mb., Motzen Mb.). However, the correlatable beds of the Schmiedwirt Mb. show that reworking was restricted to the uppermost centimetres of sediment and did not disturb the limestone-marl sequences.

***Upper Adnet Fm.*:** This situation changed after the onset of the Kehlbach Member. The occurrence of breccia layers is evidence of beginning synsedimentary tectonic activities. Seismic activities finally led to the formation of the mass flows represented by the Scheck Mb. breccias: Metre-thick debris flow deposits which eroded the underlying lithified and semi-lithified sediments (Böhm et al., 1995). The former depositional area of the Lienbacher Mb. was probably an area of erosion during this time, as is shown by the common occurrence of large stromatolite fragments in Scheck breccias overlying the Schmiedwirt Member. The outcrops in quarry XII show a nice example of bedded Lienbacher Mb. laterally grading into a zone of increasing fracturing and finally into a "Scheck breccia bed" (Böhm et al., 1995, 1997b). This example also shows the mechanisms that created the debris flows: Disruption and fracturing of underlying, (semi-) lithified sediments on the slope, probably due to seismic activities. Also the Schmiedwirt and Kehlbach Mb. were eroded by the debris flows as seen in many channels filled with breccias of the Scheck Member. The coarse-grained, erosional debris flows mostly ceased after deposition of the Scheck Member. In the Saubach Mb. there are mainly fine-grained turbidites and only rare debris flow deposits. The facies of the Saubach Mb. shows that the depositional environment had changed. Benthic bioclasts became rarer, while pelagic components became more frequent (Böhm, 1992). Overall reduced sedimentation rates and the predominance of marls point to reduced carbonate sedimentation. This trend continued through the Middle Jurassic, when sedimentation rates were further reduced in the Osterhorn area, leading to widespread non-sedimentation. Planktonic biota slowly gained predominance in the Klaus Fm. (mainly coccoliths and globigerinoids) and finally in the Ruhpolding Formation (radiolarians). However, at this time the former extensional tectonic regime during the Triassic and Early Jurassic had given way to the compressional regime of the late Middle to Late Jurassic that led to a radical reorganization of the seafloor topography. The ensuing mass flows of the Strubberg and Tauglboden Fm. dwarfed the breccias of the Scheck Mb. by orders of magnitude (Gawlick et. al., 1999; Gawlick, 2000). These events finally buried and destroyed the last remains of the Late Triassic constructional seafloor relief that, for most of the Early Jurassic times, had controlled the facies distribution of the Adnet Group.

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