Micropalaeontological analysis of olistoliths from the Wieliczka Salt Mine (Outer Carpathians, Poland)

(Figs 1–6)

Abstract. Upper Cretaceous variegated marls of a Węglówka-type facies are exposed in the form of olistoliths within the Zuber-type salt deposits at the higher exploitation level of the “Kunegunda” Drift in the Wieliczka Salt Mine. This is the southernmost zone of occurrence of redeposited blocks of the Carpathian flysch sediments within the Miocene salt deposits of the Carpathian Foredeep.

The variegated marls contain considerably diversified assemblages consisting only of small benthic foraminifers, including both agglutinated and calcareous taxa. Basing on the ranges of the characteristic species the variegated marls in the “Kunegunda” drift are dated as Turonian–Campanian. Two zones of benthonic agglutinated foraminifera have been recognised: the *Uvigerinammina jankoi* and *Goesella rugosa* zones.

The foraminiferal assemblage of the youngest segment of the Węglówka marls is dominated by calcareous benthonic taxa with *Stensioeina gracilis* Brotzen as the most numerous species. Its presence indicates a Campanian age of this part of the studied deposits.

Key words: Flysch Carpathians, Upper Cretaceous marls, Miocene salt deposits, olistoliths, benthic foraminifera, biostratigraphy, palaeoecology.

INTRODUCTION

Marly facies varieties of the Węglówka, Żegocina and Frydek type are distinctive features of the Upper Cretaceous sediments of the Subsilesian Unit. Among them the Węglówka variegated marls are very characteristic of the Subsilesian Unit. Apart from the stratotype area – Węglówka tectonic window (Huss, 1957, 1966; Gasiński et al., 1999; Machaniec, 2000, 2002b) this facies is the most common in other tectonic windows of the Subsilesian Unit (Liszkowa, 1956; Huss,
Fig. 1. Tectonic sketch map of the Polish Carpathians showing the location of the examined section (after Malata et al., 1996; supplemented). 1 – crystalline core of the Tatra Mts; 2 – sedimentary rocks of the Tatra Mts; 3 – Podhale Flysch; 4 – Pieniny Klippen Belt; 5 – Magura; 6 – Fore Magura; 7 – Dukla Unit; 8 – Grybów Unit; 9 – Miocene lying on Carpathians; 10 – Silesian Unit; 11 – Subsilesian Unit; 12 – Skole Unit; 13 – Stebnik Unit; 14 – Zglobice Unit; 15 – andesites; 16 – investigated area.

Fig. 2. Geological map at the II higher exploited level of the “Kunegunda” Drift of the Wieliczka Salt Mine (map provided by “Wieliczka” Salt Mine, modified). 1 – block of halite rocks; 2 – green salt; 3 – flysch rocks in Miocene clays; 4 – Cretaceous variegated marls; 5 – Miocene clays; 6 – investigated area.
During the Late Cretaceous, according to palinspastic reconstructions of the Carpathian flysch basin (Unrug, 1979; Koszarski, 1985; Eliaš & Eliašová, 1995) the position of the Subsilesian area of sedimentation was favourable for the development of sediments rich in diversified foraminiferal assemblages. The Węglówka marls represent a pelagic facies that was deposited on a submarine ridge beyond turbidity current influence and above the carbonate compensation depth (CCD) (Książkiewicz, 1976; Machaniec, 2002a). The dominating red colour of these deposits indicates a well-oxygenated environment and low input of organic matter.

The Węglówka marls, exposed at the second exploitation level in the “Kunegunda” drift of the Wieliczka Salt Mine (Figs 1, 2), have been examined for the purpose of this study. They occur in the form of olistoliths within the Zuber-type salt deposits (Alexandrowicz, 1976; Kolasa & Ślączka, 1985). This is the southernmost zone of occurrence of redeposited blocks of flysch sediments within the Miocene salt deposits of the Carpathian Foredeep (Figs 3, 4). In the “Kunegunda” Drift the Węglówka-facies deposits are developed as variegated, red, grey, greenish-grey as
well as black marls and marly shales with occasionally occurring spherosiderites. Strong slickensiding, considerable dipping angles, and pinching out of particular beds indicate strong tectonic disturbance (Fig. 3; Zapałowicz-Bilan, 1976).

MATERIAL AND METHODS

A total of 19 samples were collected from the Kunegunda Drift of the Wieliczka Salt Mine. The samples were disintegrated by repeated boiling and drying using Glauber salt. The samples were washed over a 63 µm sieve and dried. Most of samples contained abundant and diversified foraminiferal assemblages. Palaeoecological analyses were made based on counts of 300 specimens from each sample. The
foraminifers (collection No 90K) are housed in the Institute of Geological Sciences, Jagiellonian University.

**BIOSTRATIGRAPHY**

Basing on the ranges of the characteristic species according to the Geroch & Nowak (1984) zonation, the age of the Węglówka Marls exposed in the “Kunegunda” Drift has been assigned to the Turonian–Campanian interval. The following foraminiferal zones have been recognized.

**Uvigerinammina jankoi Zone**

Foraminiferal assemblages display considerable diversity (42 species), apart from the index taxon the following species are also quite numerous: Bulbobaculites problematicus (Neagu), Pseudonodosinella parvula (Huss), Clavulinoides amorpha (Cushman), Caudammina ovula (Grzybowski), and Glomospira charoides (Jones & Parker).

Age: Turonian–Santonian.

**Goesella rugosa Zone**

The foraminiferal assemblage is rich in agglutinated (38 species) and benthonic calcareous species (45 species). The numerous appearance of Stensioeina gracilis (Brotzen) has been noticed in this zone, while Reusella szajnochae (Grzybowski), a species considered as typical of Campanian marly deposits (Geroch et al., 1967) has not been found.

Age: Campanian.

The lower part of the studied sediments represents the Uvigerina jankoi Zone. This is based on the presence of the index taxa Uvigerinammina jankoi Majzon and Bulbobaculites problematicus (Neagu). The co-occurrence Uvigerinammina jankoi with Bulbobaculites problematicus is characteristic for the Turonian–Santonian strata as described from other parts of Subsilesian Unit (Machaniec et al., 2001).

The Turonian–Santonian assemblage is dominated by such species as: Uvigerinammina jankoi, Clavulinoides amorpha, Bulbobaculites problematicus, Glomospira charoides, Haplophragmoides bulloides (Beissel), Dorothis crassa (Mars- son), and Spiroplectinella lanceolata (Huss).

The Turonian/Coniacian boundary is considered as the last appearance datum of Bulbobaculites problematicus (Geroch & Nowak, 1984). The range of Uvigerinammina jankoi Majzon ends at the Santonian/Campanian boundary (Geroch & Nowak, 1984). Some new species appear, such as: Goesella rugosa (Hanzliková), Spiroplectinella dentata (Alth) and Ammodiscus cretaceus (Reuss). In this assemblage the agglutinated taxa are still dominating. The youngest fragment of the Węglówka marls in the “Kunegunda” Drift contains calcareous benthonic species, among which Stensioeina gracilis prevails. The presence of this species points to the Campanian age of this part of studied deposits. In deposits assigned to the Cam-
panian, planktonic foraminifera have not been found. Planktonic foraminifera are usually a frequent component of the foraminiferal assemblages of the Węglówka marls known from the other areas (Huss, 1957; Liszkowa, 1967; Gasiński et al., 1999; Machaniec & Leśniak, 2001; Machaniec et al., 2001).

**MICROPALAEONTOLOGICAL DATA**

The foraminiferal assemblages consist of benthonic taxa displaying high species diversity and predominance of agglutinated forms. Among the agglutinated taxa the following species are the most common: *Ammodiscus cretaceus*, *Glomospira charoides*, *Glomospira irregularis* (Grzybowski), *Caudammina ovula* (Fig. 5: 8), *Pseudonodosinella parvula* (Fig. 5: 2), *Haplophragmoides kirki* Wickenden, *Trochammina globigeriformis* (Jones & Parker; Fig. 5: 9), *Recurvirodes* sp., *Bulbobaculites problematicus* (Fig. 5: 1), *Uvigerinanina jankoi* (Fig. 5: 3, 4), *Spiroplectinella costata* (Huss), *Spiroplectammina lanceolata*, *Spiroplectammina navarroana* (Cushman), *Spiroplectinella dentata*, *Gaudryina* sp., *Goesella rugosa*, and *Clavulinoides amorpha*. The benthonic foraminifera are dominated by: *Stensioeina exculpata* (Fig. 6: 6), *Stensioeina gracilis* (Fig. 6: 3–5), *Stensioeina pommerana* Brotzen (Fig. 6: 1, 2), *Dentalina laticollis* Risso, *Nodosaria limbata* d’Orbigny, *Nodosaria monile* Hagenow, *Saracenaria* sp., *Aragonia ouezzanensis* (Rey) (Fig. 6: 7), *Marginulinopsis* sp. (Fig. 6: 8), *Pleurostomella wadowicensis* Grzybowski, *Ramulina* sp., *Pullenia cretacea* Cushman, *Eponides subcandidulus* (Grzybowski), *Gyroidinoides nitidus* (Reuss), and *Gyroidina megastoma* (Grzybowski).

The micropalaeontological analysis reveals the distinct dominance of agglutinated foraminifera (up to 100%) in the Turonian–Santonian assemblages. An increase in the quantity of both agglutinated species with calcareous cement and calcareous benthonic taxa has been observed up the sequence. The youngest foraminiferal assemblages contain 19–35% of benthonic calcareous taxa. The noteworthy feature is a numerous appearance of genus *Stensioeina* represented by rare specimens of *Stensioeina exculpata* (Fig. 6: 6), *S. pommerana* (Fig. 6: 1, 2) and very abundant *S. gracilis* (Fig. 6: 3–5). The amount of this genus reaches up to 80% of the total assemblage. Such a numerous occurrence of *Stensioeina* in the Subsilesian Unit is a rather rare phenomenon. So far, only single specimens of this taxon have been noticed in the Senonian deposits of the Węglówka half-tectonic window (Huss, 1957).

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**Fig. 5.** Agglutinated foraminifera from the “Kunegunda” Drift of the Wieliczka Salt Mine; SEM micrographs; *U. jankoi* Zone–*G. rugosa* Zone. Turonian–Campanian. 1 – *Bulbobaculites problematicus* (Neagu), *U. jankoi* Zone; 2 – *Pseudonodosinella parvula* (Huss), *U. jankoi* Zone; 3, 4 – *Uvigerinanina jankoi* Majzon, *U. jankoi* Zone; 5 – *Spiroplectinella costata* (Huss), *G. rugosa* Zone; 6 – *Spiroplectinella dentata* (Alth), *G. rugosa* Zone; 7 – *Kalamopsis grzybowskii* (Dylaźanka), *U. jankoi* Zone; 8 – *Caudammina ovulum* (Grzybowski), *U. jankoi* Zone; 9 – *Trochamminoides globigeriformis* (Parker & Jones), *U. jankoi* Zone; 10 – *Goesella rugosa* (Hanzlíková), *G. rugosa* Zone
in the eastern part of the Grabownica-Załuże fold (Machaniec, 2002) and in the Andrychów Klippes (Gasiński, 1998). According to Olsson & Nyong (1984) the presence of *Stensioeina* is characteristic of assemblages from 200–400 m palaeodepths.

Considering the composition of the foraminiferal assemblages and basing on the models of Haig (1979), Olsson & Nyong (1984), and Sliter & Baker (1972) it can be assumed that during Turonian–Santonian deposition of the studied deposits took place at the lower slope depth with some tendency to shallowing, and in the Campanian at palaeodepths not deeper than the upper part of the slope. The exclusively agglutinated assemblages only with some benthonic calcareous forms in the Turonian–Santonian indicate deposition near the CCD. Mixed Campanian assemblages with more numerous benthonic calcareous suggest deposition well above the CCD but below foraminiferal lysocline (FL), which is usually situated a few hundred metres above the CCD (Kennet, 1982).

**SUMMARY AND CONCLUSIONS**

In the “Kunegunda” Drift of the abandoned working of the Wieliczka Salt Mine, slump breccia of Miocene and flysch sediments are exposed. The flysch deposits are represented mainly by the Upper Cretaceous variegated Węglówka marls (Figs 1, 2). The foraminiferal assemblages reveal some differences between the presented assemblages and the assemblages of the same age interval from other occurrences of marly deposits of the Subsilesian Unit. These differences include: the lack of the planktonic foraminifera in the variegated marls assigned to the Campanian; the lack of *Reussella szajnochae* (Grzybowski); very numerous occurrence of *Stensioeina gracilis* in the Campanian assemblage. Foraminiferal assemblages of the studied deposits show considerably similarities to the assemblages described from the Grabownica-Załuże area (Liszkowa, 1957; Machaniec, 2002b).

The environmental setting of the Turonian–Santonian blocks represents lower slope depths with some shallowing trends, and upper slope depths for the Campanian blocks.

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*Fig. 6.* Benthonic calcareous foraminifera from the “Kunegunda” Drift of the Wieliczka Salt Mine; SEM micrographs; *G. rugosa* Zone, Campanian. 1 – *Stensioeina gracilis* Brotzen, dorsal side; 2 – *Stensioeina pommerana* Brotzen, edge view; 3 – *Stensioeina gracilis* Brotzen, ventral side; 4, 5 – *Stensioeina gracilis* Brotzen, dorsal side; 6 – *Stensioeina exculpta* (Reuss), dorsal side; 7 – *Aragonia ouezzanensis* (Rey); 8 – *Marginulinopsis* sp.
REFERENCES


