Netherlands Journal of Geosciences — Geologie en Mijnbouw | 85 – 4 | 293 - 297 | 2006

Geo(Im)pulse

A subrosion pipe fill in the Lower Muschelkalk, Winterswijk Quarry, Eastern Netherlands

H.W. Oosterink[1,*], **Th. Simon**[2], **H. Hagdorn**[3] & **H. Winkelhorst**[4]

1 Hortensialaan 64, 7101 XH Winterswijk, the Netherlands
2 Regierungspräsidium Freiburg, Landesamt für Geologie, Rohstoffe und Bergbau, Dienststelle Stuttgart, Urbanstraße 53, 70182 Stuttgart, Germany
3 Muschelkalkmuseum Hagdorn Ingelfingen, Schlossstr. 11, 74653 Ingelfingen, Germany
4 Molenstraat 14, 7122 ZW Aalten, the Netherlands
* Corresponding author. Email: hw.oosterink@hetnet.nl

Manuscript received: February 2006; accepted: October 2006

Abstract

In the 'Winterswijksche Steen- en Kalkgroeve', situated in the eastern Netherlands, Lower Muschelkalk limestones are quarried. A ca. 30 m wide area in the quarry face showing fragmented rock material in chaotic accumulation in between stratified Muschelkalk sediments was interpreted until now to be the result of karstification or tectonic fragmentation. The present investigation indicates that it originated as a subrosion pipe fill that formed by continuous upsection collapse which commenced in the Röt gypsum and anhydrite beds more than 200 m below. The pipe fill is dated probably to one of the Quarternary interstadials when these rocks were dissolved by groundwater at even greater depths.

Keywords: Subrosion pipe, Triassic, Lower Muschelkalk, Zechstein Salinar, Röt Salinar, Winterswijk quarry, the Netherlands

Introduction

Subrosion pipe fills caused by subrosion of deeper evaporite rocks are rarely observed in outcrops. As a result of subsurface solution of water soluble rocks, the overlying strata collapse as soon as stability becomes insufficient. A depression at the earth's surface may be formed by the progressive collaps of the rocks. Leaching of rock salt is usually followed by almost continuous settling, leading to depressed areas at the surface, whereas leaching of gypsum usually causes vertical shafts and large sink holes at the surface (Simon, 2005). These may exceed 100 m in diameter and be as deep as 20 m. Their size depends on the depth of the dissolved gypsum strata and on the size of the cavity, which is dependent on the thickness of the gypsum layers respectively. Gypsum leaching in the Zechstein Salinar and the Röt Salinar of the Central German Hills has caused subrosion pipe fills of some hundreds of metres total depth (Hundt, 1950; Jordan et al., 1986; Laemmlen, 1991). While such a cavity migrates upsection towards the surface by continuous collapse, rock material that has broken down from the ceiling accumulates in a chaotic collapse breccia that fills up deeper parts of the cavity.

In the Lower Muschelkalk quarry near Winterswijk such a structure of chaotic block layers indicating a subrosion pipe fill (Oosterink et al., 2005) was encountered between well-bedded Lower Muschelkalk limestones when the section was measured for lithostratigraphical documentation in June 2004 (Fig. 1).

Field observations

In 1989 black claystones were observed in a small area within the quarry (Fig. 2). The identification of this structure as a subrosion pipe fill allows the interpretation of these claystones as its uppermost fill. According to both palynological

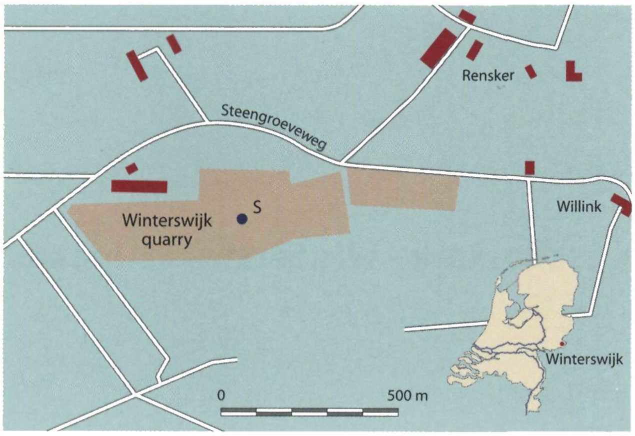

Fig. 1. Sketch of the Muschellkalk quarry of Winterswijk with position of the subrosion pipe filling (S).

(Herngreen, 1989) and micropalaeontological investigations (Lissenberg & Witte, 1989), the claystones have a Lower Jurassic age and correlate with the Hettangian/Sinemurian stage boundary. The directly underlying beds however indicate a Lower Muschelkalk age (Harsveldt, 1973; Oosterink, 1986; Diedrich, 2001). A second and much larger exposure with black claystones was recovered at the northern margin of the quarry in 2004. The palynomorphs in these sediments indicate a Rhaetian age (Herngreen, 2004). The lowermost 2 m of the black claystones in the pipe fill have red spots indicative of Rhaetian (Gerth, 1955: p. 50). Rhaetian palynomorphs or microfossils likely were not reported in 1989 because samples from the lowermost beds were not analyzed then.

The Winterswijk pipe can be seen most clearly in the 11 m thick section of the almost vertical quarry face (Fig. 2). A sheet of rock debris covering the lower quarry floor does not allow to delineate the extent of the pipe fill. However, in the upper quarry floor approximately one third of its diameter can be recognized from the distribution of the black claystone. From the size of the section the diameter of the pipe fill is estimated to be approximately 30 m. The lower part is filled with Muschelkalk debris and the upper 2 m with dark-coloured Rhaetian/Liassic claystones.

Fig. 2. Subrosion pipe with black Rhaetian/Liassic claystone infill in the upper part. Diameter ca. 30 m. Arrows: margins of the pipe.

Correlation of the Muschelkalk rocks in the pipe filling with the in-situ sediments of the quarry section indicates that the rocks dropped ca. 10 m. The Muschelkalk infill of the pipe is coarsely arranged in normal stratigraphic succession due to the way these structures are formed. Fragments of a relatively thick bed can be horizontally traced through the upper part of the infill breccia. The boulder size is related to the original thickness of the layers and to the distance to the original cleavage. Single slabs rarely exceed 1 m in diameter and 0.5 m in thickness (Fig. 3). The rock material may also be finely ground. In the heterogenous infill mass, cavities are not abundant and not larger than 20 cm. They are partly filled with brownish and blackish mud of ferrous and manganese hydroxide.

Fig. 3. Muschelkalk infill of the subrosion pipe. Single slabs exceed 1 m in diameter and 0.5 m in thickness. Measuring stick 1 m.

When dropping down, limestone blocks were broken and some clay slabs have been bent. Listric shear planes were observed which may have originated from subsequent settling.

Due to the genetic process of the pipe fill, the longitudinal axis of many slabs in the ca. 1 m wide marginal area were aligned vertically. Towards the marginal area many boulders broke away from their original layer and attain a vertical position. Moreover, settling of the pipe infill caused steep to vertical positioning of those slabs which are in contact with the stable margin of the pipe (Fig. 4). In the centre of the pipe fill boulders show a horizontal or slightly oblique position on the debris pile. In the overlying block claystones, no large slabs nor finely ground masses occur.

Fig. 4. Eastern edge of the pipe filling approximately 0,2 m to the right of the measuring stick (0,6 m). Muschelkalk rocks in original bedding have been dragged towards the pipe. On top black Rhaetian/Liassic claystones. At the edge, a 1 m wide margin of many vertically arranged blocks.

Generally the boundary between the Muschelkalk and the claystone infill in the pipe is well defined (Fig. 5). Amalgamation of Muschelkalk and claystone is found only in a thin layer of a few decimetres. Some prominent Muschelkalk boulders protrude up to 20 cm into the claystone cover. At the southern margin of the pipe filling, a mass of ca. 1 - 2 m^3 of claystone has invaded the Muschelkalk debris up to 1 m depth.

At the boundary of Muschelkalk blocks and Rhaetian/Liassic claystones, no depositional fabric was observed. Muschelkalk blocks have not been karstified. The stratigraphic gap of ca. 40 Ma is indicated only by the significant change of rock material.

The stratification outside of the pipe fill was influenced by the collapse only at its immediate margin where the beds have been slightly dragged downwards. The quarry floor which exposes the present upper surface of the pipe fill is ca. 5 - 7 m below the former surface. Assuming an average subsidence factor of ca. 10 m the orginal Muschelkalk/Rhaetian boundary outside of the subrosion pipe in the quarry is estimated to have been located at approximately 3 m above the former surface. Taking into account a general NNW dip of 5°, this estimate is corroborated by the new outcrop of black Rhaetian claystones that was recently opened by quarrying activity at the northern margin of the pit.

Fig. 5. Distinct boundary between Muschelkalk (base) and Rhaetian/ Liassic (top) subrosion pipe filling. Length of hammer 0,4 m.

Time of origin

The youngest sediments of the pipe filling are Rhaetian/Liassic and have definitely not been deposited in a sink hole that was already existing during this time period. Therefore, the subrosion pipe must have originated later than deposition of the black claystones.

The pipe collapse must have caused a sink hole at the earth's surface. However, prior to the quarry activity no depression could be seen at the surface. Moreover, in the surroundings of the quarry no additional sink holes have been observed. Therefore, the infill of the depression must have taken place not later than the Quarternary period by glacial deposits. The subrosion filling, therefore, has existed since at least the beginning of Holocene times. Possibly more subrosion pipes occur and are covered under Quarternary sediments around the quarry.

The time of origin of the subrosion pipe can be determined more exactly by means of the present dip. Generally the strata are dipping S-N. At its southern edge, which is viewing from the pipe fill against the dip, the strata have been dragged further (ca. 2 m) into the rocks than at the northern edge where the strata at a distance of ca. 1 m do not dip to the pipe fill but to the North. This can be explained only if the collapse took place when the present dip already existed. Only a general northward dip would cause a drag towards the neighbouring rocks that is stronger on the southern side than on the northern side. Thus, the pipe fill must be younger than the tilting of the strata. Around the quarry, Oligocene strata are tectonically dipping whereas Quarternary deposits are horizontal. Therefore the Winterswijk subrosion pipe must have formed past Oligocene times. However, the leaching of the subsurface Röt Salinar gives evidence for an origin much later than Oligocene.

Stratigraphy and source rock

In the stratigraphic sequence (Fig. 6, cf. Harsveldt, 1963; NITG-TNO, 1998) are two intervals with salinar rocks which could have caused the subrosion pipe. The upper one is the Röt Evaporite approximately 230 - 250 m below the surface, which consists of gypsum, anhydrite, claystone and has been partly leached. Halite has probably been dissolved completely. The lower salinar section is the ca. 400 m thick Zechstein which consists largely of halite and anhydrite (Teichmüller, 1957).

According to investigations in Central and in East and North Germany, subrosion pipes may have been initiated by leaching of rocks up to 800 m below the surface (e.g. Hundt, 1950). Therefore both, the Röt as well as the Zechstein Evaporite could have caused the Winterswijk pipe. Indeed, subrosion pipes have been observed in both these salinar sequences. Step by step upsection collapse of some hundreds of metres, rooting in the Zechstein (Hesse, Germany) have been described by Laemmlen (1991). Jordan et al. (1986) described subrosion pipes originating in the Röt or the Zechstein Evaporite (Hesse, Germany) that reach up to 500 m below surface.

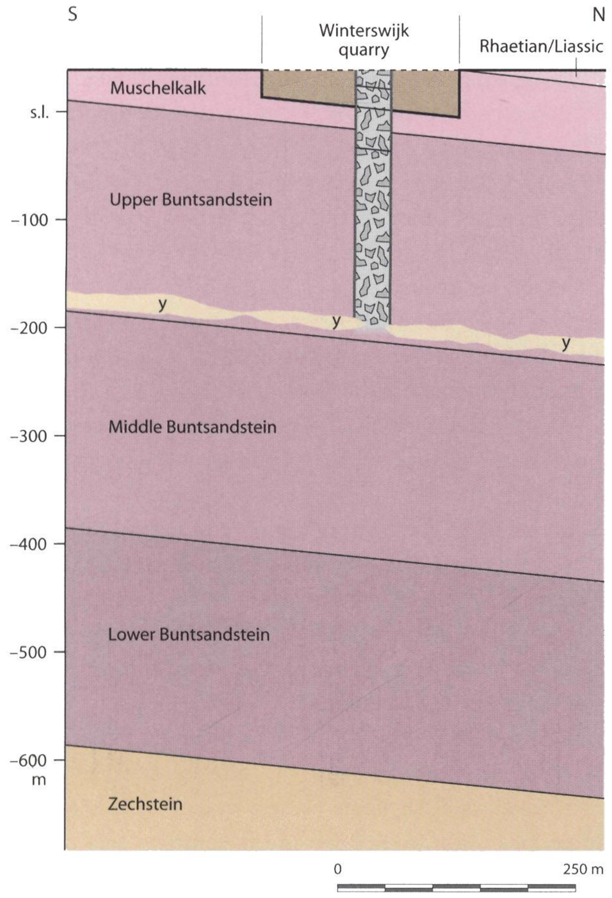

Fig. 6. Schematic section of the Röt Salinar subrosion pipe. y: gypsum.

Most probably, it is the Röt Salinar that gave rise to the Winterswijk subrosion pipe. The nearby deep well of Ratum ca. 2 km northeast of the quarry showed an evaporite succession at the base of the Röt which is leached (Bentz, 1933; Knapp, 1975). Originally, the thickness of the Röt salt was ca. 10 - 20 m, the thickness of gypsum and anhydrite was ca. 50 m (Bentz, 1933; Knapp, 1975). The latter value is large enough for continuous upsection collapse of a subrosion pipe of size of the Winterswijk pipe. The leaching process in the Röt evaporite is still going on and supports the origin of the Winterswijk subrosion pipe. Continuous collapse from Zechstein through the entire Buntsandstein sequence is less evident, because the overlying strata are at least 700 m thick. Moreover, because the leaching process in the Röt evaporites of the Ratum deep well is still active (Bentz, 1933; Knapp, 1975), there is no evidence for leaching in the Zechstein. Additionally, the state of leaching allows the conclusion that the pipe filling is not very old but dates back rather to a Pleistocene interstadial, or to Late Neogene (Miocene, Pliocene).

Implications on palaeogeography

The span between deposition of the Lower Muschelkalk and the Rhaetian/Liassic strata covers ca. 40 Ma. There are no signs indicating a strong sea-level fall in the Muschelkalk strata underlying the Rhaetian/Liassic. However, there must have been a regressive phase and even emersion. Consequently, later Muschelkalk deposits must have been eroded (Geluk, 1999, 2005; NITG-TNO, 1998; Wolburg, 1969). The present Muschelkalk carbonates have been slightly karstified in the uppermost 5 metres. Karrenfelds at the surface of the Muschelkalk deposits have been described by Crommelin (1943) and Oestreich (1943). Indication of strong and deeply seated karstification, like sinks or weathering to loam, have not been observed. There are no indications that Muschelkalk surface has not been exposed for a long time. From these considerations a scenario for the long span between Lower Muschelkalk and Rhaetian/Liassic depostition can be reconstructed: Deposition of Middle and Upper Muschelkalk, possibly also of Keuper sediments. Subsequently large scale erosion (Beutler, 2005) until sedimentation commenced again at the Rhaetian/Hettangian boundary (Herngreen et al., 2000, 2005). Afterwards the depositional environment had changed from coastal during Rhaetian to fully marine in Jurassic times.

Acknowledgements

The permission for investigating the stratigraphic section and the subrosion pipe in the Winterswijk quarry and for making available reports by the administration of the Ankerpoort Company is gratefully acknowledged. Dr. Karl-Christian Käding, Kali und Salz, D-34134 Kassel, and Dr. Jochen Farrenschon, Geologischer Dienst Nordrhein-Westfalen, D-47707 Krefeld, provided literature. Dr. Waldemar Herngreen, Laboratory of Palaeobotany and Palynology, Utrecht University and Dr. Cees Laban, TNO Built Environment and Geosciences – Geological Survey of the Netherlands, Utrecht, critically read the original manuscript in German language. Werner Simon assisted measurement, ditching and photography, Dr. Magnus Hagdorn, University of Edinburgh, improved the English. We also thank the reviewers Dr. P. L. de Boer and Dr. M. Geluk and for their helpful comments.

References

Bentz, A., 1933. Erläuterungen zu Blatt Oeding 4006. Geologische Karte von Preußen und benachbarten Ländern 1 : 25 000 (Berlin): 63 p.

Beutler, G., 2005. Diskordanzen im Keuper. Courier Forschungsinstitut Senckenberg 253: 85-93.

Crommelin, R.D., 1943. Een karrenveld bij Winterswijk. Tijdschrift Nederlands Aardrijkskundig Genootschap 60: 154-163.

Diedrich, C., 2001. Vertebrate track bed stratigraphy of the Röt and basal Lower Muschelkalk (Anisian) of Winterswijk (East Netherlands). Netherlands Journal of Geosciences 80/2: 31-39.

Geluk, M.C., 1999. Palaeogeographic and structural developement of the Triassic in the Netherlands – new insights. Zentralblatt für Geologie und Paläontologie 7-8: 545-570.

Geluk, M.C., 2005. Stratigraphy and tectonics of Permo-Triassic basins in the Netherlands and surrounding areas. – Thesis Univ. Utrecht: 1-171.

Gerth, H., mit Beiträgen von Hoffmann, K., 1955. Die Fossilführung des Jura in den Bohrungen der 'Rijksopsporing van Delfstoffen' bei Winterswijk und ihre stratigraphische Bedeutung. Mededelingen Geologische Stichting N.S. 9: 45-54.

Harsveldt, H.M., 1963. Older conceptions and present view regarding the Mesozoic of the Achterhoek, with special mention of the Triassic limestone. Verhandelingen Koninklijk Nederlands Geologisch-Mijnbouwkundig Genootschap, 21-2: 109-130.

Harsveldt, H.M., 1973. The Middle Triassic limestone (Muschelkalk) in the Achterhoek (E. Gelderland). Verhandelingen Koninklijk Nederlands Geologisch-Mijnbouwkundig Genootschap 29: 43–50.

Herngreen, G.F.W., 1989. Resultaat van het palynologisch onderzoek van een kleimonster uit steengroeve III te Winterswijk. Internal report 2217, Rijks Geologische Dienst (Haarlem): 2 p.

Herngreen, G.F.W., 2004. Palynologisch onderzoek van de afdekkende kleilaag in steengroeve IV, Winterswijk. Internal report Nederlands Instituut voor Toegepaste Geowetenschappen TNO 04-199-B (Utrecht): 7 p.

Herngreen, G.F.W., Van den Bosch, M. & Lissenberg, T., 2000. Nieuwe inzichten in de stratigrafische ontwikkeling van Jura, Krijt en Onder-Tertiair in de Achterhoek. Grondboor & Hamer 2000 (4) (Tiburg): 71-90.

Herngreen, G.F.W., Konijnenburg – van Cittert, J.H.A., van & Oosterink, H.W., 2005. New geological data (Middle Triassic, Rhaetian-Liassic and Oligocene) of the Winterswijk quarry, the eastern Netherlands. Netherlands Journal of Geosciences 84: 409-413.

Hundt, R., 1950. Erdfalltektonik. Knapp, Halle an der Saale: 145 p.

Jordan, H., mit Beiträgen von Büchner, K.-H., Nielsen, H. & Plaumann, S., 1986. Halotektonik am Leinetalgraben. Geologisches Jahrbuch 92: 3–66.

Knapp, G., 1975. Trias. *In:* Braun, F. J. & Thiermann, A. (ed.): Erläuterungen zu Blatt C 4306 Recklinghausen, Geologische Karte Nordrhein-Westfalen 1 : 100 000: 40-52.

Laemmlen, M., 1991. Subrosionschlote – Vulkanschlote – einige Beispiele aus Osthessen. Geologisches Jahrbuch, 124: 3-29.

Lissenberg, T. & Witte, L.J., 1989. Mikropaleontologisch onderzoek aan een kleimonster uit de steengroeve te Winterswijk. Internal report 497, Rijks Geologische Dienst (Haarlem): 5 p.

Netherlands Institute of Applied Geoscience TNO, 1998: Geological atlas of the subsurface of The Netherlands. Map sheet X Almelo-Winterswijk 1 : 250 000: 143 p.

Oestreich, K., 1943: Beschouwingen omtrent een blootgekomen karstoppervlak bij Winterswijk. Tijdschrift Nederlands Aardrijkskundig Genootschap 60: 163-166.

Oosterink, H.W., 1986. Winterswijk, geologie deel II – De Triasperiode (geologie, mineralen en fossielen). Wetenschappelijke Mededelingen Koninklijke Nederlandse Natuurhistorische Vereniging 178: 120 p.

Oosterink, H.W., Simon, Th., Winkelhorst, H., 2005. Een subrosieverschijnsel in de Muschelkalkgroeve van Winterswijk. Grondboor & Hamer 2005 (4): 78-83.

Simon, Th., 2005. Salz und Gips in der Trias Südwestdeutschlands – von der Entstehung bis zur Auslaugung. Laichinger Höhlenfreund 40 (2): 73-86.

Teichmüller, R., 1957. Ein Querschnitt durch den Südteil des Niederrheinischen Zechsteinbeckens. Geologisches Jahrbuch 73: 39-50.

Wolburg, J., 1969. Die epirogenetischen Phasen der Muschelkalk- und Keuperentwicklung Nordwestdeutschlands mit einem Rückblick auf den Buntsandstein. Geotektonische Forschungen 32: 1-65.