

## **The Styrian Tectonic Phase – A Series of Events at the Early/Middle Miocene Boundary Revised and Stratified (Styrian Basin, Central Paratethys)**

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The “Styrian Phase” of STILLE characterizes multiple tectonic events at the Early/Middle Miocene, i. e., Karpatian/Badenian boundary. This phase is based on the observed Neogene tectonic history in the Styrian Basin, Austria. In a geologic setting, the Styrian Basin belongs to the western part of the Intra-Carpathian Pannonian Basin system. Basin formation started during the Early Miocene, probably during Ottnangian. On top of deeply eroded Austroalpine nappes, swamp and flood deposits are transgressed by the Paratethys Sea in Karpatian time.

Angular discordances and sedimentation gaps characterize the Early/Middle Miocene, the Karpatian/Badenian boundary. On top of the Karpatian, deep-water sediments of the “Steirischer Schlier” follow a series of marine incursions of the Badenian Sea in the realm of Central Paratethys. During Badenian, tectonic activity is accompanied by extensive volcanism.

Excellent insights of these processes are represented in the outcrops Wagna brickyard and Retznei quarry (Styrian Basin, Austria). Interdisciplinary studies in sedimentology, micropalaeontology, and palaeomagnetism enabled high-resolution stratigraphy to determine the ages of these events.

### **Palaeomagnetic results**

In the Wagna section chron C5Cn.3n to chron C5ADn are recorded. A series of sedimentary gaps interrupt the continuous palaeomagnetic sequence. The sequence is continuous in the Retznei quarry from chron C5Bn.1n up to C5ADn, especially in the part of the nearby Rosenberg section. These measurements are supported by a recent  $^{40}\text{Ar}/^{39}\text{Ar}$  datum of the crystalline tuff, ranging from 14.2 to 14.39 Ma, within chron C5ADn.

Changes in sedimentation, discordances, sedimentation gaps, as well as tectonic and volcanic activity demonstrate the Styrian Phase as a multiphase event around the Early/Middle Miocene boundary. New stratigraphic results in combination with palaeomagnetic and micropalaeontological investigations allow a timing of these events.

A major event is present between the sedimentation of the Karpatian Steirischer Schlier and the lowermost Badenian silts, with tilting of the Steirischer Schlier, and a sedimentation gap between 16.5 and 16.1–16.2 Ma. The next gap occurred around the nannoplankton zone NN4/NN5 boundary (14.74 Ma) between chron C5Br and C5Bn.1n, ranging from about 15.4 to <14.8 Ma. A third discontinuity at the base of corallinean limestones is too short to be dated in the Wagna section. The sedimentation gap is extended in the Retznei sections from the top of Karpatian Steirischer Schlier to the base of carbonate sedimentation (larger gap between NN4 and NN5). Only in a few places sandy-silty sediments of the Early Badenian are intercalated below the carbonates. Volcanic ash layers and tuffites are deposited within the marls of zone NN5, in the overlapping range of *Præorbulina* and *Orbulina*, which belong to chron C5ADn (14.19–14.58 Ma).

#### *Wagna brickyard*

The Wagna brickyard section comprises Late Karpatian and Early Badenian sedimentation. About 75 m of the Karpatian Steirischer Schlier are exposed, formed by a cyclic sedimentation of dark-grey, calcareous, silty shales, interbedded with dolomitic limestones. An angular unconformity separates the shales from overlying grey silts and fine sands comprising a pebble layer of reworked Steirischer Schlier. The foraminiferal fauna and shallow water bivalves mark this discordance by a strong change from deep-water assemblages of about 250 m to those of inner neritic depth (~50 m). This discordance comprehends the Early/Middle Miocene, Karpatian/Badenian boundary, thus representing a sequence boundary.

About 8 m of grey sand, silt, and few sandstone beds follow with an intercalated patch reef and fossiliferous layers. These beds are concordantly transgressed by brownish sandstone beds, where mollusc casts are abundant. The base of the sandstones is erosive. Layered corallinean limestones of a carbonate build-up mark a distinct facies change, demonstrating a clear sedimentary discordance to the deeper sandstones.

#### *Retznei, cement quarries*

The Wagna section is continued in the cement quarries of Lafarge-Perlmooser in Retznei. A few metres of Steirischer Schlier form the base of the Badenian sedimentation, which starts locally with a small layer of silt and fine sand that is topped by a huge carbonate build-up. This build-up starts in the main quarry with a small coral reef and basal pebble layers and extends into corallinean limestones of the Weissenegg Formation ("Leithakalk"). Marly sands crown the top of the build-up and carbonate sedimentation ends after starting intense volcanic activity. Basinwards the limestones consist of transported material in a deeper water slope facies. Silty and sandy marls with some sandstone layers onlap the build-up and transgress over the limestones. Rich foraminiferal faunas point to a deepwater environment of 150 to 300 m.

### Biostratigraphy

With *Globigerinoides bisphericus* and markers of the calcareous nannoplankton zone NN4 the Steirischer Schlier biostratigraphically belongs to the Karpatian. The benthic foraminiferal marker *Uvigerina graciliformis* is common. Just above the first angular discordance, *Praeorbulina* marks the Middle Miocene, Badenian, which is correlative to the basal Langhian. Within the Badenian part of the Wagna section the NN4/NN5 boundary is observed at the discordance below the fossiliferous brown sandstone beds. A next marker presents the FOD of *Orbulina suturalis* beginning with the corallinean limestones near the top of the Wagna section. *Praeorbulina circularis* and *Orbulina suturalis* occur together also in the basal marls of the Retznei section topping the corallinean limestones. In the upper part of this section, *Praeorbulina* is reduced in number and size. Benthic assemblages correspond to the typical fauna of the Early Badenian Lagenidae Zone with *Uvigerina macrocarinata* and *Vaginulina legumen*. The nannoplankton zone NN5 is recorded throughout the section and is stratigraphically limited by the *Helicosphaera waltrans* horizon.

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