

Arbeitsbericht NAB 21-21

**TBO Bözberg-1-1:
Data Report**

**Dossier IV
Microfacies, Bio- and Chemo-
stratigraphic Analysis**

February 2022

**National Cooperative
for the Disposal of
Radioactive Waste**

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TB0 Bözberg-1-1: Data Report

Dossier IV Microfacies, Bio- and Chemo- stratigraphic Analysis

February 2022

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stable carbon isotopes

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Nagra Arbeitsberichte ("Working Reports") present the results of work in progress that have not necessarily been subject to a comprehensive review. They are intended to provide rapid dissemination of current information.

This NAB aims at reporting drilling results at an early stage. Additional borehole-specific data will be published elsewhere.

In the event of inconsistencies between dossiers of this NAB, the dossier addressing the specific topic takes priority. In the event of discrepancies between Nagra reports, the chronologically later report is generally considered to be correct. Data sets and interpretations laid out in this NAB may be revised in subsequent reports. The reasoning leading to these revisions will be detailed there.

This Dossier was prepared by a project team consisting of:

S. Wohlwend (sampling, chemostratigraphy, conceptualisation and compilation)

H.R. Bläsi (microfacies)

S. Feist-Burkhardt (palynostratigraphy)

B. Hostettler, U. Menkveld-Gfeller, V. Dietze (ammonite stratigraphy)

G. Deplazes (project management and conceptualisation)

Editorial work: P. Blaser and M. Unger

The Dossier has greatly benefitted from technical discussions with, and reviews by, external and internal experts. Their input and work are very much appreciated.

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1 Introduction

1.1 Context

To provide input for site selection and the safety case for deep geological repositories for radioactive waste, Nagra has drilled a series of deep boreholes ("Tiefbohrungen", TBO) in Northern Switzerland. The aim of the drilling campaign is to characterise the deep underground of the three remaining siting regions located at the edge of the Northern Alpine Molasse Basin (Fig. 1-1).

In this report, we present the results from the Bözberg-1-1 borehole.

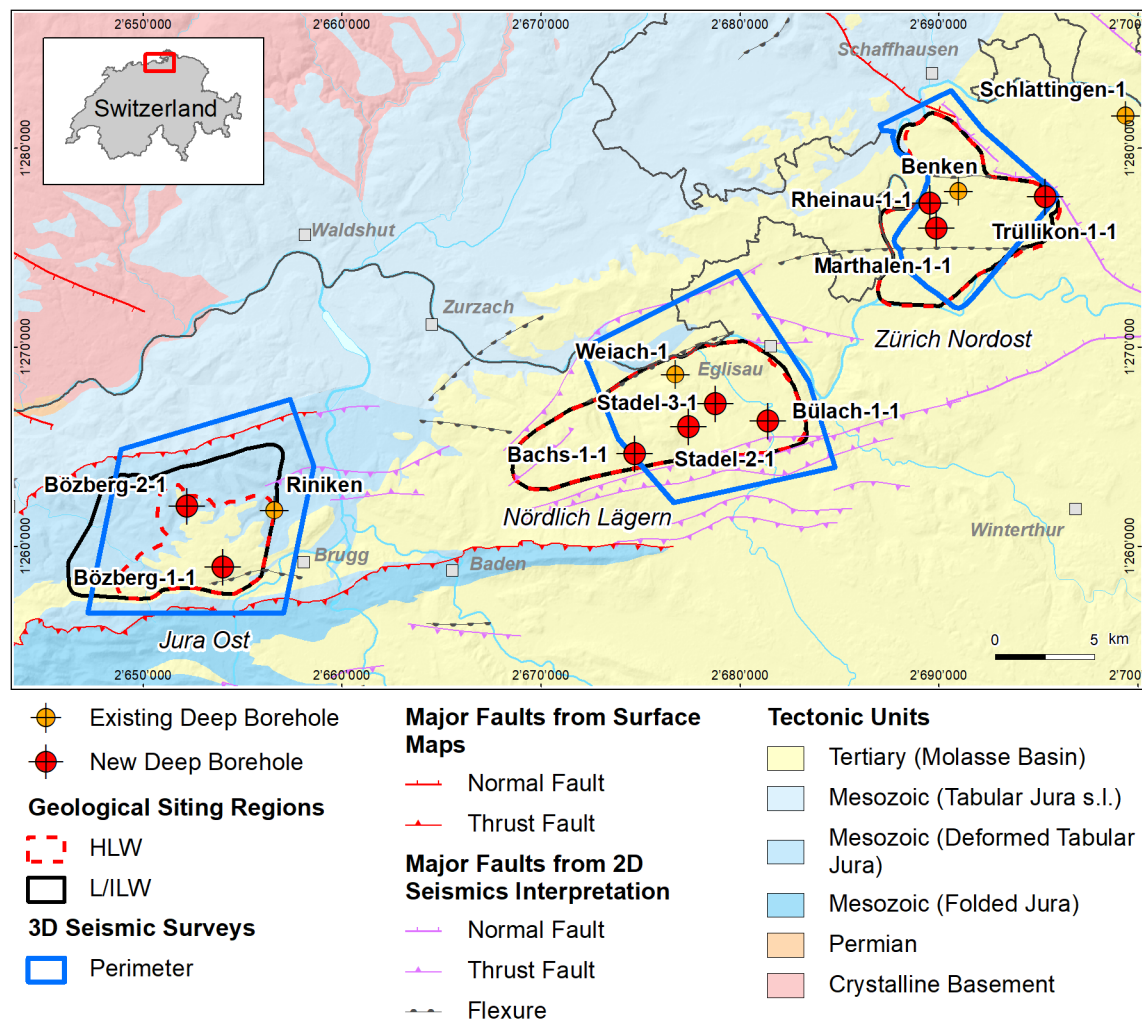


Fig. 1-1: Tectonic overview map with the three siting regions under investigation

1.2 Location and specifications of the borehole

The Bözberg-1-1 (BOZ1-1) exploratory borehole is the fourth borehole drilled within the framework of the TBO project. The drill site is located in the southern part of the Jura Ost siting region (Fig. 1-2). The borehole specifications are provided in Tab. 1-1.

Due to a lost packer system, the borehole was cemented up to 682 m MD¹ (*cf.* Dossier I). Resuming coring operations, a sidetrack was initiated with a kickoff point (KOP) at 709 m MD. This sidetrack was labelled Bözberg-1-1B (BOZ1-1B). BOZ1-1B reached a final depth of 1'037.39 m MD. For easier communication and labelling, the name BOZ1-1 is generally used for this borehole, including the sidetrack, unless stated otherwise.

Tab. 1-1: General information about the BOZ1-1 borehole

Siting region	Jura Ost
Municipality	Bözberg (Canton Aargau / AG), Switzerland
Drill site	Bözberg-1 (BOZ1)
Borehole	Bözberg-1-1 (BOZ1-1) including sidetrack Bözberg-1-1B (BOZ1-1B)
Coordinates	LV95: 2'653'995.815 / 1'258'925.446
Elevation	Ground level = top of rig cellar: 513.29 m above sea level (asl)
Borehole depth	1'037.39 m measured depth (MD) below ground level (bgl) for BOZ1-1B
Drilling period	27th April 2020 – 2nd December 2020 (spud date to end of rig release)
Drilling company	PR Marriott Drilling Ltd
Drilling rig	Rig-16 Drillmec HH102
Drilling fluid	Water-based mud with various amounts of different components such as ² : 0 – 250 m: Polymers 250 – 882 m: Potassium silicate & polymers 882 – 1'037.39 m: Sodium chloride & polymers

The lithostratigraphic profile and the casing scheme are shown in Fig. 1-3. The main lithostratigraphic boundaries in the BOZ1-1 borehole are shown in Fig. 1-4.

¹ Measured depth (MD) refers to the position along the borehole trajectory, starting at ground level, which for this borehole is the top of the rig cellar. For a perfectly vertical borehole, MD below ground level (bgl) and true vertical depth (TVD) are the same. In all Dossiers depth refers to MD unless stated otherwise.

² For detailed information see Dossier I.

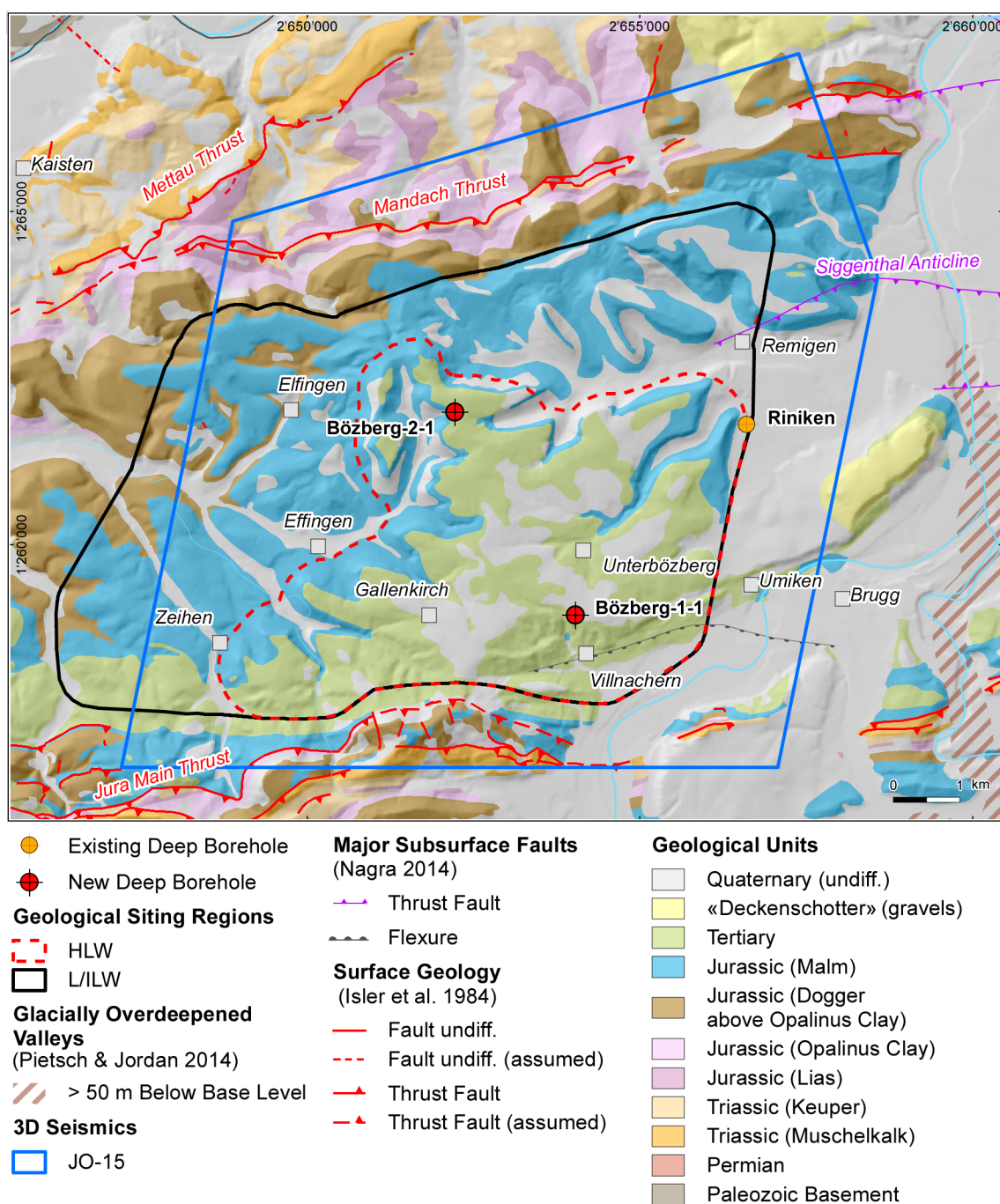
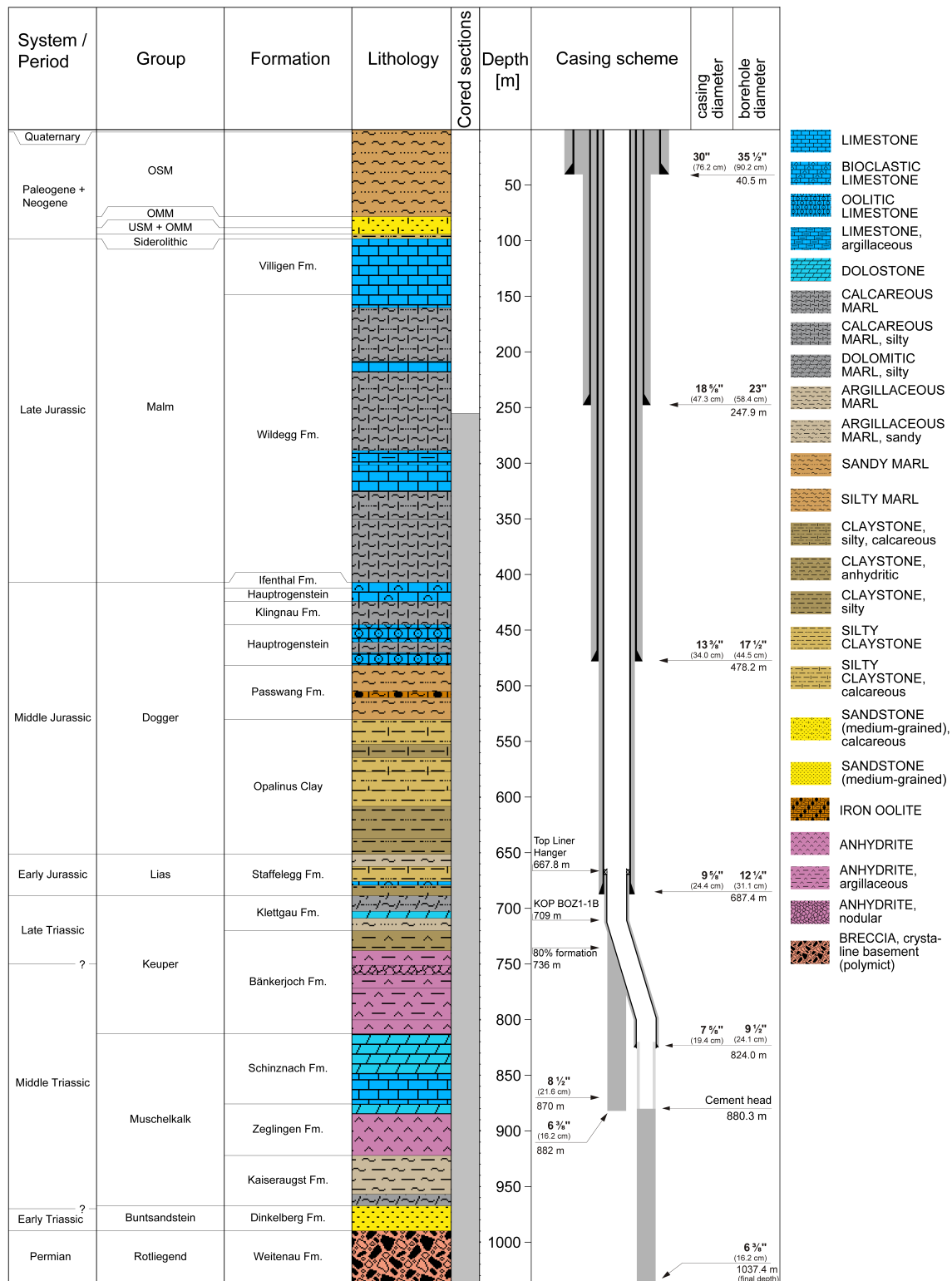


Fig. 1-2: Overview map of the investigation area in the Jura Ost siting region with the location of the BOZ1-1 borehole in relation to the boreholes Riniken and BOZ2-1

Fig. 1-3: Lithostratigraphic profile and casing scheme for the BOZ1-1 borehole³³ For detailed information see Dossier I and III.

1.3 Documentation structure for the BOZ1-1 borehole

NAB 21-21 documents the majority of the investigations carried out in the BOZ1-1 borehole, including laboratory investigations on core material. The NAB comprises a series of stand-alone dossiers addressing individual topics and a final dossier with a summary composite plot (Tab. 1-2).

This documentation aims at early publication of the data collected in the BOZ1-1 borehole. It includes most of the data available approximately one year after completion of the borehole. Some analyses are still ongoing (e.g. diffusion experiments, analysis of veins, hydrochemical interpretation of water samples) and results will be published in separate reports.

The current borehole report will provide an important basis for the integration of datasets from different boreholes. The integration and interpretation of the results in the wider geological context will be documented later in separate geoscientific reports.

Tab. 1-2: List of dossiers included in NAB 21-21

Black indicates the dossier at hand.

Dossier	Title	Authors
I	TBO Bözberg-1-1: Drilling	M. Ammen, P.-J. Palten, J. Vlieg, K. Gollob & K. Hilgendorf
II	TBO Bözberg-1-1: Core Photography	D. Kaehr & M. Gysi
III	TBO Bözberg-1-1: Lithostratigraphy	M. Schwarz, P. Schürch, H. Naef, P. Jordan, R. Felber, T. Ibele & M. Gysi
IV	TBO Bözberg-1-1: Microfacies, Bio- and Chemostratigraphic Analyses	S. Wohlwend, H.R. Bläsi, S. Feist-Burkhardt, B. Hostettler, U. Menkveld-Gfeller, V. Dietze & G. Deplazes
V	TBO Bözberg-1-1: Structural Geology	A. Ebert, L. Gregorczyk, S. Cioldi, E. Hägerstedt, & M. Gysi
VI	TBO Bözberg-1-1: Wireline Logging, Micro-hydraulic Fracturing and Pressure-meter Testing	J. Gonus, E. Bailey, J. Desroches & R. Garrard
VII	TBO Bözberg-1-1: Hydraulic Packer Testing	R. Schwarz, R. Beauheim, S.M.L. Hardie, M. Voß & A. Pechstein
VIII	TBO Bözberg-1-1: Rock Properties, Porewater Characterisation and Natural Tracer Profiles	P. Wersin, L. Aschwanden, L. Camesi, E.C. Gaucher, T. Gimmi, A. Jenni, M. Kiczka, U. Mäder, M. Mazurek, D. Rufer, H.N. Waber, C. Zwahlen & D. Traber
IX	TBO Bözberg-1-1: Rock-mechanical and Geomechanical Laboratory Testing	E. Crisci, L. Laloui & S. Giger
X	TBO Bözberg-1-1: Petrophysical Log Analysis	S. Marnat & J.K. Becker
	TBO Bözberg-1-1: Summary Plot	Nagra

1.4 Scope and objectives of this dossier

The dossier at hand complements the lithostratigraphic report (Dossier III) on the BOZ1-1 borehole and its sidetrack BOZ1-1B. The report documents data on microfacies analysis, ammonite- and palynostratigraphy as well as detailed geochemical (C, O and N isotopes) analyses. Preliminary results of these analyses already existed at data-freeze (02.02.2021), two months after the end of drilling operations and were integrated into the lithostratigraphic discussion and lithostratigraphic boundary definition (Dossier III).

The objectives of this report focusing on the Opalinus Clay and its confining units are:

- to specify the macroscopic description by a detailed microfacies analysis (components, matrix, cements),
- to allow a microfacies comparison of specific horizons, for example hardgrounds of the upper Opalinus Clay,
- to provide additional data on the diagenetic history of the sediment,
- to recover macrofossils from the stratigraphic interval of interest which are significant for facies changes and chronostratigraphic data,
- to compile an additional independent dataset of palynomorphs for chronostratigraphic data,
- to provide detailed geochemical (C, O and N isotopes) analyses with one metre spacing from the stratigraphic interval of interest,
- to allow a chemostratigraphic correlation (stable isotopes) with other deep boreholes in the three siting regions,
- to support the definition of the lithostratigraphic units.

The detailed stratigraphy of the BOZ1-1 borehole and its sidetrack BOZ1-1B with core depth in metres can be found in Fig. 1-4. The stratigraphic intervals of interest for the different investigations (microfacies analysis, ammonite- and palynostratigraphy and geochemical analyses) and their specific sampling intervals are visualised in Fig. 1-5 with respect to the 1:5'000 lithostratigraphic profile.

All depths labelled with metres [m] in this report refer to "m MD core depth" if not stated otherwise.

TBO BÖZBERG-1-1, BÖZBERG-1-1B				
System / Period	Group	Formation	Metres MD	Member / Sub-unit
Quaternary			2	
Paleogene / Neogene	OSM		78	
	OMM		88	
	USM/ OMM		94	
	Siderolithic		98	
Jurassic	Late	Malm		
			148	
	Middle	Dogger	402.75	Effingen Mb.
			406.67	Birmenstorf Mb.
			411.91	
				«Spatkalk»
			424.11	
			444.85	
			481.5	Rothenfluh Mb.
			504.87	«Humphriesi-Schichten»
			510.51	Waldenburg and lower part of Brüggli Mb.
			529.89	«Cond. equivalents of the Sissach, Hauenstein and/or Hirnichopf Mb.»
			530.28	«Sub-unit with silty calcareous beds»
			564.51	«Upper silty sub-unit»
			577.17	«Mixed clay-silt-carbonate sub-unit»
			637.33	«Clay-rich sub-unit»
			651.39	
Triassic	Late	Keuper	654.76	Gross Wolf Mb.
			659.15	Rietheim Mb.
			659.15	Grünschoholz Mb., Breitenmatt Mb. and Rickenbach Mb.
			662.27	Frick Mb.
			675.71	Beggingen Mb.
			679.06	Schambelen Mb.
			688.72	
			702.59	Gruhalde Mb.
			708.79	Gansingen Mb.
			720.03	Ergolz Mb.
	Middle	Muschelkalk	751.15	«Claystone with anhydrite nodules»
			771.91	«Cyclic sequence»
			800.27	«Thin-layered anhydrite and claystone sequence»
				«Banded massive anhydrite»
			812.62	Asp Mb.
			816.65	Stamberg Mb.
			849.01	Liedertswil Mb.
			857.45	Leutschenberg Mb. and Kienberg Mb.
			875.89	«Dolomitzone»
			884.87	«Obere Sulfatzone»
Permian	Rotlieg.	Weitenau Fm.	914.04	«Salzlager»
			915.36	«Untere Sulfatzone»
			922.22	«Orbicularismergel»
			930.69	«Wellenmergel»
			957.00	«Wellendolomit»
			967.38	
			989.89	
			1'037.39	Final depth

Fig. 1-4: Bözberg-1-1 & Bözberg-1-1B stratigraphy with core depth in metres [m MD]

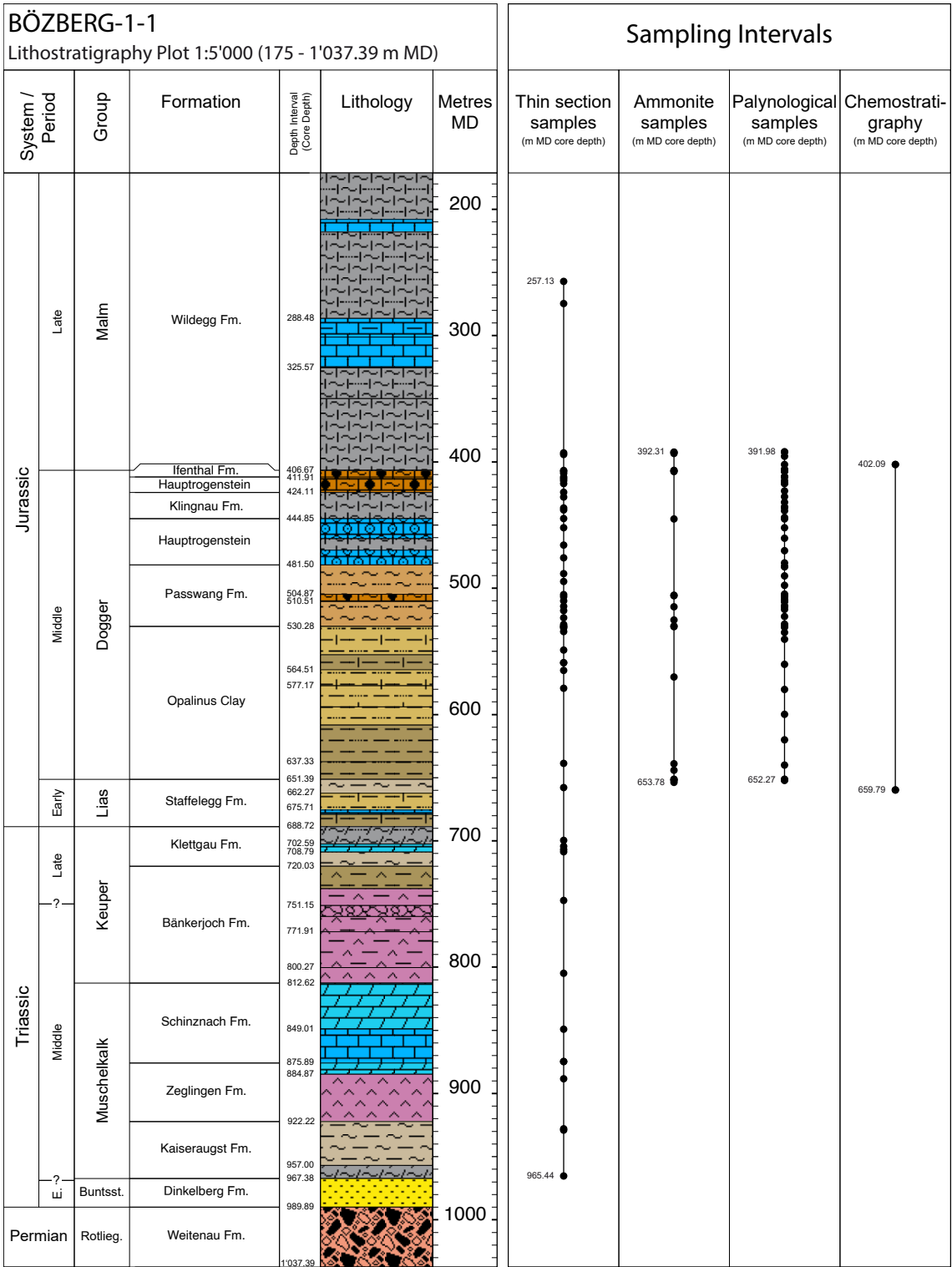


Fig. 1-5: Lithostratigraphy plot (1:5'000) from the Mesozoic succession with the individual sampling intervals for thin sections, macrofossils, palynological analysis and chemostratigraphy

1:5'000 stratigraphic plot modified from Dossier III.

2 Methods

2.1 Microfacies

Thin section preparation

All thin sections (TS) were cut edgewise from the core so that the long side is parallel to the coring direction and therefore covers as much of the stratigraphy as possible. The mean depth of the thin section corresponds to the Sample ID. Therefore, thin sections containing lithological boundaries may have Sample IDs that fall into only one of the two described intervals. However, the lower or upper range on the thin section still covers the interval. A list of all thin sections with their sampling range and Sample ID can be found in Appendix A1 of this report.

The thin sections from calcareous lithologies with a standard length of 4 cm were prepared at the University of Basel. Lithologies sensitive to water such as claystones and argillaceous sediments (swelling of clay minerals) or evaporates (dissolution of evaporitic minerals) were prepared by the Thin Section Lab (TSL) using petroleum. Thin sections prepared by TSL are only 3 cm long. For better identification of the carbonate minerals calcite, Fe-calcite and Fe-dolomite, the left half of the thin sections was stained applying the technique of Dickson (1965). Thin sections with a macroscopic porosity were impregnated during preparation using a blue coloured epoxy resin to estimate the percentage of their porosity.

Thin section analyses

52 thin sections were analysed using a Zeiss polarisation microscope. First, all allochemical components, biogenic particles, siliciclastics, matrix and diagenetic alterations as neomorphic minerals, cements and replacements were studied. Then, to obtain the percentage of the components etc., 100 points were counted with a net micrometre ocular. For detrital quartz-bearing thin sections, the average grain size was evaluated in millimetres. To count inhomogeneous sediments, two different sections were looked at and averaged. A selection of 21 thin section photographs for microfacies analysis is documented in Appendix B (Figs. B-1 to B-21).

Components, matrix and cements (definitions)

To describe thin sections, several allochemical components (described below) were counted, and their numbers are documented in Section 3.1 ('Microfacies'). Some of the specific terms used for the components or matrix are explained as follows:

Clay matrix, micrite, microsparite (or pseudosparite): Sedimented mud consisting of clay minerals, other very small silicate grains, heavy minerals (i.e. clay matrix) and/or microcrystalline carbonate ooze (i.e. micrite). Microsparite is defined as a mosaic of small calcite crystals formed by aggrading neomorphism; originally, it was micrite and not a diagenetic pore-filling cement. Alternatively, microsparite could also be the product of dedolomitisation as seen in the «Felsenkalke» and «Massenkalk» in thin sections of BUL1-1 (Wohlwend et al. 2021a).

Dolomitic matrix: primary microcrystalline dolostone ooze.

Limonitic matrix: Calcite micrite mixed with microcrystalline limonitic grains grown during diagenesis.

Limonitic echinoderms, limonitic bivalves: Fragments, parts of echinoderms and bivalves, with limonite filling the skeletal structure of the fossil.

Fe-stromatolites and stromatolitic clasts: Iron-mineralised microbial mats and/or microbial clasts.

Fe-ooids or iron-ooids: Limonitic/goethitic or chamositic ooids, with a visible concentric structure; some iron-ooids are replaced by calcite (calcitic iron-ooids), a few of them show relicts of iron mineral layers (BOZ1-1-528.80).

Intraclasts: Rock fragments of early diagenetic cemented sediment, reworked and sedimented in the same sedimentary environment.

Calcite cement (sparite): "Normal" cement, calcite crystals grown – filled in – within the primary pore space or in leached components. In this column, the amount of calcite crystal pseudomorphs after gypsum was noted.

"Stellate cement": Calcite "cement" grown within the matrix and not filling primary or secondary pore space. The calcite crystals form small "stellates", i.e. a habitus typical for "hiatus beds" (firm-, hardgrounds; Wetzel & Allia 2000) or "hiatus concretions" (Voigt 1968).

Cone-in-cone calcite: Rows of piled calcite cones grown during diagenesis which were named "Tutenmergel" in the Swabian realm.

(Fe)-Dolomite: Normally dolomite rhombohedrons that originated during diagenesis; in special cases, the dolomite replaces gypsum crystals that were sedimented as detrital gypsum crystals. In some cases, the rhombohedrons consist of iron-dolomite, which are stained blue after the thin section staining.

Dedolomite: Calcite replacement of dolomite: each single dolomite rhombohedron is replaced by a few smaller calcite crystals. When it was a total dolostone and the calcitic replacement has been completed, the result is a thoroughly crystalline, sparitic/ micro-sparitic limestone. In addition, another dedolomite type exists with larger calcite crystals jointly replacing a few dolomite crystals, thus forming a calcite mosaic similar to marble.

Anhydrite: Present in various forms: as a rock-forming mineral, as a vein mineral, mainly replacing "Fasergips", and as cement in sandstones (e.g. Ergolz Member of the Klettgau Formation; e.g. TS from TRU1-1; Wohlwend et al. 2021b).

Quartz cement: Authigenic quartz rims grown during diagenesis around detrital quartz grains; quartz/chalcedony in silicified bivalves (MAR1-1-569.18; Wohlwend et al. 2021c).

Porosity: Thin sections with a macroscopic porosity were impregnated during preparation using a blue coloured epoxy resin to estimate the volume percentage (vol.-%) of their porosity.

Hardground: Thin sections from hardgrounds document synsedimentarily cemented and lithified carbonate layers which have been exposed on the seafloor. During that time period, the hardgrounds are therefore mostly encrusted and bored by organisms and may consist of early marine calcite cements and are in parts mineralised by iron and manganese oxides or calcium phosphates.

2.2 Ammonite preparation

The BOZ1-1 cores were carefully examined for macrofossils at the Würenlingen (Canton Aargau) core storage facility. The cores were examined for ammonites and other macrofossils on the bedding and fractured surfaces as well as on the outer surface of the core; the core itself was not broken open. A list of all samples with their sampling range and Sample ID can be found in Appendix A2 of this report. In addition to ammonites, other conspicuous fossils were identified to the extent possible and entered in the list (Appendix A3), even when they were not subsequently, or only occasionally, recovered. The ammonites were then secured from the core and brought to the Natural History Museum in Bern, where they were prepared, documented, and afterwards archived in the earth sciences collection.

For the preparation, we used mechanical methods such as air tools and fine sandblasting equipment as well as a chemical etching method using potassium hydroxide (KOH). Sodium hydrogen carbonate was mainly used as abrasive. Residual material from sawing and preparing seven ammonite samples (marked in grey in Appendix A4) was used as material for palynological samples. Before being photographed, we applied ammonium chloride steam to the fossils to compensate for variation in contrast caused by different colouring. A selection of ammonites is documented on four plates (Plate I – IV) in Appendix C.

The names of several ammonite taxa are followed by a question mark, for example in *Pleydellia?* sp. The question mark after the genus name was used to indicate a question regarding the correct taxonomical assignment of the species to the genus.

2.3 Palynological sample preparation and quantitative analysis

Palynological processing of the rock samples was carried out by PLS Palynological Laboratory Services Ltd. (Holyhead, Anglesey, UK). Processing follows the standard protocol (Wood et al. 1996) using concentrated HCl and concentrated HF, followed by a short oxidation with HNO₃ and, if necessary, treatment with ultrasound. The residues are sieved at a mesh size of 15 µm. Residues are mounted on microscope slides and analysed using transmitted light microscopy. A list of all samples with their sampling range and Sample ID can be found in Appendix A4 of this report.

Two consecutive counts were carried out in the quantitative microscopic analysis. In a first count 200 grains of all palynomorphs were counted and the number of dinoflagellate cysts is noted (column 'DA *Dinocysts (count 1)*' in Appendix D1). In a second count, only dinoflagellate cysts are counted until a total of 100 dinoflagellate cysts is reached. The remainder of the slide is checked for additional, out-of-count species. Taxa recorded out of count are marked with a '+' in the range chart. Taxa only questionably identified are marked with a '?' in the range chart. Occurrences of fungal remains are recorded semi-quantitatively (R = Rare, O = Occasional, C = Common, A = Abundant, S = Superabundant). Rock samples from some sample levels were processed and analysed more than once. After the first analysis there were some concerns regarding possible contamination and/or a potential mix-up of several samples. As a precaution, and to dispel any doubts, the samples in question were re-processed from scratch and analysed again. Analyses of the repeat preparations are marked as such in Tab. 3-3 and charts in Appendices D1 and D2.

Results are illustrated using the software package StrataBugs v2.1 (Appendices D1 and D2). Numerical age dates used for the Composite Standard and the Depth/Age plot are in line with those of the *Geologic Time Scale 2016* (Ogg et al. 2016). On the range chart Appendix D1 several abbreviations are used (AC = Acritarchs, ALBO = Algae, *Botryococcus* and *Pediastrum*, ALPR = Algae, Prasinophytes, ALZY = Algae, Zygnematophyceae, DA = Dinocyst abundance, DC =

Dinoflagellate cysts, FT = Foraminiferal test linings, FU = Fungi, MP = Miscellaneous palynomorphs, SP = Spores and pollen. Several dinoflagellate cyst taxa contain a question mark in the name, as for example in *Evansia? eschachensis*. The question mark after the genus name indicates uncertainty regarding the correct taxonomical assignment of the species to the genus.

2.4 Chemostratigraphy

The sampling of the BOZ1-1 borehole focused primarily on the Dogger and Lias Groups and therefore primarily on clay mineral-rich layers of the Opalinus Clay. The sampling resolution was one metre, except for some intervals with denser sampling density (mainly hardgrounds, condensed intervals and the Rietheim Member of the Staffelegg Formation). All 299 samples were drilled with a micro-drill. In general, clay mineral-rich lithologies were sampled. Diagenetic calcite and siderite veins and nodules were avoided. The drilled powder amounted to around 1 g of material. A list of specific samples (n = 40) with results from calcareous beds, calcareous concretions, and macrofossils (e.g. belemnites) can be found in Appendix E1 of this report.

Inorganic (carbonate) analyses

The 298 samples were analysed for **stable carbon** ($\delta^{13}\text{C}_{\text{carb}}$) and **oxygen isotope** ($\delta^{18}\text{O}_{\text{carb}}$) of bulk carbonate, 276 continuous samples (roughly in metre resolution) and additional 22 samples mainly from specific calcareous beds and concretions in the Opalinus Clay (Appendix E1). Varying amounts of powder to reach approximately 120 μg of carbonate in the vial were weighed using a Mettler Toledo MT5 Fact microbalance in 12 ml vacutainers. The headspace was flushed with pure He, and then the samples were reacted with 100 % phosphoric acid at 72 °C in a ThermoFisher GasBench II carbonate device connected to a ThermoFisher Delta V PLUS mass spectrometer. The instrument is calibrated with international carbonate standards NBS19 and NBS18 distributed by the International Atomic Energy Agency (IAEA), Vienna and internal standards (MS2 "Carrara marble"; $\delta^{13}\text{C}_{\text{carb}} = 2.16 \text{ ‰}$, $\delta^{18}\text{O}_{\text{carb}} = -1.85 \text{ ‰}$). The reproducibility of the measurements based on replicated standards was $\pm 0.05 \text{ ‰}$ for $\delta^{13}\text{C}_{\text{carb}}$ and $\pm 0.06 \text{ ‰}$ for $\delta^{18}\text{O}_{\text{carb}}$. All isotope measurements were performed at the Stable Isotope Laboratory of the ETH Zurich (Geological Institute). The isotope values are reported in the conventional delta notation with respect to the Vienna Pee Dee Belemnite (VPDB).

The **Total Carbonate content** (TCarb) was calculated based on a calibration using extracted CO_2 from the known weight of the internal standard material (MS2), which is composed to 100% of carbonate (calcite). The mean area of the m/z 44 peak (corresponding to the most abundant isotopologue $^{12}\text{C}^{16}\text{O}_2$) in the mass spectrometer allows the carbonate content to be estimated from the individual bulk rock samples. The individual uncertainty for TCarb, represents the average from all standard deviations from the MS2 and is $\pm 7.35 \text{ ‰}$. However, the TCarb values calculated from the reaction of the phosphoric acid with the bulk rock, only reflect the carbonate that was able to react during the reaction time ($\sim 60 \text{ min}$). However, ankerite and especially siderite, for example, roughly require 60 h reaction time for full dissolution at 70 °C (Fernandez et al. 2016). Therefore, the calculated carbonate content (TCarb) does not completely represent the total amount of all different carbonates. The data reflect a mixed signal composed mostly of calcite and dolomite with a smaller component of the other more resistant carbonates (see also Wohlwend et al. 2019a).

Organic analyses

The powders remaining after inorganic analysis from 210 samples were decarbonated in quantities of less than 1 g in 10 ml of 3 M HCl for 12 h in 15 ml centrifuge tubes, to ensure the complete removal of carbonate. For neutralisation purposes, the residue was subsequently washed three

times with deionised water, and then centrifuged and decanted. After drying at 70 °C in an oven for at least 72 h the samples were homogenised with a mortar and pestle. Depending on the organic carbon content of each specific sample, a different amount was weighed in a tin capsule using a Mettler Toledo MT5 Fact microbalance, so that approximately the same amount of organic carbon was always measured.

$\delta^{13}\text{C}_{\text{org}}$ and $\delta^{15}\text{N}_{\text{org}}$ were measured by flash combustion on a ThermoFisher Scientific FlashEA elemental analyser connected to a Delta V isotope ratio mass spectrometer (IRMS) operated in continuous flow mode. The samples were combusted in an O_2 atmosphere in a quartz reactor at 1'020 °C packed with $(\text{Co}_3\text{O}_4)\text{Ag}$ and Cr_2O_3 to form CO_2 , N_2 , NO_x and H_2O . These gases were then transferred through a reduction reactor containing elemental Cu at 600 °C to remove excess O_2 and to reduce NO_x to N_2 . H_2O and SO_x were subsequently removed using anhydrous $\text{Mg}(\text{ClO}_4)_2$ and elemental Ag. Then, N_2 and CO_2 were separated in a packed gas chromatographic column and analysed for their isotopic composition using the IRMS. Isotope ratios are reported in conventional delta notation with respect to atmospheric N_2 (AIR) and VPDB standards, respectively. The methods were calibrated with the International Atomic Energy Agency (IAEA)-N1 ($\delta^{15}\text{N} = 0.45 \text{ ‰}$), IAEA-N2 ($\delta^{15}\text{N} = +20.41 \text{ ‰}$) and IAEA-N3 ($\delta^{15}\text{N} = +4.72 \text{ ‰}$) reference materials for nitrogen, and NBS22 ($\delta^{13}\text{C} = -30.03 \text{ ‰}$) and IAEA-CH-6 ($\delta^{13}\text{C} = -10.46 \text{ ‰}$) for carbon. Reproducibility of the measurements is better than $\pm 0.2 \text{ ‰}$ for both nitrogen and carbon. Reproducibility and accuracy of the measurements are based on replicate analyses of the internal laboratory standards atropine, peptone and nicotinamide. All geochemical measurements were performed at the Stable Isotope Laboratory of the ETH Zurich (Geological Institute).

The **Total Organic Carbon** ($\text{TOC}_{\text{decarb}}$) and **Total Nitrogen** ($\text{TN}_{\text{decarb}}$) contents of the decarbonised samples were calculated based on the known carbon and nitrogen contents of atropine (70.56 wt.-% C, 4.84 wt.-% N). The individual uncertainty for $\text{TOC}_{\text{decarb}}$ represents the average from all standard deviations from atropine during that calculation and is $\pm 2.58 \text{ ‰}$, respectively $\pm 0.28 \text{ ‰}$ for the $\text{TN}_{\text{decarb}}$. The calculated $\text{TN}_{\text{decarb}}$ reflects a mixture of bound inorganic and organic nitrogen and therefore also contains ammonium, which substitutes for K^+ in the interlayer exchange sites of illite (Scheffer & Schachtschnabel 1984).

The **Carbon-to-Nitrogen ratio** (C/N ratio) is a ratio of the mass of carbon to the mass of nitrogen. In this study, the ratio was calculated using the $\text{TOC}_{\text{decarb}}$ and the $\text{TN}_{\text{decarb}}$. As mentioned above, the C/N ratios can also be influenced by inorganic nitrogen in the form of soil-derived ammonium (Scheffer & Schachtschnabel 1984). Due to this inorganic nitrogen, the C/N ratios of sediments containing additional inorganic nitrogen will decrease. Therefore, C/N ratios are referred to as organic carbon/total nitrogen ($\text{TOC}_{\text{decarb}}/\text{TN}_{\text{decarb}}$) giving the ratio of the C and N masses of the decarbonised samples ($\text{C}_{\text{org}}/\text{N}_{\text{org}}$). The calculated ratios allow to distinguish between marine ($\text{C/N} \leq 10$; Parsons 1975) *versus* terrigenous matter ($\text{C/N} \geq 12$; Kukal 1971) in marine sediments.

$$\frac{\text{C}_{\text{org}}}{\text{N}_{\text{org}}} = \frac{\text{TOC}_{\text{decarb}}}{\text{TN}_{\text{decarb}}} * \frac{\text{atomic mass (C)}}{\text{atomic mass (N)}} = \frac{\text{TOC}_{\text{decarb}}}{\text{TN}_{\text{decarb}}} * \frac{14.007}{12.011}$$

The **Total Organic Carbon** (TOC) of the whole/bulk sample was calculated using the semi-quantitative carbonate content (TCarb) and semi-quantitative $\text{TOC}_{\text{decarb}}$ content based on the following equation:

$$\text{TOC} = (1 - \text{TCarb}) * \text{TOC}_{\text{decarb}}$$

3 Results

3.1 Microfacies

Kaiseraugst Formation (BOZ1-1B-965.44, 929.13, 928.07)

The lowermost sample, BOZ1-1B-965.44, taken in a sandstone sequence, should help to distinguish marine (Kaiseraugst Formation) or fluvial, terrestrial (Dinkelberg Formation) origin of this sediment. The thin section shows coarse-grained sandstone layers alternating with dolomicritic layers. The total content of quartz and siliciclastic rock fragments add up to 70 vol.-% (Tab. 3-1). The sandstone layers have some porosity (13 vol.-%), quartz cement (4 vol.-%) and dolomicritic matrix (13 vol.-%). If the dolomite layers were built by microbial mats is still open. So, the question could not be answered.

The two samples BOZ1-1B-929.13 and 928.07 are both fine-crystalline anhydrite (86 vol.-%, resp. 70 vol.-%, Tab. 3-1) with dolomite rhombohedrons (14 vol.-%) and, in the case of sample 928.07, with argillaceous interlayers (16 vol.-%).

Zeglingen Formation (BOZ1-1B-888.47)

Thin section BOZ1-1B-888.47 shows a very special facies within the Zeglingen Formation: a dolomitised oolite. Now it's a dolostone, which shows original ooids (35 vol.-%; Tab. 3-1), some bivalves (7 vol.-%), foraminifera (other biogenes: 2 vol.-%), intraclasts (8 vol.-%), dolomite rhombohedrons (37 vol.-%) and anhydrite crystals (11 vol.-%), grown in primary porespace and within pores of leached ooids and bivalves.

Schinznach Formation (BOZ1-1B-874.87, BOZ1-1-874.79, 849.23)

The sample BOZ1-1B-874.87 and BOZ1-1-874.79 are showing very similar microfacies of an oolitic limestone: composed of ooids (22, resp. 41 vol.-%; Tab. 3-1), micritised ooids, pellets (15, resp. 4 vol.-%) and some biogenes (10, resp. 12 vol.-%). All components have a small rim of radial fibrous calcite cement (9, resp. 11 vol.-%; Fig. B-1, Appendix B for all figures in this section), so that they are looking like superficial ooids ("Rindenooide"). Large clear anhydrite crystals (15, resp. 22 vol.-%), as well as micrite matrix (24, resp. 5 vol.-%) appear moreover in the limestone bed. Fluorite crystals, which have been supposed, couldn't be found.

Such anhydrite crystals are also developed in the biopelmicrosparite of thin section BOZ1-1-849.23 (Fig. B-2). They take one third (35 vol.-%; Tab. 3-1) of the thin section. Bivalves (11 vol.-%), echinoderm skeletal elements (7 vol.-%) and pellets (13 vol.-%) are the components in the micritic, microsparitic matrix (18 vol.-%), where dolomitic (16 vol.-%) patches appear too.

Bänkerjoch Formation (BOZ1-1-804.94, 747.27)

Looking at Bänkerjoch Formation in a macroscopic point of view, beds with round components have been seen. Are these eventually ooids? The sample BOZ1-1-804.94 contains no ooids, but spheres of dolomite (Fig. B-3), with an intern structure of radial dolomite crystals, which have grown pseudomorph after twinned gypsum crystals. Overall, the sample consists of 46 vol.-% dolomite (Tab. 3-1), 38 vol.-% anhydrite and 16 vol.-% dolomicrite.

Thin section BOZ1-1-747.27 shows an anhydrite layer (62 vol.-%; Tab. 3-1) and a slightly wavy, laminated dolostone layer (38 vol.-%), which has been developed by microbial mats.

Klettgau Formation (BOZ1-1-708.75, 706.90, 704.41, 699.70)

The three samples BOZ1-1-708.75, 706.90 and 704.41 are taken from the Gansingen Member, BOZ1-1-699.70 from the Gruhalde Member.

BOZ1-1-708.75 is a porous (15 vol.-%; Tab. 3-1) dolostone (64 vol.-% = 37 vol.-% dolomicrite and 27 vol.-% dolomite rhombohedrons; Tab. 3-1) with anhydrite needles (16 vol.-%) in the pores (Fig. B-4) and some pyrite (5 vol.-%). Because of the intense diagenetic transformations, the original sediment is not identifiable. On the other hand, BOZ1-1-706.90, an also strongly altered dolostone, still shows its original composition. This thin section consists of bivalves (27 vol.-%), ooids (22 vol.-%), dolomite rhombohedrons (27 vol.-%) and leaching pores (24 vol.-%) (Fig. B-5).

Sample BOZ1-1-704.41 is a stromatolitic dolostone (95 vol.-% dolomicrite; Tab. 3-1) with anhydrite (5 vol.-%; Tab. 3-1) filling fenestrae pores.

Thin section BOZ1-1-699.70 of the Gruhalde Member has been analysed with the idea to find siliciclastic detritus as evidence for the Seebi Member. The bed consists of dolomitic marl (40 vol.-%; Tab. 3-1) alternating with dolostone layers (30 and 24 vol.-%) and few (6 vol.-%) quartz and siliciclastic rock fragments.

Staffelegg Formation (BOZ1-1-657.91)

The only studied sample of the Staffelegg Formation (BOZ1-1-657.91), a limestone bed of the Rietheim Member («Homogene Kalkbänke» *sensu* Kuhn & Etter (1994): 657.85 – 658.08 m), shows a special facies. The thin section, which is representative for the whole bed, is largely composed of shells of tiny gastropods (counted as other biogenes: 32 vol.-%; Tab. 3-1), as well as micrite matrix (64 vol.-%; Fig. B-6). The superabundance of the tiny gastropod *Coelodiscus minutus* (Schuebler) is very typical for the «Homogene Kalkbänke» and also the «Oberer Stein» (Kuhn & Etter 1994). Teichert & Nützel (2015) assign the gastropod (*C. minutus*) to the holoplanktonic organisms, which could allow them to escape the local hostile bottom conditions, such as anoxia or heavily oxygen depleted conditions during the Toarcian Oceanic Anoxic Event (T-OAE).

Opalinus Clay (BOZ1-1-638.74, 579.27, 565.14, 559.07, 559.02, 549.02, 534.39, 531.52, 530.56)

With 4 of the 9 analysed thin sections, we characterise the different subfacies of the Opalinus Clay. The other 5 come from calcareous horizons, which interrupt the normal sedimentation of the silty claystones.

BOZ1-1-638.74, part of the «Clay-rich subunit», is a claystone, calcareous: calcareous due to the content of bivalves (16 vol.-%; Tab. 3-1) in the claystone (80 vol.-%). Few pyrite (4 vol.-%) is contained too.

The two samples BOZ1-1-579.27 and BOZ1-1-565.14 are both calcareous silt- to sandstone lenses within the silty claystones of the thick «Mixed clay-silt-carbonate sub-unit» and the smaller «Upper silty sub-unit» above. BOZ1-1-579.27 shows small ripple laminae consisting of quartz silt (22 vol.-%; Tab. 3-1), biogene components (bivalves, echinoderms) (15 vol.-%), calcite cement (11 vol.-%), dolomite (6 vol.-%), alternating with claystone laminae (40 vol.-%). Sample BOZ1-1-565.14, taken from a bigger sandstone lense than 579.27, contains coarser quartz-grains

and more biotritus, namely: quartz sand (35 vol.-%; Tab. 3-1), biogene components (28 vol.-%), pellets (7 vol.-%), calcite cement (16 vol.-%) and dolomite (3 vol.-%) as well as clay matrix (8 vol.-%) and pyrite (3 vol.-%).

Samples BOZ1-1-559.07 and 559.02 as well as 549.02 are coming from a section (about 548 – 560 m) with several carbonate-rich, harder horizons, composed of calcitic, sideritic nodules, intraclasts, iron-stromatolitic flasers, few iron-ooids and many biogene components, which is structured using the informal term «Sub-unit with silty calcareous beds». These horizons are either "hiatus beds", where a cementation – formation of nodules and "stellate calcite cement" – took place within the deposited marly or argillaceous mud, or true hardgrounds with early cementation, often with crusts and mineralisation, on the surface area of the sea floor.

BOZ1-1-559.07 and 559.02 are very similar: a big sideritic, calcitic nodule (56 resp. 45 vol.-%; Tab. 3-1), iron-mineralised flasers (4 resp. 3 vol.-%, Fig. B-7), calcitic iron-ooids (2 resp. 1 vol.-%), biogene components (13 vol.-%) and a quartz silty (10 resp. 11 vol.-%), argillaceous matrix (10 resp. 24 vol.-%), and pyrite (2 resp. 3 vol.-%). The here mentioned calcitic iron-ooids have been noted in the "Fe-ooids" column in Tab. 3-1 with an asterisk behind the number.

BOZ1-1-549.02 shows iron-oolitic, bioclastic intraclasts (50 vol.-%; Tab. 3-1, Fig. B-8), biogene components (24 vol.-%), iron-ooids (3 vol.-%), "stellate cement" (8 vol.-%) and marly matrix (13 vol.-%) with little pyrite (2 vol.-%).

The next higher sample, BOZ1-1-534.39, comes again from a section rich in sandstone lenses: calcitic cemented quartz sand and biotritus laminae alternate with calcitic quartz silt laminae and claystone interlayers. The sample consists of quartz (14 vol.-%; Tab. 3-1), biotritus (12 vol.-%), pellets (3 vol.-%), pyrite (4 vol.-%), mica (2 vol.-%) and clay matrix (65 vol.-%).

BOZ1-1-531.52 was taken at the top of a 26 cm thick limestone bed: it is a fine-bedded to laminated silty to sandy limestone with 33 vol.-% carbonate particles (echinoderms, bivalves, other biogenes, pellets), 23 vol.-% calcite cement and 28 vol.-% quartz grains (Tab. 3-1), moreover a bit clay matrix (5 vol.-%), dolomite (5 vol.-%), pyrite (3 vol.-%) and mica (3 vol.-%). It looks like a sandstone, but the carbonate content is higher than the quartz grain content, therefore it is a silty to sandy limestone.

BOZ1-1-530.56 derives from the uppermost calcareous bed of the Opalinus Clay, composed of bioclasts (27 vol.-%; Tab. 3-1) and quartz sand (13 vol.-%), partly together with marly matrix (16 vol.-%), partly cemented by calcite 10 vol.-%) and "stellate cement" (8 vol.-%), as well as iron-dolomite (12 vol.-%) and relatively much pyrite (14 vol.-%).

Passwang Formation (BOZ1-1-530.17, 528.80, 523.47, 517.80, 514.38, 510.08, 506.72, 505.10, 494.72, 488.54)

The Passwang Formation represents a lithological very heterogenous formation. We analysed iron-oolitic hardgrounds (BOZ1-1-530.17 and 528.80) from the lowermost beds, then calcareous beds (BOZ1-1-523.47, 517.80 and 514.38), which are interlayered in the marly interval Waldenburg to lower part of Brüggli Member. The next three samples (BOZ1-1-510.08, 506.72 and 505.10) are iron-oolitic beds, taken from the «Humphriesi-Schichten», and the uppermost two (BOZ1-1-494.72 and 488.54) are limestones of the Rothenfluh Member.

The sample BOZ1-1-530.17 shows only a part of a multi-layered hardground with iron-ooids (15 vol.-%; Tab. 3-1), beautiful intraclasts (9 vol.-%) (Fig. B-9), iron-stromatolites (4 vol.-%), bioclasts (20 vol.-%), limonitic bioclasts (15 vol.-%) and calcite cement (11 vol.-%) as well as

"stellate cement" (8 vol.-%). BOZ1-1-528.80 is an iron-oolitic, biotrititic, sandy limestone with chamositic and calcified iron-oolids (Fig. B-10). The bed consists of bioclasts (23 vol.-%; Tab. 3-1), limonitic bioclasts (7 vol.-%), iron-oolids (17 vol.-%), intraclasts (7 vol.-%), quartz sand (17 vol.-%), micritic matrix (21 vol.-%), pyrite (4 vol.-%) and limonitic pellets (4 vol.-%).

The two limestone beds, where BOZ1-1-523.47 and 517.80 are coming from, show very similar microfacies: biogene components (27, resp. 35 vol.-%; Tab. 3-1), namely echinoderm skeletal elements, bivalves, serpulids, sponge spicules and few foraminifera (2 vol.-%), quartz sand (26, resp. 22 vol.-%), micrite/microsparite (22, resp. 27 vol.-%), pyrite (5, resp. 4 vol.-%) and calcite cement (15, resp. 8 vol.-%). The sample BOZ1-1-523.47 has, in contrast to 517.80, a nodular concentration of microsparite and calcite cement (Fig. B-11).

Thin section BOZ1-1-514.38, a limonitic, bioclastic limestone, consists of limonitic components: limonitic oncolids (10 vol.-%; Tab. 3-1), limonitic biotrititus (13 vol.-%), iron-oolids (4 vol.-%), limonitic pellets (8 vol.-%), as well as other bioclasts (17 vol.-%), limonitic matrix (15 vol.-%), micrite (11 vol.-%), calcite cement (11 vol.-%) and "stellate cement" (7 vol.-%).

The sample BOZ1-1-510.08, taken from the lower part of the «Humphriesi-Schichten», shows a similar composition with limonitic oncolids (5 vol.-%; Tab. 3-1), iron-oolids (7 vol.-%), limonitic pellets (8 vol.-%), limonitic biotrititus (8 vol.-%), biogene components (26 vol.-%) (Fig. B-12). But this limonitic limestone is rich in quartz sand (17 vol.-%).

Higher up the «Humphriesi-Schichten» are iron-oolites: BOZ1-1-506.72 and 505.10 are composed of more or less structure-less iron-oolids (30, resp. 35 vol.-%; Tab. 3-1), with diameters up to 1 mm, limonitic biotrititus (18, resp. 22 vol.-%), limonitic calcareous matrix (BOZ1-1-506.72: 44 vol.-%) or limonitic marly matrix (BOZ1-1-505.10: 36 vol.-%), little quartz grains, calcite cement and iron-dolomite.

BOZ1-1-494.72 and 488.54 have been taken from limestone beds/lenses, which are interstratified in the calcareous or argillaceous marls of the Rothenfluh Member. They are silty to sandy biotritites, composed of small biogene components, such as sponge spicules (18, resp. 14 vol.-%; Tab. 3-1), echinoderms and bivalves (21, resp. 16 vol.-%), pellets (8 vol.-%), quartz (12 vol.-%) and microsparite (35, resp. 42 vol.-%; Fig. B-13).

Hauptrogenstein (BOZ1-1-476.00, 465.92, 452.17, 444.88)

The Hauptrogenstein of Bözberg-1 looks not like the famous Hauptrogenstein in his main region further west, where the «Lower and Upper Hauptrogenstein» are limestone successions and they consist of sparitic oolites (oosparites, grainstones) for the most part. Here, where we found a marl/limestone alternation, the limestone-microfacies are also different: BOZ1-1-476.00 and 465.92 have indeed spheroidal components, but these are oncolids, sometimes with an ooid nucleus, however with a black microbial and/or foraminiferal rim (Figs. B-14 and B-15). The beds consist of oncolids (30, resp. 28 vol.-%; Tab. 3-1), echinoderm skeletal elements (14, resp. 16 vol.-%), bivalves (10, resp. 14 vol.-%), foraminifera and other biogene components (3 vol.-%) as well as micrite matrix (33, resp. 24 vol.-%). The sample BOZ1-1-476.00 has some pellets (5 vol.-%) and quartz-grains (5 vol.-%), but BOZ1-1-465.92 additional iron-dolomite (15 vol.-%).

The samples BOZ1-1-452.17 and 444.88 are biotrititic limestones with a few ooids (5, resp. 2 vol.-%; Tab. 3-1) and oncoids (2, resp. 5 vol.-%) (Fig. B-16). Most of the components are bivalves (24, resp. 29 vol.-%), echinoderm skeletal elements (16, resp. 22 vol.-%) and pellets (16 vol.-%) in the case of BOZ1-1-452.17. Micrite and microsparite (29, resp. 38 vol.-%) complete the composition.

Klingnau Formation (BOZ1-1-438.08, 436.51, 427.88)

The two samples BOZ1-1-438.08 and 436.51 were taken to test if the two beds really contain iron-ooids, as it looks like in a macroscopic point of view. Both are limonitic, bioclastic limestone, consisting of limonitic bioclasts (40, resp. 44 vol.-% echinoderms, bivalves and serpulids; Tab. 3-1) (Fig. B-17). Most of all serpulids are limonitic, and their central circular "Wohnröhre" have similarity to round iron-ooids. The two samples contain few intraclasts (4 vol.-%), limonitic pellets (4, resp. 8 vol.-%) and quartz silt (5, resp. 3 vol.-%) too. The components are embedded in a limonitic matrix (37, resp. 38 vol.-%), whereat BOZ1-1-438.08 is marlier than BOZ1-1-436.51.

BOZ1-1-427.88 shows a biotrititic limestone with small (0.2 – 0.8 mm) biogene components of echinoderms (14 vol.-%; Tab. 3-1), bivalves (27 vol.-%) and others (8 vol.-%), whereof many are black coloured foraminifera of different species. Micritic matrix and marly lenses (together 34 vol.-%), the last one with quartz silt (5 vol.-%), as well as few calcite cement areas (12 vol.-%) complete the microfacies.

Hauptrogenstein («Spatkalk») (BOZ1-1-424.05, 417.22, 414.92, 413.38, 412.02)

The lowermost analysed thin section of the «Spatkalk» (Hauptrogenstein), BOZ1-1-424.05, has nearly the same microfacies as BOZ1-1-427.88 of the underlying interval: small biogene components (33 vol.-% bivalves and echinoderms; Tab. 3-1), 13 vol.-% other biogenes with a lot of these strange black foraminifera, micritic matrix (27 vol.-%), calcite cement (12 vol.-%) and iron-dolomite (15 vol.-%).

The sample BOZ1-1-417.22 is a true "Spatkalk", developed as sparitic, bioclastic limestone: 45 vol.-% bioclasts of bivalves and echinoderms (Tab. 3-1) and 18 vol.-% calcite cement. Additionally, are present: serpulids and other biogenes (7 vol.-%), pellets, oncoids and intraclasts (15 vol.-%), iron-dolomite (3 vol.-%) and micritic matrix (12 vol.-%).

The three samples (BOZ1-1-414.92, 413.38, 412.02) of the upper section of the «Spatkalk» (Hauptrogenstein) are strongly limonitic, bioclastic limestones: limonite exists within the matrix and the biogene components. BOZ1-1-414.92 is a coarse-grained (0.5 – 5 mm) limonitic, bioclastic limestone (Fig. B-18), consisting of limonitic echinoderms and bivalves (28 vol.-%; Tab. 3-1), other echinoderms and bivalves (15 vol.-%), further biogenes (8 vol.-%), limonitic nodules (8 vol.-%), with limonitic matrix (24 vol.-%) and calcite cement (12 vol.-%) as well as few iron-dolomite rhombohedrons (5 vol.-%).

The sample BOZ1-1-413.38 is more or less similar developed, what concerns the components, but regarding matrix and cement, the limestone is calcite-cemented and not micritic: limonitic bioclasts (22 vol.-%; Tab. 3-1), echinoderms (9 vol.-%), bivalves (6 vol.-%), serpulids and other biogenes (12 vol.-%), intraclasts (6 vol.-%) and limonitic nodules (4 vol.-%) are cemented by calcite (24 vol.-%) and iron-dolomite (14 vol.-%) (Fig. B-19).

Sample BOZ1-1-412.02 looks less limonitic than the two others, but the composition is very similar. So, the content of limonite within the micritic matrix can be less. We count 16 vol.-% echinoderms, 7 vol.-% bivalves, 20 vol.-% limonitic bivalves and echinoderms, 12 vol.-% other biogenes, 5 vol.-% limonitic grains and 31 vol.-% limonitic matrix, as well as 4 vol.-% calcite cement and 5 vol.-% iron-dolomite.

Ifenthal Formation (BOZ1-1-409.06, 407.49, 406.83)

Each of the three analysed beds shows another microfacies: BOZ1-1-409.06, a limonitic, bioclastic limestone, consists of, often closely packed, different limonitic bioclasts – echinoderms, bivalves, serpulids and others – (36 vol.-%; Tab. 3-1), limonitic pellets (9 vol.-%), non-limonitic bioclasts (7 vol.-%), limonitic matrix (34 vol.-%) and some calcite cement (14 vol.-%). A couple of limonitic bioclasts have not only limonite in their biogene structure but also a small limonitic crust around the grain.

Thin section BOZ1-1-407.49, also a limonitic, bioclastic limestone, has additional to the limonitic and non-limonitic bioclasts (totally 49 vol.-%; Tab. 3-1) round "components", where iron-dolomite (Fig. B-20) replaces an earlier material or components. But no relicts of the earlier material or components are visible. The round form of these components could indicate they were originally iron-oids (18 vol.-%). Limonitic matrix (18 vol.-%) and dolomite rhombohedrons (7 vol.-%) complete the composition.

Sample BOZ1-1-406.83 comes from the uppermost layers of the Ifenthal Formation. It is a multi-layered hardground with an iron-stromatolite (13 vol.-%; Tab. 3-1), which has enclosed iron-oids (Fig. B-21), then iron-oolitic, biotrititic layers (23 vol.-% iron-oids, 15 vol.-% bioclasts), structureless limonitic grains (8 vol.-%) and partly limonitic micrite matrix (totally 33 vol.-%).

Wildegge Formation (BOZ1-1-394.18, 392.88, 274.67, 257.13)

The two lower samples (BOZ1-1-394.18 and 392.88) come from limestones near the base of the Effingen Member, the two upper ones (BOZ1-1-274.67 and 257.13) are calcareous marls higher up in the Effingen Member.

The two limestone beds (BOZ1-1-394.18 and 392.88) are sponge limestones. They consist of sponge nodules (63 resp. 48 vol.-%; Tab. 3-1), whereat few of them are black coated, and echinoderm skeletal elements (5 vol.-%), plus limonitic components (3 resp. 6 vol.-%), sedimented with micrite matrix (16 resp. 25 vol.-%). Moreover BOZ1-1-394.13 shows quartz silt (5 vol.-%), oncoids (5 vol.-%) and small iron-stromatolite nodules (3 vol.-%), whereas BOZ1-1-392.88 has a serpulid incrustation (16 vol.-%) on a sponge nodule.

The calcareous marl samples (BOZ1-1-274.67 and 257.13) contain nothing else than few quartz grains (6 resp. 4 vol.-%; Tab. 3-1), few biogene components (9 resp. 5 vol.-%), pyrite (2 vol.-%) and marly matrix (83 resp. 88 vol.-%).

Tab. 3-1: Microfacies analysis from BOZ1-1 (874.79 – 257.13 m) and BOZ1-1B (965.44 – 874.87 m); numbers in vol.-%

Microfacies analysis BOZ1-1 (874.79 - 257.13 m) BOZ1-1B (965.44 - 874.87 m)	clay matrix, micrite, microsparite	dolomitic matrix	limonitic matrix	components (and biohermal organisms)												cements, diagenesis								mica	porosity		
				calclitic biogenes						allochems						calcite cement	"stellate cement" (s) cone-in-cone calcite (c)	(Fe)-dolomite	dedolomite	anhydrite, gypsum	quartz cement	pyrite	limonite, Fe-min. nodules			siderite	
				echinoderms	bivalves	limonitic echinod. + bivalves	serpulids	corals	sponges, spicules	other biogenes	Fe-stromatolitic clasts	pellets, peloids	ooids	oncoids	Fe-ooids												intraclasts, nodules
257.13m: calcareous marl Wildegg Fm. (Efringen Mb.)	88			2	3							3				5	0.04									2	
274.67m: calcareous marl Wildegg Fm. (Efringen Mb.)	83			2	4							3				6	0.04									2	
392.88m: sponge-limest. (packst., biom.) Wildegg Fm. (Efringen Mb.)	25			5			16		48																		
394.18m: sponge-limest. (packst., biom.) Wildegg Fm. (Efringen Mb.)	16			5					63		3			5		5	0.05										
406.83m: hardg.: iron-strom.+ iron-oolite Iferthal Fm.	15	18	6	2	5					2	13					23	8									8	
407.49m: biocl. limestone (iron-oolitic) Iferthal Fm.		18	17	10	12	3				7						18											
409.06m: biocl. limestone (limonitic) Iferthal Fm.		34	4	3	28	5				3								14								9	
412.02m: biocl. limestone (limonitic) Hauptrogenstein («Spalkalk»)			31	16	7	20	5			7								4	5							5	
413.38m: biocl. limestone (limonitic) Hauptrogenstein («Spalkalk»)			3	9	6	22	4			8						6		24	14							4	
414.92m: biocl. limestone (limonitic) Hauptrogenstein («Spalkalk»)			24	11	4	28	4			4								12	5							8	
417.22m: biocl. limestone (grainstone) Hauptrogenstein («Spalkalk»)	12			24	21		3			4	5		5	5				18	3								
424.05m: bioclitr. limest. (wacke.-pack.) Hauptrogenstein («Spalkalk»)	27				23	10				13								12	15								
427.88m: bioclitr. limestone (wackest.) Klingnau Fm.	34			14	27					8								5	0.05	12							
436.51m: biocl. limestone (limonitic) Klingnau Fm.			38				36	8		3						4	3	0.04								8	
438.08m: biocl. limest. (limonit., arg.) Klingnau Fm.			37	3	3	18	22									4	5	0.04	4							4	
444.88m: bioclitr. limest. (wacke.-pack.) Hauptrogenstein	38			22	29					4			2	5													
452.17m: biotetrilic limestone (packst.) Hauptrogenstein	29			16	24					2	16	5	2														
465.92m: bioclitr. limestone (oncolitic) Hauptrogenstein	24			16	14					3				28													
476.00m: bioclitr. limestone (oncolitic) Hauptrogenstein	33			14	10					3	5		30					5	0.07								
488.54m: bioclitr. limestone (sandy) Passwang Fm. (Rathenfluh Mb.)	42			7	9				14	3	8							12	0.07							5	
494.72m: bioclitr. limestone (sandy) Passwang Fm. (Rathenfluh Mb.)	35			12	9				18	3	8							12	0.07							3	
505.10m: iron-oolite, marly Passwang Fm. («Humphries-Sch.»)		36				22										35	2	0.07	3	2							
506.72m: iron-oolite, calcareous Passwang Fm. («Humphries-Sch.»)		44				18				2						30	3	0.07		3							
510.08m: bioclitr. limest. (sandy, Fe-O.) Passwang Fm. («Humphries-Sch.»)	10			12	7	8			4	3			5	7	17	0.08	9	8	3						7		
514.38m: biocl. limestone (limonitic) Passwang Fm. (Waldenburg Mb. + i.p. of Bruggl Mb.)	11	15	11	6	13								10	4			11	7							8		
517.80m: bioclitr. limestone (sandy) Passwang Fm. (Waldenburg Mb. + i.p. of Bruggl Mb.)	27			14	12		2		5	2	4						22	0.07	8						4		
523.47m: bioclitr. limestone (sandy) Passwang Fm. (Waldenburg Mb. + i.p. of Bruggl Mb.)	22			12	10		3			2	5						26	0.08	15						5		
528.80m: hardg.: iron-oolite + intracl. Passwang Fm. (Waldenburg Mb. + i.p. of Bruggl Mb.)	21			17	6	7										17	7	0.07							4	4	
530.17m: hardg.: iron-strom.+iron-oolite Passwang Fm. («Cond. equiv. Si., Hb. + H. Mb.»)	10	8	9	11	15						4					15	9		11	8							
530.56m: bioclitr. limest. (sandy, pyritic) Opalinus Clay	16			14	11					2								13	0.08	10	8	12			14		
531.52m: silty to sandy limestone Opalinus Clay	5			16	10					2	5							28	0.06	23	5				3		3
534.39m: clayst. + calc. silt-sandst. layers Opalinus Clay	65			8	4						3							14	0.06						4		2
549.02m: "hiatus bed": iron-ool. intracl. Opalinus Clay	13			16	5					3						3	50			8					2		
559.02m: "hiatus bed": sider., calc. nod. Opalinus Clay	24			10	3						3					1*	45	11	0.05						3		
559.07m: "hiatus bed": sider., calc. nod. Opalinus Clay	10			11	2						4					2*	56	10	0.05						2	1	
565.14m: calc. sandstone (biotetrilic) Opalinus Clay	8			16	9					3	7							35	0.08	16	3				3		
579.27m: calc. siltstone (biotetrilic) Opalinus Clay	40			10	4				1									22	0.05	11	6				3		3
638.74m: claystone (calcareous) Opalinus Clay	80					16																			4		
657.91m: limestone (wackest., biomic.) Stiefellegg Fm. (Rietheim Mb.)	64									32																	
699.70m: dolomitic marl Klettgau Fm. (Grubelde Mb.)	40	30																6	0.08							4	
704.41m: dolostone, stromatolite Klettgau Fm. (Garsingen Mb.)		95																							5		
706.90m: bioclitr. dolost., ool., porous Klettgau Fm. (Garsingen Mb.)												22															
708.75m: dolostone (anhydritic) Klettgau Fm. (Garsingen Mb.)		37																							16	5	
747.27m: anhydrite + dolost., stromat. Bärkerloch Fm.		38																							62		
804.94m: anhyd. (dolom.) + dolost.(arg.) Bärkerloch Fm.		16																							38		
849.23m: bioclitr. limestone (anhydr.) Schinznech Fm. (Liederswil Mb.)	18		7	11								13													35		
874.79m: oolitic limestone (anhydr.) Schinznech Fm. (Leutschenberg Mb. & Kienberg Mb.)	5		3	4						5	4	41								11	2	22					
874.87m: oolitic limestone (anhydr.) Schinznech Fm. (Leutschenberg Mb. & Kienberg Mb.)																											
888.47m: dolostone (form. ool. limest.) Zegglingen Fm. («Obere Sulzzone»)				3	4					3	15	22						9		3					15		
928.07m: anhydrite Kaiseraugst Fm. («Orbicularismergel»)	16									2		35													70		
929.13m: anhydrite Kaiseraugst Fm. («Orbicularismergel»)																									14		
965.44m: sandstone Kaiseraugst Fm.																									86		
		13																70	0.30						4		13

3.2 Ammonite stratigraphy

From the recovered ammonites (list in Appendix A2), only two specimens (depth 407.72 m and 406.73 m) could not be extracted because there was no separation between the rock matrix and the fossils, and the rock matrix hardly reacted to potassium hydroxide. Several ammonites were unfortunately so truncated by the drilling or sampling process that neither the genus nor the species could be determined (e.g. 529.96 m). One ammonite (392.48 m) was too juvenile for identification, it had not yet developed any characteristic features.

As with other similar drill cores, the ammonites were distributed very differently over the individual temporal sections of the borehole. They are relatively common in the Late Toarcian and the lower parts of the Opalinus Clay. In the Late Aalenian and Early Bajocian, ammonites are rare with the exception of the «Humphriesi-Schichten». In the Late Bajocian, only one ammonite could be found. In the Bathonian and Callovian there was only sparse evidence of ammonites. In addition, the objects could not at all, or only with uncertainty, be determined because of their small size or poor preservation. Only in the Oxfordian succession of the drill cores the ammonites become more numerous, but they are difficult to determine due to incomplete preservation. Due to the generally small sample quantity and the poor, often incomplete preservation, a more-or-less large uncertainty in the age determination must be expected, which can have an effect on the biostratigraphic classification.

We documented a selection of ammonites with photographs, and these are shown on four plates (Plates I – IV) in Appendix C. In addition to ammonites, other conspicuous fossils were identified to the extent possible (Appendix A3), even when they were not subsequently, or only occasionally, recovered.

In general, the more ammonites are present in a specific profile section, the more precisely we can determine the biostratigraphic classification of that section (Tab. 3-2). Furthermore, it must be considered that not all ammonites have the same index value and that the state of preservation of the objects also plays an important role in the biostratigraphic determination. In this respect, a certain error must always be expected. This error is in the range of about one ammonite Subzone (SZ) but can be as high as one ammonite Zone (Z), when the available data are insufficient.

Staffelegg Formation

- 653.75 m: *Pseudogrammoceras* ex gr. *fallaciosum* (Bayle, 1878). Steinkern. Age: the species is common in the Late Toarcian, in the Thouarsense Zone, probably Fallaciosum Subzone. Lithology: light- to dark-grey biodetritic limestone with pyrite. Other fossils include belemnites, a rhynchonellid brachiopod, and an oyster. The ammonite is illustrated on Plate I, Fig. 1.
- 653.82 m: *Perilytoceras jurensense* (Zieten, 1833). Steinkern. Age: the species is common in the Thouarsense Zone. Lithology: dark-grey marl with numerous belemnites. This ammonite is not illustrated.
- 652.26 m: *Pleydellia* sp. Three truncated ammonites. Age: Aalensis Zone, probably Aalensis Subzone. Lithology: light-grey limestone (argillaceous) with ammonites. Other fossils are an echinid spine and a rhynchonellid brachiopod. The ammonite is illustrated on Plate I, Fig. 2.

- 651.60 m: *Cotteswoldia* ex gr. *lotharingica* (Branco, 1879) or *Cotteswoldia* ex gr. *pseudo-lotharingica* (Maubeuge, 1950). Flattened steinkern. Age: Aalensis Zone, Torulosum Subzone. Lithology: dark-grey biotrititic (echinoderm) marl. The ammonite is illustrated on Plate I, Fig. 3.

Opalinus Clay

- 651.27 m: *Leioceras* ex gr. *subglabrum* (Buckman, 1902). Flattened clay steinkern. Age: Opalinum-Zone, Opalinum-Subzone. Lithology: dark-grey biotrititic claystone (shell fragments, echinoderms). Other fossils: a *Bositra buchi*. The ammonite is illustrated on Plate I, Fig. 4.
- 644.18 m: *Leioceras opalinum* (Reinecke, 1818), large umbilicus variety. Inner coil, flattened with partial preservation of shell, partially encrusted with pyrite. The body chamber is partially preserved as three-dimensional steinkern. Age: Opalinum Zone, Opalinum Subzone. Lithology: grey silty claystone. The ammonite is illustrated on Plate II, Fig. 1.
- 639.03 m: *Leioceras* ex gr. *subglabrum* (Buckman, 1902). Flattened specimen with three-dimensional body chamber. Age: these ammonites occur in the Opalinum Zone, Opalinum Subzone. Lithology: dark-grey, somewhat silty claystone. The ammonite is illustrated on Plate II, Fig. 2.
- 570.35 m: *Pleurolytoceras torulosum* (Zieten, 1830). Microconch. A somewhat flattened specimen preserved as steinkern. Age: Torulosum Subzone (Aalenis Zone) to early Opalinum Subzone (Opalinum Zone). Lithology: dark-grey siltstone. The ammonite is illustrated on Plate II, Fig. 3.

Remark: it is unusual that this ammonite appears ca. 80 m above the base of the Opalinus Clay. In Southern Germany, this species only occurs in the basal «Torulosum-Knollenlage» of the Opalinuston Formation (Dietze et al. 2021)!

After rechecking, it appears that the ammonite was indeed taken at that depth, this would have the following possible biostratigraphic implications:

1. Assuming that a similar sedimentation rate prevailed in both regions, this is the youngest occurrence of *Pleurolytoceras torulosum* known to date. The discovery in borehole BOZ1-1 is about 80 m above the youngest known occurrence in Southern Germany. This is surprising insofar that fossils of the Opalinus Clay have been collected for more than 200 years!
2. Assuming that the ammonite horizons are of the same age (only 2 – 3 m of sedimentation in Southern German *versus* about 80 m of sedimentation in BOZ1-1) which would indicate very differential sedimentation rate and/or subsidence.

- 530.54 m: *Leioceras* ex gr. *bifidatum* ? (Buckman, 1899). Incomplete, truncated specimen with recrystallised calcitic shell preservation, encrusted with pyrite. Age: Opalinum Zone, Bifidatum Subzone (previously «Comptum» Subzone; Dietze et al. 2021). Lithology: dark-grey, biotrititic, pyrite-interspersed, bioturbated limestone. Other fossils are ammonites and echinoderm ossicles (echinids und crinoids). The ammonite is illustrated on Plate II, Figs. 4a and 4b.

Passwang Formation

- 529.96 m: Ammonite fragment, truncated specimen with recrystallised, calcitic shell preservation. Lithology: dark-brown marl (iron-oolitic) to grey limestone (argillaceous) with limonitic intraclasts. Other fossils are belemnites and bivalves. Age: The numerous occurrences of belemnites (ca. 6 specimens in this sample) could possibly indicate the Concavum Zone, Formosum Subzone or the early Discites Zone (e.g. Profile Böttstein-Buechhalde; Wohlwend et al. 2019a). The ammonite is not illustrated.
- 525.20 m: *Euhoplloceras* sp. Steinkern with partially calcitic inner whorls. Age: Early Bajocian, Laeviuscula Zone? Lithology: grey sandy limestone with numerous burrows. Other fossils are shell fragments. The ammonite is illustrated on Plate III, Fig. 1.
- 514.77 m: *Sonninia* sp. or *Witchellia* sp.? Truncated, partially flattened ammonite, Macroconch. Age: Early Bajocian. Lithology: dark-grey, somewhat mottled biotrititic limestone with single ooids. Other fossils include an ammonite, oysters and echinid remains (primary spines). The ammonite is illustrated on Plate III, Figs. 2a and 2b.
- 506.04 m: *Stephanoceras* sp. Incomplete specimen. Age: Humphriesianum Zone, Humphriesianum Subzone? Lithology: reddish-brown iron-oolite. The iron-ooids are goethitic or limonitic and arranged in a cloudlike fashion. The diameter of the largest iron-ooid is about 0.8 mm, the ooids are mostly somewhat flattened. Other fossils are an ammonite fragment, bivalves, and a belemnite fragment. The ammonite is illustrated on Plate III, Fig. 3.
- 505.57 m: *Stephanoceras* sp. Macroconch, truncated steinkern. Age: Humphriesianum Zone, Humphriesianum Subzone. Lithology: very fine-grained, dark-grey-brown iron-oolite. Diameter of the iron-ooids ca. 0.1 mm. Other fossils are bivalves and belemnites. The ammonite is illustrated on Plate III, Figs. 4a and 4b.

Hauptrogenstein

- 445.22 m: *Parkinsonia* sp. Truncated ammonite in shell preservation. Age: Parkinsoni Zone. Lithology: grey-brown, oolitic limestone (partly argillaceous). The ooids reach diameters up to ca. 1.1 mm. Other fossils are bivalves. The ammonite is illustrated on Plate IV, Fig. 1.

Ifenthal Formation

- 407.72 m: *Perisphinctidae* indet. Truncated ammonite with recrystallised shell preservation. Age: Bathonian to Callovian. Lithology: Iron-oid-bearing, grey biotrititic (echinoderm) limestone. Other fossils are a belemnite and a terebratulide. The ammonite is not illustrated.
- 407.17 m: *Oecotraustes* sp.? Truncated specimen with recrystallised shell. Age: Bathonian? Lithology: dark, grey-brown, iron-oid-bearing to iron-oolitic limestone (partly argillaceous). Diameters of the iron-oids range up to ca. 1 mm. The shape of the iron-oids is round to oval in cross section. They are limonitic/goethitic. Other fossils are ammonites, bivalves (*Entolium* a.o.) and a gastropod. The ammonite is illustrated on Plate IV, Figs. 2a and 2b.
- 406.73 m: Indeterminate ammonite in steinkern preservation. Age: not determinable. Lithology: dark brown to reddish iron-oolite with limonitised areas (around intraclasts?). The iron-oids are distributed in a cloud-like fashion. Diameters of the iron-oids range up to ca. 1.6 mm. The shape of the iron-oids is round to oval in cross section. Other fossils are a belemnite and a bivalve. The ammonite is not illustrated.

Wildegge Formation

- 393.36 m: *Dichotomoceras* sp. Flattened steinkern. Age: Middle to Late Oxfordian. Transversarium Zone, Rotoides Subzone or Bifurcatus Zone, Stenocycloides Subzone? Lithology: dark-grey biotrititic marl. Other fossils include ammonite fragments, small belemnites, crinoid skeletal elements, a bivalve, and sponge fragments. The ammonite is illustrated on Plate IV, Fig. 3.
- 392.48 m: Ammonite, *Perisphinctidae* indet. Truncated young specimen in steinkern preservation. Age: Oxfordian. Lithology: grey limestone (argillaceous). Other fossils include a crinoid stem and sponge fragments. The ammonite is not figured.
- 392.31 m: *Dichotomoceras* ex gr. *bifurcatoides*? (Enay, 1966). Truncated fragment in steinkern preservation. Age: Bifurcatus Zone. Lithology: dark-grey marl with intraclasts. Other fossils are ammonite fragments. The ammonite is not figured.

Tab. 3-2: Ammonite and other macrofossil determination from BOZ1-1

Depth [m MD]	Identification	Ammonite Zone (Subzone) or Age
392.31	<i>Dichotomoceras</i> ex gr. <i>bifurcatoides</i> ? (Enay, 1966)	Bifurcatus Zone
392.48	Perisphinctidae indet.	Oxfordian
393.36	<i>Dichotomoceras</i> sp.	Transversarium Zone (Rotoides Subzone) or Bifurcatus Zone (Stenocycloides Subzone?)
406.73	Ammonite in steinkern preservation	
407.17	<i>Oecotraustes</i> sp.?	Bathonian?
407.72	Perisphinctidae indet.	Bathonian to Callovian
445.22	<i>Parkinsonia</i> sp.	Parkinsoni Zone
505.57	<i>Stephanoceras</i> sp.	Humphriesianum Z (Humphriesianum SZ)
506.04	<i>Stephanoceras</i> sp.	Humphriesianum Z (Humphriesianum SZ?)
514.77	<i>Sonninia</i> sp. or <i>Witchellia</i> sp.?	Early Bajocian
525.20	<i>Euhoplloceras</i> sp.	Laeviuscula Zone?
529.96	Ammonite fragment & 6 belemnites	possibly Concavum Zone (Formosum SZ) or early Discites Zone
530.54	<i>Leioceras</i> ex gr. <i>bifidatum</i> ? (Buckman, 1899)	Opalinum Zone (Bifidatum Subzone)
570.35	<i>Pleurolytoceras torulosum</i>	Aalensis Zone (Torulosum Subzone) to Opalinum Zone (early Opalinum Subzone)
639.03	<i>Leioceras</i> ex gr. <i>subglabrum</i> (Buckman, 1902)	Opalinum Zone (Opalinum Subzone)
644.18	<i>Leioceras opalinum</i> (Reinecke, 1818)	Opalinum Zone (Opalinum Subzone)
651.27	<i>Leioceras</i> ex gr. <i>subglabrum</i> (Buckman, 1902)	Opalinum Zone (Opalinum Subzone)
651.60	<i>Cotteswoldia</i> ex gr. <i>lotharingica</i> (Branco, 1879) or <i>Cotteswoldia</i> ex gr. <i>pseudo-</i> <i>lotharingica</i> (Maubeuge, 1950)	Aalensis Zone (Torulosum Subzone)
652.26	<i>Pleydellia</i> sp.	Aalensis Zone (Aalensis Subzone?)
653.82	<i>Perilytoceras jurense</i> (Zieten, 1833)	Thouarsense Zone
653.75	<i>Pseudogrammoceras</i> ex gr. <i>fallaciosum</i> (Bayle, 1878)	Thouarsense Zone (Fallaciosum Subzone?)

Jurassic				Jurassic							
System	Stage	Zone	Subzone	System	Stage	Zone	Subzone				
Jurassic	Late	Oxfordian	Bifurcatus	Grossouvrei	Jurassic	Early	Toarcian	Aalensis	Torulosum		
				Stenocycloides				Aalensis			
				Rotoides				Moorei			
				Schilli				Levesquei			
			Middle	Transversarium				Luciaeformis	Insigne	Dispansum	
								Parandieri		Insigne	
				Early				Plicatilis	Antecedens	Thouarsense	Fallaciosum
									Vertebrale		Thouarsense
									Cordatum	Variabilis	
									Costicardia	Bifrons	Crassum
		Bukowski						Fibulatum			
		Praecordatum						Commune			
		Scarburgense						Falcifer			
		Lamberti						Elegans			
		Henrici					Exaratum				
	Middle	Athleta	Spinosum					Elegantulum			
			Proniae				Semicelatum				
			Phaenium				Clevelandicum				
			Coronatum	Grossouvrei				Paltum			
				Obductum							
			Jason	Jason				Spinatum			
				Medea							
			Calloviense	Enodatum				Margaritatus			
				Calloviense							
	Early	Koenigi	Galilaei								
			Curtilobus								
			Gowerianus								
			Herveyi	Kamptus							
				Terebratus							
				Kepleri							
			Discus	Discus							
				Hollandi							
			Orbis	Hannoveranus							
				Blanazense							
	Middle										
	Early										
Late											
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BOZ1-1

Grey highlighted zones and subzones are documented in the drill core with ammonites. Fields with additional interrogation points are not surely proven with ammonites.

Biostratigraphy modified after Cariou & Hanzpergue (1997)

* after Dietze et al. (2021), former «Comptum» Subzone

Fig. 3-1: Zones and subzones which are documented by ammonites in BOZ1-1

3.3 Palynostratigraphy

The studied samples yielded mostly a good palynological residue with rich and diverse palynofloras. Preservation is good. The palynomorph assemblages are composed of mainly dinoflagellate cysts and pollen and spores. Minor components are prasinophytes, acritarchs, fungal remains, foraminiferal test linings and green algae (e.g. *Botryococcus*). A total of 188 dinoflagellate cyst taxa, 27 other aquatic palynomorphs and 50 pollen and spore taxa are recorded.

Some reworked sporomorphs (*Densosporites* spp., *Ovalipollis* spp.) indicate erosion of Triassic sediments in the source area. Other reworking is indicated by the occurrence of a few single specimens of the dinoflagellate cyst *Luehndea spinosa*, a typical Early Jurassic species with a main distribution in the Late Pliensbachian and earliest Toarcian.

The studied samples from BOZ1-1 cores are dated to span the interval from the latest Toarcian to the Oxfordian. There are 24 sample intervals differentiated and, where possible, assigned to ammonite biostratigraphy. A list of the analysed samples and the age dating of each sample is given in Tab. 3-3. The indicated ages, zones (Z) and subzones (SZ) for each sample are the result of the palynostratigraphical analysis and interpretation. The results of the quantitative analysis are illustrated in a Range Chart (Appendix D1). A Depth/Age plot is illustrated in Appendix D2.

Sample 652.27 m (1 sample): Late Toarcian, Aalensis Zone

The dinoflagellate cyst assemblage in this sample is of low diversity. Most abundant are *Evansia*? cf. *granochagrinata*, *Kallosphaeridium praussii* and *Mancodinium semitabulatum*. Other taxa present, though in low numbers, are *Nannoceratopsis* spp., *N. gracilis* s.l., *Scriniocassis limbicavatus*, *S. weberi*, *Walldinium laganum* and a few representatives of the families Phallogocystaceae (*Dodekovia bullula*, *Reutlingia cardobarbata*) and Valvaediniaceae (*Valvaedinium sphaerechinatum*, *V. vermipellitum*). The species *Evansia*? cf. *granochagrinata* is abundant but does not dominate the palynoflora as in the sample interval above.

The interval is defined by the occurrence of *Kallosphaeridium praussii* together with *Walldinium laganum*, without the extreme dominance of *Evansia*? cf. *granochagrinata* as in the interval above.

The FAD (First Appearance Datum) of *Kallosphaeridium praussii* is in the Late Toarcian Aalensis Zone. *Evansia*? cf. *granochagrinata* is known to be superabundant and dominating in samples straddling the Toarcian/Aalenian boundary.

The sample is interpreted Late Toarcian Aalensis Zone.

Sample 651.57 m (1 sample): Late Toarcian, Aalensis Zone to Early Aalenian, Opalinum Zone, Opalinum Subzone

The palynoflora in this sample is characterised by the very high abundance of one dinoflagellate cyst species, *Evansia*? cf. *granochagrinata*. The species dominates the palynoflora, reaching 83 % of all palynomorphs counted. Other dinoflagellate cysts present, though in low numbers, are *Kallosphaeridium praussii*, *Mancodinium semitabulatum*, *Nannoceratopsis* spp., *Scriniocassis limbicavatus*, *S. priscus*, *S. weberi*, *Valvaedinium brevipellitum*, *V. cavum* and *V. sphaerechinatum*.

The sample interval is defined by the dominant occurrence of *Evansia*? cf. *granochagrinata*.

The composition of the dinoflagellate cyst assemblage is typical for the interval straddling the Toarcian/Aalenian boundary. *Evansia?* cf. *granochagrinata* has its FAD in the Late Toarcian, probably Levesquei Zone. *Kallosphaeridium praussii* first appears in the Late Toarcian Aalensis Zone. The very high abundance or dominance of *Evansia?* cf. *granochagrinata* is typical for an age of the sample straddling the Toarcian/Aalenian boundary (Aalensis Zone to Opalinum Zone, Opalinum Subzone). This characteristic bioevent at the Early to Middle Jurassic boundary defines the palynostratigraphic unit A of Feist-Burkhardt & Pross (2010).

Sample interval 651.27 – 540.47 m (7 samples): Early Aalenian, Opalinum Zone, Opalinum Subzone

Dinoflagellate cyst assemblages of this sample interval are rich and diverse. They are composed of common to abundant *Evansia?* cf. *granochagrinata*, diverse Phallocystaceae (*Andreedinium* spp., *A.* aff. *elongatum*, *Dodekovia* spp., *D. bullula*, *D. knertensis*, *D. pinna*, *D. pseudochytroides*, *D. syzygia*, *D. tegillata*, *Ovalicysta hiata*, *Parvocysta? tricornuta*, *Phallocysta? frommernensis* (common), *Reutlingia cardobarbata*, *R. nasuta*, *Susadinium scrofoides*) and Valvaediniaceae (*Comparodinium punctatum*, *Valvaeodinium* spp., *V. brevepellitum*, *V. cavum*, *V. sphaerechinatum*, *V. vermipellitum*), species of *Nannoceratopsis* (*Nannoceratopsis* spp., *Nannoceratopsis* sp., B., *Nannoceratopsis* sp. 1, *N. ambonis*, *N. gracilis* s.l. and ss., *N. plegas dictyornata*, *N. triangulata*, *N. tricerias*) and *Scrinioicassis* (*S. limbicavatus*, *S. priscus*, *S. weberi*), as well as *Hystrichodinium?* sp., *Kallosphaeridium praussii*, *Mancodinium semitabulatum* and *Wallogdinium laganum*. The species *Evansia?* cf. *granochagrinata* is very abundant in the sample at the base of the interval (651.27 m) but its abundance decreases up section. *Phallocysta? frommernensis* is fairly common throughout and occurs last in the upper part of the interval (560.33 m) coinciding with the top of its acme.

The interval is defined by the first occurrence of *Phallocysta? frommernensis* to the last occurrence of *Scrinioicassis weberi* and unquestionable *Nannoceratopsis triangulata*.

According to Feist-Burkhardt & Pross (2010) there are four marker species for the Early Aalenian Opalinuston Formation: *Kallosphaeridium praussii*, *Phallocysta? frommernensis*, *Nannoceratopsis triangulata* and *Wallogdinium laganum*. All four marker species occur in this interval. The acme of *Phallocysta? frommernensis* defines the palynostratigraphical unit B of Feist-Burkhardt & Pross (2010) of the Opalinuston Formation.

The sample interval is dated as Early Aalenian Opalinum Zone, Opalinum Subzone, and corresponds largely to palynostratigraphic unit B of Feist-Burkhardt & Pross (2010).

The occurrence of *Luehndea spinosa* (540.47 m, 640.10 m) indicates reworking of Early Jurassic Late Pliensbachian to earliest Toarcian sediments in the source area.

Sample interval 535.09 – 530.25 m (2 samples): Early Aalenian, Opalinum Zone, probably Bifidatum Subzone

Assemblages in this interval are reduced in the diversity of phallocystacean dinoflagellate cysts. The base of the interval is characterised by the first occurrence of *Nannoceratopsis plegas plegas* and *Batiacasphaera* sp. A in Feist-Burkhardt & Pross (2010). *Reutlingia cardobarbata* and *Wallogdinium laganum* have their last occurrence at the top of the interval.

The interval is defined from the first occurrence of *Batiacasphaera* sp. A to the last occurrence of *Reutlingia cardobarbata* and *Wallogdinium laganum*.

Batiacasphaera spp. has its FAD in the upper part of the Opalinum Zone with *Batiacasphaera* sp. A often being abundant in the Bifidatum Subzone of Opalinum Zone (previously «Comptum» Subzone; Dietze et al. 2021). The LADs (Last Appearance Datums) of *Reutlingia cardobarbata* and *Wallodinium laganum* are considered at the top of Opalinum Zone.

The interval is dated as Early Aalenian Opalinum Zone, probably Bifidatum Subzone.

The occurrence of *Luehndea spinosa* (535.09 m) indicates reworking of Early Jurassic Late Pliensbachian to earliest Toarcian sediments in the source area.

Sample interval 530.01 – 529.00 m (3 samples): Early Bajocian, Discites Zone

The dinoflagellate cyst assemblages in this interval differ a lot from the samples below. Representatives of the genus *Dissiliodinium* are abundant. There are numerous first occurrences at the base of the interval, i.a. *Andreedinium elongatum*, *Batiacasphaera* spp., *Dissiliodinium* spp., *D. lichenoides*, *Dissiliodinium* aff. *giganteum*, *Evansia?* *eschachensis*, *E?* *spongogranulata*, questionable *Gongylodinium erymnoteichon*, *Moesiodinium raileanui*, *Pareodinia* spp. and *Valvaeodinium spongiosum*. In the next sample up there is also *Pareodinia* sp. 4. Last occurrences at the top of the interval are those of *Andreedinium elongatum*, *Nannoceratopsis* sp. B and *Pareodinia* sp. 4.

The interval is defined from the first occurrence of *Dissiliodinium* aff. *giganteum* and questionable *Gongylodinium erymnoteichon* to the last occurrence of *Nannoceratopsis* sp. B and *Pareodinia* sp. 4.

Dissiliodinium aff. *giganteum* and *Gongylodinium erymnoteichon* have their FADs in the Discites Zone. *Nannoceratopsis* sp. B and *Pareodinia* sp. 4 have so far only been observed in the Discites Zone.

The interval is dated Discites Zone.

Sample 528.51 m (1 sample): Early Bajocian, Ovale Zone

In addition to the species known from below, the dinoflagellate cyst assemblage is characterised by the first occurrences of *Dissiliodinium giganteum*, *Durotrigia daveyi*, unquestionable *Gongylodinium erymnoteichon*, *Valvaeodinium euareatum* and a first questionable specimen of *Batiacasphaera laevigata*. Last occurrence in this sample shows *Evansia?* *eschachensis*.

The interval is defined from the first occurrences of *Dissiliodinium giganteum* and *Durotrigia daveyi* to the last occurrence of *Evansia?* *eschachensis*.

The FADs of *Dissiliodinium giganteum* and *Durotrigia daveyi* are in the Ovale Zone. The LAD of *Evansia?* *eschachensis* is also in the Ovale Zone.

The sample is dated Ovale Zone.

Sample interval 522.45 – 516.83 m (2 samples): Early Bajocian, Laeviuscula Zone

Assemblages in this interval show the first occurrences of unquestionable *Batiacasphaera laevigata* and *Cavatodissiliodinium hansgochtii*. Last occurrences in this interval have *Hystrichodinium?* sp., *Nannoceratopsis dictyambonis* and *N. plegas plegas*.

The interval is defined from the first occurrence of *Batiacasphaera laevigata* and *Cavatodissiliodinium hansgochtii* at the base of the interval to the last occurrence of *Hystrichodinium?* sp. at the top and the first occurrence of *Kallosphaeridium hypornatum* in the interval above.

The FADs of *Batiacasphaera laevigata* and *Cavatodissiliodinium hansgochtii* are in the Laeviuscula Zone. The LAD of *Hystrichodinium?* sp. is in the Laeviuscula Zone. The FAD of *Kallosphaeridium hypornatum* is in the Sauzei Zone.

The interval is dated Laeviuscula Zone.

Sample interval 514.49 – 514.00 m (2 samples): Early Bajocian, Sauzei Zone

Assemblages in this interval show the first occurrence of *Kallosphaeridium hypornatum* and the last occurrence of *Dissiliodinium giganteum*.

The interval is defined from the first occurrence of *Kallosphaeridium hypornatum* to the last occurrence of *Dissiliodinium giganteum*.

The FAD of *Kallosphaeridium hypornatum* is in the Sauzei Zone. The LAD of *Dissiliodinium giganteum* is in the Sauzei Zone.

The interval is dated Sauzei Zone.

Sample interval 510.81 – 509.01 m (3 samples): Early Bajocian, Sauzei to Humphriesianum Zone

Assemblages in this interval show the first occurrences of *Cavatodissiliodinium* spp., *C. sp. 1*, *C. sp. 3*, *Durotrigia filapicata* and *Wanaea* sp. 1. Last occurrences at the top of the interval are those of *Cavatodissiliodinium hansgochtii* and *Evansia? spongogranulata*. *Durotrigia daveyi* is abundant.

The interval is defined by the co-occurrence of *Cavatodissiliodinium* spp., *C. sp. 1*, *C. sp. 3*, *Durotrigia filapicata*, *Wanaea* sp. 1 on one hand, and *Cavatodissiliodinium hansgochtii* and *Evansia? spongogranulata* on the other.

The FADs of *Cavatodissiliodinium* spp., *C. sp. 1*, *C. sp. 3*, *Durotrigia filapicata* and *Wanaea* sp. 1 are considered to be early in the Humphriesianum Zone. The LADs of *Cavatodissiliodinium hansgochtii* and *Evansia? spongogranulata* were so far considered to be in the late Sauzei Zone.

Based on the co-occurrence of the taxa mentioned the interval is interpreted Sauzei to Humphriesianum Zone.

Sample 506.92 m (1 sample): Early Bajocian, Humphriesianum Zone

The sample is characterised by the common occurrence of several species of *Cavatodissiliodinium* (*C. spp.*, *C. sp. 1*, *C. sp. 3*) and the first occurrences of common *Acanthaulax crista*, common *Valensiella/Ellipsoidictyum spp.* and *Wanaea sp. 2*. A single last questionable specimen of *Cavatodissiliodinium hansgochtii* is recorded.

The interval is defined from the first occurrence of *Acanthaulax crista* to the first occurrence of *Phallocysta thomasi* in the interval above.

The FAD of *Acanthaulax crista* is in the Humphriesianum Zone. The range of *Phallocysta thomasi* is considered to be restricted to the Romani Subzone and Humphriesianum Subzone of the Humphriesianum Zone.

The sample is dated Humphriesianum Zone, probably the early part of Humphriesianum Zone.

Sample interval 505.59 – 503.34 m (2 samples): Early Bajocian, Humphriesianum Zone, Romani – Humphriesianum Subzone

Assemblages in this interval are similar to before but *Phallocysta thomasi* is recorded in the basal sample (505.59 m). At the same depth *Atopodinium sp. 1* and *Meiourogoniaulax spp.* have their first occurrences. In the sample at the top of the interval (503.34 m) *Rhynchodiniopsis? sp. 1* has its first occurrence and questionable "*Hypolytadinium*" sp. has its last occurrence.

The interval is defined from the first occurrence of *Phallocysta thomasi* to the last occurrence of questionable "*Hypolytadinium*" sp.

The ranges of "*Hypolytadinium*" sp. and *Phallocysta thomasi* are considered to be restricted to the Romani and Humphriesianum subzones of the Humphriesianum Zone.

Sample 504.74 m (1 sample): Early Bajocian, Humphriesianum Zone

The sample is similar to before but lacks "*Hypolytadinium*" sp. In addition, there is the first occurrence of *Meiourogoniaulax valensii*.

Meiourogoniaulax valensii has its FAD in Humphriesianum Zone.

The sample is dated Humphriesianum Zone (undifferentiated).

Sample interval 497.79 – 483.01 m (3 samples): Early Bajocian, Humphriesianum Zone, Blagdeni Subzone to Late Bajocian Niortense Zone

The assemblages are characterised by numerous first occurrences. In the basal sample these include *Aldorfia aldorfensis*, *Endoscrinium asymmetricum*, *Nannoceratopsis spiculata* and *Valvaodinium spinosum*. Higher up section, the first occurrences include *Korystocysta gochtii*, *Rhynchodiniopsis? regalis*, *Rosswangia simplex* (questionable), *Wanaea indotata*, and finally *Gongylodinium hocneratum*. The first few single specimens of *Ctenidodinium sellwoodii* and *Ctenidodinium spp.* (both questionable) are recorded. *Mancodinium semitabulatum* has its last occurrence in the sample at 490.31 m. *Nannoceratopsis gracilis* s.l. occurs in all samples.

The FADs of the first occurring species are in the Blagdeni Subzone of Humphriesianum Zone (*Aldorfia aldorfensis*, *Rhynchodiniopsis? regalis*), in the Niortense Zone (*Atopodinium polygonale*, *Rosswangia simplex*, *Korystocysta gochtii*, *Valvaeodinium spinosum*) and higher within Niortense Zone (*Endoscrinium asymmetricum*, *Gongylodinium hocneratum*). The LAD of *Mancodinium semitabulatum* is considered to be in the Blagdeni Subzone, that of *Nannoceratopsis gracilis* s.l. in the Niortense Zone.

The dinoflagellate cyst taxa indicate an age corresponding to the Niortense Zone. The concurrent occurrence of *Mancodinium semitabulatum*, however, suggests a slightly older age of latest Humphriesianum Zone (Blagdeni Subzone).

Sample interval 480.01 – 470.34 m (2 samples): Late Bajocian, Niortense to Garantiana Zone

The assemblages are characterised by the common occurrence of representatives of the genus *Ctenidodinium*, including *Ctenidodinium* spp., *Ct. continuum*, *Ct. ornatum* and *Ct. sellwoodii* group. First occurrences include *Batiacasphaera* sp. 1, *Carpathodinium predae*, *Carpathodinium* sp. 2, *Gonyaulacysta pectinigera*, questionable *Wanaea cornucavata*. Last occurrences in this interval are those of *Durotrigia daveyi* and *Nannoceratopsis gracilis* s.l.

The FADs of *Carpathodinium predae*, *Ctenidodinium continuum* and *Gonyaulacysta pectinigera* are in the Niortense Zone, that of *Ctenidodinium sellwoodii* group is in the Garantiana Zone. The LAD of *Nannoceratopsis gracilis* s.l. is in the Niortense Zone, that of *Durotrigia daveyi* is in the Garantiana Zone.

The interval is interpreted Niortense to Garantiana Zone.

Sample interval 460.49 – 438.75 m (5 samples): Late Bajocian, Parkinsoni Zone

Dinoflagellate cyst assemblages are quite similar to below, with *Acanthaulax crispa* consistently occurring up to the top of the interval and commonly occurring representatives of *Ctenidodinium* including *Ctenidodinium* spp., *Ct. continuum* and *Ct. sellwoodii* group. *Ctenidodinium combazii* does not yet occur but is recorded at the base of the interval above. First occurrences in this interval are i.a. *Gonyaulacysta eisenackii*, *Meiourogoniaulax* sp. 1, *Microdinium* sp. of Feist-Burkhardt & Wille (1992), *Orobodinium automobile*, *O. rete* and *Sirmiodiniopsis* sp. of Feist-Burkhardt & Wille (1992). Last occurrences at the top of the interval are *Acanthaulax crispa* and *Meiourogoniaulax valensii*.

The interval is defined from the first occurrence of *Gonyaulacysta eisenackii*, *Orobodinium automobile*, both questionable, and *Sirmiodiniopsis* sp. to the last occurrence of *Acanthaulax crispa*.

The FADs of *Gonyaulacysta eisenackii*, *Orobodinium automobile* and *Sirmiodiniopsis* sp. are in the Parkinsoni Zone. The LAD of *Acanthaulax crispa* is in the Parkinsoni Zone.

The interval is dated Parkinsoni Zone.

Sample interval 435.93 – 423.04 m (5 samples): Early Bathonian, Zigzag Zone, Tenuiplicatus Subzone

Assemblages in this interval are characterised by abundant and diverse representatives of the genus *Ctenidodinium*. Abundance of *Ctenidodinium* increases up section. First occurrences in the interval include the first chorate dinoflagellate cyst namely *Cleistosphaeridium* spp. as well as *Ctenidodinium combazii*, *Lithodinia jurassica*, *Tubotuberella dangeardii* and *Valvaeodinium vermicylindratum*. The species *Meiourogonyaualax valensii* is last recorded in the interval below.

The interval is defined from the first occurrence of *Cleistosphaeridium* spp. and the last occurrence of *Meiourogonyaualax valensii* in the interval below to the first occurrence of questionable *Nannoceratopsis pellucida* in the interval above.

The FAD of *Ctenidodinium combazii* is within the upper part of the Parkinsoni Zone, those of *Lithodinia jurassica* and *Tubotuberella dangeardii* are in the Zigzag Zone. The LAD of *Meiourogonyaualax valensii* is in the Zigzag Zone. The FAD of *Cleistosphaeridium* spp. is in the Tenuiplicatus Subzone of Zigzag Zone, that of *Nannoceratopsis pellucida* is in the Progracilis Zone.

The interval is dated Tenuiplicatus Subzone of the Zigzag Zone.

Sample interval 417.22 – 411.71 m (5 samples): Early Bathonian, Zigzag Zone, Tenuiplicatus Subzone to Late Bathonian, Hodsoni Zone

The assemblages are quite similar to those from below with abundant and diverse representatives of the genus *Ctenidodinium*. Abundance of *Ctenidodinium* increases up section. There are several first occurrences within the interval including *Atopodinium prostaticum*, *Ambonosphaera* sp. 2, *Gonyaulacysta jurassica*, *Endoscrinium luridum*, (questionable) *Nannoceratopsis pellucida* and the first complex skolochorate dinocysts indeterminate. Last occurrences in the interval include unquestionable *Carpathodinium predae*, *Dissiliodinium minimum* and *Lithodinia jurassica*.

The interval is defined from the first questionable occurrence of *Nannoceratopsis pellucida* to the first occurrences of *Pareodinia prolongata*, *Rigaudella* spp. and *Sirmiodiniopsis orbis* in the interval above.

The FADs of *Gonyaulacysta jurassica* and *Nannoceratopsis pellucida* are in the Progracilis Zone. The LAD of *Carpathodinium predae* is in the Morrissi Zone. The FADs of *Atopodinium prostaticum*, *Pareodinia prolongata*, *Rigaudella filapicata* and *Sirmiodiniopsis orbis* are in the Hodsoni Zone.

The interval is interpreted Tenuiplicatus Subzone of the Zigzag Zone to Hodsoni Zone.

Sample interval 407.72 – 407.19 m (2 samples): Late Bathonian, Hodsoni to Discus Zone

The assemblages are similar to below with abundant and diverse species of *Ctenidodinium*. In addition, there are the first occurrences of i.a. *Eodinia* spp., *Pareodinia prolongata*, *Rigaudella* spp., *Sirmiodiniopsis orbis* and *Valensiella* sp. 2. Last occurrences in this interval are i.a. *Ctenidodinium combazii*, *Gongylodinium hocneratum*, *Gonyaulacysta pectinigera*, *Rhynchodiniopsis? regalis* and *Valvaeodinium spinosum*.

The interval is defined from the first occurrences of *Pareodinia prolongata*, *Rigaudella* spp. and *Sirmiodiniopsis orbis* to the last occurrence of *Valvaeodinium spinosum*.

The FADs of *Pareodinia prolongata*, *Rigaudella filamentosa* and *Sirmiodiniopsis orbis* are in the Hodsoni Zone. The LAD of *Valvaeodinium spinosum* is in the Discus Zone.

The interval is dated Hodsoni to Discus Zone.

Sample 406.85 m (1 sample): Early Callovian, Herveyi Zone

The composition of the dinoflagellate cyst assemblage in this sample is different to below. Species of *Ctenidodinium* are absent. Complex skolochorate dinocysts indet. are common. There are several first occurrences, i.a. *Hapsidaulax margarethae*, *Lithodinia caytonensis*, *Rhynchodiniopsis cladophora*, common *Sentusidinium? varispinosum* and *Sirmiodinium grossii*. Last occurrences in this sample are *Atopodinium polygonale*, *Hapsidaulax margarethae*, *Lithodinia caytonensis* and *Sentusidinium? varispinosum*.

The interval is defined from the first occurrences of *Lithodinia caytonensis*, *Rhynchodiniopsis cladophora*, *Sentusidinium? varispinosum* and *Sirmiodinium grossii* to the last occurrence of *Atopodinium polygonale*.

The FADs of *Lithodinia caytonensis*, *Rhynchodiniopsis cladophora*, *Sentusidinium? Varispinosum* and *Sirmiodinium grossii* are in the Herveyi Zone. The LAD of *Atopodinium polygonale* is also in the Herveyi Zone.

The sample is dated Herveyi Zone.

Sample 406.73 m (1 sample): dating not possible

The sample yielded very little residue with only a few single grains. Processing of the sample was repeated twice and came to the same result. Dating is not possible.

Sample interval 406.66 – 406.55 m (2 samples): Middle Callovian, Jason Zone to Middle Oxfordian, Plicatilis Zone

Composition of the dinoflagellate cyst assemblages is different to below. Chorate dinoflagellate cysts are abundant. There are numerous first and last occurrences. First occurrences in this interval include *Acanthaulax* spp., *Compositosphaeridium polonicum*, *Leptodinium arcuatum*, *Liesbergia scarburghensis*, *Rigaudella aemula*, *Scriniodinium crystallinum*, *Stephanelytron scarburghense* and *Systematophora areolata*. Last occurrences in this interval are i.a. *Nannoceratopsis spiculata* and *Orobodinium automobile*.

There are species with FADs in the Middle and Late Callovian (*Compositosphaeridium polonicum*, *Liesbergia scarburghensis*, *Rigaudella aemula*, *Scriniodinium crystallinum*), in the Early Oxfordian (*Acanthaulax* spp.) and in the Middle Oxfordian Plicatilis Zone (*Leptodinium arcuatum*, *Systematophora areolata*). There are species with LADs in the Jason Zone (*Nannoceratopsis spiculata*) and in the Coronatum Zone (*Orobodinium automobile*).

The co-occurrence of these species indicates that there is a mixture of palynofloras of different age. The interval is interpreted Jason to Plicatilis Zone.

Sample 405.84 m (1 sample): Middle Oxfordian, Plicatilis Zone

This sample shows several first occurrences including *Ctenidodinium chondrum*, *Endoscrinium galeritum*, questionable *Glossodinium dimorphum*, *Leptodinium mirabile*, *L. subtile*, *Polygonifera* spp. and *Wanaea thysanota*. Last occurrences in this interval are *Ambonosphaera* sp. 2, *Rigaudella aemula*, *Scrinioidinium crystallinum* and *Wanaea thysanota*.

The interval is defined from the first occurrence of questionable *Glossodinium dimorphum* and *Leptodinium mirabile* to the last occurrence of *Scrinioidinium crystallinum* and *Wanaea thysanota*.

The FADs of *Glossodinium dimorphum* and *Leptodinium mirabile* are in the Plicatilis Zone. The LADs of *Scrinioidinium crystallinum* and *Wanaea thysanota* are also in the Plicatilis Zone. The FADs of *Leptodinium subtile* and *Polygonifera evittii* are supposed to be near the base of Transversarium Zone.

The sample is interpreted Plicatilis Zone. The presence of the first single specimens of *Leptodinium subtile* and *Polygonifera* spp. indicates an age close to the base of Transversarium Zone.

Sample 402.10 m (1 sample): Middle Oxfordian, Plicatilis to Transversarium Zone

The sample shows the first occurrences of *Belodinium asaphum*, *Gonyaulacysta dualis*, questionable *Neuffenia willei*, *Prolixosphaeridium anasillum*, *Stephanelytron caytonense*, *S. redcliffense*, *Tehamadinium* spp., and *Wallodinium* sp. 1. Last occurrences in the sample are *Belodinium asaphum*, *Compositosphaeridium polonicum* and *Liesbergia scarburghensis*.

There are species with FADs in the Plicatilis Zone (*Glossodinium dimorphum*, *Leptodinium arcuatum*, *Systematophora areolata*) and in the Transversarium Zone (*Leptodinium subtile*). There are species with LADs in the Transversarium Zone (*Belodinium asaphum*, *Compositosphaeridium polonicum*, *Liesbergia scarburghensis*).

The sample is interpreted as Plicatilis to Transversarium Zone.

Sample interval 395.59 – 391.98 m (3 samples): Middle Oxfordian, Transversarium to Late Oxfordian, Bifurcatus Zone

Composition of the dinoflagellate cyst assemblages in this interval is quite similar to below. In addition, there are the first occurrences of *Endoscrinium galeritum reticulatum*, *Lithodinia arcanitabulata*, *Mendicodinium* sp. A of Brenner (1988), *Scrinioidinium dictyotum*, *Taeniophora iunctispina*, and the first single specimens of *Cribroperidinium* spp. and *Tubotuberella apatela*. Other important taxa present up to the top of the interval are i.a. *Ctenidodinium ornatum*, *Endoscrinium galeritum*, *Gonyaulacysta eisenackii* and *Leptodinium subtile*. The species *Nannoceratopsis pellucida* is recorded for the last time at the base of the interval.

There are species with FADs in the Transversarium Zone (*Leptodinium subtile*, *Taeniophora iunctispina*) and in the Bifurcatus Zone (*Lithodinia arcanitabulata*). The LADs of some species are considered to be in the Transversarium Zone (*Ctenidodinium ornatum*, *Endoscrinium galeritum*, *Gonyaulacysta eisenackii*, *Nannoceratopsis pellucida*).

The interval is interpreted Transversarium to Bifurcatus Zone.

Tab. 3-3: List of analysed palynology samples from BOZ1-1

The indicated ages, zones and subzones for each sample are the result of the palynostratigraphical analysis and interpretation. Depths marked with one asterisk are processed and analysed a second time, with two asterisks even a third time.

Depth [m MD]	Age	Zone & Subzone
391.98	Late – Middle Oxfordian	Bifurcatus – Transversarium Zone
392.31	Late – Middle Oxfordian	Bifurcatus – Transversarium Zone
395.59	Late – Middle Oxfordian	Bifurcatus – Transversarium Zone
402.10	Middle Oxfordian	Transversarium – Plicatilis Zone
405.84	Middle Oxfordian	Plicatilis Zone
406.55	M. Oxfordian – M. Callovian	Plicatilis – Jason Zone
406.66	M. Oxfordian – M. Callovian	Plicatilis – Jason Zone
406.73	inconclusive (contaminated sample)	
406.73*	dating not possible (insufficient residue)	
406.73**	dating not possible (insufficient residue)	
406.85	Early Callovian	Herveyi Zone
407.19	Late Bathonian	Discus – Hodsoni Zone
407.72	Late Bathonian	Discus – Hodsoni Zone
411.71	Late – Early Bathonian	Hodsoni – Zigzag Zone (Tenuiplicatus SZ)
411.99	Late – Early Bathonian	Hodsoni – Zigzag Zone (Tenuiplicatus SZ)
414.92	Late – Early Bathonian	Hodsoni – Zigzag Zone (Tenuiplicatus SZ)
417.07	Late – Early Bathonian	Hodsoni – Zigzag Zone (Tenuiplicatus SZ)
417.22	Late – Early Bathonian	Hodsoni – Zigzag Zone (Tenuiplicatus SZ)
423.04	Early Bathonian	Zigzag Zone (Tenuiplicatus SZ)
427.56	Early Bathonian	Zigzag Zone (Tenuiplicatus SZ)
432.00	Early Bathonian	Zigzag Zone (Tenuiplicatus SZ)
435.76	Early Bathonian	Zigzag Zone (Tenuiplicatus SZ)
435.93	Early Bathonian	Zigzag Zone (Tenuiplicatus SZ)
438.75	Late Bajocian	Parkinsoni Zone
444.03	Late Bajocian	Parkinsoni Zone
445.20	Late Bajocian	Parkinsoni Zone
445.20*	Late Bajocian	Parkinsoni Zone
452.17	Late Bajocian	Parkinsoni Zone
460.49	Late Bajocian	Parkinsoni Zone
470.34	Late Bajocian	Garantiana – Niortense Zone
480.01	Late Bajocian	Garantiana – Niortense Zone
480.01*	Late Bajocian	Garantiana – Niortense Zone
483.01	Late – Early Bajocian	Niortense – Humphriesianum Zone (Blagdeni SZ)
483.01*	Late – Early Bajocian	Niortense – Humphriesianum Zone (Blagdeni SZ)
490.31	Late – Early Bajocian	Niortense – Humphriesianum Zone (Blagdeni SZ)
490.31*	Late – Early Bajocian	Niortense – Humphriesianum Zone (Blagdeni SZ)
497.79	Late – Early Bajocian	Niortense – Humphriesianum Zone (Blagdeni SZ)
497.79*	Late – Early Bajocian	Niortense – Humphriesianum Zone (Blagdeni SZ)
504.74	Early Bajocian	Humphriesianum Zone
504.74*	Early Bajocian	Humphriesianum Zone
505.34	Early Bajocian	Humphriesianum Z (Humphriesianum SZ – Romani SZ)
505.34*	Early Bajocian	Humphriesianum Z (Humphriesianum SZ – Romani SZ)
505.59	Early Bajocian	Humphriesianum Z (Humphriesianum SZ – Romani SZ)
505.59*	Early Bajocian	Humphriesianum Z (Humphriesianum SZ – Romani SZ)
506.92	Early Bajocian	Humphriesianum Zone

Tab. 3-3: (continued)

Depth [m MD]	Age	Zone & Subzone
509.01	Early Bajocian	Humphriesianum – Sauzei Zone
510.08	Early Bajocian	Humphriesianum – Sauzei Zone
510.81	Early Bajocian	Humphriesianum – Sauzei Zone
514.00	Early Bajocian	Sauzei Zone
514.49	Early Bajocian	Sauzei Zone
516.83	Early Bajocian	Laeviuscula Zone
522.45	Early Bajocian	Laeviuscula Zone
528.51	Early Bajocian	Ovale Zone
529.00	Early Bajocian	Discites Zone
529.67	Early Bajocian	Discites Zone
530.01	Early Bajocian	Discites Zone
530.52	Early Aalenian	Opalinum Zone (probably Bifidatum SZ)
530.81	Early Aalenian	Opalinum Zone (probably Bifidatum SZ)
535.09	Early Aalenian	Opalinum Zone (probably Bifidatum SZ)
540.47	Early Aalenian	Opalinum Zone (Opalinum SZ)
560.33	Early Aalenian	Opalinum Zone (Opalinum SZ)
580.23	Early Aalenian	Opalinum Zone (Opalinum SZ)
599.91	Early Aalenian	Opalinum Zone (Opalinum SZ)
620.10	Early Aalenian	Opalinum Zone (Opalinum SZ)
640.10	Early Aalenian	Opalinum Zone (Opalinum SZ)
651.27	Early Aalenian	Opalinum Zone (Opalinum SZ)
651.57	E. Aalenian – L. Toarcian	Opalinum Zone (Opalinum SZ) – Aalensis Zone
652.27	Late Toarcian	Aalensis Zone
652.27*	insufficient residue for a second analysis (first analysis is OK)	

3.4 Chemostratigraphy

The sampling of the BOZ1-1 cores focused primarily on the upper part of the Lias Group (Figs. 3-2 and 3-3) and Dogger Group (Figs. 3-4 to 3-7) and, therefore inter alia on clay mineral-rich layers of the Opalinus Clay. The summary Figs. 3-8 and 3-9 illustrate the fully analysed interval from the upper part of the Staffelegg Formation up to the lowermost part of the Wildeggen Formation (659.79 – 402.09 m). The data presented here (applies for all subsequent figures in this section) is shown in comparison to other data collected during the drilling campaign: Stratigraphic profile after Dossier III, DryClay (values in wt.-% vertical axis in m MD log depth; *cf.* Dossier X), XRD measurements (horizontal bars; calcite: blue, dolomite and ankerite: green, siderite: red; *cf.* Dossier VIII) and C(org) measurements also with blue horizontal bars (*cf.* Dossier VIII). In addition, formation boundaries were highlighted with black lines and other formal or informal subintervals with grey lines. The following stratigraphic abbreviations were used in Figs. 3-2 to 3-9: F. = Frick Member; G.B.R. = Grünschholz Member, Breitenmatt Member and Rickenbach Member; R. = Rietheim Member; G. W. = Gross Wolf Member; OPA = Opalinus Clay; W. & l.B. = Waldenburg and lower part of Bruggli Member; «H.-S.» = «Humphriesi-Schichten»; Bi. = Birmenstorf Member; Ef. = Effingen Member.

In addition to the continuous samples (roughly in metre resolution), some specific samples were taken (Appendix E1) to complete the information about the calcareous beds and macrofossils. Some of the firm- to hardground samples were drilled directly from the remaining thin section blocks to correlate the bulk geochemical data with the microfacies analysis. All these data points are distinguished in different colours on Figs. 3-2, 3-4 and 3-6 (in light blue: calcareous samples (firm- and hardgrounds, "hiatus beds", "hiatus concretions", calcareous concretions); in violet: septarian nodules; in green: macrofossils) but may not be shown on the individual plots because of the data ranges (see Appendix E1 for data).

The data will be discussed in three intervals: Lias Group, the lower part of the Dogger Group – mainly Opalinus Clay and the upper part of the Dogger Group. Not all data are discussed to the same extent as for example the $\delta^{18}\text{O}_{\text{carb}}$ and $\delta^{15}\text{N}_{\text{org}}$ data. The oxygen isotopes are strongly influenced by diagenesis. This can be exemplarily shown with the measured belemnites in the Lias Group in MAR1-1 (Fig. 3-2 in Wohlwend et al. 2021c). These are 3 to 4 ‰ more positive than the marlier bulk rock and therefore much less diagenetically overprinted. The nitrogen isotopes may not be as meaningful in some cases, because the combined $\delta^{13}\text{C}_{\text{org}}$ and $\delta^{15}\text{N}_{\text{org}}$ measurements showed a too low concentration of N in most of the measurements.

Although, the calculated carbonate content (TCarb) is only a semi-quantitative method, the values presented here correspond quite good to the XRD values measured at the University of Bern (*cf.* Dossier VIII). The XRD data are illustrated in the following Figs. 3-2, 3-4 and 3-6 to provide a visual comparison between the data presented here and those from Dossier VIII. As discussed in Wohlwend et al. (2019b) based on measurements from the BDB-1 borehole at the Mont Terri Rock Laboratory, the values calculated here follow nicely the calcite and dolomite wt.-% with an additional mixed signal from the other carbonates (mainly siderite). Because during the reaction time of 60 min at 72 °C, a complete reaction for example for siderite does not take place, the TCarb values are slightly too low in siderite-rich successions (red bars in the XRD data), which is for example often the case in the «Mixed clay-silt-carbonate sub-unit» (637.33 – 577.17 m; Fig. 3-4).

In contrast to the carbonate measurements (bulk samples), the organic measurements were not always measured in metre resolution, depending on the variability of the expected isotope data. If no major isotope changes occur over longer stratigraphic successions, as can be expected in the middle part of the Opalinus Clay as well as from the Rothenfluh Member (Passwang Formation) up to the Hauptrogenstein, only every second sample (mainly 2 m interval) was analysed.

Lias Group

Starting from the bottom up (Fig. 3-2), the oldest sediments measured belong to the Early Jurassic (probably Late Pliensbachian). The lowermost measurements (659.79 – 659.20 m) are coming from the uppermost combined Grünschholz Member, Breitenmatt Member and Rickenbach Member. The following ones, between 659.10 m and 651.56 m, represent the upper two members of the Staffelegg Formation. They show larger variations in their individual data, which can be explained by the overall higher sampling resolution in the Lias Group (some intervals in the Rietheim Member with around 20 cm spacing) as well as by the nodular calcareous lithology of the Gross Wolf Member.

The semi-quantitative carbonate content (TCarb) values represent the lithological variations in the Rietheim Member and the hanging Gross Wolf Member up to the Opalinus Clay. In the Rietheim Member the TCarb values show an increasing trend from around 11 wt.-% to values slightly above 50 wt.-%. The interval between the base of the Rietheim Member (659.15 m) and the «Unterer Stein» (658.58 – 658.35 m) clearly contains less carbonate than the hanging interval to the top of the Rietheim Member. The whole succession of the member is interrupted by higher values measured from the four calcareous interbeds («Unterer Stein»: 658.58 – 658.35 m, «Homogene Kalkbänke»: 658.08 – 657.85 m, «Oberer Stein»: 657.34 – 657.19 m and «Monotishank» (655.14 – 655.30 m); nomenclature *sensu* Kuhn & Etter 1994). The TCarb data from these four beds are documented in Appendix E1 and marked by blue dots in Fig. 3-2. The overlying Gross Wolf Member shows similar values as below, measured mostly from the marly sediment. The calcareous nodules to nodular beds clearly show higher values, indicated by one measurement drilled from a calcareous part (91 wt.-% at 653.50 m).

The $\delta^{13}\text{C}_{\text{carb}}$ values document at the base of the Rietheim Member a negative trend with the most negative value (-2.4 ‰ at 658.58 m) just below the «Unterer Stein». The negative trend is subsequently followed by a rapid increase. The most positive $\delta^{13}\text{C}_{\text{carb}}$ values were documented just above the «Oberer Stein» with 1.9 ‰ at 656.90 m. The values stabilise thereafter to the top of the Gross Wolf Member and show a continuous decreasing trend to around -0.5 ‰. The discussed negative excursion below the «Unterer Stein» represents one of the major Mesozoic negative carbon-isotope excursions (CIE) – the Toarcian Oceanic Anoxic Event (T-OAE).

The negative CIE of the T-OAE can also be seen by the $\delta^{13}\text{C}_{\text{org}}$ values (Fig. 3-3). The most negative one, with a value of -32.9 ‰ at 658.98 m, is slightly lower than the most negative one from the $\delta^{13}\text{C}_{\text{carb}}$. The following rapid positive shift is also clearly documented in the organic matter, where the most positive value (-26.9 ‰) was measured from the sample from the «Oberer Stein» at 657.23 m. The $\delta^{13}\text{C}_{\text{org}}$ curve shows great similarity with the data documented from the Riniken cores by Fantasia et al. (2018, 2019). Although, the abrupt shift or even jump at the base of the Rietheim Member, seems to indicate an erosive phase or a longer condensation at BOZ1-1 compared to Riniken.

As already mentioned, the Rietheim Member is very bituminous. The member itself was defined by the bituminous shale. The semi-quantitative organic carbon content (TOC) as well as the C/N ratio (both Fig. 3-3) limit the range of the Rietheim Member. Both plots show very increased values within this member. The highest TOC value with 14.2 wt.-% was measured from the sample just below the «Unterer Stein» at 658.58 m. In average, the semi-quantitative TOC content from the bituminous shale and the argillaceous marl lies between 2.5 to 6.5 wt.-%, whereby the four calcareous beds (marked by blue dots in Fig. 3-3) clearly show lower TOC values. The hanging Gross Wolf Member has an obvious different lithological composition which is nicely documented by the very stable but much lower TOC content, which is clearly below 0.5 wt.-%.

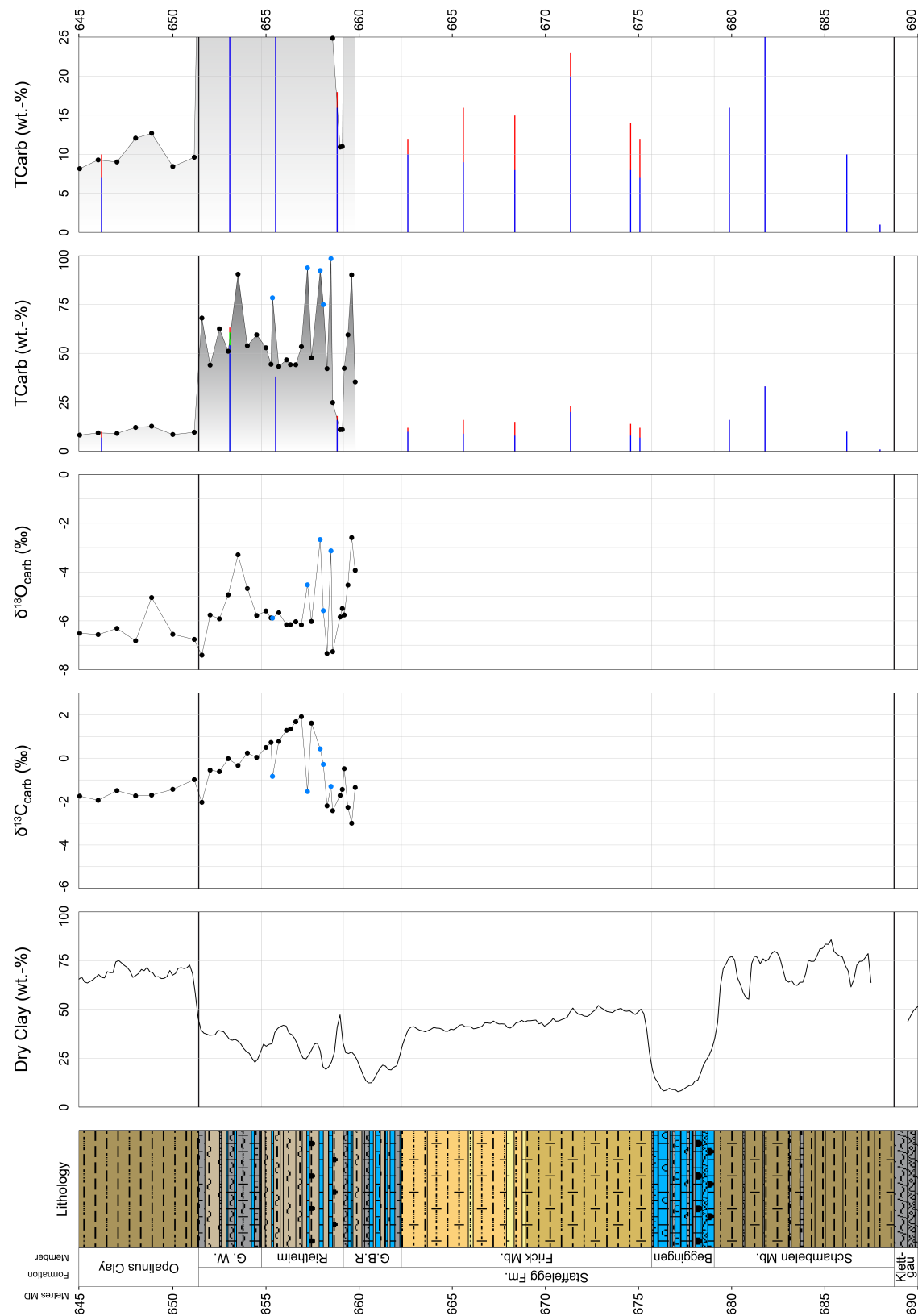


Fig. 3-2: Bulk rock (carbonate) isotopic data from the Lias Group

Geochemical data from 659.79 – 645.00 m, additional explanations and references see text at the beginning of Section 3.4.

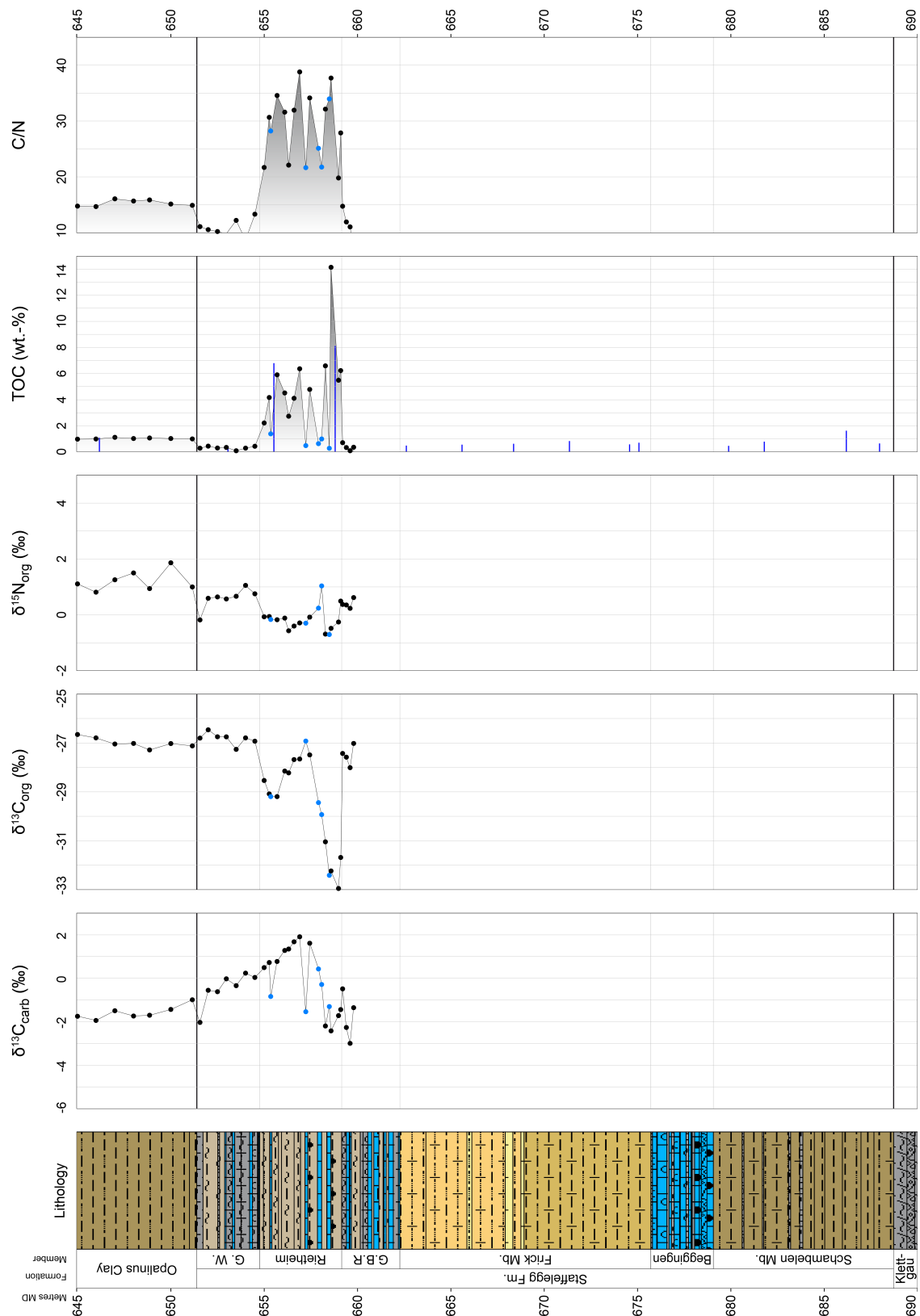


Fig. 3-3: Organic isotopic data from the Lias Group

Geochemical data from 659.79 – 645.00 m, additional explanations and references see text at the beginning of Section 3.4.

The C/N ratios show the same trend as the TOC with the highest ratios measured contemporaneous with the bituminous lower and middle part of the Rietheim Member (ratios between 30 and 39). The overlying Gross Wolf Member shows again a striking different C/N ratio, which is much lower (8 – 12). Such high C/N ratios, measured in the Rietheim Member, are normally very unusual for marine organic matter, which usually has values between 5 and 8 (e.g. Emerson & Hedges 1988, Meyers 1997) and would therefore pretend that the organic material would be of terrigenous source. However, such high C/N ratios were also reported from mid-Pleistocene sapropels from the Tyrrhenian Basin (Meyers & Bernasconi 2005) which are also clearly produced by marine organic matter. Van Mooy et al. (2002) proposed a model for these very unusual C/N ratios in which they determined from sediment trap studies that suboxic microbial degradation via denitrification preferentially utilises nitrogen-rich amino acids and hence leaves a larger proportion of the nitrogen-poor organic matter components intact than under oxic conditions. C/N values of the surviving organic matter necessarily rise.

Lower part of the Dogger Group – mainly Opalinus Clay

The interval described in the following section, the lower part of the Dogger Group (the Opalinus Clay and the transition into the lower part of the Passwang Formation), is also the interval at the main focus of these investigations (Figs. 3-4 and 3-5).

The semi-quantitative carbonate content (TCarb) values from the more homogeneous clay mineral-dominated lithologies are rather low and very stable compared to those from the underlying Staffelegg Formation (Fig. 3-4). In the lowermost succession of the Opalinus Clay the average TCarb values are around 10 wt.-%. Upsection, the TCarb shows slightly lower values with an average around 5 – 7 wt.-% between 631.02 m to 611.74 m. Just above, between the two samples 611.74 m and 611.14 m an obvious shift to slightly higher values is documented. Up to the sample at 602.98 m the TCarb values increase to 14 wt.-% followed by an abrupt shift to lower values to 601.86 m with a TCarb value of around 4 wt.-%. Additionally, from 611.74 m upwards the «Mixed clay-silt-carbonate sub-unit» (637.33 – 577.17 m) and the «Upper silty sub-unit» (577.17 – 564.51 m) document several increasing trends reaching the most calcareous sample at 564.96 m with a content around 19 wt.-% (and an outlier at 571.00 m with 26 wt.-%). The uppermost informal sub-unit («Sub-unit with silty calcareous beds»: 564.51 – 530.28 m) shows measurements with a broader range between 8 and around 20 wt.-%. There is even an interval with higher values, reaching a content of up to 34 wt.-% at 558.00 m. In the uppermost 2 m of the Opalinus Clay a clear trend to more calcareous beds (values up to 80 wt.-%) is documented. In the hanging Passwang Formation, with the very thin «Condensed equivalents of the Sissach, Hauenstein and/or Hirnichopf Members» (530.28 – 529.89 m) and in the lowermost succession of the Waldenburg Member and lower part of Bruggli Member, the TCarb values vary strongly due to the very different lithologies.

The above-mentioned uppermost informal «Sub-unit with silty calcareous beds» comprises several calcareous beds, mainly firm- to hardgrounds (see Appendix E1 for data and Section 3.1 for microfacies description). They are illustrated in Fig. 3-4 by thicker light blue lines ending with blue dots marking the TCarb values. Some of them are classified as measurements from "hiatus beds", "hiatus concretions" and calcareous or sideritic concretions. In addition, also several septarian nodules were measured, illustrated in violet. The calcareous beds (mainly "hiatus beds" or "hiatus concretions") comprise semi-quantitative carbonate contents that are typical for calcareous marl (50 – 75 wt.-%) to limestone (75 – 100 wt.-%). The lowermost calcareous concretions, or here mainly septarian nodules, between 639.67 m and 639.24 m (marked in violet), belong to a level in the «Clay-rich sub-unit» (651.39 – 637.33 m), which can be correlated over several boreholes and siting regions (e.g. BUL1-1: Wohlwend et al. 2021a; TRU1-1: Wohlwend et al. 2021b).

The $\delta^{13}\text{C}_{\text{carb}}$ data show two negative excursions or intervals (Fig. 3-4): a lower one in the «Clay-rich sub-unit» and an upper one in the «Sub-unit with silty calcareous beds». The last-mentioned (upper one) shows around 2 – 3 ‰ more negative $\delta^{13}\text{C}_{\text{carb}}$ values ($\delta^{13}\text{C}_{\text{carb}}$ values: -5.5 to -3.9 ‰ from 554.04 – 549.49 m) and is clearly restricted by two calcareous beds below and above. The two bounding calcareous beds are located at 555.92 m to 555.76 m and 549.04 m to 548.84 m (*cf.* Dossier III). The lower one contains also calcitic iron-ooids; the upper one contains iron-oid bearing intraclasts (Section 3.1). The enclosed succession comprises a single calcareous bed or rather a large septarian nodule at 552.62 m to 552.50 m (94 wt.-% at 552.55 m). The lower negative excursion is represented by a clear decreasing trend, reaching the most negative values (-4.6 ‰ at 640.00 m and -4.5 ‰ at 639.67 m) just below the horizon with the calcareous concretions or mainly septarian nodules between 639.67 m to 639.24 m. The increasing trend above this horizon is then less gradual with a larger scatter in the $\delta^{13}\text{C}_{\text{carb}}$ values. From 548.50 m to the top of Opalinus Clay the values show a slight increasing trend and then from 540.96 m upwards again with a larger scatter with several negative measurements (-6.9 ‰ at 539.97 m and -7.4 ‰ at 534.00 m). Crossing the lithological boundary to the hanging Passwang Formation the $\delta^{13}\text{C}_{\text{carb}}$ values start to increase and reaching +1.4 ‰ at 520.00 m (top of plot in Fig. 3-4).

The $\delta^{13}\text{C}_{\text{carb}}$ data from the calcareous beds and/or intraclasts document possibly an early diagenetic signal (e.g. Wetzel & Allia 2000). The calcareous concretions to septarian nodules are the only macroscopic features with a very negative $\delta^{13}\text{C}_{\text{carb}}$ values (-18.3 to -24.9 ‰, Appendix E1). However, very fine authigenic calcite was probably also precipitated in the very fine original porosity of the Opalinus Clay, which would lead to the more negative $\delta^{13}\text{C}_{\text{carb}}$ values in the lower and upper negative excursions, discussed above (see also Wohlwend et al. 2016.). Also remarkable is the scatter of the individual measurements (metre resolution) in the «Mixed clay-silt-carbonate sub-unit» between 612.97 m and 591.00 m. The succession seems to be very homogeneous with only very thin silt, sideritic laminae and no larger sideritic concretions.

The $\delta^{13}\text{C}_{\text{org}}$ data (Fig. 3-5) show a different picture compared to the $\delta^{13}\text{C}_{\text{carb}}$ values. The curve is relatively stable. The Opalinus Clay succession can be subdivided based on $\delta^{13}\text{C}_{\text{org}}$ values into three subintervals: The lowermost (first) interval can be described from the base of the Opalinus Clay with a slight increasing trend followed by an abrupt negative shift, reaching the most negative value at 637.05 m with -28.1 ‰. The middle (second) interval follows from 636.00 m to 592.00 m. Taking the $\delta^{13}\text{C}_{\text{carb}}$ data into account maybe also up to 591.00 m. This sample was not analysed for organic isotopes. The interval documents a very gradual increasing trend from -27.1 ‰ to -26.4 ‰. The uppermost (third) interval can be described by a gradual decreasing and followed by an increasing trend to the top of Opalinus Clay. In this interval the most negative value of -27.3 ‰ was analysed at 574.03 m. The $\delta^{13}\text{C}_{\text{org}}$ value at the top of Opalinus Clay is -26.4 ‰. Crossing the lithological boundary to the hanging Passwang Formation the $\delta^{13}\text{C}_{\text{carb}}$ value jump from -26.4 ‰ at 530.38 m to -25.8 ‰ just above at 530.00 m. The lithological boundary is therefore also nicely visible by the clear shift in the $\delta^{13}\text{C}_{\text{org}}$ data between the values below and above from the Passwang Formation.

The TOC as well as the C/N ratio will be discussed in the same paragraph because they behave the same. The TOC is rather stable with around 1 wt.-% throughout the lower part of the Opalinus Clay, with only one exception at 637.05 with 1.4 wt.-%. Similar stable conditions can be observed by the C/N ratios until 567.96 m. From then on, the TOC as well as the C/N ratios start to change. The TOC content seems to change abruptly upsection with the obvious largest shift at the uppermost calcareous bed (549.04 – 548.84 m). There the TOC jumps from 0.9 wt.-% to contents above 1.3 wt.-%, decreasing then from 537.01 m to the top of the Opalinus Clay to contents less than 0.5 wt.-%. A similar obvious jump can also be observed by the C/N ratio, from around 17 to ratios around 22. The uppermost 4 m also comprise a shift to lower C/N ratios. The TOC as well as the C/N ratios document a clear change in the sediment input into the shallow marine basin.

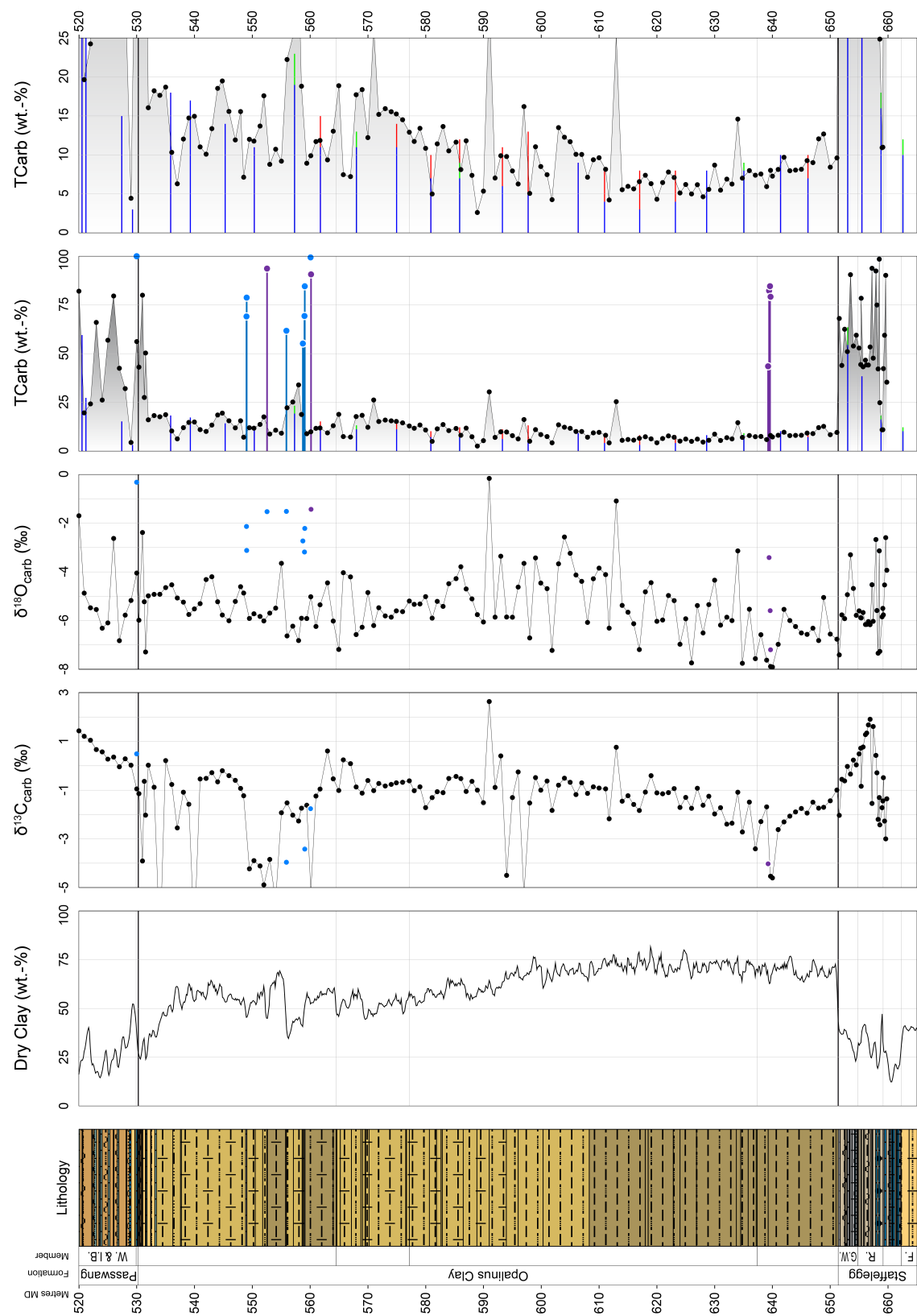


Fig. 3-4: Bulk rock (carb.) isotopic data from the lower Dogger Group – mainly Opalinus Clay
Geochemical data from 659.79 – 520.00 m, additional explanations and references see text
at the beginning of Section 3.4.

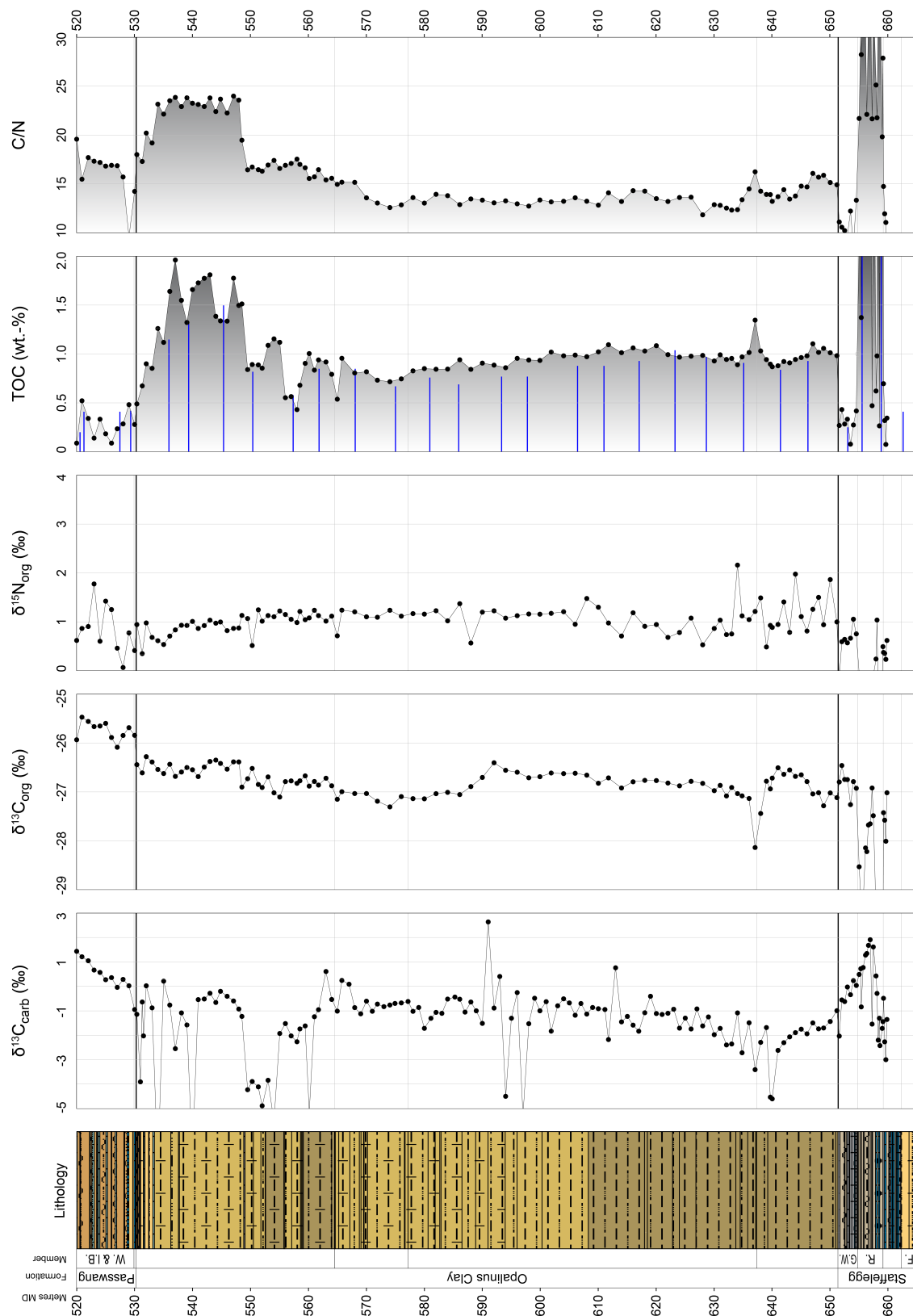


Fig. 3-5: Organic isotopic data from the lower Dogger Group – mainly Opalinus Clay
 Geochemical data from 659.79 – 520.00 m, additional explanations and references see text at the beginning of Section 3.4.

Upper part of the Dogger Group

The following described interval, the upper Dogger Group (Passwang Formation, Hauptrogenstein, Klingnau Formation, Ifenthal Formation and Wildegg Formation), covers in time the whole Middle Aalenian to Middle Oxfordian substages (Figs. 3-6 and 3-7).

The semi-quantitative TCarb (Fig. 3-6) represents the alternation of silty claystone, argillaceous to calcareous marl and limestone in the upper part of the Dogger Group. But what is most striking, the TCarb content from BOZ1-1 documents clearly a more calcareous succession in comparison to eastern locations (e.g. MAR1-1: Wohlwend et al. 2019c). BOZ1-1 was cored in the Celtic ("Rauracian") facies of the Dogger – the more calcareous facies; in comparison to the more eastern location which were cored in the Swabian facies – the basinal facies equivalent. However, the TCarb contents are somehow underestimated because of the sampling strategy of not sampling every single limestone bed (focus on the bulk, clay mineral-rich to calcareous sediments). Nevertheless, the carbonate content curve reflects the inverse DryClay content curve (*cf.* Dossier X).

Based on the TCarb content, the Passwang Formation can be divided into three subintervals, representing three different lithologies: The lower one (from the base to around 517.00 m, lithological boundary in the profile at 516.80 m) includes several calcareous marl to limestone beds in an argillaceous to silty marl. The large scatter in the TCarb data can be explained by random sampling of calcareous beds and marl intervals. The sampling spacing was strictly one metre not to generate an artefact by only measuring one lithology. The following interval (515.94 – 512.26 m) is marked by very low carbonate contents of around 5 – 13 wt.-%. The TCarb data follow nicely the lithological description (*cf.* Dossier III). The hanging «Humphriesi-Schichten» as well as the Rothenfluh Member differ clearly from the lying successions. The transition from the Passwang Formation into the hanging Hauptrogenstein is documented by a trend to more and more calcareous lithologies. The subsequent documented shift to less calcareous successions (444.67 – 426.05 m) was therefore defined as a succession belonging to the more basinal Klingnau Formation. The uppermost samples, taken from the «Spatkalk» of the Hauptrogenstein, the Ifenthal Formation and Wildegg Formation are once again more calcareous.

As already mentioned above, the $\delta^{13}\text{C}_{\text{carb}}$ data show an overall positive trend from the top of the Opalinus Clay upsection. This trend is interrupted by more negative values (almost 0 ‰) from the lower to middle «Humphriesi-Schichten». The most positive value with almost +2.0 ‰ was measured at 505.00 m, in the uppermost 13 cm of the iron-oolitic «Humphriesi-Schichten» (510.51 – 504.87 m). The $\delta^{13}\text{C}_{\text{carb}}$ data document thereafter a very stable situation until the uppermost part of the Hauptrogenstein. From 450.04 m upsection the $\delta^{13}\text{C}_{\text{carb}}$ data shift to more negative values, reaching the most negative ones in the lower to middle part of the Klingnau Formation (values around +0.3 ‰). From 435.00 m the $\delta^{13}\text{C}_{\text{carb}}$ values commute around +1.0 ‰ before they jump by more than +1.5 ‰ from the top of the Ifenthal Formation (+1.0 ‰ at 407.00 m) to the hanging Wildegg Formation (+2.7 ‰ at 406.00 m). The striking positive shift of more than +1.5 ‰ to values around +2.7 ‰ is typical for the Callovian/Oxfordian boundary and was already documented by Rais et al. (2007) in other locations and the Weiach borehole and was for example also documented in the Bülach-1 borehole (Wohlwend et al. 2021a). The most positive $\delta^{13}\text{C}_{\text{carb}}$ values found by Rais et al. (2007) are from the Middle Oxfordian (Transversarium Zone).

The $\delta^{13}\text{C}_{\text{org}}$ data (Fig. 3-7) show a somehow similar overall increasing trend throughout the lower part of the Passwang Formation as discussed above. Although, $\delta^{13}\text{C}_{\text{org}}$ data reaching the most positive values of -23.7 ‰ much lower at 514.00 m, followed by a second positive peak within the «Humphriesi-Schichten» (-24.0 ‰ at 508.00 m). From now on the $\delta^{13}\text{C}_{\text{org}}$ data document an overall slight decreasing trend to the top of the Dogger Group. This trend is only interrupted by a somehow strange positive peak in the «Spatkalk» of the Hauptrogenstein: from 414.98 m to

411.98 m, with the most positive value of -23.5 ‰ at 412.96 m. Like the $\delta^{13}\text{C}_{\text{carb}}$ data, the $\delta^{13}\text{C}_{\text{org}}$ data also document the striking positive shift to a value of -24.8 ‰ at 406.00 m close to the Callovian/ Oxfordian boundary, here also marked by the boundary between the Dogger Group and the Malm Group.

The strange positive "excursions" in the $\delta^{13}\text{C}_{\text{org}}$ data, documented in the upper part of the «Spatkalk» (414.98 m, 412.96 m and 411.98 m) and subordinate also in the «Humphriesi-Schichten» (508.00 m), are marked in Fig. 3-7 by dashed lines. The four samples concerned could also be more positive because the decarbonatisation was not complete, which is normally rather unusual. The four samples were taken from very reddish, iron-oolitic and limonitic intervals. Maybe, there are more ankerite or other iron-carbonates in those intervals which were not completely dissolved during the decarbonatisation with the 3 M HCl for 12 h at room temperature. Therefore, they have been decarbonised a second time for 12 h, but this time at 70 °C. The additional remeasurements document lower $\delta^{13}\text{C}_{\text{org}}$ values (marked by open data points). Therefore, the assumption of incomplete decarbonatization thus seems to be confirmed.

The semi-quantitative TOC content is in principle slightly below 0.5 wt.-%, reaching never more than 0.9 wt.-%. The lowest TOC values were documented from the lower part of the Passwang Formation (lower succession of the Waldenburg Member and lower part of the Brüggli Member) as well as from the carbonate-rich Hauptrogenstein succession.

The C/N ratios nicely document the lithological transition from the Hauptrogenstein to the hanging Klingnau Formation at 444.85 m. Throughout the Hauptrogenstein the C/N ratio is almost constant between 17 and 18. The shift to ratios to around 12 at the base of the Klingnau Formation could document a change in facies to more marine or more basinal (less terrigenous). This could therefore indicate a transgressive phase.

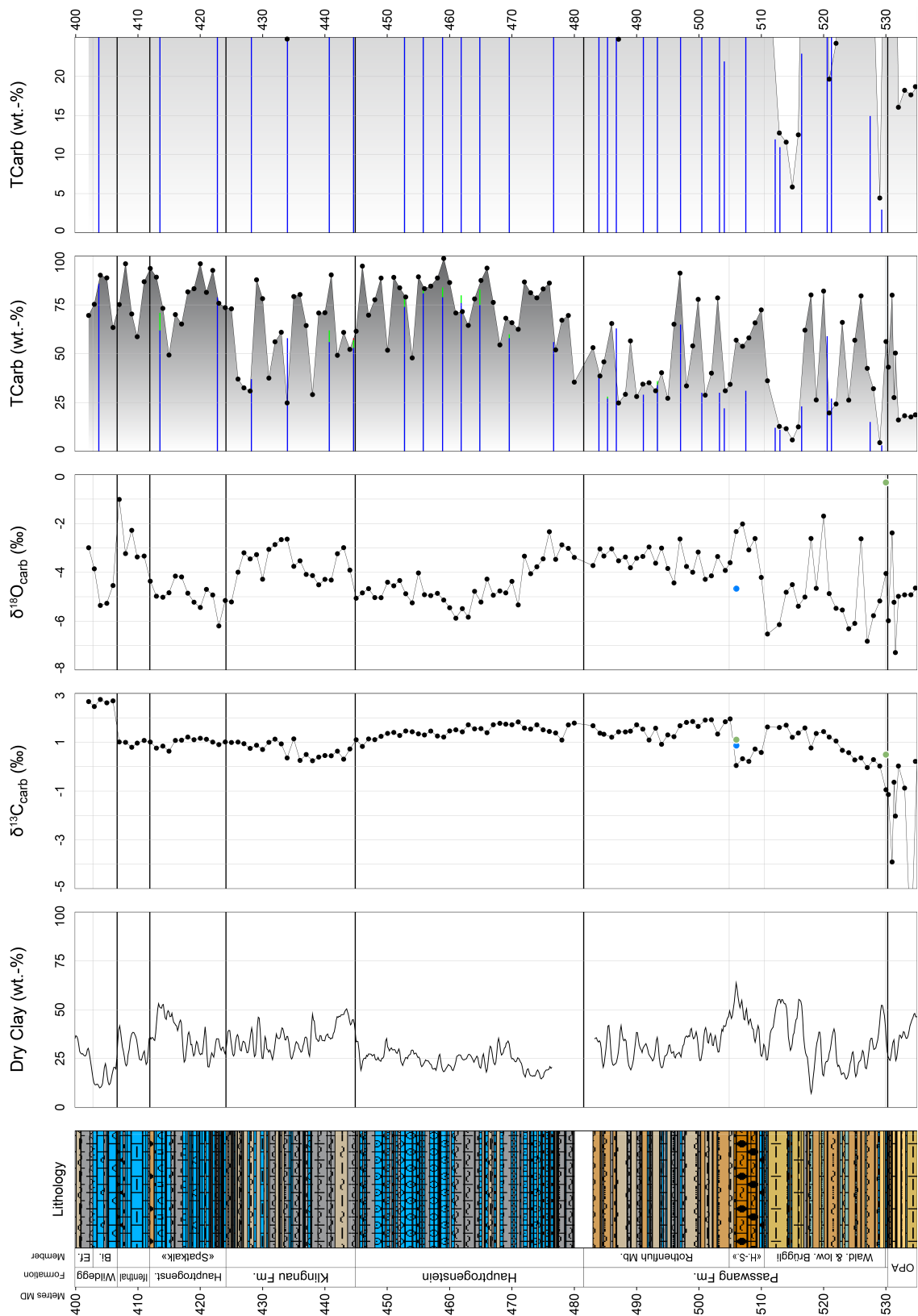


Fig. 3-6: Bulk rock (carbonate) isotopic data from the upper part of the Dogger Group
 Geochemical data from 535.00 – 402.09 m, additional explanations and references see text at the beginning of Section 3.4.

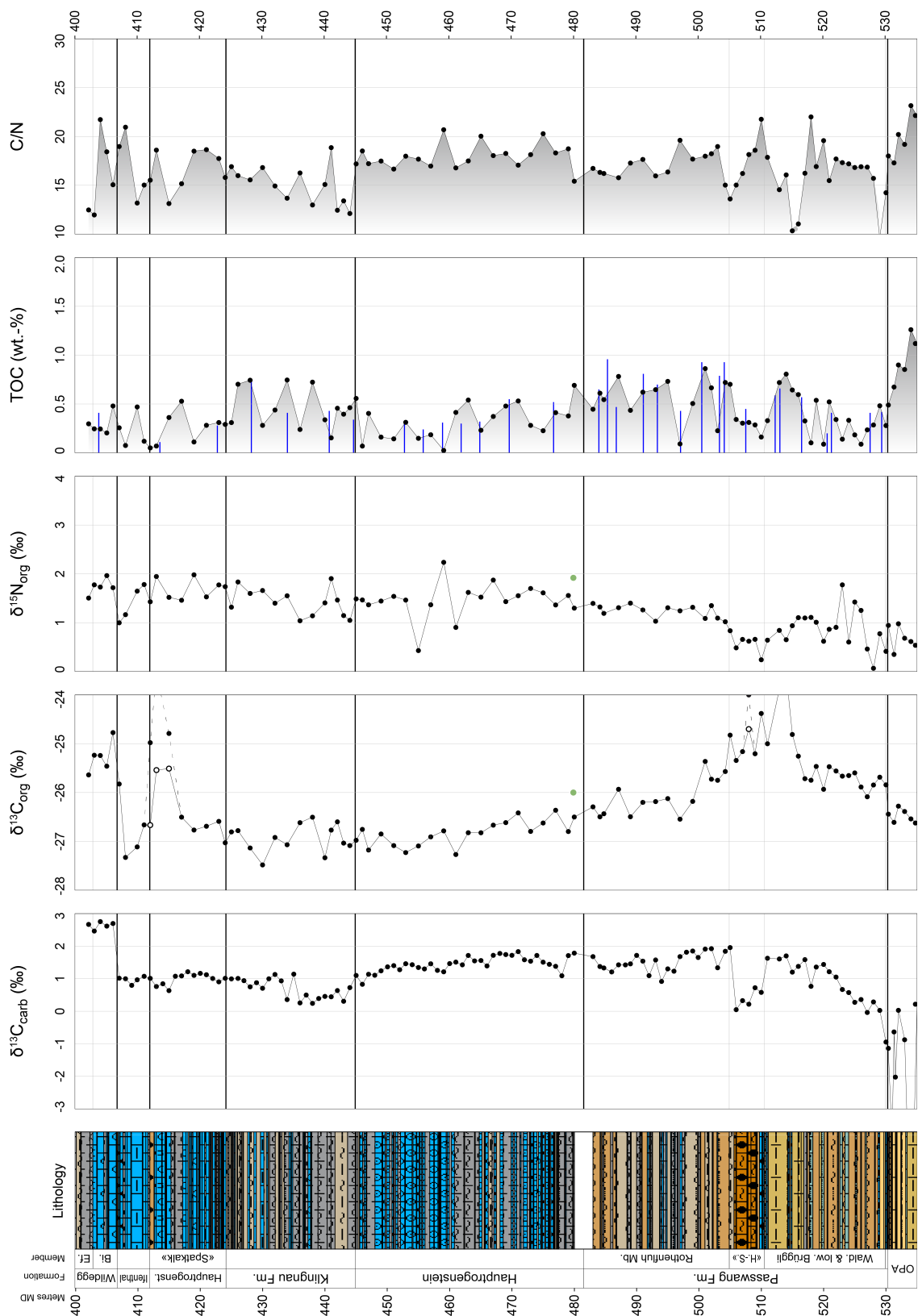


Fig. 3-7: Organic isotopic data from the upper part of the Dogger Group

Geochemical data from 535.00 – 402.09 m, additional explanations and references see text of Section 3.4.

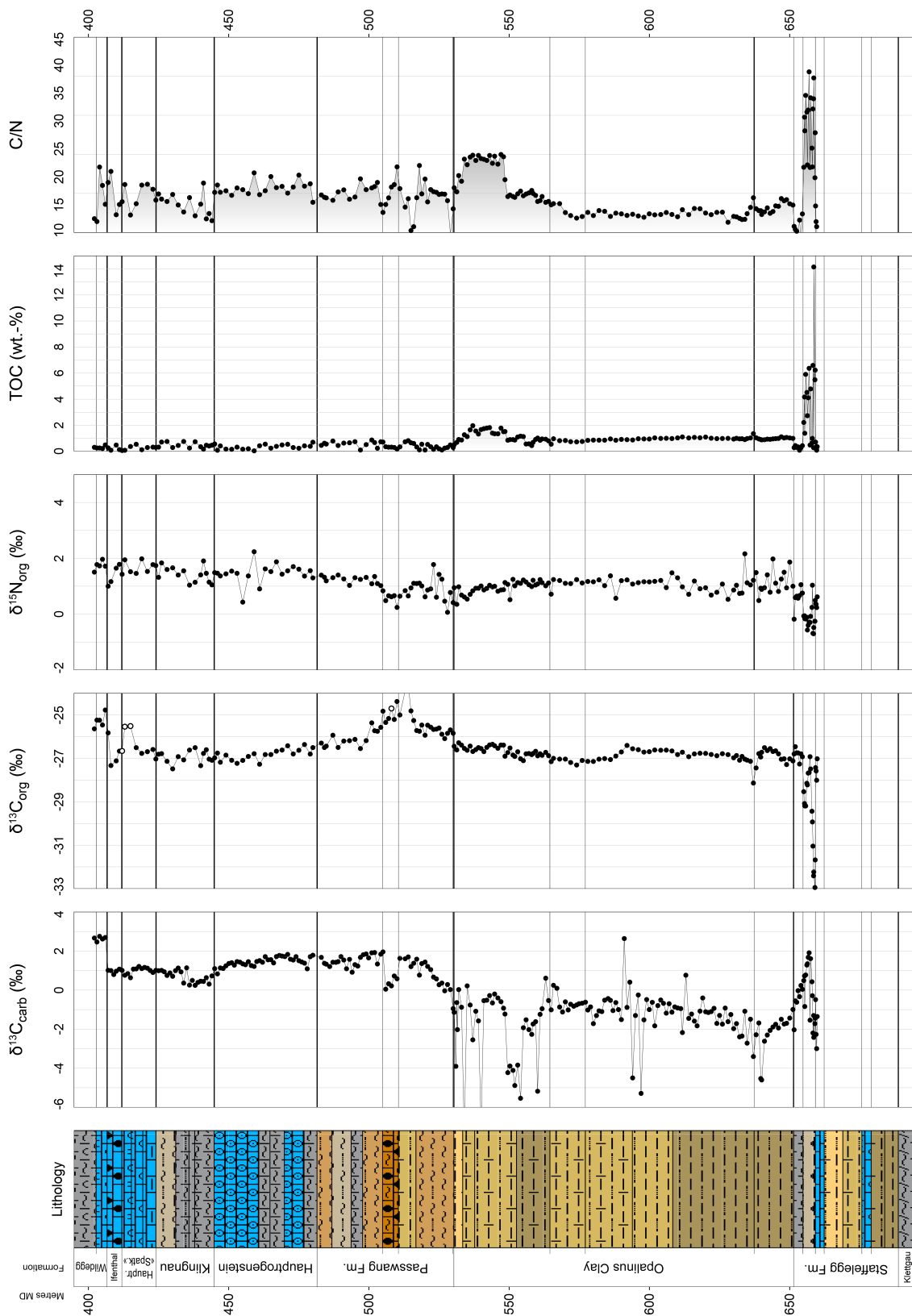


Fig. 3-9: Whole organic isotopic data from BOZ1-1

Geochemical data from 659.79 to 402.09 m, additional explanations and references see text at the beginning of Section 3.4.

4 Definition of specific lithostratigraphic boundaries

The boundaries between stratigraphical units, as also shown in the stratigraphical logs of the lithostratigraphy report (Dossier III), were mostly defined by using lithological criteria. According to the guidelines on stratigraphical nomenclature of Remane et al. (2005), the definition of lithostratigraphical units should be based, both vertically and horizontally, on lithological variations regardless of their age. In fact, the formation boundaries, as used by Nagra for the ongoing borehole campaign of Stage 3 of the Sectoral Plan for Geological Repositories (Jordan & Deplazes 2019), were not always obvious in the borehole and definitions were difficult to apply, either because of the small core diameter or because of differences in facies. The exact location of some of the formation boundaries caused discussions during core description and the process of quality control. Most of the important data for questionable boundaries were already present before the data-freeze (02.02.2021) and were used for the log descriptions and drawings. In the following paragraphs, the underlying considerations are explained for providing a better understanding of how boundaries were demarcated. We are aware of the fact that several boundaries are no longer based on lithological criteria alone and that chronostratigraphic criteria (ammonite, palyno- and chemostratigraphy) are included in the definitions.

Opalinus Clay (651.39 – 530.28 m)

The *lower boundary* of the Opalinus Clay is set at 651.39 m at the uppermost surface of a fossiliferous calcareous marl from the underlaying Staffelegg Formation (*cf.* Dossier III). The lithological boundary is therefore evident above all in the carbonate content (TCarb: Figs. 3-2 and 3-4). The value decreases from 68 wt.-%, measured from the uppermost sample (651.56 m) of the Gross Wolf Member, to values between 8 and 12 wt.-% in the basal Opalinus Clay (Fig. 3-2). The lithological change between the Gross Wolf Member and the Opalinus Clay is also visible in the slight increase in TOC from values < 0.5 wt.-% to values around 1 wt.-% in the Opalinus Clay (Fig. 3-5). The described ammonites (Section 3.2) document that the lithological boundary is very close to the Toarcian / Aalenian stage boundary. The uppermost ammonite (*Cotteswoldia* ex gr. *lotharingica*) from the Gross Wolf Member, taken at 651.60 m, yields Aalensis Zone (Torulosum Subzone). The lowermost ammonite (*Leioceras* ex gr. *subglabrum*) from the Opalinus Clay from 651.27 m can be dated as Opalinum Zone (Opalinum Subzone).

The *upper boundary* of the Opalinus Clay is set at 530.28 m at the base of the overlying very condensed limestone to limestone (iron-oolitic) interval with many dark reddish encrusted intraclasts and iron-stromatolites (530.28 – 529.89 m). Placing the boundary at this level was not based on lithological reasons alone. The argillaceous siltstone from 529.89 m to 529.00 m, which directly overlays the multi-layered hardground, cannot clearly be distinguished from intervals from the upper part of the Opalinus Clay and iron-ooids were already documented in several beds in the Opalinus Clay. (e.g. BUL1-1; Wohlwend et al. 2021a). However, the TCarb measurement from the sample 529.01 m documents a very low carbonate content of only 4.4 wt.-%, which is also compared to the upper part of the Opalinus Clay very low. The boundary was also placed at this level by comparison with the newly adapted stratigraphy in the Rinken borehole and other outcrops of the Jura Ost siting region (Wohlwend et al. 2019a). A similar condensed bed from the Wasserflue outcrop (Wohlwend et al. 2019a), where palynological samples and ammonites were taken directly from the hardground, has given an age from Bradfordensis to Concavum Zone.

In BOZ1-1 the ammonite (*Leioceras* ex gr. *bifidatum* ?) taken in the uppermost decimetre from the Opalinus Clay (530.54 m) can be dated to the Bifidatum Subzone (Opalinum Zone). The numerous occurrences of belemnites (ca. 6 specimens in the sample at 529.96 m) could possibly indicate the Concavum Zone (Formosum Subzone) or the early Discites Zone. The palynological samples taken in the uppermost part of the Opalinus Clay and just above the lithological boundary (defined at 530.28 m) document the multi-layered hardground. The palynological sample just below at 530.52 m is dated Opalinum Zone (probably Bifidatum Subzone), the upper sample in the hanging bed at 530.01 m yields already Discites Zone (Early Bajocian). These biostratigraphic findings confirm the correlation to similar beds in the Jura Ost siting region. Placing the boundary at this level therefore fits the lithological as well as the biostratigraphical description of the base of the Passwang Formation by Burkhalter (1996) and the new findings by Wohlwend et al. (2019a).

The positive chemostratigraphic shift or even jump with an amplitude of around +0.6 ‰ in the $\delta^{13}\text{C}_{\text{org}}$ values, discussed above in Section 3.4 (Fig. 3-5), also fits to similar shifts found in the same intervals (e.g. Wohlwend et al. 2021a).

Passwang Formation (530.28 – 481.5 m)

The *lower boundary* of the Passwang Formation is set at 530.28 m at the base of the very condensed limestone to limestone (iron-oolitic) interval with many dark reddish encrusted intraclasts and iron-stromatolites (530.28 – 529.89 m). The thin section from that hardground (BOZ1-1-530.17 m) documents iron-oids, intraclasts, iron-stromatolites, bioclasts and limonitic bioclasts and calcite cement as well as "stellate cement". The multiphase hardground, as already discussed above, covers several ammonite zones. The ammonite (*Leioceras* ex gr. *bifidatum* ?) taken a few decimetres below the base of the Passwang Formation (530.54 m) can be dated to the Bifidatum Subzone (Opalinum Zone). The numerous occurrences of belemnites (ca. 6 specimens in the sample at 529.96 m) could possibly indicate the Concavum Zone (Formosum Subzone) or the early Discites Zone. The palynological samples, taken from the discussed bed (530.25 m and 530.01 m), document the multi-layered hardground. The lower sample is dated Opalinum Zone (probably Bifidatum Subzone), the upper sample yields already Discites Zone (Early Bajocian). The original definition of the individual members of the Passwang Formation (Burkhalter 1996) would indicate that the 39 cm thick bed covers the equivalent sedimentation time of the Sissach Member to possibly Hirnichopf Member. Therefore, the bed was named «**Condensed equivalents of the Sissach, Hauenstein and/or Hirnichopf Members**». This condensation fits into the regional expression of the evolution during that time in the Jura Ost siting region (Wohlwend et al. 2019a).

The **Waldenburg Member and lower part of the Brüggl Member** were combined during the work of Wohlwend et al. (2019a) by several reasons. The lithological separation into two individual members is especially for the Jura Ost siting region not feasible. Although, the lithological expression fits with the observed and studied outcrops. The *lower boundary*, as discussed above, is set at the top of the multi-layered, iron-oolitic hardground at 529.89 m. The *upper boundary* is set at 510.51 m at the lithologically defined boundary to the «Humphriesi-Schichten». The onset of the iron-oids and/or limonitic components define the boundary. The informally combined interval covers in time the Ovale Zone to Sauzei Zone, whereby the uppermost palynological sample at 510.81 m could already be Humphriesianum Zone.

The «**Humphriesi-Schichten**» are defined on lithological criteria with the on- and offset of iron-oids and limonitic components (Burkhalter 1996). The *lower boundary* is set at 510.51 m and the *upper boundary* at 504.87 m. The ammonites found in the interval at 506.04 m and 505.57 m

(both *Stephanoceras* sp.) indicate Humphriesianum Zone (Humphriesianum Subzone). The palynological samples confirm this age. However, the two samples from the lower part (510.08 m and 509.01 m) could also be slightly older, i.e. Sauzei to Humphriesianum Zone.

The **Rothenfluh Member** starts at its *lower boundary* by the offset of the iron-ooids and/or limonitic components at 504.87 m. The *upper boundary*, which is as well the upper boundary of the Passwang Formation, is defined by the onset of (calcitic) ooids from the hanging Hauptrogenstein. The boundary was set arbitrarily in the centre of an interval without any evidence from cores or cuttings at 481.5 m. The closest core above shows ooids, the core below not yet. The overarching trend also shows an increasing trend to more calcareous sediments (see Fig. 3-8). The age of the Rothenfluh Member can be ranged by the palynological samples from 504.74 m to 483.01 m as Blagdeni Subzone of Humphriesianum Zone, maybe to earliest Niortense Zone at 483.01 m.

Klingnau Formation (444.85 – 424.11 m)

The drilling BOZ1-1 is situated in the transition area between the carbonate platform of the formation Hauptrogenstein in the west and the more basinal Klingnau Formation in the east. The two formations are interlocking and therefore a separation is not always straightforward. It was decided that in the investigated area the Klingnau Formation would only be distinguished if it reaches a thickness of more than ca. 15 m. Sequences with this thickness could certainly be mapped in the field. This mappable aspect is important for an individual distinction as an independent formation.

The *lower boundary* is clearly documented by a shift from oolitic limestone to calcareous to argillaceous marl at 444.85 m. The shift is also visible in Fig. 3-6 by the decrease in the TCarb value from around 90 wt.-% to around 50 wt.-% or even lower. In addition, the C/N ratios (Fig. 3-7) also mimic this lithological transition.

The *upper boundary* is documented by a transition from a marlier succession to the hanging «Spatkalk» of the Hauptrogenstein at 424.11 m. The lithological boundary is therefore also documented in the TCarb values in Fig. 3-6. The hanging mostly bioclastic limestone can also be separated from the Klingnau Formation by lower $\delta^{18}\text{O}_{\text{carb}}$ values.

The age of the Klingnau Formation, as it is lithologically defined in BOZ1-1, is dated by palynological samples from the Parkinsoni Zone to the Tenuiplicatus Subzone of the Zigzag Zone. The boundary between the Parkinsoni and Zigzag Zone lies between the two samples taken at 438.75 m and 435.93 m. In-between these two samples a condensed succession of calcareous marl with limonitic bioclasts and limonitic pellets is documented (437.90 m – 435.84 m). The beds may also include iron-ooids, but this could not be confirmed with the thin section (BOZ1-1-436.51). The beds show lithological similarities to the condensed beds from the profile Acheberg-Klingnau (bed 34 to 38; Wohlwend et al. 2019a). There the ammonites from the Parkinsoni Zone (Acris and Truellei Subzones) allow a correlation with either one or both «Parkinsonien Beds» by Schmassmann (1945).

5 Conclusion

The present study documents data on microfacies analysis, ammonite stratigraphy and palynostratigraphy as well as detailed geochemical analyses (C, O and N isotopes). With this data collection, it was possible to predict the delimitation of the Mesozoic strata more accurately. Most of the important data for the boundaries in question were already present at the data-freeze (02.02.2021). Therefore, the present report complements the lithostratigraphic report of Dossier III for the deep borehole Bözberg-1-1 and its sidetrack Bözberg-1-1B. The lithological boundaries, and therefore the stratigraphic profile, were mostly defined by lithological criteria. Nevertheless, the customary formal and informal formation boundaries were not always obvious in the drill cores, either because of the small core diameter or changing facies conditions. The exact location of specific formation boundaries led to discussions requiring additional data to determine the exact profile description and illustration. We are aware that certain boundaries are thus no longer based solely on lithological criteria, and that the definitions therefore also include chronostratigraphic criteria (ammonite stratigraphy, palyno- and chemostratigraphy).

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Appendix A: List of all samples

Appendix A1:	List of all thin sections from BOZ1-1 & BOZ1-1B (965.44 – 257.13 m).....	A-2
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Appendix A1: List of all thin sections from BOZ1-1 & BOZ1-1B (965.44 – 257.13 m)

For the description and individual counting of the thin sections see Section 3.1; selected photos can be found in Appendix B.

Top [m]	Bottom [m]	Avg. depth [m]	Formation	Retrieval date [dd.mm.yyyy]	Sample ID
257.11	257.14	257.13	Wildeggen Fm.	08.08.2020	BOZ1-1-257.13-TS
274.65	274.68	274.67	Wildeggen Fm.	08.08.2020	BOZ1-1-274.67-TS
392.86	392.89	392.88	Wildeggen Fm.	08.08.2020	BOZ1-1-392.88-TS
394.16	394.19	394.18	Wildeggen Fm.	08.08.2020	BOZ1-1-394.18-TS
406.80	406.84	406.83	Ifenthal Fm.	12.10.2020	BOZ1-1-406.83-TS
407.47	407.51	407.49	Ifenthal Fm.	12.10.2020	BOZ1-1-407.49-TS
409.04	409.08	409.06	Ifenthal Fm.	12.10.2020	BOZ1-1-409.06-TS
412.00	412.04	412.02	Hauptrogenstein	12.10.2020	BOZ1-1-412.02-TS
413.36	413.40	413.38	Hauptrogenstein	25.10.2020	BOZ1-1-413.38-TS
414.90	414.94	414.92	Hauptrogenstein	25.10.2020	BOZ1-1-414.92-TS
417.20	417.24	417.22	Hauptrogenstein	25.10.2020	BOZ1-1-417.22-TS
424.03	424.07	424.05	Hauptrogenstein	25.10.2020	BOZ1-1-424.05-TS
427.86	427.90	427.88	Klingnau Fm.	25.10.2020	BOZ1-1-427.88-TS
436.49	436.53	436.51	Klingnau Fm.	25.10.2020	BOZ1-1-436.51-TS
438.06	438.10	438.08	Klingnau Fm.	25.10.2020	BOZ1-1-438.08-TS
444.86	444.90	444.88	Hauptrogenstein	25.10.2020	BOZ1-1-444.88-TS
452.15	452.19	452.17	Hauptrogenstein	25.10.2020	BOZ1-1-452.17-TS
465.90	465.94	465.92	Hauptrogenstein	25.10.2020	BOZ1-1-465.92-TS
475.98	476.02	476.00	Hauptrogenstein	25.10.2020	BOZ1-1-476.00-TS
488.52	488.56	488.54	Passwang Fm.	25.10.2020	BOZ1-1-488.54-TS
494.70	494.74	494.72	Passwang Fm.	25.10.2020	BOZ1-1-494.72-TS
505.08	505.11	505.10	Passwang Fm.	25.10.2020	BOZ1-1-505.10-TS
506.70	506.73	506.72	Passwang Fm.	27.11.2020	BOZ1-1-506.72-TS
510.06	510.10	510.08	Passwang Fm.	27.11.2020	BOZ1-1-510.08-TS
514.36	514.40	514.38	Passwang Fm.	03.06.2021	BOZ1-1-514.38-TS
517.78	517.82	517.80	Passwang Fm.	09.12.2020	BOZ1-1-517.80-TS
523.45	523.49	523.47	Passwang Fm.	09.12.2020	BOZ1-1-523.47-TS
528.78	528.82	528.80	Passwang Fm.	09.12.2020	BOZ1-1-528.80-TS
530.15	530.19	530.17	Passwang Fm.	09.12.2020	BOZ1-1-530.17-TS
530.54	530.58	530.56	Opalinus Clay	24.09.2020	BOZ1-1-530.56-TS
531.50	531.54	531.52	Opalinus Clay	09.12.2020	BOZ1-1-531.52-TS
534.37	534.40	534.39	Opalinus Clay	09.12.2020	BOZ1-1-534.39-TS
549.00	549.03	549.02	Opalinus Clay	09.12.2020	BOZ1-1-549.02-TS
559.00	559.03	559.02	Opalinus Clay	09.12.2020	BOZ1-1-559.02-TS
559.05	559.08	559.07	Opalinus Clay	09.12.2020	BOZ1-1-559.07-TS
565.12	565.15	565.14	Opalinus Clay	09.12.2020	BOZ1-1-565.14-TS
579.25	579.28	579.27	Opalinus Clay	09.12.2020	BOZ1-1-579.27-TS
638.72	638.75	638.74	Opalinus Clay	09.12.2020	BOZ1-1-638.74-TS
657.89	657.93	657.91	Staffellegg Fm.	21.01.2021	BOZ1-1-657.91-TS
699.68	699.72	699.70	Klettgau Fm.	14.12.2020	BOZ1-1-699.70-TS
704.39	704.43	704.41	Klettgau Fm.	14.12.2020	BOZ1-1-704.41-TS
706.88	706.92	706.90	Klettgau Fm.	14.12.2020	BOZ1-1-706.90-TS
708.73	708.77	708.75	Klettgau Fm.	14.12.2020	BOZ1-1-708.75-TS
747.25	747.28	747.27	Bänkerjoch Fm.	27.11.2020	BOZ1-1-747.27-TS
804.92	804.95	804.94	Bänkerjoch Fm.	27.11.2020	BOZ1-1-804.94-TS
849.21	849.25	849.23	Schinznach Fm.	27.11.2020	BOZ1-1-849.23-TS
874.77	874.81	874.79	Schinznach Fm.	15.12.2020	BOZ1-1-874.79-TS
874.85	874.89	874.87	Schinznach Fm.	21.01.2021	BOZ1-1B-874.87-TS
888.45	888.49	888.47	Zeglingen Fm.	21.01.2021	BOZ1-1B-888.47-TS
928.05	928.09	928.07	Kaiseraugst Fm.	21.01.2021	BOZ1-1B-928.07-TS
929.11	929.15	929.13	Kaiseraugst Fm.	21.01.2021	BOZ1-1B-929.13-TS
965.42	965.46	965.44	Kaiseraugst Fm.	21.01.2021	BOZ1-1B-965.44-TS

Appendix A2: List of all sampled macrofossils from BOZ1-1 (653.78 – 392.31 m)

For the definitive determination of the individual macrofossils see Section 3.2 (Tab. 3-2).

Top [m]	Bottom [m]	Sample depth [m]	Formation	Retrieval date [dd.mm.yyyy]	Sample ID
392.29	392.34	392.31	Wildegge Fm.	08.08.2020	BOZ1-1-392.31-BS(MF)
392.47	392.50	392.48	Wildegge Fm.	08.08.2020	BOZ1-1-392.48-BS(MF)
393.34	393.37	393.36	Wildegge Fm.	08.08.2020	BOZ1-1-393.34-BS(MF)
406.71	406.75	406.73	Ifenthal Fm.	24.09.2020	BOZ1-1-406.73-BS(MF)
407.15	407.19	407.17	Ifenthal Fm.	24.09.2020	BOZ1-1-407.17-BS(MF)
407.69	407.74	407.72	Ifenthal Fm.	24.09.2020	BOZ1-1-407.72-BS(MF)
445.19	445.24	445.22	Hauptrogenstein	24.09.2020	BOZ1-1-445.22-BS(MF)
505.53	505.60	505.57	Passwang Fm.	24.09.2020	BOZ1-1-505.57-BS(MF)
506.00	506.07	506.04	Passwang Fm.	24.09.2020	BOZ1-1-506.04-BS(MF)
514.74	514.80	514.77	Passwang Fm.	24.09.2020	BOZ1-1-514.77-BS(MF)
525.17	525.22	525.20	Passwang Fm.	24.09.2020	BOZ1-1-525.20-BS(MF)
529.92	529.99	529.96	Passwang Fm.	24.09.2020	BOZ1-1-529.96-BS(MF)
530.50	530.58	530.54	Opalinus Clay	24.09.2020	BOZ1-1-530.54-BS(MF)
570.325	570.37	570.35	Opalinus Clay	12.10.2020	BOZ1-1-570.35-BS(MF)
639.00	639.05	639.03	Opalinus Clay	12.10.2020	BOZ1-1-639.03-BS(MF)
644.16	644.20	644.18	Opalinus Clay	12.10.2020	BOZ1-1-644.18-BS(MF)
651.25	651.295	651.27	Opalinus Clay	12.10.2020	BOZ1-1-651.27-BS(MF)
651.56	651.60	651.58	Staffelegg Fm.	12.10.2020	BOZ1-1-651.60-BS(MF)
652.24	652.28	652.26	Staffelegg Fm.	12.10.2020	BOZ1-1-652.26-BS(MF)
653.735	653.83	653.78	Staffelegg Fm.	12.10.2020	BOZ1-1-653.78-BS(MF)

Appendix A3: List of other provisionally determined conspicuous macrofossils from BOZ1-1 (682.26 – 323.77 m)

Top [m]	Bottom [m]	Fossil	Determination (provisional)
323.77		Ammonite	Opellidae indet.
332.58		Ammonite	Opellidae indet.
355.84		Ammonite	Perisphinctidae indet.
367.35		Crinoid ossicles	<i>Balanocrinus</i> sp.
392.29	392.34	Ammonite	<i>Dichotomoceras</i> ?
392.47	392.50	Ammonite	<i>Dichotomoceras</i>
393.08		Ammonite	<i>Dichotomoceras</i>
393.34	393.37	Ammonite	<i>Dichotomoceras</i>
394.18		Ammonite	Perisphinctidae indet.
405.61		Ammonite	Perisphinctidae indet.
406.71	406.75	Ammonite	indet.
406.87		Echinid	<i>Holactypus</i> sp.
407.15	407.19	Ammonite	Opellidae indet.
407.69	407.74	Ammonite	Perisphinctide indet.
441.69		Ammonite	<i>Parkinsonia</i> ?
445.19	445.24	Ammonite	<i>Parkinsonia</i> ?
484.27		Belemnite	Megateuthis
505.53	505.60	Ammonite	<i>Stephanoceras</i>
506.00	506.07	2 ammonites	<i>Stephanoceras</i>
508.23		Bivalve	<i>Actinostreon marshi</i>
508.34		Bivalve	Ctenostreon
514.27		Ammonite	<i>Sonninia</i> ?
525.17	525.22	Ammonite	<i>Sonninia</i> ?
528.90		Gryphaea frequently	Gryphaea
529.92	529.99	Ammonite	indet.
530.50	530.58	Ammonites	<i>Leioceras</i>
547.69		Ammonite	<i>Leioceras</i> ex gr. <i>opalinum</i>
607.67		Ammonite	<i>Leioceras</i> sp. Fragment
614.38		Ammonite	<i>Leioceras opalinum</i>
615.24		Aptychus	indet.
635.58		Ammonite	<i>Leioceras</i>
638.63		Ammonite	<i>Leioceras opalinum</i>
638.70		Ammonite	<i>Leioceras opalinum</i> ?
639.00	639.05	Ammonites	<i>Leioceras</i> sp.
644.16	644.20	Ammonite	<i>Leioceras</i> sp.
651.25	651.30	Ammonite	<i>Leioceras subglabrum</i>
651.56	651.60	Ammonite	<i>Pleydellia lotharingica</i>
652.24	652.28	Ammonite	<i>Pleydellia</i> ? sp.
653.69		Ammonite	<i>Lytoceras</i>
654.04		Ammonite	<i>Pseudogrammoceras fallaciosum</i>
673.21		Crinoid ossicles	indet.
682.26		Bivalves	Modiolus

Appendix A4: List of all palynological samples from BOZ1-1 (652.27 – 391.98 m)

Palynological samples in grey are taken from ammonite samples retrieved at specific depths. Sampling was always as close as possible to the ammonite.

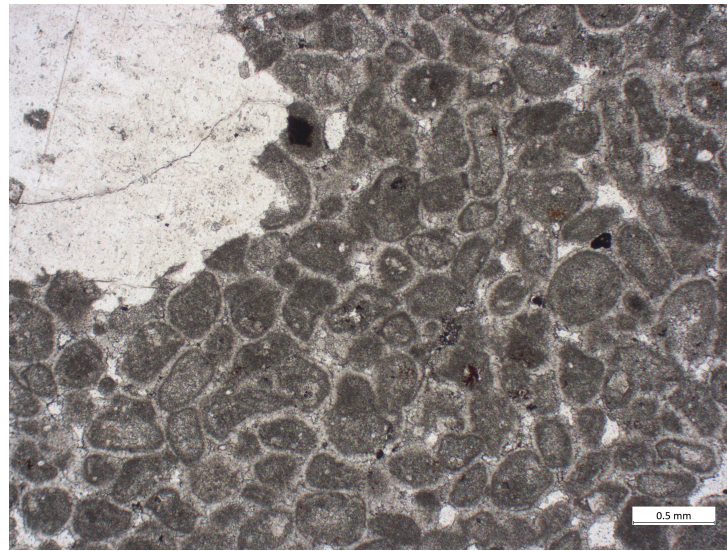
Top [m]	Bottom [m]	Avg. Depth [m]	Formation	Retrieval date [dd.mm.yyyy]	Sample ID
391.98	391.99	391.98	Wildeggen Fm.	08.08.2020	BOZ1-1-391.98-BS(PA)
392.29	392.34	392.31	Wildeggen Fm.	08.08.2020	BOZ1-1-392.31-BS(PA)
395.58	395.60	395.59	Wildeggen Fm.	08.08.2020	BOZ1-1-395.59-BS(PA)
402.09	402.11	402.10	Wildeggen Fm.	12.10.2020	BOZ1-1-402.10-BS(PA)
405.83	405.85	405.84	Wildeggen Fm.	12.10.2020	BOZ1-1-405.84-BS(PA)
406.54	406.56	406.55	Wildeggen Fm.	12.10.2020	BOZ1-1-406.55-BS(PA)
406.65	406.67	406.66	Wildeggen Fm.	12.10.2020	BOZ1-1-406.66-BS(PA)
406.73		406.73	Ifenthal Fm.	04.11.2020	BOZ1-1-406.73-BS(PA)
406.73		406.73	Ifenthal Fm.	12.01.2021	BOZ1-1-406.73-BS(PA)
406.84	406.86	406.85	Ifenthal Fm.	12.10.2020	BOZ1-1-406.85-BS(PA)
407.19		407.19	Ifenthal Fm.	04.11.2020	BOZ1-1-407.19-BS(PA)
407.72		407.72	Ifenthal Fm.	12.01.2021	BOZ1-1-407.72-BS(PA)
411.70	411.72	411.71	Ifenthal Fm.	12.10.2020	BOZ1-1-411.71-BS(PA)
411.98	412.00	411.99	Hauptrogenstein	12.10.2020	BOZ1-1-411.99-BS(PA)
414.90	414.94	414.92	Hauptrogenstein	25.10.2020	BOZ1-1-414.92-BS(PA)
417.06	417.08	417.07	Hauptrogenstein	25.10.2020	BOZ1-1-417.07-BS(PA)
417.20	417.24	417.22	Hauptrogenstein	25.10.2020	BOZ1-1-417.22-BS(PA)
423.03	423.05	423.04	Hauptrogenstein	25.10.2020	BOZ1-1-423.04-BS(PA)
427.55	427.57	427.56	Klingnau Fm.	25.10.2020	BOZ1-1-427.56-BS(PA)
431.99	432.01	432.00	Klingnau Fm.	25.10.2020	BOZ1-1-432.00-BS(PA)
435.75	435.77	435.76	Klingnau Fm.	25.10.2020	BOZ1-1-435.76-BS(PA)
435.92	435.94	435.93	Klingnau Fm.	25.10.2020	BOZ1-1-435.93-BS(PA)
438.74	438.76	438.75	Klingnau Fm.	25.10.2020	BOZ1-1-438.75-BS(PA)
444.02	444.04	444.03	Klingnau Fm.	25.10.2020	BOZ1-1-444.03-BS(PA)
445.20		445.20	Hauptrogenstein	04.11.2020	BOZ1-1-445.20-BS(PA)
452.15	452.19	452.17	Hauptrogenstein	25.10.2020	BOZ1-1-452.17-BS(PA)
460.48	460.50	460.49	Hauptrogenstein	25.10.2020	BOZ1-1-460.49-BS(PA)
470.33	470.35	470.34	Hauptrogenstein	25.10.2020	BOZ1-1-470.34-BS(PA)
480.00	480.02	480.01	Hauptrogenstein	25.10.2020	BOZ1-1-480.01-BS(PA)
483.00	483.02	483.01	Passwang Fm.	25.10.2020	BOZ1-1-483.01-BS(PA)
483.00	483.02	483.01	Passwang Fm.	06.01.2021	BOZ1-1-483.01-BS(PA)
490.30	490.32	490.31	Passwang Fm.	25.10.2020	BOZ1-1-490.31-BS(PA)
497.78	497.80	497.79	Passwang Fm.	25.10.2020	BOZ1-1-497.79-BS(PA)
504.73	504.75	504.74	Passwang Fm.	25.10.2020	BOZ1-1-504.74-BS(PA)
505.33	505.35	505.34	Passwang Fm.	25.10.2020	BOZ1-1-505.34-BS(PA)
505.59		505.59	Passwang Fm.	04.11.2020	BOZ1-1-505.59-BS(PA)
506.91	506.93	506.92	Passwang Fm.	27.11.2020	BOZ1-1-506.92-BS(PA)
509.00	509.02	509.01	Passwang Fm.	27.11.2020	BOZ1-1-509.01-BS(PA)
510.06	510.10	510.08	Passwang Fm.	27.11.2020	BOZ1-1-510.08-BS(PA)
510.80	510.82	510.81	Passwang Fm.	27.11.2020	BOZ1-1-510.81-BS(PA)
513.99	514.01	514.00	Passwang Fm.	27.11.2020	BOZ1-1-514.00-BS(PA)
514.48	514.50	514.49	Passwang Fm.	27.11.2020	BOZ1-1-514.49-BS(PA)
516.82	516.84	516.83	Passwang Fm.	09.12.2020	BOZ1-1-516.83-BS(PA)
522.44	522.46	522.45	Passwang Fm.	09.12.2020	BOZ1-1-522.45-BS(PA)
528.50	528.52	528.51	Passwang Fm.	09.12.2020	BOZ1-1-528.51-BS(PA)
528.99	529.01	529.00	Passwang Fm.	09.12.2020	BOZ1-1-529.00-BS(PA)
529.66	529.68	529.67	Passwang Fm.	09.12.2020	BOZ1-1-529.67-BS(PA)
530.00	530.02	530.01	Passwang Fm.	09.12.2020	BOZ1-1-530.01-BS(PA)
530.50	530.53	530.52	Opalinus Clay	24.09.2020	BOZ1-1-530.52-BS(PA)
530.80	530.82	530.81	Opalinus Clay	09.12.2020	BOZ1-1-530.81-BS(PA)
535.08	535.10	535.09	Opalinus Clay	09.12.2020	BOZ1-1-535.09-BS(PA)
540.46	540.47	540.47	Opalinus Clay	09.12.2020	BOZ1-1-540.47-BS(PA)

(continued)

Top [m]	Bottom [m]	Avg. Depth [m]	Formation	Retrieval date [dd.mm.yyyy]	Sample ID
560.32	560.34	560.33	Opalinus Clay	09.12.2020	BOZ1-1-560.33-BS(PA)
580.22	580.24	580.23	Opalinus Clay	09.12.2020	BOZ1-1-580.23-BS(PA)
599.90	599.92	599.91	Opalinus Clay	09.12.2020	BOZ1-1-599.91-BS(PA)
620.09	620.11	620.10	Opalinus Clay	09.12.2020	BOZ1-1-620.10-BS(PA)
640.09	640.11	640.10	Opalinus Clay	09.12.2020	BOZ1-1-640.10-BS(PA)
651.27		651.27	Opalinus Clay	04.11.2020	BOZ1-1-651.27-BS(PA)
651.57		651.57	Staffelegg Fm.	04.11.2020	BOZ1-1-651.57-BS(PA)
652.27		652.27	Staffelegg Fm.	04.11.2020	BOZ1-1-652.27-BS(PA)

Appendix B: Photos microfacies

Fig. B-1:	Thin section BOZ1-1-874.79, Schinznach Fm.	B-2
Fig. B-2:	Thin section BOZ1-1-849.23, Schinznach Fm. (Liedertswil Mb.)	B-2
Fig. B-3:	Thin section BOZ1-1-804.94, Bänkerjoch Fm.	B-2
Fig. B-4:	Thin section BOZ1-1-708.75, Klettgau Fm. (Gansingen Mb.)	B-3
Fig. B-5:	Thin section BOZ1-1-706.90, Klettgau Fm. (Gansingen Mb.)	B-3
Fig. B-6:	Thin section BOZ1-1-657.91, Staffelegg Fm. (Rietheim Mb.)	B-3
Fig. B-7:	Thin section BOZ1-1-559.02, Opalinus Clay	B-4
Fig. B-8:	Thin section BOZ1-1-549.02, Opalinus Clay	B-4
Fig. B-9:	Thin section BOZ1-1-530.17, Passwang Fm. (condensed equivalent of the Sissach, Hauenstein and/or Hirnichopf Mb.)	B-4
Fig. B-10:	Thin section BOZ1-1-528.80, Passwang Fm. (Waldenburg and lower part of Brüggli Mb.)	B-5
Fig. B-11:	Thin section BOZ1-1-523.47, Passwang Fm. (Waldenburg and lower part of Brüggli Mb.)	B-5
Fig. B-12:	Thin section BOZ1-1-510.08, Passwang Fm. («Humphriesi-Sch.»)	B-5
Fig. B-13:	Thin section BOZ1-1-488.54, Passwang Fm. (Rothenfluh Mb.)	B-6
Fig. B-14:	Thin section BOZ1-1-476.00, Hauptrogenstein	B-6
Fig. B-15:	Thin section BOZ1-1-465.92, Hauptrogenstein	B-6
Fig. B-16:	Thin section BOZ1-1-444.88, Hauptrogenstein	B-7
Fig. B-17:	Thin section BOZ1-1-436.51, Klingnau Fm.	B-7
Fig. B-18:	Thin section BOZ1-1-414.92, Hauptrogenstein («Spatkalk»)	B-7
Fig. B-19:	Thin section BOZ1-1-413.38, Hauptrogenstein («Spatkalk»)	B-8
Fig. B-20:	Thin section BOZ1-1-407.49, Ifenthal Fm.	B-8
Fig. B-21:	Thin section BOZ1-1-406.83, Ifenthal Fm.	B-8

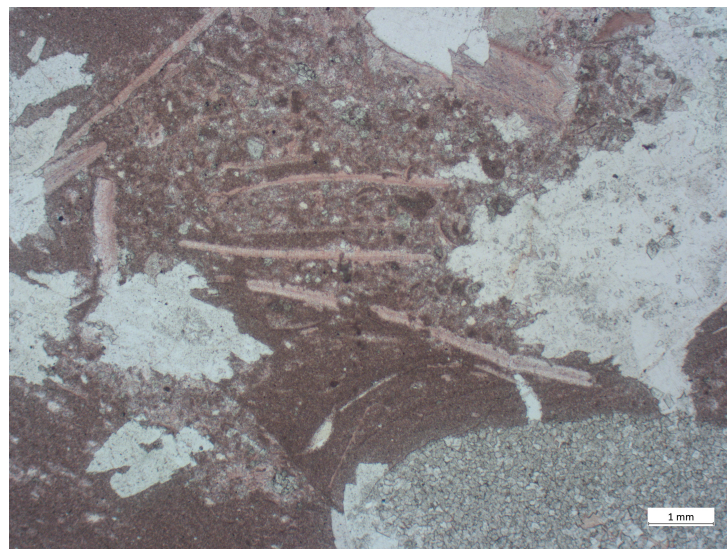
**Fig. B-1:**

Ooids and spherical micritic components, all with a small radial calcite cement rim; and a big anhydrite crystal (white) replacing the oolitic limestone

thin section photo

BOZ1-1-874.79

Schinznach Fm.

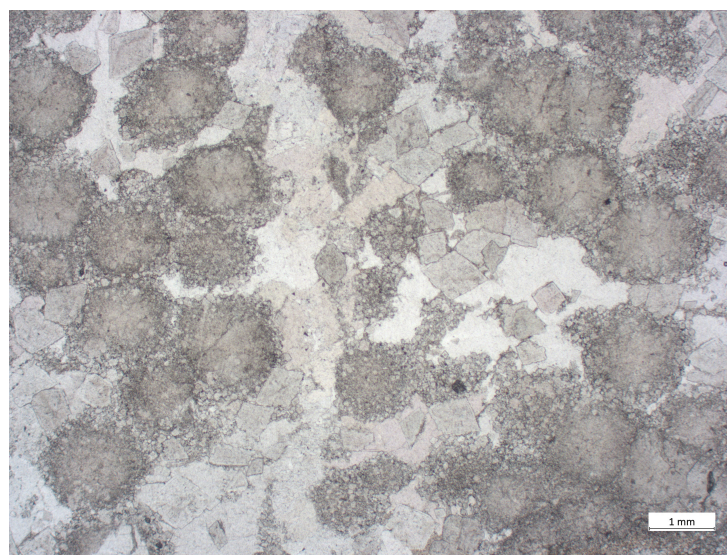
**Fig. B-2:**

Biopelmicrosparite with bivalves, big anhydrite crystals and a dolomitised part (bottom right corner), composed of rhombohedron shaped dolomite crystals

thin section photo
TS stained for calcite = red

BOZ1-1-849.23

Schinznach Fm.
(Liedertswil Mb.)

**Fig. B-3:**

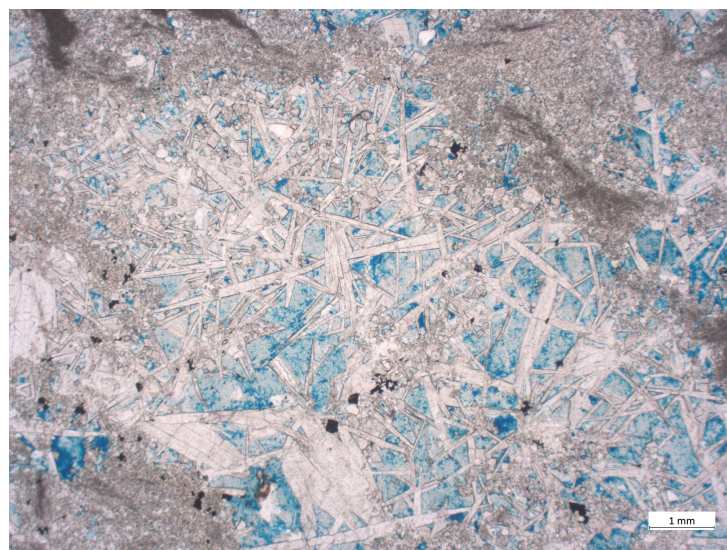
Spheres of dolomite (beige), composed of radiating fibres (only visible by crossed nicols), and anhydrite; the dolomite spheres are pseudomorphs after twinned gypsum crystals

thin section photo

BOZ1-1-804.94

Bänkerjoch Fm.

Selected photos of microfacies from Schinznach Fm. and Bänkerjoch Fm.

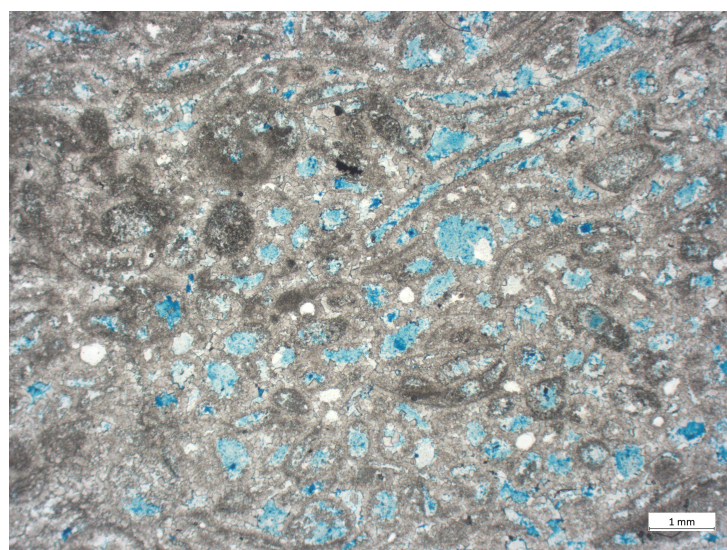
**Fig. B-4:**

Anhydrite needles, grown in the space of leaching pores, and dolomicrosparite

thin section photo
(pore space filled with blue coloured glue)

BOZ1-1-708.75

Klettgau Fm.
(Gansingen Mb.)

**Fig. B-5:**

Porous dolostone: first a bioclastic, oolitic limestone, then dolomitised and leached (ooids and bivalves)

thin section photo
(pore space filled with blue coloured glue)

BOZ1-1-706.90

Klettgau Fm.
(Gansingen Mb.)

**Fig. B-6:**

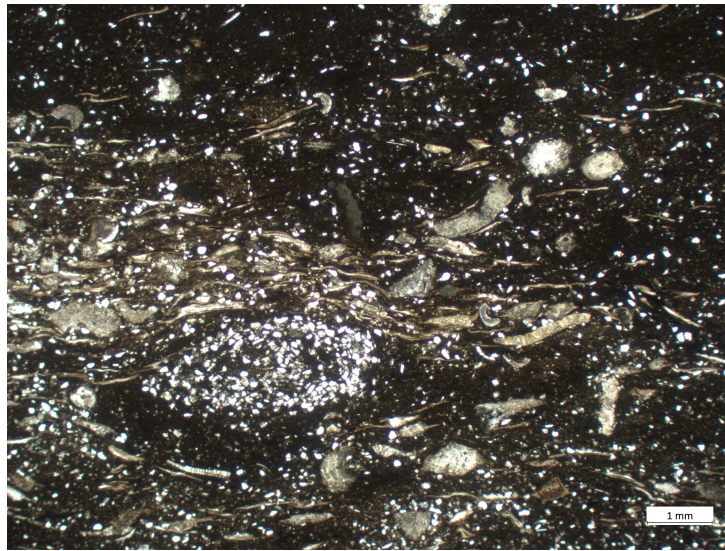
Limestone bed mainly composed of tiny gastropods (*Coelodiscus minutus*); some of the numberless fossils are showing their spiral shell

thin section photo

BOZ1-1-657.91

Staffelegg Fm.
(Rietheim Mb.)

Selected photos of microfacies from Klettgau Fm. and Staffelegg Fm.

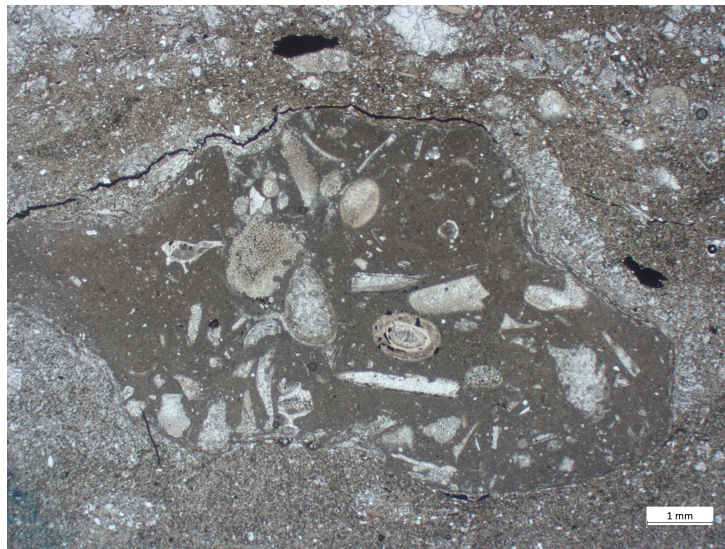
**Fig. B-7:**

Silty claystone with quartz-
(small white grains) silt rich
burrow, echinoderm skeletal
elements and iron-minera-
lised flasers

thin section photo

BOZ1-1-559.02

Opalinus Clay

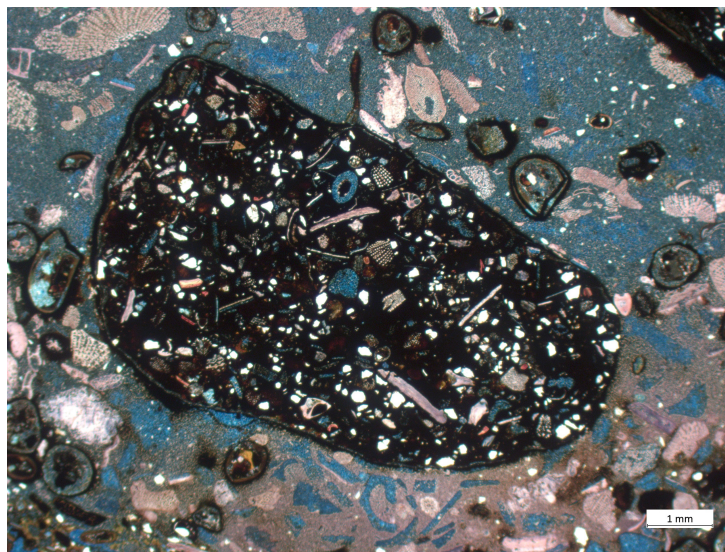
**Fig. B-8:**

Iron-oolitic intraclast, lying
in a bioclastic calcareous
marl with "stellate cement"
hardground, respectively
hiatus bed

thin section photo

BOZ1-1-549.02

Opalinus Clay

**Fig. B-9:**

Intraclast in an iron-oolitic,
biotrititic limestone layer of
a multiphase hardground

thin section photo

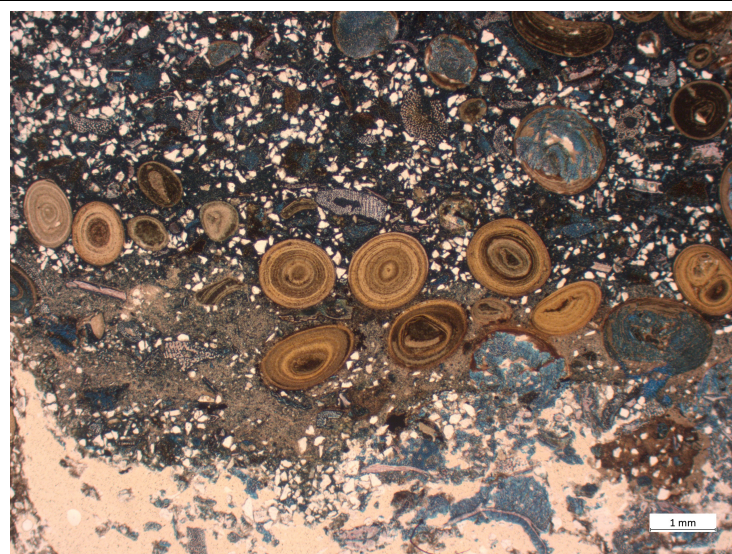
TS stained for calcite = red,
ferroan calcite = blue

BOZ1-1-530.17

Passwang Fm.

(condensed equivalent of the
Sissach, Hauenstein and/or
Hirnichopf Mb.)

Selected photos of microfacies from Opalinus Clay and Passwang Fm.

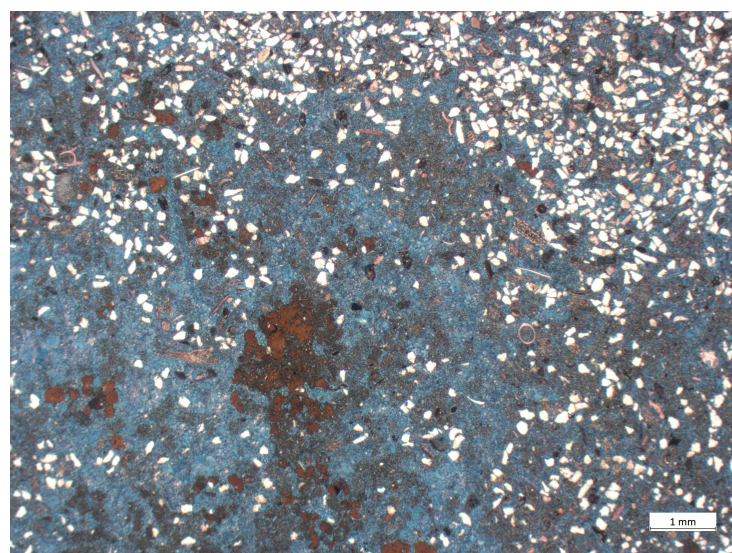
**Fig. B-10:**

Iron-oolitic, biotrititic,
sandy limestone with
chamositic and few calcitic
iron-oooids

thin section photo
TS stained for calcite = red,
ferroan calcite = blue

BOZ1-1-528.80

Passwang Fm.
(Waldenburg and lower part
of Brüggl Mb.)

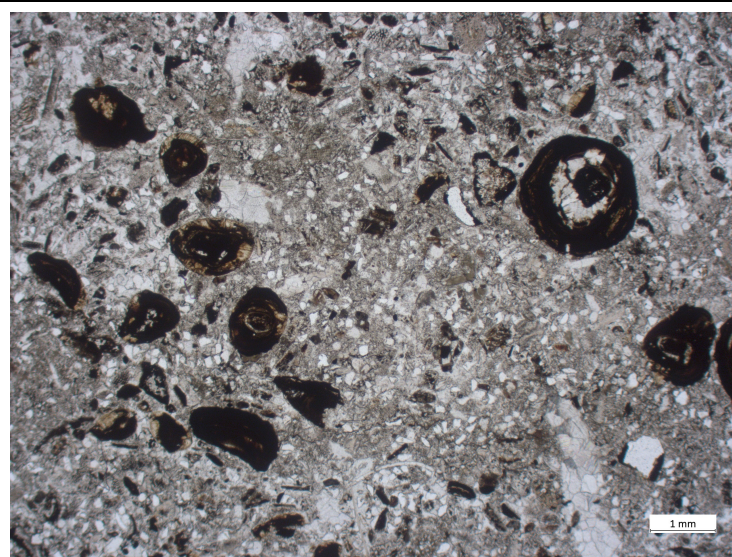
**Fig. B-11:**

Calcareous bed composed of
sandy biopelmicrosparite
with calcite "nodules", which
contain some brownish
limonitic pellets

thin section photo
TS stained for calcite = red,
ferroan calcite = blue

BOZ1-1-523.47

Passwang Fm.
(Waldenburg and lower part
of Brüggl Mb.)

**Fig. B-12:**

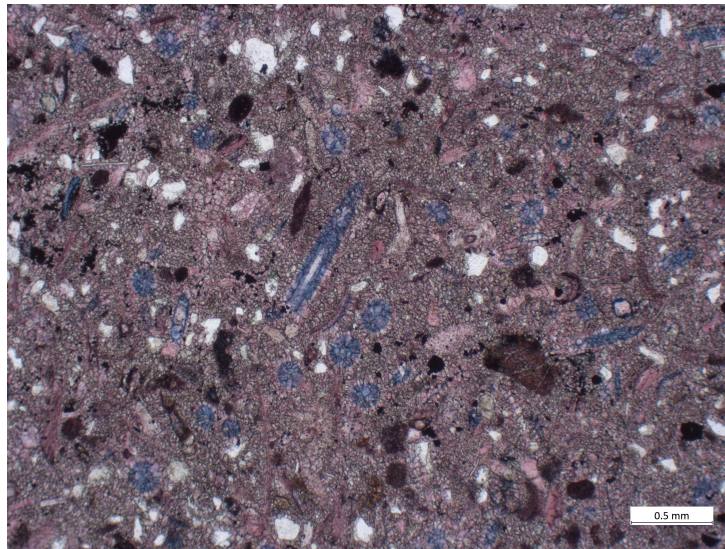
Sandy biotrititic limestone
with iron-oooids and small
limonitic components

thin section photo

BOZ1-1-510.08

Passwang Fm.
(«Humphriesi-Schichten»)

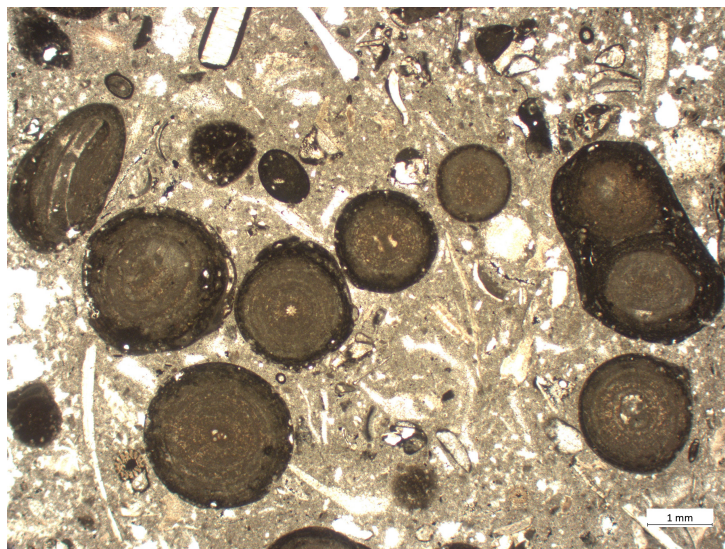
Selected photos of microfacies from Passwang Fm.

**Fig. B-13:**

Biotrititic limestone with sponge spicules (blue coloured circles and long cross sections), bivalves, echinoderms, pellets and quartz grains

thin section photo
TS stained for calcite = red,
ferroan calcite = blue

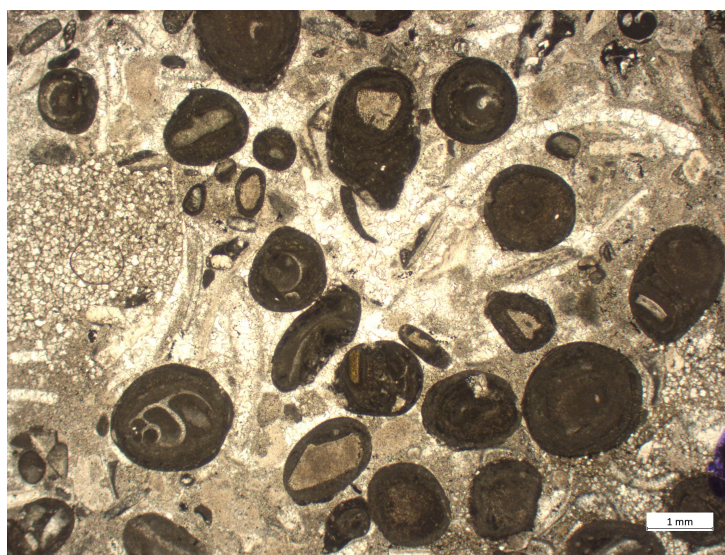
BOZ1-1-488.54
Passwang Fm.
(Rothenfluh Mb.)

**Fig. B-14:**

"Oncoid-ooids" consisting of an ooid core and a black biogene envelope, the oncoidal rim of these composed components; they are part of an oncoidal biomicrite

thin section photo

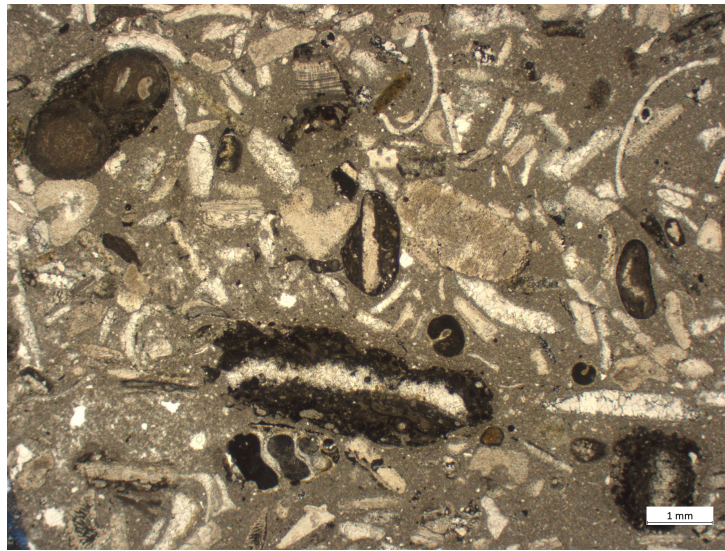
BOZ1-1-476.00
Hauptrogenstein

**Fig. B-15:**

Oncoids are the dominant components in this biotrititic oncomicrosparite

thin section photo

BOZ1-1-465.92
Hauptrogenstein

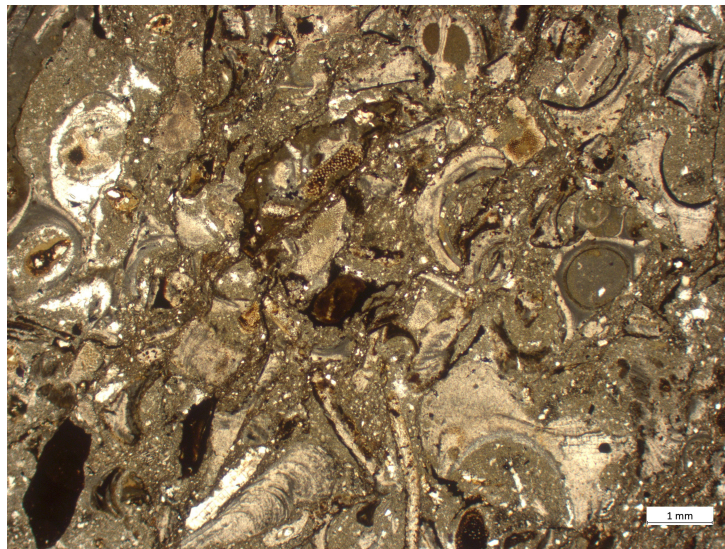
**Fig. B-16:**

Biotrititic limestone, composed of bivalves, echinoderms, a gastropod and some black oncoids, sedimented with micritic matrix

thin section photo

BOZ1-1-444.88

Hauptrogenstein

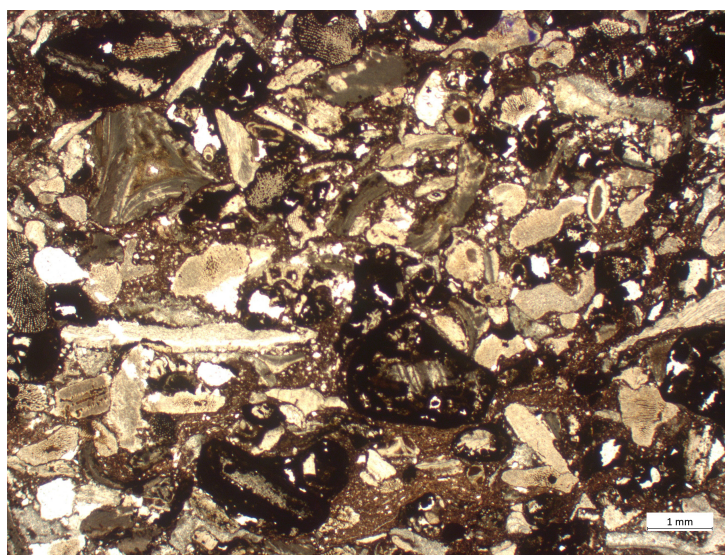
**Fig. B-17:**

Limonitic, biotrititic limestone with limonitised bivalves, echinoderms, serpulids and limonitic flasers

thin section photo

BOZ1-1-436.51

Klingnau Fm.

**Fig. B-18:**

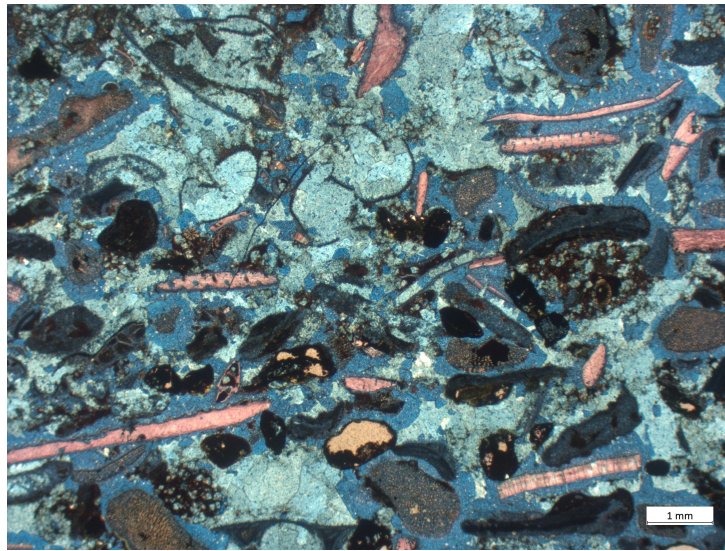
Limonitic, bioclastic limestone: strongly limonitised micritic matrix and limonitic biogene components

thin section photo

BOZ1-1-414.92

Hauptrogenstein
(«Spatkalk»)

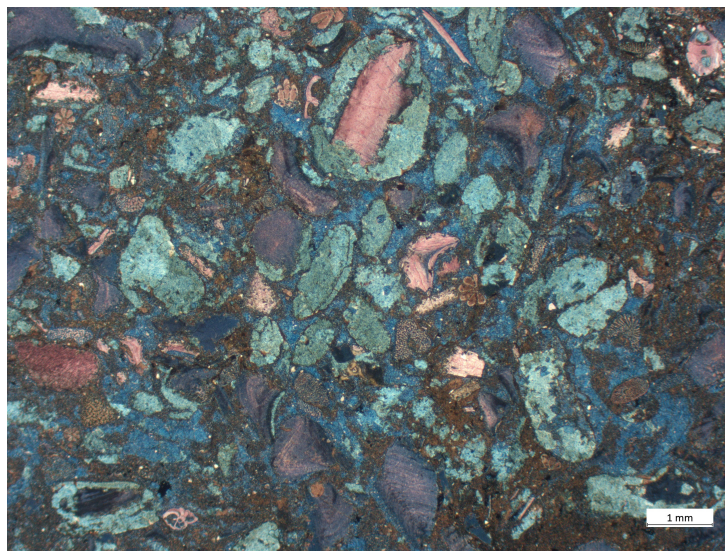
Selected photos of microfacies from Hauptrogenstein and Klingnau Fm.

**Fig. B-19:**

Limonitic, bioclastic limestone: limonitic bioclasts and brachiopod shells (red coloured), cemented by ferroan calcite (blue) and iron-dolomite (light blue)

thin section photo
TS stained for calcite = red,
ferroan calcite = blue

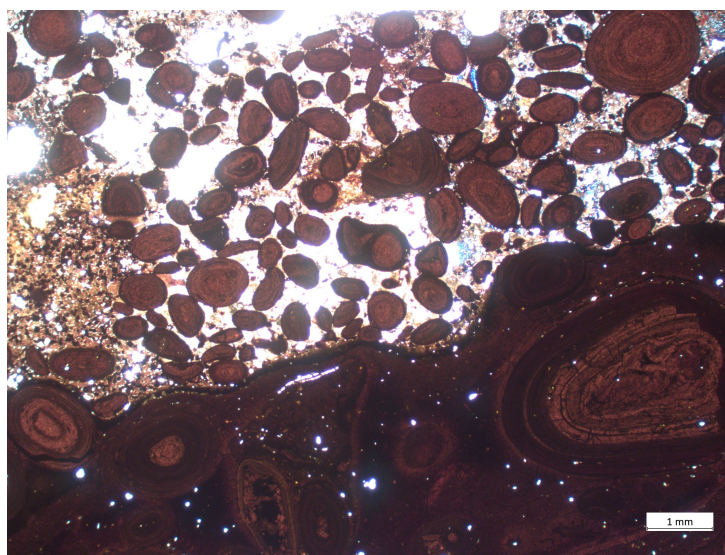
BOZ1-1-413.38
Hauptrogenstein
(«Spatkalk»)

**Fig. B-20:**

Bioclastic limestone: biogene components, closely packed, with some micrite matrix; iron-dolomite (light blue) replaces some round components, which probably were originally iron-ooids

thin section photo
TS stained for calcite = red,
ferroan calcite = blue

BOZ1-1-407.49
Ifenthal Fm.

**Fig. B-21:**

Hardground: composed of an iron-stromatolite with embedded iron-ooids (bottom) and an iron-oolitic, biotrititic limestone above

thin section photo

BOZ1-1-406.83
Ifenthal Fm.

Selected photos of microfacies from Hauptrogenstein and Ifenthal Fm.

Appendix C: Plates of ammonites

Plate I:	BOZ1-1 (653.75 – 651.27 m)	C-3
Plate II:	BOZ1-1 (644.18 – 530.54 m)	C-5
Plate III:	BOZ1-1 (525.20 – 505.57 m)	C-7
Plate IV:	BOZ1-1 (445.22 – 393.36 m)	C-9

Plate I BOZ1-1 (653.75–651.27 m)

- Fig. 1: *Pseudogrammoceras* ex gr. *fallaciosum* (Bayle, 1878), depth: 653.75 m, Staffelegg Fm. (Gross Wolf Mb.), Thouarsense Zone, probably Fallaciosum Subzone.
- Fig. 2: *Pleydellia* sp., depth: 652.26 m, Staffelegg Fm. (Gross Wolf Mb.), Aalensis Zone, probably Aalensis Subzone.
- Fig. 3: *Cotteswoldia* ex gr. *lotharingica* (Branco, 1879) or *C.* ex gr. *pseudolotharingica* (Maubeuge, 1950), depth: 651.60 m, Staffelegg Fm. (Gross Wolf Mb.), Aalensis Zone, Torulosum Subzone.
- Fig. 4: *Leioceras* ex gr. *subglabrum* (Buckman, 1902), depth: 651.27 m, Opalinus Clay, Opalinum Zone, Opalinum Subzone.

All figures are illustrated in individual scales; black bars indicate 1 cm.

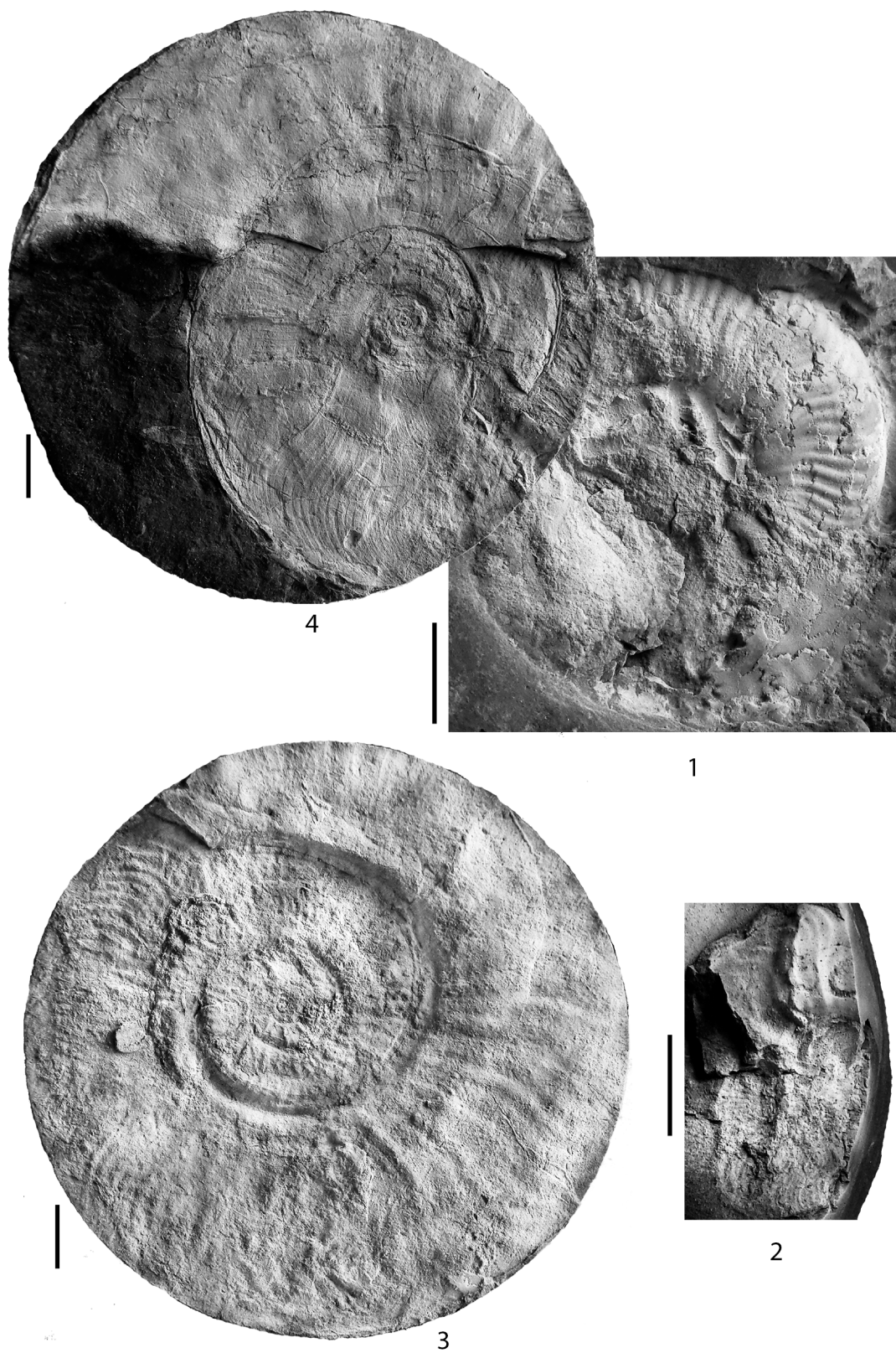
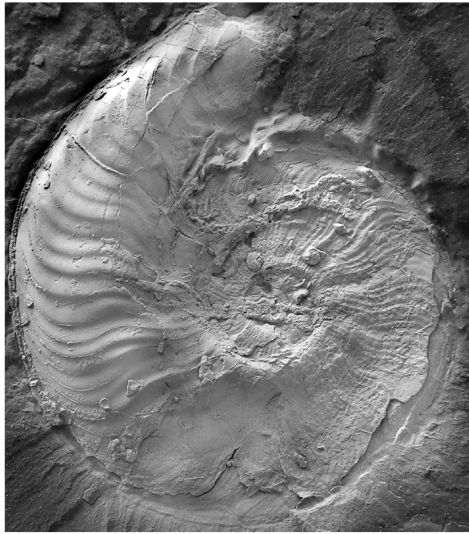


Plate I: BOZ1-1 (653.75 – 651.27 m)

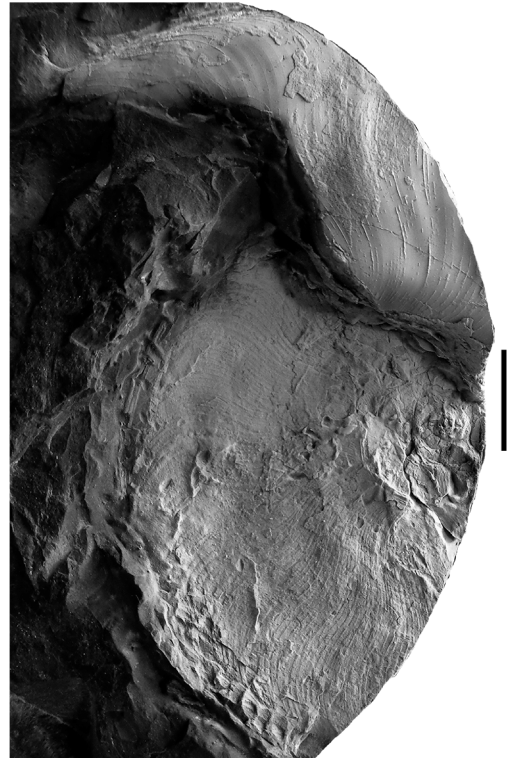
Plate II BOZ1-1 (644.18 – 530.54 m)

- Fig. 1: *Leioceras opalinum* (Reinecke, 1818), depth: 644.18 m, Opalinus Clay, Opalinum Zone, Opalinum Subzone.
- Fig. 2: *Leioceras* ex gr. *subglabrum* (Buckman, 1902), depth: 639.03 m, Opalinus Clay, Opalinum Zone, Opalinum Subzone.
- Fig. 3: *Pleurolytoceras torulosum* (Zieten, 1833), depth: 570.35 m, Opalinus Clay, Aalensis Zone, Torulosum Subzone to Opalinum Zone, early Opalinum Subzone.
- Figs. 4a, b: *Leioceras* ex gr. *bifidatum*? (Buckman, 1899), depth: 530.54 m, Opalinus Clay, Opalinum Zone, Bifidatum Subzone (former «Comptum» Subzone). Fig. 4a: lateral view, 4b: cross section.

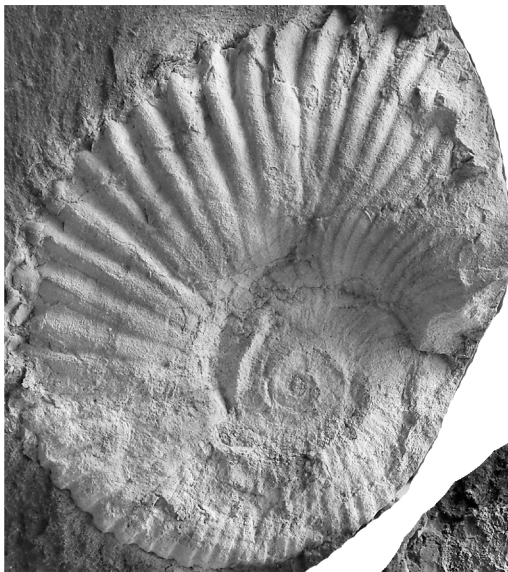
All figures are illustrated in individual scales; black bars indicate 1 cm.



1



2



3



4a

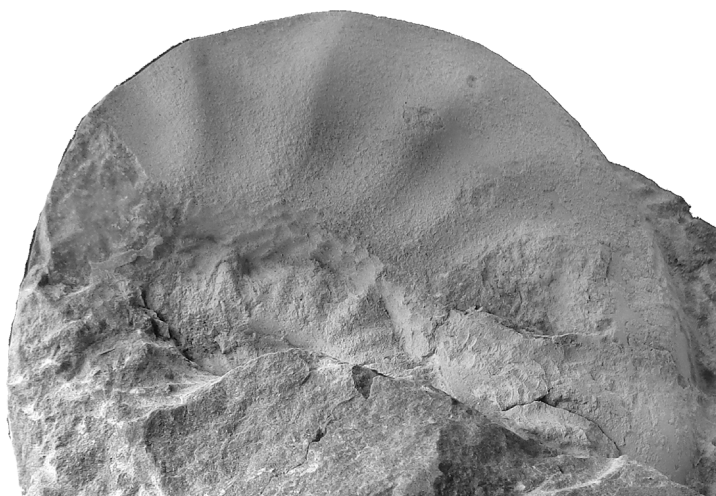


4b

Plate III BOZ1-1 (525.20 – 505.57 m)

- Fig. 1: *Euhoploceras* sp., depth: 525.20 m, Passwang Fm. (Waldenburg and lower part of Bruggli Mb.), early Bajocian, probably Laeviuscula Zone. Lateral view.
- Figs. 2a, b: *Sonminia* sp.? or *Witchellia* sp.?, depth: 514.77 m, Passwang Fm. (Waldenburg and lower part of Bruggli Mb.), Early Bajocian, Fig. 2a: lateral view, 2b: cross section.
- Fig. 3: *Stephanoceras* sp., depth: 506.04 m, Passwang Fm. («Humphriesi-Schichten»), Humphriesianum Zone, probably Humphriesianum Subzone. Lateral view.
- Figs. 4a, b: *Stephanoceras* sp., depth: 505.57 m, Passwang Fm. («Humphriesi-Schichten»), Humphriesianum Zone, Humphriesianum Subzone. Fig. 4a: lateral view, 4b: cross section.

All figures are illustrated in individual scales; black bars indicate 1 cm.



1



2b



2a



3



4a



4b

Plate III: BOZ1-1 (525.20 – 505.57 m)

Plate IV BOZ1-1 (445.22 – 393.36 m)

- Fig. 1: *Parkinsonia* sp., Macroconch, depth: 445.22 m, Hauptrogenstein, Parkinsoni Zone. Lateral view.
- Figs. 2a, b: *Oecotraustes* sp., Macroconch, depth: 407.17 m, Ifenthal Fm., probably Bathonian. Fig. 2a: lateral view, 2b: cross section.
- Fig. 3: *Dichotomoceras* sp., depth: 393.36 m, Wildegg Fm. (Effingen Mb.), Middle to Late Oxfordian, probably Transversarium Zone, Rotoides Subzone or Bifurcatus Zone, Stenocycloides Subzone?. Lateral view.

All figures are illustrated in individual scales; black bars indicate 1 cm.

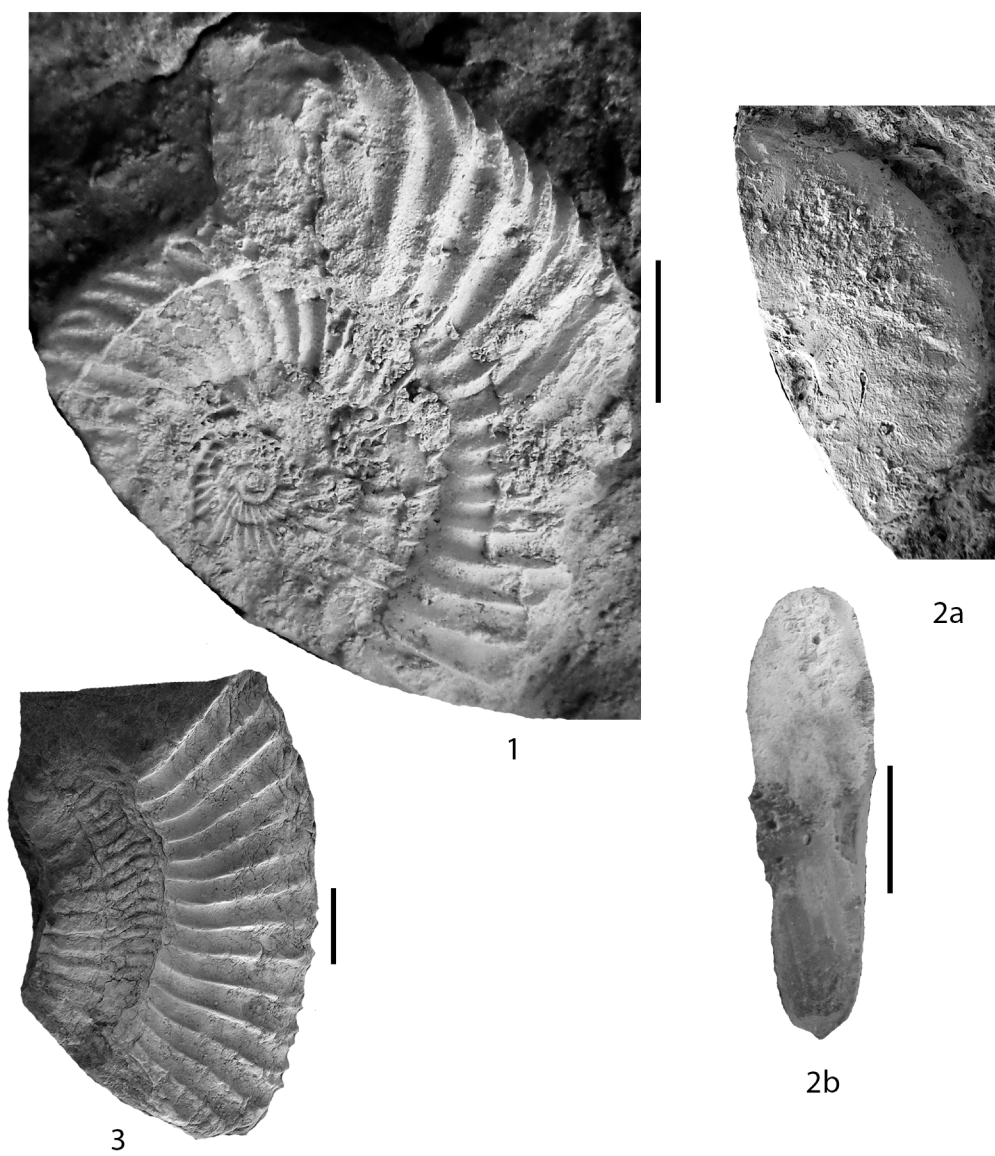


Plate IV: BOZ1-1 (445.22 – 393.36 m)

Appendix D: Palynostratigraphy

Appendix D1: Range Chart: Quantitative stratigraphic distribution of Middle Jurassic palynomorphs in the Bözberg-1-1 borehole

Appendix D2: Depth/Age plot: Bözberg-1-1 borehole

Note: The appendices are only included in the digital version of this report (PDF) and can be found under the paper clip symbol.

Please note the change in vertical scale between 406 m and 408 m in the Appendix D1.

Appendix E: Chemostratigraphy

Appendix E1:	List of all geochemical samples and results mainly drilled from specific calcareous beds and concretions in the Opalinus Clay and its confining units.	E-2
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Appendix E1: List of all geochemical samples and results mainly drilled from specific calcareous beds in the Opalinus Clay and its confining units

Data are discussed in Section 3.4 and partly illustrated in Fig. 3-4 (part of the data points lie outside the presented scale for the $\delta^{13}\text{C}_{\text{carb}}$): HB: drilled from a "hiatus bed", HC: drilled from a "hiatus concretion", CC: drilled from a calcareous concretion, SC: drilled from a sideritic concretion, SN: drilled from a septarian nodule, MF: drilled from macrofossil, TS: drilled directly from thin section sample (see microfacies description in Section 3.1). For definition of "hiatus bed" & "hiatus concretion" see Section 2.1. The driftwood sample at 479.91 m is an organic measurement ($\delta^{13}\text{C}_{\text{org}}$).

Depth [m]	Description of sample		TS	$\delta^{13}\text{C}_{\text{carb}}$ [‰ VPDB]	$\delta^{18}\text{O}_{\text{carb}}$ [‰ VPDB]	Carbonate [wt.-%]
479.91	Driftwood (organic sample)	MF		-26.00		
506.00	Belemnite	MF		1.10	0.61	100.0
506.00	Calcite filling of belemnite			0.87	-4.67	68.1
529.99	Belemnite	MF		0.49	-0.32	100.0
548.99	Intraclast	HC		-16.55	-2.13	69.1
549.02	Intraclast	HC		-10.14	-3.12	78.8
552.55	Calcareous bed or septarian nodule	?		-18.28	-1.53	93.7
555.89	Sideritic concretion	SC		-3.96	-1.51	61.8
558.75	Sideritic concretion	SC		-7.42	-2.73	55.2
559.02	Sideritic concretion	HB	×	-7.27	-3.18	69.3
559.07	Sideritic concretion	HB	×	-3.42	-2.21	84.6
560.15	Calcite vein from septarian nodule			-1.77	-8.33	99.4
560.16	Septarian nodule	SN		-22.36	-1.43	90.7
639.24	Calcareous concretion?	CC		-4.02	-8.74	43.5
639.42	Septarian nodule	SN		-23.53	-3.41	82.3
639.57	Septarian nodule	SN		-23.49	-7.20	84.6
639.61	Septarian nodule	SN		-24.87	-5.59	79.1
639.67	Septarian nodule	SN		-22.57	-7.19	79.2
655.35	«Monotisbank» (Rietheim Mb.)			-0.84	-5.89	78.4
657.23	«Oberer Stein» (Rietheim Mb.)			-1.54	-4.52	93.8
657.91	«Homog. Kalkbank» (Rietheim Mb.)		×	0.43	-2.67	92.4
658.08	«Homog. Kalkbank» (Rietheim Mb.)			-0.29	-5.58	75.0
658.49	«Unterer Stein» (Rietheim Mb.)			-1.30	-3.13	98.5