2.2. The Neogene of the Vienna Basin

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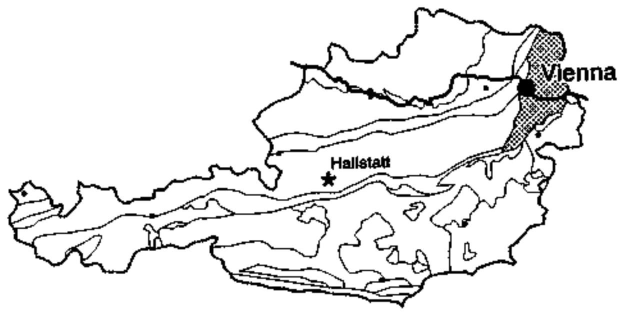

Introduction

The Vienna Basin, located between the Eastern Alps, the West Carpathians and the western part of the Pannonian Basin represents one of the best studied large pull-apart basins of the world (ROYDEN, 1985; WESSELY, 1988). Similar to other European Tertiary Basins (e.g., Paris Basin, London Basin, Mainz Basin) the Vienna Basin was the goal of very early geological studies (e.g., STÜTZ, 1807; PREVOST, 1820; SUESS, 1885; SCHAFFER, 1907). The importance for hydrocarbon exploration, however, distinctly enhanced our stratigraphic, sedimentologic and tectonic knowledge of the basin during the last 60 years. The different fields of interest studied cover all topics from palaeontology, sedimentology, stratigraphy, tectonics, to natural resources like thermal water and hydrocarbon.

Due to this overall importance the Vienna Basin was the target for several field trips in the course of earth science conferences during the last years. As a result of these activities a variety of field guides were produced (e.g., PILLER & KLEEMANN, 1991; PILLER & VAVRA, 1991; SAUER et al., 1992; PILLER, 1993; PILLER et al., 1996) and the following presentation widely duplicates earlier papers.

Geographical setting

The Vienna Basin is of rhombohedral shape, strikes roughly southwest-northeast, is 200 km long and nearly 60 km wide, and extends from Gloggnitz (Lower Austria) in the SSW to Napajedl in Czekia in the NNE. The western border is bound to the south by the morphological eastern margin of the Northern Alps (represented by several Alpine tectonic units: Greywacke Zone, Northern Calcareous Alps, Flysch Zone) and to the north by the Waschberg Zone. In the east it is bordered in the south by the hills of the Rosaliengebirge, Leithagebirge and the Hainburger Berge, and in the north by the Little Carpathian Mountains; all four hill ranges are part of the Alpine-Carpathian Central Zone. The Vienna Basin is connected with the Little Hungarian Basin via the Hainburger Pforte and with the Eisenstadt Basin via the Wiener Neustädter Pforte. The Eisenstadt Basin has a triangular shape and is bordered in the east by the Ruster Höhenzug, in the north by the Leithagebirge, in the west by the Rosaliengebirge, and in the south by the Brennberg. Its maximum dimensions are approx. 20 by 20 km. The subsurface separation from the Vienna Basin is represented by the continuation between the Rosalien- and Leithagebirge; its tectonic and sedimentary history, however, is very similar and the Eisenstadt Basin is therefore considered as a subbasin of the Vienna Basin.

Stratigraphy, facial and tectonic development

The Vienna Basin is part of the Paratethys which formed together with the Mediterranean Sea after vanishing of the Tethys Ocean. Due to its isolated position for most of the time a regional stratigraphic stage system different from that of the Mediterranean had to be established (e. g., RÖGL & STEININGER, 1983; SENES & STEININGER, 1985; STEININGER et al., 1988; STEININGER et al., 1990; RÖGL, 1996; Fig. 14).
Due to the rhombohedral shape and the left-stepping pattern of en-enchelon faults firstly ROYDEN (1985) interpreted the basin as pull-apart structure. This idea was strengthened later on (ROYDEN, 1988; WESSELY, 1988), however, based on more profound data a much more complex tectonic evolution was shown by several authors (DECKER et al., 1994; DECKER, 1996; DECKER & LANKREIJER, 1996; DECKER & PERESSON, 1996). The pull-apart mechanism started to act during the Karpatian (STEININGER et al., 1986; SEIFERT, 1992; DECKER, 1996), older sediments (Eggenburgian-Ottnangian) at the base of the northern part of the Vienna Basin belong to an earlier piggy-back basin of the Molasse cycle (STEININGER et al., 1986, p. 295, PILLER et al., 1996; DECKER, 1996). Between the Karpatian and Pannonian the subsidence in the central Vienna Basin reached up to 5.5 km (WESSELY et al., 1993). Since the basin is subdivided by a morphological high structure, the Spannberg ridge, into a northern and a southern part, during the Karpatian sedimentation was restricted to the north (north of the Danube) and extended into the south only during the Badenian. Due to the complex fault system the basin was internally highly structured into horst and graben systems. Especially at the western border of the basin, relatively uplifted blocks occur; these are separated from the deep depressions located in the east along major faults (e.g., Mistelbach block along the Steinberg fault in the northern, Mödling block along the Leopoldsdorf fault in the southern basin). The interplay of highly active synsedimentary tectonics with rapid changing trans- and regression cycles (RÖGL & STEININGER, 1983) produced a complex facial pattern inside the basin depending on distance from land and on position of the particular blocks.
The basement of the basin is built by those Alpine-Carpathian nappes bordering the basin also on the surface. The Neogene sediment fill of the basin reaches a thickness of up to 6000 m. At the base mainly clastic sediments are developed representing fluvial facies; occasionally lignite deposits occur (STEININGER et al., 1989). A fully marine development over the entire basin was established only in the Early Badenian (Lower Lagenid Zone). These sediments consist not only of clastics but also carbonates were deposited. This facial development with local coral reefs and widespread coralline algal limestones is restricted to the Badenian. During the Sarmatian, a reduction in salinity already started leading to non-marine and subsequently continental conditions in the Pannonian-Pontian. Although tectonic subsidence was high the basin was rapidly filled due to the short distance to the source of clastic sediments and the basin cycle is therefore limited to the Middle Miocene.

Badenian (16.4. - 13 ma bp)

Due to the major marine transgression at the beginning of the Middle Miocene (RÖGL & STEININGER, 1983, 1984) subtropical biotas entered the Paratethys. In the Vienna Basin conditions for carbonate sedimentation and growth of coral buildups were favourable only during the Badenian stage. Within the context of the meeting the development and facial distribution for this period should be discussed in more detail.

The general biostratigraphic subdivision (PAPP et al., 1978) into Lower Badenian (Lower and Upper Lagenid Zone), Middle Badenian (*Spiroplectammina* Zone) and Upper Badenian (*Bulimina-Bolivina* Zone, *Rotalia* Zone) is based on typical foraminiferal assemblages, reflecting in fact an ecostratigraphical sequence. This sequence documents the salinity reduction in the uppermost Badenian. The zonal scheme works well in central basinal sections, in marginal position, however, reliability is limited. Besides these assemblages, planktic foraminifers and certain benthic groups are also of special importance, e.g., uvigerinids, bolivinids, and to some extent also calcareous nannoplankton (e.g., STEININGER, 1977; PAPP, CICHA & CTYROKA, 1978; PAPP et al., 1978; PAPP & SCHMID, 1978; PAPP, 1978; FUCHS & STRADNER, 1977). Some species of the larger foraminferal genus *Planostegina* (= *Heterostegina* in older literature) were considered as stratigraphically usefull (e.g., PAPP & KÜPPER, 1954; PAPP, 1978). Recent investigations, however, brought forth opposite results (PILLER et al., 1995; ABDELGHANY et al., 1996).
The sediments of the lowermost Badenian (Lower Lagenid Zone) are confined to the northern Vienna Basin. During the Upper Lagenid Zone, sedimentation is fully developed in the entire basin. At the same time marine sedimentation starts in the Eisenstadt Subbasin and facial differentiation reached its climax.

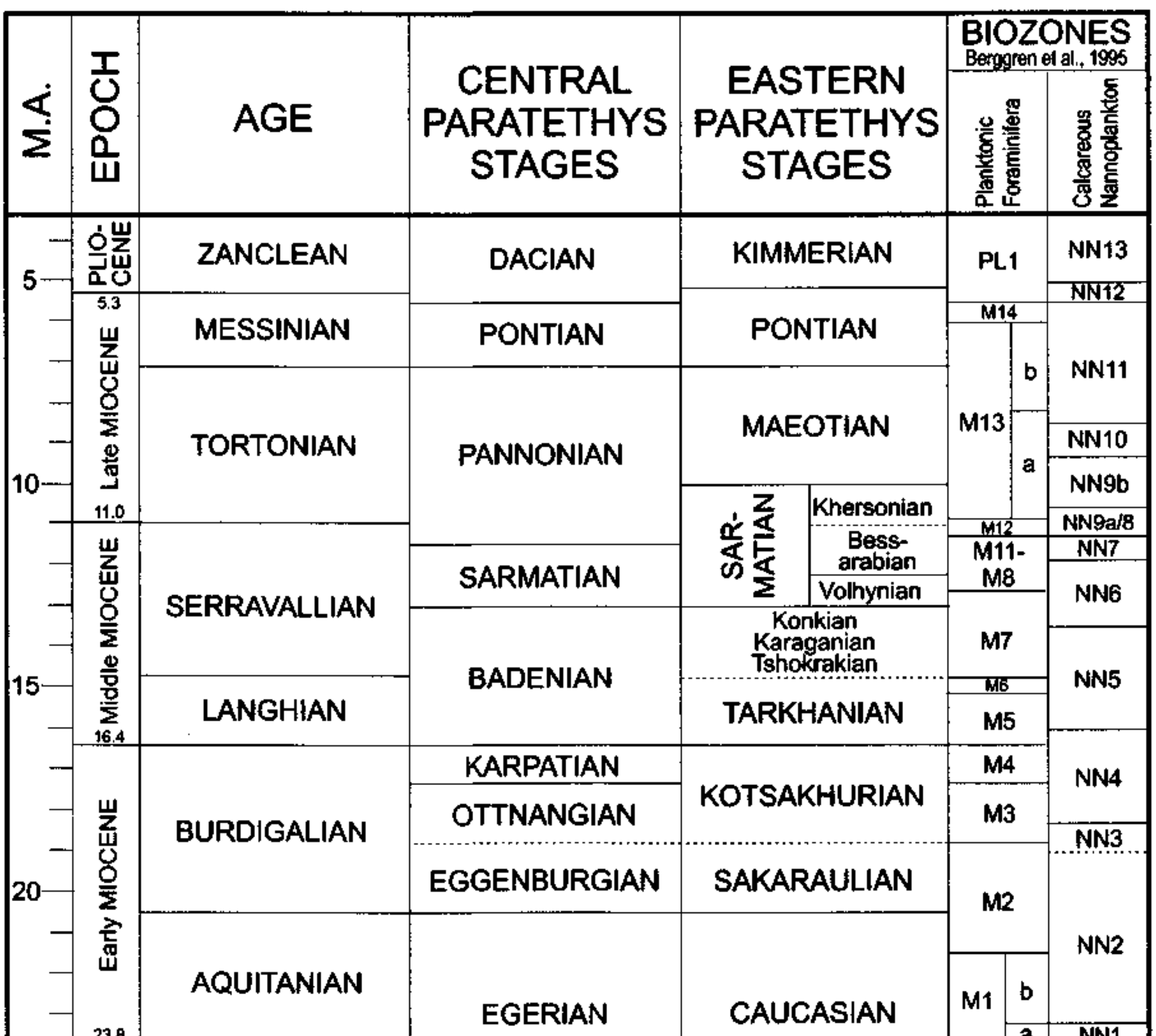

Fig. 2.2.1.: Chronostratigraphy and marine biochronology of the Miocene (after RÖGL, 1996)

The facial development roughly reflects a distinction between marginal and central basin facies:
Along the basin margins in dependence on the hinterland and coastal morphology the most complex facies pattern is developed. In general siliciclastics and carbonates can be differentiated, both exhibting a rich facial diversity.
In general, the western border of the southern Vienna Basin is highly influenced by the clastic sediment influx from the Northern Alps. Around the Leithagebirge, which represented an island, a chain of islands or a shoal during the Badenian, and along the Ruster Höhenzug, autochthonous carbonate sediments dominate (irrespective of sometimes thick basal transgressive sediments).
The coastal development along the western margin shows strong fluvial influx at some locations, expressed by thick conglomerates dominated by material derived from the Northern Calcareous Alps as well as the Flysch Zone (Baden [Vöslau] Conglomerate; comp. BRIX & PLÖCHINGER, 1988). In some places, steep rocky shores with large boulders are also preserved (e.g., W' Sooß), while wide coastal or marginal areas are covered by sands (Gainfarn Sands) with a rich and excellently preserved fauna. These sands interfinger with the basinal Baden Tegel.

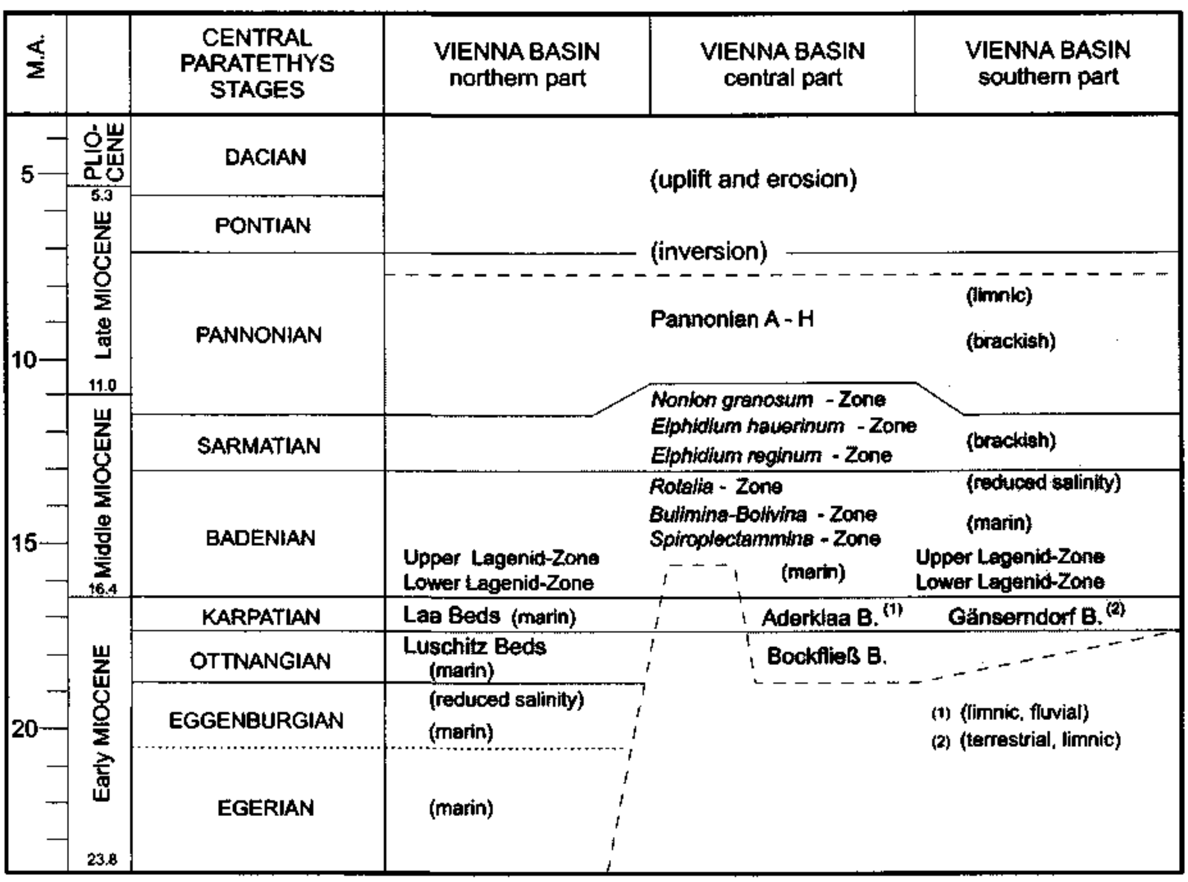

Fig. 2.2.2.: Facial development and stratigraphy of the Vienna Basin with schematic representation of the spannberg ridge in the central part of the basin (after WESSELY, 1988, changed).

The most widespread facies unit along the Leithagebirge and the Ruster Höhenzug as well as at certain sites along the western margins of the Vienna Basin with reduced terrigenous input (e.g., around Wöllersdorf) is the Leitha Limestone. The name of this unit was already established by KEFERSTEIN (1828) and is well known also outside the Vienna Basin. The unit was redefined by PAPP & STEININGER (in:) PAPP et al. (1978) considering the broad facial range and selecting a faciostratotype (comp. Stop 4). The microfacial diversity was worked out by DULLO (1983) into detail describing 10 microfacies types.

Due to its high abundance of coralline red algae this Leithakalk is also well known as Nullipora or Lithothamnium Limestone. Historically important is the first description of a fossil coralline red algae out of this limestone: *Nullipora ramosissima* REUSS 1847. The original material of this taxon was recently rediscovered and the species was assigned to the genus *Lithothamnion* (PILLER, 1994).

In general, the limestone is characterized by the occurrence of coralline algae in various growth forms, ranging from rhodolith dominated types of various growth forms to maërl facies. Coral buildups of limited size are developed only locally. Such buildups are rare along the western margin of the Vienna Basin due to the high terrigenous input and represented only by small patch reefs. Also along the Ruster Höhenzug no significant coral settlement is developed (or preserved); organic buildups are predominantly made up of bivalve beds accompanied, in some places, by corals (comp. DULLO, 1983, p. 37). The best developed coral buildups are present at the southern tip of the Leithagebirge, where the limestones reach the greatest spatial extent and the thickest sequences (about 50 m). Here, due to the island position, no major terrigenous influx restricted coral growth. On the contrary, it can be assumed that water currents or relatively strong waves favoured their growth at the southern tip of the Leithagebirge. The corals are represented mainly by various taxa of *Porites*, accompanied by *Tarbellastraea*, *Caulastrea*, *Acanthastrea*, and *Stylocora* (PILLER & KLEEMANN, 1991).

The basinal facies is characterized by the Baden Tegel, a marl with variable sand and clay content. Intercalated into the marls are sandy layers. This latter material is transported from marginal sources. The marls and sandy interbeddings are highly fossiliferous, containing an extremely rich micro- (foraminifers, ostracods) and macrofauna as well as calcareous nannoplankton (comp. PAPP et al., 1978). The macrofauna is well documented since the 19th century (e.g., D'ORBIGNY, 1846; REUSS, 1849; KARRER, 1861; HÖRNES, 1856, 1870; HÖRNES & AUINGER, 1879) and is represented by solitary scleractinians, brachiopods, decapod crustaceans, molluscs, and fish remains (teeth and otoliths). In the sediments of the Lower Badenian the foraminiferal fauna is extremely rich, containing not only planktic and smaller benthic representatives but in the sandy interbeddings also larger forms as *Amphistegina*, *Planostegina* and *Borelis melo*. Remarkable is the high diversity and good preservation of molluscs (gastropods, bivalves, scaphopods).

The depositional depth of this fine-clastic material can be interpreted as being not deeper than 50 - 100 m (PAPP & STEININGER [in:] PAPP et al., 1978, p. 140) or 100 - 200 m (TOLLMANN, 1985, p. 500). The sandy layers are transported by gravitational transport from marginal areas. Although subsidence of the basin during the Badenian was very rapid, the relatively shallow water depth of the autochthonous sediments can be explained by a high sedimentation rate leading to a sediment accumulation of approx. 1500 m in the central basin during the Badenian (e.g., WESSELY, 1988, p. 342). In the Eisenstadt Basin thickness of the Baden Tegel is distinctly less.

Sarmatian (13 - 11.5 ma bp)

The salinity reduction which already started in the uppermost Badenian continues during the Sarmatian. Salinity decreased generally from 30-17 ‰ and reflects the isolation of the Paratethys from the world oceans. The westernmost extension of the Paratethys during the Sarmatian ended in Lower Austria (near Langenlois). The sedimentological inventory ranges from coastal gravel and sands, to calcareous sandstones ("Atzgersdorfer Stein") and marls (Tegel) exhibiting similarities to Badenian sediments. Additionally, "detrital Leitha Limestone" occurs which mainly represents reworked Badenian Leitha Limestone. The total thickness of Sarmatian sediments surpasses 1000 m in central basin positions.
The reduced salinity of the Sarmatian sea caused a low diversity fauna rich in individuals. Stenohaline organisms are nearly absent, some groups (e. g., foraminifers, bryozoa, molluscs) are represented by a few genera only but occur in high densities (for molluscs comp. Stop 5). In contrast to the diverse Badenian algal flora only 2 species of coralline algae were described (KAMPTNER, 1942). These coralline algae produce small buildups in coastal areas together with the sessile foraminifer *Sinzowella caespitosa* (STEINMANN). In some locations also thin serpulid biostromes and ooliths are developed.
Based on macro- and microfaunal associations an ecostratigraphic subdivision of the Sarmatian is possible into 5 zones:

Late Sarmatian:	“Verarmungszone“
Middle Sarmatian:	*Mactra* Beds (= middle *Nonion granosum* zone)
	Upper *Ervilia* Beds (= lower *Nonion granosum* zone)
	Lower *Ervilia* Beds (= *Elphidium hauerinum* zone)
Early Sarmatian:	*Mohrensternia* Beds (= *Rissoa* Beds) (= *Elphidium reginum* zone)

Pannonian (11.5 - 7.1 ma bp)

After a short regressive phase at the Sarmatian/Pannonian boundary which corresponds to a worldwide regressive tendency and local/regional tectonics the Pannonian Basin became finally isolated from the Eastern Paratethys (STEININGER & RÖGL, 1983, 1984). A following transgression was linked with a further salinity reduction to 5 ‰. In the uppermost part of the Pannonian (Zones F-H) limnic-fluvial conditions already prevailed. In central basin positions sedimentation of marls (Tegel) continued reaching a thickness > 1.500 m; in marginal positions sands and gravelly sediments were deposited.
According to the salinity reduction biotic diversity decreased further compared to the Sarmatian and particularly mollusc faunas are characterized by mass occurrences of a few taxa only which exhibit, however, a fast evolutionary development. Most important taxa are *Melanopsis*, *Congeria*, and *Limnocardium* (Stop 5), whose evolutionary lineages provide the base for the subdivision of the Pannonian into 5 zones (Zone A - E) (PAPP, 1949, 1951, 1953).

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