3.2. Lagoon, fringing reef and Eiberg Basin (Day 2)

The huge Dachstein carbonate platforms represent a fossil counterpart to the modern Bahamian carbonate system. The bedded Dachstein Limestone together with the Hauptdolomit make up the majority of the extensive carbonate plateaus of the Northern Calcareous Alps, reaching more than 1000 m in thickness. These units reflect a variety of shallow water facies (ooids ridges, oolithic facies, grapestone facies, foraminifera and algal facies, mud facies, pellet mud facies changing laterally into muddy tidal flats with the typical "loferites" and supratidal areas with lateritic palaeosols. The frequently regular vertical arrangement of these deposits led to the formation of the well- known "Lofer cyclothem" (FISCHER, 1964).
The Dachstein carbonate platform also contains shelf-edge reefs and reef material, which are some of the oldest reefs to be built by scleractinian corals. The drowning history of Rhaetian coral builds-up is superimposed by the end-Triassic mass extinction and makes the story in the Austrian Alps thrilling.
The mixed carbonate-terrigenous intrashelf Eiberg basin allows for a comparison with the age-equivalent off-shore homogeneous carbonatic and terrigenous facies of the Hallstatt and Zlambach Facies

3.2.1. Route

From Abtenau we take the road to Golling an der Salzach along state road 162, from there 4 km to the south and stop at Pass Lueg on state road 159. Then we go back to the north along motorway A 10 in direction of Salzburg, take then exit Hallein to and through the village of Adnet and up to the quarries. We drive then further through Berchtesgaden (Germany) to the Steinplatte. As we have no time to visit Steinplatte itself we will stop along state road 178 to have a nice panoramic view on the reef margin. We move then further west on state road 173 to the Eiberg Quarry near Kufstein and through motorway A 12 and state road 181 to Achenkirch for overnight.

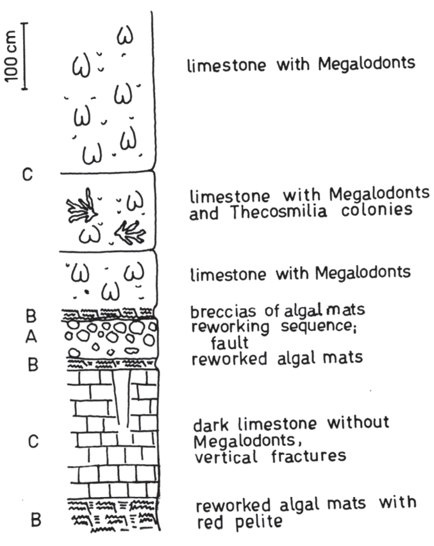

Fig. 21. Lofer Cyclothem at Pass Lueg (from FLÜGEL et al., 1975).

3.2.2. Locality 5 – Pass Lueg: The classical Lofer cycle

In the central and eastern Northern Calcareous Alps, the cyclic, meter-sized bedding of the Dachstein Limestone is a characteristic morphological feature, well visible along the steep slopes as well as on the top of the large plateau mountain ranges. Meter-scale cycles were recognised as early as 1936 by SANDER. FISCHER (1964) gave a description of this phenomenon, which remains a classic even now. Based on sequences from the plateaus of the Dachstein and the Loferer Steinberge, Fischer termed these units "Lofer cycles". The cycles are interbedding of lagoonal limestones, thin layers of variegated argillaceous material, thin layers of intertidal to supratidal laminated or fenestral dolomites and dolomitic limestones (Fig. 21). The main sediment is a light-coloured limestone (layer C, thickness up to some meters), containing oncoids, dasycladacean and codiacean algae, foraminifera, bryozoan, gastropoda, large megalodontids and other bivalves. The weathered and solution-riddled surface of this limestone is overlain and/or penetrated by reddish or greenish argillaceous limestone (layer A), which may include limestone clasts and which are interpreted as former terrestrial soils. Layer A is commonly not developed as a distinct bed, because of its erosional origin; however, remnants of A are abundant infillings in veins, cavities, and biomoldic pores (gastropod and megalodontid shells). Layer B consists of intertidal carbonates of a variety of rock types like "loferites" or birds-eye limestone of laminated or massive type, non-loferitic mudstone and intraclasts. The flat or crinkled lamination is interpreted as filamentous algal mats, also characteristic of modern tidal flats. Fenestral pores and mud cracks seem to be the result of shrinkage of unconsolidated sediment due to desiccation. All types of layer B are more or less dolomitic, some of them formed as contemporaneous brittle surface crusts, as shown by intraclasts, demonstrating the intertidal/supratidal setting. FISCHER (1964) explains the formation of the cyclothems by periodic fluctuations of the sea-level which is superimposed on the general subsidence. An amplitude of up to 15 m and 20,000 to 100,000 years is assumed for one cycle. Because this model does not explain the gradual lateral transition into the Hauptdolomit Formation and the lateral wedging of intertidal and supratidal sediments within short distance, ZANKL (1971) proposed an alternative model: Current activity and sediment producing and binding algae created mud mounds and tidal mud flats. Subsidence and eustatic sea-level fluctuations of centimetre amplitudes and periods of several hundred years may have modified growth pattern and shape of the tidal flats by erosion and transgression. FISCHER (1964) interpreted the ideal Lofer cycle: disconformity, A, B, C as an upward-deepening facies trend. HAAS (1994) proposed a symmetrical ideal cycle, whereas GOLDHAMMER et al. (1990) and SATTERLEY (1994) proposed a shallowing upward interpretation. ENOS & SAMANKASSOU (1998) pointed to the lack of evidence for subaerial exposure and interpreted it as rhythmic cycle with allocyclicity as the predominant control. HAAS et al. (2007, 2009) and HAAS (2008) however provided several evidences for subaerial exposure and related karstification. HAAS et al. (2010) pointed a differential development of the Lofer Cycle on the Dachstein Range between internal area and sections situated near the margin of the platform. The cycles shown by HAAS et al. (2010) can be summarised:

The disconformity displays erosion features and karstification in both internal and marginal areas.

- Facies A is reddish or greenish, argillaceous, 1mm to 10cm thick. It is a mix of storm redeposited carbonate mud, air transported carbonate and argillite, blackened intraclast and consolidated sediment. It is thicker with pedogenese trace in marginal sea than in internal area.
- Facies B (stromatolites, loferites) is usually present in the internal part of the range, but absent in the marginal area.
- Facies C is a peloidal bioclastic wackestone in the platform area, whereas in the reef-near zone it is an oncoidal packstone or grainstone.

The differences can be explained by the setting. The marginal zone, near the offshore edge developed oncoid shoals, whereas stromatolites develop preferentially on the slightly deeper platform interior, protected by the shoals. The sea-level drop affected both areas, but the longer shoals allowed for the development of palaeosols in the marginal part. This model reinforces the shallowing-upward trend of FISCHER (1964).

At Pass Lueg itself, a “Lofer Cyclothem” with partly reworked stromatolite, brecciated layers and bioclastic limestones rich in megalodontids, corals and echinoderm (FLÜGEL et al., 1975) is exposed (Fig. 21). Several species of *Megalus, Parmegalus, Conchodus* have been described from levels usually rich in individuals but poor in species (FLÜGEL et al., 1975).

3.2.3. Locality 6 – Adnet

The quarries of Adnet, located in the north-western Osterhorn Block, south-east of the city of Salzburg (Figs. 1, 22) expose upper Rhaetian to Lower Jurassic limestones, deposited at the southern rim of the Eiberg Basin (Fig. 5). They clearly display the succession from the Late Triassic reef-dominated carbonate factory (Stops 6.1 and 6.2) to the aphotic deep-water hemipelagic sedimentation of the Jurassic (Stops 6.2 and 6.3). If both Adnet and Steinplatte have been described as typical warm-water photic-zone reefs (e.g. STANTON & FLÜGEL, 1989, 1995; BERNECKER, 2005), STANTON (2006) proposed rather nutrient rich water favourable to heterotrophic corals. Intermediate reef drowning stages of the Hettangian are nicely exposed in the lower slope sections (Stop 6.3). The Adnet quarries have been the topic of palaeontological, sedimentological, stratigraphic, geochemical, mineralogical, palaeomagnetic, and geotechnical studies for more than 150 years (see KIESLINGER, 1964; BERNECKER et al., 1999; BÖHM et al., 1999; BÖHM, 2003; BERNECKER, 2005; REINHOLD & KAUFMANN, 2010). Nevertheless there are still considerable unknowns in the Rhaetian-Liassic sedimentary history of the area. The continuing quarrying activities create 3-dimensional views and expose new sedimentary structures every few years, but also threaten to destroy older outcrops.

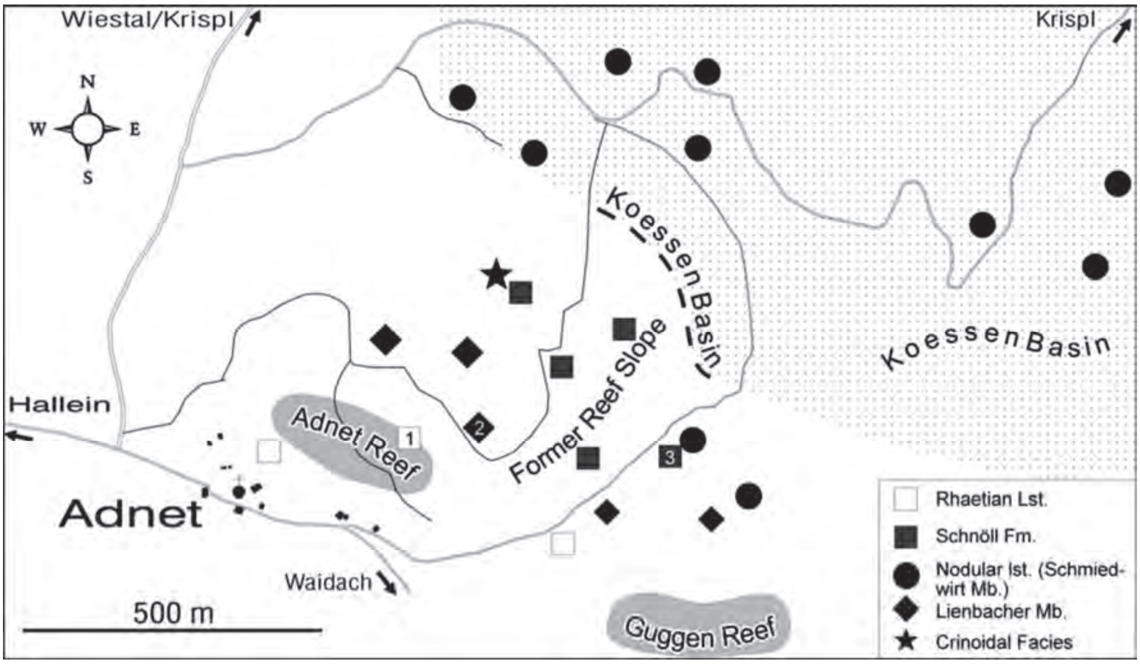

Fig. 22. Detail map of the Adnet quarries with facies distribution (from KRYSTYN et al., 2005 after BÖHM, 1992).

Outcrop 6.1 – Tropf Quarry

The Tropf quarry 47°41.7819' N / 13°08.2109' E, Fig. 22) is the most famous of the Adnet quarries, as it exposes a 3 dimensional view of a Rhaetian coral reef with metre-sized coral colonies, analogue to the late Rhaetian Steinplatte Limestone. Its facies and palaeontology were studied in detail by SCHÄFER (1979) and BERNECKER et al. (1999). Unfortunately, during the past years the most spectacular walls became unsightly or were removed by quarrying. The big branching coral colonies dominating most walls (Figs. 23, 24, 25) belong to the