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The transgression history of the Saxonian Cretaceous revisited or: the imperative for a complete stratigraphic reappraisal (Cenomanian, Elbtal Group, Germany)

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Abstract: Until a few years ago, the onset of continental to deeper marine deposition in the Saxonian Cretaceous Basin (SCB) was largely assigned to the *naviculare* transgression of the early Late Cenomanian. Based on the integrated investigation of 39 Cenomanian surface and subsurface sections, a completely revised stratigraphic framework for the lower Elbtal Group is presented herein. The new data show that Cretaceous sedimentation started already in the early Early Cenomanian, indicated by the contemporaneous onlap of non-marine (Niederschöna Formation) and marine strata (Oberhäslich Formation). The Cenomanian transgressions proceeded on a broad front from the north, at first following the course of roughly south–north-discharging palaeovalleys of a fluvial palaeodrainage system dewatering an elevated principal source area in the southwest. The sequence stratigraphic analysis demonstrates the presence of four complete, unconformity-bounded Cenomanian depositional sequences (DS) and a fifth one, DS Ce-Tu 1, which started in the mid-Late Cenomanian and lasted into the Early Turonian. The depositional sequences comprise six major transgressive phases that overstepped each other and enlarged the depositional realm by means of non-marine and/or marine onlap: A, early Early Cenomanian (equivalent to the "*ultimus*/*Aucellina* Transgression"), DS Ce 1+2; B, late Early Cenomanian, DS Ce 3; C, early Middle Cenomanian (*primus* Transgression), reflecting the most prominent sea-level rise within the SCB, DS Ce 4; D, early Late Cenomanian (*naviculare* Transgression), DS Ce 5; E, late Late Cenomanian (*plenus* Transgression), DS Ce-Tu 1; F, earliest Turonian (Lohmgrund Horizon), maximum flooding of DS Ce-Tu 1. The marine Oberhäslich Formation was accompanied by collateral fluvial deposits of the Niederschöna Formation during the early Early to early Late Cenomanian, respectively. The marine transgressions reached the Úštěk-Bad Schandau Sea Bight, the deepest of the north-sloping palaeovalleys, first and produced an up to 120-m-thick marine sedimentary record (Oberhäslich and Pennrich formations), subdivided into five almost equally thick depositional sequences. This maximum thickness is in the order of the accommodation generated during the Cenomanian age and corresponds to a rather low sedimentation rate of 20 m/myr. Therefore, the thickness changes observed within the lower Elbtal Group can be explained quite simply by the pre-transgression topography and sequence stratigraphic onlap patterns onto the elevated palaeotopography in the southwest. The new stratigraphic framework of the lower Elbtal Group thus shows that tectonic inversion in the SCB was essentially a post-Cenomanian process.

Kurzfassung: Bis vor wenigen Jahren wurde das Einsetzen der kontinentalen bis tiefermarinen Ablagerungen des Sächsischen Kreide-Beckens (SCB) ganz überwiegend der *naviculare*-Transgression des späten Cenomaniums zugeordnet. Basierend auf der integrierten Untersuchung von 39 Übertage-Aufschlüssen und Bohrungen des Cenomaniums wird hier eine komplette stratigraphische Revision der unteren Elbtal-Gruppe vorgestellt. Neue Daten zeigen, dass die Kreide-Sedimentation bereits im frühen Untercenomanium beginnt, belegt durch die zeitgleiche Auflagerung von nicht-marinen (Niederschöna-Formation) und marinen Schichten (Oberhäslich-Formation). Die cenomanen Transgressionen kamen auf breiter Front von Norden und folgten als Erstes den überwiegend Süd–Nord-ausgerichteten Paläosenken eines Drainagesystems, welches ein südwestlich gelegenes Hochgebiet entwässerte. Sequenzstratigraphische Untersuchungen belegen vier komplette, von sedimentären Diskordanzen begrenzte Ablagerungssequenzen (DS) im Cenomanium und eine fünfte, DS Ce-Tu 1, die vom mittleren Obercenomanium bis ins Unterturonium reicht. Die sechs übergeordneten transgressiven Phasen der Ablagerungssequenzen, die jeweils einander übertrafen und den Ablagerungsraum durch nicht-marine und/oder marine Auflagerung vergrößerten, sind Folgende: A, unteres Untercenomanium (Äquivalent der "*ultimus*/*Aucellina*-Transgression"), DS Ce 1+2; B, oberes Untercenomanium, DS Ce 3; C, unteres Mittelcenomanium (*primus*-Transgression) mit dem prominentesten Meeresspiegel-Anstieg im SCB, DS Ce 4; D, unteres Obercenomanium (*naviculare*-Transgression), DS Ce 5; E, oberes Obercenomanium (*plenus*-Transgression), DS Ce-Tu 1; F, basales Turonium (Lohmgrund-Horizont), maximale Überflutung von DS Ce-Tu 1. Die marine Oberhäslich-Formation wurde dabei während des frühen Unter- bis frühen Obercenomaniums lateral von zeitgleichen fluviatilen Ablagerungen der Niederschöna-Formation begleitet. Die marinen Transgressionen erreichten die Úštěk-Bad Schandauer Meeresbucht, das tiefste der Nord–Süd ausgerichteten Paläotäler, zuerst und erzeugten

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eine bis zu 120 m mächtige marine Abfolge (Oberhäslich- und Pennrich-Formation), die in fünf annähernd gleich mächtige Ablagerungssequenzen unterteilt ist. Diese maximale Mächtigkeit entspricht in etwa dem gesamten im Cenomanium erzeugten Akkommodationsraum und belegt eine ziemlich geringe Sedimentationsrate von 20 m/Mio Jahre. Die Unterschiede der Sedimentmächtigkeiten innerhalb der unteren Elbtal-Gruppe spiegeln die prä-Transgressionstopographie und sequenzstratigraphische Stapelungsmuster auf dem südwestlich angrenzenden Hochgebiet wider. Der neue stratigraphische Rahmen der unteren Elbtal-Gruppe zeigt daher überzeugend auf, dass die tektonische Inversion des SCB ein post-cenomaner Prozess war.

Keywords: Lower Upper Cretaceous, stratigraphic revision, marine vs. continental lithofacies, sequence stratigraphy, biostratigraphy, correlation, onlap history

Schlüsselwörter: Untere Oberkreide, stratigraphische Revision, marine vs. kontinentale Lithofazies, Sequenzstratigraphie, Biostratigraphie, Korrelation, Transgressionsgeschichte

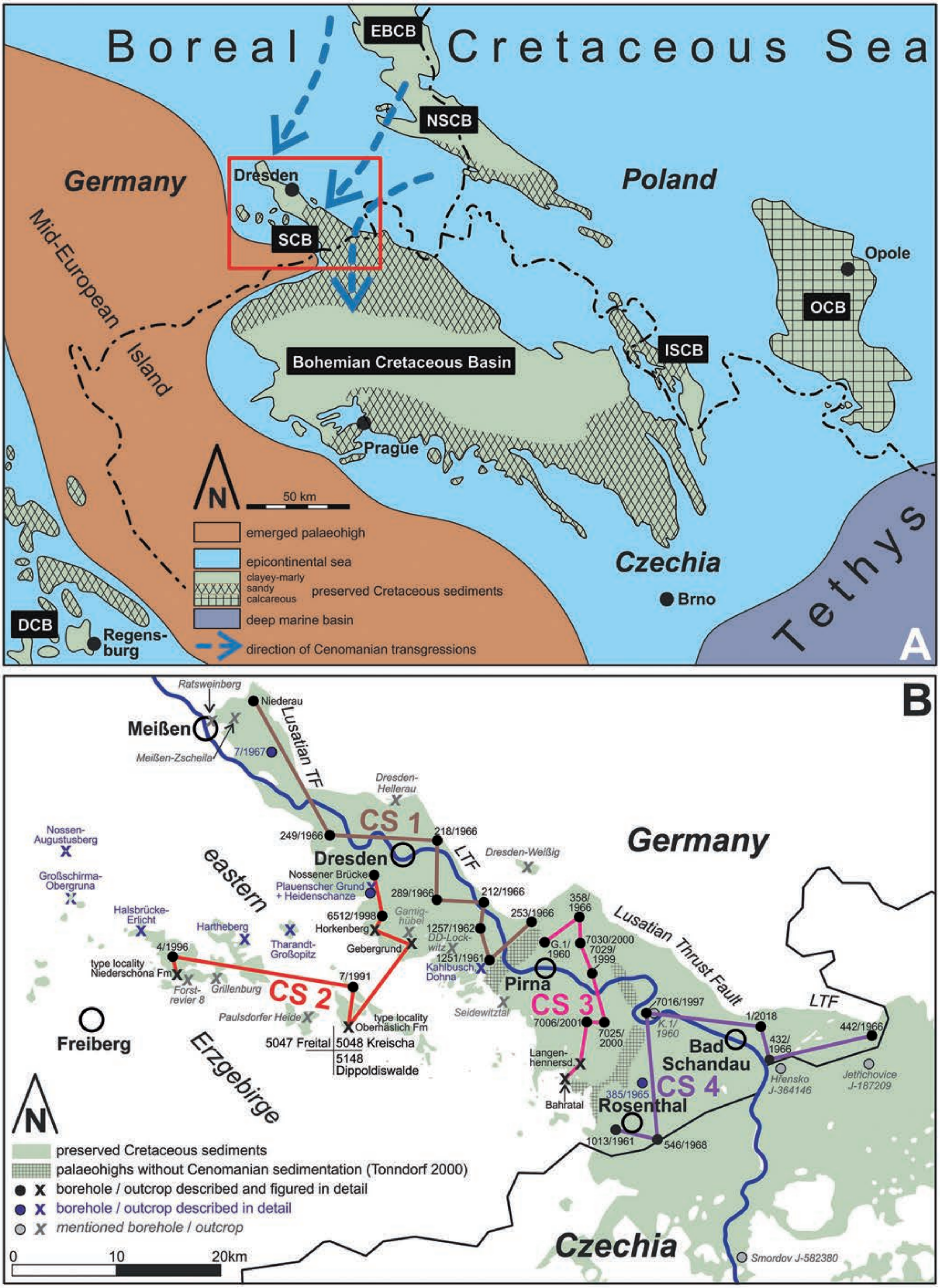
1. Introduction

The Cretaceous strata of the Elbtal Group in Saxony (eastern Germany), Cenomanian to early Coniacian in age, are an apparently very well-studied regional geological unit that has been investigated in terms of its palaeontology, stratigraphy and sedimentology for almost two centuries. In particular, the transgression history of the early Late Cretaceous is a long-debated geological issue in the entire Western and Central Europe, including Saxony (e.g. Suess 1875; Bärtling 1920; Schander 1923; Prescher 1957; Hancock & Kauffman 1979; Hancock 1989; Robaszynski et al. 1998; Wilmsen 2003; Wilmsen & Niebuhr 2010). In a nutshell, the geoscientific research of the late 20th and early 21st century boiled down to the perceived consensus that the early Late Cretaceous transgression in Saxony proceeded from the northwest, first reaching in the Early Cenomanian the Meißen area (Meißen Formation; Prescher & Tröger 1989). In the Middle Cenomanian, progressing costal onlap with a terrestrial source from the west and north was allegedly documented by the fluvial Niederschöna Formation only (Voigt 2009), and marine onlap continued in the Late Cenomanian with the *naviculare* and *plenus* transgressions, respectively (e.g. Voigt 1994; Tröger 2003; Voigt et al. 2006). Some authors even assigned the deposition of the Niederschöna Formation to the *naviculare* Transgression (Voigt 1994, 1997, 1998).

However, some important new findings such as the presence of hitherto unknown offshore marine Middle Cenomanian strata in the northwestern outcrop area of the Elbtal Group (Wilmsen et al. 2019a) or the widespread presence of Middle Cenomanian ammonites in the Oberhäslich Formation (an allegedly Upper Cenomanian unit; Wilmsen et al. 2022) recently casted considerable doubts on the traditional views on the stratigraphic subdivision and the transgression history of the Elbtal Group that are deeply entrenched in the literature. Consequently, Wilmsen et al. (2019a) partly rewrote the transgression history for the northwestern area of the Elbtal Group (Meißen–Niederau area), re-dating the Meißen Formation as Middle Cenomanian, extending the range of the marine marlstones of the Mobschatz Formation to the same substage, and leaving the Klippensandstein as the only (informal) Lower Cenomanian member of the Elbtal Group. However, the lack of Middle Cenomanian sandy nearshore facies and the disjunct stratigraphic placement of the allegedly Middle Cenomanian Niederschöna Formation without any link to the marine part of the basin remained unsolved problems. An impetus to the still due solution of the considerable stratigraphic issues was presented by Wilmsen et al. (2022) who demonstrated that the lower part of the Oberhäslich Formation, hitherto thought to exclusively represent the lower Upper Cenomanian, contains a Middle Cenomanian member, well-dated by its ammonite faunas, and that the underlying Niederschöna Formation is older, i.e. of Early Cenomanian age, as already suggested by Krutzsch (1963, 1966), at least in the sections on the eastern Erzgebirge.

The aim of the present paper is, thus, to expand the stratigraphic revision to all Cenomanian strata of the Elbtal Group from the northwesternmost part of the outcrop belt through the Dresden area and the eastern Erzgebirge into the Saxonian Switzerland to the German-Czech border in order to understand stratigraphic patterns, palaeogeographic evolution and the transgression history. Based on the detailed logging and correlation of numerous new and already known outcrop and core sections as well as on the reassessment of comprehensive core data provided by the Saxon State Geological Survey (LfULG), we present a complete stratigraphic reappraisal of the lower Elbtal Group herein. The new integrated stratigraphic framework is based on detailed macrofossil biostratigraphic data (partially new) and important palynological data, published already in the 1960th and fallen into oblivion, as well as on sequence stratigraphy and stratigraphic events.

Fig. 1: (**A**) Simplified palaeogeographic situation at the southwestern and northeastern margin of the Bohemian Massif without existence of the West and East Sudetic islands at the end of the Cenomanian. Red: study area; epicontinental subbasins: DCB – Danubian, SCB – Saxonian, EBCB – East Brandenburg, NSCB – North Sudetic, ISCB – Intra-Sudetic and OCB – Opole Cretaceous Basin. (**B**) Distribution of preserved Cretaceous strata (light green) in Saxony and northwestern Bohemia (Czechia), following the course of the Elbe River. Cross-sections 1–4 of this paper, measured drillings and outcrops are marked.


Boreal Cretaceous Sea
EBCB
NSCB
Germany
Poland
Dresden
SCB
Opole
OCB
Mid-European Island
ISCB
Bohemian Cretaceous Basin
Prague
50 km
N
emerged palaeohigh
epicontinental sea
clayey-marly
sandy
calcareous
preserved Cretaceous sediments
deep marine basin
direction of Cenomanian transgressions
Czechia
Brno
Tethys
DCB
Regens-burg
A
B
Ratsweinberg
Niederau
Meißen
Meißen-Zscheila
7/1967
Lusatian TF
Dresden-Hellerau
CS 1
249/1966
218/1966
Dresden
LTF
Dresden-Weißig
Germany
Nossen-Augustusberg
Großschirma-Obergruna
eastern
Nossener Brücke
Plauenscher Grund + Heidenschanze
289/1966
212/1966
Halsbrücke-Erlicht
Hartheberg
6512/1998
Gamig-hübel
253/1966
358/1966
Lusatian Thrust Fault
Tharandt-Großopitz
Horkenberg
1257/1962
DD-Lockwitz
G.1/1960
7030/2000
7029/1999
4/1996
Gebergrund
1251/1961
type locality Niederschöna Fm
Kahlbusch Dohna
Pirna
7/1991
Forst-revier 8
Grillenburg
CS 2
CS 3
Seidewitztal
7016/1997
LTF
1/2018
K.1/1960
Paulsdorfer Heide
type locality Oberhäslich Fm
7006/2001
7025/2000
442/1966
432/1966
Freiberg
5047 Freital
5048 Kreischa
5148 Dippoldiswalde
Bad Schandau
Erzgebirge
Langen-hennersd.
Hřensko J-364146
Jetřichovice J-187209
385/1965
CS 4
Bahratal
Rosenthal
N
1013/1961
546/1968
preserved Cretaceous sediments
palaeohighs without Cenomanian sedimentation (Tonndorf 2000)
borehole / outcrop described and figured in detail
borehole / outcrop described in detail
mentioned borehole / outcrop
Czechia
Smordov J-582380
0
10
20km

2. Geological framework

2.1 Palaeogeographic setting

The Cretaceous strata of Saxony form a NW–SE-elongated outcrop belt along the Elbe River valley from the city of Meißen in the northwest to Bad Schandau (and beyond) in the southeast (Fig. 1). According to the revision presented herein, marine strata chronostratigraphically range from the lower Lower Cenomanian into the Middle Coniacian while continental sediments were deposited in early Early to early Late Cenomanian times (see also Krutzsch 1963, 1966; Wilmsen et al. 2019a, 2022; Niebuhr et al. 2020 for important data pertaining to this revision). In the Turonian–Early Coniacian, rather coarse-grained siliciclastic shallow-water sedimentation prevailed towards the southeast in what is today the Saxonian Switzerland (the Elbsandsteingebirge), while offshore-marine marly-calcareous sedimentation of the Meißen–Dresden Subgroup (Wilmsen et al. 2019a) predominated in the northwest; in between, a zone of interfingering offshore and nearshore lithofacies, the so-called facies transition zone (e.g. Seifert 1955), was located in the Pirna area (Figs. 1A, B, 15). This general lithofacies variability reflects the principal palaeogeographic setting and the grain sized-graded facies zonation of the Saxonian Cretaceous Basin (SCB) during the Turonian (e.g. Petrascheck 1900; Beeger 1963; Voigt 1999). Palaeogeographically, the SCB represents a southeastwards narrowing passage between the Bohemian Massif as part of the large Mid-European Island in the southwest and the small West-Sudetic Island in the northeast. Towards the northwest, the SCB gradually opened into the extensive northern German shelf sea (e.g. Wilmsen & Niebuhr 2014) that forms part of the Boreal Realm.

2.2 Litho- and biostratigraphy

The lithostratigraphic units of the Saxonian Cretaceous were combined in the Elbtal Group by Voigt & Tröger (in Niebuhr et al. 2007). To a very large extent, strata of the Elbtal Group rest unconformably on Neoproterozoic to Palaeozoic crystalline and metasedimentary rocks as well as on lower Permian (Rotliegend) volcanic and sedimentary deposits (see Pälchen & Walter 2008 for geological overview). The macrobiostratigraphic subdivision of the marine part of the Elbtal Group is based on inoceramid bivalves and ammonites while belemnites are of subordinate importance. The lithostratigraphic scheme of the Cenomanian is strongly modified herein, especially with respect to the fluvial and brackish Niederschöna Formation and the sandstone-dominated, shallow-marine Oberhäslich Formation (Fig. 2).

The fluvial to brackish Niederschöna Formation was deposited in palaeovalleys (e.g. Schander 1923; Prescher 1957) and cannot be dated using the classical index (macro-)fossils. However, at three localities, including the type locality in Halsbrücke-Niederschöna, Krutzsch (1959, 1963, 1966) classified the microfloral content from fluvial sediments of the formation as lower Peruc palynoassemblage of Early Cenomanian age ("unteres Perucer Bild", exclusively freshwater pollen and spores, without representatives of the advanced Normapolles group). In Bohemia, Czechia, first representatives of the Normapolles group, e.g. *Complexiopollis*, and therefore, the upper Peruc palynoassemblage, appear just above the base of the Middle Cenomanian in the "Upper claystone of the Peruc Formation" (cf. Pacltová 1971, 1977, 1978; Uličný et al. 2009a; Špičáková et al. 2014; see Fig. 2). Nevertheless, the Niederschöna Formation has been assigned to the Middle and/or lower Upper Cenomanian in many subsequent publications (e.g. Voigt 1994, 1997, 1998, 2009; Voigt & Tröger 1996; Tröger & Voigt in Niebuhr et al. 2007; Janetschke & Wilmsen 2014). Predominantly consisting of fluvial strata with local conglomerates at the base (historical "Grundschotter" and plant-rich "Crednerienschichten", e.g. Schander 1923), the Niederschöna Formation contains a conspicuous brackish-estuarine unit in the Pirna–Königstein area, the so-called Wurmsandstein (Tonndorf 2000; Janetschke & Wilmsen 2014; Wilmsen & Niebuhr 2014). Furthermore, recent re-dating of lithostratigraphic units in the northwestern outcrop belt of the Elbtal Group based on macro- and nannofossil biostratigraphy as well as carbon stable isotopes demonstrated that the oldest marine strata of the Niederau area, the Klippensandstein Member of the Oberhäslich Formation (with the ammonite *Schloenbachia varians*; see Fig. 2), is also of Early Cenomanian age (Wilmsen et al. 2019a) while the Meißen Formation (Red Conglomerate with the index ammonite *Turrilites costatus*), formerly assigned to the Early Cenomanian (Prescher & Tröger 1989), is now known to be of Middle Cenomanian age (Wilmsen & Nagm 2014; Wilmsen et al. 2019a; see Fig. 2). These latter authors also demonstrated that the Mobschatz Formation (marlstones and Pläner [planar bedded silty marlstones to marly siltstones, see Fig. 3C]), hitherto thought of as representing the marly-glauconitic offshore equivalent of the sandstones of the lower Upper Cenomanian Oberhäslich Formation, ranges down to the lower Middle Cenomanian *primus* Event, including the first appearance of *Inoceramus atlanticus* (*Tu. costatus* Subzone of the lower *Acanthoceras rhotomagense* Zone; Wilmsen et al. 2019a) in the northwestern part of the SCB (see Fig. 2).

This observation raised the question of a potential contemporaneous Middle Cenomanian sandy nearshore equivalent, conforming to the general lithofacies zonation of the Elbtal Group as demonstrated for the Turonian (cf. Petrascheck 1900; Beeger 1963; Voigt 1999; Wilmsen & Niebuhr 2014; Niebuhr et al. 2020). Recently, a re-evaluation of the ammonite faunas from the lower part of the Oberhäslich Formation overlying the fluvial Lower Cenomanian Niederschöna Formation on the eastern Erzgebirge showed that it also contains different Middle Cenomanian taxa of the *Acanthoceras rhotomagense* and *Ac. jukesbrownei* zones, including both zonal index ammonites (Wilmsen et al. 2022). Thus, the Oberhäslich Formation in this area, the historical "Unterquader" of Geinitz (1871–1875), consists of two distinct members, Middle and early Late Cenomanian in age (Merbitz and Werksandstein Member). Further biostratigraphic sup-

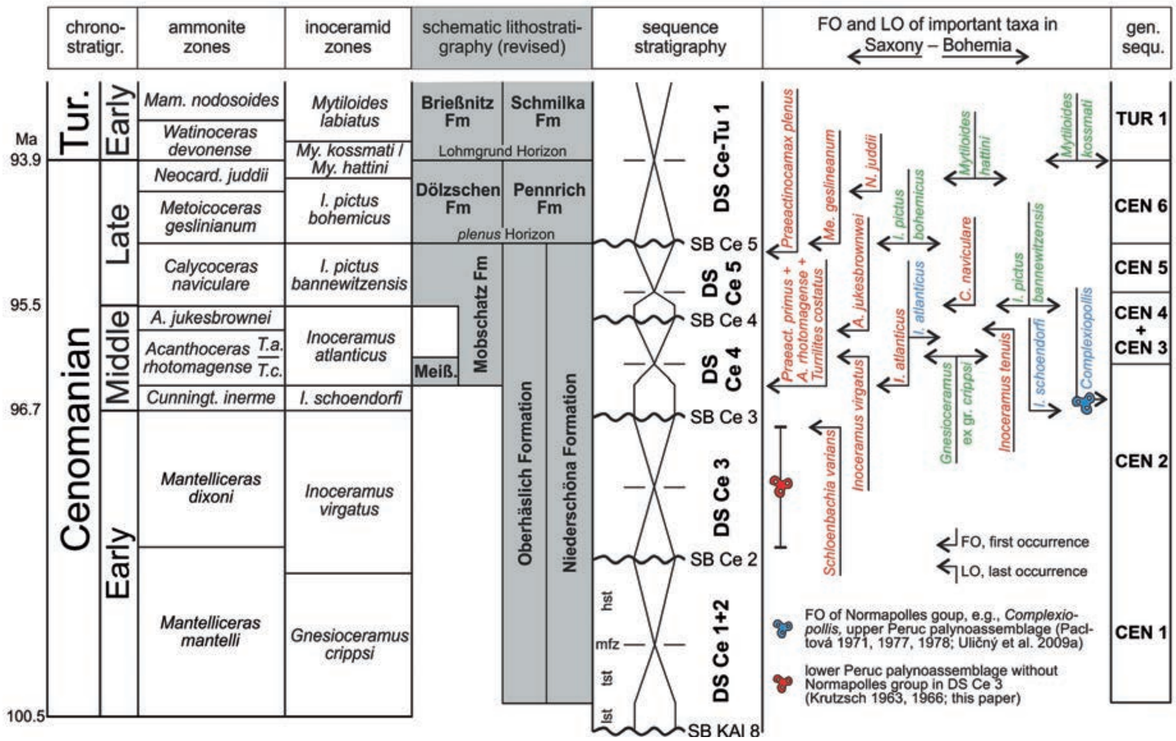


Fig. 2: Chrono-, bio-, schematic litho- and sequence stratigraphic framework. Revised biostratigraphic data are based on FO and LO of important taxa proven in the Saxony (in red, according to Geinitz 1840, 1871–1875; Tröger 1976; Wilmsen & Nagm 2013, 2014; Tröger & Niebuhr 2014; Wilmsen et a. 2019a, 2022; this paper: Fig. 3H); Bohemia (in blue), according to Uličný et al. (2009a: Fig. 9) and Špičáková et al. (2014: Fig. 3) or in both Cretaceous basins (in green). Note the difference in the first appearances of *I. atlanticus* between Saxony and Bohemia. Schematic lithostratigraphy revised in this paper; Meiß. – Meißen Formation. Sequence stratigraphy modified according to Wilmsen (2003), Haq (2014) and Janetschke & Wilmsen (2014); genetic sequences in Bohemia after Uličný et al. (2009a: app. 1, D1, borehole Hřensko J-364146). Timescale (Ma) after Gale et al. (2020).

port for the Middle Cenomanian is provided by findings of *Inoceramus tenuis* in the lower part of the Mobschatz Formation at Niederau (Dietze 1959; section 1 of this paper) and the Merbitz Member of the core 2-26/1995 in Dresden-Coschütz (section 13; see Figs. 2, 3H, 10). It must be noted that, due to the fact that the historical "Unterquader" was mistakenly regarded exclusively as lower Upper Cenomanian by previous authors, Tröger (1967, 2014) placed all Saxonian inoceramids of the lower parts of both the marly Mobschatz Formation and the sandy Oberhäslich Formation of the eastern Erzgebirge in the Late Cenomanian *Inoceramus pictus* group. Thus, systematic revisions are required in order to disentangle this taxonomic muddle. However, rich lower Upper Cenomanian (*Ca. naviculare* zonal) inoceramid bivalve and ammonite faunas are in fact present (Tröger 1967, 1969, 2014; Wilmsen & Nagm 2013, 2014; Tröger & Niebuhr 2014; Wilmsen 2017), but have been collected from the upper fine-grained and homogenous Werksandstein Member that has, in contrast to the underlying Merbitz Member, widely been quarried as freestone (Niebuhr et al. 2021), explaining the conspicuous biostratigraphic bias. Rare finds of the belemnite *Praeactinocamax* are known from the uppermost metres of the Werksandstein Member at Bannewitz (Geinitz 1840; Tröger 1976; near sections 15 and 16, see Figs. 2, 10).

For the overlying predominantly calcareous Dölzschen Formation (historical "Plänermergel"; e.g. Geinitz 1839, 1871–1875) and siliciclastic Pennrich Formation (historical "Plänersandsteine"; e.g. Geinitz 1839, 1871–1875), late Late Cenomanian ages (*Me. geslinianum* and *Ne. juddii* zones) are proved based on integrated ammonite, belemnite, inoceramid, calcareous nannofossil and carbon stable isotope records (e.g. Häntzschel 1933; Uhlig 1941; Tröger 1956, 2014; Voigt et al. 2006; Wilmsen & Nagm 2013, 2014; Tröger & Niebuhr 2014; Wilmsen 2014; Wilmsen et al. 2019a; see Fig. 2). Their deposition reflects a major sea-level rise (i.e. the *plenus* Transgression of authors) that finally compensated the pre-transgression topography in Saxony, terminating in the earliest Turonian maximum flooding event characterised by the Lohmgrund Horizon, a fine-grained marker bed that can be traced across different formations (Niebuhr et al. 2020). Following this transgressive maximum, a grain-size graded shelf was established during Early Turonian times, with marly-calcareous offshore deposits (Brießnitz Formation) grading into shallow-marine siliciclastic sediments (Schmilka Formation) in the southeast (e.g. Beeger 1963; Voigt 1999; Janetschke & Wilmsen 2014; see Fig. 2).

2.3 Sequence stratigraphy

The subdivision of the Cenomanian stage by means of five sequence boundaries (SB Ce 1–5) into depositional sequences (DS Ce 1–Ce-Tu 1) is well established (Robaszynski et al. 1998; Wilmsen 2003; Haq 2014). Depositional sequence DS Ce 1+2 (commonly starting with lowermost Cenomanian transgressive deposits above the uppermost Albian SB KAl 8 of Haq 2014; e.g. Bornemann et al. 2017) and DS Ce 3 are of Early Cenomanian age, forming two depositional cycles of almost equal duration. DS Ce 4 is largely a Middle Cenomanian sequence while DS Ce 5 corresponds to the early Late Cenomanian. DS Ce-Tu 1 started in the mid-Late Cenomanian, straddled the Cenomanian–Turonian boundary and was terminated at the latest Early Turonian SB Tu 1 (see Figs. 2, 15). This subdivision has been applied to the Elbtal Group by Janetschke & Wilmsen (2014), erroneously placing the Meißen Formation in the Early and the Niederschöna Formation in the Middle Cenomanian, and was further elaborated by Wilmsen et al. (2019a). The latter authors demonstrated the presence of marine strata of depositional sequence DS Ce 3 for the northwestern part of the Saxonian Cretaceous Basin (Klippensandstein; cf. Schander 1923), re-dated the Meißen Formation and the lower part of the Mobschatz Formation as Middle Cenomanian, following the *primus* Transgression, and combined these marine strata with the Niederschöna Formation in DS Ce 4. A first attempt to calibrate the depositional sequences identified in Saxony to the genetic sequential framework of the Bohemian Cretaceous Basin (BCB; cf. Uličný et al. 2009a) was presented by Janetschke & Wilmsen (2014). This approach as been further developed by Niebuhr et al. (2020) based on the successions around Zittau (northern BCB) who correlated the genetic sequences CEN 1–CEN 6 into the Elbtal Group (Fig. 2). However, all these sequence stratigraphic approaches were limited by the still insufficient knowledge on the bio- and lithostratigraphy of the lower Elbtal Group.

3. Material and methods

The studied stratigraphic sections (numerous outcrops and cored boreholes, 39 sites in total) have been logged in bed-by-bed in great detail or are based on the stratigraphic re-interpretation of Wismut core logs that have been produced in the 1960s. In this time, the former SDAG Wismut (today Wismut GmbH) carried out a detailed prospection on uranium in Cenomanian strata of the Elbtal Group (see Tonndorf 2000 for overview). The logs, which were produced contemporaneously to the drilling by means of descriptions of the fresh cores, are deposited as so-called "kolonkas" and have no individual authors. Core material of the first drilling campaign is, unfortunately, no longer available in most cases, and preliminary results were published by Decker (1963). In our paper, information from 14 carefully selected Wismut kolonkas, referred to as "boreholes" (in contrast to the "cores" of which the core section was available for our own investigations), is included, providing crucial stratigraphic information for the compilation of the four cross-sections presented below. In the years 1996–2004, the surroundings of the uranium deposit Königstein was hydrogeologically re-investigated and several new cores were drilled that are still available, some of which were measured in detail (e.g. Tröger et al. 1998; Neumann 2004; Janetschke & Wilmsen 2014; Melchisedech 2021). Furthermore, some exploration drillings without any relationship to the Königstein mine with preserved cores are available (e.g. Voigt 1998; Tröger 2008; Wilmsen et al. 2019a; Wilmsen & Bansal 2021). Ultimately, it was the integration of all data available to us obtained from both the 14 Wismut kolonkas as well as from the detailed personal evaluation and logging of 25 outcrops and core sections that finally created the comprehensive dataset necessary to reconstruct the stratigraphic architecture of the Cenomanian deposits of the Elbtal Group presented herein (see four cross-sections CS 1–4). All sections are shown as standardised grain-size logs and are calibrated to topographical height above (ASL) or below sea level (BSL). The datum line in all cross-sections is the mid-Late Cenomanian unconformity SB Ce 5, a marker horizon already demonstrated in the sandstone quarries of the eastern Erzgebirge (Pietzsch 1914; Niebuhr et al. 2021) and the boreholes of the Pirna Palaeovalley (Tonndorf 2000).

The pre-Cretaceous rocks that form the substrate of the studied sedimentary succession are predominantly Neoproterozoic to Palaeozoic crystalline rocks of the Lusatian and Meißen massifs and the eastern Erzgebirge as well as Palaeozoic metasediments of the Elbtalschiefergebirge and the Nossen-Wilsdruffer Schiefergebirge (together forming the basement), and lower Permian (Rotliegend) volcanic and sedimentary deposits of the Tharandt Caldera and the Döhlen Basin (see Pälchen & Walter 2008 for an overview). In core and outcrop sections the affinity of the substrate has been specified wherever possible; however, the pre-Cretaceous rocks have not always been specifically addressed in the Wismut kolonkas so that in these cases the lithological nature of the substrate has to be left open or is given in quotation marks (see description and cross-sections).

During logging, standard sedimentary field methods have been applied (e.g. Stow 2005; Tucker 2011). Grain size and components were first analysed by hand-lens; thin-sections have been prepared from selected rock samples with a Logitech preparation line including a GTS-1 thin-section saw and a LP50 lapping and polishing jig equipped with a PLJ7 lapping jig. Thin-sections were studied using a Leica M125 stereo-microscope. The thin-sections and fossil specimens collected from the stratigraphic sections are stored in the palaeozoological collection of the Senckenberg Naturhistorische Sammlungen Dresden, Museum für Mineralogie und Geologie (SNSD-MMG). The Wismut kolonkas studied herein are archived by the Sächsisches Landesamt für Umwelt, Landwirtschaft und Geologie (LfULG). The core sections are housed in the core archives of the LfULG in Freiberg and the SNSD. Furthermore, material from the geological collection of the TU Bergakademie Freiberg (TUB) was studied.

The sequence stratigraphic analysis applied herein focuses on the identification of 3rd-order sequence-bounding unconformities that define corresponding depositional sequences (cf. Posamentier & Vail 1988; Posamentier et al. 1988; Vail et al. 1991). Depositional sequences (DS) in shallow shelf settings such as represented by the Elbtal Group commonly consist of retro- and progradational facies units, i.e. transgressive and highstand systems tracts (TST, HST) only; lowstand deposits (LST) are mostly missing or only subordinately developed due to the lack of accommodation during falling and low sea-level stands. Consequently, sequence boundaries (SB) indicate substantial erosional and/or non-depositional phases (stratigraphic gaps). Maximum flooding periods are represented by thin stratigraphic intervals reflecting the most distal facies development within a depositional sequence rather than by a distinct maximum flooding surface. The Cenomanian sequence and sequence boundary nomenclature follows Wilmsen (2003; see also synopsis in Janetschke et al. 2015) with only one exception: the early Early Cenomanian sequences DS Ce 1 and DS Ce 2, both *Mantelliceras mantelli* Zone in age, are combined in one depositional sequence, i.e. DS Ce 1+2 (Figs. 2, 9–15). For sequence stratigraphic terminology and procedure, we refer to Catuneanu et al. (2011). The fluvial deposits of the Niederschöna Formation are likewise named according the depositional sequences in which they have been deposited (fluvial cycles 1+2, 3, 4 and 5 of DS 1+2 to DS Ce 5).

4. Results – The stratigraphic sections

Four cross-sections were constructed from six to eight subsurface and/or outcrop sections each. For this, a total of twelve Wismut kolonkas were chosen and are figured herein for the first time, supplemented by twelve core sections. The Cenomanian parts of eight cores have already been published (pars Voigt 1998; Tröger 2008; Janetschke & Wilmsen 2014; Wilmsen et al. 2019a; Melchisedech 2021; Wilmsen & Bansal 2021), but some were re-measured and/or reinterpreted for this investigation (Wilmsen & Niebuhr 01/2018, 06/2021, 03/2022), and are illustrated for the first time; from three cores, the existing data (Tröger et al. 1998; Neumann 2004) were calibrated to the detailed photo-documentation of the LfULG (Niebuhr 02/2022), likewise firstly displayed herein. Furthermore, the stratigraphic logs of six (partly well-known, partly new) outcrops are included, two of which were measured and illustrated for the first time (Niebuhr & Wilmsen 03/2022; Wilmsen & Niebuhr 03/2022). In total, 39 stratigraphic sites with Cenomanian strata were detailed of which 30 were used for the cross-sections. Localities 2, 9, 12, 13, 19, 20, 23, 24 and 35 are not displayed in the cross-sections due to lack of certain essential information, e.g. thicknesses of lithounits, or precise descriptions of the successions were missing. However, the stratigraphic and palaeogeographic information provided by these sections is important, too; thus, they have been included in the descriptive part of the present work. The position of all sections can be found in Fig. 1B. In order to facilitate the understanding of the correlation within the cross-sections and the sequence stratigraphic subdivision in the discussion, sequence boundaries and corresponding depositional sequences are already mentioned in the following descriptions (where appropriate).

4.1 Elbe Valley between Meißen and Pirna; stratigraphic sections 1–10 (CS 1; Fig. 9 from left to right)

(1) Niederau, composite section

TK 25: 4847 Coswig; core Niederau-Gröbern 2/1991, zone 5: R 5398860/H 5674660; Niederau-Oberau railway slope cut, zone 5: R 5397757/H 5674338

This northwesternmost Cretaceous succession was figured, described in detail and stratigraphically calibrated using an integrated approach by Wilmsen et al. (2019a; see also Schander 1923 and Dietze 1961). At 109 m ASL, Cretaceous strata overlie the Palaeozoic basement (a syenite of the Meißen Massif). The oldest Cretaceous deposit is the wedge-shaped upper Lower Cenomanian Klippensandstein Member of the lower Oberhäslich Formation, a well-sorted, fine-grained sandstone with numerous, in part silicified shells. Its thickness is unknown. The 1–3-m-thick lower Middle Cenomanian Oberau Conglomerate of the basal Mobschatz Formation, representing the *primus* Event (Wilmsen et al. 2019a), overlies both the basement rocks of the Meißen Massif and the Klippensandstein Member unconformably, and consists of angular to subrounded basement pebbles and cobbles in a strongly glauconitic sandy-marly matrix. Up-section, initially strongly glauconitic Pläner of the lower Mobschatz Formation follow (Middle Cenomanian, ca. 12.5 m thick). Biostratigraphic support for the Middle Cenomanian age of the lower part are given by calcareous nannofossils and *Inoceramus atlanticus* in the Oberau Conglomerate (Wilmsen et al. 2019a; *I. pictus bohemicus* of Dietze 1959 and Tröger 2014) as well as by the occurrence of *Inoceramus tenuis* (of Dietze 1959; *I. pictus pictus* of Tröger 2014) and *Gnesioceramus* ex gr. *crippsi* (*Inoceramus crippsi* of Dietze 1959; *I. pictus pictus* of Tröger 2014). In the upper part of the Mobschatz Formation (lower Upper Cenomanian), ca. 7-m-thick argillaceous Pläner with planktic foraminifers and lower Upper Cenomanian ammonites predominate (Wilmsen & Nagm 2014; Wilmsen et al. 2019a). The lithostratigraphic boundary to the up-section following 19-m-thick upper Upper Cenomanian Dölzschen Formation, an intercalation of calcareous and more argillaceous Pläner deposits, is difficult to draw and was placed at a thin shell bed at 159 m ASL, the bed of which corresponds to SB Ce 5; support for this subdivision is provided by carbon isotopes and nannofossil occurrences (Wilmsen et al. 2019a) as well as from recent finds of late Late Cenomanian ammonites (*Metoicoceras geslinianum* and *Euomphaloceras septemseriatum*) from this interval in the Niederau-Oberau railway slope cut and EUGAL gas pipeline trench sections (SNSD-MMG collections). At 178 m ASL the monotonous marlstones of the upper part of the Dölzschen Formation pass into the dark Lohmgrund Horizon at the base of the following Lower Turonian Brießnitz Formation.

(2) Borehole Nord-Coswig 7/1967
TK 25: 4847 Coswig; zone 5: R 5400486/H 5668095 (not shown in the cross-section).

The borehole was drilled and first described by the Wismut, later noted by Tonndorf (2000). At 19 m ASL, Cretaceous strata overlie a granitoid of the Meißen Massif. The lowermost 1.5 m consists of a coarse-grained, brownish-red calcareous sandstone with kaolinised feldspar and glauconite; the following 1-m-thick glauconitic-sandy conglomerate with calcareous cement is greenish-grey in colour. Both clastic units belong to the Oberau Conglomerate of the basal Mobschatz Formation and are followed by marls in the lower and strongly cemented Pläner with calcareous nodules in the upper part (Middle to lower Upper Cenomanian). At 36 m ASL, a 3-m-thick glauconitic marl appears interpreted here as belonging to the *plenus* Horizon at the base of the Dölzschen Formation (upper Upper Cenomanian) overlain by a 3-m-thick, strongly cemented, light-grey Pläner. This lithologic succession resembles that of the "lower (a) part" of the boreholes Waldschule Dresden 218/1966, Dresden-Zschertnitz 289/1966 and Nossener Brücke (sections 4, 5 and 11; see below and Figs. 9 and 10). Above 42 m ASL, the succession is composed of monotonous marls and Pläner and a separation between Cenomanian (Dölzschen Formation) and Turonian strata (Brießnitz Formation) without biostratigraphic data is impossible. To address this problem, the marly Meißen–Dresden Subgroup was introduced by Wilmsen et al. (2019a).

(3) Borehole Dresden-Merbitz 249/1966
TK 25: 4947 Wilsdruff; zone 5: R 5404815/H 5660331

The borehole was drilled and first described by the Wismut, redescribed by Tröger (in Alexowsky et al. 2001), first illustrated and reinterpreted herein. At 177 m ASL, Cretaceous strata rest on sedimentary rocks of the Döhlen Basin (Rotliegend). The Niederschöna Formation consists of a lower 2.8-m-thick fluvial fining-upward cycle with medium-grained sandstones grading into dark-grey carbonaceous claystones at the top, rich in plant debris, overlain by a 1.4-m-thick brownish fine- to medium-grained sandstone. This fluvial succession is interpreted as upper Lower Cenomanian DS Ce 3. The Merbitz Member of the Oberhäslich Formation rests with a sharp base on the Niederschöna Formation (SB Ce 3) and represents DS Ce 4. It consists of a 2-m-thick medium- to coarse-grained greensand with an intercalated thin conglomeratic layer and a 2.3-m-thick, grey-coloured, fine-grained sandstone bed yielding Middle Cenomanian ammonites in the nearby former outcrop Zschonergrund (Wilmsen et al. 2022). Up-section, the clayey-calcareous, 12-m-thick upper part of the Mobschatz Formation and the lower part of the Dölzschen Formation (marlstones and Pläner above 199 m ASL) follow, respectively. They are separated by a marly-argillaceous bed interpreted as *plenus* Horizon, the base of which represents SB Ce 5.

(4) Borehole Waldschule Dresden 218/1966
TK 25: 4948 Dresden; zone 5: R 5415587/H 5660705

The borehole was drilled and first described by the Wismut, redescribed by Tröger (in Alexowsky et al. 2001), and is reinterpreted and figured for the first time herein. At 306 m BSL the Oberhäslich Formation rests on the Palaeozoic basement ("Granit"). The 18-m-thick Merbitz Member (Middle Cenomanian) is characterised by a fine-grained, partly argillaceous sandstone with a few thin medium- to coarse grained layers, calcareous-cemented and rich in fossils. The 11-m-thick calcareous-cemented Werksandstein Member (lower Upper Cenomanian) is rich in glauconite throughout the section, the lower 3.5 m consisting of argillaceous fine-grained greensands with intercalated thin medium-grained layers, the upper part of a massive argillaceous medium-grained greensand. The 20-m-thick Dölzschen Formation above 276 m BSL starts with a marly clay (*plenus* Horizon with SB Ce 5 at its base), followed by argillaceous Pläner and Pläner with calcareous nodules. A dark conspicuous argillaceous layer above 256 m BSL represents the Lohmgrund Horizon at the base of the Lower Turonian Brießnitz Formation.

(5) Borehole Dresden-Zschertnitz 289/1966
TK 25: 4948 Dresden; zone 5: R 5412840/H 5654829

The borehole was drilled and has been first described by the Wismut, later redescribed by Tröger (in Alexowsky et al. 2001). It is illustrated for the first herein, but our stratigraphic interpretation differs strongly from the former evaluations. At 1 m ASL, Cretaceous strata rest on the Palaeozoic basement ("Rotlehm-Verwitterung, Granit"). The Niederschöna Formation consists of a 1.7-m-thick coarse-grained to conglomeratic quartz sandstone, followed by a 0.6-m-thick dark claystone, representing a truncated upper Lower Cenomanian fluvial cycle 3, capped by SB Ce 3. The Oberhäslich Formation has a thickness of 33 m, the top surface (SB Ce 5) being located at 36 m ASL. The 13-m-thick Merbitz Member (Middle Cenomanian) is in its major part represented by a fining-upward cycle grading from a basal conglomerate via coarse- and medium-grained quartz sandstones with several thin clay layers to fine-grained quartz sandstones; towards the top of the member, a slight coarsening trend is accompanied by a weak glauconite content and oyster occurrences. The 20-m-thick early Late Cenomanian Werksandstein Member is a monotonous fine- to medium-grained, well sorted quartz sandstones, likewise with a weak glauconite content towards the top. The 14-m-thick Dölzschen Formation starts at 36 m ASL with a 2-m-thick calcareous claystone (*plenus* Horizon), its base representing SB Ce 5. The following 4-m-thick calcareous Pläner are overlain by an 8-m-thick interval of argillaceous Pläner. At 50 m ASL, the Lower Turonian Brießnitz Formation starts, likewise with Pläner deposits, bearing pyrite concretions at its base.

(6) Borehole Dresden-Hosterwitz 212/1966
TK 25: 4949 Dresden-Ost; zone 5: R 5420066/H 5654181; Heidenau Palaeovalley

The borehole was drilled and briefly described by the Wismut and is first illustrated and reinterpreted here. At 199 m BSL, Cretaceous strata overlie Palaeozoic metasediments ("Tonschiefer"). The Niederschöna Formation consists of the 7.5-m-thick fluvial cycle 3, reflecting the non-marine onlap of DS Ce 3 (upper Lower Cenomanian). The lower part shows brownish to grey, medium- to coarse-grained sandstones with thin intercalated conglomeratic layers. In-between, a thin carbonaceous claystone is intercalated. Indeterminate plant remains occur, partly vertical in live position. In the upper half a siltstone is followed by a coarse-grained horizon and terminated by a next coaly claystone. The Oberhäslich Formation (Merbitz and Werksandstein members, Middle to lower Upper Cenomanian) is represented by a 31-m-thick grey, argillaceous fine-grained sandstone with weak glauconite content, fossil debris, bivalves (*Rhynchostreon suborbiculatum*) and the ichnofossil *Ophiomorpha saxonica*. The boundary between the two members and, thus, SB Ce 4 could not be located unequivocally. At the top of the Oberhäslich Formation, a medium-grained, less silicified greensand occurs, its top surface being located at 162 m BSL (SB Ce 5). Up-section, a 1-m-thick siltstone bed (*plenus* Horizon) follows, its base marking the base of the 9-m-thick sandy and glauconitic Pennrich Formation. The 1.5-m-thick dark marlstone above 153 m ASL represents the Lohmgrund Horizon at the base of the Lower Turonian Brießnitz Formation. Up-section, typical Pläner deposits follow.

(7) Borehole Dresden-Großzschachwitz 1257/1962
TK 25: 5049 Pirna; zone 5: R 5419320/H 5652097; Heidenau Palaeovalley

The borehole, drilled and initially described by the Wismut, is illustrated for the first time and reinterpreted herein. At 90 m BSL, the Cretaceous strata rest on the Palaeozoic basement ("Biotitgranit"). The Niederschöna Formation is similar to the succession in borehole Dresden-Hosterwitz 212/1966 and consists of an 11-m-thick fluvial fining-upward cycle 3 (upper Lower Cenomanian). It consists of a 3.5-m-thick basal conglomerate followed by an alternation of medium- to coarse-grained sandstones with thin clay horizons grading into a 3-m-thick carbonaceous silt- to fine-grained sandstone, overlain by a 1.5-m-thick claystone rich in plant debris. The 15-m-thick Merbitz Member of the Oberhäslich Formation (Middle Cenomanian) is represented by argillaceous fine-grained sandstones with common oysters (*Rhynchostreon suborbiculatum*). Above 64 m BSL, the fine-grained sandstones of the 12-m-thick Werksandstein Member (lower Upper Cenomanian) contain some glauconite, the content of which increases towards the top at 52 m BSL (SB Ce 5). The 8-m-thick Pennrich Formation (upper Upper Cenomanian) consists of dark argillaceous siltstones and fine-grained glauconitic sandstones. The Pläner of the Lower Turonian Brießnitz Formation above 44 m BSL bear calcareous nodules at the base.

(8) Borehole Meuschaer Höhe 1251/1961, Dohna
TK 25: 5049 Pirna; zone 5: R 5419356/H 5649048

Drilled and first described by the Wismut, the borehole is reinterpreted here and figured for the first time. At 91 m ASL, Cretaceous strata rest on the Palaeozoic basement ("Granit"). The lower 8 m belong to the fluvial Niederschöna Formation, the lower half consisting of a quartz conglomerate, the upper half of coarse-grained sandstones alternating with dark grey carbonaceous clays. Based on its position directly below the lower Upper Cenomanian Werksandstein Member of the Oberhäslich Formation, this fluvial cycle 4 is of Middle Cenomanian age. The Werksandstein Member is 5.8 m in thickness, consisting of a quartz conglomerate fining-upward in a dark grey argillaceous sandstone, capped at 110 m ASL by SB Ce 5. Up-section, the Dölzschen Formation starts with a dark grey argillaceous bed (*plenus* Horizon), at the base yielding isolated quartz granules. The overlying fossil-rich Pläner is weakly glauconitic in its lowest part. The boundary to the Lower Turonian Pläner of the Brießnitz Formation has not been exposed in the borehole.

(9) Abandoned quarry Kahlbusch in Dohna
TK 25: 5049 Pirna; zone 5: R 5420415/H 5647195 (not shown in the cross-section).

The Kahlbusch in Dohna exposes the fossil-rich rocky shore facies of the Dölzschen Formation with the index belemnite *Praeactinocamax plenus* (*plenus* Transgression of DS Ce-Tu 1, late Late Cenomanian). In the former Rotliegend rhyolite quarry, several up to 6-m-deep surf pockets are exposed in a topographic height between ca. 170–190 m ASL (Petrascheck 1900; Beeger & Quellmalz 1965), filled with well-rounded rhyolite pebbles and cobbles in a fossiliferous sandy-calcareous matrix. Higher-up at the eastern quarry margin between ca. 190–205 m ASL, additional depressions have been observed, filled with siliceous sponge-rich marls and Pläner, likewise assigned to the Dölzschen Formation (Voigt 1994). However, the Early Turonian index fossils from the locality preserved in marly Pläner lithology, hosted in the Heimatmuseum Dohna, suggest that the final drowning of the Kahlbusch Island dates into the earliest Turonian.

(10) Borehole Pirna-Großgraupa 253/1966
TK 25: 4949 Dresden-Ost; zone 5: R 5424243/H 5652519

The borehole, drilled and described by the Wismut, is firstly figured and reinterpreted herein. At 207 m BSL, the Oberhäslich Formation overlies the Palaeozoic basement. The succession is similar to that of the borehole 1257/1962 in Dresden-Großzschachwitz; oysters (*Rhynchostreon suborbiculatum*) and *Ophiomorpha* burrows appear in abundance throughout the section. The non-glauconitic, 15-m-thick Merbitz Member (Middle Cenomanian) is dominated by coarse-grained sandstones intercalated by medium-grained sandstones with fossil debris in the lower third while fine-grained sandstones predominate the upper two thirds. The fine-grained, glauconitic Werksandstein Member, early Late Cenomanian in age, has a thickness of 11 m, unconformably capped by SB Ce 5 at 180 m BSL. The up-section following upper Upper Cenomanian Dölzschen Formation starts with the argillaceous *plenus* Horizon that yields, at its base, glauconitic sandstone clasts derived from the underlying Werksandstein Member and is overlain by a grey, 1-m-thick fine-grained sandstone bed. Above, the formation is dominated by Pläner deposits. The boundary to the Lower Turonian Pläner of the Brießnitz Formation is placed at

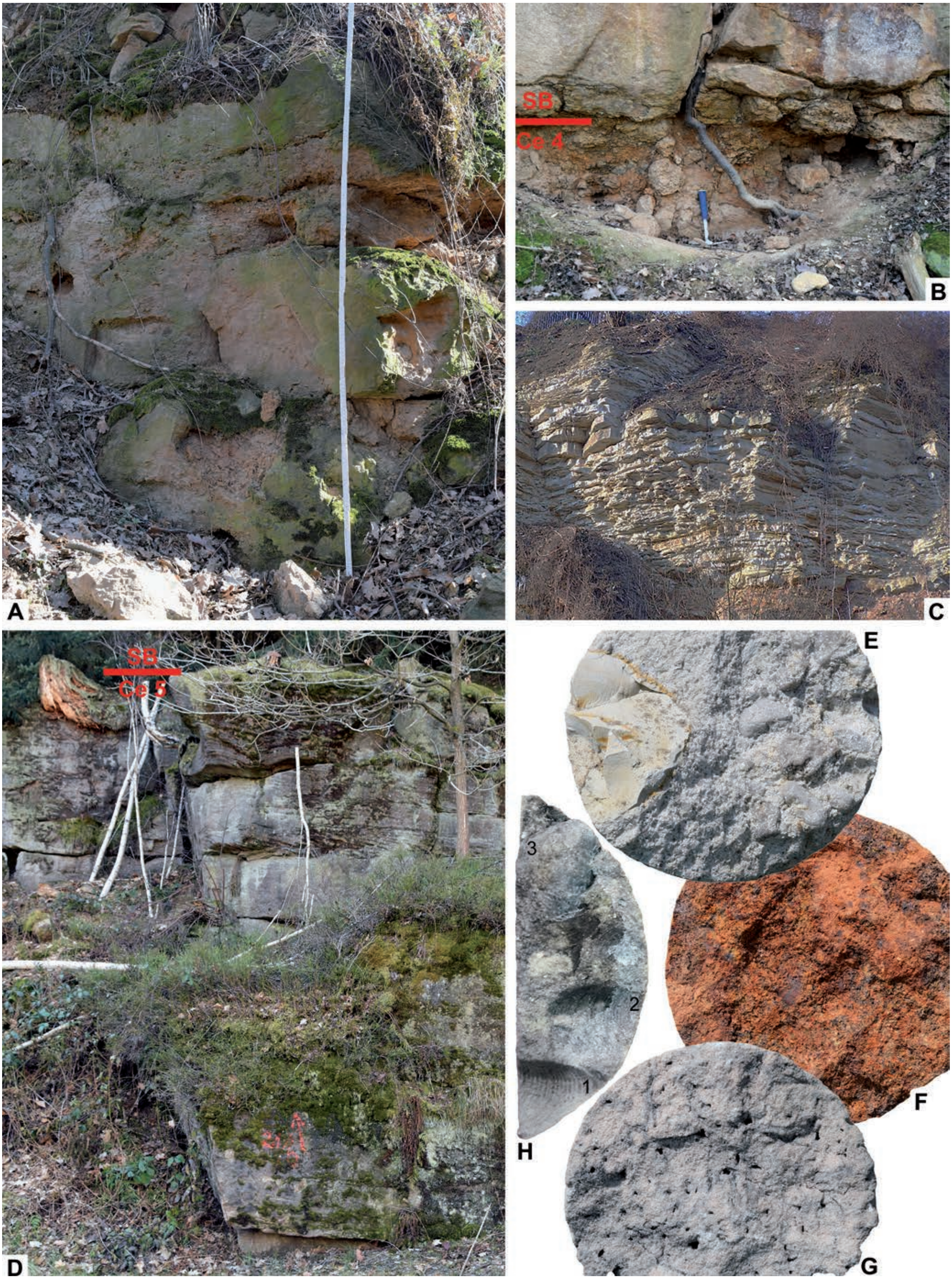

SB
Ce 4
B
A
C
SB
Ce 5
E
3
2
1
H
F
D
G

Fig. 3: Outcrop and core photographs. (**A**, **B)** Oberhäslich Formation (Middle to lower Upper Cenomanian) in the outcrop Gebergrund south of Bannewitz-Goppeln, cross-section 2. (**A**) Merbitz Member, consisting of rubbly, medium-bedded oyster shell beds; height of section 1.8 m. (**B**)Sequence boundary SB Ce 4 between the oyster beds of the Merbitz Member and the bioturbated sandstones of the Werksandstein Member, the sequence boundary is marked by an orange-brown mottled argillaceous horizon indicating pedogenic overprint; see hammer for scale. (**C**) Onlap of Pläner of the Dölzschen Formation (upper Upper Cenomanian) from north (right) to south (left) onto the Carboniferous monzonite of the Meißen Massif, type locality, Ratssteinbruch in Dresden-Dölzschen; height of the section ca. 7 m; re-figured from Lehr (2022: Fig. 11). (**D**) Werksandstein Member of the Oberhäslich Formation (lower Upper Cenomanian) in the composite Bahratal section, cross-section 3; uppermost ca. 6 m of the medium- to coarse-grained, cross-bedded sandstones, terminated by sequence boundary SB Ce 5. (**E–G**) core Niederschöna 4/1996, cross-section 2; core diameter 100 mm, bedding surfaces. (**E**) Large isolated quartz pebbles and a rimmed kaolinitic clast in a texturally immature, coarse-grained sandstone matrix, fluvial cycle 1+2 of the Niederschöna Formation (DS Ce 1+2); 39.8 m core depth. (**F**) Irregularly mottled pedogenic iron crust in a medium-grained sandstone with large isolated quartz grains, top of the Merbitz Member of the Oberhäslich Formation at sequence boundary SB Ce 4; 15.6 m core depth. (**G**) Root horizon in a fine- to medium-grained sandstone, upper part of the fluvial cycle 3 (DS Ce 3) of the Niederschöna Formation; 21.8 m core depth. (**H**) Core Heidenschanze 2-26/1995 (see Fig. 4A); core diameter 100 mm, bedding surface of a dark brown arkosic sandstone with three small inoceramids (probably *Inoceramus tenuis*), upper part of the Merbitz Member of the Oberhäslich Formation (DS Ce 4, upper Middle Cenomanian); 10.8 m core depth.

167 m BSL at the base of a poorly cemented, 1–1.5-m-thick argillaceous interval, interpreted as the Lohmgrund Horizon.

4.2 Erosion remnants of southern Dresden to the eastern Erzgebirge; stratigraphic sections 11–24 (CS 2; Fig. 10 from right to left)

(11) Core Nossener Brücke, Dresden-Löbtau
TK 25: 4948 Dresden; zone 5: ca. R 5410050/H 5656570

This succession was illustrated and described in considerable detail by Wilmsen & Bansal (2021). At 49 m ASL, Cretaceous strata overlie a Carboniferous monzonite of the Meißen Massif. The lower part of the succession belongs to the 8-m-thick upper part of the Mobschatz Formation (lower Upper Cenomanian). The lowermost 2 m consist of strongly glauconitic conglomerates and sandstones containing numerous *Macaronichnus* burrows which gradationally pass into glauconitic and non-glauconitic marls and Pläner. At 57 m ASL, the tripartite 20-m-thick upper Upper Cenomanian Dölzschen Formation (upper Upper Cenomanian) starts with its basal argillaceous *plenus* Horizon, followed by nodular Pläner deposits in the lower (a) part of the section. 6.5 m above, an argillaceous, weakly glauconitic layer occurs and calcareous nodules begin to disappear. Up-section, the monotonous marlstones of the middle (b) and upper (c) parts of the Dölzschen Formation follow, passing into the lowermost Turonian Lohmgrund Horizon of the Brießnitz Formation (base at 77 m ASL).

(12) Cretaceous localities of the Plauenscher Grund, SW Dresden (Fig. 3C)
TK 25: 4948 Dresden; zone 5: R 5409189/H 5655080 (Hoher Stein, Dresden-Plauen), R 5409224/H 5655016 (Teichbruch, Dresden-Plauen), R 5408834/H 5655326 (Ratssteinbruch, Dresden-Dölzschen), not shown in the cross-section.

The Hoher Stein on the eastern margin of the Vereinigte Weißeritz River in Dresden-Plauen at a topographic height of ca. 190 m ASL is the most famous locality of the Saxonian Cretaceous, first mentioned and illustrated by Geinitz (1871–1875: 11, fig. 2) and further detailed by Tröger (1956), Voigt et al. (1994), Voigt et al. (2006) and Niebuhr (2021). During the *plenus* Transgression of DS Ce-Tu 1 in the late Late Cenomanian, several up to 5 m deep and 3–5 m wide surf pockets were eroded into the Variscan basement (a Carboniferous monzonite of the Meißen Massif) that formed a local positive structure at that time (Plauen Island). The fossiliferous rocky shore facies of the Dölzschen Formation infilling the pockets yielded the index belemnite *Praeactinocamax plenus*. Laterally, on the contemporaneous abrasion platform, the nearby Teichbruch section shows siliceous sponge biostromes directly on the Carboniferous monzonite, overlain by siliceous Pläner of the Dölzschen Formation (Voigt et al. 1994; Voigt et al. 2006; Wilmsen & Niebuhr 2016).

Right across at the western slope of the Vereinigte Weißeritz in Dresden-Dölzschen, the Ratssteinbruch is located, a former quarry in which the Carboniferous monzonite was mined. The northern part of the quarry is the type locality of the Pläner of the Dölzschen Formation (Prescher 1981; Tröger et al. 2020; Lehr 2022; see Fig. 3C). Approaching from the north, Pläner with *Praeactinocamax plenus* onlap onto the monzonite of the Ratssteinbruch (Voigt et al. 2006), compensating for a palaeotopography of ca. 20 m, until they overlap the former Plauen Island from a topographic height of ca. 180 m ASL (Wilmsen & Niebuhr 2016; Wilmsen in Niebuhr 2021: 118, 119). In the southern part of the Ratssteinbruch, the Pläner of the Dölzschen Formation reach up to at least ca. 190 m ASL, yielding with *Metoicoceras geslinianum* and *Neocardioceras juddii* both index ammonites of the upper Upper Cenomanian. The Cretaceous marine onlap surface farther northwards, at the entry to the Bienertpark (ca. 140 m ASL) and at the former Floßrechen in the Vereinigte Weißeritz (ca. 135 m ASL), most likely correspond to the *primus* Transgression of the lower Mobschatz Formation (Middle Cenomanian).

(13) Abandoned sandstone quarry at the Heidenschanze and core 2-26/1995, Dresden-Coschütz (Fig. 4A)
TK 25: 4948 Dresden; zone 5: R 5408273/H 5654717 (sandstone quarry), ca. R 5408284/H 5654717 (core 2-26/1995); not shown in the cross-section.

The historical "Steinbruch von Kanner in Coschütz" (Nessig 1898: 116) was first mentioned by Cotta (1857) and figured by Geinitz (1871–1875: 10, fig. 1). At this site, the historical "Unterquader" (= Werksandstein Member of the Oberhäslich Formation) has been quarried as a local freestone, e.g. for buildings along the railway line Dresden–Tharandt (Geinitz 1871–1875). Albeit already Cotta (1857) explained that the famous "Koschützer Muschelfelsen" (Lehmann 1749), a shell-rich calcareous sandstone facies, correspond to a stratiform deposit below the Quadersandstein and not to a crevice filling in the basement, the geological discussion around the lower unit continued into the late 20th century when Walter & Suhr (1997) finally published sedimentological and stratigraphic data of the new core 2-26/1995, drilled ca. 10 m east of the quarry wall. They confirmed von Cotta's (1857) stratigraphic conclusion of the Koschützer Muschelfelsen below the historical "Unterquader" and we re-measured the core in August 2022 (Fig. 4A). In the core succession, at 202 m ASL Cretaceous strata overlie the Carboniferous monzonite of the Meißen Massif. The lower, 5.1-m-thick unit is developed in the conspicuous sandy-bioclastic facies of the Koschützer Muschelfelsen, a tempestitic unit composed of shells mainly of the bivalve *Glycymeris obsoleta* in a sandy matrix (Walter & Suhr 1997;

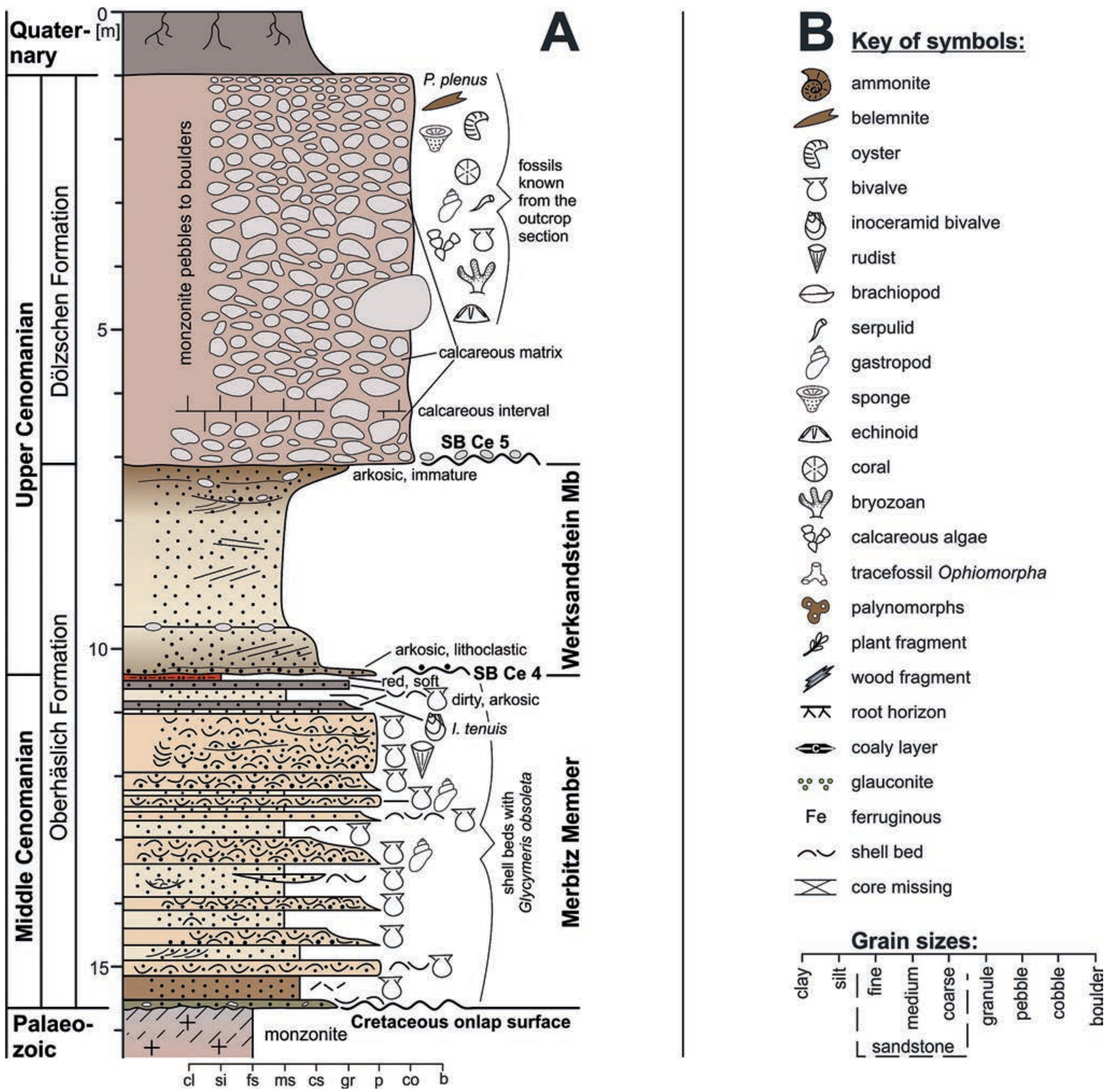


Fig. 4: (**A**) Detailed log of the core Heidenschanze 2-26/1995 (logging by Wilmsen & Niebuhr 08/2022). (**B**) Key to symbols and grain sizes.

Niebuhr et al. 2014: 113, fig. 6k; Wilmsen & Niebuhr 2016), intercalated by thinner medium-grained calcareous sandstone layers. This unit is interpreted here as belonging to the Merbitz Member of the Oberhäslich Formation (Middle Cenomanian). At the top of the Merbitz Member in the core 2-26/1995, at 207 m ASL, a dark brown arkosic sandstone layer was logged with three inoceramid specimens occurring at its top, probably belonging to *Inoceramus tenuis* (Fig. 3H). A thin, red-coloured, silty-argillaceous horizon above, almost completely squeezed out during drilling, marks sequence boundary SB Ce 4. The following 3.3–5.5-m-thick Werksandstein Member, late Early Cenomanian in age, consists of thick-bedded, medium-grained sandstone with a few conglomeratic layers, the number and thickness of which increasing to a nearby basement cliff (Voigt et al. 1994). The Dölzschen Formation unconformably rests on the Oberhäslich Formation at 210 m ASL (SB Ce 5), starting with a ca. 6-m-thick conglomerate consisting of well-rounded monzonite pebbles to boulders within a fossiliferous calcareous matrix, sharply overlain by silty marlstones and Pläner deposits. From the upper part of the conglomerate and the lower part of the Pläner exposed in the outcrop section, the index belemnite *Praeactinocamax plenus* is known (Voigt et al. 1994; Wilmsen & Niebuhr 2016).

(14) Core Mariaschacht 6512/1998, Bannewitz-Boderitz
TK 25: 4948 Dresden; zone 5: R 5409493/H 5652396

The Mariaschacht core succession, first figured and described by Wilmsen & Bansal (2021), exposes the 5.5-m-thick Oberhäslich Formation and the Pennrich Formation. At 257 m ASL, the Cretaceous onlap surface caps the lower Permian sedimentary rocks of the Döhlen Basin. The Oberhäslich Formation consists of a thin (1.2 m) Merbitz Member (Middle Cenomanian) comprising glauconitic sandstones with abundant large *Macaronichnus* burrows. The Werksandstein Member of late Late Cenomanian age starts with a coarse-grained sandstone that fines upwards into a thin siltstone while the upper part shows a coarsening-upward trend up to the capping SB Ce 5 at 258 m ASL. The argillaceous siltstone above (*plenus* Horizon) forms the lowermost part of the 12-m-thick upper Upper Cenomanian Pennrich Formation that consists of fossiliferous, fine- to medium-grained sandstones. It shows a subdivision into three coarsening-upward cycles (a–c parts), 5 m, 3.5 m and 3.5 m in thickness, the top of the middle (b) part marked by bioclasts and ferruginous staining. The dark mudstone bed starting at 270 m ASL belongs to the Lohmgrund Horizon of the overlying Lower Turonian siliciclastic Schmilka Formation.

(15) Abandoned sandstone quarry at the Horkenberg in Bannewitz
TK 25: 5048 Kreischa; zone 5: R 5408834/H 5651584

The succession at the Horkenberg near Bannewitz, also known as Prinzenhöhe, was early figured and described in detail by Beck (1890, 1892; with historical designations in quotation marks), and is reinterpreted herein. At 305 m ASL, the Oberhäslich Formation rests on Permian sedimentary rocks (Rotliegend of the Döhlen Basin). The 5-m-thick Merbitz Member (Middle Cenomanian) is represented by weakly silicified, yellow-brownish, fine-grained sandstones with an oyster bed ("Exogyrenbank", yielding *Rastellum carinatum* and *Rhynchostreon suborbiculatum*) in its upper part. It is worth noting that Middle Cenomanian ammonites were found in the Merbitz Member of the area (Wilmsen et al. 2022: figs. 6–9). The upper Upper Cenomanian Werksandstein Member, 6-m-thick, has been quarried as freestone for several centuries ("Werksteinbank" of Beck 1892: fig. 2) and consists of a fine-grained, massive quartz sandstones. The SNSD-MMG and TUB collections have a lot of fossils from the member, especially bivalves (*Rastellum carinatum*, *Rhynchostreon suborbiculatum*, *Spondylus striatus*, *Inoceramus* ex gr. *pictus* and *Neithea aequicostata*; e.g. Tröger 1967, 2014; Niebuhr et al. 2014). At Bannewitz-Welschhufe, 1.5 km to the west, the lower Upper Cenomanian index ammonite *Calycoceras naviculare* was found in this stratigraphic interval (Wilmsen & Nagm 2014). Above 316 m ASL, the Pennrich Formation starts with a 1.2–2.3-m-thick argillaceous siltstone (*plenus* Horizon) followed by an alternation of 0.5-m-thick, fine-grained sandstones separated by thin silty interbeds ("Plänersandsteine") in which the upper Upper Cenomanian index ammonite *Metoicoceras geslinianum* first appears (Wilmsen & Nagm 2014).

(16) Outcrop Gebergrund, Bannewitz-Goppeln (Figs. 3A, B)
TK 25: 5048 Kreischa; zone 5: R 5413025/H 5650608

The hitherto undescribed section was measured by the authors in 03/2022 in the upper reaches of a narrow valley cut by a small ephemeral creek discharging northwards into the Geberbach. At 242 m ASL, fine-grained sandstones of the Middle Cenomanian Merbitz Member of the Oberhäslich Formation are exposed, resting on Upper Palaeozoic (Rotliegend) strata of the Döhlen Basin that crop out slightly below. The succession shows a coarsening-upward trend into medium-grained brownish sandstones with oyster shell-beds and *Ophiomorpha* burrows that is terminated by an iron-stained erosion surface at 245 m ASL. The fabric of the sandstones below this surface is highly irregular and shows ferruginous mottling, suggesting a subaerial overprint by surface processes (redox alteration, pedogenic convolution); consequently, the surface is interpreted as a sequence boundary (cf. Kraus 1999) (SB Ce 4). A Middle Cenomanian ammonite from a nearby former quarry in Bannewitz-Golberode (Wilmsen et al. 2022: fig. 6A) unequivocally belongs into the stratigraphic interval below SB Ce 4, i.e. the Merbitz Member. Above the sequence boundary, the succession fines upwards into bioturbated, fine-grained grey-beige sandstones of the Werksandstein Member of the upper Oberhäslich Formation (lower Upper Cenomanian).

(17) Abandoned sandstone quarry Schmidt near Dippoldiswalde-Oberhäslich
TK 25: 5048 Kreischa; zone 5: R 5407006/H 5642605

"Schmidt's Steinbruch bei Dippoldiswalde" (Schalch 1887, 1888) is the type locality of the Oberhäslich Formation (Prescher 1981; Tröger & Voigt in Niebuhr et al. 2007). The

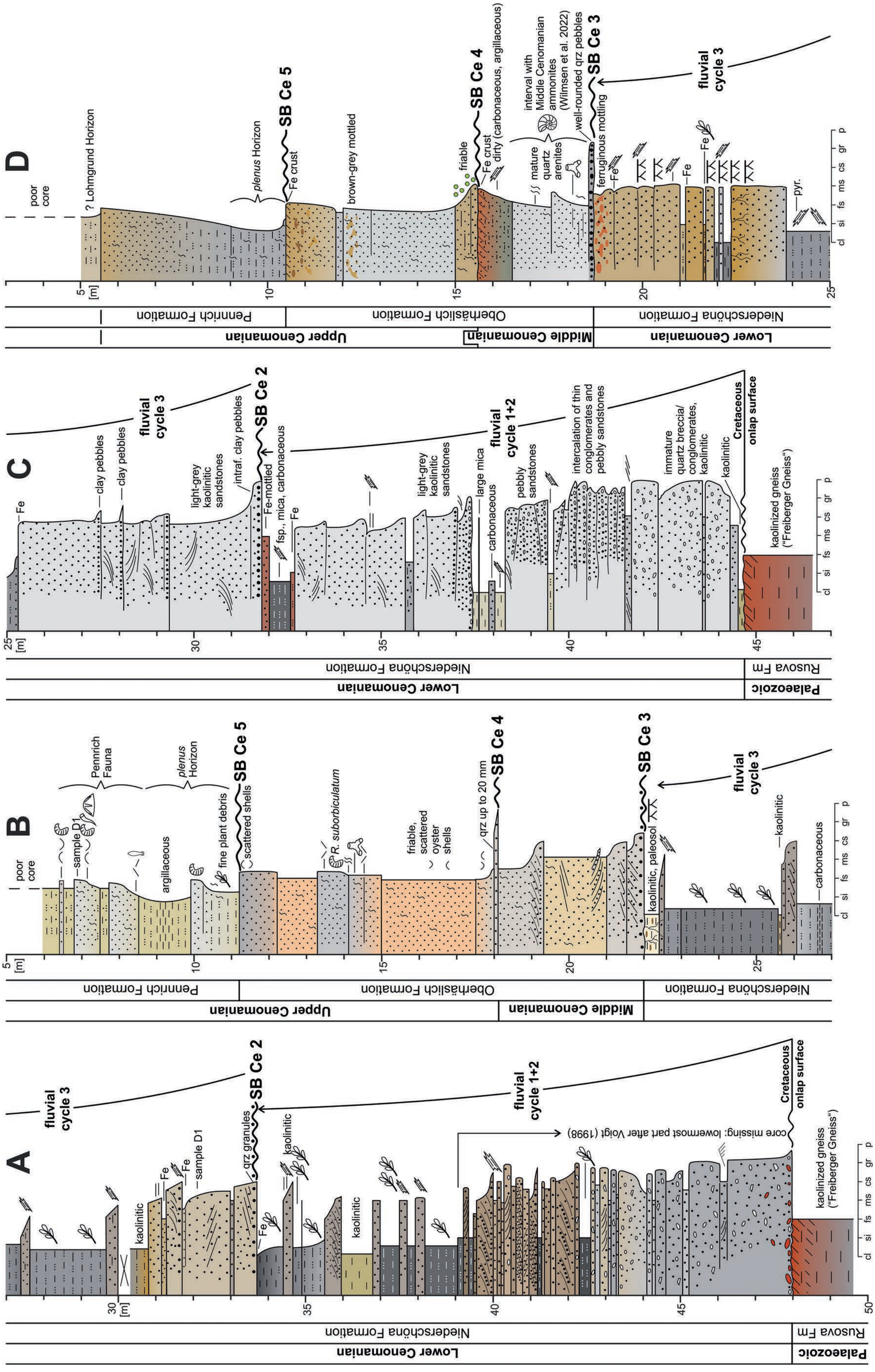


Fig. 5: Detailed logs of (**A, B**) the core Rabenau-Oelsa 7/1991 (logging by Wilmsen & Niebuhr 06/2021), and (**C, D**) the core Halsbrücke-Niederschöna 4/1996 (logging by Wilmsen & Niebuhr 03/2022). For key to symbols and grain sizes see Fig. 4B.

quarry section has been restored herein, based on the detailed description (with historical designations in quotation marks) by Schalch (1888: fig. 2). At 405 m ASL, the Oberhäslich Formation rests on the Palaeozoic basement ("Freiberger Gneis"), while only ca. 1 km to the north the Oberhäslich Formation transgressed on top of the fluvial cycle 3 of the Niederschöna Formation (see Alexowsky et al. 1999). The 5-m-thick Merbitz Member is represented by a coarse-grained sandstone with a conglomerate at the base ("Grundstein") followed by a 3-m-thick fine-grained sandstone which was the main freestone of this quarry ("Hauptbaustein"). Schalch (1888: 56) mentioned "*Acanthoceras* (*Ammonites*) *Mantelli*, Sow." from this quarry which probably corresponds to Middle Cenomanian *Calycoceras* (*Proeucalycoceras*) *picteti* (specimen no. RS 10617 in the LfULG collection). The lower Upper Cenomanian Werksandstein Member also starts with a conglomeratic layer ("Kieselschale"), the base of which corresponding to sequence boundary SB Ce 4. The following 1-m-thick, reddish, medium-grained sandstone bed was also used as a freestone ("Rotwilder"). Above a thin, coarse-grained sandstone bed, fossiliferous, light-grey to reddish, fine- and medium-grained sandstones predominate up to the top of the Oberhäslich Formation at 416 m ASL (SB Ce 5). The Pennrich Formation commences with fossiliferous, thin-bedded to platy fine-grained sandstones ("Plänersandsteine"). The SNSD-MMG and TUB collections contain a lot of fossils from this locality, such as sponges, bivalves, brachiopods, echinoids, serpulids, gastropods and several different bivalve species (Geinitz 1871–1875).

(18) Core Rabenau-Oelsa 7/1991 (Fig. 5A, B)
TK 25: 5048 Kreischa; zone 5: R 5407460/H 5646430

The Niederschöna Formation of this succession was first figured by Voigt (1998: fig. 14); the complete core was measured by the authors in 06/2021 and is presented here (Figs. 5A, B). At 305 m ASL, Cretaceous strata rest on the Palaeozoic basement ("Freiberger Gneiss"). The Niederschöna Formation is typically developed for the Tharandt Palaeovalley of the eastern Erzgebirge (Tonndorf 2000) and represented by two fluvial cycles that show an overall upwards-fining trend. The lower fluvial cycle 1+2 (corresponding to DS Ce 1+2) is 14 m in thickness and comprises light-grey coloured conglomerates and breccia at its base (historical "Grundschotter", 5.5-m-thick). The fining-upward trend above is continued by cross-bedded, coarse-grained, conglomeratic sandstones with abundant wood remains in the lower part and silty claystones rich in plant debris in the upper part (historical "Crednerienschichten"). In the 12-m-thick upper fluvial cycle 3 (corresponding to DS Ce 3), the overall fining-upward trend is repeated, but the lower part is less coarse and the plant debris-rich clay layers in the upper part reach several metres in thickness. The Niederschöna Formation is terminated by a kaolinitic, rooted palaeosol (SB Ce 3). The Oberhäslich Formation above is 11 m in thickness with a 4-m-thick Merbitz Member (Middle Cenomanian) and a 7-m-thick Werksandstein Member (lower Upper Cenomanian). The Merbitz Member is medium- to coarse-grained while the Werksandstein Member consists of massive, monotonous fine- to medium-grained quartz sandstones with several scattered oyster shells. Both members are separated by a thin conglomeratic layer consisting of well-rounded quartz granules and small pebbles; its base corresponds to SB Ce 4. The top of the Oberhäslich Formation (SB Ce 5) is placed at 342 m ASL. The Pennrich Formation above consists of 1–2-m-thick coarsening-upward cycles from siltstones to fine-grained sandstones and contains an argillaceous *plenus* Horizon in its lower part.

(19) Cretaceous around Tharandt-Großopitz
TK 25: 4947 Wilsdruff and 5047 Freital, zone 5: around R 5401285/H 5652405; not shown in the cross-section.

Around Tharandt-Großopitz, up to 10-m-thick Upper Cenomanian strata (ca. 355–365 m ASL) rest on Rotliegend sedimentary rocks of the Döhlen Basin. In the northern part, the condensed, only 2-m-thick, oyster-rich Werksandstein Member of the upper Oberhäslich Formation is developed while the following Pennrich Formation ("Plänersandsteine" of Sauer 1899, 1891; Dalmer & Beck 1893, 1894) in most cases directly transgresses across the Freiberg gneiss in that area. The Pennrich Formation consists of well-bedded, clayey siltstones rich in glauconite and bears abundant bivalves, serpulids and spines of the regular echinoid *Tylocidaris sorigneti*, a characteristic element of the Pennrich fauna (Sauer 1899, 1891; Häntzschel 1933; Tröger in Alexowski et al. 2005). Up-section, the 0.5-m-thick argillaceous Lohmgrund Horizon ("Thonbank" of Dalmer & Beck 1893, 1894) of earliest Turonian age and the lower part of the sandy Schmilka Formation ("Plänersandsteine der Labiatusstufe" of Dalmer & Beck 1893, 1894) follow.

(20) Abandoned sandstone quarries at the Hartheberg, west of Tharandt
TK 25: 5047 Freital, zone 5: around R 5397194/H 5650711; not shown in the cross-section.

In the Tharandt Forest, fluvial and marine Cenomanian strata overlie the Rotliegend rhyolite of the Tharandt Caldera. At the Hartheberg, between 358 and 375 m ASL, the Niederschöna Formation is developed (Sauer 1891; Pietzsch 1912; Schreiter 1927; Niebuhr et al. 2021) with a fluvial succession of Early Cenomanian age. Up-section, the ca. 20-m-thick Oberhäslich Formation follows (375–395 m ASL; Niebuhr et al. 2021; Merbitz and Werksandstein members, Middle to lower Upper Cenomanian). The best description of the marine succession is found in Schreiter (1927: 93, translated from German): "… we are at the foot of the abruptly falling, up to 20-m-high quarry walls. The massif of the Hartheberg is made of the Lower Quadersandstein with *Pecten asper*, *Ostrea carinata*, *Exogyra columba*, *Serpula* and so on in its lower part [= Oberhäslich Formation], which is overlain by Plänersandstein with *Cidaris Sorigneti* and others [= Pennrich Formation]", of which 3 m are still preserved today (Eberlein 2004).

Similar thicknesses of the Middle to lower Upper Cenomanian Oberhäslich Formation are developed in the Forstrevier 8 and Grillenburg sandstone quarries of the Tharandt

Forest (ca. 20 m; Niebuhr et al. 2021) as well as in the Paulsdorfer Heide, ca. 10 km to the east-southeast (18 m; Janetschke & Wilmsen 2014). The Lower Cenomanian fluvial cycles 1+2 and 3 of the Niederschöna Formation reach 17–25 m in thickness at the mentioned localities and are, thus, very similar compared to the situation in the cores Rabenau-Oelsa 7/1991 and Halsbrücke-Niederschöna 4/1995 (see below).

(21) Core Halsbrücke-Niederschöna 4/1996 (Figs. 3E–G, 5C, D)
TK 25: 5046 Freiberg; zone 4: R 4600795/H 5648734

In less detail, a log of the succession of core Halsbrücke-Niederschöna 4/1996 was presented by Tröger (2008: fig. 4.4-5, I). We carefully re-measured the core section in 03/2022 and provide a detailed log with revised stratigraphic interpretation herein (Figs. 5A, B). At 359 m ASL, a thin yellow-beige kaolinite layer overlies the Palaeozoic basement ("Freiberger Gneiss"). Such as in the core Rabenau-Oelsa 7/1991, the Niederschöna Formation of the Tharandt Palaeovalley at Halsbrücke-Niederschöna consists of two thick fluvial cycles, each of which ca. 13 m in thickness. The lower fluvial cycle 1+2 comprises a ca. 7-m-thick, light-grey coloured succession of conglomerates and coarse-grained pebbly sandstones at its base, followed by light-grey, cross-bedded, medium- to coarse-grained sandstones (Fig. 3F). It is capped by a dark-grey, silty claystone with plant debris and terminated by a ferruginous, mottled paleosol (SB Ce 2). The upper fluvial cycle 3 consists of cross-bedded, coarse-grained, grey sandstones with thin conglomerate beds in the lower part (6.5 m), a central, 1.5-m-thick, dark-grey, plant-debris bearing silty claystone and an upper unit of medium- to thick-bedded, brownish, commonly rooted sandstones with abundant plant-debris and wood remains (5.5 m; Fig. 3G). This unit undoubtedly forms the lower part of the succession exposed in the nearby former sandstone quarry at the Forsthaus in Halsbrücke-Niederschöna (see below). It is capped by a sandstone bed with irregular ferruginous mottling suggesting redox alteration and possibly a pedogenic overprint (SB Ce 3). The Oberhäslich Formation starts with a thin quartz conglomerate overlain by bioturbated, light-grey, mature, fine- to medium-grained quartz sandstones of the ca. 3-m-thick Merbitz Member of Middle Cenomanian in age. The upper metre of the member shows a coarsening-upward trend and increasing ferruginous staining culminating into a terminal iron crust (SB Ce 4; Fig. 3F). The overlying lower Upper Cenomanian Werksandstein Member consists of medium-grained, dark reddish-brown glauconitic sandstones in its lower part and above of fine-grained, friable, bioturbated brownish sandstones. At 393 m ASL, an iron crust and sharp facies change to fine-grained sediments (Pennrich Formation) marks the top of the Oberhäslich Formation and the position of SB Ce 5. The Pennrich Formation starts with grey argillaceous siltstones (1.5-m-thick *plenus* Horizon) grading into fine-grained, bioturbated sandstones above.

(22) Abandoned sandstone quarry at the Forsthaus in Halsbrücke-Niederschöna (Fig. 6)
TK 25: 5046 Freiberg; zone 5: R 4601142/H 5648444

The former sandstone quarry at the Forsthaus in Halsbrücke-Niederschöna is the type locality of the Niederschöna Formation (Prescher 1981; Tröger & Voigt in Niebuhr et al. 2007). Together with several adjacent small quarries it provides an outcrop transect of the uppermost Niederschöna and lowermost Oberhäslich formations (Fig. 6). The section of the sandstone quarry was displayed and described by Sauer (1899, 1900: fig. 1) and, for example, Kleditzsch (1987), Voigt (1998) and Eberlein (2004: fig. 5.36a), the latter presenting an instructive photograph of the ca. 8 m high outcrop wall. The lower 5.5 m of the section belongs to the upper part of the fluvial cycle 3 of the Niederschöna Formation (upper Lower Cenomanian; cf. section 21, core Halsbrücke-Niederschöna 4/1996; Figs. 5C, D). The predominately medium-grained sandstones pinch-out to the east within the limits of the outcrop (Fig. 6); the three uppermost sandstone beds contain root horizons with vertical, closely spaced, 0.5 m deep and 2–5 mm thin, clay-filled tubes probably representing roots of a reed-like plant (e.g. Voigt 1998: fig. 15). Thin, silty and carbonaceous claystones with the famous plant fossils are intercalated (e.g. see Ettingshausen 1867). Krutzsch (1959, 1966) described an Early Cenomanian freshwater microfloral association from these clayey intercalations which consists of primitive longaxona while all modern angiosperm pollen with short axes, e.g. of the Normapolles group, are completely missing. At 384 m ASL, a thin transgressive conglomerate bed marks the base of the Merbitz Member of the Oberhäslich Formation of which only the lower 3 m are preserved. The marine fine- to medium-grained sandstones yielded Middle Cenomanian *Acanthoceras rhotomagense* and *Calycoceras* (*Proeucalycoceras*) *picteti* (Wilmsen et al. 2022: figs. 2, 10–12).

(23) Outcrops around Halsbrücke-Erlicht (between Halsbrücke-Niederschöna in the south and Reinsberg-Dittmannsdorf in the north)
TK 25: 5046 Freiberg; zone 4: between R 4599570/H 5650130 and R 4600883/H 5651945 (excavation of OPAL pipeline), zone 4 R 4600357/H 5850212 (sandstone quarry in Halsbrücke-Erlicht), not shown in the cross-section.

From Halsbrücke-Oberschaar in the southwest and the Dittmannsdorf creek in the northeast, excavations for the OPAL pipeline in 2011 temporarily exposed Cretaceous strata. In the southwest, the succession starts with the fluvial Niederschöna Formation while in the northeast marine sandstones of the Oberhäslich and Pennrich formations rest directly on the Palaeozoic basement. The Niederschöna Formation (upper Lower Cenomanian) is represented by coarse-grained pebbly sandstones with conglomerate lenses ("Grundschotter" of Tröger 2017: fig. 4B), comprising the fluvial cycle of DS Ce 3. The following Merbitz Member of the Oberhäslich Formation ("fluvial Niederschöna Formation up-section of the Grundschotter" of Tröger 2017: fig. 4C) consists of fine-grained, silty, micaceous, grey to reddish-coloured sandstones which are partly cross-bedded –

Fig. 6: Upper Lower Cenomanian fluvial cycle 3 (DS Ce 3) at the type locality of the Niederschöna Formation (sandstone quarry at the Forsthaus in Halsbrücke-Niederschöna), at sequence boundary SB Ce 3 (red arrow) overlain by the Merbitz Member of the Oberhäslich Formation (Middle Cenomanian, DS Ce 4). Note pinching-out of sandstone bodies to the east (right) within the limits of the outcrop. Section ca. 8 m in height. Historical photograph of Walter Möbius (1929); Deutsche Fotothek, df_hauptkatalog_0006912, SLUB Dresden.

comprising the same lithology as in the core Halsbrücke-Niederschöna 4/1996 and the sandstone quarry at the Forsthaus in Halsbrücke-Niederschöna (see Figs. 5C–D, 10) from where Wilmsen et al. (2022) described Middle Cenomanian ammonites. Correspondingly, the Middle Cenomanian ammonite *Calycoceras* (*Newboldiceras*) *asiaticum asiaticum*, found in white-grey fine-grained sandstones of the Oberhäslich Formation near Halsbrücke-Erlicht (Wilmsen et al. 2022: fig. 13), most likely derives from a former sandstone quarry in the Merbitz Member of the Oberhäslich Formation immediately northwest of Halsbrücke-Erlicht (see Sauer 1886). The lower Upper Cenomanian Werksandstein Member is a fine- to medium-grained sandstone with layers of argillaceous and sandy siltstones, grey to white-grey in colour ("upper part of the Niederschöna Formation" of Tröger 2017: 140, fig. 4D). The Pennrich Formation above 371 m ASL (upper Upper Cenomanian) starts with a basal greensand ("Mobschatz Formation" of Tröger 2017: fig. 4D), followed by argillaceous to silty, fine-grained sandstones, so-called "Plänersandsteine" (Sauer 1886, 1887).

In addition to the find of a Middle Cenomanian ammonite in sandstones erroneously assigned to the "fluvial Niederschöna Formation" (Tröger 2017), our stratigraphic interpretation of the area is also supported by the early mapping surveys: Sauer (1886) mapped the fluvial Niederschöna Formation as the lowermost Cretaceous unit, overlain by a bipartite "Unterquader" of Geinitz (1871–1875) (c1= Middle and lower Upper Cenomanian Merbitz and Werksandstein members of the Oberhäslich Formation) and the "Unterer glaukonitischer Plänersandstein" as the topmost Cenomanian unit (c2, upper Upper Cenomanian Pennrich Formation of the modern lithostratigraphic terminology). Lithological units of both areas were assigned to the "Mobschatz Formation" by Tröger (2017: fig. 3) but were originally (and correctly) mapped as c2 (= Pennrich Formation) by Sauer (1886).

(24) Cenomanian remnants between Nossen and Großschirma

TK 25: 4945 Roßwein; Nossen-Augustusberg, zone 4: R 4590795/H 5657175; Großschirma-Obergruna; zone 4: R 4591726/H 5654419, not shown in the cross-section.

The area between Nossen and Großschirma exposes the westernmost remnants of marine Cenomanian deposits (see Fig. 1B). In this region, the Pennrich Formation rests transgressively on the Palaeozoic metasedimentary basement (Nossen-Wilsdruffer Schiefergebirge). At Nossen-Augustusberg, 5-m-thick, medium- to coarse-grained glauconitites (more glauconite than quartz grains) were exposed, fining-upward to the top and questionably assigned to the *plenus* Zone by Tröger (1969); at Großschirma-Obergruna, glauconitic silty clays were temporarily visible of which 4–5 m are preserved (Elicki et al. 2020). This lithology is similar to that of the Pennrich Formation between Halsbrücke-Niederschöna and Reinsberg-Dittmannsdorf (see "c2, unterer glaukonitischer Plänersandstein" of Sauer 1886; "Mobschatz Formation" of Tröger 2017; section 23 of this paper). Both upper Upper Cenomanian deposits between Nossen and Großschirma bear marine microfossils (foraminifera, sponge spicules, ostracods and vertebrate debris; Elicki et al. 2020).

4.3 Pirna Palaeovalley; stratigraphic sections 25–32 (CS 3; Fig. 11 from left to right)

(25) Core Pirna-Neugraupa G.1/1960
TK 25: 5050 Bad Schandau; zone 5: R 5425053/H 5651283

The borehole was drilled and interpreted by the Wismut, described again by Tröger et al. (1963) as well as Tröger (in Alexowsky et al. 1997). The core was re-measured by the authors in 01/2018, illustrated and interpreted herein. The drill site is located at the edge of the Copitz Peninsula NW of Pirna-Graupa, a palaeohigh without deposition in Cenomanian times (Tonndorf 2000) which separates the western Heidenau Palaeovalley (this paper) from the eastern Pirna Palaeovalley (Tonndorf 2000). At 170 m BSL, Cretaceous strata with reduced thickness compared to the Pirna Palaeovalley sections (see below) overlie the Palaeozoic basement. The 5-m-thick Niederschöna Formation is represented by the brackish Wurmsandstein (cf. Tonndorf 2000), assigned here to DS Ce 4 (Middle Cenomanian). A carbonaceous layer in the middle of the fine- to coarse-grained sandstones yields *Ophiomorpha* burrows. The boundary to the 12-m-thick lower Upper Cenomanian Werksandstein Member of the Oberhäslich Formation is sharp (SB Ce 4). The lower 7 m fine upwards from coarse- to fine-grained sandstones. Above, a ca. 1-m-thick conglomerate follows; up-section, a siltstone bed that coarsens upwards into a coarse-grained sandstone concludes the Werksandstein Member. The 6.5-m-thick upper Upper Cenomanian Pennrich Formation starts at 152 m BSL (SB Ce 5) with a 3.5-m-thick argillaceous to silty horizon, overlain by a 3-m-thick, fine-grained sandstone with *Ophiomorpha* burrows. Up-section, a 10-m-thick package of argillaceous Pläner follow, assigned to the Lower Turonian Brießnitz Formation. Above, a 2.3-m-thick argillaceous siltstone bed and the more than 50-m-thick Cottaer Bildhauersandstein of the Schmilka Formation follow.

(26) Borehole Porschendorf 358/1965
TK 25: 4949 Dresden-Ost; zone 5: R 5429613/H 5652808

The borehole is located at the northern outflow of the Pirna Palaeovalley and was drilled and initially described by the Wismut; the section figured and reinterpreted herein for the first time. At 262 m BSL, Cretaceous strata overlie the Palaeozoic basement ("Granit"). The fluvial cycle 1+2 of the lower Niederschöna Formation (lower Lower Cenomanian) consists of a 2-m-thick conglomerate at the base and 6 m of medium- to coarse-grained sandstones with intercalated conglomeratic and greenish fine-grained layers. The following 12-m-thick light grey, fine-grained sandstone with abundant plant debris (and without shell remains) are interpreted herein as the brackish Wurmsandstein of DS Ce 3 (upper Lower Cenomanian). Above, the Oberhäslich Formation (Middle to lower Upper Cenomanian) is represented by a 41-m-thick, argillaceous, fine-grained sandstone with oysters (*Rhynchostreon suborbiculatum*, *Rastellum carinatum*) and indeterminate calcareous shell debris, at the top with subordinate glauconite content. A lower Merbitz Member and an upper Werksandstein Member and, thus, the limiting SB Ce 4, cannot be distinguished. The upper Upper Cenomanian Pennrich Formation above 201 m BSL is only ca. 4 m thick, characterised by a 2-m-thick glauconitic claystone below (*plenus* Horizon), at the base yielding sandstone clasts from the underlying Oberhäslich Formation (SB Ce 5), and an almost 2-m-thick glauconitic, fine-grained sandstone with oysters above. At 197 m BSL, the Pläner of the Lower Turonian Brießnitz Formation follow.

(27) Core Lohmen 7030/2000
TK 25: 5050 Bad Schandau; zone 5: R 5429139/H 5650341

The detailed core description of Neumann (2004) has been transferred into a stratigraphic log and is partly reinterpreted herein. At 258 m BSL, Cretaceous strata rest on the Palaeozoic basement. The 17-m-thick fluvial cycle 1+2 (lower Lower Cenomanian DS Ce 1+2, lower Niederschöna Formation; Table 1) is strongly dominated by grey to yellowish-grey, coarse-grained sandstones with wood remains, intercalated by only a few conglomeratic and fine-grained layers. The 9-m-thick medium- to coarse-grained brackish Wurmsandstein of DS Ce 3 (upper Lower Cenomanian) contains abundant plant debris and several horizons with *Ophiomorpha* burrows (Neumann 2004). The Middle to lower Upper Cenomanian Oberhäslich Formation has a thickness of 35 m; the top surface (SB Ce 5) is located at 200 m BSL. The lithology is dominated by fine- to medium-grained, well sorted light grey quartz sandstones. The lower half (Merbitz Member of DS Ce 4) is monotonous, massive and unfossiliferous; the upper half (Werksandstein Member of DS Ce 5) is rich in oysters, serpulids and *Ophiomorpha* burrows, and bears three coarse-grained intervals at the base, the middle and the upper parts. The following ca. 6.5-m-thick Pennrich Formation consists of fine-grained sandstones with serpulids and bioturbated argillaceous siltstones. The boundary to the thick Lower Turonian Pläner of the Brießnitz Formation is drawn at a clay bed at 194 m BSL (Lohmgrund Horizon). The first appearance of (upper) Lower Turonian *Mytiliodes labiatus* is 52 m above the base of the Pläner facies (Tröger in Neumann 2004).

(28) Core Dorf Wehlen 7029/1999
TK 25: 5050 Bad Schandau; zone 5: R 5647502/H 5430067

Based on the detailed core description of Neumann (2004), the log of the Dorf Wehlen 7029/1999 succession is illustrated and in part reinterpreted here. At 160 m BSL, Cretaceous strata rest on the Palaeozoic basement, starting with a 21-m-thick fluvial cycle 1+2 of the lower Niederschöna Formation (lower Lower Cenomanian; Table 1). It consists of an alternation of fine- to medium-grained sandstones with several thin conglomeratic layers in the lower 7–8 m; up-section, the succession is dominated by light grey, coarse-grained sandstones with abundant wood remains, intercalated by few thin coaly-clayey layers. The Niederschöna Formation continues with the brackish Wurmsandstein (13 m thick, DS Ce 3, upper Lower Cenomanian), consisting of grey to dark grey, partly also reddish coarse-grained sandstones and conglomerates and showing common *Ophiomorpha* burrows, oyster debris, wood remains and several coaly layers. The boundary to the Oberhäslich Formation is drawn above the uppermost carbonaceous claystone layer at 126 m BSL (SB Ce 3). The Merbitz Member is rather thin (11 m) and consists of monotonous, massive fine- to medium-grained quartz sandstones with *Ophiomorpha* burrows; 3 m above the base, a last fine-grained carbonaceous siltstone layer is intercalated. The 18-m-thick Werksandstein Member consists of monotonous, massive fine- to medium-grained sandstones below, showing a clear coarsening-upwards trend into thick-bedded to massive coarse-grained sandstones and conglomerates in the upper part of the member. At 97 m BSL, SB Ce 5 caps the Oberhäslich Formation and the following Pennrich Formation shows a 2-m-thick fossiliferous interval fining into the *plenus* Horizon. Above a thin fine-grained sandstone bed, argillaceous siltstones terminate the 6-m-thick Pennrich Formation. Up-section, Pläner deposits overlie the Pennrich Formation and the boundary to the Lower Turonian Brießnitz Formation has been placed at 91 m BSL. The first appearance of *Mytiliodes labiatus* is 107 m above the base of the Pläner facies (Tröger in Neumann 2004).

(29) Core Pirna-Struppen 7025/2000 (Fig. 7)
TK 25: 5050 Bad Schandau; zone 5: R 5430491/H 5643317

This key succession for the Pirna Palaeovalley was described in detail and illustrated by Melchisedech (2021). At 17 m BSL, Cretaceous strata unconformably rest on the Palaeozoic basement (Lusatian Granodiorite). The tripartite Niederschöna Formation is extraordinarily thick (52 m; Table 1). The fluvial cycle of DS Ce 1+2 is 27-m-thick and dominated by coarse-grained sandstones, breccia and conglomerates with a few, thin silty-argillaceous layers. Above, the fluvial cycle of DS Ce 3 has 18 m in thickness; the lower half consists of coarse-grained sandstones, rich in plant debris, while the upper half bears three thick fining-upward cycles from sharp-based sandstones below to rooted silty claystones above. These cycles resemble deposits produced by point-bar migration of meandering rivers (e.g. Allen 1970). The upper of these point-bar cycles is terminated by a conspicuous coal bed. Up-section, the 8-m-thick brackish Wurmsandstein (Middle Cenomanian, DS Ce 4) is characterised by several levels with *Ophiomorpha* burrows, increasing in abundance towards the top (Melchisedech 2021). The Oberhäslich Formation consists of the upper Werksandstein Member only (DS Ce 5, lower Upper Cenomanian), 17 m in thickness. It comprises of medium-grained quartz sandstones in the lower half while the upper part shows a clear coarsening-upward trend into coarse-grained, pebbly quartz sandstones, similar to the situation in the core Dorf Wehlen 7029/1999. The progradational trend is terminated at SB Ce 5, and above 50 m ASL, the 5-m-thick, clayey-silty Pennrich Formation follows, showing a conspicuous glauconitic siltstone bed in its lower part and a weak coarsening-upward trend. The boundary to the Lower Turonian Pläner of the Brießnitz Formation has been placed at 55 m ASL.

(30) Core Pirna-Krietzschwitz 7006/2001
TK 25: 5050 Bad Schandau; zone 5: R 5429198/H 5643156

The Pirna-Krietzschwitz core succession was illustrated and described in detail by Janetschke & Wilmsen (2014). At 45 m ASL, Cretaceous strata of the Niederschöna Formation rest on the Palaeozoic basement (Lusatian Granodiorite). Based on the correlation to the nearby Pirna-Struppen 7025/2000 core, it can be shown that the lower fluvial cycle 1+2 is missing here and that the Niederschöna Formation starts with fluvial cycle 3 in the upper Lower Cenomanian DS Ce 3, 11 m in thickness (Table 1). The fluvial cycle starts with a basal conglomerate followed by grey, mainly coarse-grained, cross-bedded sandstones. Upward, thin sandstone beds and dark grey, rooted, fine sandy-silty claystones with intercalated black carbonaceous layers predominate, forming small-scale fining-upward cycles, similar to those observed in the nearby core Pirna-Struppen 7025/2000. The 7.4-m-thick brackish Wurmsandstein of DS Ce 4 (Middle Cenomanian) has a sharp-based and coarse-grained basal bed, marking SB Ce 3, and is characterised above by dirty (i.e. carbonaceous-argillaceous), thick-bedded medium-grained sandstones with *Ophiomorpha* burrows, terminated by a rhizolithic surface ("Wurzelhorizont", SB Ce 4). The overlying 20-m-thick Oberhäslich Formation (lower Upper Cenomanian Werksandstein Member, DS Ce 5) consists of light grey, compact, fine- to medium-grained quartz sandstones with some coarse-grained intercalations and oyster shell concentrations (historical "Exogyrenlagen"). The Werksandstein Member shows a coarsening-upward trend towards the top surface at 84 m ASL, representing SB Ce 5. The fine-grained transgressive strata above (Pennrich Formation, in total 8 m thick) rest with a sharp lithological change on the unconformity and start with argillaceous sediments (*plenus* Horizon) that embrace a fine-sandy glauconitic siltstone bed in the lower part. Up-section, silty Pläner deposits follow, showing a faint upwards-coarsening trend. At 92 m ASL, the ca. 2-m-thick basal Turonian Lohmgrund Horizon marks the base of the Lower Turonian Brießnitz Formation.

(31) Outcrop Langenhennersdorf, former railway station
TK 25: 5049 Berggießhübel; zone 5: R 5429024/H 5639656

The succession near Langenhennersdorf, first mentioned, described and illustrated by Beck (1888, 1889: 66, pl. 1, fig. 3), is reinterpreted herein. The Cenomanian strata are strongly reduced in thickness here, being only ca. 8 m thick.

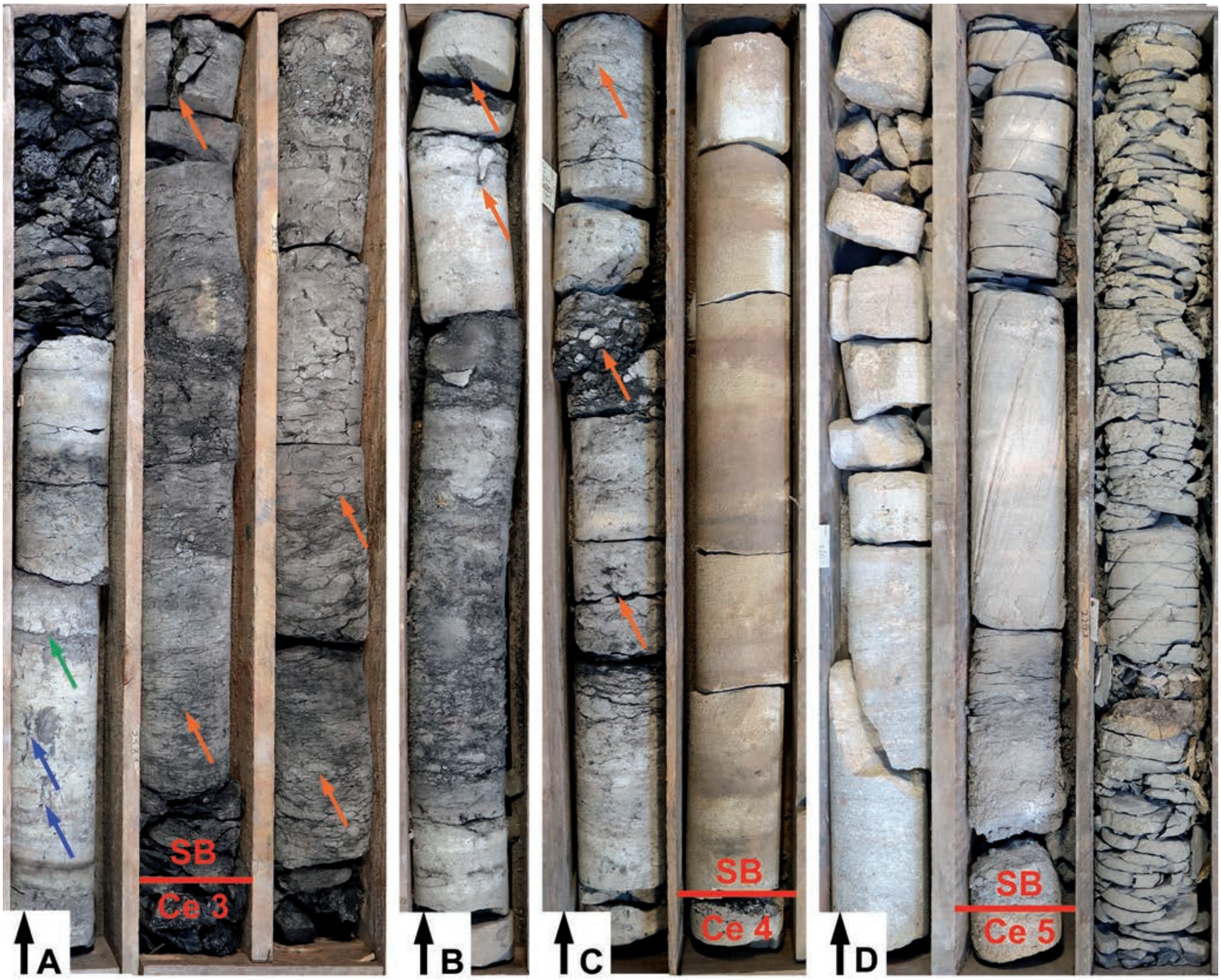


Fig. 7: Selected one-meter-long segments of the core Pirna-Struppen 7025/1999, Pirna Palaeovalley, cross-section 3 (the intervals of the core photos are keyed to the log, see Fig. 11; core photography by the LfULG). (**A**) Core depth 256–253 m, Niederschöna Formation, at 254.8 m = SB Ce 3 with fluvial cycle 3 below and brackish Wurmsandstein above. Note vertical root traces (blue arrows) and root horizon (green arrow) in the upper part of fluvial cycle 3 as well as several *Ophiomorpha* burrows in the Wurmsandstein (orange arrows). (**B**) Core depth 252–251 m, Niederschöna Formation, brackish Wurmsandstein. Note several *Ophiomorpha* burrows in the Wurmsandstein (orange arrows). (**C**) Core depth 246–244 m, at 244.9 m = SB Ce 4 with brackish Wurmsandstein of the Niederschöna Formation below and Werksandstein Member of the upper Oberhäslich Formation above. Note several *Ophiomorpha* burrows in the Wurmsandstein (orange arrows). (**D**) Core depth 229–226 m, at 227.9 m = SB Ce 5 with Werksandstein Member of the upper Oberhäslich Formation below and Pennrich Formation with basal *plenus* Horizon above.

At 287 m ASL, the 1.5-m-thin Niederschöna Formation overlies the Palaeozoic basement (Markersbach Granite) starting with a light grey sandstone followed by a weakly silicified, dark grey carbonaceous sandstone with isolated larger quartz grains. According to the stratigraphic position, the Niederschöna Formation is interpreted to correspond to DS Ce 4 at this place. The Oberhäslich Formation above (Werksandstein Member, DS Ce 5) starts with a thin conglomerate at the base of a strongly silicified, white-coloured, fine-grained quartz sandstones with common *Rhynchostreon suborbiculatum*, followed by a yellowish fine-grained sandstone, both of which 2 m in thickness. The 2–2.5-m-thick Pennrich Formation also starts with a thin conglomerate at 293 m ASL (SB Ce 5) and is overlain by a friably, fine-grained 0.5-m-thick sand bed (*plenus* Horizon) and yellow, fine-grained sandstones ("Plänersandsteine" in Beck 1888, 1889). The more than 2-m-thick, blue-grey clay above 295 m ASL corresponds to the Lohmgrund Horizon, marking the base of the sandy Lower Turonian Schmilka Formation ("Quadersandstein mit *Inoceramus labiatus* Schloth"; Beck 1889: 71).

(32) Outcrop Bahratal, composite section (Fig. 3D)
TK 25: 5049 Berggießhübel; zone 5: R 5428392/H 5638426

The lower part of this succession was photographically illustrated and described by Barthel (1958), recently remeasured by the authors in 03/2022. In the lower part of the succession (between 257–260 m ASL according to our evaluation), medium- to coarse-grained sandstones intercalated by dark grey clay layers with plant debris and wood remains were exposed (Barthel 1958: pl. 1, figs. 1, 2). However, the base of the Niederschöna Formation or the top of the Palaeozoic basement (Markersbach Granite), respectively, was not reached. Krutzsch (1963) described the lower Peruc palynoassemblage (= Lower Cenomanian) without representatives of the Normapolles group from a 0.5-m-thick clay bed at the top of the unit; thus, the fluvial facies of the Niederschöna Formation can be assigned to DS Ce 3 here. Between 260–264 m ASL, thick-bedded, greyish-green medium-grained sandstones with plant debris follow, assigned to the Wurmsandstein of the Niederschöna Formation (DS Ce 4, Middle Cenomanian). Above 264 m ASL, the Niederschöna Formation is overlain with a sharp lithofacies shift (SB Ce 4) by well-bedded, medium-grained sandstones of the Werksandstein Member of the Oberhäslich Formation (lower Upper Cenomanian, DS Ce 5). This part of the succession is poorly exposed today but was nicely illustrated in Barthel (1958: pl. 2, fig. 2; "Unterquader") from the eastern flank of the Bahra creek. The upper 6 m of the Oberhäslich Formation crop out at the western flank of the local road to Bahra between a topographic height of 274–280 m ASL (Fig. 3D), consisting of in part cross-bedded, medium- to coarse-grained quartz sandstones that show a coarsening-upwards trend. The top surface of the Oberhäslich Formation at 280 m ASL is sharp, corresponding to SB Ce 5. Above, soft, brittle, fine-grained sandy strata, probably representing the Pennrich Formation, follow, covered by vegetation.

4.4 Saxonian Switzerland; stratigraphic sections 33–39 (CS 4; Fig. 12 from left to right)

(33) Borehole Schweizermühle 1013/1961 west of Rosenthal; Rosenthal–Tisá Palaeovalley
TK 25: 5150 Rosenthal-Bielatal; zone 5: R 5432638/H 5634466

The borehole was drilled and described by the Wismut and is first illustrated and reinterpreted herein. At 291 m ASL, the 21-m-thick fluvial Niederschöna Formation rests on the Palaeozoic basement. It consists of poorly sorted coarse-grained sandstones and conglomerates with kaolinised feldspars intercalated by thin, dark grey clay layers with plant debris. According to the stratigraphic position below marine strata assigned to the upper Upper Cenomanian Dölzschen Formation (see below), the fluvial cycle is interpreted as belonging to DS Ce 5 (lower Upper Cenomanian). Thus, it is time-equivalent to the marine Oberhäslich Formation in the borehole Hühnerberg 546/1968, located 5 km to the east-southeast (see below). The first marine strata in the borehole Schweizermühle 1013/1961 are marls and Pläner of the 12-m-thick upper Upper Cenomanian Dölzschen Formation that rest sharply on the fluvial strata at 311 m ASL (SB Ce 5). The following 15-m-thick sandy Pennrich Formation, likewise of late Late Cenomanian age, is fine-grained at the base and coarsening-upwards to the top, consisting of two sub-cycles (Table 3). An approximately 1-m-thick yellowish-grey clay layer between 338–339 m ASL represents the Lohmgrund Horizon at the base of the sandy Lower Turonian Schmilka Formation.

(34) Borehole Hühnerberg 546/1968 southeast of Rosenthal; Rosenthal–Tisá Palaeovalley
TK 25: 5150 Rosenthal-Bielatal; zone 5: R 5437446/H 5633234

The borehole was drilled and initially described by the Wismut, reinterpreted herein and graphically shown here for the first time. Between 278–290 m ASL, the Werksandstein Member of the Oberhäslich Formation (lower Upper Cenomanian) forms the first Cretaceous unit that overlies the Palaeozoic basement. The lower part consists of fine- to medium-grained sandstones with intercalated thin, fine-grained conglomerates while the upper part comprises fossiliferous fine-grained sandstones with upwards increasing clay admixture. SB Ce 5 at 290 m ASL is overlain with sharp lithological contrast by a thin argillaceous horizon (*plenus* Horizon), followed by 8 m silty marlstones to marly siltstones (Pläner) with thin fine-grained sandstone layers (Dölzschen Formation, upper Upper Cenomanian). The remaining part of the uppermost Cenomanian is formed by the more than 13-m-thick Pennrich Formation (Table 3), consisting of fine-grained oyster-bearing sandstones, glauconitic in the lower half and non-glauconitic in the upper half. Above a 6.5-m-thick interval without core information, light-grey Pläner deposits of the Lower Turonian Brießnitz Formation follow.

(35) Borehole Reichstein 385/1965 east of Bielatal; Rosenthal–Tisá Palaeovalley
TK 25: 5150 Rosenthal-Bielatal; zone 5: R 5434987/H 5637972 (only mentioned in cross-section 4).

The borehole, originally drilled and described by the Wismut, is stratigraphically reinterpreted. At 175 m ASL, the only 3-m-thick Dölzschen Formation transgresses with fossil-rich Pläner deposits directly onto the Palaeozoic basement. Between 178–183 m ASL, fine-grained, argillaceous-calcareous sandstones with oyster beds (*Rhynchostreon suborbiculatum*) that represent the Pennrich Formation follow (Table 3), concluding a faint uppermost Cenomanian coarsening-upward cycle above the *plenus* Horizon that is obvious in many sections (see cross-sections and also Wilmsen & Bansal 2021). Up-section, a 1-m-thick marl bed follows (basal Turonian Lohmgrund Horizon), overlain by Pläner deposits of the Brießnitz Formation.

(36) Borehole Königstein-Halbestadt 7016/1997
TK 25: 5050 Bad Schandau; zone 5: R 5434737/H 5643796; Königstein Palaeovalley

The core description of Tröger et al. (1998) and the detailed photographic documentation of the core by the LfULG were used to compile a stratigraphic log of the succession that can be integrated into the new stratigraphic framework proposed herein. At 2 m ASL, Cretaceous strata rest on the Palaeozoic basement, starting with the 19-m-thick Niederschöna Formation. The lower 4.5 m of the 11-m-thick fluvial cycle 3 (upper Lower Cenomanian) are dominated by claystones while above, sandstones and conglomerates appear, both lithologies of which rich in plant debris. It is worth noting that, in the nearby Königstein K.1/1960 borehole (R 5435727 / H 5643485; measured by Tröger 1960), Krutzsch (1963) identified the lower Peruc palynoassemblage (= Lower Cenomanian) from the lower Niederschöna Formation. Between 13–21 m ASL, sandstones of the brackish Wurmsandstein represent DS Ce 4 (Middle Cenomanian), showing marine influence by common *Ophiomorpha* burrows. The sequence ends in a 1-m-thick dark-coloured, argillaceous palaeosol (SB Ce 4). The following 10-m-thick sandstones of the Werksandstein Member of the Oberhäslich Formation (lower Upper Cenomanian) comprise a yellowish, medium- to coarse-grained lower part and a fossil-rich, fine-grained upper part, both of which nearly of the same thickness. The upper Upper Cenomanian Pennrich Formation consists of 3.5-m-thick, glauconitic, nodular, silty claystones with a thin conglomeratic layer at the base, resting on SB Ce 5 at 31 m ASL. Up-section of 35 m ASL, typical Pläner of the Brießnitz Formation follow, biostratigraphically calibrated by the first appearance of *Mytiloides labiatus* between 3–6 m above the base of the Pläner facies (Tröger et al. 1998).

(37) Core Nasser Grund 1/2018, Bad Schandau (Fig. 8)
TK 25: 5051 Sebnitz; zone 5: R 5445315/H 5643109; Königstein Palaeovalley and Úštěk–Bad Schandau Sea Bight

The drilling Nasser Grund 1/2018 was planned and deepened as an upgrade of the old hydrogeological borehole 21/1982. The succession was first illustrated and described in detail by Wilmsen & Bansal (2021), and is stratigraphically reinterpreted herein, representing a key succession for the understanding of the stratigraphic architecture of the Königstein Palaeovalley and the Úštěk–Bad Schandau Sea Bight (this paper). At 147 m BSL the 100-m-thick Cenomanian succession overlies the crystalline Palaeozoic basement. The oldest Cretaceous lithostratigraphic unit, the 10-m-thick brackish Wurmsandstein is assigned to DS Ce 1+2 (lower Lower Cenomanian). It consists of argillaceous-carbonaceous and poorly sorted breccia, conglomerates and coarse-grained sandstones. Thin coal seams and lenses as well as wood debris are common and *Ophiomorpha* burrows have been observed at several levels. The overlying fully-marine Oberhäslich Formation is 70 m in thickness (see Table 1; 137–67 m BSL) and all three lithostratigraphic members are observed with more or less similar thicknesses (21–27 m; Table 2). The lower Klippensandstein Member (DS Ce 3, upper Lower Cenomanian) is 27 m in thickness; in the lower half of the succession, thin quartz conglomeratic layers intercalate with thick coarse-grained, cross-bedded quartz sandstones while the upper half consists of thick-bedded to massive, medium-grained and rather homogenous quartz sandstones with sparse *Ophiomorpha* burrows. The 21-m-thick Merbitz Member (DS Ce 4, Middle Cenomanian) rests with an erosional unconformity on the Klippensandstein Member (SB Ce 3, 110 m BSL) and shows a basal conglomerate containing varicoloured quartz pebbles and reworked speleothems. It consists of glauconitic, commonly greenish, coarse- to fine-grained bioturbated sandstones and shows a fining- and a coarsening-upward trend culminating in SB Ce 4 at 89 m BSL. The following Werksandstein Member is 22 m thick and dominated by grey-coloured, bioturbated fine-grained sandstones with scattered fauna (oysters, inoceramids). In the topmost part, a pronounced coarsening-upward trend culminates in SB Ce 5 at 67 m BSL. Above, the tripartite, 20-m-thick Pennrich Formation starts with a thin argillaceous *plenus* Horizon followed by a lower (a) part of grey, fine-grained bioturbated sandstones, a middle (b) interval of strongly glauconitic fine- to medium-grained sandstones, and an upper (c) part of grey, fine-grained sandstones with accessory glauconite; all parts are between 6–7 m in thickness (Table 3). Fauna, mainly oysters, and bioturbation are common. An argillaceous interval between 47–45 m BSL represents the Lohmgrund Horizon at the base of the Lower Turonian Brießnitz Formation, formed by several decametres of Pläner deposits above.

(38) Borehole Schmilka 432/1966, Bad Schandau
TK 25: 5151 Reinhardtsdorf-Schöna; zone 5: R 5446106/H 5639648; Úštěk–Bad Schandau Sea Bight

The borehole, drilled and initially described by the Wismut, is first illustrated and interpreted herein. Schmilka 432/1966 has the thickest Cenomanian succession known so far from boreholes on Saxonian territory (118 m; see Table 2) and is only 3.6 km away from the core Nasser Grund 1/2018. At 105 m BSL, fully-marine Cretaceous strata of the 100-m-thick Oberhäslich Formation overlie the Palaeozoic basement, showing all three members. The 53-m-thick Klippensandstein Member includes here the depositional sequences DS Ce 1+2 and 3 (lower and upper Lower Cenomanian), and consists almost exclusively of coarse-grained sandstones and conglomerates. Sequence boundary SB Ce 2 is tentatively placed 23 m above the base of the Cretaceous succession due to the presence of abundant plant debris and drift wood below the boundary, while SB Ce 3 is correlated from core Nasser Grund 1/2018 to the base of a conglomeratic unit starting at 52 m BSL. However, the Merbitz and Werksandstein members, together 45 m in thickness, cannot be separated because the crucial defining unconformity, SB Ce 4, remained elusive from the sketchy Wismut core descriptions. Both members consist of fine-grained sandstones, in parts with glauconite. The uppermost 5.5 m of the Oberhäslich Formation is a fossil-rich greensand and the terminal SB Ce 5 has been placed at a conspicuous lithofacies shift to fine-grained, non-glauconitic sandstones with clay flasers (*plenus* Horizon) at 7 m BSL. The 20-m-thick argillaceous- and calcareous-cemented, fine-grained sandstones of the Pennrich Formation (Table 3; upper Upper Cenomanian, TST of DS Ce-Tu 1) show a tripartition with a conspicuous 6-m-thick middle (b) part in which fossils (bivalves) and glauconite are

Fig. 8: Selected one-meter-long segments of the core Nasser Grund 1/2018, Úštěk–Bad Schandau Sea Bight, cross-section 4 (the intervals of the core photos are keyed to the log, see Fig. 12; core photography by the LfULG). (**A**) Core depth 320–317 m, at 318.2 m = SB Ce 2 with brackish Wurmsandstein of the Niederschöna Formation below and marine Klippensandstein Member of the lower Oberhäslich Formation above. Note several *Ophiomorpha* burrows in the Wurmsandstein (orange arrows). (**B**) Core depth 292–290 m, Oberhäslich Formation, at 291.1 m = SB Ce 3 with Klippensandstein Member below and Merbitz Member above; note thin quartz conglomerate above the sequence boundary. (**C**) Core depth 272–270 m, Oberhäslich Formation, at 270.4 m = SB Ce 4 with partly glauconitic Merbitz Member below and Werksandstein Member above. Note several *Ophiomorpha* burrows in the Merbitz Member (orange arrows), partly filled by clayey material from above. (**D**) Core depth 249–248 m, at 248.5 m = SB Ce 5 with Werksandstein Member of the upper Oberhäslich Formation below and Pennrich Formation with basal *plenus* Horizon and *Ophiomorpha* burrows (orange arrow) above. (**E**) Core depth 237–235 m, glauconitic sandstones of the middle Pennrich Formation with scattered oyster shells and shell beds.

enriched, very similar to the situation in the core Nasser Grund. At 13 m ASL, the Pennrich Formation is superimposed by Pläner deposits of the Lower Turonian Brießnitz Formation.

(39) Borehole Hinterhermsdorf 442/1966

TK 25: 5052 Hinterhermsdorf; zone 5: R 5456313/H 5641650; Hinterhermsdorf–Jetřichovice Palaeovalley and Úštěk–Bad Schandau Sea Bight

The borehole, deepened and first described by the Wismut, is illustrated and reinterpreted herein. Hinterhermsdorf 442/1966 has almost the same huge Cenomanian thickness as the borehole Nasser Grund 1/2018, ca. 11 km to the west (103 m of Cenomanian strata). At 151 m BSL, conglomerates of the Niederschöna Formation overlie the Palaeozoic basement. Up-section, coarse-grained and plant debris-rich dark claystones form conspicuous fining-upward cycles. The in total 18-m-thick fluvial succession corresponds to DS Ce 1+2 (lower Lower Cenomanian). The three depositional sequences corresponding to the three members of the 70-m-thick Oberhäslich Formation (DS Ce 3–5, 133–63 m BSL) have an almost equal thickness (21–26 m; Table 2), as in the core Nasser Grund. The 26-m-thick Klippensandstein Member of the lower Oberhäslich Formation (DS Ce 3, upper Lower Cenomanian) is dominated by conglomerates interbedded by m-scale, medium-grained sandstones; ca. 6 m above the base, marine bivalves were found. The 21-m-thick Merbitz Member (DS Ce 4, Middle Cenomanian) is characterised by an alternation of argillaceous fine-grained sandstones rich in fossil debris and medium-grained sandstones with occasional conglomeratic layers. The lower half of the 23-m-thick Werksandstein Member is characterised by an alternation of fine- to medium-grained argillaceous sandstones with admixture of fossil debris and some glauconite, and thin conglomeratic interbeds. In the upper half, two medium-grained, glauconitic sandstones of 2 and 4 m thickness occur, and the coarsening-upward trend is concluded by a massive conglomerate, capped by SB Ce 5 at 63 m BSL. The 15-m-thick Pennrich Formation above (Table 3) consists of mostly glauconitic fine-grained sandstones, argillaceous towards the top. A 2-m-thick marl above 48 m BSL (Lohmgrund Horizon) and the following Pläner mark the onset of the Lower Turonian Brießnitz Formation.

5. Discussion

5.1 Correlation (cross-sections 1–4)

The 39 drill cores and/or outcrops described above, 30 of which figured herein, form the comprehensive stratigraphic basis for four cross-sections that show the revised correlations along distinct instructive transects in order to elucidate the stratigraphic architecture and onlap patterns of the Cenomanian in Saxony. Cross-section 1 (sections 1–10) runs along the Elbe Valley from Meißen in the northwest to Pirna in the southeast. Cross-section 2 (sections 11–24) connects the erosion remnants of the Cretaceous strata on the eastern Erzgebirge with the core Nossener Brücke in Dresden-Löbtau, central Elbtal. Cross-section 3 (sections 25–32) covers the Pirna Palaeovalley (Tonndorf 2000), a key area for the understanding of the Cenomanian stratigraphy of the Elbtal Group, and cross-section 4 (sections 33–39) correlates sections within the Saxonian Switzerland, also establishing a connection to successions on Czech territory (Úštěk–Bad Schandau Sea Bight [this paper] and Hinterhermsdorf–Jetřichovice Palaeovalley [Tonndorf 2000; Uličný et al. 2009a]). All sections are tied along the mid-Late Cenomanian sequence boundary SB Ce 5 which forms a conspicuous unconformity that is used as a datum line in all four cross-sections. Only in the most distal northwestern part of the study area (Niederau composite section, cross-section 1), a correlative conformity developed in the deeper part of the SCB (Wilmsen et al. 2019a). Down-section, the number of preserved depositional sequences in relation to the pre-transgression topography provides a consistent picture of the stratigraphic architecture and onlap patterns of the lower Elbtal Group that, up-section, culminated in an earliest Turonian maximum flooding interval represented by the overlapping marker bed of the Lohmgrund Horizon. Macro- and microfossil biostratigraphic data, both published and new, are in very good agreement with the new stratigraphic model.

5.1.1 Cross-section 1: Elbe Valley between Meißen and Pirna (Fig. 9)

The northwestern part of the Elbe Valley between Niederau and western Dresden is characterised by the argillaceous–calcareous, deeper marine Mobschatz Formation starting with depositional sequence DS Ce 4 in the early Middle Cenomanian (Wilmsen et al. 2019a). A fully-marine sandstone locally found below the Mobschatz Formation represents the Klippensandstein Member of the lower Oberhäslich Formation, here assigned to DS Ce 3 (upper Lower Cenomanian; cf. Wilmsen et al. 2019a). At Dresden-Merbitz, DS Ce 3 is represented by fluvial cycle 3 of the Niederschöna Formation, followed in DS Ce 4 by the fully-marine, ca. 5-m-thick Merbitz Member of the middle Oberhäslich Formation bearing Middle Cenomanian ammonites (Wilmsen et al. 2022: figs. 4, 5). Above, Pläner corresponding to the upper part of the Mobschatz Formation onlap the Merbitz Member during DS Ce 5 that is developed in marly offshore facies with planktic foraminifers and calcareous nannofossils in the Niederau area.

The Elbe Valley from the western part of Dresden to Dresden-Pillnitz in the southeast is characterised by a 27–34-m-thick middle to upper Oberhäslich Formation (comprising the Merbitz and Werksandstein members of Middle to early Late Cenomanian age). These successions correspond to DS Ce 4 and DS Ce 5, respectively, albeit it has to be stressed that unconformity SB Ce 4 that is crucial for the separation of the two members cannot be unequivocally identified in the Wismut borehole data. In the Heidenau Palaeovalley (this paper), the marine Middle Cenomanian overlies a maximal 12-m-thick fluvial cycle 3 of DS Ce 3 (Niederschöna Formation, upper Lower Cenomanian). The Heidenau Palaeovalley is separated from the Pirna Palaeovalley to the southeast by the Copitz Peninsula near Pirna-Graupa without deposition during Cenomanian times (Tonndorf 2000; Fig. 1B) and delayed onset of sedimentation and strongly reduced thickness at its margins. At the western edge (Meuschaer Höhe 1251/1961), the onset of non-marine deposition occurred in Middle Cenomanian times with fluvial cycle 4 of the Niederschöna Formation (DS Ce 4) that replaces the marine Merbitz Member up-dip. Initial marine flooding and deposition of the Werksandstein Member of the Oberhäslich Formation during the early Late Cenomanian (DS Ce 5) characterises this place.

Following SB Ce 5 in the mid-Late Cenomanian, the *plenus* Transgression of DS Ce-Tu 1 resulted in the widespread deposition of the 12–20-m-thick marly-calcareous Dölzschen Formation during the latest Cenomanian. In the northwestern part of the cross-section (Niederau composite), SB Ce 5 is developed as a correlative conformity and lowstand deposits are preserved (Wilmsen et al. 2019a). Only in some places, deposition of fine-grained, glauconitic, calcareous sandstones of the Pennrich Formation (historical “Plänersandsteine”) prevailed during the latest Cenomanian, the clastics of which being unequivocally sourced from the eastern Erzgebirge.

5.1.2 Cross-section 2: Erosion remnants of southern Dresden to the eastern Erzgebirge (Fig. 10)

Large parts of the eastern Erzgebirge were sites of non-deposition and/or erosion before the Middle Cenomanian and directly onlapped by marine strata of the Merbitz Member of the Oberhäslich Formation during the early Middle Cenomanian (DS Ce 4; Wilmsen et al. 2022). The superposition of the Niederschöna Formation, preserved below in palaeovalleys within the basement rocks, by these Middle Cenomanian marine strata dates the deposition of the fluvial sediments below into the Early Cenomanian. The Niederschöna Formation of the Tharandt Palaeovalley shows two conspicuous 12–15-m-thick fining-upward cycles that represent the fluvial segments of depositional sequences DS 1+2 and DS 3 (lower and upper Lower Cenomanian), thus reflecting the non-marine onlap during the two oldest transgressions of the Saxonian Cretaceous Basin (rise in base-level). Fluvial cycle 3 at the type locality of the Niederschöna Formation was dated as belonging to the Lower Cenomanian lower Peruc palynoassemblage by Krutzsch (1963, 1966).

The fully-marine Merbitz and Werksandstein members of the Oberhäslich Formation (formerly termed as "Unterquader", e.g. Geinitz 1871–1875), either resting on the fluvial Niederschöna Formation, the gneissic basement of the eastern Erzgebirge or on the Rotliegend rocks, are relatively condensed in the measured sections (10–12 m in thickness; see Fig. 10), albeit up to 20 m are known locally, e.g. from the Paulsdorfer Heide and the Tharandt Forest (Janetschke & Wilmsen 2014; Niebuhr et al. 2021). The reduced thicknesses reflect the low availability of accommodation space on the topographic high of the eastern Erzgebirge during the initial phases of the Middle and early Late Cenomanian transgressions of DS Ce 4 and DS Ce 5. The Werksandstein Member of the upper Oberhäslich Formation is commonly fine-grained and often very homogenous (i.e. bioturbated throughout), reflecting the progressive deepening during the *naviculare* Transgression. It is generally 5–7 m thick and, based on its uniform and massive fabric, was quarried as a famous freestone (Pietzsch 1912, 1914: 103; Niebuhr et al. 2021). The sections of the Oberhäslich Formation at the type locality in Dippoldiswalde-Oberhäslich and the sandstone quarry area at Bannewitz, ca. 9.5 km to the north (e.g. at the Horkenberg), where the Oberhäslich Formation transgresses onto the Palaeozoic basement, are quite similar in thickness and lithofacies (see Fig. 10). In the Bannewitz area, Middle and lower Upper Cenomanian ammonites were found in the Merbitz Member below and Werksandstein Member above, respectively (Wilmsen & Nagm 2014: fig. 6e; Wilmsen et al. 2022: figs. 6–9). Between the borehole sections in Bannewitz-Boderitz and the Nossener Brücke in Dresden-Löbtau, 4.3 km to the north, the facies transition from the sandy to marly facies took place in early Late Cenomanian times (DS Ce 5, Werksandstein Member of the Oberhäslich Formation and upper part of the Mobschatz Formation).

Above SB Ce 5, which is a well-developed mid-Upper Cenomanian unconformity across the eastern Erzgebirge transect, the *plenus* Horizon forms an easily discernible, fine-grained transgressive marker bed that yielded the eponymous index belemnite *Praeactinocamax plenus* at some localities (Wilmsen 2014). As a result of the present-day regional erosion level, the Cenomanian /Turonian transition is not preserved in most sections. However, in the core Mariaschacht Bannewitz-Boderitz 6512/1998, at the Hartheberg and around Tharandt-Großopitz, the argillaceous-silty Lohmgrund Horizon of basal Turonian age is overlain by fine-grained sandstones of the lower Schmilka Formation.

5.1.3 Cross-section 3: Pirna Palaeovalley (Fig. 11)

The Pirna Palaeovalley excellently exemplifies the time-transgressive non-marine and marine onlap from the north to the south following a large gently inclined palaeovalley in the Neoproterozoic–Palaeozoic basement (Lusatian Granodiorite, Markersbach Granite) before the headlands were flooded during the later stages of the Cenomanian transgression. In the deepest parts of the palaeovalley, the basal fluvial cycle 1+2 of the Niederschöna Formation was deposited (lower Lower Cenomanian), corresponding to the non-marine onlap of depositional sequence DS Ce 1+2. The thickness of this fining-upward unit increases more or less continuously from Porschendorf 358/1966 in the north (8 m) via Lohmen 7030/2000 (17 m) and Dorf Wehlen 7029/1999 (22 m) to Pirna-Struppen 7025/1999 in the south (27 m). Towards the margins of the Pirna Palaeovalley (Copitz Peninsula to the NW, Wehlen Island to the NE and Bahra–Königstein Peninsula to the S–SE; Tonndorf 2000; Figs. 1B, 14A, B), the strata of DS Ce 1+2 pinch out rapidly (e.g. from Pirna-Struppen 7025/1999 to Pirna-Krietzschwitz 7006/2001), indicating in part a steep palaeotopography of the Early Cenomanian landscape. In the northern drill sites, the fluvial cycle of DS 1+2 is followed by the 9–13-m-thick brackish Wurmsandstein of DS Ce 3 while south of the Elbe River, in Pirna-Struppen, Pirna-Krietzschwitz and in the Bahratal section, fluvial facies persisted during the late Early Cenomanian and the up to 16-m-thick fluvial cycle of DS Ce 3 was deposited (palynologically dated in the Bahratal section by Krutzsch 1963), onlapping former non-depositional sites at the rising flanks or in up-dip settings to the south and thus documenting the progressive infilling of the Pirna Palaeovalley (Fig. 11). This facies succession undoubtedly shows that the fluvial input during DS Ce 1+2 and 3 predominantly took place from the south while the Cenomanian Sea with its marine influence ingressed from the north into the palaeovalley.

A similar up-dip succession of facies units along the axis of the Pirna Palaeovalley is seen in depositional sequence DS Ce 4 (Middle Cenomanian): the thickness of the fully-marine Merbitz Member of the Oberhäslich Formation conspicuously decreases from north to south and it is replaced by the 9–10-m-thick brackish Wurmsandstein of the Niederschöna Formation south of the Elbe River (Pirna-Struppen 7025/1999, Pirna-Krietzschwitz 7006/2001 and Bahratal sections). Simultaneously, the northwestern edge of the Co-

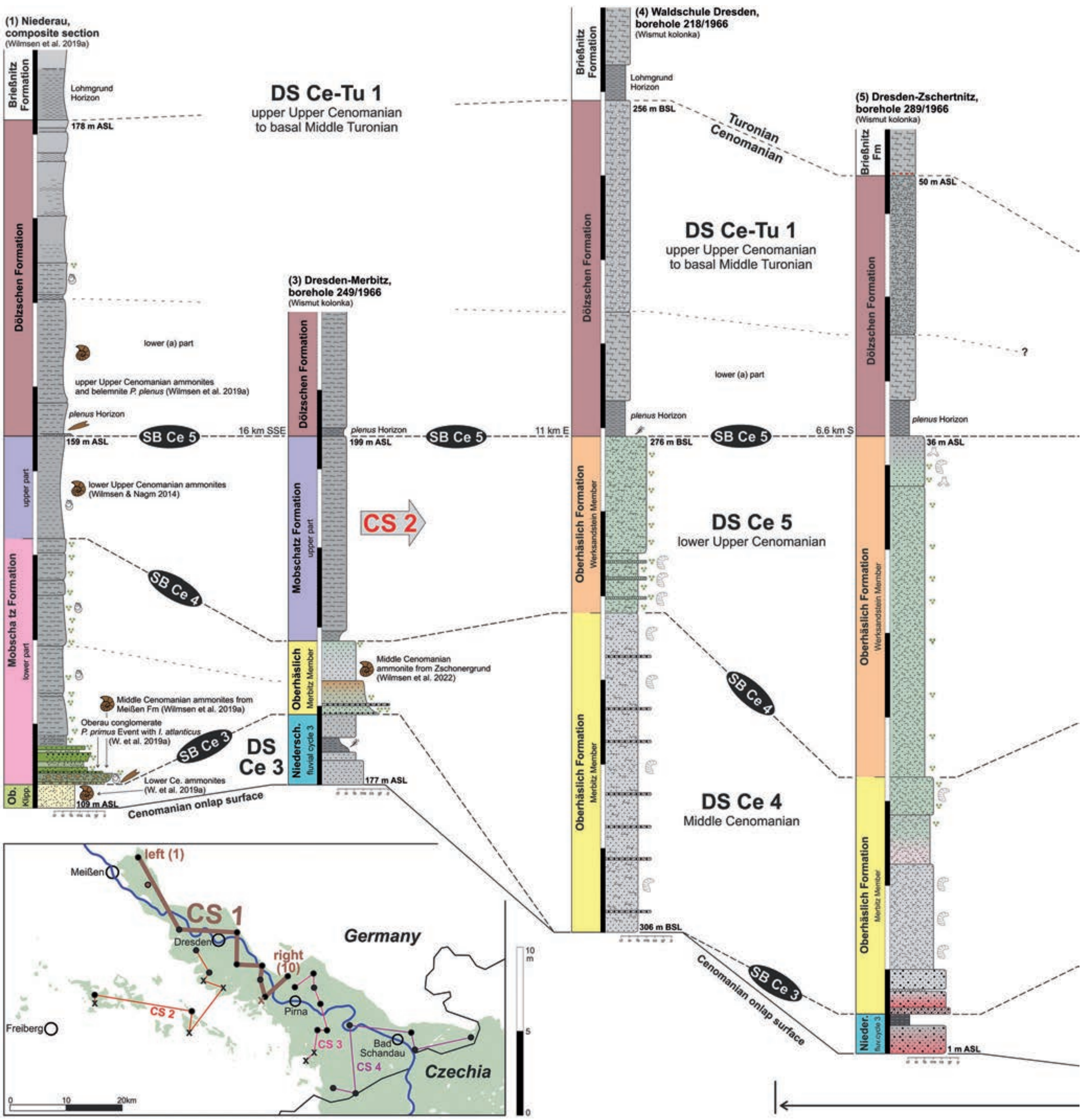


Fig. 9: Cross-section 1: Elbe Valley between Meißen and Pirna. For key to symbols and grain sizes see Fig. 4B.

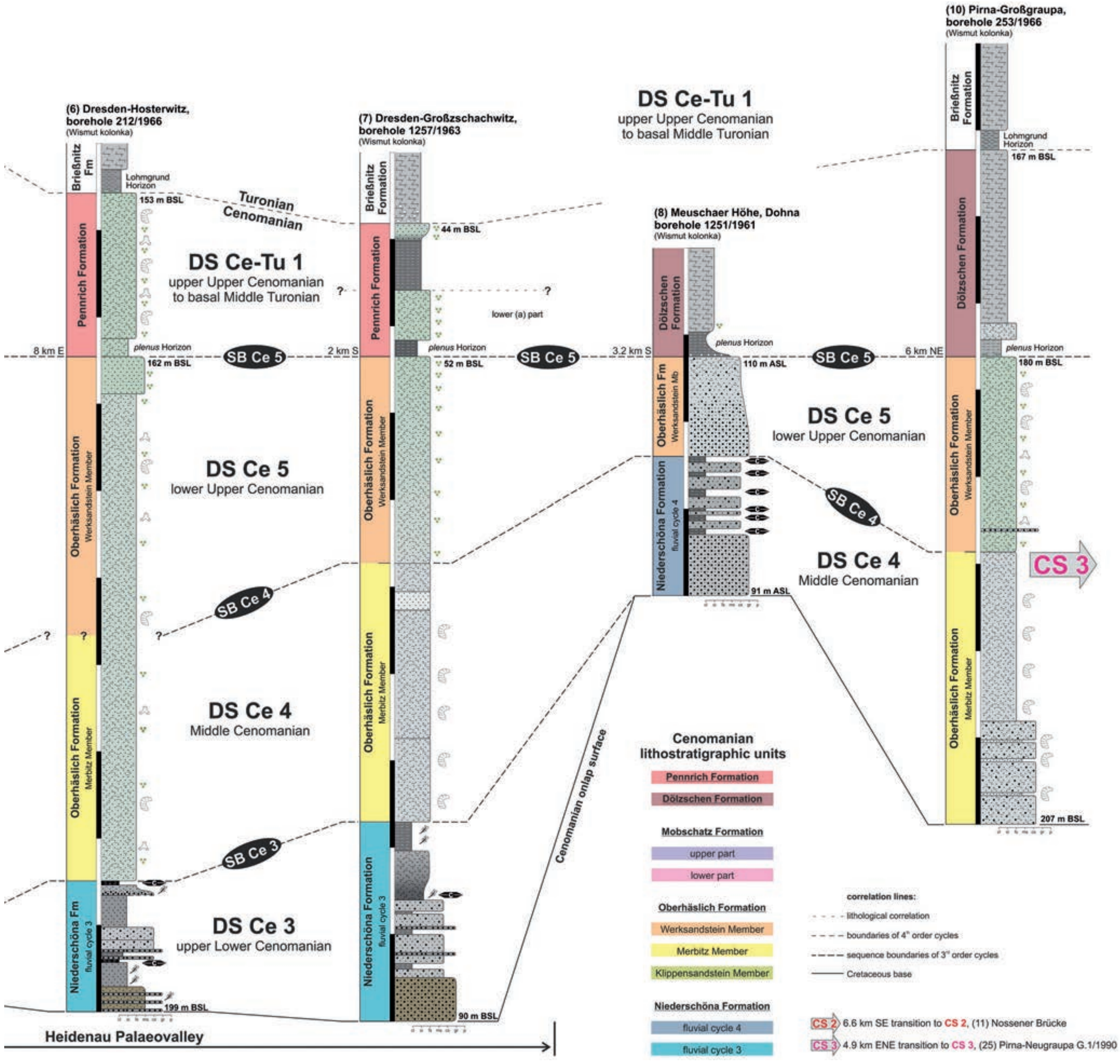

(6) Dresden-Hosterwitz, borehole 212/1966 (Wismut kolonka)
(7) Dresden-Großzschachwitz, borehole 1257/1963 (Wismut kolonka)
(8) Meuschaer Höhe, Dohna borehole 1251/1961 (Wismut kolonka)
(10) Pirna-Großgraupa, borehole 253/1966 (Wismut kolonka)
DS Ce-Tu 1
upper Upper Cenomanian to basal Middle Turonian
DS Ce 5
lower Upper Cenomanian
DS Ce 4
Middle Cenomanian
DS Ce 3
upper Lower Cenomanian
SB Ce 5
SB Ce 4
SB Ce 3
Turonian
Cenomanian
Brießnitz Formation
Lohmgrund Horizon
Pennrich Formation
Dölzschen Formation
Oberhäslich Formation
Werksandstein Member
Merbitz Member
Niederschöna Formation
fluvial cycle 3
fluvial cycle 4
plenus Horizon
lower (a) part
8 km E
2 km S
3.2 km S
6 km NE
153 m BSL
162 m BSL
199 m BSL
44 m BSL
52 m BSL
90 m BSL
110 m ASL
91 m ASL
167 m BSL
180 m BSL
207 m BSL
Cenomanian onlap surface
Heidenau Palaeovalley
CS 3
Cenomanian lithostratigraphic units
Pennrich Formation
Dölzschen Formation
Mobschatz Formation
upper part
lower part
Oberhäslich Formation
Werksandstein Member
Merbitz Member
Klippensandstein Member
Niederschöna Formation
fluvial cycle 4
fluvial cycle 3
correlation lines:
lithological correlation
boundaries of 4th order cycles
sequence boundaries of 3rd order cycles
Cretaceous base
CS 2 6.6 km SE transition to CS 2, (11) Nossener Brücke
CS 3 4.9 km ENE transition to CS 3, (25) Pirna-Neugraupa G.1/1990

Fig. 9: cont.

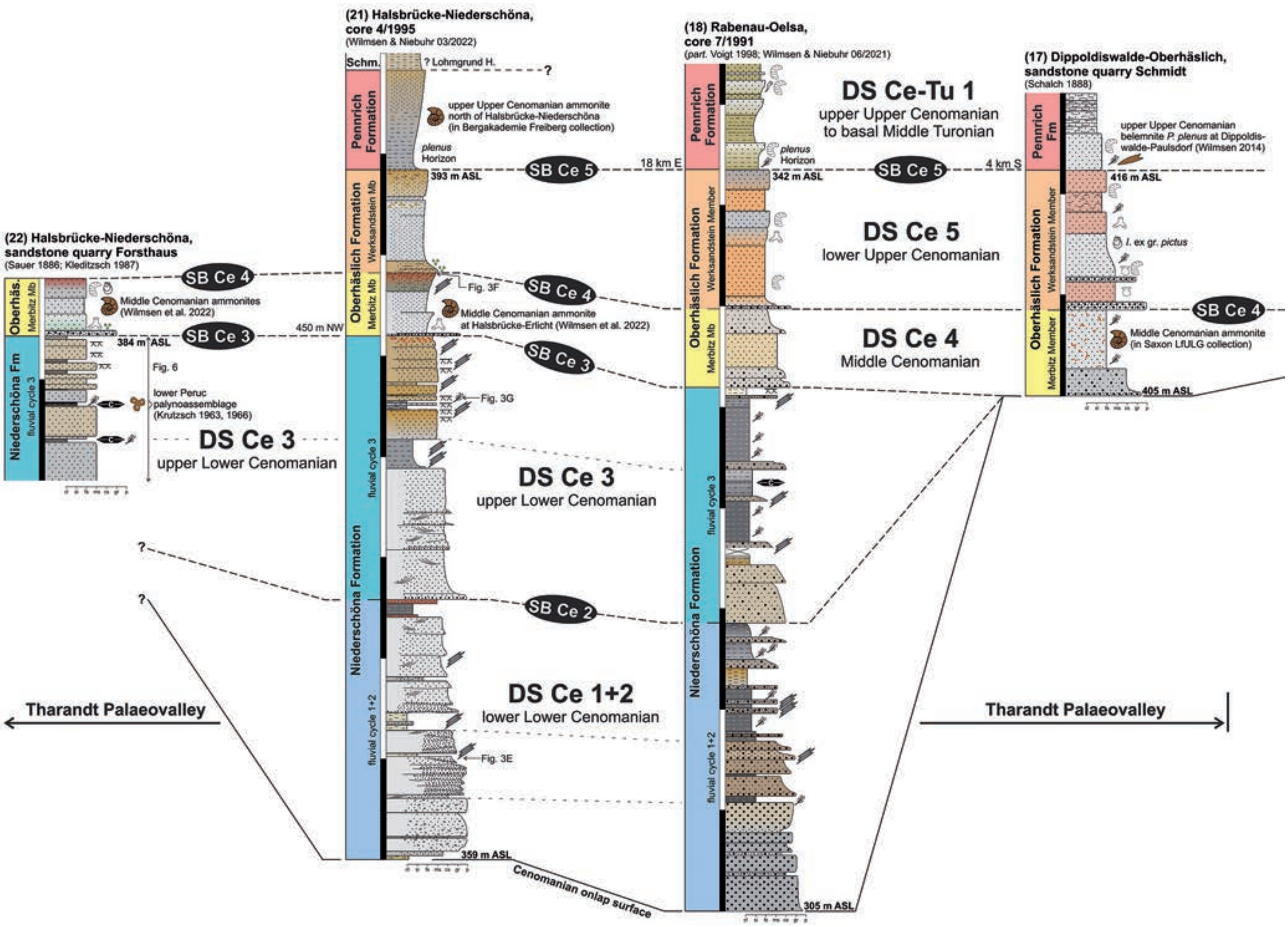


Fig. 10: Cross-section 2: Erosion remnants of southern Dresden to the eastern Erzgebirge. For key to symbols and grain sizes see Fig. 4B.

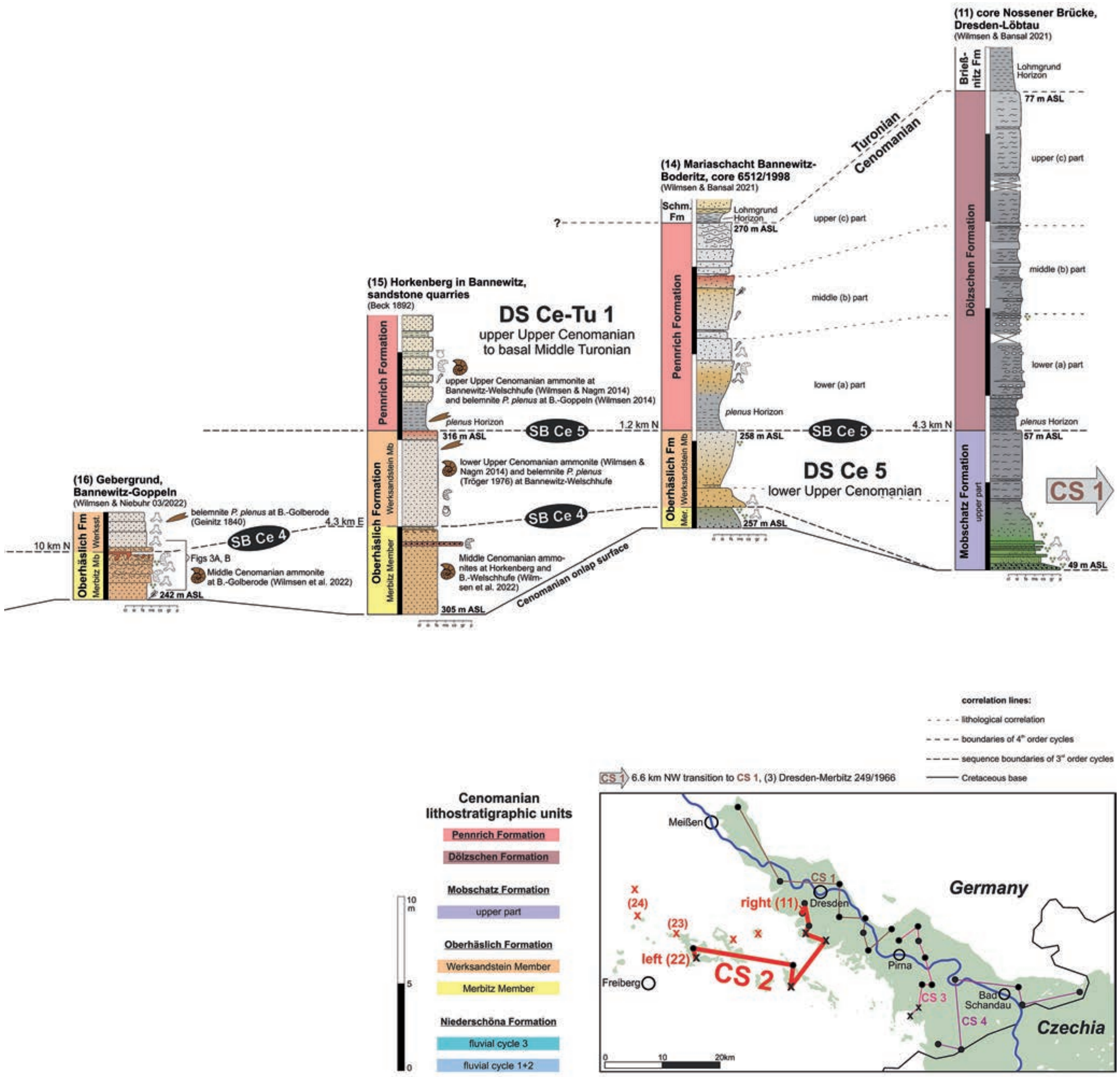

(11) core Nossener Brücke, Dresden-Löbtau
(Wilmsen & Bansal 2021)
(14) Mariaschacht Bannewitz-Boderitz, core 6512/1998
(Wilmsen & Bansal 2021)
(15) Horkenberg in Bannewitz, sandstone quarries
(Beck 1892)
(16) Gebergrund, Bannewitz-Goppeln
(Wilmsen & Niebuhr 03/2022)
DS Ce-Tu 1
upper Upper Cenomanian to basal Middle Turonian
DS Ce 5
lower Upper Cenomanian
SB Ce 5
SB Ce 4
Turonian
Cenomanian
Cenomanian onlap surface
CS 1
Pennrich Formation
Dölzschen Formation
Mobschatz Formation
Oberhäslich Formation
Cenomanian lithostratigraphic units
Werksandstein Member
Merbitz Member
Niederschöna Formation
fluvial cycle 3
fluvial cycle 1+2
correlation lines:
lithological correlation
boundaries of 4th order cycles
sequence boundaries of 3rd order cycles
Cretaceous base
6.6 km NW transition to CS 1, (3) Dresden-Merbitz 249/1966
Germany
Czechia
Meißen
Dresden
Pirna
Freiberg
Bad Schandau
CS 2
CS 3
CS 4
right (11)
left (22)

Fig. 10: cont.

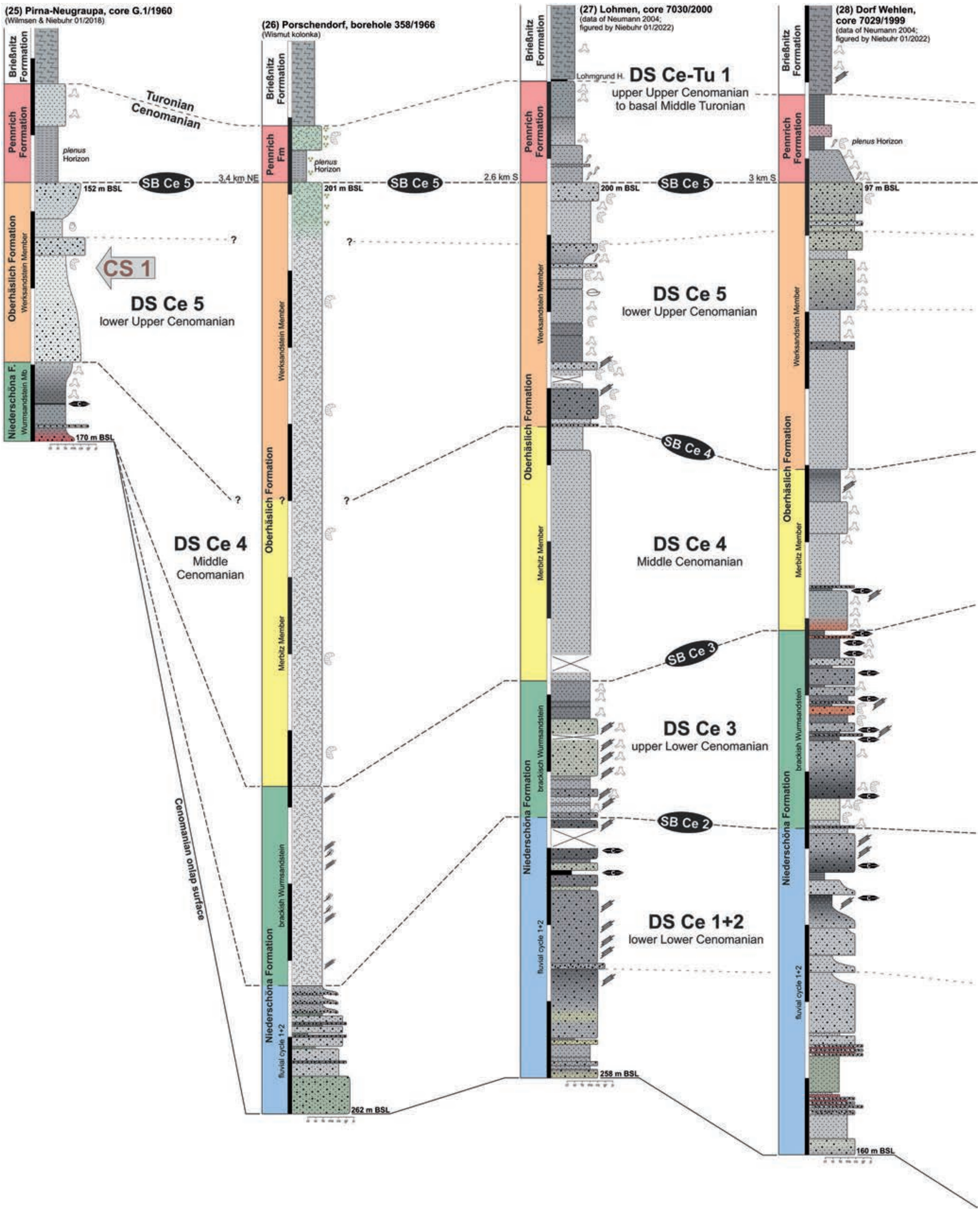


Fig. 11: Cross-section 3: Pirna Palaeovalley. For key to symbols and grain sizes see Fig. 4B.

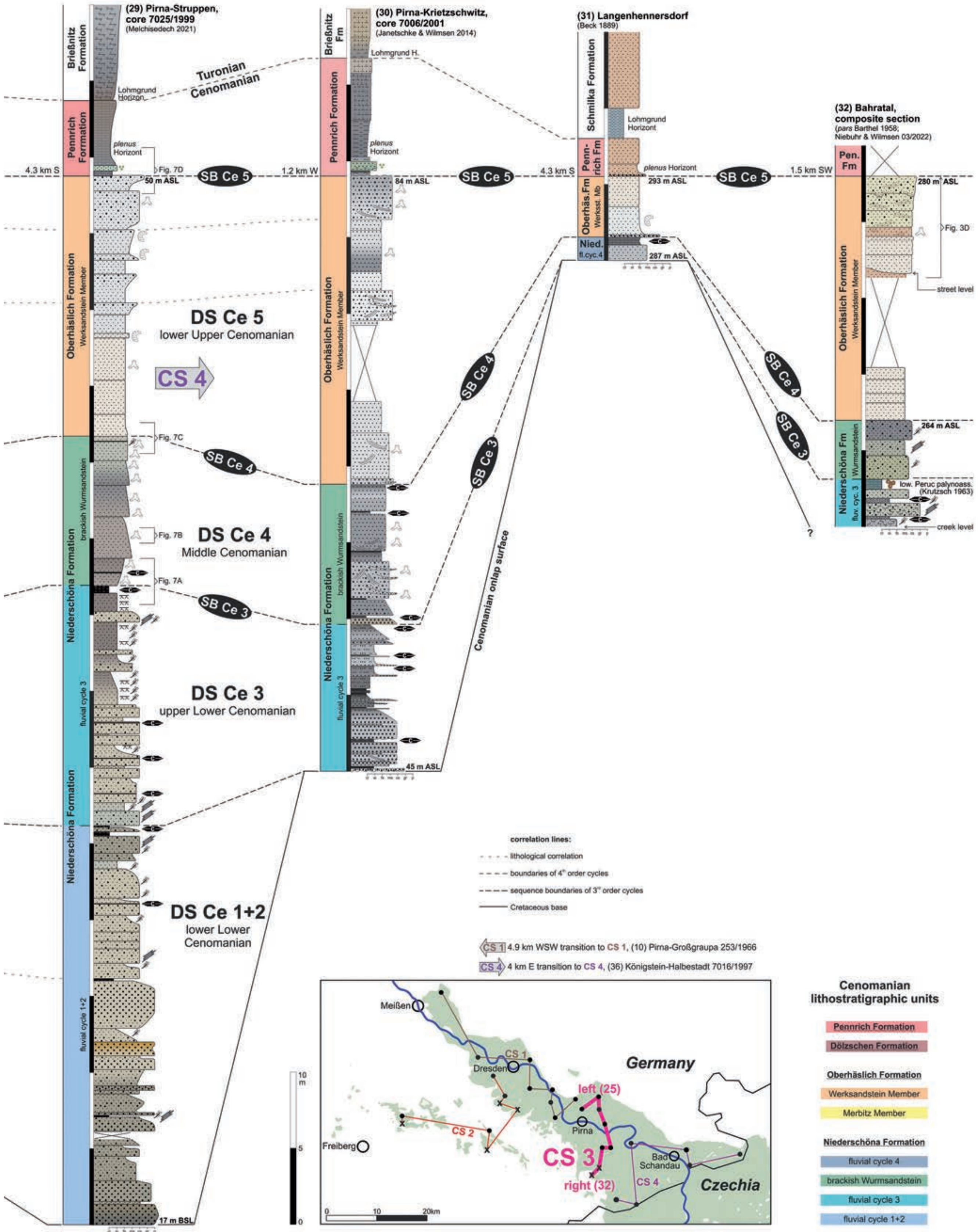

(29) Pirna-Struppen, core 7025/1999
(Melchisedech 2021)
(30) Pirna-Krietzschwitz, core 7006/2001
(Janetschke & Wilmsen 2014)
(31) Langenhennersdorf
(Beck 1889)
(32) Bahratal, composite section
Turonian
Cenomanian
SB Ce 5
SB Ce 4
SB Ce 3
DS Ce 5
lower Upper Cenomanian
DS Ce 4
Middle Cenomanian
DS Ce 3
upper Lower Cenomanian
DS Ce 1+2
lower Lower Cenomanian
CS 4
Cenomanian onlap surface
correlation lines:
lithological correlation
boundaries of 4th order cycles
sequence boundaries of 3rd order cycles
Cretaceous base
CS 1 4.9 km WSW transition to CS 1, (10) Pirna-Großgraupa 253/1966
CS 4 4 km E transition to CS 4, (36) Königstein-Halbestadt 7016/1997
Germany
Czechia
Meißen
Dresden
Freiberg
Pirna
Bad Schandau
CS 3
left (25)
right (32)
Cenomanian lithostratigraphic units
Pennrich Formation
Dölzschen Formation
Oberhäslich Formation
Werksandstein Member
Merbitz Member
Niederschöna Formation
fluvial cycle 4
brackish Wurmsandstein
fluvial cycle 3
fluvial cycle 1+2

Fig. 11: cont.

Table 1: Stratigraphic thicknesses and lithofacies in Cenomanian times documented by four drill cores from the Pirna Palaeovalley (see cross-section 3 in Fig. 11); fluvial cycles 1+2 and 3 (lower and upper Lower Cenomanian) in blue, the brackish Wurmsandstein (upper Lower and Middle Cenomanian) in green, the shallow-marine, sandy Oberhäslich Formation (Middle to lower Upper Cenomanian) in beige, and the sandy Pennrich Formation (upper Upper Cenomanian) in pink colour. Larger differences in thickness occur in the fluvial and brackish facies in the lower part of the successions, documenting the levelling of the pre-transgression topography. In total, DS Ce 3–5 have nearly the same thicknesses independent of facies (42–43 m) in the three complete drillings.

	Lohmen 7030/2000 (N)	Dorf Wehlen 7029/1999	Pirna-Struppen 7025/1999 (S)	Pirna-Krietzschwitz 7006/2001
Cenomanian total	**56 m**	**68 m**	**74 m**	**47 m**
low. DS Ce-Tu 1	4 m	3 m	5 m	8 m
DS Ce 5	16 m	19 m	17 m	20 m
DS Ce 4	17 m	11 m	10 m	9 m
DS Ce 3	9 m	13 m	16 m	9 m
DS Ce 1+2	17 m	22 m	26 m	-

pitz Peninsula near Pirna-Graupa was first involved into sedimentation when the brackish Wurmsandstein was deposited in reduced thickness (5.5 m, core Pirna-Neugraupa G.1/1960). From the correlation in cross-section 3 is evident that the Wurmsandstein is a time-transgressive brackish facies unit, appearing in Porschendorf 358/1966, Lohmen 7030/2000 and Dorf Wehlen 7029/1999 in depositional sequence DS Ce 3 while it occurs in Pirna-Neugraupa G.1/1960, Pirna-Struppen 7025/1999, Pirna-Krietzschwitz 7006/2001 and in the Bahratal within DS Ce 4. In the southern part of the transect (Langenhennersdorf), fluvial facies of the Niederschöna Formation (<2 m) persisted in an up-flank position at the margin of the Pirna Palaeovalley into the Middle Cenomanian (DS Ce 4). The observed facies pattern with the overall retrogradational stacking of depositional sequences can be explained by the general 2nd-order sea-level rise of the Cenomanian (Robaszynski et al. 1998; Wilmsen 2003; Kuhnt et al. 2009) in which each transgression overstepped the preceding one and intervening sea-level falls were small in magnitude and short in time. The Werksandstein Member of the upper Oberhäslich Formation overlies both the brackish and fully-marine facies with thicknesses of 12–20 m and it reaches far south, documenting the final flooding of the palaeovalley during the early late Cenomanian (DS Ce 5). Strongly reduced thicknesses of 4–5 m were only observed towards the upper margins of the Pirna Palaeovalley (Langenhennersdorf section) but the deposition of marine strata in this site shows that the former headlands were now submerged as well.

SB Ce 5 is a well-developed mid-Upper Cenomanian unconformity also within the Pirna Palaeovalley transect and the *plenus* Horizon forms an easily discernible, fine-grained transgressive marker bed, at some places underlain by retrogradational facies. The Pennrich Formation is between 2–7 m thick and may show a faint coarsening-upward trend, followed by the fine-grained, argillaceous Lohmgrund Horizon (lowermost Brießnitz and Schmilka formations), marking the maximum flooding of DS Ce-Tu 1 near the base of the Turonian.

5.1.4 Cross-section 4: Saxonian Switzerland (Fig. 12)

Cross-section 4 shows the depositional area in the Saxonian Switzerland subdivided into different zones with varying sedimentary development during Cenomanian times. The main feature is the 40-km-long Úštěk–Bad Schandau Sea Bight (this paper), i.e. a narrow, N–S-elongated embayment in which a thick succession of fully marine sediments accumulated, already starting during earliest Cenomanian times (e.g. Schmilka 432/1966). The Hinterhermsdorf–Jetřichovice Palaeovalley (Tonndorf 2000; Uličný et al. 2009a) is a small branch to the east of the Úštěk–Bad Schandau Sea Bight. To the west, the palaeotopography was steeply rising towards a N–S-trending palaeohigh, the divide of which being close to the eastern margin of the Pirna Palaeovalley (see cross-section 3). The elevated zone between the divide and Úštěk–Bad Schandau Sea Bight was involved into deposition during different times: in the western Königstein Palaeovalley at its edge (Wehlen Island and Königstein Peninsula; Tonndorf 2000), fluvial and brackish sediments accumulated during late Early Cenomanian times while the non-marine and marine onlap in the southern Rosenthal–Tisá Palaeovalley (Tonndorf 2000; Uličný et al. 2009a) did not start before the early Late Cenomanian. Between both areas a palaeohigh is located which is first flooded with the 5th transgression at late Late Cenomanian times (Reichstein 385/1995). In general, deposition in the western Königstein Palaeovalley (Königstein-Halbestadt 7016/1997) resembles that of the southern Pirna Palaeovalley (e.g. Pirna-Struppen 7025/199 and Pirna-Krietzschwitz 7006/2001), but the thickness is strongly reduced to about two-thirds (upper Lower to lower Upper Cenomanian strata are only 29 m in thickness compared to the same lithostratigraphic succession of 44 m and 39 m, respectively). However, the Pirna and Königstein palaeovalleys were first connected in early Late Cenomanian times (Tonndorf 2000). 16 km to the east of Königstein-Halbestadt 7016/1997, Cenomanian strata in the Nasser Grund 1/2018 reach 100 m in thickness. Between both sites, an eastward-sloping palaeotopography of at least 60 m into the Úštěk–

Table 2: Stratigraphic thicknesses and lithofacies in Cenomanian times of the three drill sites of the Saxonian part of the Úštěk–Bad Schandau Sea Bight (see cross-section 4 in Fig. 12); the fluvial cycle of DS Ce 1+2 (lower Lower Cenomanian) in blue, the brackish Wurmsandstein (lower Lower Cenomanian) in green, shallow-marine, sandy Oberhäslich Formation (lower Lower to lower Upper Cenomanian) in beige, and the sandy Pennrich Formation (upper Upper Cenomanian) in pink colour. Larger differences concern only the Early Cenomanian depositional sequences DS Ce 1+2 and DS Ce 3. DS Ce 4 and 5 are equal in thickness while the Pennrich Formation (lower part of DS Ce-Tu 1) decreases eastwards. *Genetic sequences of the Czech part of the Úštěk–Bad Schandau Sea Bight (e.g. Hřensko J-364146; Uličný et al. 2009a: app. 1, D1).

	Genetic sequences*	Nasser Grund 1/2018 (W)	Schmilka 432/1966	Hinterhermsdorf 442/1966 (E)
Cenomanian total	**ca. 92 m**	**100 m**	**118 m**	**103 m**
lower DS Ce-Tu 1	CEN 6	20 m	20 m	15 m
DS Ce 5	CEN 5	22 m	45 m	23 m
DS Ce 4	CEN 3+4	21 m		21 m
DS Ce 3	CEN 1+2	27 m	30 m	26 m
DS Ce 1+2		10 m	23 m	18 m

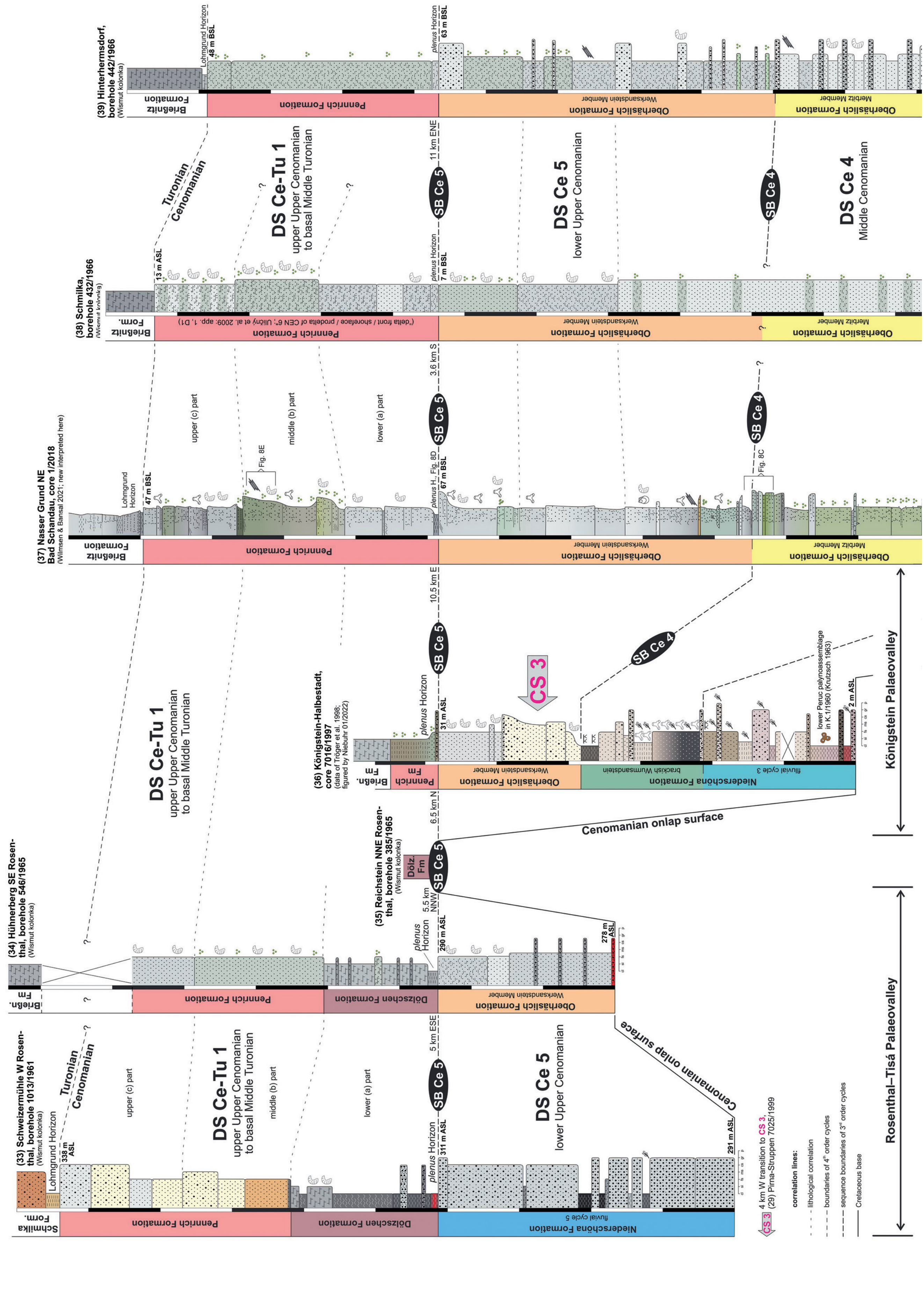
Table 3: Stratigraphic thicknesses and lithofacies in late Late Cenomanian times of the six drill sites of the Rosenthal–Tisá Palaeovalley and the Saxonian part of the Úštěk–Bad Schandau Sea Bight, Saxonian Switzerland (see cross-section 4 in Fig. 12); marly-clayey Dölzschen Formation in violet and sandy Pennrich Formation in pink colour. The 15-m-thick upper Upper Cenomanian section of the borehole Hinterhermsdorf 442/1966 cannot be subdivided.

	Schweizermühle 1013/1961 (WSW)	Hühnerberg 546/1965	Reichstein 385/1965	Nasser Grund 1/2018	Schmilka 432/1966	Hinterhermsdorf 442/1966 (ENE)
lower DS Ce-Tu 1	**27 m**	**> 22 m**	**8 m**	**20 m**	**20 m**	**15 m**
upper (c)	9 m	> 5 m	5 m	7 m	6 m	15 m
middle (b)	7 m	9 m		7 m	6 m	
lower (a)	11 m	8 m	3 m	6 m	8 m	

Bad Schandau Sea Bight has to be assumed across a distance of 10.5 km.

Sections on the Czech territory within the Úštěk–Bad Schandau Sea Bight were first logged and correlated in its longitudinal extent by Uličný et al. (2009a: app. 1, D1). The boreholes Schmilka 432/1966 and Hřensko J-364146, both located directly at the German/Czech border, are only few kilometres apart, and allow the correlation between the depositional sequences defined for the German territory (Jantschke & Wilmsen 2014) and the genetic sequences of the Czech territory (Uličný et al. 2009a). In both sequence stratigraphic models, the onset of deposition is placed in the early Early Cenomanian with shallow-marine conglomerates of the Klippensandstein Member of the Oberhäslich Formation (DS Ce 1+2; this paper) and the "subtidal sandstone-dominated facies of CEN 1+2" of Uličný et al. (2009a: 599, app. 1, D1), respectively. The sea first reached both the Saxonian and Bohemian parts of the Cretaceous Basin in early Early Cenomanian times, unequivocally coming from the north. In Schmilka 432/1966, the fully-marine Cenomanian strata are 118-m-thick while in the Nasser Grund 1/2018, the lowermost 10 m of the 100-m-thick Cenomanian succession belongs to the brackish Wurmsandstein, and the lowermost 18 m of the 103-m-thick section in Hinterhermsdorf 442/1966 are of fluvial origin (brackish and fluvial facies of the Niederschöna Formation in DS Ce 1+2). During Early Cenomanian times, the palaeotopography of the Úštěk–Bad Schandau Sea Bight was largely filled by predominately coarse-grained sandstones of the Klippensandstein Member of the Oberhäslich Formation (maximum 53 m in Schmilka 432/1966) while the Merbitz and Werksandstein members have been deposited in nearly equal thicknesses in Nasser Grund 1/2018, Schmilka 432/1966 and Hinterhermsdorf 442/1966 (43–45 m; Table 2). However, towards the western margin (Königstein and Rosenthal–Tisá palaeovalleys), both members considerably decrease in thickness.

In the Rosenthal–Tisá Palaeovalley, the Cretaceous onlap started in DS Ce 5 (early Late Cenomanian). The 12-m-thick Werksandstein Member of the Oberhäslich Formation in borehole Hühnerberg 546/1965 is replaced up-dip by the fluvial cycle 5 of the Niederschöna Formation only 5 km to the west (Schweizermühle 1013/1961). At both sites, the successions are capped by SB Ce 5 and directly overlain by marine upper Upper Cenomanian strata (Dölzschen and Pennrich formations). Strata of the *plenus* transgression of DS Ce-Tu 1 directly rest on top of the Palaeozoic basement in core Reichstein 385/1965 east of the Bielatal, 5.5 km to the north-


(33) Schweizermühle W Rosenthal, borehole 1013/1961
(34) Hühnerberg SE Rosenthal, borehole 546/1965
(35) Reichstein NNE Rosenthal, borehole 385/1965
(36) Königstein-Halbestadt, core 7016/1997
(37) Nasser Grund NE Bad Schandau, core 1/2018
(38) Schmilka, borehole 432/1966
(39) Hinterhermsdorf, borehole 442/1966
Pennrich Formation
Dölzschen Formation
Niederschöna Formation
Oberhäslich Formation
Werksandstein Member
Merbitz Member
Brießnitz Formation
Schmilka Form.
fluvial cycle 5
fluvial cycle 3
brackish Wurmsandstein
plenus Horizon
Lohmgrund Horizon
Turonian
Cenomanian
DS Ce-Tu 1
upper Upper Cenomanian to basal Middle Turonian
DS Ce 5
lower Upper Cenomanian
DS Ce 4
Middle Cenomanian
SB Ce 5
SB Ce 4
CS 3
upper (c) part
middle (b) part
lower (a) part
Cenomanian onlap surface
Königstein Palaeovalley
Rosenthal–Tisá Palaeovalley
5 km ESE
5.5 km NNW
6.5 km N
10.5 km E
3.6 km S
11 km ENE
311 m ASL
291 m ASL
338 m ASL
290 m ASL
278 m ASL
31 m ASL
2 m ASL
47 m BSL
67 m BSL
13 m ASL
7 m BSL
48 m BSL
63 m BSL
correlation lines:
lithological correlation
boundaries of 4th order cycles
sequence boundaries of 3rd order cycles
Cretaceous base
4 km W transition to CS 3, (29) Pirna-Struppen 7025/1999

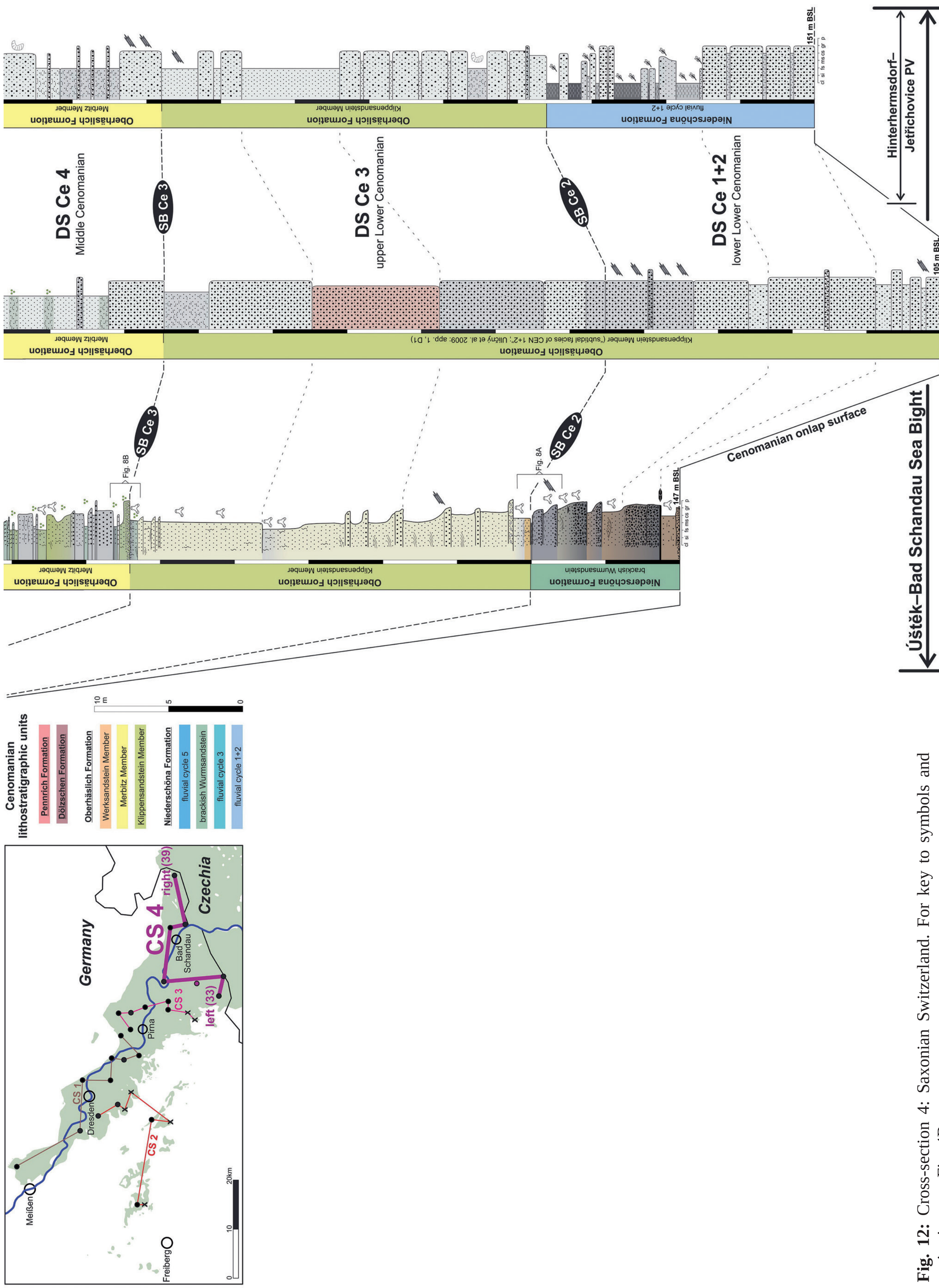


Fig. 12: Cross-section 4: Saxonian Switzerland. For key to symbols and grain sizes see Fig. 4B.

northwest of borehole Hühnerberg 546/1965. Therefore, it can be demonstrated that each transgression of shallow-marine, sandy strata of the Oberhäslich Formation (early Early, late Early, Middle and early Late Cenomanian) was accompanied by a contemporaneous fluvial cycle in DS Ce 1+2, 3, 4 and 5, respectively, reflecting the non-marine onlap during the Cenomanian transgressions.

The datum unconformity, SB Ce 5, is well-marked in the western part of cross-section 4 (Königstein and Rosenthal–Tisá palaeovalleys), overlain by fine-grained sandstones (Pennrich Formation) and in part calcareous lithofacies (marlstones and Pläner of the Dölzschen Formation). In the Úštěk–Bad Schandau Sea Bight, a late highstand progradation below SB Ce 5 and the overlying argillaceous *plenus* Horizon are well-developed in the Nasser Grund 1/2018 and Hinterhermsdorf 442/1966 sections while grain-size shift at the unconformity surface in Schmilka 432/1966 is faint. The upper Upper Cenomanian succession in the Rosenthal–Tisá Palaeovalley up to the Lohmgrund Horizon reaches up 27 m in thickness and medium to coarse grain sizes, reflecting persisting terrigenous input from the west-southwest, while to northern Königstein Palaeovalley was sediment-starved filled only with 3–4-m-thick glauconitic, fine-grained siliciclastics of the Pennrich Formation. In the Úštěk–Bad Schandau Sea Bight, the Pennrich Formation slightly decreases in thickness from west to east (20 m vs. 20 m vs. 15 m) in the three drillings. Characteristic for the Dölzschen and Pennrich formations of the Úštěk–Bad Schandau Sea Bight and the Rosenthal–Tisá PV is the tripartition, comprising lower (a), middle (b) and upper (c) parts (see Fig. 12).

In summary it can be stated that Cenomanian deposits of the drillings Nasser Grund 1/2018, Schmilka 432/1966 and Hinterhermsdorf 442/1966 reach the maximum thickness of the Saxonian Cretaceous Basin of 100–120 m (Table 2). This results in sedimentation rates of 20 m/myr in the Úštěk–Bad Schandau Sea Bight which is rather low.

5.2 Sequence stratigraphy, palaeogeography and putative basin inversion

The sequence stratigraphy of the Cenomanian stage has been studied in considerable detail for more than three decades now (e.g. Robaszynski et al. 1993, 1998; Wilmsen 2003; Haq 2014). According to the mentioned authors, there is a general consensus that, after a conspicuous sea-level fall and lowstand across the Albian–Cenomanian boundary (e.g. Bornemann et al. 2017), the age was characterised by a retrogradational stack of five depositional sequences (DS Ce 1–5) and the lower part of a following sequence (DS Ce-Tu 1) culminating in a global earliest Turonian maximum flooding interval (mfs K140 of Sharland et al. 2001; Lohmgrund Horizon of this paper; see Figs. 2, 13, 15). During the ca. 6-myr-long time interval, one of the largest Phanerozoic transgressions took place (e.g. Hallam 1992), with an estimated overall eustatic rise in sea-level in the order of 70–100 m (Wilmsen 2003; Kuhnt et al. 2009; Haq 2014). Each of the Cenomanian transgressions overstepped the preceding one, producing an overall retrogradational stack of facies units and depositional sequences. The excellent trans-continental correlation of the depositional sequences and their bounding unconformities (SB Ce 1–5; e.g. Gale et al. 2002) within the close-meshed integrated stratigraphic framework of the Cenomanian Stage suggest that climatically driven eustasy was the main cause of the observed short-term sea-level changes (Ray et al. 2019). The only adaption applied to the established Cenomanian sequence stratigraphic subdivision is the combination of DS Ce 1 and 2 to a composite early Early Cenomanian depositional sequence DS Ce 1+2, comprising the larger part of the *M. mantelli* Zone (Figs. 2, 15). The reason for this combination is the growing body of evidence that SB Ce 1 is a subordinate surface compared to the succeeding SB Ce 2 that equates to the Sub-*dixoni* Erosion Surface in the Anglo-Paris Basin (Wright et al. 2017) and that the respective stratigraphic interval in-between corresponds to a high-frequency sequence of less than 500 kyr duration (see also Haq 2014). Thus, it has been integrated into the new DS Ce 1+2, and SB Ce 2 is subdividing the Early Cenomanian into two almost equally long depositional sequences of 3rd order.

The principal sequence stratigraphic subdivision of the Cenomanian is well reflected in the temporal and spatial distribution of the strata of the lower Elbtal Group. The general representation of the different lithostratigraphic units in Cenomanian depositional sequences DS Ce 1+2 to DS Ce-Tu 1 is shown in Figs. 13 and 15. It should be emphasised that the sea-level falls and lowstands that punctuated the overall 2nd-order Cenomanian rise were rather short and of relatively low magnitude. Thus, erosion at sequence boundaries was limited and accumulation prevailed in the depositional systems documented by the Cenomanian strata of the Elbtal Group. Such unconformities, at which accommodation was never markedly negative, were termed type 3 sequence boundaries by Schlager (1999). From the eastern Erzgebirge and southeastern Dresden via the Pirna Palaeovalley and Bad Schandau to Hinterhermsdorf in the Saxonian Switzerland (columns 3–5 in Fig. 13), non-marine and marine deposition started with the lower Lower Cenomanian depositional sequence DS Ce 1+2. The onlap surface thus corresponds to the *ultimus*/*Aucellina* Transgression of the lower *M. mantelli* Zone, originally identified in northern Germany (Ernst et al. 1983; see also Bornemann et al. 2017). The *primus* Transgression of DS Ce 4 had a major magnitude with a wide spread of marine Middle Cenomanian strata while Cretaceous sedimentation in the Rosenthal–Tisá Palaeovalley (column 6 in Fig. 13) partially did not start before the late Late Cenomanian with onlap during the *plenus* transgression (DS Ce-Tu 1).

5.2.1 Cenomanian palaeotopography

Especially during the Early and Middle Cenomanian, the deposition in the study area was strongly influenced by the pre-Cenomanian palaeotopography (see also Malkovský 1976 and Klein et al. 1979 for the Bohemian Cretaceous Basin). Likewise, Tröger & Voigt (2000) were of the opinion

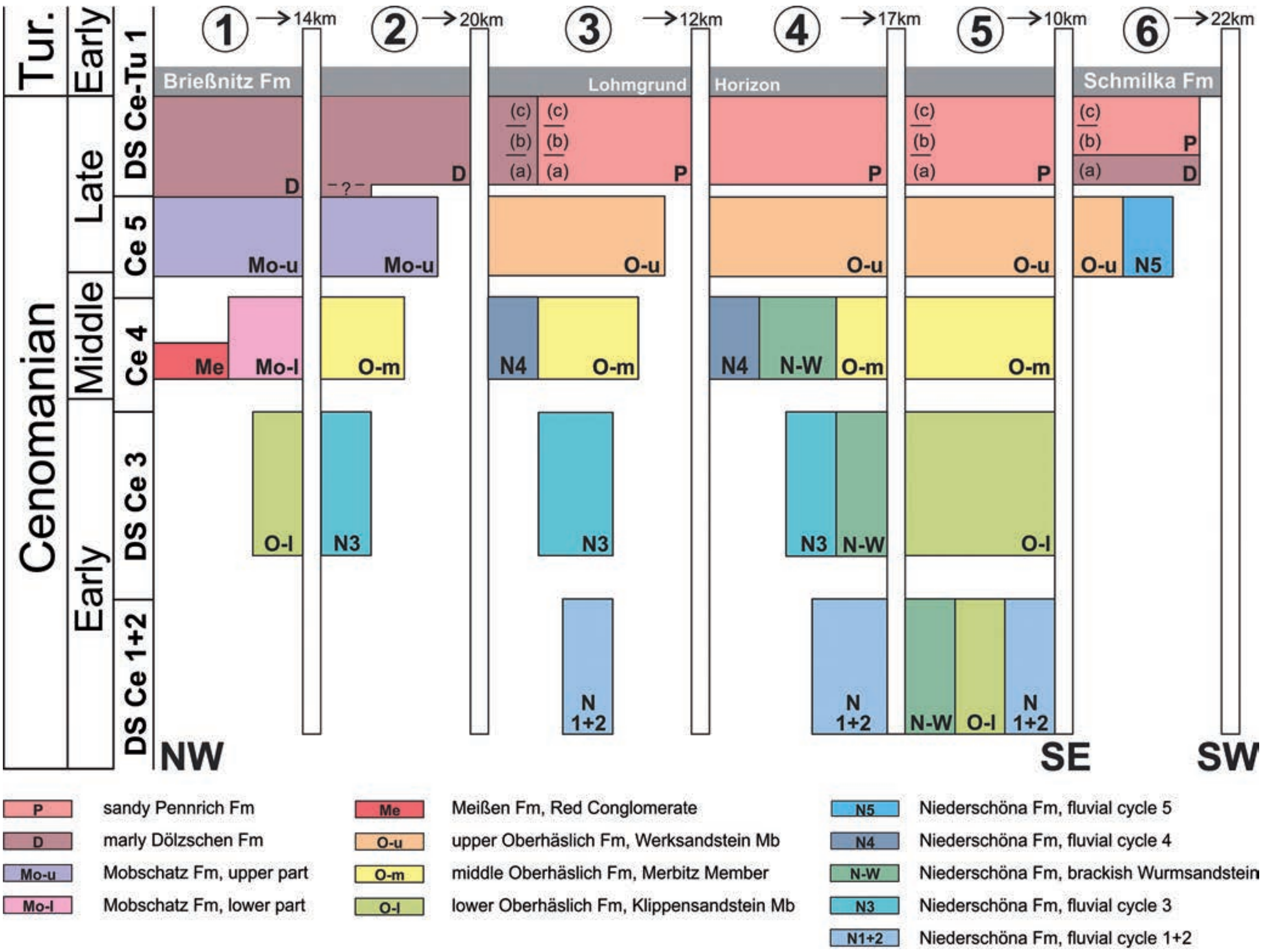


Fig. 13: Schematic representation of the different lithostratigraphic units of the Elbtal Group in Cenomanian depositional sequences DS Ce 1+2 to lower DS Ce-Tu 1. Numbers 1–6 refer to different depositional domains within the Saxonian Cretaceous Basin: 1 – Meißen–Niederau; 2 – northwestern Dresden; 3 – southern Dresden to eastern Erzgebirge; 4 – Pirna and western Königstein palaeovalleys; 5 – Bad Schandau–Hinterhermsdorf (Úštěk–Bad Schandau Sea Bight); 6 – Rosenthal–Bielatal.

that "relief differences of more than 100 m are within the realm of possibility". The more than 40 km long N–S-striking western margin of the Úštěk–Bad Schandau Sea Bight can be traced from the Lusatian Thrust Fault north of Bad Schandau via the German/Czech border to Hřensko and Děčín, is crossing the NE–SW-striking Erzgebirgsabbruch/Krušné hory Fault Zone and ends at the NW–SE-striking Labe Fault Zone near Úštěk in the south (cf. Uličný et al. 2009a: fig. 6). The exact N–S-direction of this depression does not correspond to any of the known fault systems (see Jelínek et al. 2020). On Saxonian territory, the western margin forms a ramp, several tenths of metres in height, gently sloping eastwards. The Cenomanian sea bight east of this structure (Úštěk–Bad Schandau Sea Bight of this paper; see Figs. 14A, B) is completely filled with fully-marine sediments, the deposition of which already started with the earliest Cenomanian transgression of DS Ce 1+2, corresponding to genetic sequence CEN 1 on Czech territory (Western Trunk Palaeovalley of Uličný et al. 2009a: 599, figs. 13, 14D1, 15B; app. 1, D1).

The Rosenthal–Tisá Palaeovalley was first flooded in early Late Cenomanian times (e.g. Schmilka 432/1966 vs. Hühnerberg 546/1965; Figs. 12, 14D). On Czech territory near Třebušín the fluvial Western Palaeodrainage System discharged into this embayment (Uličný et al. 2009a: fig. 11) while the fluvial Niederschöna Palaeodrainage System of Saxony probably flowed via the Pirna and Königstein palaeovalleys directly into the Boreal shelf sea to the north (Fig. 14A, B; Voigt 1998). The Early Cenomanian palaeotopography of the Tharandt Palaeovalley of the eastern Erzgebirge was in the order of 30 m and is well-reflected in cross-section 2 (Fig. 10). The palaeohighs separating the Heidenau, Pirna and Königstein palaeovalleys (Copitz Peninsula, Wehlen Island and Bahra–Königstein Peninsula; Tonndorf 2000; see Figs. 1B, 14A–D) also exhibit a palaeotopographic difference to the centres of the palaeovalleys of several tenth of metres (e.g. Meuschaer Höhe 1251/1961 vs. Dresden-Großzschachwitz 1257/1963, Fig. 9; Pirna-Neugraupa G.1/1960 vs. Porschendorf 358/1966 and Lohmen 7030/2000, Fig. 11; Pirna-Struppen 7025/1999 *vs*. Königstein-Halbestadt 7016/1997, Figs. 11, 12).

5.2.2 Depositional sequence DS Ce 1+2 (Fig. 14A)

The oldest transgression of both the SCB and BCB is represented in the Úštěk–Bad Schandau Sea Bight at the German/Czech border (Schmilka 432/1966 as well as e.g. Hřensko J-364 146 and Smordov J-582 380 in Czechia; see Fig. 1B). The conglomerates and coarse-grained sandstones of the lower Klippensandstein Member of the Oberhäslich Formation and the subtidal, sandstone-dominated facies of the Korycany Member of CEN 1 (Uličný et al. 2009a) are of early Early Cenomanian age according to the integrated correlation presented herein. The time-equivalent brackish Wurmsandstein of the Niederschöna Formation was deposited at the transition to the Königstein Palaeovalley north of Bad Schandau (core Nasser Grund 1/2018; Figs. 1B, 12, 14A). The fluvial cycle 1+2 is known as infill of the lowest part of the palaeovalleys (PV), e.g. from the Hinterhermsdorf–Jetřichovice PV (Hinterhermsdorf 442/1966 and Jetřichovice J-187209; Figs. 1B, 12), the Pirna PV (Porschendorf 358/1966, Lohmen 7030/2000, Dorf Wehlen 7029/1999 and Pirna-Struppen 7025/1999; Figs. 1B, 11) as well as the Tharandt PV of the eastern Erzgebirge (Rabenau-Oelsa 7/1991 and Halsbrücke-Niederschöna 4/1996; Figs. 1B, 10). The Niederschöna Drainage System reached the area of Freiberg from the south-southwest as indicated by the index mineral amethyst from Wolkenstein, middle Erzgebirge, in the basal conglomerates of the Niederschöna Formation at several localities of the Tharandt Palaeovalley (Leutwein 1951; Prescher 1957; Göhler 2008; see Fig. 14A). In the northern to central Elbe Valley between Meißen and SE Dresden, neither fluvial nor marine sediments are currently known to correspond to DS Ce 1+2 (Fig. 14A).

5.2.3 Depositional sequence DS Ce 3 (Fig. 14B)

The sedimentary unconformity between DS Ce 1+2 and DS Ce 3, the mid-Early Cenomanian SB Ce 2, is well reflected in the palaeovalleys where it delineates the two conspicuous early Cenomanian fluvial and/or brackish cycles of the Niederschöna Formation (e.g. Halsbrücke-Niederschöna 4/1996, Rabenau-Oelsa 7/1991, Lohmen 7030/2000, Dorf Wehlen 7029/1999 and Pirna-Struppen 7025/1999). In the Úštěk–Bad Schandau Sea Bight, it separates brackish to fluvial deposits of the Niederschöna Formation below from overlying marine sandstones (Klippensandstein Member of the Oberhäslich Formation) and is only difficult to identify in the continuously marine section of the Schmilka 432/1966 core (cross-section 4, Fig. 12). The succeeding late Early Cenomanian transgression of DS Ce 3 enlarged the Úštěk–Bad Schandau Sea Bight, indicated by the onlap of marine deposits onto its margins seen at Bad Schandau (Nasser Grund 1/2018) and in the northern part of the Hinterhermsdorf–Jetřichovice PV (Hinterhermsdorf 442/1966; Fig. 14B). Furthermore, the Klippensandstein Member of the Oberhäslich Formation reflects marine onlap in the northwesternmost Elbe Valley (cross-section 1; Fig. 9) where the lower Cenomanian ammonite *Schloenbachia varians* is known from shallow-marine sandstones in the Niederau-Oberau railway slope cut (Wilmsen et al. 2019a). Also, the fluvial deposits of DS Ce 3 (fluvial cycle 3) have a wider distribution than those of the underlying fluvial cycle 1+2, reflecting the concomitant non-marine onlap during the late Early Cenomanian. They are also preserved as erosion remnants in the Elbe Valley around Dresden and in the Heidenau PV (Dresden-Merbitz 249/1966, Dresden-Zschertnitz 289/1966, Dresden-Hosterwitz 212/1966 and Dresden-Großzschachwitz 1257/1963; Figs. 1B, 9). Furthermore, the fluvial strata in Dresden-Hellerau (Seifert 1938; Niebuhr 2018) most likely belong to this depositional sequence. In the Pirna Palaeovalley, DS Ce 3 is represented by the brackish Wurmsandstein in the north (Porschendorf 358/1966, Lohmen 7030/2000 and Dorf Wehlen 7029/1999) and fluvial facies in the south (Pirna-Struppen 7025/1999 and Pirna-Krietzschwitz 7006/2001, also in the composite Bahratal section; Figs. 1B, 11). The western Königstein Palaeovalley (Königstein-Halbestadt 7016/1997 and Königstein K.1/1960; Figs. 1B, 12) are also represented by fluvial cycle 3 in this depositional sequence; the latter borehole was measured by Krutzsch (1963). Also, in the Tharandt Palaeovalley, fluvial facies continued during DS Ce 3. At the type locality of the Niederschöna Formation (core Halsbrücke-Niederschöna 4/1996, outcrops at the Forsthaus), the succession below SB Ce 3 is characterised by closely spaced root horizons and incipient palaeosols which is typical for fluvial settings under low accommodation conditions during a late highstand (Kraus 1999). The persistence of fluvial facies in the Tharandt PV during DS Ce 3 may indicate that the mouth of the Niederschöna Palaeodrainage System was in fact located in the Pirna Palaeovalley, finally discharging to the north. In the southern part of the Hinterhermsdorf–Jetřichovice PV (Jetřichovice J-187209; acc. Valečka 1979, cited in Uličný et al. 2009a), estuarine conditions prevailed during DS Ce 3. The assumption of Uličný et al. (2009a) that the fluvial Niederschöna Formation of the Tharandt Palaeovalley, eastern Erzgebirge (fluvial cycles 1+2 and 3, Lower Cenomanian; see Figs. 13, 15), is older than the subtidal sandstone-dominated facies with abundant ichnofossils and bivalve shells of CEN 1+2 in the Western Trunk Palaeovalley, e.g. the Czech part of the Úštěk–Bad Schandau Sea Bight, cannot been confirmed.

5.2.4 Depositional sequence DS Ce 4 (Fig. 14C)

The basal unconformity of DS Ce 4, the latest Early Cenomanian SB Ce 3, is well developed as a palaeosol in the Tharandt Palaeovalley (cross-section 2; Fig. 10) and can also be traced from brackish to fluvial facies in the Pirna Palaeovalley (cross-section 3; Fig. 11). In the Úštěk–Bad Schandau Sea Bight (cross-section 4; Fig. 12), it has been identified at the junction of the Klippensandstein and the Merbitz members of the Oberhäslich Formation, separating non-glauconitic siliciclastics below from glauconitic and fossiliferous, lithologically more variable strata above (for the enhanced glaucony formation in this interval, see Wilmsen & Bansal 2021). The early Middle Cenomanian *primus* Transgression (transgressive systems tract of DS Ce 4) flooded the palaeovalleys of the Niederschöna Palaeodrainage System and inundated large parts of the hitherto emergent basement of the Meißen Massif and the eastern Erzgebirge – from Niederau to Coswig, western Dresden via Halsbrücke-Niederschöna to the Bahratal in the Saxonian Switzerland (see cross-sections 1–3; Figs. 9–11, 14C). Only at the fringes of the few remaining palaeohighs (Meuschaer Höhe 1251/1961, Königstein-Halbestadt 7016/1997, Pirna-Neugraupa G.1/1960), near Rosenthal (Schweizermühle 1013/1961) and in the southern Pirna PV (Pirna-Struppen 7025/1999, Pirna-Krietzschwitz 7006/2001, Langenhennersdorf and Bahratal sections), small areas with fluvial or brackish conditions persisted, representing backfilled remnants of the former palaeovalleys. A very few shallow islands also remained in the Elbe zone, e.g. in Dresden-Löbtau (core Nossener Brücke, cross-section 2; Fig. 10) and in Dresden-Plauen (Tröger 1956; Voigt et al. 1994; Voigt et al. 2006) as well as in Dresden-Lockwitz and Dohna (e.g. Wilmsen et al. 2011). In the northwestern part of the study area (Niederau), the *primus* Transgression is reflected by the glauconitic, belemnite-bearing Oberau Conglomerate, followed by the deposition of offshore sediments (Pläner) during DS Ce 4 (Wilmsen et al. 2019a).

In the Elbe Valley between Dresden (Waldschule Dresden 218/1966) and the Úštěk–Bad Schandau Sea Bight in the Saxonian Switzerland (Nasser Grund 1/2018, Schmilka 432/1966 and Hinterhermsdorf 442/1966), parallel to the course of the Lusatian Thrust Fault (see Fig. 1B), the Merbitz Member of the Oberhäslich Formation reaches thicknesses of 18 m, 14–16 m, 11–17 m and 21 m (Fig. 14C) – regardless of whether the transgression of DS Ce 4 proceeded above the marine Klippensandstein Member of the Oberhäslich Formation or the fluvial strata of the Niederschöna Formation in the former palaeovalleys. The new data also suggests that the deposition of the well-known marine sandstones at Dresden-Weißig (Klemm 1888, 1892; Lapp et al. 2017; Niebuhr 2018) and Dresden-Hellerau (Seifert 1938; Niebuhr 2018) started in the Middle Cenomanian. On the eastern Erzgebirge, the Merbitz Member reaches an average thickness of 10 m in the Tharandt Forest (Niebuhr et al. 2021), 8 m in the Paulsdorfer Heide (Janetschke & Wilmsen 2014), as well as 5 m in Halsbrücke-Niederschöna (Halsbrücke-Niederschöna 4/1996), the Dippoldiswalder Heide (Rabenau-Oelsa 7/1991 and sandstone quarry Schmidt) and between Dresden-Merbitz and Bannewitz (see cross-sections 1 and 2; Figs. 9, 10). The thickness variation of the Merbitz Member thus reflects a distal–proximal gradient from north to south.

In a nutshell, the *primus* Transgression of DS Ce 4 was the most striking Cenomanian transgression in the Saxonian Cretaceous Basin (Wilmsen et al. 2022) with the largest lateral spread of marine deposits. It corresponds in the Bohemian Cretaceous Basin to the boundary between genetic sequences CEN 2 and CEN 3; consequently, genetic sequence CEN 3 is marked by a significant flooding of much of the BCB which merged into a single depositional area during this time (Uličný et al. 2009a).

5.2.5 Depositional sequence DS Ce 5 (Fig. 14D)

A late Middle Cenomanian sea-level fall and lowstand caused the development of SB Ce 4 which is a conspicuous sedimentary unconformity across the eastern Erzgebirge (cross-section 2; Fig. 10), separating the Merbitz Member below from the Werksandstein Member above. It is more difficult to identify in the Oberhäslich Formation of the Elbe Valley sections to the north (cross-section 1; Fig. 9) but is well developed by striking facies and/or grain-size shifts in the Pirna, Königstein and Rosenthal–Tisá palaeovalleys as well as in the Úštěk–Bad Schandau Sea Bight (Figs. 11, 12). Deposition of DS Ce 5 started with the early Late Cenomanian *naviculare* Transgression. In the northwestern Elbe Valley, the deeper marine marly upper Mobschatz Formation was deposited (Niederau-Gröbern 2/1991, Nossener Brücke and Dresden-Merbitz 249/1966; Figs. 1B, 9; Wilmsen et al. 2019a). To the south and southeast, widespread uniform sedimentation of fine- to medium-grained, homogenous sandstones of the Werksandstein Member of the Oberhäslich Formation prevailed across large parts of the depositional space of the Elbtal Group, producing a famous freestone all across the eastern Erzgebirge (Niebuhr et al. 2021). For the first time, also the Pirna and Königstein palaeovalleys were connected by partial flooding of the area between the Wehlen Island and the Königstein Peninsula (Tonndorf 2000).

During the *naviculare* Transgression, also the relief at the western margin of the Úštěk–Bad Schandau Sea Bight was finally levelled and the Rosenthal–Tisá PV to the west was involved into deposition for the first time. Accommodation was filled with a 12-m-thick Werksandstein Member and time-equivalent 21-m-thick fluvial deposits (fluvial cycle 5), e.g. at Hühnerberg 546/1965 and Schweizermühle 1013/1961 (Figs. 12, 14D). In the sections of the eastern Erzgebirge, the Werksandstein Member reaches thicknesses of 5–10 m (Niebuhr et al 2021; see cross-section 2 and section 20: Hartheberg; Figs. 10, 14D). The area around Tharandt-Großopitz (section 19) was first involved into deposition, but only a ca. 2-m-thick succession rests on top of the Freiberger Gneiss. In some of the boreholes based on descriptions from the 1960s, sequence boundary SB Ce 4 cannot readily be identified (see above) and, therefore, the delineation to the underlying Merbitz Member sometimes remains open (e.g. see cross-section 1). However, in the boreholes where SB Ce 4 was observed, the Werksandstein Member reaches 10–15 m in the central Elbe Valley in Dresden, 17–20 m in the Pirna PV, and 22–23 m in the Úštěk–Bad Schandau Sea Bight (Figs. 9–12, 14D, Table 1). Together with the regular thickness variations within the underlying Merbitz Member (see above), these observations strongly suggest that thickness changes in the Cenomanian strata of the Elbtal Group are unrelated to any perceived early activity of the northwest–southeast orientated Lusatian Thrust Fault (cf. Voigt et al.

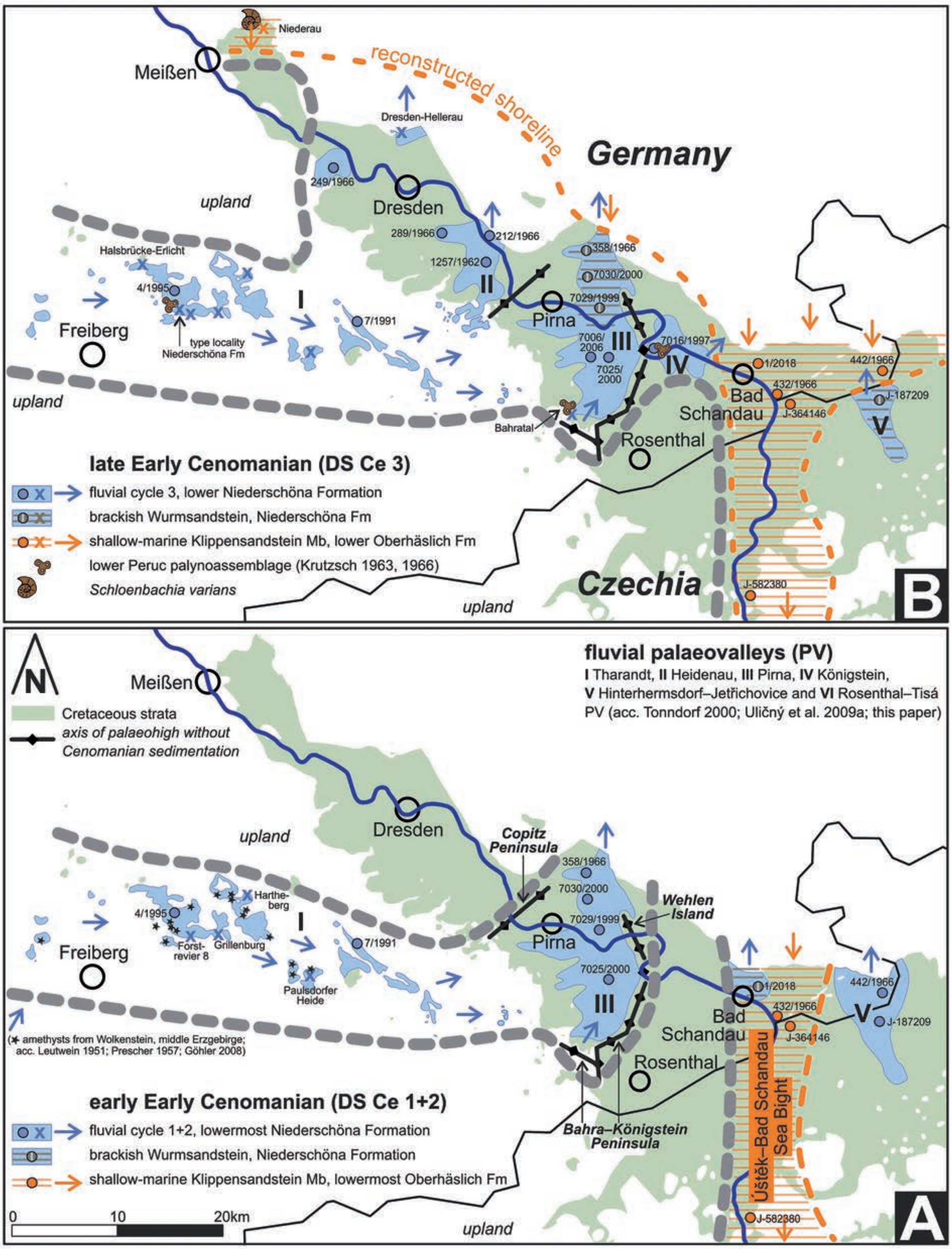


Fig. 14: Palaeogeography of the study area in time slices; arrows: assumed directions of blue = fluvial transport, and orange = marine transgressions. (**A**) Early Early Cenomanian depositional sequence DS Ce 1+2. (**B**) Late Early Cenomanian DS Ce 3. (**C**) Middle Cenomanian DS Ce 4. (**D**) Early Late Cenomanian DS 5 and 5th transgression on pre-Cretaceous substrate in DS Ce-Tu 1 (Dölzschen and Pennrich formations).

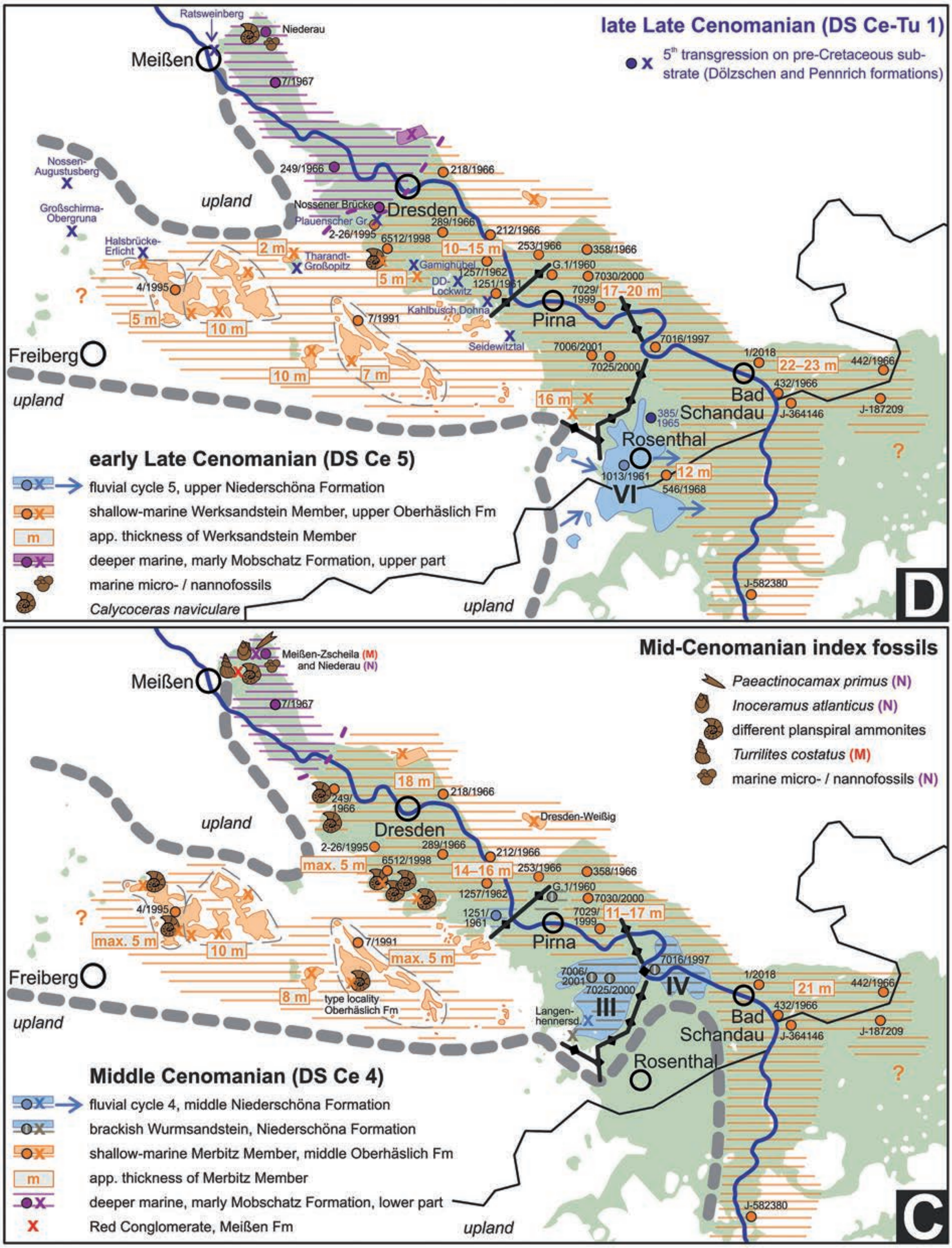

late Late Cenomanian (DS Ce-Tu 1)
5th transgression on pre-Cretaceous substrate (Dölzschen and Pennrich formations)
Ratsweinberg
Niederau
Meißen
7/1967
Nossen-Augustusberg
Großschirma-Obergruna
Halsbrücke-Erlicht
upland
249/1966
218/1966
Nossener Brücke
Plauenscher Gr.
Dresden
2-26/1995
6512/1998
289/1966
212/1966
2 m
Tharandt-Großopitz
10–15 m
253/1966
358/1966
Gamighübel
257/1962
G.1/1960
7030/2000
4/1995
5 m
DD-Lockwitz
1251/1961
7029/1999
17–20 m
Kahlbusch Dohna
Pirna
5 m
10 m
7/1991
Seidewitztal
7016/1997
Freiberg
7006/2001
7025/2000
1/2018
10 m
7 m
22–23 m
442/1966
Bad Schandau
432/1966
upland
16 m
385/1965
J-364146
J-187209
Rosenthal
early Late Cenomanian (DS Ce 5)
fluvial cycle 5, upper Niederschöna Formation
1013/1961
12 m
shallow-marine Werksandstein Member, upper Oberhäslich Fm
VI
546/1968
app. thickness of Werksandstein Member
deeper marine, marly Mobschatz Formation, upper part
marine micro- / nannofossils
J-582380
Calycoceras naviculare
upland
D
Meißen-Zscheila (M) and Niederau (N)
Mid-Cenomanian index fossils
Meißen
7/1967
Paeactinocamax primus (N)
Inoceramus atlanticus (N)
different planspiral ammonites
Turrilites costatus (M)
marine micro- / nannofossils (N)
18 m
218/1966
249/1966
upland
Dresden-Weißig
Dresden
2-26/1995
289/1966
212/1966
max. 5 m
6512/1998
14–16 m
253/1966
358/1966
G.1/1960
1257/1962
7030/2000
4/1995
1251/1961
7029/1999
11–17 m
max. 5 m
10 m
7/1991
Pirna
max. 5 m
7016/1997
Freiberg
7006/2001
7025/2000
IV
1/2018
21 m
442/1966
8 m
type locality Oberhäslich Fm
III
Bad Schandau
432/1966
upland
Langen-hennersd.
J-364146
J-187209
Rosenthal
Middle Cenomanian (DS Ce 4)
fluvial cycle 4, middle Niederschöna Formation
brackish Wurmsandstein, Niederschöna Formation
shallow-marine Merbitz Member, middle Oberhäslich Fm
app. thickness of Merbitz Member
deeper marine, marly Mobschatz Formation, lower part
J-582380
Red Conglomerate, Meißen Fm
upland
C

Fig. 14: cont.

2021) but to the arrangement along the Elbe Zone and to distal–proximal gradients.

5.2.6 Depositional sequence DS Ce-Tu 1 (Cenomanian part only)

The mid-Late Cenomanian sequence boundary SB Ce 5 forms a conspicuous, easily correlatable sequence stratigraphic surface across all investigated sections; consequently, it was used as a datum line in all four cross-sections (Figs. 9–12). It is always overlain by strongly retrogradational facies stacks, either siliciclastic, calcareous or mixed, related to the latest Cenomanian *plenus* Transgression (e.g. Schander 1923; Häntzschel 1933; Tröger 1956, 2003; Voigt et al. 1994; Voigt et al. 2006; Wilmsen et al. 2011; Janetschke & Wilmsen 2014). Up to the overlapping marker bed of the fine-grained Lohmgrund Horizon at the base of the overlying Brießnitz and Schmilka formations (Fig. 13), reflecting the earliest Turonian maximum flooding interval (maximum flooding surface K140 of Sharland et al. 2001, also seen in the curve of Haq 2014), the uppermost Cenomanian Dölzschen and Pennrich formations represent the transgressive systems tract (TST) of DS Ce-Tu 1. A brief interruption of the sea-level rise at the Cenomanian–Turonian boundary is reflected by a commonly weak progradation seen in some sections (e.g. borehole Schweizermühle 1013/1961) just below the Lohmgrund Horizon (e.g. Wilmsen et al. 2011; Janetschke & Wilmsen 2014; see also Richardt et al. 2013 for the Danubian Cretaceous Basin).

The marly-argillaceous Dölzschen Formation of the northwestern Elbe Valley and Dresden has thicknesses of 20–16 m (Niederau-Gröbern 2/1991, Waldschule Dresden 218/1966, core Nossener Brücke, Dresden-Zschertnitz 289/1966). Contrary, the sandy Pennrich Formation is always thinner, reaching 3–6 m in Königstein-Halbestadt 7016/1997 and the Pirna Palaeovalley (e.g. Pirna-Großgraupa 253/1966, Pirna-Struppen 7025/1999, Pirna-Krietzschwitz 7006/2001) as well as 8–12 m in Dresden (Dresden-Hosterwitz 212/1966, Dresden-Großzschachwitz 1257/1963) and Bonnewitz-Boderitz 6512/1998 (cross-sections 1 and 2; Figs. 9, 10). In most of the sections on the eastern Erzgebirge, the top of the Pennrich Formation is not preserved due to Cenozoic erosion. Only at the Hartheberg, the area around Tharandt-Großopitz and the core Mariaschacht 6512/1998 in Bannewitz-Boderitz preserve a complete Pennrich Formation, maximal 15 m in thickness, overlain by the Lohmgrund Horizon of the Schmilka Formation (Figs. 1B, 10).

The Cenomanian part of DS Ce-Tu 1 often shows a tripartition, both in the marly and sandy facies, demonstrated such as by the correlation of the 20-m-thick marly Dölzschen Formation of the Nossener Brücke core vs. the 12-m-thick sandy Pennrich Formation of the Mariaschacht 6512/1998 in Bannewitz-Boderitz, located only 4.3 km to the south (see Fig. 10). Especially the middle (b) part bears strongly glauconitic sediments (e.g. Dresden-Großzschachwitz 1257/1996, Hühnerberg 546/1965, Nasser Grund 1/2018, Schmilka 432/1966). Wilmsen & Bansal (2021) suggest that the glaucony formation in this interval is related to the palaeoenvironmental effects of Oceanic Anoxic Event (OAE) 2. In the expanded sections in the Úštěk–Bad Schandau Sea Bight of the Saxonian Switzerland between Bad Schandau and Hinterhermsdorf, the tripartite Pennrich Formation has sediment thicknesses of 15–20 m (Table 3). In the Rosenthal–Tisá Palaeovalley, the lower (a) part of the upper Upper Cenomanian has been assigned to the marly Dölzschen Formation (Schweizermühle 1013/1961, Hühnerberg 546/1965, Reichstein 385/1965) whereas the following middle (b) and upper (c) parts belong to the sandy Pennrich Formation, each showing a coarsening-upward trend. These cycles most likely represent parasequences forming the TST of DS Ce-Tu 1. In this area, the maximum thickness of the Cenomanian part of DS Ce-Tu 1 is reached (27 m in Schweizermühle 1013/1961), reflecting the landward-shift of the depocentres during the TST of DS Ce-Tu 1, while distal settings, e.g. in the Pirna and western Königstein palaeovalleys (see Figs. 11, 12) were sediment-starved.

Strata of the *plenus* Transgression that rest directly on top of the pre-Cretaceous substrate (5th Cenomanian transgression in Figs. 14D, 15) are documented from different areas (for locations see Figs. 1B, 14D): (A) The Riesenstein Granite at the Ratsweinberg in Meißen, northwesternmost Elbe Valley, was first flooded by fossil-rich glauconitic Pläner of the Dölzschen Formation (Wilmsen et al. 2019a). (B) In the well-known rocky shore facies of the Dölzschen Formation (e.g. at Hoher Stein, Teichbruch and Ratssteinbruch in the Plauenscher Grund in Dresden, section 12; Gamighübel; Dresden-Lockwitz; Kahlbusch in Dohna, section 9; Seidewitztal; Schander 1923; Tröger 1956, 1969, 2003; Voigt et al. 1994; Voigt et al. 2006; Wilmsen et al. 2011; this paper). (C) Around Tharandt-Großopitz up to 8 m thick “Plänersandsteine” (of the Pennrich Formation) transgress directly on top of the Freiberg gneiss, followed by the clayey Lohmgrund Horizon of earliest Turonian age (section 19). (D) The Pennrich Formation north of Halsbrücke-Erlicht (section 23) overlies the Oberhäslich Formation as well as the Palaeozoic basement in that area. (E) The westernmost exposures of the upper Upper Cenomanian Pennrich Formation that were found between Nossen and Großschirma (eastern Erzgebirge, section 24). (F) In the borehole Reichstein 385/1965, east of Bielatal, the marly-argillaceous Dölzschen Formation is resting directly on top of the Palaeozoic basement (section 35).

The magnitude of the *plenus* Transgression was similar to that of the early Mid-Cenomanian *primus* Transgression, ranging between 30–50 m (Voigt et al. 2006; Wilmsen 2007; Richardt et al. 2013). The Lohmgrund Horizon at the base of the overlying Brießnitz, Schmilka and Oybin formations in Saxony (Figs. 2, 13, 15) and a corresponding horizon at the base of the Bílá Hora Formation in the Bohemian Cretaceous Basin match the lower boundary of genetic sequence TUR 1 in Czechia (Uličný et al. 2009b), a basinwide maximum transgressive surface.

The basal Turonian Lohmgrund Horizon correlates to the maximum flooding of the 2nd order trans-/regressive Early Cenomanian–Late Turonian depositional cycle (Fig. 15) that has been identified in basins around the Mid-European Is-

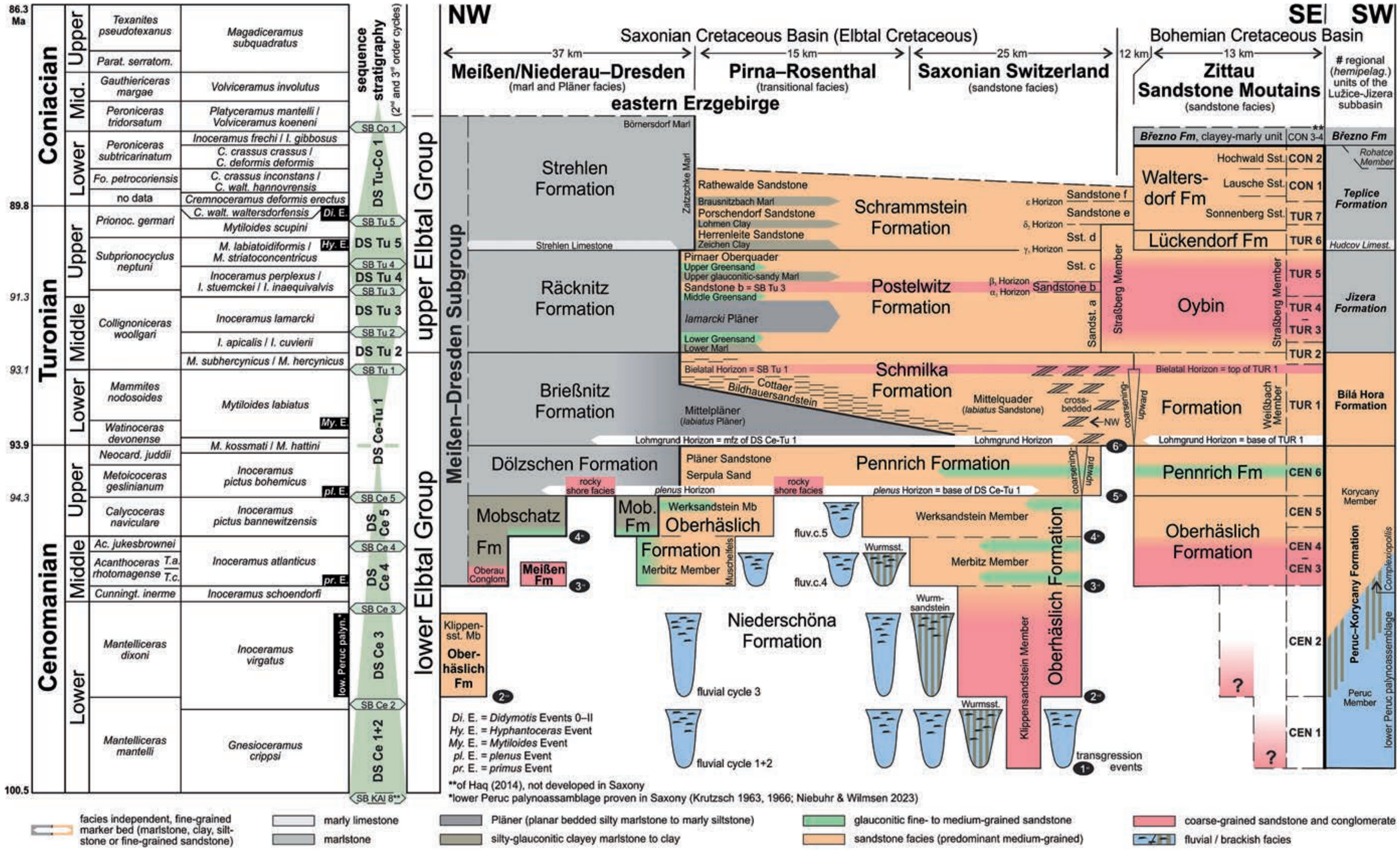


Fig. 15: Revised detailed chrono-, bio-, litho- and sequence stratigraphy of the Elbtal Group in the Saxonian Cretaceous Basin and the northwestern Bohemian Cretaceous Basin (sequence stratigraphy and Cenomanian part completely new, Turonian–Coniacian modified after Niebuhr et al. 2020: fig. 2); 1st–6th = major transgressions on pre-Cretaceous substrate that enlarged the depositional area considerably; ** – genetic sequences according to Uličný et al. (2009a, b), Nádaskay & Uličný (2014) and Nádaskay et al. (2019); # – schematic regional lithostratigraphic units of the Lužice–Jizera subbasin according to Nádaskay et al. (2019: fig. 1C). The age of the first Cenomanian transgression in the Zittau Sandstone Mountains is questionable.

land (Niebuhr et al. 2014; Wilmsen et al. 2019b). The former palaeohighs around Pirna (Copitz Peninsula, Wehlen Island and the Bahra–Königstein Peninsula; Tonndorf 2000) were flooded. Likewise, in the area around Berggießhübel and Rosenthal, Saxonian Switzerland, the Schmilka Formation transgressed directly onto the Palaeozoic basement (Beck 1888, 1889: 71). Henceforth, the Saxonian Cretaceous Basin was linked in the southeast to the Bohemian Cretaceous Basin across a broad front. Only the Markersbach Granite south of the former Bahra Peninsula near Bad Gottleuba (see Fig. 14A) stayed emergent and formed an island until the Middle Turonian (Seifert 1955; Tonndorf 2000).

5.2.7 Putative Cenomanian basin inversion

Voigt (2009) and recently Voigt et al. (2021) proposed, based on borehole data, facies distribution and thickness maps, that tectonic inversion in several basins of Central Europe, including the Saxonian and Bohemian Cretaceous basins, already started within the Cenomanian, at 95 Ma (Middle–Late Cenomanian boundary interval), ca. 5 myr earlier than commonly assumed (cf. Kley & Voigt 2008). Also, Uličný et al. (2009a, b) inferred an early phase of basin-scale tectonic subsidence, accompanied by establishment of new source areas and by local intrabasinal uplifts, for the Late Cenomanian and Early Turonian. However, the reconstruction of Voigt et al. (2021) for Saxony of a reversal of the hitherto north-northeast-directed palaeodrainage, the development of a northeastern source area (Westsudetic Island; cf. Klein et al. 1979; Voigt 1994, 2009) and the formation of a northwest–southeast-directed depocentre in the Elbe Zone that is nearly identical to the later (i.e. Middle Turonian to Coniacian) marginal trough already at 95 Ma is based on the erroneous stratigraphic assumption that all marine siliciclastic deposits of the Oberhäslich Formation, up to 120 m in thickness, are Late Cenomanian in age (Voigt et al. 2021: 1452). The supposed high sedimentary thicknesses of the Upper Cenomanian along the NW margin of the Bohemian Cretaceous Basin also led Klein et al. (1979) to the assumption of the development of a trough and the uplift of a source area in the NE, i.e. the Westsudetic Island. In contrast, the stratigraphic reappraisal presented herein produces a completely different picture: the general north- to northeast-directed drainage in the palaeovalleys did not change during the Cenomanian; instead, the palaeovalleys were flooded from the north-northeast and the principal source area remained the eastern Erzgebirge in the south-southwest. The marine transgression reached the deepest depression (Úštěk–Bad Schandau Sea Bight) already in the earliest Cenomanian (DS Ce 1+2; see Fig. 14A) and their backfill followed the Cenomanian depositional sequences outlined above. The highest thicknesses are consequently realised in the deepest drowned valleys and do not follow a putative depocentre formed by a supposedly rising structure in the northeast. The maximum thickness of up to 120 m of marine Cenomanian (100–94 Ma) recorded from the Úštěk–Bad Schandau Sea Bight results in a rather low sedimentation rate of only 20 m/myr and is, in fact, congruent to the accommodation generated by the overall Cenomanian eustatic rise in sea-level (70–100 m, e.g. Wilmsen 2003; Kuhnt et al. 2009; Haq 2014) plus a low regional subsidence of a few metres per myr. The principal WNW–ESE-trend of the facies belts is related to the general advance of the Cenomanian transgression from the north while the thickness changes reflect the pre-transgression topography and simple stratigraphic (marine and non-marine) onlap patterns onto the eastern Erzgebirge in the south-southwest; large parts of the eastern Erzgebirge were already inundated during the Middle Cenomanian (Wilmsen et al. 2022). Thus, the new stratigraphic framework of the lower Elbtal Group presented herein comprehensively demonstrates that tectonic inversion in the Saxonian (and Bohemian) Cretaceous Basin was essentially a post-Cenomanian process that probably started not before the Middle Turonian, as observed in other Cretaceous basins around the Mid-European Island (e.g. Niebuhr et al. 2011). Interestingly, very similar conclusions were already drawn by Malkovský (1976, 1987: 36) for the Bohemian Cretaceous Basin; he stated that the Early and Middle Cenomanian accumulation of freshwater deposits was rather controlled by the palaeotopography than by tectonic lineaments and that the same probably applies for the Cenomanian marine series. Cautious indication for potential local tectonic movements (e.g. in the Blansko Graben, southeasternmost Bohemian Cretaceous Basin) in the Late Cenomanian were based on the supposed high thicknesses which are, however, not exceptional in the view of the new stratigraphic framework presented herein (see above). Furthermore, according to Malkovský (1976, 1987) there is no clear evidence for syndepositional tectonic activity during the Early Turonian (cf. Uličný et al. 2009b) and the Lusatian fault system became active during the Middle Turonian. In Late Turonian times during peak inversion of the Lusatian Block, sedimentation rates of ca. 175 m/myr can be reconstructed for the Winterberg area near the German/Czech border (this paper, according to Seifert 1955) while extremely high ratios of up to 340 m/myr were reached in the sandstone facies of the northwestern Bohemian Cretaceous Basin (Uličný et al. 2009b).

6. Conclusions

A completely new stratigraphic framework of the lower Elbtal Group is presented herein, based on the detailed integrated investigation of 39 stratigraphic surface and subsurface sections with Cenomanian strata that have been correlated in four cross-sections. Our study allows drawing the following conclusions:

– Cretaceous deposition started in early Early Cenomanian times in both, the Saxonian and Bohemian Cretaceous basins, indicated by contemporaneous non-marine (continental Niederschöna Formation / Peruc Member of the Peruc–Korycany Formation) and marine onlap (Oberhäslich Formation / Korycany Member of the Peruc–Korycany Formation).
– The Cenomanian transgressions proceeded in Saxony on a broad front from the north and, at first, followed the

course of roughly south–north-discharging palaeovalleys of a fluvial drainage system dewatering an elevated principal source area in the southwest. Their retrogradational backfill followed the pulsative Cenomanian sea-level rise.

- The sequence stratigraphic analysis demonstrates the presence of four complete, unconformity-bounded Cenomanian depositional sequences and a fifth one, DS Ce-Tu 1, which started in the mid-Late Cenomanian and lasted into the Early Turonian. Its basal unconformity, sequence boundary SB Ce 5, forms a conspicuous correlative surface across all investigated sections and was used as a datum line in the cross-sections.
- In total, six marine transgressions can be identified, related to the transgressive systems tracts (TST) of the depositional sequences (DS): (A) Early Early Cenomanian (equivalent to the "*ultimus/Aucellina* Transgression"), TST of DS Ce 1+2; (B) late Early Cenomanian, TST of DS Ce 3; (C) early Middle Cenomanian (*primus* Transgression), TST of DS Ce 4; (D) early Late Cenomanian (*naviculare* Transgression), TST of DS Ce 5; (E) late Late Cenomanian (*plenus* Transgression), TST of DS Ce-Tu 1; and (F) earliest Turonian (Lohmgrund Horizon), maximum flooding of DS Ce-Tu 1.
- Each transgression overstepped the preceding one, thus continuously enlarging the depositional realm by means of non-marine and/or marine onlap. The early Middle Cenomanian *primus* Transgression reflects the most striking Cenomanian sea-level rise within the Saxonian Cretaceous Basin (genetic sequence CEN 3 in the Bohemian Cretaceous Basin). Promontories, interfluves between palaeovalleys and large parts of the eastern Erzgebirge were flooded.
- The marine Oberhäslich Formation was accompanied by collateral fluvial/brackish deposits of the Niederschöna Formation during the early Early to early Late Cenomanian in DS Ce 1+2 to DS Ce 5, respectively.
- The marine transgressions reached the Úštěk–Bad Schandau Sea Bight, the deepest of the north-sloping palaeovalleys, first and produced an up to 120-m-thick marine Cenomanian sedimentary record (Oberhäslich and Pennrich formations), subdivided into five almost equally thick (20–26 m) depositional sequences. The total thickness approximately corresponds to the accommodation generated by the Cenomanian eustatic sea-level rise (70–100 m) and an overall low regional subsidence, resulting in rather low sedimentation rates of 20 m/myr.
- The thickness changes observed within the lower Elbtal Group reflect the pre-transgression topography and simple sequence stratigraphic patterns (marine and non-marine onlap) onto the eastern Erzgebirge in the southwest during the Cenomanian (and Early Turonian) age.
- The new stratigraphic framework of the lower Elbtal Group presented herein thus convincingly shows that tectonic inversion in the Saxonian Cretaceous Basin was essentially a post-Cenomanian process that probably did not really start before the Middle Turonian.

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8. References

Alexowsky, W., Wolf, L., Kurze, M., & Tröger, K.-A. (1997). *Geologische Karte des Freistaates Sachsen 1: 25 000 und Erläuterungen zu Blatt 5049 Pirna* (3rd ed.). Freiberg: Sächsisches LfUG.

Alexowsky, W., Koch, E. A., Kurze, M., Schneider, J. W., Tröger, K.-A., & Wolf, L. (1999). *Geologische Karte des Freistaates Sachsen 1: 25 000 und Erläuterungen zu Blatt 5048 Kreischa* (3rd ed.). Freiberg: Sächsisches LfUG.

Alexowsky, W., Schneider, J. W., Tröger, K.-A., & Wolf, L. (2001). *Geologische Karte des Freistaates Sachsen 1: 25 000 und Erläuterungen zu Blatt 4948 Dresden* (4th ed.). Freiberg: Sächsisches LfUG.

Allen, J. R. L. (1970). Studies in fluviatile sedimentation: A comparison of fining-upwards cyclothems with special reference to coarse-member composition and interpretation. *Journal of Sedimentary Research, 40*(1), 298–323.

Bärtling, R. (1920). Transgressionen, Regressionen und Faziesverteilung in der Mittleren und Oberen Kreide des Beckens von Münster. *Zeitschrift der Deutschen Geologischen Gesellschaft, 72*, 161–217.

Barthel, M. (1958). Ein neuer Aufschluß in den Niederschönaer Schichten. *Jahrbuch des Staatlichen Museums für Mineralogie und Geologie zu Dresden, 1958*, 102–106.

Beck, R. (1888). *Geologische Specialkarte des Königreichs Sachsen.* Blatt 102, Section 1760 Berggiesshübel (1st ed.). Leipzig: Engelmann.

Beck, R. (1889). *Erläuterungen zur geologischen Specialkarte des Königreichs Sachsen. Blatt 102, Section Berggiesshübel* (1st ed.). Leipzig: Engelmann.

Beck, R. (1890). *Geologische Specialkarte des Königreichs Sachsen.* Blatt 82, Section 1764 Kreischa (1st ed.). Leipzig: Engelmann.

Beck, R. (1892). *Erläuterungen zur geologischen Specialkarte des Königreichs Sachsen.* Blatt 82, Section 1766 Kreischa (1st ed.). Leipzig: Engelmann.

Beeger, H. D. (1963). Die petrographische Ausbildung und die Obergrenze des Labiatus-Sandsteins im Gebiet von Pirna und Königstein. *Berichte der Geologischen Gesellschaft in der DDR für das Gesamtgebiet der Geologischen Wissenschaften, 8*, 205–213.

Beeger, H. D., & Quellmalz, W. (1965). *Geologischer Führer durch die Umgebung von Dresden*. Dresden: Steinkopff.

Bornemann, A., Erbacher, J., Heldt, M., Kollaske, T., Wilmsen, M., Lübke, N., . . . Wonik, T. (2017). The Albian–Cenomanian transition and Oceanic Anoxic Event 1d – an example from the Boreal Realm. *Sedimentology, 64*(1), 44–65. https://doi.org/10.1111/sed.12347

Catuneanu, O., Galloway, W. E., Kendall, C. G. S. C., Miall, A. D., Posamentier, H. W., Strasser, A., & Tucker, M. E. (2011). Sequence stratigraphy: Methodology and nomenclature. *Newsletters on Stratigraphy, 44*(3), 173–245. https://doi.org/10.1127/0078-0421/2011/0011

Cotta, B. (1857). Über den Granit und Jura-Kalk auf dem Quader-Sandstein bei Schandau. Mittheilungen an Geheimen-Rath von Leonhard. *Neues Jahrbuch für Mineralogie, Geognosie*. *Geologie und Petrefaktenkunde, 1857*, 552–553.

Dalmer, K., & Beck, R. (1893). *Geologische Specialkarte des Königreichs Sachsen. Blatt 65, Section Wilsdruff-Potschappel* (1st ed.). Leipzig: Engelmann.

Dalmer, K., & Beck, R. (1894). *Erläuterungen zur geologischen Specialkarte des Königreichs Sachsen. Blatt 65, Section Wilsdruff-Potschappel* (1st ed.). Leipzig: Engelmann.

Decker, F. (1963). Beiträge zur Kenntnis des Cenomans im Elbsandsteingebirge. *Berichte der Geologischen Gesellschaft in der DDR für das Gesamtgebiet der geologischen Wissenschaften, 8*, 141–151.

Dietze, H. (1959). Die Inoceramen von Oberau in Sachsen – Obercenoman bis Unterturon. *Geologie, 8*, 856–883.

Dietze, H. (1961). Paläontologische und stratigraphische Untersuchungen der Klippenfazies von Oberau und Meißen (Sächsische Oberkreide). *Jahrbuch des Staatlichen Museums für Mineralogie und Geologie zu Dresden, 1960*, 1–74.

Eberlein, M. (2004). *Die Geotope des Tharandter Waldes – Inventarisierung und Bewertung* [unpubl.]. Diploma thesis, TU Dresden.

Elicki, O., Suhr, P., & Walter, H. (2020). Oberkretazische Foraminiferen aus Reliktvorkommen bei Siebenlehn (Mittelsachsen). *Freiberger Forschungshefte, C 558*, 121–139.

Ernst, G., Schmid, F., & Seibertz, E. (1983). Event-Stratigraphie im Cenoman und Turon von NW-Deutschland. *Zitteliana, 10*, 531–554.

Ettingshausen, C. von (1867). Die Kreideflora von Niederschoena in Sachsen, ein Beitrag zur Kenntnis der ältesten Dicotyledonengewächse. *Sitzungsberichte der Königlich-Kaiserlichen Akademie der Wissenschaften. Mathematisch-Naturwissenschaftliche Classe Wien, 55*, 235–264.

Gale, A. S., Hardenbol, J., Hathway, B., Kennedy, W. J., Young, J. R., & Phansalkar, V. (2002). Global correlation of Cenomanian (Upper Cretaceous) sequences: Evidence for Milankovitch control of sea level. *Geology, 30*(4), 291–294. https://doi.org/10.1130/0091-7613(2002)0302.0.CO;2

Gale, A. S., Mutterlose, J., Batenburg, S., Gradstein, F. M., Agterberg, F. P., Ogg, J. G., & Petrizzo, M. R. (2020). The Cretaceous Period. In F. M. Gradstein, J. G. Ogg, M. D. Schmitz, & G. M. Ogg (Eds.), *Geologic Time Scale 2020* (pp. 1023–1086). Amsterdam: Elsevier; https://doi.org/10.1016/B978-0-12-824360-2.00027-9

Geinitz, H. B. (1839). *Charakteristik der Schichten und Petrafacten des sächsischen Kreidegebirges. Erstes Heft. Der Tunnel bei Oberau in geognostischer Hinsicht, und die dieser Ablagerung verwandten Ablagerungen zwischen Oberau, Meissen und dem Plauenschen Grunde bei Dresden*. Leipzig: Arnold.

Geinitz, H. B. (1840). *Charakteristik der Schichten und Petrafacten des sächsischen Kreidegebirges. Zweites Heft. A. Das Land zwischen dem Plauen'schen Grunde bei Dresden und Dohna. B. Fische, Crustaceen, Mollusken*. Leipzig: Arnold.

Geinitz, H. B. (1871–1875). Das Elbthalgebirge in Sachsen. Erster Theil: Der untere Quader. *Palaeontographica, 20*(I), I.1–I.319, pls I.1–II.67. Cassel: Fischer.

Göhler, T. (2008). Zur Problematik der Amethystgerölle in den cenomanen Basalkonglomeraten der fluvialen Niederschöna-Formation im Tharandter Wald. *Beiträge zur Geologie der Sächsischen Kreide, 4*, 1–15.

Häntzschel, W. (1933). Das Cenoman und die Plenus-Zone der sudetischen Kreide. *Abhandlungen der Preußischen Geologischen Landesanstalt, N. F., 150*, 1–161.

Hallam, A. (1992). *Phanerozoic sea-level changes*. New York: Columbia University Press.

Hancock, J. M. (1989). Sea-level changes in the British region during the Late Cretaceous. *Proceedings of the Geologists' Association, 100*(4), 565–594. https://doi.org/10.1016/S0016-7878(89)80027-6

Hancock, J. M., & Kauffman, E. G. (1979). The great transgressions of the Late Cretaceous. *Journal of the Geological Society, 136*(2), 175–186. https://doi.org/10.1144/gsjgs.136.2.0175

Haq, B. U. (2014). Cretaceous eustasy revisited. *Global and Planetary Change, 113*, 44–58. https://doi.org/10.1016/j.gloplacha.2013.12.007

Janetschke, N., & Wilmsen, M. (2014). Sequence stratigraphy of the lower Upper Cretaceous Elbtal Group (Cenomanian–Turonian of Saxony, Germany). *Zeitschrift der Deutschen Gesellschaft für Geowissenschaften, 165*(2), 179–208. https://doi.org/10.1127/1860-1804/2013/0036

Janetschke, N., Niebuhr, B., & Wilmsen, M. (2015). Inter-regional sequence stratigraphical synthesis of the Plänerkalk, Elbtal and Danubian Cretaceous groups (Germany): Cenomanian–Turonian correlations around the Mid-European Island. *Cretaceous Research, 56*, 530–549. https://doi.org/10.1016/j.cretres.2015.04.007

Jelínek, J., Krentz, O., Mlčoch, B., Nádaskay, R., & Valečka, J. (2020). Tektonik. In Š. Mrázová, T. Tomanová Petrová, & O. Krentz (Eds.), *Geologie des Sächsisch-Böhmischen Kreidebeckens zwischen Erzgebirge und Jeschken* (pp. 49–58). Praha: ČGS.

Kleditzsch, O. (1987). *Exkursionsführer Tharandter Wald und Umgebung* [unpubl.]. Study thesis, TU Bergakademie Freiberg.

Klein, V., Müller, V., & Valečka, J. (1979). Lithofazielle und paläogeographische Entwicklung des Böhmischen Kreidebeckens. *International Union of Geological Sciences, A 6*, 435–466.

Klemm, G. (1888). *Geologische Specialkarte des Königreichs Sachsen. Blatt 67, Section Pillnitz* (1st ed.). Leipzig: Engelmann.

Klemm, G. (1892). *Erläuterungen zur geologischen Specialkarte des Königreichs Sachsen. Blatt 67, Section Pillnitz* (1st ed.). Leipzig: Engelmann.

Kley, J., & Voigt, T. (2008). Late Cretaceous intraplate thrusting in central Europe: Effect of Africa-Iberia-Europe convergence, not Alpine collision. *Geology, 36*(11), 839–842. https://doi.org/10.1130/G24930A.1

Kraus, M. J. (1999). Paleosols in clastic sedimentary rocks: Their geologic applications. *Earth-Science Reviews, 47*(1-2), 41–70. https://doi.org/10.1016/S0012-8252(99)00026-4

Krutzsch, W. (1959). Einige neue Formgattungen und -Arten von Sporen und Pollen aus der mitteleuropäischen Oberkreide und dem Tertiär. *Palaeontographica. Abteilung B, Paläophytologie, 105*, 125–157.

Krutzsch, W. (1963). Beitrag zur Kenntnis der Niederschönaer Schichten: eine kleine Mikroflora aus der Bohrung Königstein 1. *Berichte der Geologischen Gesellschaft in der DDR für das Gesamtgebiet der geologischen Wissenschaften, 8*, 224–236.

Krutzsch, W. (1966). Die sporenstratigraphische Gliederung der Oberkreide im nördlichen Mitteleuropa – Methodische Grundlagen und gegenwärtiger Stand der Untersuchungen. *Abhandlungen des Zentralen Geologischen Instituts, 5*, 111–137.

Kuhnt, W., Holbourn, A., Gale, A., Chellai, E. H., & Kennedy, W. J. (2009). Cenomanian sequence stratigraphy and sea-level fluctuations in the Tarfaya Basin (SW Morocco). *Geological Society of America Bulletin, 121*(11–12), 1695–1710. https://doi.org/10.1130/B26418.1

Lapp, M., Hübner, F., & Richter, L. (2017). *Geologische Karte des Freistaates Sachsen 1: 25 000 und Erläuterungen zu Blatt 4949 Dresden Ost* (4th ed.). Freiberg: LfULG.

Lehmann, J. G. (1749). Sammlung einiger mineralischer Merckwürdigkeiten des Plauischen Grundes bey Dresden. In C. G. Grundig (Ed.), *Neue Versuche nützlicher Sammlungen zur Natur- und Kunstgeschichte, sonderlich von Ober-Sachsen, 1* (pp. 580–597). Schneeberg: Fulden.

Lehr, R. (2022). Pläner: A traditional building stone in Saxo-Bohemian Cretaceous and Münsterland Cretaceous Basin. *Environmental Earth Sciences, 81*(7), 219. https://doi.org/10.1007/s12665-022-10218-x

Leutwein, F. (1951). Über die Herkunft der Amethyste in den cenomanen Schottern des Erzgebirges. *Urania, 14*, 373–375.

Malkovský, M. (1976). Saxonische Tektonik der Böhmischen Masse. *Geologische Rundschau, 65*(1), 127–143. https://doi.org/10.1007/BF01808459

Malkovský, M. (1987). The Mesozoic and Tertiary basins of the Bohemian Massif and their evolution. *Tectonophysics, 137*(1–4), 31–42. https://doi.org/10.1016/0040-1951(87)90311-8

Melchisedech, M. (2021). *Integrierte Stratigraphie und Faziesanalyse der Elbtal-Gruppe (Cenomanium–Turonium, untere Oberkreide) in der Bohrung HG 7025 (Strubben-Siedlung) nahe Königstein (Elbsandsteingebirge, Sachsen)* [unpubl.]. Master thesis, TU Bergakademie Freiberg.

Nádaskay, R., & Uličný, D. (2014). Genetic stratigraphy of Coniacian deltaic deposits of the northwestern part of the Bohemian Cretaceous Basin. *Zeitschrift der Deutschen Gesellschaft für Geowissenschaften, 165*(4), 547–575. https://doi.org/10.1127/zdgg/2014/0024

Nádaskay, R., Kochergina, Y. V., Čech, S., Švábenická, L., Valečka, J., Erban, V., . . . Čejková, B. (2019). Integrated stratigraphy of an offshore succession influenced by intense siliciclastic supply: Implications for Coniacian tectono-sedimentary evolution of the West Sudetic area (NW Bohemian Cretaceous Basin, Czech Republic). *Cretaceous Research, 102*, 127–159. https://doi.org/10.1016/j.cretres.2019.06.005

Nessig, W. R. (1898). *Geologische Exkursionen in der Umgebung von Dresden*. Dresden: Heinrich.

Neumann, E. (2004). Lithofazielle Untersuchungen des basalen Mittel-Turons im Gebiet Lohmen, Wehlen, Königstein (unter Berücksichtigung von Bohrungen und Übertageaufschlüssen) [unpubl.]. Diploma thesis, TU Bergakademie Freiberg.

Niebuhr, B. (2018). Kreidesandsteine auf der Lausitz (Sachsen): Hinweise zu Paläogeographie und Inversionstektonik. *Freiberger Forschungshefte, C 553*, 51–78. https://doi.org/10.23689/fidgeo-4230

Niebuhr, B. (2021). *Sandstein – Seestern – Saurier: Sachsen in der Kreidezeit. Begleitband zur Sonderausstellung* (228 pp.). Kamenz: Museum der Westlausitz.

Niebuhr, B., Hiss, M., Kaplan, U., Tröger, K.-A., Voigt, S., Voigt, T., . . . Wilmsen, M. (2007). Lithostratigraphie der norddeutschen Oberkreide. *Schriftenreihe der Deutschen Gesellschaft für Geowissenschaften, 55*, 1–136.

Niebuhr, B., Wilmsen, M., Chellouche, P., Richardt, N., & Pürner, T. (2011). Stratigraphy and facies of the Turonian (Upper Cretaceous) Roding Formation at the southwestern margin of the Bohemian Massif (Southern Germany, Bavaria). *Zeitschrift der Deutschen Gesellschaft für Geowissenschaften, 162*(3), 295–316. https://doi.org/10.1127/1860-1804/2011/0162-0295

Niebuhr, B., Schneider, S., & Wilmsen, M. (2014). Muscheln. *Geologica Saxonica, 60*(1), 83–168.

Niebuhr, B., Wilmsen, M., & Voigt, T. (2020). Die Oberkreide (Cenomanium–Mittelconiacium) im Zittauer Sandsteingebirge (Deutschland, Tschechien). *Zeitschrift der Deutschen Gesellschaft für Geowissenschaften, 171*(2), 163–197. https://doi.org/10.1127/zdgg/2020/0223

Niebuhr, B., Haubrich, F., & Fengler, M. (2021). Der Grillenburger Sandsteinbruch am Flügel Jägerhorn (Cenomanium, Tharandter Wald, Sachsen) – historisch berühmt und geologisch verkannt. *Geologica Saxonica, 67*, 1–28. https://doi.org/10.3897/gs.67.e78579

Pacltová, B. (1971). Palynological study of Angiospermae from the Peruc Formation (?Albian–Lower Cenomanian) of Bohemia. *Sbornik Geologických Ved. Paleontologie, 13*, 105–141.

Pacltová, B. (1977). Cretaceous angiosperms of Bohemia–Central Europe. *Botanical Review, 43*(1), 128–142. https://doi.org/10.1007/BF02860851

Pacltová, B. (1978). *Significance of palynology for the biostratigraphic division of the Cretaceous of Bohemia*. In V. Pokorný (Ed.), Paleontological Conference, Department of Paleontology, Faculty of Natural Sciences, Charles University, Praha (pp. 93–109). Prague: Charles University.

Pälchen, W., & Walter, H. (2008). Geographisch-geologischer Überblick. In W. Pälchen & H. Walter (Eds.), *Geologie von Sachsen. Geologischer Bau und Entwicklungsgeschichte* (pp. 1–16). Stuttgart: Schweizerbart.

Petrascheck, W. (1900). Studien über die Faciesbildungen im Gebiete der sächsischen Kreideformation. *Sitzungsberichte und Abhandlungen der naturwissenschaftlichen Gesellschaft ISIS in Dresden, 1899*, 31–84.

Pietzsch, K. (1912). *Geologische Spezialkarte des Königreichs Sachsen. Blatt 81, Section Tharandt* (2nd ed.). Leipzig: Engelmann.

Pietzsch, K. (1914). *Erläuterungen zur geologischen Spezialkarte des Königreichs Sachsen. Blatt 81, Section Tharandt* (2nd ed.). Leipzig: Engelmann.

Posamentier, H. W., & Vail, P. R. (1988). Eustatic controls on clastic deposition II – Sequence and systems tract models. In C. K. Wilgus, B. S. Hastings, C. G. S. C. Kendall, H. W. Posamentier, C. A. Ross, & J. C. Van Wagoner (Eds.), *Sea-level changes: An integrated approach. Society of Economic Paleontologists and Mineralogists – Special Publication, 42, 125–154*. https://doi.org/10.2110/pec.88.01.0125

Posamentier, H. W., Jervey, M. T., & Vail, P. R. (1988). Eustatic controls on clastic deposition I – conceptual framework. In C. K. Wilgus, B. S. Hastings, C. G. S. C. Kendall, H. W. Posamentier, C. A. Ross, & J. C. Van Wagoner (Eds.), *Sea-level changes: An integrated approach. Society of Economic Paleontologists and Mineralogists – Special Publication, 42, 109–124*. https://doi.org/10.2110/pec.88.01.0109

Prescher, H. (1957). Die Niederschönaer Schichten der sächsischen Kreide. *Freiberger Forschungshefte, C 34*, 1–96.

Prescher, H. (1981). Probleme der Korrelation des Cenomans und Turons in der Sächsischen und Böhmischen Kreide. *Zeitschrift für Geologische Wissenschaften, 9*, 367–373.

Prescher, H., & Tröger, K.-A. (1989). Die „Meißner Schichten" der sächsischen Kreide (Forschungsgeschichte, Litho- und Biostratigraphie). *Abhandlungen des Staatlichen Museums für Mineralogie und Geologie zu Dresden, 36*, 155–167.

Ray, D. C., van Buchem, F. S. P., Baines, G., Davies, A., Gréselle, B., Simmons, M. D., & Robson, C. (2019). The magnitude and cause of short-term eustatic Cretaceous sea-level change: A synthesis. *Earth-Science Reviews, 197*, 102901. https://doi.org/10.1016/j.earscirev.2019.102901

Richardt, N., Wilmsen, M., & Niebuhr, B. (2013). Late Cenomanian–Early Turonian facies development and sea-level changes in the Bodenwöhrer Senke (Danubian Cretaceous Group, Bavaria, Germany). *Facies, 59*(4), 803–827. https://doi.org/10.1007/s10347-012-0337-x

Robaszynski, F., Gale, A. S., Juignet, P., Amédro, F., & Hardenbol, J. (1998). Sequence stratigraphy in the Upper Cretaceous series of the Anglo-Paris Basin: Exemplified by the Cenomanian stage. *Special Publication - Society of Economic Paleontologists and Mineralogists, 60*, 363–385. https://doi.org/10.2110/pec.98.02.0363

Robaszynski, F., Hardenbol, J., Caron, M., Amédro, F., Dupuis, C., Gonzales-Donoso, J. M., . . . Gartner, S. (1993). Sequence stratigraphy in a distal environment: The Cenomanian of the Kalaat Senan region (central Tunisia). *Bulletin des Centres de Recherches Exploration-Production Elf-Aquitaine, 17*, 395–433.

Sauer, A. (1886). *Geologische Specialkarte des Königreichs Sachsen. Blatt 80, Section Freiberg* (1st ed.). Leipzig: Engelmann.

Sauer, A. (1887). *Erläuterungen zur geologischen Specialkarte des Königreichs Sachsen. Blatt 80, Section Freiberg* (1st ed.). Leipzig: Engelmann.

Sauer, A. (1891). *Erläuterungen zur geologischen Specialkarte des Königreichs Sachsen. Blatt 80, Section Tharandt* (1st ed.). Leipzig: Engelmann.

Sauer, A. (1899). *Geologische Specialkarte des Königreichs Sachsen. Blatt 80, Section Freiberg* (2nd ed.). Leipzig: Engelmann.

Sauer, A. (1900). *Erläuterungen zur geologischen Specialkarte des Königreichs Sachsen. Blatt 80, Section Freiberg* (2nd ed.). Leipzig: Engelmann.

Schalch, F. (1887). *Geologische Specialkarte des Königreichs Sachsen. Blatt 101, Section Glashütte-Dippoldiswalde* (1st ed.). Leipzig: Engelmann.

Schalch, F. (1888). *Erläuterungen zur geologischen Specialkarte des Königreichs Sachsen. Blatt 101, Section Glashütte-Dippoldiswalde* (1st ed.). Leipzig: Engelmann.

Schander, H. (1923). Die cenomane Transgression im mittleren Elbtalgebiet. *Geologisches Archiv, 2*, 49–96.

Schlager, W. (1999). Type 3 sequence boundaries. *Society for Sedimentary Geology – Special Publication, 63*, 35–45. https://doi.org/10.2110/pec.99.11.0035

Schreiter, R. (1927). *Geologischer Führer durch das Erzgebirge*. Freiberg: Maukisch.

Seifert, A. (1938). Das Cenoman-Vorkommen westlich vom Letzten Heller bei Dresden. *Sitzungsberichte und Abhandlungen der Naturwissenschaftlichen Gesellschaft ISIS in Dresden, 1936/1937*, 54–58.

Seifert, R. (1955). Stratigraphie und Paläogeographie des Cenomans und Turons im sächsischen Elbtalgebiet. *Freiberger Forschungshefte, C 14*, 1–218.

Sharland, P. R., Archer, R., Casey, D. M., Davies, R. B., Hall, S. H., Heward, A. P., . . . Simmons, M. D. (2001). Arabian Plate sequence stratigraphy. *GeoArabia Special Publication, 2*, 1–371.

Špičáková, L., Uličný, D., & Svobodová, M. (2014). Phases of the mid-Cenomanian transgression recorded in a composite palaeovalley fill – the Horoušany quarry, Bohemian Cretaceous Basin. *Zeitschrift der Deutschen Gesellschaft für Geowissenschaften, 165*(4), 591–619. https://doi.org/10.1127/zdgg/2014/0028

Stow, D. A. V. (2005). *Sedimentary rocks in the field. A colour guide*. London: Manson Publishing. https://doi.org/10.1201/b15204

Suess, E. (1875). *Die Entstehung der Alpen*. Wien: Braumüller.

Tonndorf, H. (2000). Die Uranlagerstätte Königstein. *Bergbau in Sachsen, 7*, 1–206.

Tröger, K.-A. (1956). Über die Kreideablagerungen des Plauenschen Grundes (sedimentpetrographische und biostratinomisch-paläontologische Untersuchungen). *Jahrbuch des Staatlichen Museums für Mineralogie und Geologie zu Dresden, 2*, 22–124.

Tröger, K.-A. (1960). *Kartierungsbohrung Königstein 1/1960*. Internal report, Geological Survey of Saxony [unpubl.].

Tröger, K.-A. (1967). Zur Paläontologie, Biostratigraphie und faziellen Ausbildung der unteren Oberkreide (Cenoman bis Turon). Teil 1: Paläontologie und Biostratigraphie der Inoceramen des Cenomans bis Turons Mitteleuropas. *Abhandlungen des Staatlichen Museums für Mineralogie und Geologie zu Dresden, 12*, 13–207.

Tröger, K.-A. (1969). Zur Paläontologie, Biostratigraphie und faziellen Ausbildung der unteren Oberkreide (Cenoman bis Turon). Teil 2: Stratigraphie und fazielle Ausbildung des Cenomans und Turons in Sachsen, dem nördlichen Harzvorland (subherzyne Kreide) und dem Ohm-Gebirge. *Abhandlungen des Staatlichen Museums für Mineralogie und Geologie zu Dresden, 13*, 1–70.

Tröger, K.-A. (1976). Nachweis eines Belemniten im Unterquader (Ober-Cenoman der sächsischen Kreide). *Abhandlungen des Staatlichen Museums für Mineralogie und Geologie zu Dresden, 25*, 61–63.

Tröger, K.-A. (2003). The Cretaceous of the Elbe valley in Saxony – a review. *Carnets de Géologie, 2003(A 03)*, 1–14. https://hal.archives-ouvertes.fr/hal-00140955

Tröger, K.-A. (2008). Kreide – Oberkreide. In W. Pälchen & H. Walter (Eds.), *Geologie von Sachsen. Geologischer Bau und Entwicklungsgeschichte* (pp. 311–358). Stuttgart: Schweizerbart.

Tröger, K.-A. (2014). Obercenomane Inoceramen aus der sächsischen Kreide. *Geologica Saxonica, 60*(3), 377–425.

Tröger, K.-A. (2017). Facies changes in the Cenomanian (Cretaceous) of the northwestern Elbe Valley near Dresden (Saxony, Germany). *Acta Geologica Polonica, 67*(1), 135–144. https://doi.org/10.1515/agp-2017-0008

Tröger, K.-A., & Niebuhr, B. (2014). Inoceramide Muscheln. *Geologica Saxonica, 60*(1), 169–199.

Tröger, K.-A., & Voigt, T. (2000). Sachsen. *Courier Forschungsinstitut Senckenberg, 226*, 123–128.

Tröger, K.-A., Wolf, L., & Uhlig, I. (1963). Bericht über die Ergebnisse der Kartierungsbohrungen Graupa 1/60 und Bonnewitz 1/61 im Jahre 1961. *Wissenschaftlich-Technischer Informationsdienst VEB Feste Minerale, 4*, 25–26.

Tröger, K.-A., Horna, F., & Magnus, M. (1998). *Profilaufnahme der Bohrung Königstein-Halbestadt 7016/1997* [unpubl.].

Tröger, K.-A., Voigt, T., Niebuhr, B., & Wilmsen, M. (2020). *Dölzschen-Formation*. In LithoLex [Online-Datenbank], Datensatz-Nr. 10000084 vom 02.09.2020. Hannover: BGR. https://litholex.bgr.de

Tucker, M. E. (2011). *Sedimentary rocks in the field: A practical guide* (4th ed.). New York: Wiley.

Uhlig, A. (1941). Die cenoman-turone Übergangszone in der Gegend von Dresden. *Mitteilungen der Reichsstelle für Bodenforschung, 2*, 1–74.

Uličný, D., Špičáková, L., Grygar, R., Svobodová, M., Čech, S., & Laurin, J. (2009a). Palaeodrainage systems at the basal unconformity of the Bohemian Cretaceous Basin: Roles of inherited fault systems and basement lithology during the onset of basin filling. *Bulletin of Geosciences, 84*(4), 577–610. https://doi.org/10.3140/bull.geosci.1128

Uličný, D., Laurin, L., & Čech, S. (2009b). Controls on clastic sequence geometries in a shallow-marine, transtensional basin: The Bohemian Cretaceous Basin, Czech Republic. *Sedimentology, 56*(4), 1077–1114.
https://doi.org/10.1111/j.1365-3091.2008.01021.x

Vail, P. R., Audemard, F., Bowman, S. A., Eisner, P. N., & Perez-Cruz, C. (1991). The stratigraphic signatures of tectonics, eustasy and sedimentology – an overview. In G. Einsele, W. Ricken, & A. Seilacher (Eds.), *Cycles and events in stratigraphy* (pp. 617–659). Berlin: Springer.

Voigt, S., Gale, A. S., & Voigt, T. (2006). Sea-level changes, carbon cycling and palaeoclimate during the Late Cenomanian of northwest Europe; an integrated palaeoenvironmental analysis. *Cretaceous Research, 27*(6), 836–858. https://doi.org/10.1016/j.cretres.2006.04.005

Voigt, T. (1994). *Faziesentwicklung und Ablagerungssequenzen am Rand eines Epikontinentalmeeres. Die Sedimentationsgeschichte der Sächsischen Kreide* [unpubl.]. PhD thesis, TU Bergakademie Freiberg.

Voigt, T. (1997). Hinweise auf spätmesozoisch-känozoische Blattverschiebungen in der Elbezone. *Freiberger Forschungshefte, C 468*, 279–287.

Voigt, T. (1998). Entwicklung und Architektur einer fluviatilen Talfüllung – die Niederschöna Formation im Sächsischen Kreidebecken. *Abhandlungen des Staatlichen Museums für Mineralogie und Geologie zu Dresden, 43–44*, 121–139.

Voigt, T. (1999). Ablagerungsbedingungen und Taphonomie der Schmilka-Formation (Unter-Turon) südlich von Pirna (Sächsisches Kreidebecken). *Greifswalder Geowissenschaftliche Beiträge, 6*, 193–207.

Voigt, T. (2009). Die Lausitz-Riesengebirgs-Antiklinalzone als kreidezeitliche Inversionsstruktur: Geologische Hinweise aus umgebenden Kreidebecken. *Zeitschrift für Geologische Wissenschaften, 37*(1–2), 15–39.

Voigt, T., & Tröger, K.-A. (1996). Sea-level changes during Late Cenomanian and Early Turonian in the Saxonian Cretaceous Basin. *Mitteilungen aus dem Geologisch-Paläontologischen Institut der Universität Hamburg, 77*, 275–290.

Voigt, T., Voigt, S., & Tröger, K.-A. (1994). Faziesentwicklung einer ertrunkenen Felsküste – die obercenomane Monzonitklippe westlich von Dresden. *Freiberger Forschungshefte, C 452*, 23–34.

Voigt, T., Kley, J., & Voigt, S. (2021). Dawn and dusk of Late Cretaceous basin inversion in central Europe. *Solid Earth, 12*(6), 1443–1471. https://doi.org/10.5194/se-12-1443-2021

Walter, H., & Suhr, P. (1997). Proximale Tempestite aus dem tieferen Obercenoman (*naviculare*-Zone) von Dresden-Coschütz. *Freiberger Forschungshefte, C 468*, 305–317.

Wilmsen, M. (2003). Sequence stratigraphy and palaeoceanography of the Cenomanian Stage in northern Germany. *Cretaceous Research, 24*(5), 525–568. https://doi.org/10.1016/S0195-6671(03)00069-7

Wilmsen, M. (2007). Integrated stratigraphy of the upper Lower–lower Middle Cenomanian of northern Germany and southern England. *Acta Geologica Polonica, 57*(3), 263–279.

Wilmsen, M. (2014). Belemniten. *Geologica Saxonica, 60*(1), 241–248.

Wilmsen, M. (2017). Macroinvertebrate fauna and depositional environment of the lower Upper Cenomanian Oberhäslich Formation in the Saxonian Cretaceous Basin (Germany). *Annales de Paléontologie, 103*(1), 33–44. https://doi.org/10.1016/j.annpal.2016.11.003

Wilmsen, M., & Bansal, U. (2021). Depositional setting and limiting factors of early Late Cretaceous glaucony formation: Implications from Cenomanian glauconitic strata (Elbtal Group, Germany). *Facies, 67*(3), 24. https://doi.org/10.1007/s10347-021-00627-y

Wilmsen, M., & Nagm, E. (2013). Upper Cenomanian–Lower Turonian ammonoids from the Saxonian Cretaceous (lower Elbtal Group, Saxony, Germany). *Bulletin of Geosciences, 88*(3), 647–674. https://doi.org/10.3140/bull.geosci.1390

Wilmsen, M., & Nagm, E. (2014). Ammoniten. *Geologica Saxonica, 60*, 201–240.

Wilmsen, M., & Niebuhr, B. (2010). On the age of the Upper Cretaceous transgression between Regensburg and Neuburg an der Donau (Bavaria, southern Germany). *Neues Jahrbuch für Geologie und Paläontologie. Abhandlungen, 256*(3), 267–278. https://doi.org/10.1127/0077-7749/2010/0051

Wilmsen, M., & Niebuhr, B. (2014). Die Kreide in Sachsen. *Geologica Saxonica, 60*(1), 3–12.

Wilmsen, M., & Niebuhr, B. (2016). *Field trip 1. Paläontologie, Stratigraphie und Ablagerungsbedingungen der Kreide in Sachsen (Elbtal-Gruppe, Cenomanium-Unterconiacium).* In B. Niebuhr, M. Wilmsen, L. Kunzmann, & C. Stefen (Eds.), 87th Annual Conference of the Paläontologische Gesellschaft e.V., Dresden, September 11–15, 2016 (pp. 171–209). Dresden: Senckenberg.

Wilmsen, M., Vodrážka, R., & Niebuhr, B. (2011). The Upper Cenomanian and Lower Turonian of Lockwitz (Dresden area, Saxony, Germany): lithofacies, stratigraphy and fauna of a transgressive succession. *Freiberger Forschungshefte, C 540*, 27–45.

Wilmsen, M., Niebuhr, B., Fengler, M., Püttmann, T., & Berensmeier, M. (2019a). The Late Cretaceous transgression in the Saxonian Cretaceous Basin (Germany): Old story, new data and novel findings. *Bulletin of Geosciences, 94*(1), 71–100. https://doi.org/10.3140/bull.geosci.1723

Wilmsen, M., Dölling, B., Hiss, M., & Niebuhr, B. (2019b). The lower Upper Cretaceous of the south-eastern Münsterland Cretaceous Basin, Germany: Facies, integrated stratigraphy and inter-basinal correlation. *Facies, 65*(2), 13. https://doi.org/10.1007/s10347-018-0552-1

Wilmsen, M., Niebuhr, B., & Kennedy, W. J. (2022). Middle Cenomanian ammonites from the Oberhäslich Formation (Elbtal Group, Germany): Stratigraphic and palaeogeographic implications for the Saxo-Bohemian Cretaceous. *Neues Jahrbuch für Geologie und Paläontologie. Abhandlungen, 303*(3), 271–294. https://doi.org/10.1127/njgpa/2022/1048

Wright, C. W., Kennedy, W. J., Hancock, J. M., & Gale, A. S. (2017). The Ammonoidea of the Lower Chalk. Part 7. *Monographs of the Palaeontographical Society, 171*(648), 461–561. https://doi.org/10.1080/02693445.2017.11963959

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