Biostratigraphic correlation, paleoenvironmental stress, and sinkhole collapse: Dutch Rhaetian (uppermost Triassic) shales uncover their secrets

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Abstract – A sinkhole or subsidence pipe is a geologic phenomenon resulting from dissolution of strata in the subsurface causing the overlying sediments to collapse. The sinkhole in the Winterswijk quarry complex in the eastern Netherlands yielded rare, dark-colored shales. Bivalves and palynomorphs indicate that the shales were deposited during the Rhaetian (uppermost Triassic). In addition, detailed correlation with other NW European localities in Great Britain, Austria, and Germany further constrained the age of the shales to middle Rhaetian. The shales were deposited in a nearshore environment and contained a low diversity macroinvertebrate fauna with bivalves and some brittle stars. These organisms lived in a hostile environment, probably caused by changing/slow salinity and oxygen levels. These middle Rhaetian shales were mixed with dark-colored, middle to late Hettangian (earliest Jurassic) sediments, both overlying Anisian (Middle Triassic) strata which are present in the sinkhole as well. The presence of Rhaetian sediments in the sinkhole reopens the discussion of its age of formation. We suggest that a collapse during the Eocene is most likely. This research expands the knowledge of the marine realms in the uppermost Triassic in Europe, just prior to the Triassic–Jurassic extinction event.

Biostratigraphic correlation

The 30 m wide sinkhole filled yielded, among other sediments, dark shales in which fossils such as bivalves, brittle stars, and bones were discovered in 2007 and 2008. The bivalves were studied in detail along with palynomorphs from two samples taken from the dark shales. The three dominant bivalve species, Mytilopsis sp., Turbovinia clausina, and Rhabdoceras contortum, comprise >95% of the bivalve fauna. The palynomorphs are dominated (50-60%) by representatives of the Cucurbitales-formgoup (Corellina meyeronis, Cucurbitites spp., and Corellina zwitlina). The bivalve Rhabdoceras contortum is known as an index species for the Rhaetian. Moreover, similar bivalves were encountered in the shales at Quarry IV, which were previously dated to be Rhaetian in age based on palynomorph evidence (Herngreen et al., 2005). This result is corroborated by palynomorphs from the sinkhole as the simultaneous occurrence of Cerebropolites pseudomassulae, Lunatopollis scarti, Ovalipollis pseudoalatus, Rhabtopolis germanicus, and Recurvotea tuberculata points to an assemblage that is Rhaetian in age. These Rhaetian sediments belong to the upper part of the Strem Formation, which is the lowest unit of the Alnera Group.

To determine the age more precisely, correlation to the Rhaetian shales from the Winterswijk quarry complex (sinkhole and Quarry IV) to sediments in Austria, Germany, and Great Britain was attempted. In terms of sediment, the Rhaetian (but not uppermost) Westbury Formation in Great Britain is similar to the Dutch Rhaetian shales. Both also yield (pyritized) bone beds. Additionally, the palynomorphs also suggest correlation to the Westbury Formation. All bivalve species found in Rhaetian shales of the Winterswijk quarry complex were also encountered in the Westbury Formation. The absence of bivalves Lithopecten brevis, ‘Gerrilla’ ornata, Isocyprina depressus, Isocyprina pyrenaica, and Mytilopsis clausina from the shales of Winterswijk suggests a correlation to the upper part of the Westbury Formation.

The bivalves Isocyprina sp., Modiolus sp., Protocardia rhexatica, and Rhabdoceras contortum were also found in Rhaetian sediments from Austria (Kozen Formation). The latter two bivalves are found in the Rhaetian Rhaetogenus naupliae, a zone which is not considered to be equivalent to the uppermost Rhaetian. An age older than uppermost Rhaetian is also suggested by the palynomorphs. Palynological correlation to German Rhaetian sediments suggests a middle to upper Rhaetian age for the shales from the Winterswijk quarry complex. In conclusion, the detailed analysis of bivalves and palynomorphs indicates that the Dutch Rhaetian sediments most likely were deposited during the middle Rhaetian. This is in line with the notion of Feise-Burkhardt et al. (2008) that the most pronounced transgression occurred in the middle Rhaetian indicated by a marine-influenced fauna.

Paleoenvironmental stress

Prior to the Triassic–Jurassic extinction event, environments may have already been stressed in Western Europe. This is suggested by the low number of bivalve species at Winterswijk (eight in total). Fossil evidence at Winterswijk suggests low oxygen levels and/or changing salinity levels in this near-coastal environment. The former is suggested by the absence of corals as well as by the palynodebris of the sinkhole that is converted to structureless organic matter. The presence of a low diversity bivalve fauna indicates that at least some oxygen must have been present at the bottom for some periods of time. The absence of typical marine organisms such as cephalopods, corals, sponges, bryozoans, and brachiopods from the Rhaetian shales, as well as echiurids (except for some brittle stars) suggests low/changes salinity levels as these organisms cannot withstand these conditions. The low percentage (<5%) of marine elements (mainly the dinoflagellate Rhaetozygonus) corroborates this interpretation.

Sinkhole collapse

With the shales dated, the stratigraphy of the sinkhole could be determined. The lower 9 m consists of Middle Triassic (Anisian, Bathonian) calcareous sediments, followed by a 2-3 m thick mixture of uppermost Triassic (middle Rhaetian) shales and Lower Jurassic (middle to late Hettangian) clays, based on ammonite evidence (Klompmaker & Van den Berkmoot, 2007). The upper 5-7 m of the sinkhole was lost due to excavation. The sediments at Quarry IV consist of tens of meters of Anisian strata, followed by 7 m of Norian-Rhaetian strata, 4 m of middle Rhaetian shales, and 3 m of Oligocene clay. Oosterink et al. (2006) suggested that the sinkhole formed well after the Oligocene because Oligocene sediments are tilted in the neighborhood of the quarry, whereas Quaternary strata are not. This is based on their observation that the sinkhole would be vertical. The dip of the Oligocene strata is also low with 0°-9°. A perfectly vertical dip is, however, hard to establish based on the sinkhole edges and, thus, might be similar to the dip of the Oligocene strata. Furthermore, the Hettangian sediments from the sinkhole should have been removed by the erosional phase that removed the sediments on top of the Rhaetian at Quarry IV if the sinkhole formed after the deposition of the Oligocene. This is, however, not the case. Thus, a collapse well after the Oligocene is unlikely. Van den Bosch (1999) noted that the marine sediments of the nearby Eocene Dongen Formation, exhibiting a dip of about 10°, were disconformably overlain by younger, horizontally-living Eocene marine sediments, also from the Dongen Formation. During the hiatus represented by the unconformity, the Winterswijk area might have been above sea level, enhancing leaching in the subsurface as low mineralized groundwater can dissolve and migrate faster than marine waters. As a result, leaching could have taken place in the Eocene and, subsequently, caused the collapse of strata forming the sinkhole.

Key References:

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