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Facies changes in the Cenomanian (Cretaceous) of the northwestern Elbe Valley near Dresden (Saxony, Germany)

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ABSTRACT:

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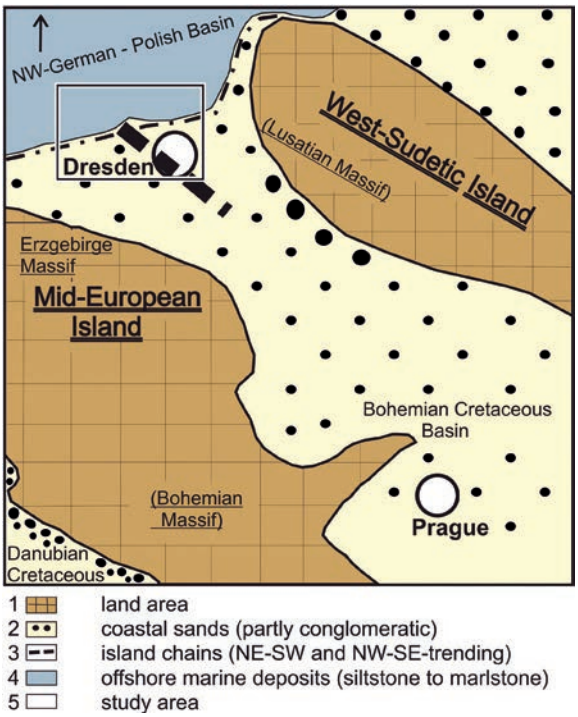
The Upper Cretaceous of the Elbe Valley in Saxony and the erosion outliers west of it mark an Upper Cretaceous NW–SE-running strait between the Westsudetic Island in the NE and the Mid-European Island to the west. This street connected the NW-German-Polish Basin in the north and the Bohemian Cretaceous Basin (and adjacent regions of the Tethys) in the south. However, post-Cretaceous erosion north of Meißen removed any Upper Cretaceous deposits but erosion outliers at Siebenlehn and especially north of the Forest of Tharandt proof the presence of a marly through silty belt in this area. Three transgressions (base of uppermost Lower to Middle Cenomanian, base of Upper Cenomanian and base of the *geslinianum* Zone in the mid-Upper Cenomanian) have taken place. The sedimentation was influenced by the topography of the mentioned islands and by movements at structural lines in the Proterozoic and Palaeozoic basement. During the early Late Cenomanian, a marly-silty sedimentation (Mobschatz Formation) in the north existed besides sandy sedimentation in the south (Oberhäslich Formation). The transgression at the base of the *geslinianum* Zone caused the final submergence of island chains between Meißen, Dresden and Pirna, and a litho- and biofacies bound to cliffs and submarine swells formed. A silty–marly lithofacies, a mixed sandy–silty lithofacies (Dölzschen Formation) and a sandy lithofacies in the south (Sächsisches Elbsandsteingebirge) co-existed during the latest Cenomanian. The first mentioned biofacies yields a rich fauna mainly consisting of oysters, pectinids, rudists, and near-shore gastropods accompanied by echinids and, in some cliffs, teeth of sharks. The Pennrich fauna (Häntzschel 1933; Uhlig 1941) especially consists of the very common serpulids *Pyrgopolon* (*P.*) *septemsulcata* and *Glomerula lombricus* (formerly *Hepteris septemsulcata* and *G. gordialis*).

Key words: Upper Cretaceous; Cenomanian; Elbe Valley zone; Biostratigraphy; Lithostratigraphy; Facies changes; Tectonics.

INTRODUCTION

The Upper Cretaceous of the Elbe Valley (Elbtal Group) is situated between Meißen, Dresden and the Saxonian state boundary, south of Bad Schandau. The marine sedimentation took place in a strait between the West Sudetic Island in the northeast (Lusatian Massif of Scupin 1936) and the Mid-European Island (Erzgebirge Mountains, Bohemian Massif) in the southwest (Text-fig. 1). This strait connected the Boreal NW-German-Polish Basin in the north and the Cretaceous Bohemian Basin, which opened to the Tethyan Realm in the south. The reconstruction of the original extent of the strait is difficult because greater parts of its re-



Text-fig. 1. Late Cenomanian palaeogeography of a part of Central Europe between the Mid-European and West-Sudetic islands (according to Scupin 1936; modified by data in Seifert 1955; Diener 1967; Tröger 1967; Musstow 1968; Klein *et al.* 1979; Wilmsen *et al.* 2011)

cord were removed by erosion during post-Cretaceous times. This is particularly the case north of Meißen, well shown in the overview map of Diener (1968, fig. 20). The erosion outliers around the Elbe Valley (see Kiesel, unpublished report for the Geological Survey of Saxony) are exposed west of the Tharandt Forest (Tharandter Wald), in the Dippoldiswalde region (Dippoldiswaldaer Heide, Paulshainer Heide, Höckendorfer Heide), and between Siebenlehn and Nossen (see Pietzsch 1962, fig. 126). Horna *et al.* (2011) described Lower Coniacian deposits from Börnersdorf in the eastern part of the Erzgebirge Mountains. The erosion outliers at Siebenlehn and north of the Tharandt Forest are the scope of this paper.

GEOLOGICAL SETTING AND STRATIGRAPHY

In the northern part of the Elbe Valley, including the Elbe Graben, between the Lusatian overthrust and the Niederwartha fault (Text-figs 2, 5), the Cenomanian is represented by the marine Lower to Middle Cenomanian Meißen Formation (Prescher and Tröger 1989), the lower Upper Cenomanian Oberhäslich Formation (Prescher 1981), interfingering with the Mobschatz Formation (Tröger 2008), and the upper Upper Cenomanian Dölzschen Formation (Prescher 1981). The terrestrial / fluviatile Niederschöna Formation (Geinitz' 1871–1875 "Niederschönaer Schichten") underlies the Upper Cenomanian succession (Text-fig. 2). An overview of Cenomanian facies development of the Elbtal Group is provided by Tröger (2003a, b).

The Meißen Formation was deposited during the **first Late Cretaceous transgression** entering from the north and reaching the region of Meißen– Oberau. The transgression took place in the latest Early Cenomanian *Mantelliceras dixoni* Zone (Prescher and Tröger 1989) and continued into the (early) Middle Cenomanian (Janetschke and Wilmsen 2014; Wilmsen and Nagm 2014; Wilmsen and Niebuhr 2014). The late Early to Middle Cenomanian age of the Meißen Formation is proven by the presence of *Schloenbachia varians subtuberculata*, *Schloenbachia varians costata, Turrilites costatus, Inoceramus virgatus, Inoceramus* sp. ex gr. *crippsi* and *Neohibolites ultimus* (Prescher and Tröger 1989; Köhler and Spaeth 1997; Wilmsen and Nagm 2014). Besides a cliff facies (red fossiliferous conglomerates), comprising the Meißen Formation proper, an overlying nearshore facies consisting of a basal greensand overlain by marls and calcareous siltstones with sand lenses is present (see Text-fig. 2). This facies is possibly Middle Cenomanian in age and transitional between the Meißen and Mobschatz formations. It awaits formal lithostratigraphic assignment, either as an additional upper marly member of the Meißen Formation or as a lower member of the Mobschatz Formation.

The second transgression, at the beginning of the Late Cenomanian *Calycoceras naviculare* Zone, affected the whole Elbe Valley lineamental zone. The oyster *Rhynchostreon suborbiculatum* is especially common in the sandstones of the Oberhäslich Formation (Unterquader of Geinitz 1871–1875). This oyster is widely distributed in the Tethyan Realm and testifies a northward faunal migration. The key fossils of the Oberhäslich Formation are *Calycoceras naviculare*, *Inoceramus pictus pictus*, *Inoceramus pictus bannewitzensis*, *Inoceramus pictus concentricoundulatus* and *Neithea aequicostata.*

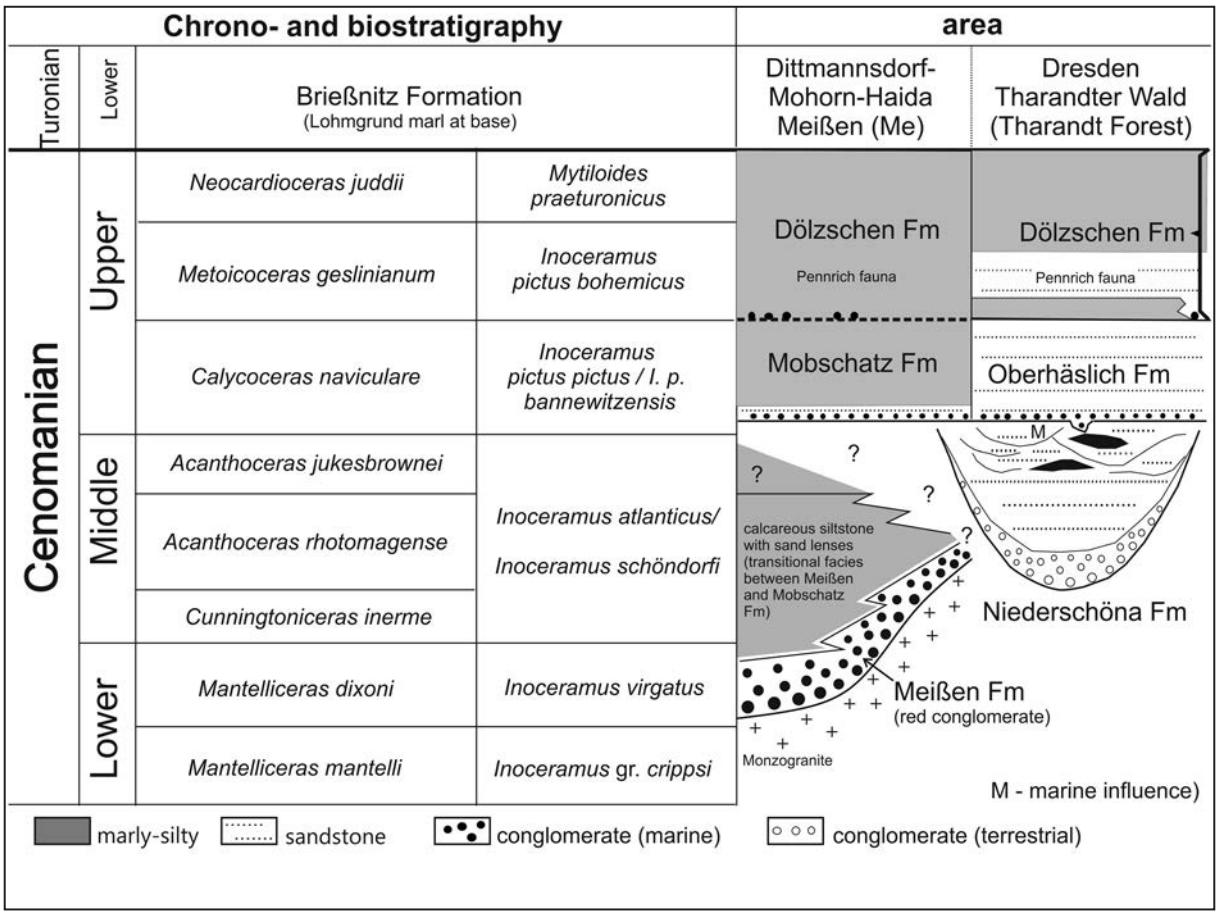
The third transgression took place in the *Metoicoceras geslinianum* Zone of the mid-Late Cenomanian. The Dölzschen Formation was formed during this transgression. Its lower part yielded rare *Metoicoceras geslinianum*, *Praeactinocamax plenus* and, sometimes common *Inoceramus pictus bohemicus.* Its upper part yielded rare *Neocardioceras juddii* [see Wilmsen and Nagm 2013, redescription of Geinitz' (1871–1875) *Ammonites neptuni*], as well as rare *Mytiloides praeturonicus* Tröger 2014 (Tröger and Niebuhr

2014), documenting its range into the latest Cenomanian *Neocardioceras juddii* Zone. In the lower part of the Dölzschen Formation, there is an important key horizon with the so-called Pennrich fauna, consisting of (according to Häntzschel 1933 and Uhlig 1941): *Glomerula lombricus* (very common), *Pyrgopolon* (*P.*) *septemsulcata* (common), *Entolium membranaceum* (common), *Pseudolimea granulata* (common), *Camptonectes virgatus* (rare to common), and of *Neithella notabilis* (common). It should be noted that *P.* (*P.*) *septemsulcata* and *G. lombricus* have been formerly known as *Hepteris septemsulcata* and *G. gordialis* (see recent revision of serpulids and sabellids from the Elbtal Group by Jäger 2014) and also the names of some common bivalves have changed following the revision by Niebuhr *et al.* (2014a).

The silty-marly strata of the Mobschatz and Dölzschen formations south of Meißen and the influence of transgressions and of the regional tectonics are discussed below. An overview of facies development of the Upper Cretaceous of the Bohemian Basin was published by Klein *et al.* (1979). The facies development and stratigraphy of the Danubian Cretaceous Group, deposited to the southwest of the Bohemian Massif (see Text-fig. 1) and characterized by overall great similarities to the Elbtal Group, has been detailed by Niebuhr *et al.* (2014b).

THE MOBSCHATZ AND DÖLZSCHEN FORMATIONS ADJACENT TO THE THARANDT FOREST AND IN THE ELBE GRABEN SW OF MEISSEN

The region of Niederschöna, Dittmannsdorf and Hutha is situated immediately west of the Tharandt Forest. A 2–3 m deep, NE/SW-running trench for the OPAL pipeline (abbreviation for "Ostsee-Pipeline-Anbindungsleitung") was excavated in this region in 2011 (Text-figs 3, 4A). A further exposure was available in 1983 west of Hutha. The exposed Cretaceous beds, dipping slightly to the north, overlie the Proterozoic gneiss, and are commonly covered by c. 2-m-thick Pleistocene loess clay deposits. The following Cretaceous succession was observed from the hanging to the lying wall:



Text-fig. 2. Cenomanian successions of the Dittmansdorf and Dresden areas, with lithostratigraphy, biozonation, and chronostratigraphic interpretation

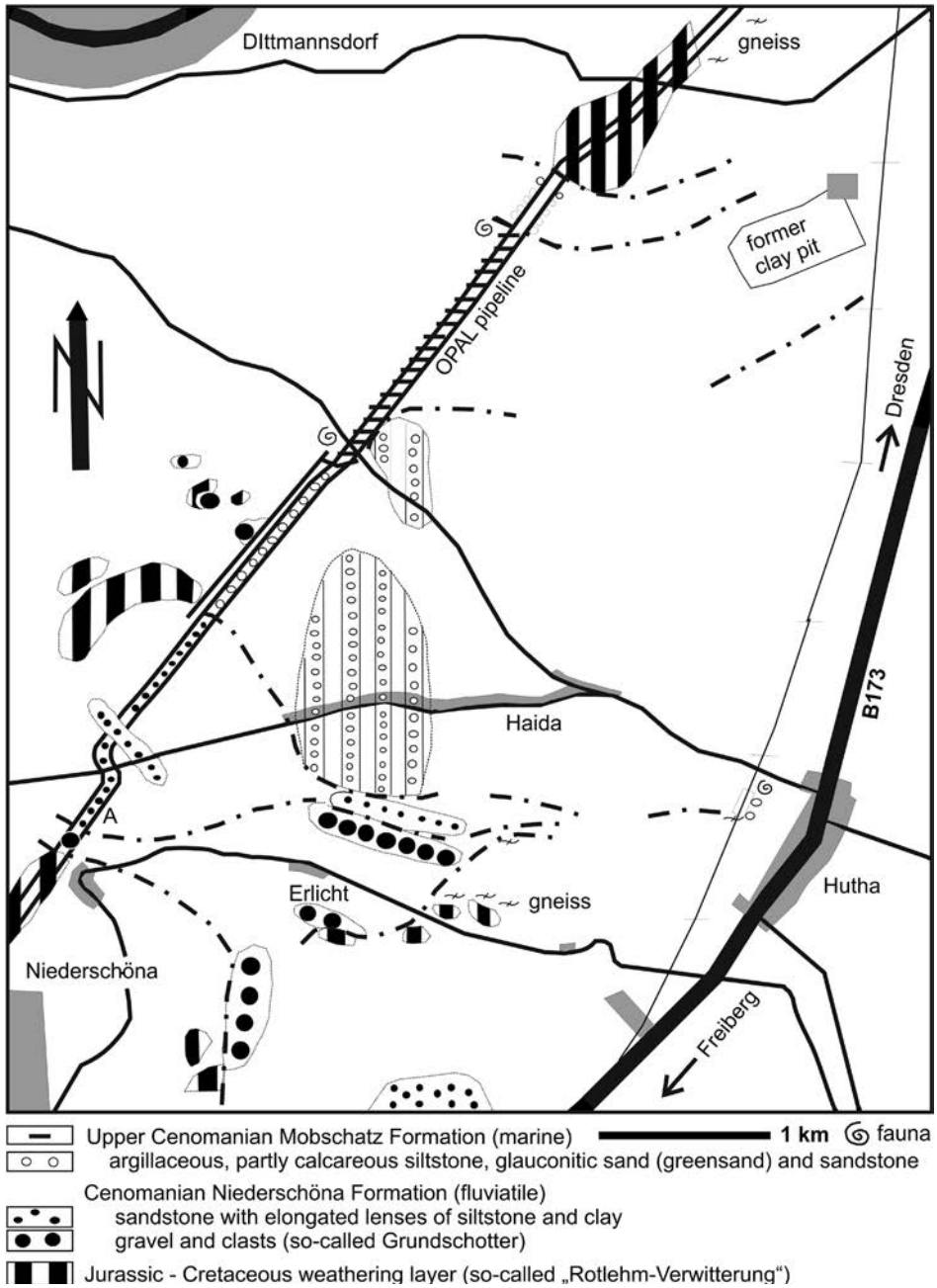
Dölzschen Formation

Siltstone, argillaceous with sandy lenses, micaceous, dark grey
Siltstone with numerous silicified specimens of *Glomerula lombricus* (Pennrich fauna)
Siltstone, sandy, micaceous, glauconite present
Sandstone, fine-grained with glauconite, grey / yellow
Greensand, basal layers with well-rounded pebbles of quartz

Erosion – erosional cavities filled with greensand

Mobschatz Formation

Siltstone, argillaceous, sandy lenses, micaceous with lumachelle of *Neithea aequicostata*
Sandstone, fine- through medium-grained, glauconitic
Greensand, basal layers with some quartz pebbles (Text-fig. 4D)



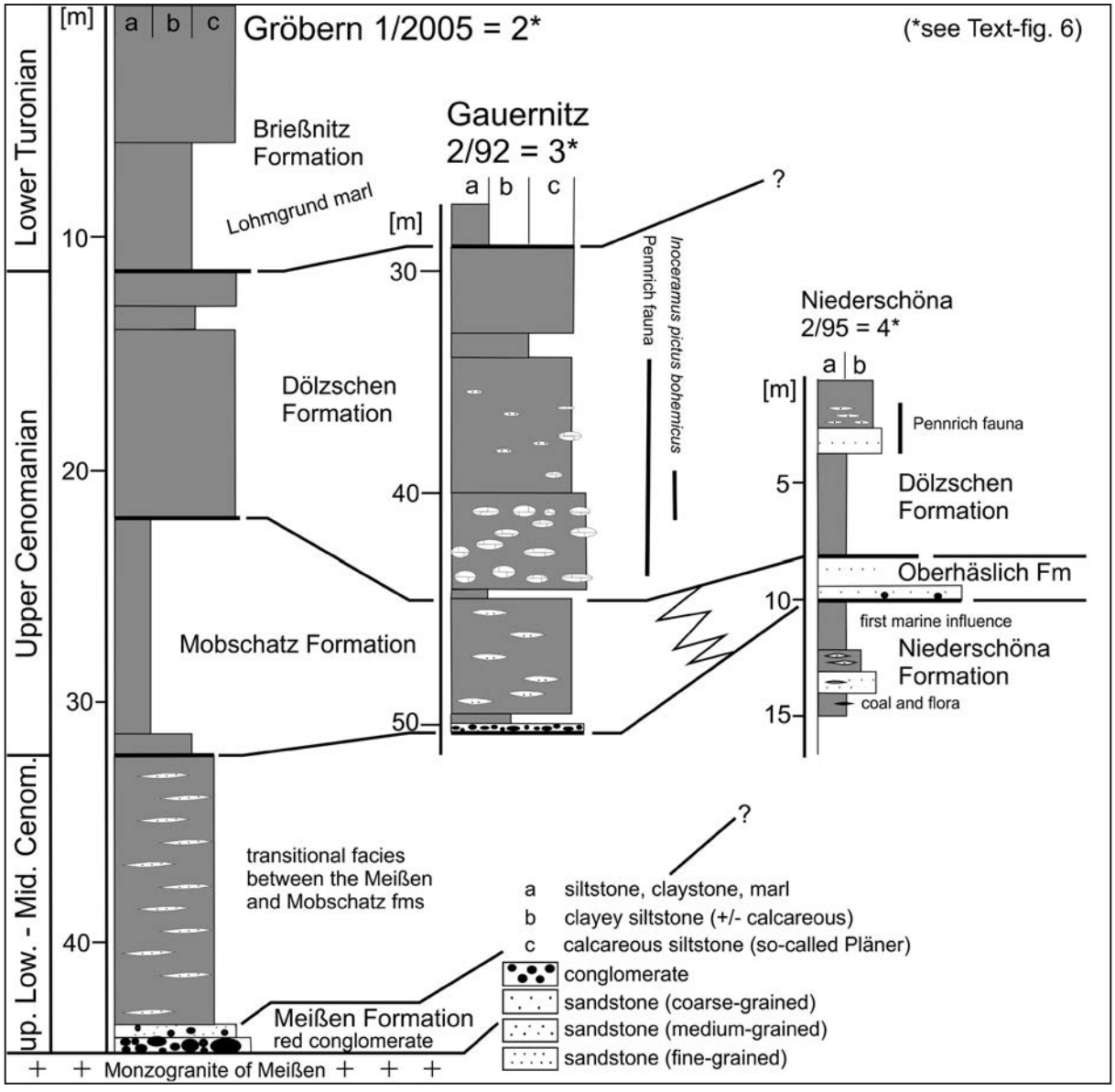
Text-fig. 3. Cretaceous exposures in the Dittmansdorf area (subsurface view)

Text-fig. 4. Field aspects during excavations for the OPAL pipeline in the Dittmannsdorf area in 2011. **A** – trench of the OPAL pipeline north of Niederschöna (view towards the northeast). In the foreground, fluvial strata of the Niederschöna Formation are exposed; in the background (behind the wooded belt), Proterozoic gneiss crops out capped by a red-weathered palaeosol (caused by pre-Cenomanian "Rotlehm-Verwitterung"). **B** – lower part of the fluvial Niederschöna Formation consisting of coarse-grained pebbly sandstones with conglomerate lenses (so-called "Grundschotter"). **C** – cross-bedded fluvial sandstones of the Niederschöna Formation up-section of the Grundschotter. **D** – detail of the OPAL pipeline trench 2.5 km northwest of Haida showing the contact of the Niederschöna Formation below and a basal greensand of the Mobschatz Formation above (arrows); the uppermost part of the section is composed of Quaternary loess

In the northern part of the section, the marine Upper Cretaceous is overlapping the gneiss including a red-weathering palaeosol (so-called "Rotlehm-Verwitterung"; Text-fig. 4A). In the southern part, near Niederschöna, the marine Upper Cretaceous is overlapping the terrestrial-fluviatile Niederschöna Formation (see Text-figs 2, 4B, C) with the following layers from the hanging to the lying wall:

Niederschöna Formation **Sandstone**, medium- to fine-grained with layers of argillaceous and sandy siltstone, micaceous, grey to white-grey with mostly poorly preserved plants. In the quarries of Niederschöna (at the former forest house), the uppermost siltstone layers yield grains of glauconite testifying a first marine influence (see Text-fig. 2)
Sandstone, fine-grained, silty, micaceous, red-coloured (Text-fig. 4C)
Sandstone, medium- to fine-grained, basal part coarse grained, micaceous, grey

Niederschöna Formation **Gravel,** mainly of quartz, pebbles consisting of rocks belonging to the basement are rare but present (so-called "Grundschotter", i.e. basal gravels; Text-fig. 4B)



Text-fig. 5. Important sections (schematic) of the Cenomanian in the northwestern part of the Elbtal Group

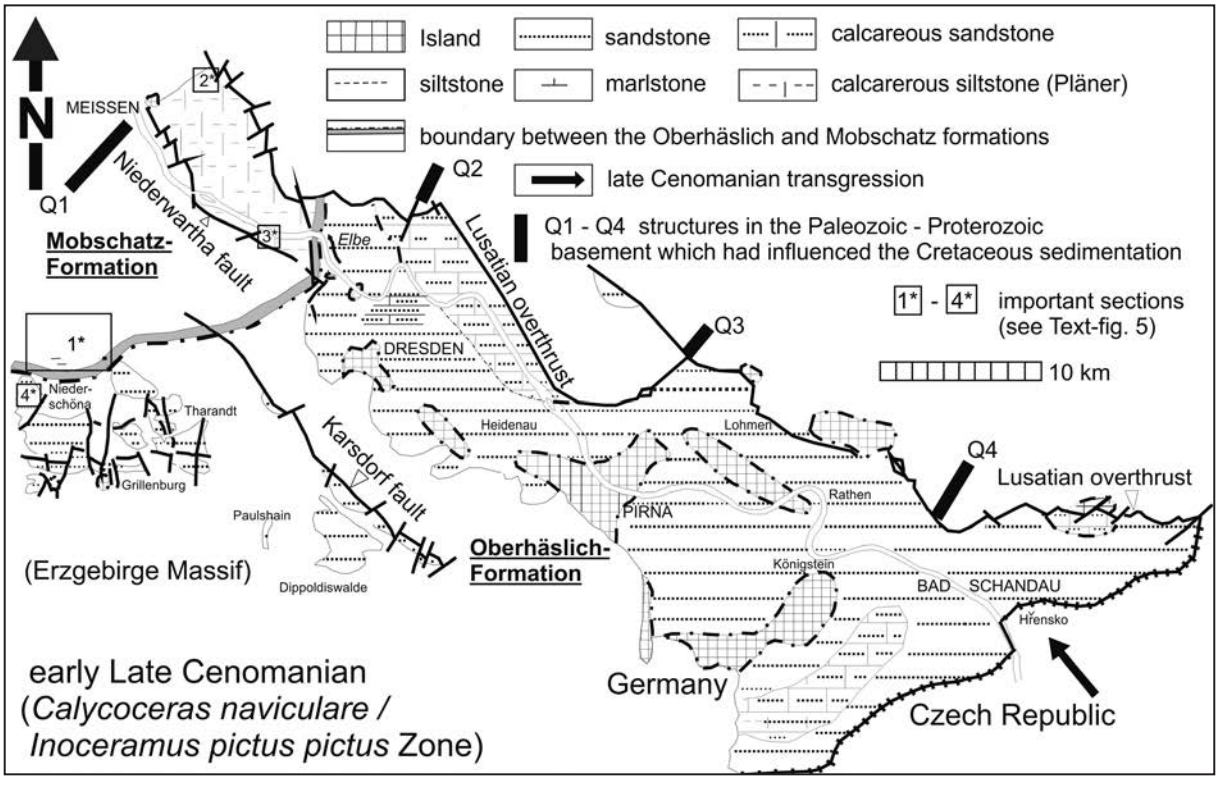
Text-fig. 4 shows some lithofacies details of the different layers which were exposed in the pipeline trench. This section is similar to the section which was exposed in the clay pit Augustusburg at the road Siebenlehn–Nossen, mentioned by Pietzsch (1962). A lacquer section of the strata at Siebenlehn is housed in the main collection of the Geological Institute in Freiberg.

Sections in core drillings in the northern part of the Elbe Valley Cretaceous (Text-fig. 5) allow a comparison of facies development between the two areas. Between Meißen and Gröbern, the transitional facies between the Meißen and Mobschatz formations potentially forms a shallow-marine equivalent of the fluvial strata of the Niederschöna Formation. However, further investigations are needed to fully understand the lateral facies relationships during the late Early and Middle Cenomanian that are not in the focus of this study. The Mobschatz Formation of the Meißen and Gröbern area consists of fine-grained marls and calcareous siltstones (core drilling Gröbern 2005). To the south, for example core drilling Gauernitz 2/92, the Mobschatz Formation comprises calcareous siltstones with intercalated lenses of calcareous, fine-grained sandstones. Not far away, a transition into the sandstones of the Oberhäslich Formation can be observed and the same situation is visible near Niederschöna (core drilling Niederschöna 2/95; see Text-fig. 5). Thicknesses decrease from the distal (Gröbern) to the proximal areas (Niederschöna), paralleling the facies trends. The hanging Dölzschen Formation overlaps the lower Upper Cenomanian Mobschatz and Dölzschen formations (Text-fig. 5). Its litho- and biofacies records a significant deepening across the investigated transect and its onlap onto basement highs documents the final drowning of remaining isolated islands during the latest Cenomanian (e.g., Tröger 2003a; Wilmsen *et al*. 2011).

FACIES CHANGES IN THE CENOMANIAN OF THE ELBTAL GROUP

The early Late Cenomanian *naviculare* Zone transgression, through the NW/SE striking Elbe Valley Lineament Zone, connected the Late Cretaceous Bohemian Basin in the south and the NW-German-Polish Basin in the north (Text-fig. 1). The Elbe Zone, forming a marine strait, was bordered by the Lusatian Massif in the north and the Erzgebirge Massif in the south.

Two main facies developments are visible in the Elbe zone during the early Late Cenomanian. The northern marly-silty offshore facies (the Mobschatz Formation) stretches between Siebenlehn and Meißen (Text-fig. 6). Further to the south, a sandy facies (Oberhäslich Formation) covers the area between the

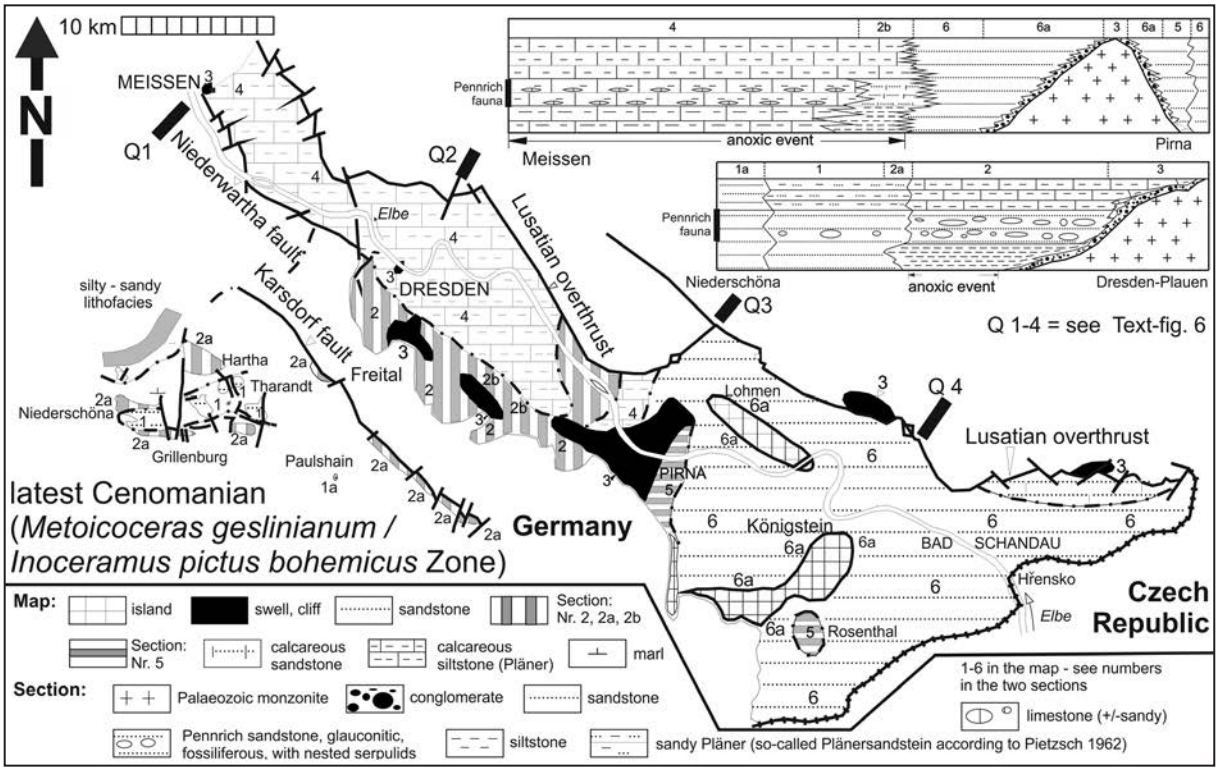


Text-fig. 6. Palaeogeography of the early late Cenomanian in Saxony (*Calycoceras naviculare* / *Inoceramus pictus pictus* Zone; Tröger 2008, modified)

Tharandt Forest, Dresden, Pirna and Bad Schandau (see Text-figs 1, 6). The sedimentation in this region was highly influenced by the uplifting Lusatian Massif. Several small basins including a marginal trough south of the Lusatian Massif developed in the centre of the Elbe Valley zone. These basins are limited by NW/SE- and NE/SW-striking island chains with small isles and rocky coasts (Decker 1963; Tröger 1967; Voigt 1994; Voigt *et al*. 1994). The islands follow the structure of the Palaezoic and Proterozoic basement. In the centres of some intervening basins, calcareous sandstones were deposited. The fauna in the sandstones consists mainly of bivalves. Ammonites are scarce and belemnites occur in very rare cases only (Tröger 1976). The common oyster *Rhynchostreon suborbiculatum* testifies Tethyan influences. The biofacies and macrobenthic assemblage of the Oberhäslich Formation has recently been investigated in detail by Wilmsen (2017) who concluded for a well-oxygenated and nutrient-rich shallow-marine environment.

The mid-Late Cenomanian *geslinianum* Zone transgression completely changed the palaeogeographic picture. The silty-marly facies was limited to the northern border of the Tharandt Forest and Meißen (Text-fig. 7). All islands from Meißen to Hohnstein (Saxonian Switzerland) were flooded and a facies of submarine swells and cliffs developed. This lithofacies consists mainly of conglomerates with a glauconitic-calcareous matrix and overlying glauconitic limestones and calcareous siltstones (= p*lenus* Pläner). The taxonomically diverse and abundant fauna varies from swell to swell. This fauna consists of sponges (mainly in the Pläner lithofacies), corals, brachiopods, bryozoans, bivalves (oysters, pectinids and small monopleurid and radiolitid rudists), echinids and locally common shark teeth (the latter known e.g., from the Hoher Stein in Dresden-Plauen). Ammonites (*Metoicoceras geslinianum*) and belemnites (*Praeactinocamax plenus*) are rare but allow for a precise bio- and event stratigraphic calibration of the sections.

An off-swell facies consisting of alternating siltstones (partly sandy), glauconitic and calcareous fine-grained sandstones and calcareous silstones (*plenus* Pläner), is present around the submarine swells and cliffs between Meißen, Dresden, Pirna and Hohnstein. The succession in this area shows the deepening trend during the latest Cenomanian by means of a general decrease in clastic input and a fining-upward in grain size. The fauna of this facies (the so-called Pennrich fauna, see Häntzschel 1935 and Uhlig 1941) yields small solitary corals, brachiopods, bivalves (e.g., *Pseudolimea granulata*, *Entolium membranaceum, Neithella notabilis* and common small oysters). Ammonites (*Metoicoceras geslinianum*) and belemnites



Text-fig. 7. Palaeogeography of the latest Cenomanian in Saxony (*Metoicoceras geslinianum* / *Inoceramus pictus bohemicus* Zone; Tröger 2008, modified)

(*Praeactinocamax plenus*) are very rare. The most important and common members of the Pennrich fauna are the serpulids *Glomerula lombricus* and *Pyrgopolon* (*P.*) *septemsulcata*. Offshore calcareous siltstones, rarely fossiliferous or devoid of fossils at all, are distributed in a marginal trough immediately south of the Lusatian overthrust between Meißen, Dresden and Pirna. The pure sandy near-shore facies influenced by the uplifting Lusatian Massif developed in the Saxonian ("Sächsische Schweiz") and adjacent Bohemian Switzerland ("Böhmische Schweiz", Czech Republic).

A comparable facies development during the *plenus* transgression occurred contemporaneously in the Danubian Cretaceous Basin to the southwest of the Bohemian Massif (see Text-fig. 1): a massive onlap of marine strata onto formerly emergent basement areas has been documented by Wilmsen *et al.* (2010) and Richardt *et al.* (2013) during the latest Cenomanian to earliest Turonian, and similar rocky near-shore and off-cliff facies zones with nearly identical bio- and lithofacies developed. These observations highlight the significance of the Late Cenomanian transgressions for formation of inter-basinal stratigraphic patterns and overall facies development.

CONCLUSIONS

The Cenomanian (early Late Cretaceous) sedimentation in the Elbe Zone was influenced mainly by the uplift of the surrounding Proterozoic massifs, bordering the zone to the NE and SW, and by successive Cenomanian transgressions. During two main transgressions in the early and mid-Late Cenomanian, the marine strait of the Elbe Zone, between the Ergebirge and the Lusatian massifs, was opened. This strait connected the temperate Boreal Realm to the north and the Tethyan Realm to the south, facilitating faunal exchange. The facies record of these early late Cretaceous changes in the Elbe Valley zone is documented by the lower Upper Cenomanian Mobschatz and Oberhäslich formations as well as the uppermost Cenomanian Dölzschen Formation. Following the first Late Cenomanian transgression, the *naviculare* transgression in the early Late Cenomanian, an offshore marly-silty sedimentation (Mobschatz Formation) in the north existed laterally to proximal sandy sedimentation in the south (Oberhäslich Formation). The next transgression at the base of the *geslinianum* Zone (*plenus* transgression) caused the final submergence of island chains between Meißen, Dresden and Pirna and a fossiliferous litho- and biofacies bound to cliffs and submarine swells formed.

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