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The Styrian Tectonic Phase – A series of events at the Early/Middle Miocene boundary revised and stratified in the Styrian Basin

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The *Styrian Phase* of Stille (1924) characterises multiple tectonic events at the Early/Middle Miocene, i.e., Karpatian/Badenian boundary. Excellent insights of these processes are represented in the outcrops Wagna brickyard and Retznei quarry (Styrian Basin, Austria). Interdisciplinary studies in sedimentology, micropaleontology, and paleomagnetism enabled high-resolution stratigraphy to determinate the ages of these events.

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. The mean paleodepth estimation by benthic foramnifera (Hohenegger 2005) varies insignificantly between –225 and –315m. 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 an abrupt change from deep-water assemblages of about 250 m to those of inner neritic depth ($\sim$ 50 m). This discordance comprehends the Early/Middle Miocene, Karpatian/Badenian boundary, thus representing a sequence boundary (Rögl et al. 2002, Spezzaferri et al. 2002).

About 8 m of grey sand, silt, and few sandstone beds follow with an intercalated patch

reef and fossiliferous layers. The oldest Badenian sample signalises depth around 50m. Depths became slightly shallower towards the section part, where large corals are found (t30m), afterwards continuing to decrease (t15m) up to that layer, where mollusc casts are abundant and nannofossils (NN4/NN5 boundary) as well as magnetostratigraphic measurements indicate a further unconformity (gap ∼600,000y). These beds are concordantly transgressed by brownish sandstone beds. The base of the sandstones is erosive. Layered corallinacean limestones of a carbonate buildup mark a distinct facies change, demonstrating a clear sedimentary discordance (parasequence boundary) to the deeper sandstones that is confirmed by paleodepth estimations between 50 and 60m.

The Wagna section is continued in the cement quarries of Lafarge-Perlmooser in Retznei. A few meters of S*teirischer Schlier* form the base of the Badenian sedimentation (paleodepth ∼250m; Spezzaferri et al.2002), which starts locally with a small layer of silt and fine sand that is topped by a huge carbonate buildup. This buildup starts in the main quarry (comp. Friebe 1993) with a small coral reef and basal pebble layers and extends into corallinacean limestones of the Weissenegg Formation (*Leithakalk*). Marly sands drown the top of the buildup and carbonate sedimentation ends after starting intense volcanic activity. Basinwards the limestones consist of transported material in a deeper water slope facies (paleodepth ∼170m). Silty and sandy marls with some sandstone layers onlap the buildup and transgress over the limestones. Rich foraminiferal faunas point to a deeper-water environment (150 to 300 m).

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 (parasequence boundary) below the fossiliferous brown sandstone beds. A next marker represents the FOD of *Orbulina suturalis* beginning with the corallinacean limestones (parasequence boundary) near the top of the Wagna section. *Praeorbulina circularis* and *Orbulina suturalis* occur also together in the basal marls of the Retznei section topping the corallinacean 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 Lagenid 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.

Paleomagnetic results: In the Wagna section chron C5Cn.3n to chron C5ADn are recorded. A series of sedimentary gaps interrupt the continuous paleomagnetic se-

quence. 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 chronostratigraphic positions are supported by a recent $^{40}Ar/^{39}Ar$ datum of the crystalline tuff, ranging from 14.20 to 14.39 Ma (Handler et al. 2005), thus positioned 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 paleomagnetic and micropaleontological 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 corallinacean 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 belonging to NN4 are intercalated below the carbonates. Volcanic ash layers and tuffites are deposited within the marls of zone NN5, in the overlapping range of *Praeorbulina* and *Orbulina*, which belong to chron C5ADn (14.19 – 14.58 Ma).

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