RHAETIAN BIVALVES AND THE NORIAN / RHAETIAN BOUNDARY

Christopher A. McROBERTS

Department of Geology, State University of New York at Cortland, P.O. Box 2000, Cortland, NY-13045, USA.
mcroberts@cortland.edu

As the youngest stage of the Triassic, the status of the Rhaetian has long been under contention with conflicting definitions and even a proposal to abandon the stage name altogether. At the heart of the issue is correlating the type Rhaetian which was defined by GÜMBEL (1859) using the pteriid bivalve *Rhaetavicula contorta* from shallow-water facies of the Kössen Formation which is otherwise poor in age-diagnostic macro and micro fauna. In practice, however, most researchers would delimit the boundary between the Norian and Rhaetian stages either on the first occurrence of several ammonoid taxa such as *Sagenites reticulatus*, *Paracochloceras/Cochloceras*, and *Choristoceras*, or with the apparently global disappearance of the pectinacean bivalve *Monotis* (e.g. DAGYS & DAGYS, 1994). With few exceptions, the uppermost stage of the Triassic is characterized not so much by the emblematic pelagic bivalves (e.g. *Monotis* and *Otapiria*), but by level bottom shallow-water bivalve assemblages with long-ranging species. A few notable species, such as *Rhaetavicula contorta*, however, have significant biochronologic value.

The basal Rhaetian and the question of the Kössen Formation

Based on recent voting and lack of acceptable alternatives, it appears likely that the Subcommission on Triassic Stratigraphy will define the Norian/Rhaetian boundary as the first occurrence of the conodont *Misikella posthernsteini* from the upper part of the Hallstatt Formation in the Steinbergkogel, Austria (KRYSTYN et al. 2007a, 2007b). Although this clear choice seems to satisfy many issues, it still leaves in question a precise correlation into the shallow-water sequence in the Kössen basin and, perhaps more importantly, to strata of the circum-Pacific where *Misikella* in general and *M. postherstieni* in particular is not only rare or absent, but likely first occurs in significantly younger strata (e.g. ORCHARD &TOZER, 1997; CARTER & ORCHARD, 2007). In these and other areas, palynomorph, radiolarian or other biochronologic or geochemical proxies will need to employed.

With respect to a Norian/Rhaetian boundary within the Kössen, recognition of the first occurrence of *Misikella posthernsteini* in the Kössen Formation is most important. At the type section of the Kössen Formation at Weißloferbach, *Misikella posternsteini* occurs within 1 meter of the base of section B and nearly 20 meters below the first occurrence of *Rhabdoceras suessi* (URLICHS,1972; MOSTLER et al.,1978). Subsequently, GOLEBIOWSKI (1990) reports some tens of meters between the first occurrence of *Misikella hernsteini* and *M. posthernsteini* which first appears in Unit 2 of the Hochalm member. Thus,

GOLEBIOSKI (1990, see also 1991) attributed most of the Hochalm member of the lower Kössen Formation to the upper Norman (Sevatian I). More recently, however, KOZUR (1996) reports the occurrence of *M. posthernsteini* within the basal Kössen. Within the Hallstatt sequences, the stratal thickness between the FOD of *M. hernsteni* and *M. posternsteini* is much less. For example, at proposed GSSP at Steinberkogel, KRYSTYN *et al.* (2007a, 2007b) report 40 cm between the two events. At the Hernstein section in Lower Austria, the difference between the FOD of *M. hernsteini* and *M. posterhsteini* is still less than 1 meter (McROBERTS et al. 2008). Caution should be exercised, however, when interpreting depositional rates to the stratal thickness between the FODs of *M. hernsteini* and *M. posthernstini*,

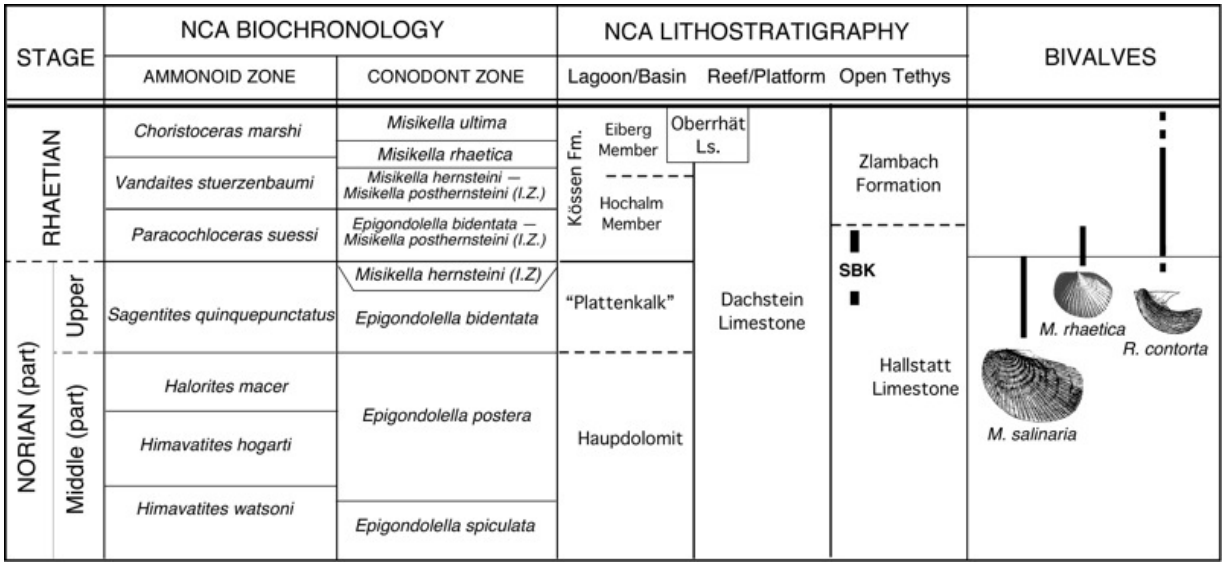

Fig. 1: Distribution of important upper Norian and Rhaetian bivalves within the Northern Calcareous Alps. SBK = Steinbergkogel section.

Bivalves and the Norian/Rhaetian boundary

Many researchers have long recognized that. It has been long assumed that *Monotis* experienced mass extinction close to the Norian/Rhaetian boundary as defined by first appearance of the conodont *Misikella posthernsteini* and its ammonoid equivalents (various *Paracochloceras* and perhaps *Sagentites reticulatus*). Recent finds in Hallstatt limestone in Austria records two surviving and dwarfed species of *Monotis* above this event, one of which, *Monotis rhaetica* is new (McROBERTS et al. 2008).

Although species of *Otapiria* are known from strata as old as Carnian and continue through the Early Jurassic, they take particular temporal significance in the Norman and Rhaetian. For example, *Otapiria ussuriensis* (Voronetz) is the name bearer of a well established zone in the Middle Norman of Siberia (KIPARASOVA et al. 1966; ZAKHAROV et al. 1997) and *Otapiria dissimilis* is distinctive of the Rhaetian of New Zealand (MARWICK 1957). A species

referred to as *Otapiria marshalli alpina* is known with *Misikella hernsteini* from the Zlambach Formation at Raschbergwiese section near Goisern and at other localities in the Austrian Alps (ZAPFE, 1973). Although the generic assignment of *Otapiria marshalli alpina* is questionable (see GOLEBIOWSKI, 1990), it remains a potentially valuable index of regional biochronologic significance.

The distinctive pteriid bivalve *Rhaetavicula contorta* is perhaps the most commonly recognized bivalve and key index of the Rhaetian in shallow-water facies of the western Tethys, southern Germany and across northwestern Europe. GOLEBIOWSKI (1990) provided a most useful summary of the facies, geographical, and temporal distribution of *R. contorta*. Based on the then current interpretations of a Norian/Rhaetian boundary, GOLEBIOWSKI (1990, see also 1991) attributed most of the Hochalm member of the lower Kössen Formation, in which *R. contorta* is most common, to belong to the upper Norman. Accepting the base of the Rhaetian to be the first occurrence of the conodont *Misikella posternsteni* (see above) which is already present in the basal Hochalm Member of the Kössen Formation (KOZUR 1996), most *R. contorta* likely occur safely within the Rhaetian. Other claims of *R. contorta* in the eastern Tethys and circum-Pacific (e.g. HEALEY 1908; MULLER & FERGUSON 1939) may indeed be Rhaetian, but have yet to receive satisfactory study to warrant assignment to *R. contorta*.

In the Boreal realm, the Rhaetian is characterized by the pectinid *Tosapecten*. *Tosapecten sensu stricto* can be traced as early as the Carnian of Japan and other east-Asian, western Panthalassa, and Boreal regions. *Tosapecten efimovae* Polubotko has been a key index for the Rhaetian strata of Boreal Russia (e.g. POLUBOTKO & REPIN 1990). This zone encompassing the entire Rhaetian can be subdivided into a lower *Campontectes nanus* subzone and an upper *Tosapecten efimovae* subzone (POLUBOTKO & REPIN 1990; DAGYS & DAGYS 1994). ZAKHAROV et al. (1997) seems to have inverted the *Tosapecten effimove* and *Camptonectes nanus* subzones.

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