The Ottenthal Formation revised – sedimentology, micropaleontology and stratigraphic correlation of the Oligocene Ottenthal sections (Waschberg Unit, Lower Austria)

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Abstract: In the Waschberg Unit, at Ottenthal, Lower Austria, Oligocene sections have been investigated. The type section of the former "Ottenthal Schichten" is presented with results of calcareous and siliceous nannofossils, planktic foraminifera, and mineralogical investigations. In the parallel section "Waldweg" the stratigraphic subdivision of the sequences is supported. According to lithology and microfossil content different lithostratigraphic units have been separated. The (Upper Eocene? to) Lower Oligocene Ottenthal Formation comprises three members. The Ottenthal Member, consisting of *Globigerina*-marls, banded marls with interbedded cyclic layers of dark bituminous clay, and brown calcareous shales is dated as nannoplankton zones NP 21 to NP 22, and foraminifera zones (Upper Eocene?) P 18 to P 19. The Galgenberg Member is a sequence of diatomites, menilites/cherts and diatomaceous shales, corresponding to upper NP 22 to lower NP 23. A distinct lithologic unit forms the nannofossil-chalk of the Dynow Marlstone with low species diversity of predominantly *Dictyococcites ornatus*, with the co-occurrence of *Transversopontis fibula*, of NP 23 age. Of entirely different lithology is the Thomasl Formation, consisting of dark variegated shales with some calcareous and marly layers and sand to silt intercalations. In the basal part a horizon of sand and pebble layers and lenses documents submarine slumps as result of the so-called "Sitborice Event", with similar sedimentological evidence in South Moravia. The heavy mineral research showed a distinct change from the Ottenthal Formation with a tourmaline-zircon-garnet dominance to predominantly garnet in the Thomasl Formation. For reasons of lithology and facies development these sediments have been separated as the Thomasl Formation from the "Ottenthaler Schichten". The Thomasl Formation is dated in Ottenthal as upper NP 23 to NP 24, or P 20 to 21a respectively; in deep drillings it continues into NP 25. The Ottenthal Formation comprises the Upper Eocene? to Lower Kiscellian (Upper Priabonian? to Lower Rupelian), the Thomasl Formation the Upper Kiscellian to Lower Egerian (Upper Rupelian to Lower Chattian) in the Central Paratethys regional stage system.

The sequences in Ottenthal show a continuous environmental change according to the development of the Paratethys. This development is strongly influenced by sea-level changes

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and orbital cyclicity. Open marine deep water conditions dominate in the lower part of the Ottenthal Member. Gradually, the restriction of open oceanic circulations and climatic fluctuations between dry and wet periods in the Early Oligocene caused dysaerobic bottom conditions and a lowering of salinity in the surface waters. On top of the upper Ottenthal Member the sedimentation of banded and laminated marls changed to laminated marine diatomites of the Galgenberg Member, finally dominated by low salinity species. Returning to somewhat higher salinity values, blooms of few calcareous nannoplankton species bring about the thick layers of nannofossil-chalk of the Dynow Marlstone with endemic small bivalves of the *Cardium lipoldi*-fauna. In the Dynow Marlstone a remarkable content of diatoms occurs. A gradual but fluctuating return to normal conditions is observed in the Thomasl Formation, deposited in deep water of outer shelf to upper slope.

A stratigraphic correlation with the Upper Eocene to Middle Oligocene sediments in the Pouzdrany and Zdanice Units in South Moravia is presented. The lower part of the Ottenthal Member is similar to the lower and middle part of Pouzdrany Formation and to the Sheshory Member of the Nemcice Formation in the Zdanice Unit. The laminated and banded marls of the upper Ottenthal Member are partly similar to the upper Pouzdrany Marl, which are silicified in the upper part like the "Subchert member" in the Zdanice Unit. In all units a distinct pteropod horizon occurs in the banded marls. A correlative horizon of diatomaceous shales marks the begin of diatomite sedimentation with marine diatoms, followed by brackish and fresh water diatoms in the upper part. This succession is similar to the Waschberg Unit in the lower part of the Uhercice Formation in the Pouzdrany Unit. In the Zdanice Unit the diatomites of the "Chert member" are diagenetically altered, preserved as menilite/cherts. The superimposed Dynow Marlstone is silicified in the Zdanice Unit. The Thomasl Formation correlates in facies and fossils with the Sitborice Member in the Zdanice Unit. Distinct differencies exist between the sedimentation of the Waschberg Unit and the Molasse Basin. The only well correlated horizon is present in the nannofossil-chalk of Dynow Marlstone, the so-called "Heller Mergelkalk" in the Molasse Basin; but diatoms are missing there.

Zusammenfassung: In der Waschbergzone wurden in der Ortschaft Ottenthal, Niederösterreich, mehrere Abfolgen oligozäner Sedimente untersucht. Resultate der Untersuchung von kalkigem Nannoplankton, planktonischen Foraminiferen, kieseligen Mikrofossilien und der Mineralogie des Typusprofils der ursprünglichen „Ottenthaler Schichten" werden präsentiert. In einer parallelen Abfolge (Profil „Ottenthal-Waldweg") konnte die Unterteilung der Schichtfolge besser dokumentiert werden. Nach mikropaläontologischen Ergebnissen und lithologischer Entwicklung wurden mehrere Formationen und Subformationen unterschieden. Die (obereozäne? bis) unteroligozäne Ottenthal-Formation wurde in drei Subformationen gegliedert. Die Ottenthal-Subformation besteht im unteren Teil aus massigen Globigerinenmergeln, im oberen Teil aus gebankten und laminierten Mergeln, Tonmergeln und Tonen, die teilweise zyklische Einlagerungen von bituminösen Tonen aufweisen. Alterseinstufung: Nannoplanktonzonen NP 21–NP 22, planktonische Foraminiferenzonen (Obereozän?) P 18–P 19. Die Galgenberg-Subformation beginnt mit kalkfreien, diatomitischen Tonen, gefolgt von blätterigen, marinen Diatomiten und Menilit-Bänken (Hornstein), die nach oben deutliche Verbrackung erkennen lassen. Nach Einstufung der Basis und Lagerung umfasst die Galgenberg-Subformation die Nannoplanktonzonen der oberen NP 22 bis unteren NP 23. Eine lithologisch deutlich ausgeprägte Einheit bildet der Dynow Marlstone. Es handelt sich um einen aus kalkigem Nannoplankton bestehenden, weißlichen Mergel (nannofossil-chalk), vorwiegend *Dictyococcites ornatus*, gemeinsam mit *Transversopontis fibula* mit einem höheren Anteil an Diatomeen. Er wird in die Nannoplanktonzone NP 23 eingestuft. Die Ottenthal-Formation umfaßt das (obere Eozän? bis) untere Kiscellium (unteres Rupelium).

Auf Grund der Lithologie wird von den „Ottenthaler Schichten" ein Schichtpaket abgetrennt und der Thomasl-Formation zugerechnet. Es handelt sich um dunkle, bunte Tone, Tonsteine und Tonmergel mit wenigen dünnen Lagen von kalkigem Nannoplankton und dünnen Silt- und Sandlagen. An der Basis tritt ein Horizont mit submarinen Eingleitungen, Sanden und Geröllen auf. Nach vergleichbaren Abfolgen in Südmähren wurde diese Einschüttung durch den „Sitborice

Event", durch tektonische Vorgänge und eine gleichzeitige Meeresspiegelschwankung hervorgerufen. Schwermineraluntersuchungen zeigen einen deutlichen Wechsel von einer Turmalin-Zirkon-Granat Vormacht in der Ottenthal-Formation zu einer Dominanz von Granat in der Thomasl-Formation. Die Thomals-Formation umfaßt im Untersuchungsgebiet die Nannoplanktonzonen der oberen NP 23 bis NP 24, beziehungsweise die Planktonzonen 19/20 bis 21a, oberes Kiscellium (oberes Rupelium). In den Tiefbohrungen der Waschbergzone reicht die Thomasl-Formation bis in die NP 25 (unteres Egerium, unteres Chattium).

Die Entwicklung der Abfolgen in Ottenthal entspricht den Veränderungen in der Paratethys, die durch tektonische Bewegungen, Meeresspiegelschwankungen und Milankovich-Zyklen stark beeinflußt ist. Beginnend mit offen-marinen Tiefwasserablagerungen in der unteren Ottenthal-Subformation folgt ab der oberen Ottenthal-Subformation eine kontinuierliche Einschränkung der Verbindungen zu den Ozeanen, verbunden mit sauerstoffarmen Bodenbedingungen und einer Reduktion der Salinität im Oberflächenwasser. Klimatisch wirken sich Abkühlung und Wechsel von trockenen und feuchten Perioden aus. Dies führte zu gebänderten und laminierten Sedimenten mit einer starken Einschränkung der Artenvielfalt. Die Veränderung bewirkte das Massenauftreten weniger Arten von kalkigem Nannoplankton und kleinwüchsigen Planktonforaminiferen, Pteropoden-Horizonten, Ablagerung von Diatomiten (Galgenberg-Subformation) und des Nannoplankton-Mergels des Dynow Marlstone. Im Dynow Marlstone tritt eine endemische, für die gesamte Paratethys charakteristische, kleinwüchisge Bivalvenfauna, die *Cardium lipoldi*-Fauna auf. In der Thomasl-Formation kehren allmählich wieder normale, vollmarine Bedingungen zurück.

Eine stratigraphische Korrelation mit den Abfolgen in Südmähren wurde durchgeführt. Der unteren Ottenthal-Subformation entspricht die untere bis mittlere Pouzdrany-Formation in der Pouzdrany Einheit und die Sheshory-Subformation in der Zdanice Einheit. Die vergleichbaren Einheiten der oberen Ottenthal-Subformation sind ähnlich der oberen Pouzdrany-Formation. Dort sind jedoch die obersten Bereiche ebenso wie die „Subchert Subformation" in der Zdanice Einheit stark verkieselt. In allen drei Einheiten tritt ein Pteropoden Horizont auf, der einen charakteristischen Leithorizont in der Paratethys bildet. Die marinen und brackischen Diatomite des Galgenberg-Subformation entsprechen der unteren Uhercice-Formation in der Pouzdrany Einheit. In der „Chert Subformation" der Zdanice Einheit sind die Diatomite diagenetisch in Menilit (Hornstein) umgewandelt. Der Dynow Marlstone ist in der Zdanice Einheit ebenfalls stark verkieselt. Die Thomasl-Formation läßt sich direkt mit der Sitborice-Formation in der Zdanice Einheit vergleichen. Die oligozäne Schichtfolge der Waschbergzone läßt sich mit derjenigen in der Molassezone kaum vergleichen, nur der Dynow Marlstone („Heller Mergelkalk") stellt einen ausgezeichneten Korrelationshorizont dar, enthält aber in der Molassezone keine Diatomeen.

Keywords: Waschberg Unit, Ottenthal Formation, Thomasl Formation, Paratethys, Oligocene, Micropaleontology

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1. INTRODUCTION

The sediments in the area of the village Ottenthal, in the Waschberg Unit for the first time have been described by JÜTTNER (1938, 1940) and compared with the "Niemtschitzer Schichten" with intercalated "Pausramer Schiefer und Mergel" in southern Moravia. Later they have been dated by calcareous nannoplankton as Late Eocene to earliest Oligocene (GRILL, 1968; STRADNER, 1962). A section at the east side of the village has been selected by SEIFERT (1982) as the type section for his "Ottenthaler Schichten". This section has been studied and correlated with the Oligocene development in the northern Hungarian Paleogene basin (SEIFERT et al., 1991). Some microfossil studies exist from the type section, e.g., spot samples by PERCH-NIELSEN et al. (1985), selected calcareous nannoplankton by STRADNER & SEIFERT (1980), and archaeomonadaceans by BRAUNSTEIN (1985).

Parallel to the type section, a tectonically less disturbed section of "Ottenthal Beds" was studied (RÖGL et al., 1997). During the investigation of this section, and in comparison with South Moravian sections it was necessary to revise the original content of the Ottenthal Beds. In the present research the "Ottenthal Beds" are re-defined and revised as Ottenthal Formation, and subdivided in different members. The investigation of calcareous nannoplankton and foraminifera made possible a detailed biostratigraphic and paleoecological interpretation of the sequence. An investigation of dinoflagellates was carried out and demonstrated similarities with the Eastern Paratethys (ZAPOROZHETS, personal communication). Research of stable isotopes (δ ^{13}C, ^{18}O) has started, and preliminary results showed constantly lighter values as global oceanic records (SENGÜLER et al., 1999). A correlation to the Pouzdrany and Zdanice Units in southern Moravia is presented, and the relation to the Molasse Basin is discussed.

2. GEOLOGICAL SETTING

The Waschberg Unit forms a distinct tectonical nappe along the outer fringe of the Alpine-Carpathian system. The Waschberg Unit is thrust to NW over the beds of the

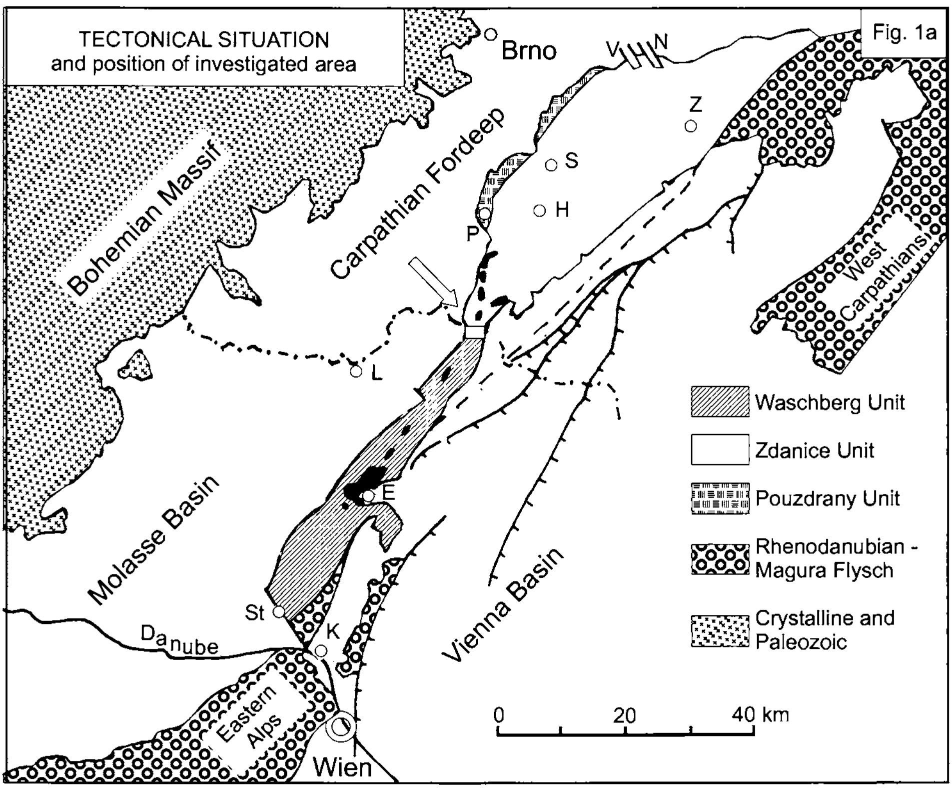
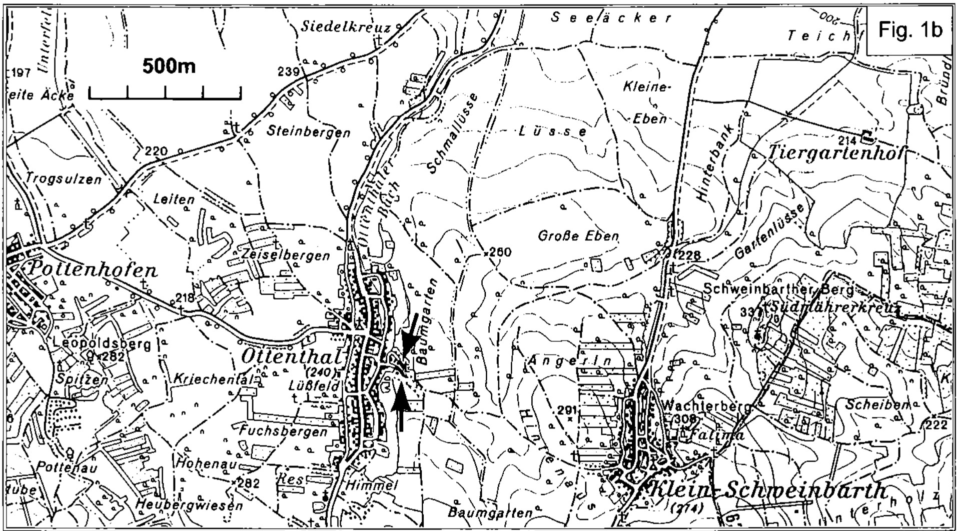


Fig. 1a: Waschberg, Zdanice and Pouzdrany Units at the front of the Alpine-Carpathian system (acc. HAMILTON et al., 1990), with position of the study area. Explanations: black spots = Mesozoic klippen; abbreviations: E = Ernstbrunn, H = Hustopece, K = Korneuburg, L = Laa, N = Nesvacilka Graben, P = Pouzdrany, S = Sitborice, St = Stockerau, V = Vranovice Graben, Z = Zdanice.



16° 35' E

Fig. 1b: Topographic position of Ottenthal (Lower Austria) and sections in the Ottenthal village (arrows). ÖK 1:50 000, sheets no. 10 Wildendürnbach and no. 11 Drasenhofen (Bundesamt f. Eich- u. Vermessungswesen, Wien).

Molasse Basin, and is overthrusted itself by the Rhenodanubian Flysch. It extends in a northeastern direction from the Danube at Stockerau to the Czech border at Mikulov (Nikolsburg). In Moravia the continuation is considered in the Zdanice Unit, a part of the outer West Carpathian Flysch belt (Elias et al., 1990). In Austria, the Waschberg Unit was included in the allochthonous Molasse (imbricated or subalpine Molasse) which continues to the west in the tectonic wedges of Kilb and Rogatsboden, but is distinctly different by the imbricated Mesozoic klippen. The Waschberg Unit consists of a strongly tectonized and imbricated sequence of Oligocene to Lower Miocene sediments with klippen of different shallow and deep water rocks of Late Jurassic to Eocene age, sheared off from the basement (Brix et al., 1977).

The investigated sections of Ottenthal (Fig. 1b) belong to a strongly tectonized wedge of Oligocene sediments, embedded in the Lower Miocene "Schieferige Tonmergel". They extend along the east and west sides of Ottenthal, near the northern Austrian border. More to the south the continuation of these sediments is recorded only locally, e.g., at the Galgenberg near Falkenstein, Altruppersdorf, Ernstbrunn, Niederhollabrunn, and in some deep drill sites as Ameis 1 (Grill, 1962; Seifert, 1982; Herlicska, 1989).

3. DESCRIPTION OF SECTIONS

3.1. Ottenthal, type section

Ottenthal, east side of the village, Untere Leithen, along the cart road to Klein-Schweinbarth. The section was excavated for a distance of about 80 m with more than 40 m of real thickness of beds. The opened section started 70 m E of the fire-point at the begin of the cart road. Today the section is overbuilt in the lower part, and the upper part is partly covered and overgrown. The sequence is tectonically disturbed, thrusted, and partly overturned. The main thrust dividing the normal and overturned parts occurs at 32 m. A large set of samples for micropaleontology and sedimentology was collected and investigated. Furthermore samples were studied for heavy mineral, insoluble residue and XRD analysis. A first lithological description was given by SEIFERT et al. (1991). A revised section of measured real thickness, including stratigraphical results is presented in Fig. 2. The outcrop is presented in Fig. 3a.

Description of the section:

Ottenthal Member: 0.00–0.40 m, dark brown to brown soft marl; 0.40–1.00 m, brown calcareous shale; 1.00–1.25 m, brown marl; 1.25–1.50 m, dark grey-brown diatomaceous claystone; 1.50–3.10 m, brown thin-bedded and laminated calcareous shale with abundant fish remnants.

Galgenberg Member: 3.10–4.15 m, grey-brown to light grey laminated diatomites.

Thomasl Formation: 4.15–5.10 m, grey-brown banded claystone and calcareous shale; 5.10–5.50 m, brown calcareous shale.

Ottenthal Member: 5.50–7.30 m, dark brown banded marl with silty intercalations; 7.30–7.80 m, brown thin-bedded and laminated calcareous shale with abundant fish remnants.

Galgenberg Member: 7.80–7.85 m, black-brown clay; 7.85–7.90 m, brown laminated calcareous shale; 7.90–8.55 m, grey-brown diatomaceous claystone; 8.55–10.05 m, grey-brown and brown laminated diatomite.

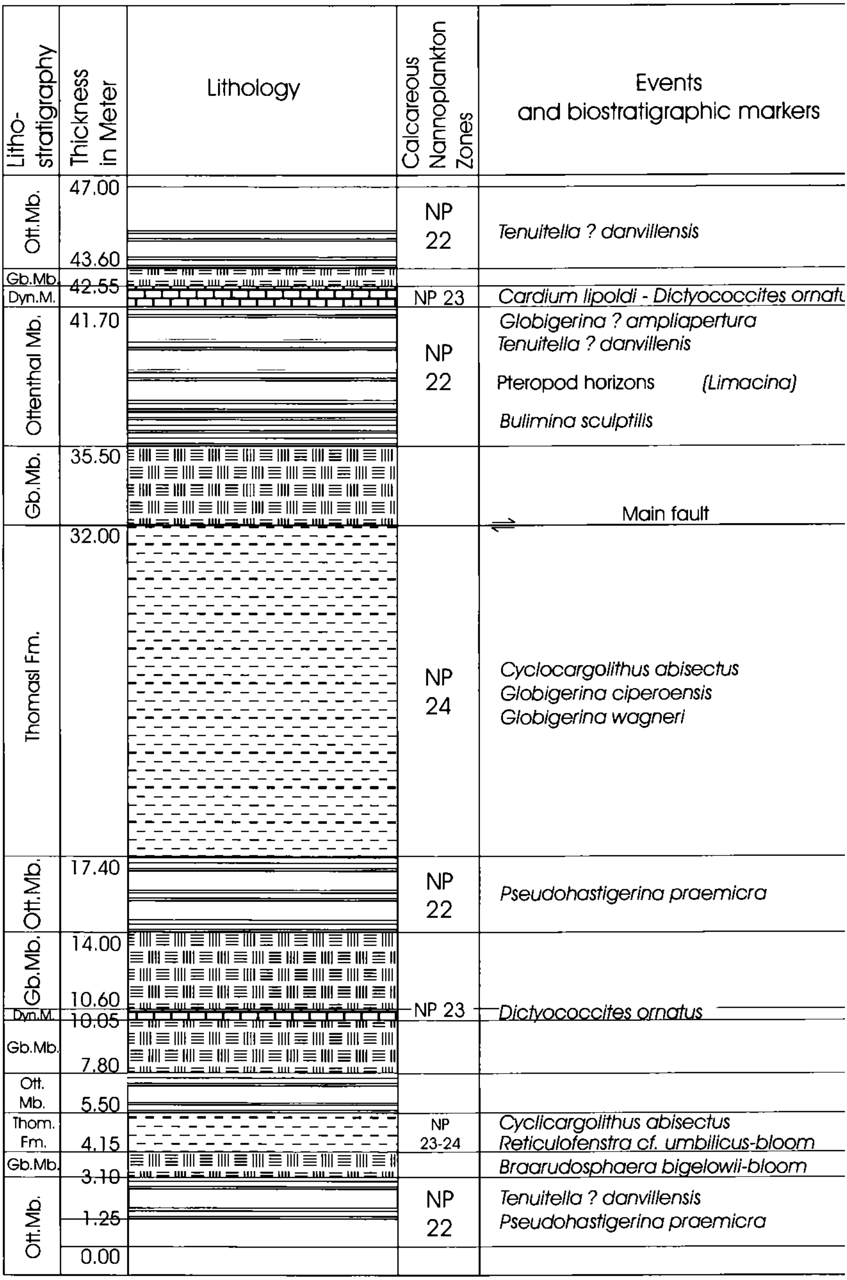
Dynow Marlstone: 10.05–10.60 m, whitish to light grey, layered silty endurated marl, nannofossil-chalk.

Galgenberg Member: 10.60–11.45 m, dark brown laminated claystone, with thin layers of light grey diatomite; 11.45–11.60 m, whitish laminated diatomite; 11.60–14.00 m, brown claystone with diatomaceous laminae.

Ottenthal Member: 14.00–14.10 m, dark brown soft marl; 14.10–14.15 m, dark brown to black bituminous clay with rusty iron-oxides; 14.15–14.50 m, dark brown marls; 14.50–16.90 m, dark brown to light grey layered marls and calcareous shales; 16.90–17.15 m, yellowish-brown silty marl with pteropods; 17.15–17.40 m, grey-brown calcareous shales.

Thomasl Formation: 17.40–32.00 m, dark grey-brown to light grey calcareous and non-calcareous shales, with rusty and yellowish coatings of iron-oxides and jarosite, with few layers of diatomite, tectonically strongly disturbed.

32.00 m main fault.



2: Ottenthal type section. Cart road at the east side of the village in direction of Klein-Schweinbarth. Measured real thickness, lithology, biostratigraphy, and bio-events. Abbreviations: Dyn.M. = Dynow Marlstone, Gb.Mb. = Galgenberg Member, Ott.Mb Ottenthal Member, Thom.Fm. = Thomasl Formation (explanation of lithology see Fig

Galgenberg Member: 32.00–32.60 m, brown menilite beds; 32.60–33.80 m, brown and whitish layered clay, diatomites and thin layers of fine sand; 33.80–34.40 m, grey-brown laminated diatomite; 34.40–35.10 m, brown menilite layers; 35.10–35.50 m, grey-brown claystone with thin layers of diatomite.

Ottenthal Member: 35.50–36.30 m, dark brown and brown marl with pteropods; 36.30–36.70 m, distinct yellowish-white marl bed with abundant pteropods; 36.70–40.40 m, dark and light brown banded marl and calcareous shales with pteropods; 40.40–41.20 m, grey-brown shale with diatomaceous layers; 41.20–41.70 m, greenish-brown marls with pteropods.

Dynow Marlstone: 41.70–42.55 m, whitish and light grey endurated marl, with *Cardium lipoldi* – fauna.

Galgenberg Member: 42.55–42.70 m, whitish and light grey laminated diatomite; 42.70–43.50 m, brown and light grey laminated diatomaceous clay; 43.50–43.60 m, brown menilite layer.

Ottenthal Member: 43.60–45.10 m, light and dark brown banded marl, with pteropods; 45.10–47.00 m, dark brown soft marl and calcareous shales. Additional samples have been investigated from light grey soft marls (10 and 12 m S of the Dynow Marlstone).

3.2. Ottenthal-Waldweg section

The section "Ottenthal-Waldweg" is positioned at the eastside of the village Ottenthal, in "Untere Leithen" parallel to the cart road to Klein-Schweinbarth and the Ottenthal type section. The section crops out along a sunken road in the scrub between the house no. 175 (KG Ottenthal, EZ 1156, Pz 281) and an iron wayside crucifix. It was excavated during the field season 1992 within the IGCP Project no. 326. The beginning of the section is marked by an iron rod at the first outcrop of light grey marlstone, and also every ten meters up to the end, at the transgression of fluvial gravels, with a length of 55 m. The description is given for the lower 0.5 m of the wall of the excavated trench as the upper part of the outcrop is disturbed by sliding of the slope. Measurement of real thickness seems problematic due to the strong tectonic disturbances.

The section was described shortly by Rögl et al. (1997), and was subdivided into twelve tectonical wedges. The section is strongly disturbed, thrusted and partly overturned. It consists of different lithologies which are attributed to the subformations of the Ottenthal Formation and to the Thomasl Formation (Fig. 3b).

Description of the section:

Tectonic wedge no. I, Dynow Marlstone: 0–410 cm, whitish bioturbated massive marl, nannofossil-chalk, with rare ostracods, beds of 5 to 20 cm, in the higher part (320–410 cm) with brownish silicified layers and with thin brownish laminae, angle of bedding plane 320/20°; tectonic thrust at 410 cm (138/85°).

Tectonic wedge no. II, Thomasl Formation: 410–1250 cm, variegated shales and marls: part IIa, 410–435 cm, tectonically strongly disturbed dark grey, greenish, spotty, silty non-calcareous shales with rusty and yellowish coatings of jarosite (iron sulfide); 435–445 cm, light grey clay with rusty silt; 445–490 cm, dark brown shale with jarosite; 490–515 cm, rusty silty and sandy layer with clasts of glauconitic sand, light grey silt, clay

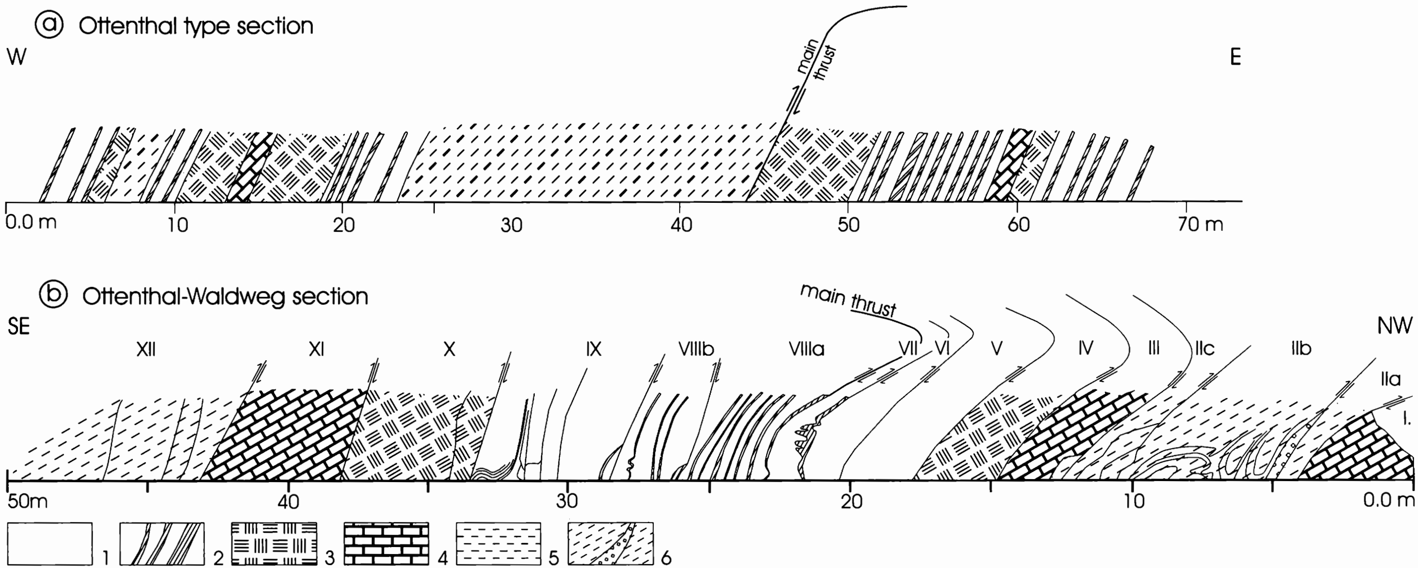


Fig. 3: Outcrops of the Ottenthal type section (Fig. 3a) and the "Ottenthal-Waldweg" section (Fig. 3b). Explanation of lithology: 1. marl; 2. alternation of banded marl and bituminous clay; 3. diatomite; 4. nannofossil-chalk; 5. shales, claystone, and calcareous shales; 6. slumps and pebble layers interbedded in the shales.

pebbles, pebbles of light grey marlstone, laminated silicites, and rarely of limestone; part IIb, 515–530 cm, grey-green shale and grey silt with rusty and yellowish coating; 530–535 cm, dark brown thinnly layered and laminated marl with white laminae of calcareous nannoplankton and sand laminae (bedding 315/45°); 535–560 cm, synclinal bedding of grey to brownish, spotty shale with rusty bedding planes and in the synclinal core with light grey marls; 560–580 cm, brownish spotty laminated marl; 580–870 cm, strongly tectonised and folded sequence of layered, dark grey and brownish-greenish, commonly non-calcareous shales and brown marls, with thin layers of glauconitic sand and lenses of granular gypsum, at 760–810 cm finely laminated; 870–1120 cm, strongly tectonised, layered light brown marls and dark brown, greenish to dark grey to black brown shales with layers of silt, sand, and gypsum; 1120–1195 cm, light grey laminated marls with thin silty and sandy layers; part IIc, 1195–1200 cm, greenish brown non-calcareous silt; 1200–1230 cm, dark greenish grey, non-calcareous shale; 1230–1235 cm, boudins of light grey, endurated, silicified, laminated marlstone; 1235–1250 cm, dark brown and light grey laminated non-calcareous shale.

Tectonic wedge no. III, Dynow Marlstone: 1250–1460 cm: a bed of whitish-yellowish marlstone (1250–1255 cm) forms the base of the wedge; greenish brown to greenish grey, non-calcareous shales at 1255–1290 cm are tectonically intercalated and belong to wedge no. II; 1290–1305 cm (in reality 1250–1305 cm), beds of partly silicified marlstone, angle of bedding plane 190/80°; 1305–1460 cm, tectonically disturbed whitish nannofossil-chalk, at the thrust limonitic coloration.

Tectonic wedge no. IV, Galgenberg Member: 1460–1780 m: light grey to whitish, laminated diatomite with strong disturbance at 1650–1700 cm, and with a dark brown bed of menilite (1760–1765 cm); angle of bedding plane 170/60°.

Tectonic wedge no. V, Galgenberg Member and uppermost Ottenthal Member: variegated shales, tectonically disturbed and folded: 1780–1785 cm, greenish-brown non-calcareous siltstone; 1785–2000 cm, change of light grey, greenish-grey and dark brown non-calcareous and calcareous, partly laminated shales; 2000–2035 cm, greenish-grey and brown laminated non-calcareous shales and slightly calcareous clays; 2035–2045 cm non-calcareous greenish-brown shale. There is no sharp boundary between calcareous and non-calcareous shales, but it occurs around 18.20 m.

Tectonic wedge no. VI, Ottenthal Member: 2045–2145 cm, tectonically disturbed dark brown, spotty and light brown calcareous shales and marls with laminated layers, with pteropods and fish remains; slickenside 174/70°; 2145–2170 cm, light brown laminated marls.

21.70 m main thrust plane

Tectonic wedge no. VII, Ottenthal Member: 2170–2175 cm, black-brown, non-calcareous bituminous clay, strongly folded and steeply inclined; 2175–2300 cm, light brown, layered marls with greenish silt at the bedding planes, in a horizontal fold.

Tectonic wedge no. VIII, Ottenthal Member (Pl. 1, Fig. 2): 2300–2890 cm, sequence of alternating light marls and dark bituminous clays; generally the marls are moved at the contact to the clay with a changing angle of the bedding plane from 32° for the marls to 40° for the clay; the marls show a gradual change in colour from yellowish to brown in direction towards the bituminous clay:

part VIIIa, 2300–2315 cm, black-brown bituminous clay with light brown calcareous laminae; 2315–2370 cm, light brown silty marls, laminated with dark brown shale layers and rusty silt; 2370–2383 cm, black-brown bituminous, non-calcareous clay; 2383–2410 cm, light brown silty marls, laminated with dark brown shale layers and silt; 2410–2419 cm, black-brown bituminous, non-calcareous clay; 2419–2457 cm, light brown silty marls, laminated with dark brown shale layers and silt; 2457–2463 cm, black-brown bituminous, non-calcareous clay; 2463–2487 cm, light brown laminated marls; 2487–2498 cm, black-brown bituminous, non-calcareous clay, tectonically squeezed; 2498–2533 cm, laminated marls; 2533–2540 cm, black-brown bituminous, non-calcareous clay; 2540–2560 cm, laminated marls; 2560–2572 cm, black-brown bituminous, non-calcareous clay; 2572–2610 cm, laminated marls with distinct silt layers (angle of thrust plane 325/45°); part VIIIb, 2610–2624 cm, layers of black-brown bituminous, non-calcareous clay with beds of light brown marls, and a rusty silt layer on top; 2624–2668 cm, laminated marls with pteropods; 2668–2678 cm, black-brown bituminous, non-calcareous clay; 2678–2698 cm, laminated marls with pteropods; 2698–2705 cm, black-brown bituminous, non-calcareous clay; 2705–2765 cm, laminated marls with layers of rusty silt, and with pteropods; 2765–2769 cm, black-brown bituminous, non-calcareous clay, tectonically cut; 2769–2778 cm, light brown to brown, laminated marls with rusty silt layers; 2778–2786 cm, dark brown and light grey brown layered clays and calcareous silt, tectonically strongly folded; 2786–2878 cm, laminated marls with rusty silt layers; 2878–2890 cm, layered dark and light brown laminated shales and marls; distinct thrust plane.

Tectonic wedge no. IX, part a, Ottenthal Member: 2890–3035 cm, alternating dark brown laminated and yellowish marls, with silt layers and lenses of gypsum; 3035–3215 cm, dark brown to greenish calcareous shales, partly laminated, with pteropods, with layers and lenses of silt, and some crusts of gypsum; 3215–3240 cm, light brown thin bedded and laminated marls with white spots and pteropods; 3240–3260 cm, dark greenish brown, calcareous shales with crusts of gypsum;
part b, Galgenberg Member: 3260–3270 cm, brown silty claystone; 3270–3350 cm, dark greenish-brown non-calcareous shales with silt layers and gypsum.

Tectonic wedge no. X, Galgenberg Member: 3350–3410 cm, light grey banded (2–3 cm) and laminated, diatomaceous non-calcareous claystone; 3410–3815 cm, light grey laminated, clayey diatomite, with an angle of bedding plane 150/60°.

Tectonic wedge no. XI, Dynow Marlstone: 3815–4305 cm: whitish to yellowish marl (nannofossil-chalk) with some dark laminae; from 40 m upwards broken, without structures.

Tectonic wedge no. XII, Thomasl Formation, tectonically strongly disturbed variegated shales: 4305–4350 cm, dark grey to greenish, with a violet tint, non-calcareous shales with sand layers; 4350–4400 cm, dark greenish-brown, rusty brown and olive-green, non-calcareous shales and thin silt layers with a 3 cm bed of whitish nanno-chalk; at the slickenside (4370–4400 cm) with a thick layer of micaceous fine sand; 4400–4460 cm, dark, greenish-brown non-calcareous shales with a 10 cm layer of nannofossil-chalk; 4460–4470 cm light brownish-grey, disturbed marl; 4470–4570 cm, dark greenish-brown calcareous shales and light brown marls with lenses and layers of gypsum; 4570–5320 cm, non-calcareous, variegated dark shales with rusty silt lenses and with layers of gypsum; 5320–5500 cm, black-grey and greenish-grey, non-calcareous shales changing

with dark greenish-brown and grey-brown, calcareous shales with a layer of whitish chalk nodules at 5320 cm (a former nannofossil-chalk layer). The section is cut at 55 m by Quaternary yellowish-brown, fluvial sands and gravels.
According to micropaleontological investigations and lithologic sequences, the section can be interpreted to consist of different normal and overturned parts. The lower part with the Dynow Marlstone and the Thomasl Formation are in a normal tectonical position. In the Thomasl Formation the "Sitborice Event" (KRHOVSKY & DJURASINOVIC, 1993) is recorded in the lower part of tectonic wedge no. II. An overturned sequence includes the wedges no. III to VII, going from Dynow Marlstone to diatomites of the Galgenberg Member, and stratigraphically downwards to laminated marls of the Ottenthal Member. From the thrust plane at 21.70 m (base of wedge no. VII) upwards, the section becomes stratigraphically younger, from the laminated marls of the Ottenthal Member to the Thomasl Formation.

4. MICROPALEONTOLOGICAL RESEARCH

4.1. Ottenthal, type section

The micropaleontological investigation of calcareous and siliceous nannofossils is presented according to the different lithologic units of the sampled section at Untere Leithen, along the cart road to Klein-Schweinbarth (comp. Fig. 2).

4.1.1. Ottenthal Member

Lower part of the Ottenthal Member: In the lowermost part (0.00–1.25 m), a rich Lower Oligocene calcareous nannofossil assemblage is present. The assemblage represents nannofossil zone NP 22 with *Coccolithus pelagicus, Ericsonia subdisticha, E. fenestrata, Reticulofenestra umbilicus, R. hillae, R. dictyoda, R. hampdenensis, R. daviesii, Cyclicargolithus floridanus, Chiasmolithus oamaruensis, Cruciplacolithus tarquinius, Dictyococcites bisectus, D. scrippsae, Cyclococcolithus luminis, Markalius hirsutus, Pyrocyclus orangensis, P. hermosus, Sphenolithus predistentus, S. pseudoradians, S. moriformis, Helicosphaera bramlettei, H. compacta, Isthmolithus recurvus, Lanthernithus minutus, Orthozygus aureus, Bramletteius serraculoides, Pontosphaera pygmaea, P. multipora, P. sigmoidalis, P. pulchra, P. obliquipons, P. latelliptica, P. distincta, P. recta, Braarudosphaera bigelowii, Rhabdosphaera spinosa, R. vitrea, Rhabdolithus tenuis* and *Zygrhablithus bijugatus.* Reworking of the Late Cretaceous and Paleocene is rare.

The assemblages of planktic foraminifera are dominated by subbotinids and catapsydracids, and consist of *Subbotina* cf. *angiporoides, S. cryptomphala, S. linaperta, S. prasaepis, S. pseudoeocaena, S. utilisindex, S. yeguaensis, Globigerina brevis, G. labiacrassata, G. officinalis, Catapsydrax pera, C. primitivus, C. unicavus, Globorotaloides suteri, Tenuitella gemma, T. liverovskae, Chiloguembelina gracillima, Pseudohastigerina naguewichiensis, P. praemicra.* Planktic foraminifera zone P 18.

Additional samples of the massive to bedded light grey to brown marls at the top of the section have been sampled recently, 10–12 m east of the tectonic wedge of Dynow Marlstone with the *Cardium lipoldi* – horizon: calcareous nannoplankton (Pl. 1): *Cocco-*

lithus pelagicus, Clausiococcus subdistichus, Chiasmolithus oamaruensis, Dictyococcites daviesii, Cyclicargolithus floridanus, Cribrocentrum coenurum, Helicosphaera euphratis, Pontosphaera multipora, P. discopora, P. latelliptica, Istmolithus recurvus, Lanternithus minutus (zone NP 21/22). Planktic foraminifera: *Globigerina officinalis, G. anguliofficinalis, Globigerina ? ampliapertura, Subbotina cryptomphala, S. gortanii, S. praeturritilina, S. prasaepis, Globorotaloides suteri, Catapsydrax primitivus, Ca. unicavus, Globoquadrina? venezuelana, Paragloborotalia opima nana, Tenuitella? danvillensis, T. liverovskae, T. evoluta, T. insolita, Tenuitellinata juvenilis, Pseudohastigerina praemicra, Ph. naguewichiensis, Chiloguembelina gracillima, Guembelitria triseriata* (zone P 18); some Cretaceous and Paleocene reworking. Benthic foraminifera assemblages are dominated by rather small and juvenile calcareous forms, with about 80–100 different species (Tab. 1). Common and of normal size are *Clavulinoides kruhelensis, Neugeborina, Stilostomella, Oridorsalis, Gyroidinoides,* and *Lenticulina.* The common *Cibicidoides* are much smaller as in normal assemblages, and many species are present only in small numbers.

Biostratigraphy: nannoplankton zone NP 21/22–NP 22, planktic foraminifera zone P 18.

Upper part of the Ottenthal Member: section 1.50–3.10 m, partly rich assemblages dominated by small globigerinids: *Globigerina officinalis, G. ouachitaensis, G. praebulloides* together with *G. labiacrassata, G. wagneri, Globigerinella megaperta, Subbotina tapuriensis, S. utilisindex, Tenuitella? danvillensis, Chiloguembelina gracillima, Pseudohastigerina naguewichiensis.*

Similar assemblages are present in part 5.50–7.80 m and 14.00–17.40 m, but with barren intervals. Additionally, following species are recorded: *Globigerina anguliofficinalis, Subbotina tripartita, Globoquadrina winkleri, Tenuitella gemma, T. liverovskae, T. munda, Pseudohastigerina praemicra.*

Plate 1

Fig. 1: Ottenthal Member: *Globigerina*-marl, nannoplankton zone NP 22. Fractured rock surface with a matrix of calcareous nannoplankton and embedded tests of globigerinas; scale bar 10 microns (Ottenthal, cart road to Klein-Schweinbarth, 10 m E of the "*Cardium lipoldi*"-horizon).

Fig. 2: Ottenthal Member: outcrop of banded marls with dark bituminous clay layers, nannoplankton zone NP 22 ("Ottenthal-Waldweg" section, tectonic wedge no. VIII).

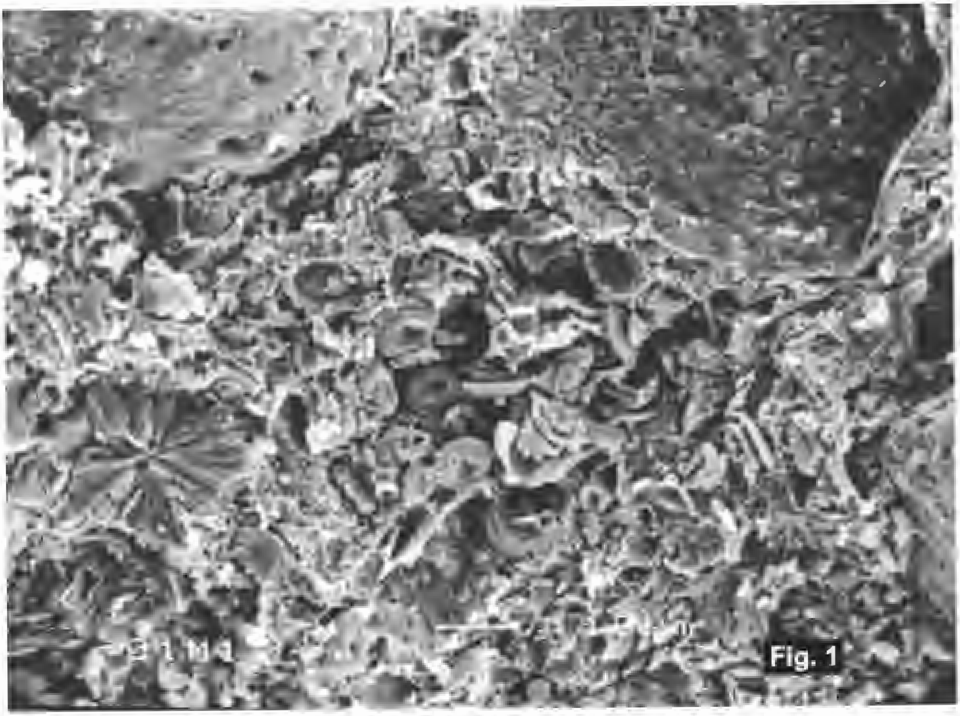


Fig. 1

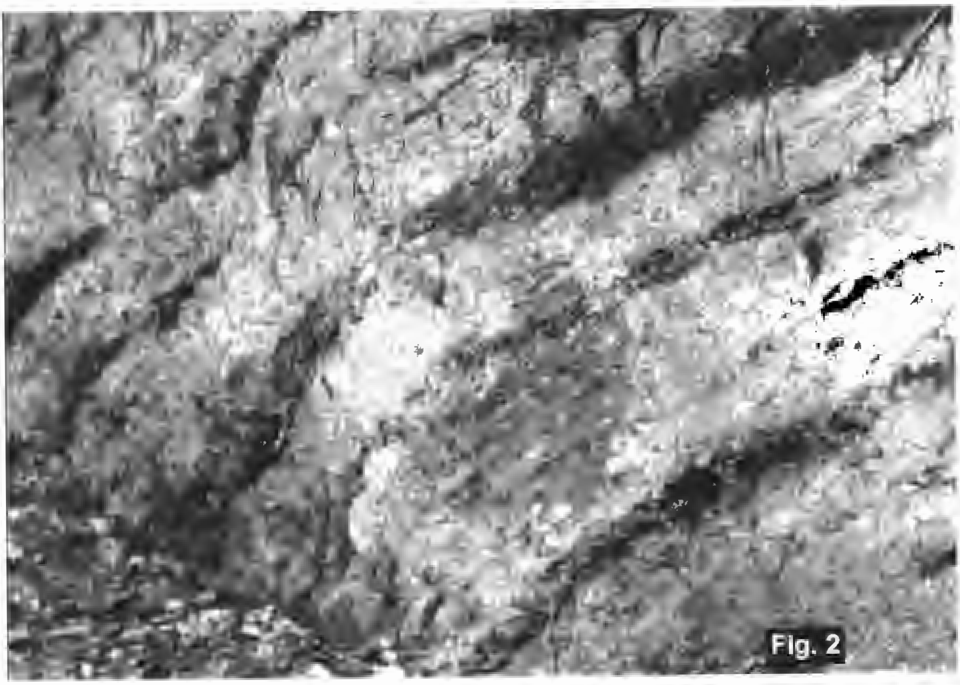


Fig. 2

OTTENTHAL - TYPESECTION Benthic Foraminifera Ottenthal Member, lower part	
Agglutinated species:	
Clavulinoides kruhelensis (WOJCIK)	*Globulina gibba* d'ORBIGNY
Arenobulimina sp.	*Globulina rotundata* (BORNEMANN)
Miliolina:	*Guttulina* sp.
Sigmoilinita tenuis (CZJZEK)	*Gyroidina borislavensis* MASLAKOVA
Calcareous species:	*Gyroidinoides altiformis* (R.E.& K.C. STEWART)
Alabamina abstrusa (FRANZENAU)	*Gyroidinoides girardanus* (REUSS)
Angulogerina germanica CUSHM.& JARVIS	*Hansenisca poignantae* SZTRAKOS
Angulogerina pulchella CUSHM.& EDWARDS	*Hanzawaia* sp.
Anomalinoides affinis (HANTKEN)	*Heronallenia vicksburgensis* CUSHMAN
Anomalinoides cf. *incrassatus* (F. & M.)	*Hoeglundina elegans* (d'ORBIGNY)
Anomalinulla sp.	*Islandiella crenulata* KRHOVSKY
Asterigerina falcilocularis SUBBOTINA	*Laevidentalina* sp.
Asterigerinata mamilla (WILLIAMSON)	*Lagena* sp.
Astrononion sp.	*Latobolivina janoscheki* (GOHRBANDT)
Biapertorbis alteconicus POKORNY	*Lenticulina budensis* (HANTKEN)
Biapertorbis biaperturatus POKORNY	*Lenticulina* spp.
Bolivina koessenensis LINDENBERG	*Lobatula carinata* (TERQUEM)
Bolivina molassica HOFMANN	*Melonis affinis* (REUSS)
Bolivina cf. *oligocaenica* SPANDEL	*Neugeborina* cf. *longiscata* (d'ORBIGNY)
Bolivina prion LINDENBERG	*Nonion? curviseptum* SUBBOTINA
Bolivina semistriata HANTKEN	*Nonionella* sp.
Bolivina vaceki bavarica LÜHR	*Oolina* sp.
Bolivina vaceki vaceki SCHUBERT	*Oridorsalis umbonatus* (REUSS)
Brizalina sp.	*Parelloides* sp.
Buchnerina sp.	*Pleurostomella acuta* HANTKEN
Bulimina alazanensis CUSHMAN	*Pleurostomella* sp.
Bulimina alsatica CUSHMAN & PARKER	*Praeglobobulimina pupoides* (d'ORBIGNY)
Bulimina cf. *truncana* GÜMBEL	*Pristinosceptrella* sp.
Bulimina subtruncana HAGN	*Pullenia bulloides* d'ORBIGNY
Cassidulina alabamensis BANDY	*Pullenia quinqueloba* (REUSS)
Ceratocancris haueri (d'ORBIGNY)	*Quadrimorphina petrolei* (ANDREAE)
Cibicides amphisyliensis (ANDREAE)	*Reussella oberburgensis* (REUSS)
Cibicides lopjanicus MYATLYUK	*Reussella tortusa* SZTRAKOS
Cibicidoides borislavensis (AISENSTAT)	*Rosalina* sp.
Cibicidoides cf. *ungerianus* (d'ORBIGNY)	*Sagrina* sp.
Elongobula sp.	*Siphonina reticulata* (CZJZEK)
Elphidiella sp.	*Stilostomella hoernesi* (HANTKEN)
Escornebovina cuvillieri (POIGNANT)	*Stilostomella* spp.
Escornebovina doebli SONNE	*Svratkina perlata* (ANDREAE)
Escornebovina orthorapha (EGGER)	*Trifarina budensis* (HANTKEN)
Favulina sp.	*Uvigerina acutocostata* HAGN
Fissurina sp.	*Uvigerina gracilis* REUSS
Frondovaginulina tenuissima (HANTKEN)	*Valvulineria complanata* (d'ORBIGNY)
Globocassidulina globosa (HANTKEN)	*Valvulineria palmarealensis* (NUTTALL)
Globocassidulina vitalisi (MAJZON)	*Virgulopsis pupoides* (NYIRÖ)

Tab. 1: Benthic foraminifera, lower part of the Ottenthal Member, *Globigerina*-marls, nannoplankton zone NP 22 (cart road from Ottenthal to Klein-Schweinbarth; sample Rö 17–96, 10 m E of the "*Cardium lipoldi* – horizon).

Lower Oligocene assemblages of nannofossil zone NP 22 are present in the calcareous shale between 36.70 m and 40.40 m. The assemblages in the light and dark brown laminated marl as well as that of the whitish marl of the "*Spiratella*" – horizon (36.30–40.40 m) are abundant. Planktic foraminifera are rich only in some layers, and have a comparable assemblage as reported above.

The pteropod ("*Spiratella*"=*Limacina*) horizon contains *Globigerina officinalis, G. ouachitaensis, G.* cf. *ciperoensis*, and *Catapsydrax unicavus* (Perch-Nielsen et al., 1985). Additional samples have been investigated separately from light coloured compact pteropod marl and brown laminated marl with pteropods and fish remnants. Light coloured marl: planktic foraminifera: *Globigerina officinalis, G. praebulloides, Globorotaloides suteri, Tenuitella? danvillensis, Tenuitellinata juvenilis;* benthic foraminifera: *Alabamina abstrusa, Biapertorbis alteconicus, Bolivina koessenensis, B. molassica, Bulimina sculptilis, B. subtruncana, Cassidulina alabamensis, Cibicides amphisyliensis, Globocassidulina vitalisi, Hansenisca parva, Lenticulina* spp., *Planulina compressa, Reussella tortusa, Stilostomella emaciata, Stomatorbina acarinata, Uvigerina moravia, U. tenuistriata, U. vicksburgensis.* Brown laminated marl: planktic foraminifera, rare: *Globigerina praebulloides, Tenuitellinata juvenilis, Pseudohastigerina naguewichiensis*; benthic foraminifera: *Alabamina abstrusa, Bolivina koessenensis, B. molassica, Bulimina sculptilis, B. subtruncana, Cassidulina alabamensis, Cibicidoides lopjanicus, Globocassidulina globosa, G. vitalisi, Globulina gibba, Lenticulina* spp., *Loxostomoides zsigmondyi, Planulina ambigua, Reussella tortusa, Stilostomella emaciata, Uvigerina moravia, U. vicksburgensis, Uvigerinella majkopica, Valvulineria complanata.* In the grey laminae of the brown laminated marl, foraminfera occur in the fine fraction only, and benthics are rare: *Globigerina? ampliapertura, Globigerina officinalis, G. praebulloides, Tenuitella munda, Tenuitellinata angustiumbilicata, Ta. juvenilis, Chiloguembelina gracillima*. Planktic foraminifera zone P 18–19.

The banded diatomaceous shales and marls from the following part of the section (40.40–41.20 m) belong also to the upper part of the Ottenthal Member as indicated by the presence of pteropods and a planktic fauna with *Globigerina? ampliapertura.*

In the calcareous shale of the uppermost part of the investigated section (45.10–47.00 m), the calcareous nannofossil assemblage is again of Early Oligocene age (NP 22). Planktic foraminifera are preserved only in few samples with a reduced assemblage of zone P 18–19, e.g.; *Subbotina cryptomphala, S. utilisindex, Globigerina? ampliapertura, Chiloguembelina gracillima*.

Biostratigraphy: nannoplankton zone NP 22, planktic foraminifera zone P 18–19.

4.1.2. Galgenberg Member

The diatomaceous Galgenberg Member is found in the section in tectonically separated parts. Menilite beds and shales with diatomites between 3.10–4.15 m and 7.80–10.05 m interfere with sediments barren of nannofossils. Common are diatoms, silicoflagellates, and archaeomonads with *A. striata, A. sphaerica, A. multipunctata, A. inconspicua, A. mangini*, together with radiolarians, and sponge spicules. In the lower part a monospecific calcareous nannoplankton flora with *Braarudosphaera bigelowii* was observed.

Shales and diatomites comprise the part of 10.60–14.00 m. In the shales, claystone with diatomites, and calcareous shale with diatomites between 32.00 and 35.50 m, silicoflagellates, diatoms, archaeomonads, and sponge spiculae occur. Barren and siliceous sediments occur between 41.70 m and 43.60 m.

Siliceous microfossils of the Galgenberg Member have been investigated (BRAUNSTEIN, 1985). The shales with menilites contained Archaeomonadacea: *Archaeomonas cratera* DEFLANDRE, *A.* cf. *chenevieri* DEFLANDRE, *A. mangini* DEFLANDRE, *Archaeosphaeridium ornatum* DEFLANDRE, *Litheusphaerella frenguelli* DEFLANDRE, *Pararchaeomonas* sp. Shales with siliceous clay show an assemblage of *Archaeomonas angulosa* DEFLANDRE, *A. glabra* DEFLANDRE, *A. mangini* DEFLANDRE, *A. mamillosa* TYNAN, *Litheusphaerella* sp. and silicoflagellates: *Corbisema triacantha* (EHRENBERG), *Naviculopsis lata* (DEFLANDRE), *Dictyocha fibula* EHRENBERG. In marine diatomites occur *Archaeomonas areolata* DEFLANDRE, *A.* cf. *chenevieri* DEFLANDRE, *Litharachaeocystis oamaruensis* DEFLANDRE, *Pararchaeomonas colligera* DEFLANDRE; whereas brackish diatomites have an assemblage of *Archaeomonas dangeardium* DEFLANDRE, *A. heteroptera* DEFLANDRE, *A. lefeburei* DEFLANDRE, *A. pachyceros* DEFLANDRE, *A. scrabulata* DEFLANDRE. Some species of the low salinity assemblage show an increase in size.

4.1.3. Dynow Marlstone

Prominent marl beds of endurated nannofossil-chalk are present in two layers in the lower and upper part of the section. The calcareous nannoplankton of the whitish marl bed at 4.55–5.10 m is defined as zone NP 23 with the zonal markers *Sphenolithus distentus, Dictyococcites ornatus,* and *Helicosphaera perch-nielseniae* together with *Coccolithus pelagicus, Reticulofenestra lockerii, R. hampdenensis, R. daviesii, R. dictyoda, Cyclicargolithus floridanus, Dictyococcites bisectus, Cyclococcolithus luminis, Sphenolithus predistentus, S. moriformis, Pyrocyclus hermosus, Transversopontis recta, Pontosphaera multipora, P. japonica, P. latelliptica, Braarudosphaera bigelowii, Rhabdosphaera tenuis, Zygrhablithus bijugatus, Helicosphaera wilcoxonii, Rhabdosphaera vitrea, R. spinosa,* and *Rhabdolithus tenuis.*

Samples of the nannofossil-chalk layer, a clayey endurated marl (*Cardium lipoldi* – horizon) at 41.70–42.55 m are of zone NP 23, consisting of a restricted assemblage with *Dictyococcites ornatus, Transversopontis fibula, Dictyococcites bisectus, Zygrhablithus bijugatus,* and *Pontosphaera multipora.*

Biostratigraphy: nannoplankton zone NP 23.

4.1.4. Thomasl Formation

Tectonically intercalated in the section are banded shales and calcareous shales, with silt laminae, at 4.15–5.50 m, containing NP 23 and NP24 calcareous nannoplankton. Calcareous nannoplankton of NP 24 was determined by the presence of *Cyclococcolithus abisectus, Sphenolithus ciperoensis , S. dissimilis, Helicosphaera recta, H. perch-nielseniae, Triquetrorhabdulus carinatus* together with *Coccolithus pelagicus, Reticulofenestra lockerii, R. hampdenensis, R. daviesii, Cyclicargolithus floridanus, Dictyococcites bisectus, Sphenolithus moriformis, Pyrocyclus hermosus, Pontosphaera multipora, P. pygmea, Braarudosphaera bigelowii, Rhabdosphaera tenuis, Zygrhablithus bijugatus* and *Helicosphaera wilcoxonii.* A horizon of a monospecific calcareous flora with *Reticulofenestra* cf. *umbilicus* together with siliceous nannofossils occurs at about 5 m.

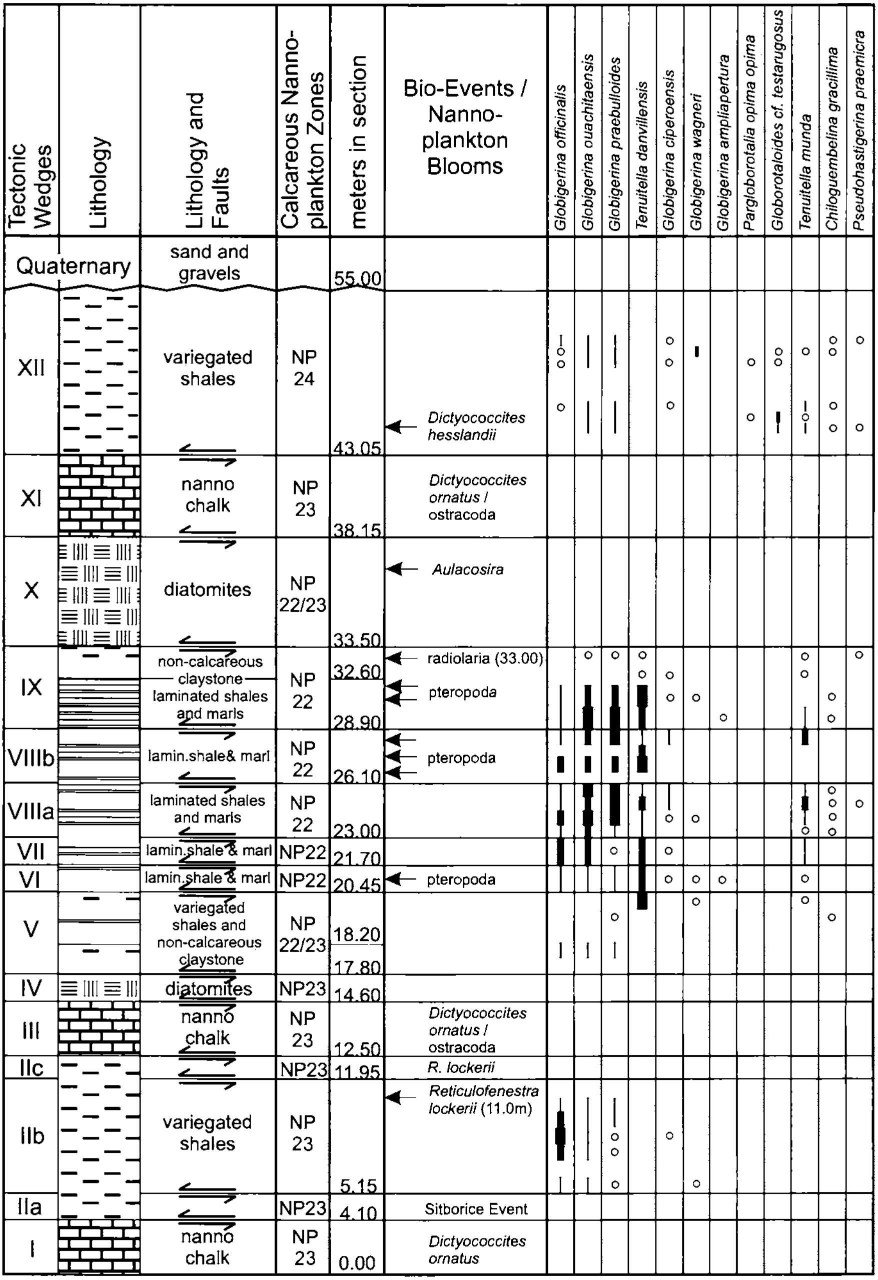


Fig. 4: "Ottenthal-Waldweg" reference section. Measured section with tectonic subdivision, lithology, bio-events, mass occurrences and stratigraphically important planktic foraminifera (explanations of lithology see Fig. 3; circle = recorded; thin line = rare; medium line = frequent; thick line = abundant).

Claystones and calcareous shales of the section between 17.40 m and 32.00 m are partly barren of nannofossils, and partly of a Late Oligocene age (NP 24). The calcareous nannofossil assemblages of some samples consist of few species only (*Cyclicargolithus abisectus*, *C. floridanus*, *Reticulofenestra lockerii*, *Dictyococcites bisectus*, *Zygrhablithus bijugatus*). Foraminifera have been observed in calcareous shales, predominantly in the lower part (18 m to 22 m), commonly limonitized. The scarce planktic assemblages are typical for the Middle Rupelian of the Central Paratethys, with *Globigerina anguliofficinalis*, *G. ciperoensis*, *G. officinalis*, *G. praebulloides*, *G. wagneri*, *Beella rohiensis*, *Globorotaloides suteri*, *Tenuitella munda*, *T. liverovskae*. An exact biostratigraphic zonation is not possible with this assemblage.

Biostratigraphy: nannoplankton zone NP 24.

4.2. Ottenthal – section "Waldweg"

The complete section has been studied in detail for calcareous nannoplankton and planktic foraminifera (Tab. 2); benthic foraminifera were investigated from selected samples. A compilation of the biostratigraphy, bio-events, and relative abundance of selected planktic species is shown in Fig. 4.

4.2.1. Ottenthal Member

Ottenthal Member, upper part: tectonic wedges no. VI (20.45–21.70 m), no. VII (21.70–23.00 m), no. VIII (23.00–28.90 m), no. IX (28.90–32.60 m).

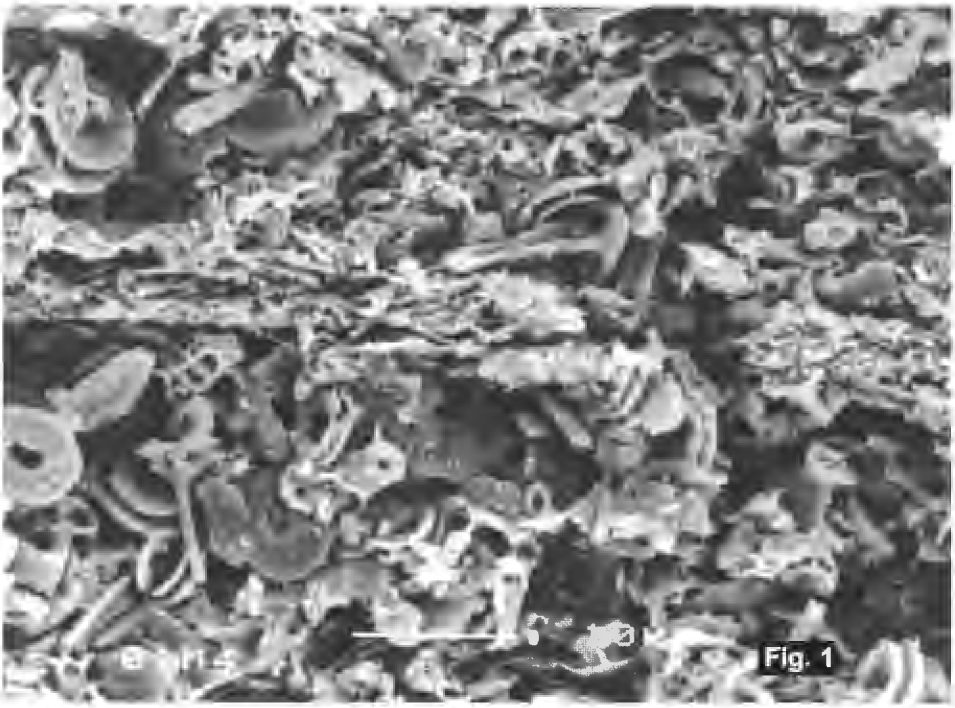
Calcareous nannoplankton: In light to dark brown laminated marls, at 20.45–21.10 m (samples 128, BH 10, 10a) occur *Coccolithus pelagicus*, *Transversopontis obliquipons*, *T. pulcheroides*, *Pontosphaera multipora*, *P. latelliptica*, *Reticulofenestra umbilicus*, *Dictyococcites bisectus*, *Zygrhablithus bijugatus*, *Lanternithus minutus*, *Isthmolithus recurvus*, *Orthozygus aureus*, *Clausicoccus fenestratus*, *Rhabdosphaera vitrea*, *Blackites spinosus*, and small Noelaerhabdaceae; some Cretaceous and Paleocene-Eocene reworking. Nannoplankton zone: upper NP 22.

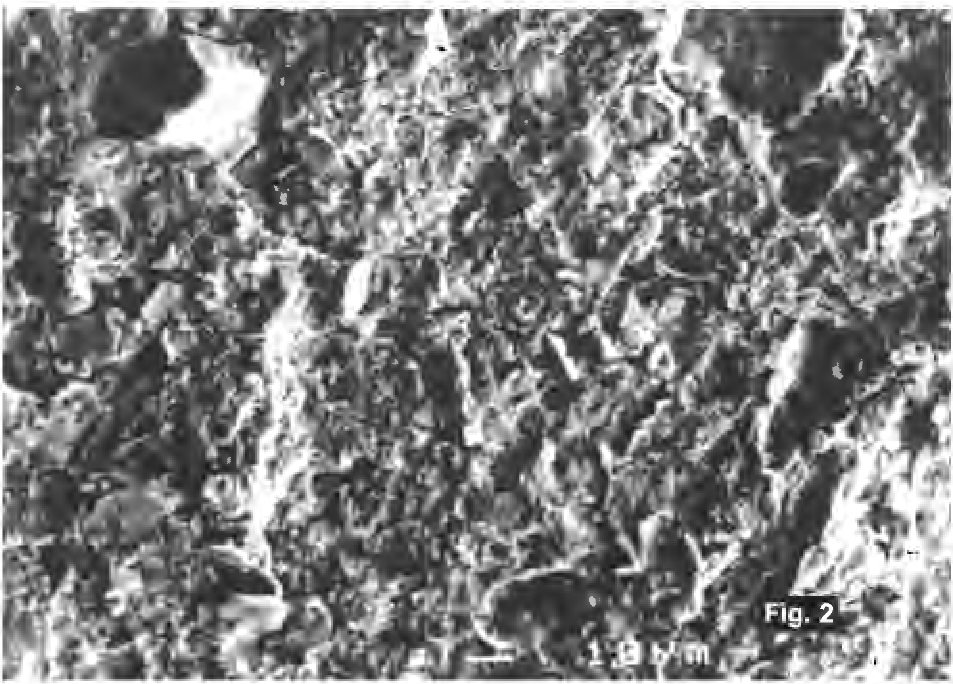
Plate 2

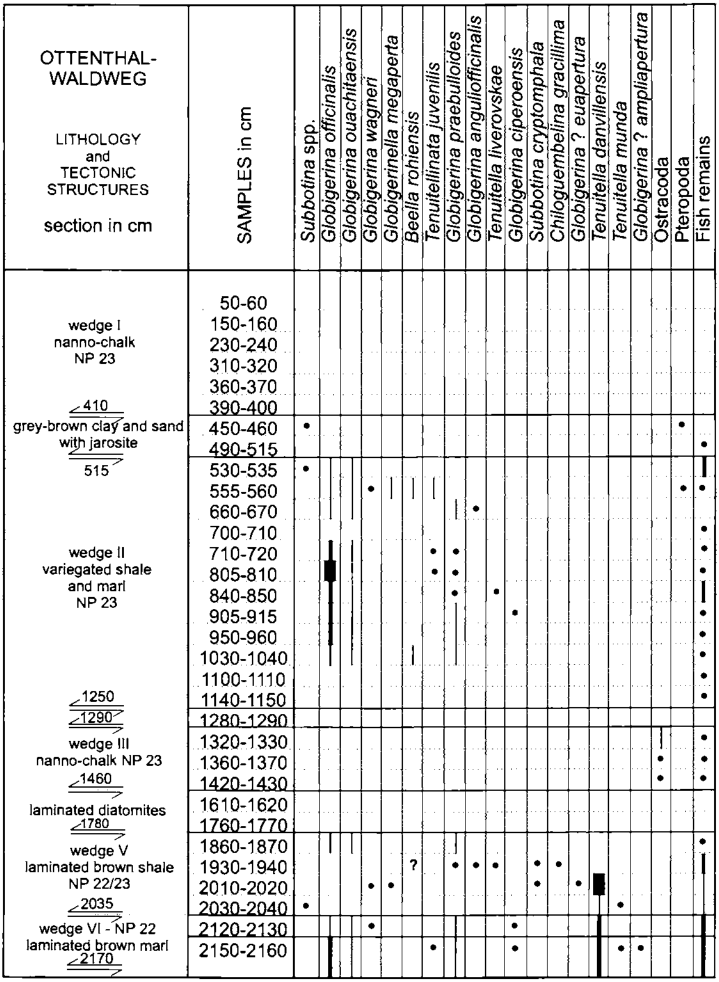
Fig. 1: Ottenthal Member: banded marls, nannoplankton zone NP 22. Fractured rock of laminated marl composed of calcareous nannoplankton, and in the middle a distinct clayey layer dividing two blooms of calcareous nannoplankton; scale bar 10 microns ("Ottenthal-Waldweg" section, tectonic wedge no. VIII).

Fig. 2: Ottenthal Member: banded marls, bituminous layer. Fractured rock surface with a matrix of clay minerals, larger flakes of phylosilicates, and grains of quartz and feldspar; scale bar 10 microns ("Ottenthal-Waldweg" section, tectonic wedge no. VIII).

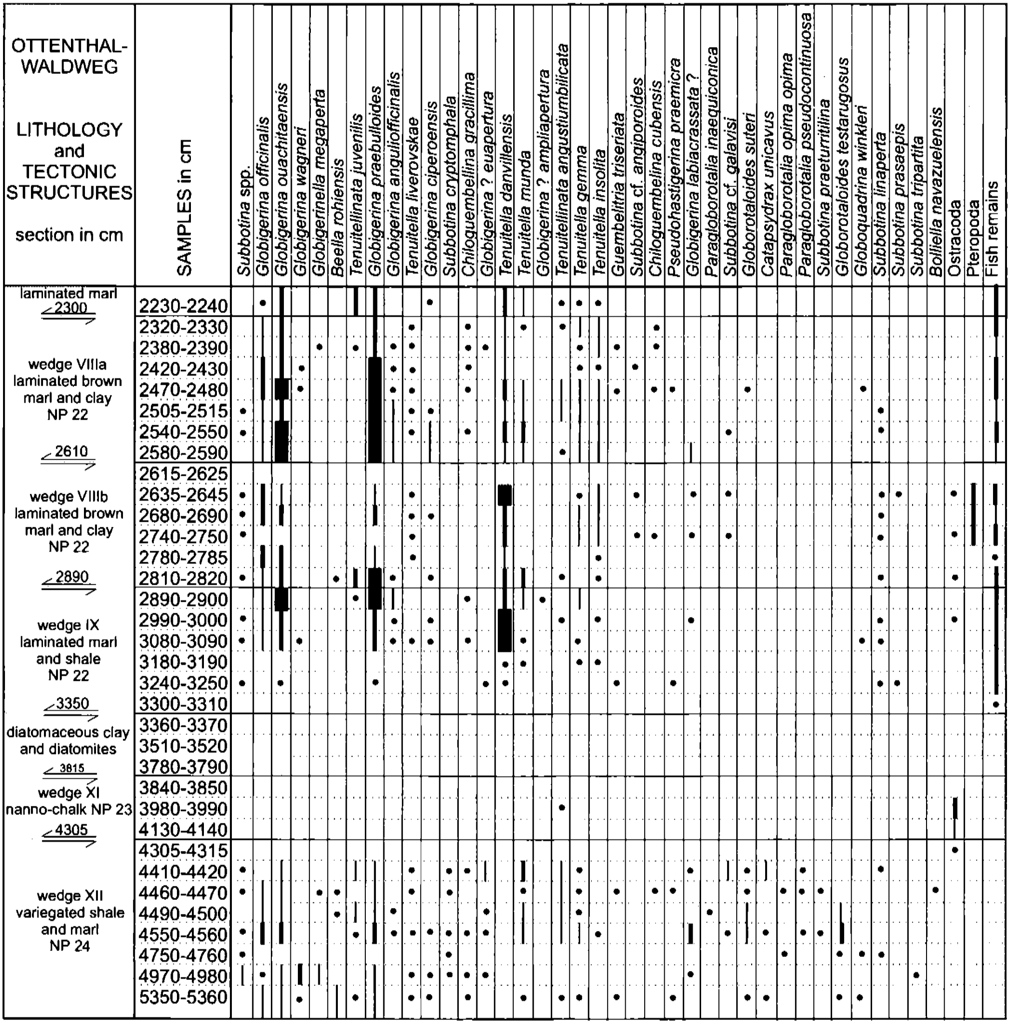
Plate 2







Tab. 2: Planktic foraminifera, ostracoda, pteropoda, fish remains. Distribution in the section "Ottenthal-Waldweg", shown with relative abundances (point = recorded; thin line = rare; medium line = frequent; thick line = abundant).



Tab. 2: continued.

Banded laminated brown marls (Pl. 2) and non-calcareous dark brown bituminous clays (21.70–28.90 m; samples 133–152, BH 1–2; Pl. 2, Fig. 2); assemblages according to lithology: a) laminated light brown marl: *Coccolithus pelagicus, Transversopontis obliquipons, T. pulcher, T. pulcheroides, Pontosphaera multipora, P. latelliptica, Reticulofenestra umbilicus, R. samodurovii, Dictyococcites bisectus, D. daviesii, Cribrocentrum reticulatum, Cyclicargolithus floridanus, C. hesslandii, Zygrhablithus bijugatus, Lanternithus minutus, Isthmolithus recurvus, Orthozygus aureus, Clausiococcus fenestratus, C. subdistichus, Rhabdosphaera vitrea, R. tenuis, Ilselithina fusca, Blackites spinosus, Lithostromation simplex, Sphenolithus moriformis,* and small Noelaerhabdaceae; some Cretaceous reworking. b) brown calcareous silty clay with rare nannofossils: *Coccolithus pelagicus, Pontosphaera multipora, P. latelliptica, Reticulofenestra umbilicus, R. samodurovii, Dictyococcites bisectus, Zygrhablithus bijugatus, Isthmolithus recurvus, Rhabdosphaera vitrea,* and small Noelaerhabdaceae; some Cretaceous reworking. c) dark brown silty clays: barren of nannofossils. A detailed analysis of individual laminae of sample 138 is given in Tab. 3. Nannoplankton zone: NP 22.

Laminated brown marls and dark clays with pteropods (28.90–32.60 m; samples 153–167): *Coccolithus pelagicus, Transversopontis obliquipons, T. rectipons, Pontosphaera multipora, P. latelliptica, Reticulofenestra umbilicus, R. samodurovii, Dictyococcites bisectus, D. daviesii, Cribrocentrum reticulatum, Zygrhablithus bijugatus, Lanternithus minutus, Isthmolithus recurvus, Orthozygus aureus, Rhabdosphaera vitrea, R. tenuis, Blackites spinosus, Lithostromation simplex, Sphenolithus moriformis,* and small Noelaerhabdaceae; some Cretaceous and Paleogene reworking. Nannoplankton zone: upper NP 22.

Planktic foraminifera: number of planktic foraminifera is strongly changing, dominated by small species, and occurring in distinct layers with blooms of single species. In the bituminous layers foraminifera are missing, beside of very thin calcareous laminae.

Banded marls of wedge no. VIII, lower part (23.00–26.10 m) *Globigerina praebulloides* occurs in blooms, accompanied by a constant number of *G. ouachitaensis* and changing frequencies of *G. officinalis*. Stratigraphically important in this horizon are *Globigerina wagneri, Globigerinella megaperta, Tenuitella gemma, T. liverovskae, T. munda,* and rare *Pseudohastigerina praemicra, Chiloguembelina cubensis,* and *Ch. gracillima*. In the upper part of wedge VIII with pteropods (26.10–28.90 m), the abundance is strongly changing, and floods of *Tenuitella? danvillensis* occur. Stratigraphically important species are rare, e.g., *Chiloguembelina gracillima,* some subbotinids are present: *Subbotina crux, S. linaperta, S. prasaepis, S. utilisindex.* In a bituminous sample (27.80–27.85 m) a small assemblage occurs with *Globigerina officinalis, G. ouachitaensis, G. praebulloides, Tenuitella insolita, T. liverovskae, T.? danvillensis.* Planktic foraminifera zone: P 18/19.

In wedge no. IX, with pteropod horizons, in the lower part, small globigerinas are most common, with floods of co-occuring *Globigerina ouachitaensis* and *G. praebulloides* or *Tenuitella? danvillensis.* The upper part shows a strongly diminished assemblage by secondary decalcification. There are very rare stratigraphically important species as *Pseudohastigerina praemicra, Chiloguembelina gracillima, Globigerina?* cf. *ampliapertura, G. wagneri.* Planktic foraminifera zone: P 18/19.

Benthic foraminifera: In the marly part of banded marls, calcareous species occur in small numbers, dominated by small uvigerinas, angulogerinas, and bolivinas, *Uvigerina*

OTTENTHAL - WALDWEG Calcareous Nannoplankton in individual laminae of sample 138 laminated marls (NP 22)	brown silty clacareous clay	light-coloured calcareous clay	light-coloured marl	brown-grey calcareous clay	light coloured marl (turbiditic)	brown-grey marl
Zygrhablithus bijugatus (DEFLANDRE)	0.00	0.40	1.10	8.70	8.60	7.30
Lanthernithus minutus STRADNER	0.00	0.00	4.00	8.30	7.00	7.30
Orthozygus aureus (STRADNER)	0.00	0.10	0.40	0.40	1.30	0.30
Holodiscus macroporus (DEFLANDRE)	0.00	0.10	1.80	0.90	2.90	1.70
Coccolithus pelagicus (WALLICH)	26.60	15.90	11.70	9.60	6.00	5.00
Clausiococcus spp.	0.60	5.50	3.60	1.40	2.20	2.00
small Noelaerhabdaceae	8.00	13.40	27.20	24.80	34.00	27.60
Reticulofenestra danica BLACK	1.30	6.70	4.50	3.20	7.00	7.70
Reticulofenestra umbilicus (LEVIN)	1.30	0.70	0.30	0.30	0.10	0.10
Dictyococcites bisectus (HAY et al.)	52.20	37.00	16.90	23.60	14.90	17.30
Dictyococcites daviesii (HAQ)	0.00	4.20	1.30	0.40	1.30	2.70
Cribrocentrum coenorum (REINHARDT)	0.10	1.70	0.90	0.10	0.00	0.00
Cyclicargolithus floridanus (ROTH & HAY)	0.00	0.00	0.00	0.10	0.10	0.00
Clyclicargolithus hesslandii (HAQ)	0.00	0.00	0.00	0.10	0.10	0.40
Blackites spinosus (DEFLANDRE)	1.30	2.50	3.60	3.70	4.10	2.80
Rhabdosphaera tenuis BRAML.& SULLIVAN	0.00	0.10	1.70	0.10	0.00	1.30
Rhabdosphaera vitrea DEFLANDRE	0.00	0.00	4.50	7.30	5.40	5.70
Pontosphaera latelliptica (BALDI-B. & BALDI)	0.00	4.20	2.70	2.70	2.20	4.70
Pontosphaera multipora (KAMPTNER)	0.60	0.80	0.10	0.10	0.00	0.10
Transversopontis pulcher (DEFLANDRE)	0.00	0.00	0.10	0.10	0.00	0.00
Transversopontis obliquipons (DEFLANDRE)	0.00	0.00	1.30	1.40	0.30	1.00
Sphenolithus moriformis (BRÖNN.& STRAD.)	0.00	0.00	0.00	0.40	0.00	0.00
Isthmolithus recurvus DEFLANDRE	8.00	6.70	1.30	2.30	2.50	5.00

Tab. 3: Ottenthal Member: calcareous nannoplankton; percentages of species distribution in single laminae in banded marls, nannoplankton zone NP 22 ("Ottenthal-Waldweg" section, sample 138, at 24.75 m).

oligocaenica, U. gracilis, Angulogerina globosa, A. pulchella, Bolivina beyrichi beyrichi, B. koessenensis, B. subalpina, B. vaceki. Regularly other small species are present, as *Cassidulina alabamensis, Globocassidulina globosa, G. vitalisi, Escornebovina doebli, Biapertorbis alteconicus, B. biaperturatus, Heronallenia vicksburgensis*, different species of *Lagena, Oolina, Fissurina*. Other species are found only in a juvenile growth stage, as *Planularia kubinyi, Globulina gibba, Guttulina* sp., *Baggina pulchra, Melonis affinis, Alabamina abstrusa, Cibicides amphisyliensis, C. lopjanicus, Stichocibicides moravicus, Planularia compressa, Anomalinoides affinis, A. granosus.*

In sample 26.35–26.45 m, banded marls with pteropods, an exceptionally rich assemblage of predominantly small forms is shown in Tab. 4. Common are *Lenticulina, Baggina, Cibicidoides, Cassidulina, Globocassidulina, Uvigerina oligocaenica,* and *Angulogerina globosa;* in low numbers and as single specimens occur many otherwise rare species.

OTTENTHAL - WALDWEG banded marls with pteropods (26.35-26.45 m) Benthic Foraminifera Ottenthal Member, upper part	
Agglutinated species:	
Semivulvulina pectinata (REUSS)	*Frondicularia* cf. *dumontana* REUSS
Siphotextularia concava (KARRER)	*Gavelinopsis* sp.
Spirorutilus adamsi (LALICKER)	*Globocassidulina globosa* (HANTKEN)
Miliolina:	*Globocassidulina vitalisi* (MAJZON)
Cycloforina ludwigi (REUSS)	*Globulina gibba* d'ORBIGNY
Spiroloculina lamposa HUSSEY	*Gyroidinoides octocameratus* (CUSH.& HANNA)
Calcareous species:	*Hansenisca parva* (CUSHMAN & RENZ)
Alabamina abstrusa (FRANZENAU)	*Heronallenia vicksburgensis* CUSHMAN
Allomorphina trigona REUSS	*Homalohedra? apioleura* (LOEBLICH & TAPPAN)
Amphicoryna badenensis (d'ORBIGNY)	*Lagena* cf. *laevis* (MONTAGU)
Angulogerina globosa (STOLTZ)	*Lagena gracilicosta* REUSS
Anomalinulla sp.	*Latobolivina janoscheki* (GOHRBANDT)
Astacolus sp.	*Lenticulina depauperata* (REUSS)
Asterigerinata mamilla (WILLIAMSON)	*Lobatula carinata* (TERQUEM)
Baggina dentata HAGN	*Melonis pompilioides* (FICHTEL & MOLL)
Baggina pulchra CUSHMAN & TODD	*Neoconorbina* sp.
Biapertorbis biaperturatus POKORNY	*Oolina globosa* (MONTAGU)
Bolivina beyrichi beyrichi REUSS	*Orthomorphina havanensis* (CUSH.& BERM.)
Bolivina danvillensis HOWE & WALLACE	*Palliolatella laevis* (SEGUENZA)
Bolivina fastigia CUSHMAN	*Planorbulina difformis* (ROEMER)
Bolivina cf. *koessenensis* LINDENBERG	*Planularia* sp.
Bolivina pseudaenariensis (MYATLYUK)	*Planulina* cf. *compressa* (HANTKEN)
Bolivina subalpina HOFMANN	*Procerolagena gracilis* (WILLIAMSON)
Buchnerina orbignyana (SEGUENZA)	*Pseudofissurina* sp.
Bulimina truncana GÜMBEL	*Pseudoolina* sp.
Cassidulina alabamensis BANDY	*Pullenia quinqueloba* (REUSS)
Caucasina coprolithoides (ANDREAE)	*Pygmaeoseistron* cf. *hispida* (REUSS)
Cibicides amphisyliensis (ANDREAE)	*Reussella elongata* (TERQUEM)
Cibicides lopjanicus MYATLYUK	*Reussella tortusa* SZTRAKOS
Cibicidoides spp.	*Riminopsis* sp.
Cushmanina tetragona (PARKER & JONES)	*Siphonodosaria verneuili* (d'ORBIGNY)
Discorbitura sp.	*Stichocibicides moravicus* POKORNY
Elphidiella turgescens (CUSHMAN)	*Stilostomella adolphina* (d'ORBIGNY)
Escornebovina doebli SONNE	*Stilostomella intermedia* (HANTKEN)
Escornebovina orthorapha (EGGER)	*Stomatorbina acarinata* POKORNY
Escornebovina trochiformis (ANDREAE)	*Trifarina budensis* (HANTKEN)
Favulina hexagona (WILLIAMSON)	*Turrilina alsatica* ANDREAE
Fissurina carinata REUSS	*Uvigerina oligocaenica* ANDREAE
Fissurina laevigata REUSS	*Uvigerina tenuistriata* REUSS

Tab. 4: Benthic foraminifera, upper part of the Ottenthal Member, banded marls with pteropods, nannoplankton zone NP 22 ("Ottenthal-Waldweg" section, 26.35–26.45 m).

4.2.2. Galgenberg Member

Galgenberg Member: tectonic wedges no. IV (14.60–17.80 m), no. V (17.80–20.45 m p.p.), upper part of no. IX (32.60–33.50 m), no. X (33.50–38.15 m). The diatomites and shales are normally barren of calcareous fossils. The base of the Galgenberg Member therefore is dated by the top of the Ottenthal Member.

Siliceous microfossils: have not been studied; marine diatoms occur in the lower part of the diatomites, e.g., *Chaetoceros* bristles, *Pyxilla, Actinoptychus, Stephanopyxis, Hemiaulax*. In the upper part occur blooms of *Aulacoseira praeislandica* Jouse (Pl. 3).

Calcareous nannoplankton: in wedge no.V, between 18.80 and 20.00 m (samples 125–127, BH 12–16) a well developed nannoplankton assemblage occurs in light grey calcareous shales near the base of the Galgenberg Member, and probably belongs to the uppermost Ottenthal Member: *Coccolithus pelagicus, Transversopontis obliquipons, Pontosphaera multipora, P. latelliptica, Reticulofenestra umbilicus, Dictyococcites bisectus, Zygrhablithus bijugatus, Lanternithus minutus, Isthmolithus recurvus, Orthozygus aureus, Clausiococcus fenestratus, Rhabdosphaera vitrea, Blackites spinosus,* and small Noelaerhabdaceae; rare Cretaceous reworking is observed. Nannoplankton zone: upper NP 22.

Base of non-calcareous shales (32.60 m; sample 168): nannofossils are rare and corroded; *Coccolithus pelagicus, Transversopontis rectipons, Pontosphaera multipora, P. latelliptica, Reticulofenestra umbilicus, Dictyococcites bisectus, Zygrhablithus bijugatus, Isthmolithus recurvus*. Nannoplankton zone: upper NP 22.

Planktic foraminifera: in wedge no. V (sample 20.10–20.20 m) a small assemblage is present with *Globigerina officinalis, G. ouachitaensis, G. praebulloides, G. wagneri, Globigerinella megaperta, Tenuitella liverovskae, T. munda, Chiloguembelina gracillima,* and with a flood of *Tenuitella? danvillensis. Globigerina? ampliapertura* is absent. This may represent a calcareous layer of the Galgenberg Member. Planktic foraminifera zone: P 18/19.

Benthic foraminifera: In the sequence of calcareous and non-calcareous shales of wedge no. V (17.80–20.45 m) a few calcareous assemblages have been investigated. The specimens are distinctly larger than in the upper Ottenthal Member, but still rather small. The assemblages consist of *Spirorutilus adamsi, Amphicoryna, Angulogerina pulchella, Anomalinoides affinis, A. granosus, Baggina pulchra, Bolivina budensis, B. crenulata, B. koessenensis, Cassidulina alabamensis, Caucasina coprolithoides, Chilostomella ovoidea, Cibicides amphisyliensis, Cibicidoides coniferus, C. mexicanus, C.* cf. *ungerianus, Elphidiella buxovillana, Escornebovina doebli, Globocassidulina globosa, G. vitalisi, Gyroidina borislavensis, Islandiella crenulata, Lenticulina, Neugeborina longiscata, Planulina compressa, P. costata, Stichocibicides moravicus, Stilostomella emaciata, Uvigerina gracilis, U. moravia.*

Radiolaria: In the basal part of the Galgenberg Member, in a non-calcareous claystone bed (33.00–33.10 m) a common occurrence of nasselariids is observed.

4.2.3. Dynow Marlstone

Dynow Marlstone: tectonic wedges no. I (0.00–4.10 m), no. III (12.50–14.60 m), no. XI (38.15–43.05 m).

Calcareous nannoplankton: In the part 0.00–3.20 m (samples 101–104) occurs a bloom of *Dictyococcites ornatus, Transversopontis fibula* Gheta, 1976 (syn. *T. pax*

STRADNER & SEIFERT, 1980), and small *Dictyococcites* sp.; rare reworking of Cretaceous and Paleocene/Eocene is observed. In part 3.20–4.00 m (sample 105, BH 39) are blooms of *Dictyococcites ornatus* and *Transversopontis fibula* only.

In wedge III, from 12.50 to 14.60 m (samples 114–116) blooms of *Dictyococcites ornatus* and *Transversopontis fibula*, together with *Transversopontis latus*, small *Dictyococcites* sp., *D. daviesii, Pontosphaera rothii, Zygrhablithus bijugatus* are determined. The assemblages at wedge XI, 38.15–43.05 m (samples 184–191) have blooms of *Dictyococcites ornatus*, together with *Transversopontis fibula, Pontosphaera rothii* (Pl. 3, Fig. 2). Nannoplankton zone: NP 23.

4.2.4. Thomasl Formation

Thomasl Formation: tectonic wedges no. II (4.10–12.50 m), no. XII (43.05–55.00 m).

Calcareous nannoplankton: wedge no. II is generally barren; in thin layers at 11.00 m (samples 107–111, BH 24–35) occurs a bloom of *Reticulofenestra lockerii*, together with an assemblage of *Coccolithus pelagicus, Transversopontis pygmaeus, Helicosphaera bramletti, Pontosphaera rothii, P. discopora, P. latelliptica, Dictyococcites bisectus, Sphenolithus moriformis, Zygrhablithus bijugatus*, and small Noelaerhabdaceae. A similar bloom is found at 12.00 m (samples 112, BH 23). Nannoplankton zone: NP 23.

Wedge no. XII, predominantly non-calcareous shales and calcareous shales with three layers of nanno-chalk (Pl. 4). Nanno-chalk at 44.10–44.20 m (sample 192) with bloom of *Dictyococcites hesslandii*, together with *Coccolithus pelagicus, Pontosphaera multipora, Reticulofenestra lockerii, R. danica, Dictyococcites bisectus, Cyclicargolithus abisectus, Holodiscolithus solidus*; some Cretaceous and Paleocene/Eocene reworking. Nannoplankton zone: NP 24.

Plate 3

Fig. 1: Galgenberg Member: brackish diatomite; fractured rock surface with diatoms: coscinodiscids and *Aulacoseira praeislandica* JOUSE; scale bar 10 microns ("Ottenthal-Waldweg" section, wedge no. X).

Fig. 2: Dynow Marlstone: fractured rock surface of nannofossil-chalk with rare corroded calcareous nannoplankton and common diatom particles; scale bar 10 microns ("Ottenthal-Waldweg" section, tectonic wedge no. XI).


Fig. 1


Fig. 2

In the calcareous shale occur marly intercalations, e.g., at 45 m (sample 193), at 45.80 m (sample 194), and at 55 m (sample 199) with assemblages of *Reticulofenestra lockerii, Coccolithus pelagicus, Braarudosphaera bigelowii, Transversopontis* cf. *pygmaeus, Helicosphaera recta, Pontosphaera multipora, Cyclicargolithus abisectus, Dictyococcites bisectus, Sphenolithus ciperoensis, S. distentus, S. moriformis, Zygrhablithus bijugatus*. Nannoplankton zone: NP 24.

Planktic foraminifera: in the lower part of the Thomasl Formation (wedge no. II, 4.10–12.50 m) calcareous layers are scarce or secondarily dissolved. Small globigerinas predominate with blooms of *Globigerina officinalis* in the part 7.10–9.60 m. *G. ouachitaensis* and *G. praebulloides* are common together with *Beella rohiensis*. Stratigraphically important species as *Globigerina ciperoensis, G. wagneri, Globigerinella megaperta, Tenuitella liverovskae* are rare.

In wedge no. XII a few calcareous layers have well developed plankton with large species: *Globigerina labiacrassata, G. wagneri, Subbotina* cf. *galavisi, Globigerinella megaperta, Beella rohiensis, Bolliella navazuelensis, Globorotaloides suteri, Globoquadrina globularis, Gq. winkleri*. Stratigraphically important are: *Paragloborotalia opima opima, Tenuitella gemma, T. munda, Chiloguembelina gracillima, Pseudohastigerina praemicra, Subbotina tripartita, S. utilisindex*. The stratigraphy is determined by the occurrence of *P. opima opima*, the last subbotinids and the absence of *Globigerina? ampliapertura*. Planktic foraminifera zone: P 20/21a.

Benthic foraminifera: In the basal part of the Thomasl Formation (4.50–4.60 m) a corroded assemblage occurs, where all calcareous forms are dissolved or present as broken casts. The fauna consists of agglutinated species with *Rhabdammina, Reophax?, Psammosphaera?, Textularia elongata, Tritaxia szaboi, Gaudryina textilaroides, Pseudogaudryina schmitti, Karreriella hantkeniana, Vulvulina haeringensis*. In some

Plate 4

Fig. 1: Thomasl Formation: whitish chalk layer (3 cm). Fractured rock surface with strongly recrystallized elements of decayed coccoliths; scale bar 10 microns ("Ottenthal-Waldweg" section, tectonic wedge no. XII, 43.50 m).

Fig. 2: Thomasl Formation: whitish nannofossil-chalk layer (10 cm). Fractured rock surface with corroded calcareous nannoplankton, coated by thin calcite crusts; same magnification as fig. 1 ("Ottenthal-Waldweg" section, tectonic wedge no. XII, 44.10–44.20 m).

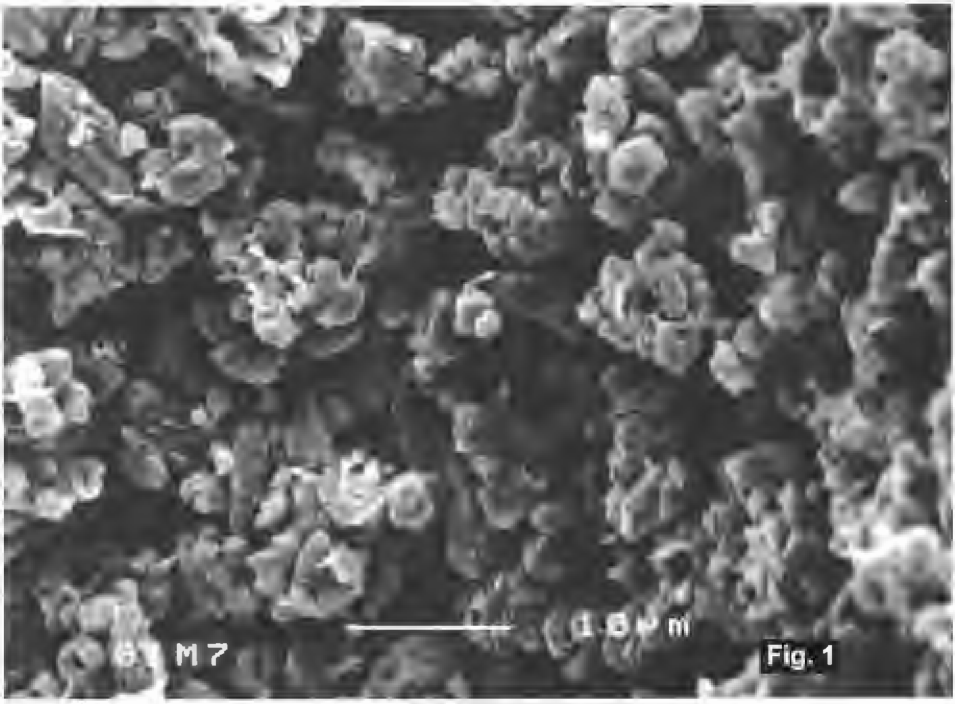


Fig. 1

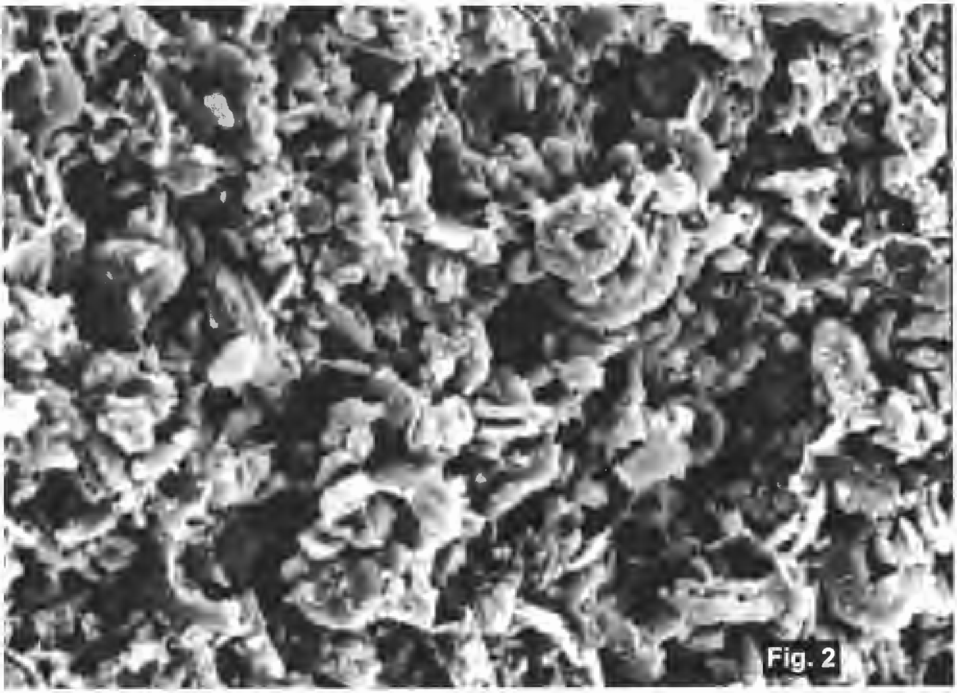


Fig. 2

calcareous layers of wedge no. II assemblages of calcareous benthics are found with strongly differing numbers, and with changing growth size. Small forms occur in sample 5.30–5.35 m with a bloom of small planktics, similar also in composition to the upper Ottenthal Member, but with *Uvigerina rudlingensis* and *Bolivina beyrichi carinata*. Of normal size are assemblages in samples at 5.60 and 8.10 m: *Anomalinoides affinis, Baggina dentata, Bolivina beyrichi beyrichi, B. beyrichi carinata, Cibicides amphisyliensis, Cibicidoides* cf. *ungerianus, Fursenkoina acuta, F. mustoni, Globocassidulina vitalisi, Gyroidinoides altiformis, Laevidentalina, Lenticulina, Planulina compressa, P. costata, Plectofrondicularia striata, Spirillina, Stichocibicides moravicus, Stilostomella, Uvigerina steyri, U. oligocaenica, Vaginulinopsis cumulicostatus.*

In wedge no. XII non-calcareous shales predominate, but also here some calcareous assemblages are present, together with large sized plankton: *Alabamina abstrusa, Angulogerina germanica, Anomalinoides affinis, Baggina dentata, Bolivina beyrichi beyrichi, B. beyrichi carinata, B. crenulata, Bulimina alsatica, B. subtruncana, Chilostomella ovoidea, Cibicides amphisyliensis, Cibicidoides* cf. *ungerianus, C. pachyderma, Dentalina, Escornebovina doebli, Fursenkoina acuta, F. mustoni, Globocassidulina vitalisi, Gyroidinoides altiformis, G. girardanus, Laevidentalina, Lenticulina, Neugeborina longiscata, Nodogenerina trincherasensis, Nodosaria rudis, Palmula budensis, Planulina compressa, P. costata, Plectofrondicularia striata, Pleurostomella acuta, P. incrassata, Pullenia bulloides, P. quinqueloba, Quadrimorphina petrolei, Spirillina, Stichocibicides moravicus, Stilostomella, Uvigerina steyri, U. oligocaenica, U. vicksburgensis*. An agglutinated assemblage is present in sample 47.50 m, dominated by *Miliammina paleocenica, Repmanina charoides*, and *Silicosigmoilina* sp., together with *Ammodiscus glabratus, Evolutinella, Haplophragmoides obliquicameratus, Recurvoides, Silicobathysiphon, Trochamminoides* cf. *subtrullisatus.*

4.3. Additional outcrops

4.3.1. Ottenthal Member

Altruppersdorf, Staglgraben: north of the Lourdes chapel, in the creek near the water reservoir; massive light grey marls of the lower part of the Ottenthal Member:

Calcareous nannoplankton (coll. KRHOVSKY, 1996): *Coccolithus formosus, Clausiococcus subdistichus, Chiasmolithus oamaruensis, Dictyococcites bisectus, D. daviesii, Reticulofenestra umbilicus, Cyclicargolithus floridanus, Blackites spinosus, Helicosphaera bramlettei, H. compacta, Istmolithus recurvus, Lanternithus minutus*. Planktic foraminifera: *Subbotina linaperta, S. cryptomphala, S.* cf. *galavisi, S. prasaepis, S. pseudoeocaena, S. pseudovenezuelana, S. utilisindex, Globigerina officinalis, Globigerina? ampliapertura, G.? euapertura, Turborotalia increbescens, Tenuitella liverovskae, Tenuitella? danvillensis, Tenuitellinata juvenilis, Pseudohastigerina praemicra, Chiloguembelina* cf. *cubensis, Ch. gracillima, Guembelitria triseriata, Cassigerinella chipolenis*; some Eocene reworking. Agglutinated benthic foraminifera with *Bathysiphon eocenicus, Psammosiphonella cylindrica, Hormosina pilulifer, Ammodiscus cretaceus, A. macilentus, Repmanina charoides, Glomospira gordialis, Haplophragmoides walteri, Cribrostomoides subglobosus, Trochamminoides dubius, T. subcoronatus, Cyclammina* sp., *Karreriella subglabra, Semivulvulina guembeli*; calcareous benthics

OTTENTHAL no.138 farmhouse L. Hauer Planktic Foraminifera Thomasl Formation	RÖ 1-91	RÖ 2-91	RÖ 3-91	RÖ 4-91	RÖ 5-91	RÖ 6-91	RÖ 7-91	RÖ 8-91
Globigerina anguliofficinalis BLOW	x	x	x	x				x
Globigerina brevis JENKINS	x							
Globgerina ciperoensis BOLLI	x				x	cf.		
Globigerina officinalis SUBBOTINA	x	x		x	x	x	x	x
Globigerina ouachitaensis HOWE & WALLACE	x	x	x	x	cf.	x		x
Globigerina praebulloides BLOW	x	x	x	x	x	x	x	x
Globigerinella obesa (BOLLI)	x			cf.	cf.	x		
Subbotina praeturritilina (BLOW & BANNER)	x			x				
Globorotaloides suteri BOLLI	x	x	x	x	x	x	x	
Globorotaloides cf. *testarugosus* (JENKINS)	x							
Paragloborotalia opima opima (BOLLI)	x	x		x	x	x		
Globigerina gnaucki BLOW & BANNER		x	x	x		x	x	x
Globigerinella megaperta RÖGL		x	cf.	x	x	x		x
Paragloborotalia? pseudocontinuosa (JENK.)		x	x	x	x			
Globoquadrina globularis BERMUDEZ		x	x	x	x	x	x	x
Globigerinita juvenilis (BOLLI)		x	x	x				
Tenuitella gemma (JENKINS)		cf.	x	x	x	x		
Globoquadrina winkleri (BERMUDEZ)			x	x		x	x	
Globigerina wagneri RÖGL			x	x		x	x	x
Globigerina labiacrassata JENKINS			x	cf.		x		
Paragloborotalia opima nana (BOLLI)			x	x	x	x		x
Paragloborotalia? semivera (JENKINS)			x	x	x	x	x	
Beella rohiensis (POPESCU)			x	x				x
Pseudohastigerina praemicra (SUBBOTINA)			cf.	x		x		
Cassigerinella boudecensis POKORNY			x					
Globigerina? ampliapertura BOLLI				x				
Subbotina gortanii (BORSETTI)				x	x			x
Subbotina tripartita (KOCH)				x				
Catapsydrax primitivus (BLOW & BANNER)				x	x	x	x	
Catapsydrax pera (TODD)				x	x	cf.	x	x
Tenuitella munda (JENKINS)				x	x	x		
Tenuitella liverovskae (BYKOVA)					x	x		
Globigerina? euapertura JENKINS						x		

Tab. 5: Planktic foraminifera, Thomasl Formation, marls and clays with lenses of sand and gravels, "Sitborice Event", planktic foraminifera zones P 19 to P 20/21 (Ottenthal no. 138, Untere Leithen, farmhouse L. Hauer).

with *Lenticulina* spp., *Laevidentalina acuta, Guttulina hantkeni, Pleurostomella acuta, P. incrassata, Siphogenerinoides vasarhelyi, Stilostomella kressenbergensis, St. emaciata, Palliolatella orbignyana, Pullenia bulloides, P. quinqueloba, Oridorsalis umbonatus, Gyroidinoides girardanus, Hanzawaia ammophila, Cibicidoides pachyderma, Heterolepa eocaena, Linaresia semicribrata.*

Biostratigraphy: nannoplankton zone NP 21, planktic foraminifera: Upper Eocene? to zone P 18.

4.3.2. Thomasl Formation

Ottenthal, Untere Leithen, farmhouse no. 138, Leopold Hauer; section E of Herlicska (1989, p. 91). Outcrop at the eastside of the yard, consisting of grey marls with lenses of black and yellowish sand and clayey silt with interbedded gravels ("Sitborice Event"); in the upper part greenish brown shales with rusty spots and layers of yellowish and black silty clay.

Planktic foraminifera (Tab. 5): Stratigraphically important species are: *Paragloborotalia opima opima, Globigerina ciperoensis, G. wagneri, Subbotina tripartita, Globigerinella megaperta, Beella rohiensis, Globoquadrina globularis, Tenuitella gemma, T. munda, Pseudohastigerina praemicra. Globigerina? ampliapertura* occurs only in the lower part of the section. Biostratigraphy: planktic foraminifera zone P 19 to P 20/21a.

Ottenthal, Untere Leithen, parking place N of house no. 180, family Weinska; section F of Herlicska (1989, p. 125). Brownish clay and banded, laminated, light and dark grey non-calcareous and calcareous shales with a carbonate content of 1–10%, and laminae of silt and fine sand; with fish scales.
Calcareous nannoplankton: massive clay: *Dictyococcites bisectus, Reticulofenestra lockerii, Pontosphaera latelliptica*; laminated shales: *Reticulofenestra lockerii, Pontosphaera latelliptica* (bloom), *P. cornifera, Pontosphaera* sp. Planktic foraminifera: dominated by small globigerinas, *Globigerina officinalis, G. ouachitaensis, G. praebulloides,* together with *Globigerina anguliofficinalis, Tenuitella munda, T. liverovskae, Beella rohiensis*; some Cretaceous to Oligocene reworking with *Chiloguembelina, Pseudohastigerina, Heterohelix.* Benthic foraminifera are very small or juvenile: *Angulogerina* cf. *angulosa, Alabamina?, Bolivina crenulata, B. molassica, B. oligocaenica, Bulimina elongata, Chilostomella ovoidea, Cibicidoides* cf. *ungerianus, C. lopjanicus, Elphidiella subnodosa, Escornebovina cuvillieri, Fissurina* sp., *Fursenkoina mustoni, Melonis affinis, Sphaeroidina bulloides, Uvigerina gracilis, Uvigerinella majkopika, Valvulineria complanata, Virgulinella chalkophila.*

Biostratigraphy: nannoplankton zone NP 23/24; planktic foraminifera zone P 21?

5. MINERALOGICAL INVESTIGATIONS

Along the type section of Ottenthal, the cart road to Klein-Schweinbarth, mineralogical investigations have been carried out (Fig. 5). The results have been correlated to the lithologic section and biostratigraphic zonation by calcareous nannoplankton.

The analysed samples were mainly various shales, partly silty. The heavy mineral composition (Fig. 5b) of the sediments of nannoplankton zones NP 22–NP 23 is characterised by a predominance of garnet, zircon and tourmaline. Subordinately TiO_2 oxides (rutile, anatase/brookite), staurolithe, kyanite, epidote/zoisite are observed. Only as traces hornblende, andalusite, sillimanite occur. The heavy mineral assemblage in the sediments of nannoplankton zone NP 24 is dominated by garnet and subordinately by zircon, TiO_2 oxides, epidote/zoisite. Tourmaline, staurolithe, kyanite, sillimanite and apatite only occur in small amounts. The analysis of insoluble residues showed that sediments of NP 22–NP 23 are enriched by $CaCO_3$ (mean: 25%, up to 67%). The sediments of NP 24 show only a mean of 10%, up to 26%).

The bulk mineralogical composition (semiquantitative XRD-analysis) of sediments of zones NP 22–NP 23 is: 25–85% total clay and mica, 5–50% calcite, 10–25% quartz, traces of feldspar, dolomite and argonite. Typical is the occurrence of clinoptilite (zeolithe). The clay mineral composition is dominated by smectite and illite, and minor kaolinite (Fig. 5a). The sediments of NP 24 have generally a similar composition, but the mineral clinoptilite is absent. Also the abundant occurrence of sulfates (gypsum, bassanite and jarosite) is significant.

6. LITHOSTRATIGRAPHIC UNITS

6.1. Ottenthal Formation

Type area: Waschberg Unit, Lower Austria.
Type section: Ottenthal, Lower Austria, Untere Leithen, cart road to Klein-Schweinbarth (ÖK 1:50 000, margin of sheet no. 10 Wildendürnbach and sheet no. 11 Drasenhofen); extending from 70 m E of the fire-point at Ottenthal no. 169 to the path deviating to the iron wayside crucifix at a length of 80 m (Figs. 1b and 3a). Today the section is overbuilt in the lower part, and along the remaining section partly overgrown and covered.
Coordinates: 48°45'30"N, 16°34'57"E (upper end of the section).
Author: Seifert (1982, p. 139, 158), Ottenthaler Schichten.
Synonymies: Jüttner (1938, p. 96), Bunte Tone, Pausramer Schiefer, and Menilitschiefer; Glaessner (1931, p. 4), Grill (1953, p.80; 1968, p. 43), Niemtschitzer Schichten; Stranik (1997, p. 291), Nemtschitzer Schichtenfolge.
Reference sections: Ottenthal, Lower Austria, section "Waldweg" (ÖK 1:50 000, margin of sheet no. 10 Wildendürnbach and sheet no. 11 Drasenhofen). This parallel section of the type section exposes the different units in a much better preservation, claryfying the succession, and will be accessible continuously. Length of section 55 m (Fig. 3 b).
Coordinates: 48°45'35"N, 16°34'54"E (base of section).
Altruppersdorf, Lower Austria, Staglgraben, north of the Lourdes chapel, in the creek at the water reservoir. The additional outcrop Altruppersdorf, Lower Austria, Staglgraben represents the stratigraphically lowest part of the Ottenthal Formation so far known.
Coordinates: 48°41'45"N, 16°33'29"E.
Lithology: the type section represents a strongly tectonized, partly overturned, and lithologically strongly varying sequence. The parts of the sections belonging to the Ottenthal Formation are defined in Fig. 2. The lithology of the formation consists of light grey to brown marls, brown to dark brown laminated marls and shales, layers of black-

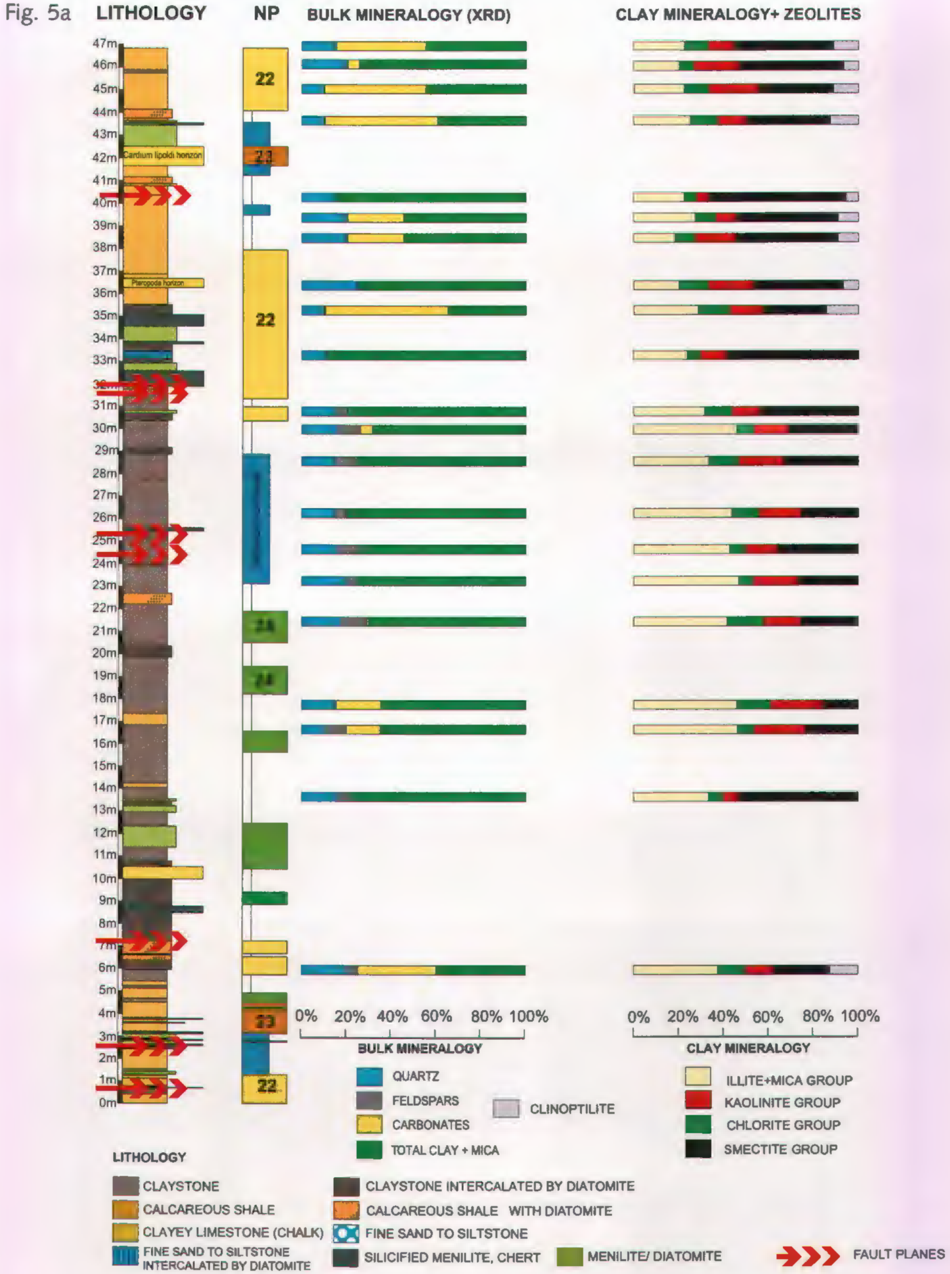
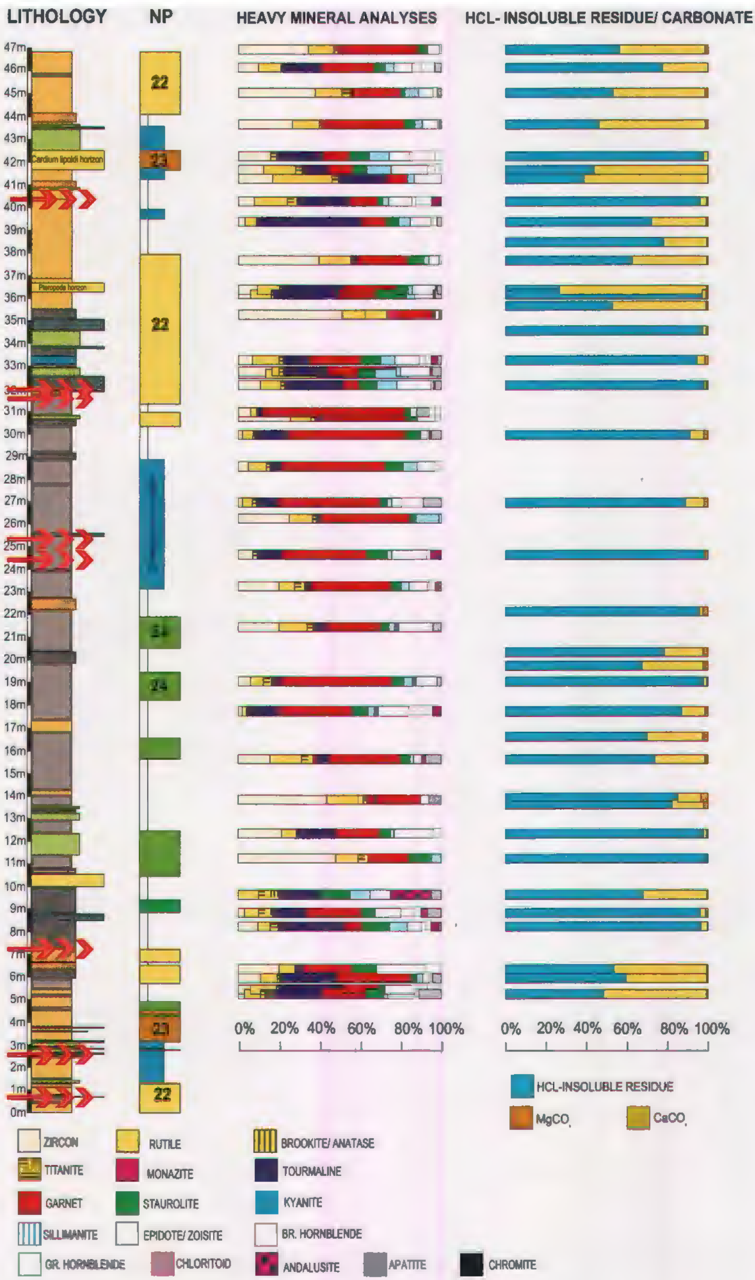


Fig. 5: Ottenthal type section. Cart road at the east side of the village in direction of Klein-Schweinbarth. Real thickness, lithology, biostratigraphy, and mineralogy. Fig. 5a: bulk mineralogy; clay mineralogy and zeolites; Fig. 5b: Heavy minerals; HCl-insoluble residue and carbonate.

Fig. 5b



LITHOLOGY
NP
HEAVY MINERAL ANALYSES
HCL- INSOLUBLE RESIDUE/ CARBONATE
47m
46m
45m
44m
43m
42m
41m
40m
39m
38m
37m
36m
35m
34m
33m
32m
31m
30m
29m
28m
27m
26m
25m
24m
23m
22m
21m
20m
19m
18m
17m
16m
15m
14m
13m
12m
11m
10m
9m
8m
7m
6m
5m
4m
3m
2m
1m
0m
Cardium lipoldi horizon
Pteropoda horizon
22
23
22
24
24
23
22
0% 20% 40% 60% 80% 100%
0% 20% 40% 60% 80% 100%
HCL-INSOLUBLE RESIDUE
MgCO
CaCO
ZIRCON
RUTILE
BROOKITE/ ANATASE
TITANITE
MONAZITE
TOURMALINE
GARNET
STAUROLITE
KYANITE
SILLIMANITE
EPIDOTE/ ZOISITE
BR. HORNBLENDE
GR. HORNBLENDE
CHLORITOID
ANDALUSITE
APATITE
CHROMITE

brown bituminous clays, non-calcareous diatomaceous shales, diatomites, and menilites, and whitish to light grey massive marls (nannofossil-chalk).

Thickness: tectonically reduced, minimum thickness (without repetition) 14–15 m at the type section.

Facies: the present investigation shows a deposition in the deeper water of outer shelf to upper slope, with some transport of microfossils from the shallower shelf. The conditions changed from open marine and aerated sea-floor with pelagic marls to low oxygen bottom conditions due to restricted circulation, and a deposition of alternating laminated marls, shales, and bituminous clay. The production of diatomites with an increasing content of low salinity species is interpreted by the nutrient and silica supply during high run-off periods. The peak of isolation was reached at the deposition of nannoplankton chalk with a higher content of diatoms at reduced salinity conditions, and with the development of the endemic "*Cardium lipoldi*" bivalve fauna.

Subdivision: the Ottenthal Formation is subdivided in the Ottenthal Member, the Galgenberg Member, and the Dynow Marlstone.

Biostratigraphy: the base of the Ottenthal Formation is not exposed; earliest sedimentation is recorded in the reference section at Altruppersdorf within nannoplankton zone NP 21, planktic foraminifera zone P 18 or earlier; upper boundary within nannoplankton zone NP 23.

Chronostratigraphy: Upper Eocene?, Upper Priabonian? to Lower Oligocene, Lower Kiscellian.

Base unit: Reingrub Formation.

Superimposed unit: Thomasl Formation.

Regional distribution: the largest area of the Ottenthal Formation is known in the region of Ottenthal. Additional scattered surface outcrops are known in the surroundings of Ernstbrunn, north of Simonsfeld, north of Loosdorf, near Wultendorf, in the Staglgraben at Altruppersdorf, and in Kautendorf in front of the Staatz Klippe (GRILL, 1953; 1968).

Plate 5

Fig. 1: Ottenthal Member: laminated brown marl with globigerinas; thin-section ds34 (Ottenthal type section).

Fig. 2: Ottenthal Member: brown pteropod marl with thin shells of pteropods and ostracods; thin section ds9 (Ottenthal type section).

Fig. 3: Galgenberg Member: silicified laminated diatomite; thin section ds33 (Ottenthal type section).

Fig. 4: Galgenberg Member: chert layer or menilite, strongly silicified diatomite; thin section ds2 (Ottenthal type section).

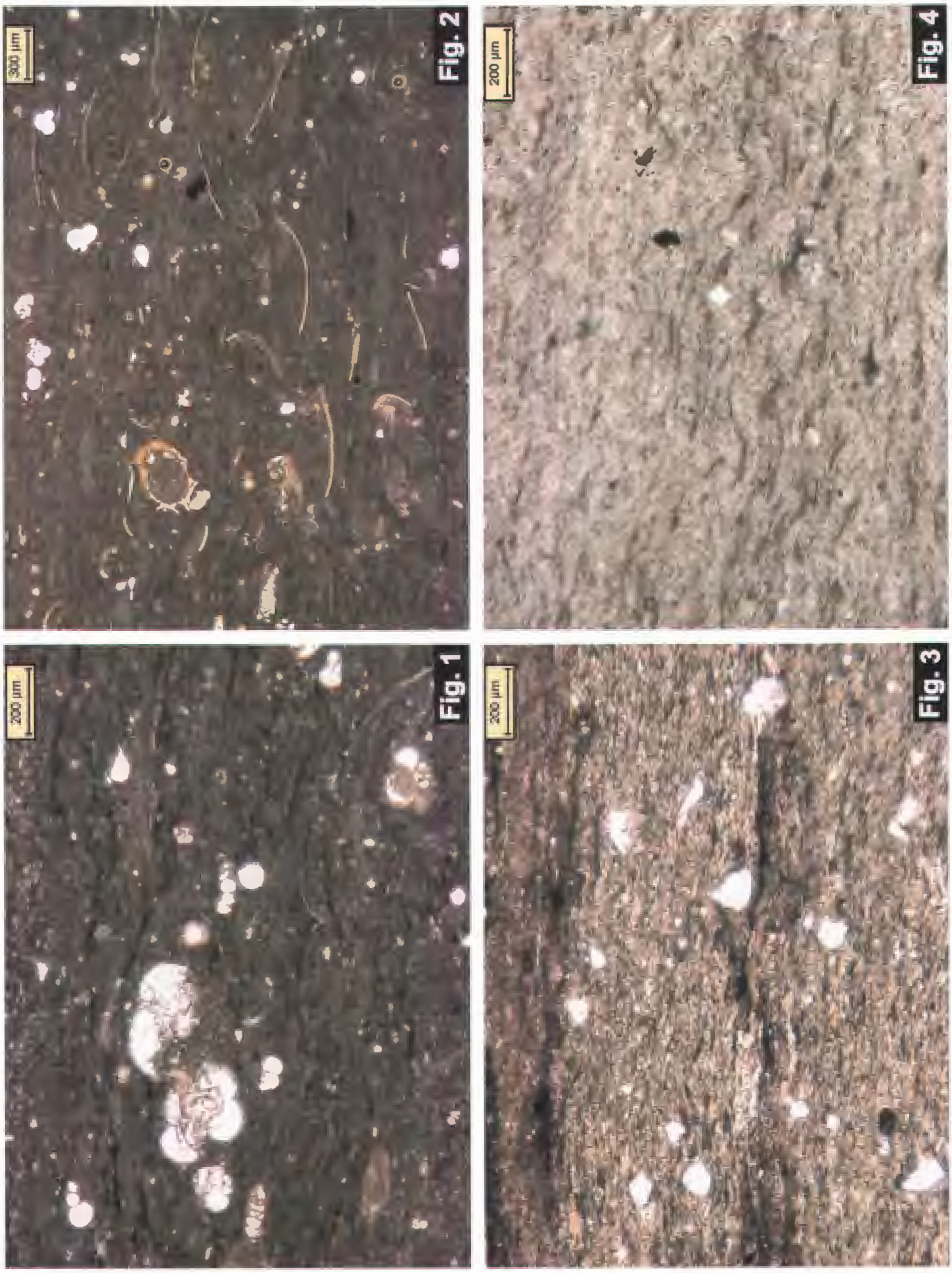


Fig. 2
300 µm
Fig. 4
200 µm
Fig. 1
200 µm
Fig. 3
200 µm

Additional outcrops are mentioned SE of Niederhollabrunn (SEIFERT, 1982), SW Galgenberg near Falkenstein (HERLICSKA, 1989), and SW Simonsfeld (STRANIK, 1997).

Remarks: new investigations in the type section (SEIFERT et al., 1991) and in the parallel "Waldweg" section in the brushwoods (RÖGL et al., 1997) demonstrated a new lithostratigraphic subdivision and more complicated tectonical and paleoecological conditions. The lithologic units in these sections are tectonically imbricated and the different lithologies require a subdivision and revision of the Ottenthal Formation. Parts of the sections have been correlated with the Thomasl Formation of PAPP et al. (1978). The base unit, the Reingrub Formation is not present in the type section. According to STRANIK (1997), SW of Simonsfeld a sequence of Lower Oligocene marls is superimposed on the Upper Eocene "Nemtschitzer Schichtenfolge", corresponding to the Reingrub Formation.

6.1.1. Ottenthal Member

Type area: Waschberg Unit, Lower Austria.

Type section: Ottenthal, Lower Austria, Untere Leithen, cart road to Klein-Schweinbarth (ÖK 1:50 000, margin of sheet no. 10 Wildendürnbach and sheet no. 11 Drasenhofen); measured in real thickness (Fig. 2).

Lower part of the Ottenthal Member: section 0.00–1.25 m and 43.60–47.00 m.

Upper part of the Ottenthal Member: section 1.25–3.10 m, 5.50–7.80 m, 14.00–17.40 m, and 35.50–41.70 m.

Coordinates: 48°45'30"N, 16°34'57"E (end of section).

Reference sections: Ottenthal, Lower Austria, Untere Leithen, section "Waldweg"; sunken road between Ottenthal no. 175 and an iron wayside crucifix. The part 18.20–32.60 m of the section belongs to this member (Fig. 4).

Altruppersdorf, Lower Austria, Staglgraben, north of the Lourdes chapel, in the creek near the water reservoir.

Lithology: the lower part of the Ottenthal Member consists of massive light grey and brown marls ("*Globigerina*-marls"; Pl. 1, Fig.1). The upper part of the Ottenthal Member form light yellowish to dark brown banded and laminated marls and calcareous shales; in a distinct part of the member, black-brown bituminous clay beds are interbedded at regular distances (Pl. 1, Fig. 2). Some layers are rich in fish bones. A horizon of pteropods, and in the upper part, diatomaceous shales are intercalated. Rock forming elements are calcareous nannoplankton and globigerinas (Pl. 1, Fig. 1; Pl. 2, Fig. 1). In thin-sections (Pl. 5, Fig. 1–2) of laminated marls and pteropod marls these sedimentary structures can be observed.

Thickness: reduced by tectonic faults; about 2–4 m of the lower part of the Ottenthal Member are exposed, the upper part comprises more than 6 m of thickness.

Facies: the *Globigerina*-marl facies of the lower part of the Ottenthal Member represents an open marine and euhaline pelagic deposition environment with rich calcareous nannoplankton, large sized benthic and planktic foraminifera. In the upper part of the Ottenthal Member the sedimentation changed to bedded, commonly laminated marls and calcareous shales with silt laminae, and interbedded non-calcareous bituminous clay layers (Pl. 2, Fig. 2). Calcareous nannoplankton has blooms of few species, planktic foraminifera assemblages show dominance of small species, benthic foraminifera are very small and commonly rare. This is interpreted as restriction in open ocean circulation,

stratification of the water column, and reduction of oxygenation of the deep basin. The setting is outer shelf to upper slope.
Biostratigraphy: the base of the Ottenthal Member is not exposed. In the reference section at Altruppersdorf occurs nannoplankton zone NP 21, planktic foraminifera zone P 18; according to the rich planktic fauna and the occurrence of *Turborotalia increbescens*, a Late Eocene age is possible. The upper boundary lies within the upper part of nannoplankton zone NP 22, planktic foraminifera zone P 18/19. The last occurrence of *Tenuitella? danvillensis* correlates with the top of the Ottenthal Member.
Chronostratigraphy: Upper Eocene?, Upper Priabonian? to Lower Oligocene, Lower Kiscellian.
Base unit: Reingrub Formation.
Superimposed unit: Galgenberg Member.
Boundaries: tectonic thrust planes occur within beds of the Ottenthal Member. In a stratigraphically normal position the upper boundary is represented by a transition from calcareous shales (Ottenthal Member) to claystones at the base of the Galgenberg Member. A 10 cm thick layer of non-calcareous silty claystone occurs at the boundary ("Ottenthal-Waldweg" section, 32.60–32.70 m).
Regional distribution: Waschberg Unit around Ottenthal, Altruppersdorf, Ernstbrunn, Simonsfeld, Loosdorf, Wultendorf, Kautendorf, Niederhollabrunn.
Fossil content: in the lower part of the member rich calcareous nannoplankton assemblages are present, with *Coccolithus formosus* as index species of NP 21; planktic foraminifera assemblages are dominated by subbotinids and catapsydracids together with *Globigerina? ampliapertura, Turborotalia increbescens,* and *Pseudohastigerina praemicra*. More agglutinated and larger calcareous benthic species are present in Altruppersdorf than in the Ottenthal sections. In the upper part of the Ottenthal Member occur diversified nannoplankton assemblages with blooms of few species, e.g., *Cyclicargolithus floridanus,* and *Dictyococcites hesslandii*. Planktic foraminifera have blooms of *Globigerina officinalis, G. praebulloides,* and *Tenuitella? danvillensis*. Benthic foraminifera are generally rare and small (below 150 microns), commonly also juvenile, e.g., *Uvigerina oligocaenica, U. gracilis, Angulogerina, Baggina, Biapertorbis, Escornebovina, Cibicidoides.* In the benthic assemblage the occurrence of normal sized *Bulimina sculptilis* in the pteropod horizon is remarkable, which is common in the time equivalent sediments of the Molasse Basin and the Lower Inn Valley.
Pteropods (*"Spiratella" = Limacina*) are common to abundant in a distinct level in the higher part of the Ottenthal Member. Fish teeth, fish bones, fish scales, and otoliths are common throughout the upper Ottenthal Member.

6.1.2. Galgenberg Member

Type area: Waschberg Unit, Lower Austria.
Type section: section D of HERLICSKA (1989, p. 88,), southwest of the small town Falkenstein, W of the Galgenberg (425 m), along the road in direction to the locality Jungfrauföhren (402 m), downhill to Falkenstein, in an old sunken road (Fig. 6). ÖK 1:50 000, margin of sheet no. 24 Mistelbach and sheet no. 25 Poysdorf. The outcrop of the Ottenthal Formation SW of Falkenstein is already mentioned by GLAESSNER (1931, p. 10), and by GRILL (1968, p. 37).
Co-ordinates: 48°42'29"N, 16°34'02"E.

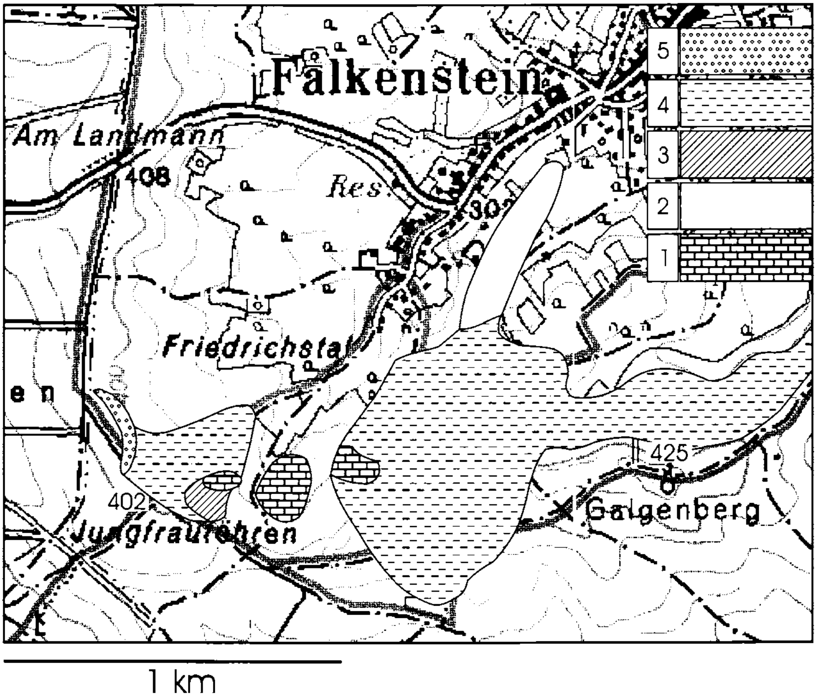


Fig. 6: Geologic map of the Falkenstein area with position of the Galgenberg Member type locality, acc. to Herlicska (1989). ÖK 1:50 000, sheets no. 24 Mistelbach and no. 25 Poysdorf (Bundesamt f. Eich- u. Vermessungswesen, Wien), and geological map 1:75 000 (Grill, 1962).
Explanations: 1. Ernstbrunn Limestone, Upper Jurassic; 2. Klement Formation, marls, Campanian; 3. Ottenthal Formation, Galgenberg Member, silicified diatomite, menilite, and variegated shales, Lower Kiscellian; 4. "Schieferige Tonmergel", sandy shales and sandstones, Eggenburgian-Ottnangian; 5. gravels, Badenian.

Nomination: According to the most prominent hill Galgenberg in the surrounding of the type locality, S of Falkenstein.
Synonymies: The "Menilit Schichten", Chert Member, Menilitic Formation, Menilite and Hornstone Beds as stratigraphic terms are used in the Waschberg Unit and in the Carpathians for the Oligocene sequences with diatomites.
Reference section: "Ottenthal – Waldweg" section, 14.60–18.20 m (wedge IV, wedge V p.p.), 32.60–33.50 m, upper part of tectonic wedge IX, and 33.50–38.15 m, tectonic wedge no.X. Best outcrops of the member including the lower boundary.
Lithology: grey and brown non-calcareous, commonly diatomaceous thin-bedded shales and claystones, light grey laminated diatomites, and at the type locality hard platy diatomites and red-brown laminated cherts (menilites); angle of bedding plane 130°/65° to 160°/65°. The rock surface of the brackish diatomites (Pl. 3, Fig. 1) exhibits coscinodiscids and *Aulacoseira praeislandica* Jouse. In thin sections from the Ottenthal type

section (cart road to Klein-Schweinbarth) a very fine lamination can be observed in silicified diatomites and chert layers (Pl. 5, Fig. 3–4).

Thickness: boundaries commonly thrust-planes, minimum thickness of menilites at the type locality 12 m. In the Ottenthal sections the laminated diatomites are about 4.50 m thick, and the diatomaceous shales and claystones comprise about 1.50 m.

Facies: shales at the base of the Galgenberg Member show normal marine intercalations by the presence of calcareous nannoplankton, foraminifera, and radiolaria in thin layers. The lower part of the diatomites is likewise full marine, whereas in the upper part the conditions change to reduced salinity. Blooms of the brackish diatom species *Aulacoseira* show lowered salinity (about 15 permille), which is supported by corresponding archaeomonad assemblages.

Biostratigraphy: lower boundary: in the "Ottenthal-Waldweg" section, wedge no. V (17.80–20.45 m) is overturned and non-calcareous shales of the Galgenberg Member do not show a sharp boundary to the Ottenthal Member. In thin calcareous shale layers small assemblages of calcareous nannoplankton and planktic foraminifera have been found (*Tenuitella? danvillensis, Chiloguembelina gracillima)*, and give an estimate of the age of the lower boundary (nannoplankton zone: upper NP 22, planktic foraminifera zone P 18/19). At 32.60 m rare and corroded nannofossils *Pontosphaera multipora, Reticulofenestra umbilicus, Isthmolithus recurvus* likewise enable a stratigraphic determination of upper NP 22 for the base of the Galgenberg Member. The upper boundary is in tectonic contact with the Dynow Marlstone. Stratigraphic range: upper NP 22 to lower NP 23 (only approximated by stratigraphic position).

Chronostratigraphy: Oligocene, Lower Kiscellian.

Base unit: Ottenthal Member.

Superimposed unit: Dynow Marlstone.

Boundaries: at the Galgenberg type section the menilite beds are bordered by faults. In the reference section "Ottenthal-Waldweg", on top of a layer of dark greenish brown calcareous clays with gypsum (Ottenthal Member, 32.40–32.60 m), a 10 cm thick brown, silty claystone represents the basal layer of the Galgenberg Member. The upper boundary is a thrust plane at 38.15 m between diatomites and the nannofossil-chalk of Dynow Marlstone, in a normal stratigraphic position.

Fossil content: diatoms have not been studied in detail. In the diatomaceous claystones and in the lower part of diatomites marine diatoms occur, e.g., *Chaetoceros* bristles, *Pyxilla, Actinoptychus, Stephanopyxis, Hemiaulax*, and in the upper diatomites blooms of *Aulacoseira praeislandica* Jouse are observed. The shales with menilites and siliceous clay of the Ottenthal type section contain rich archaeomonad assemblages (Braunstein, 1985), e.g., *Archaeomonas angulosa, A. areolata, A. cratera, A. inconspicua, A. mangini, A. multipunctata, A. striata, Archaeosphaeridium ornatum, Litheusphaerella frenguelli, Pararchaeomonas colligera, Litheusphaerella* sp. and silicoflagellates *Corbisema triacantha, Naviculopsis lata, Dictyocha fibula.* In brackish diatomites occur assemblages of *Archaeomonas dangeardium, A. heteroptera, A. lefeburei, A. pachyceros, A. scrabulata.* Radiolaria (nasselariids), sponge spicules and in a layer a monospecific calcareous nannoplankton flora with *Braarudosphaera bigelowii* was observed, whereas in another horizon a monospecific *Reticulofenestra* aff. *umbilicus* assemblage occurs together with siliceous nannofossils (Ottenthal type section).

Regional distribution: Waschberg Unit around Falkenstein, Ottenthal, Loosdorf, Wultendorf, Kautendorf, and Niederhollabrunn.

Remarks: such terms as "Menilit Schichten" or "Chert Member" do not correspond to a correctly defined lithological unit. Therefore a new member is introduced for the sequence of diatomites, cherts, diatomaceous shales and claystones within the Ottenthal Formation.

6.1.3. Dynow Marlstone

Dynow Marlstone, author: KOTLARCZYK (1979).

This lithologic unit was first described from the Polish Carpathians and is documented now along the entire Carpathian Flysch belt, in the Transylvanian Basin, and also in the Austrian Molasse Basin (the former "Heller Mergelkalk", WAGNER, 1998). A formal lithostratigraphic definition is missing. The lithostratigraphic position of the Dynow Marlstone in the Polish Carpathians, between the cherts of the Kotow Member and the sandstones and menilites of the Rudawka Member is shown by KOTLARCZYK (1988, fig. 8). In the Ottenthal sections the Dynow Marlstone consists of a whitish to light grey marl or marlstone, bedded with 10–20 cm layers, sometimes brown and silicified. This sediment is a silty nannofossil-chalk, made up nearly entirely of calcareous nannoplankton. *Dictyococcites ornatus* and *Transversopontis fibula* are the rock forming elements. In Ottenthal and southern Moravia enrichments of diatoms are observed, which cause the silicification of distinct layers; calcareous nannofossils are commonly dissolved or recrystallized (Pl. 3, Fig. 2). Smooth shelled ostracods (Cyprididae) occur, and also small bivalves, endemic to the Paratethys, e.g., *Cardium (?Loxocardium) lipoldi* ROLLE and *Janschinella melitopolitana* NOSSOVSKY (SEIFERT et al., 1991).

In the Eastern Paratethys this horizon is represented in the Lower Solenovian, as the Polbinka horizon, the Ostracod beds, and the beds with *Ergenica* (POPOV et al., 1993).

Age: Oligocene, Middle Kiscellian, NP 23.

6.2. Thomasl Formation

Thomasl Formation, authors: PAPP, KRÖLL & FUCHS (1978).

This lithologic unit has been described as "Thomasler Schichten" with a stratotype in drill site Thomasl 1 (core 1760–1765 m). The sediment consists of dark grey to black-brown, commonly sandy, somewhat micaceous shale, calcareous shales and dark claystones. Subordinate sandstone layers and siliceous horizons are intercalated. The sequence is tectonically disturbed. In a current revision of the Thomasl Formation (FUCHS et al., this volume) the stratigraphic range is given as Upper Kiscellian to Lower Egerian, nannoplankton zones: uppermost NP 23 to lower NP 25, planktic foraminifera zones: P 19/20 to P 21.

In the Ottenthal sections the lower part of the Thomasl Formation consists of thin-bedded, partly laminated olive-brown shales with layers of fine sand and silt. In the upper part variegated dark shales with a violet tint, rusty spots, yellow veins of jarosite, and with thin sand and silt layers dominate. Gypsum growth is common along bedding planes and in spots. In the lower part exists a horizon with slumps, sand lenses, and pebbles, connected with the "Sitborice Event" (KRHOVSKY & DJURASINOVIC, 1993). A few thicker layers (from 3 to 10 cm) of whitish marl (nannoplankton blooms) are interbedded in the dark shales.

Nannoplankton assemblages yield stratigraphically important markers as *Transversopontis pygmaeus, Sphenolithus distentus, Cyclicargolithus abisectus,* and *Helicosphaera* *recta*; blooms of *Reticulofenestra lockerii* and *Dictyococcites hesslandii* occur. The foraminiferal fauna has assemblages with, e.g., *Globigerina praebulloides*, *G. officinalis*, *G. ciperoensis*, *G. wagneri*, *Globigerinella megaperta*, *Beella rohiensis*, and *Paragloborotalia opima opima*. They are characteristic for the middle part of the Oligocene (Upper Kiscellian – Lower Egerian). The occurrence of *Uvigerina steyri* was used for a correlation with the Puchkirchen Formation (Egerian) in the Upper Austrian Molasse Basin, and for a differentiation from the younger Michelstetten Formation (PAPP et al., 1978). A deep water environment of outer shelf to middle bathyal is proposed as deposition depth, depending on the area within the Waschberg Unit.

7. BIOSTRATIGRAPHIC RESULTS

7.1. Ottenthal Formation

7.1.1. Ottenthal Member

In the lower part of the Ottenthal Member rich assemblages of calcareous nannoplankton and planktic foraminifera are present. In nannoplankton zone NP 21 the LO (last occurrence) of *Coccolithus formosus* defines the top of the zone; discoasters have not been observed. Assemblages of planktic foraminifera include different Upper Eocene to Lower Oligocene species, e.g., *Subbotina linaperta*, *S. cryptomphala*, *S. pseudoeocaena*, together with *Globigerina? ampliapertura*, and *Turborotalia increbescens*. The P 18 biozone may be indicated by *Pseudohastigerina praemicra* (SUBBOTINA), synonymous with *P. barbadoensis* BLOW. But the definition of the top of the zone by the LO of *Pseudohastigerina* spp. (BERGGREN & MILLER, 1988; BERGGREN et al., 1995) is not very useful, as this species has been recorded from nannoplankton zone NP 24 in samples from Zagros Mts. (HAMRSMID & RÖGL, 2000). And acc. to BLOW (1969) *Pseudohastigerina barbadoensis* has a stratigraphic range of P 16–P 19/20? Otherwise a first record of *Cassigerinella chipolensis* with a FO (first occurrence) at the base of the Oligocene (acc. to BOLLI & SAUNDERS, 1985) is recorded in Altruppersdorf. Any Eocene markers as *Hantkenina* or *Turborotalia cerroazulensis* are absent.

In the upper part of the Ottenthal Member the base of zone NP 22 is defined by the disappearance of *Coccolithus formosus*, and the top of the zone by the LO of *Reticulofenestra umbilicus*. In planktic foraminifera assemblages only blooms of few small species occur, and stratigraphically important taxa are rare, but still present: *Globigerina? ampliapertura*, *Pseudohastigerina praemicra*, *Chiloguembelina gracillima*. A zonation of P 18/19 is proposed as subbotinids are rare, and *Chiloguembelina* is still present. For a regional correlation within the Central Paratethys Kiscellian the occurrence of *Globigerina wagneri*, *Globigerinella megaperta*, and *Beella rohiensis* can be used.

Stratigraphic range: Upper Eocene? to Lower Oligocene, Lower Kiscellian, nannoplankton zone: NP 21–22, planktic foraminifera zone: ?Eocene, P 18–19.

7.1.2. Galgenberg Member

The base of the Galgenberg Member is defined by non-calcareous claystones, followed by diatomites. At the top of the Ottenthal Member, concordantly below the basal shales of the Galgenberg Member, an assemblage of calcareous nannoplankton and planktic foraminifera enabled a biostratigraphic determination. Assemblages are similar to those of the upper Ottenthal Member, but reduced in abundance. Planktic foraminifera are not very distinctive with *Chiloguembelina gracillima, Tenuitella liverovskae,* and *T. munda*. The first occurrence of *T. munda* was reported by LI (1987) as P 20, but in the Pouzdrany Unit this species occurs already at the P 18/19 boundary in the middle part of NP 22 (KRHOVSKY & KUCERA, 1994). The only interesting event is the last occurrence of *Tenuitella? danvillenis*, which disappears in Ottenthal at the top of NP 22. For stratigraphic determination only the absence of *Globigerina? ampliapertura* is a not very precise datum, which marks in open marine conditions the base of zone P 20.

The range of the Galgenberg Member is nannoplankton zone: upper NP 22 to lower NP 23?, based on the position between the upper Ottenthal Member and the Dynow Marlstone.

Stratigraphic range: Lower Oligocene, Lower Kiscellian, upper NP 22–lower NP 23?

7.1.3. Dynow Marlstone

Biostratigraphic determination is possible only by calcareous nannoplankton. In these marls occur blooms of few species, predominantly *Dictyococcites ornatus* together with *Transversopontis fibula, Dictyococcites bisectus, Zygrhablithus bijugatus* and *Pontosphaera multipora.* A determination of nannoplankton zone NP 23 is given by approximation of these regional blooms.

Stratigraphic range: Lower Oligocene, Lower Kiscellian, NP 23.

7.2. Thomasl Formation

The lower part of this formation belongs still to nannoplankton zone NP 23. The zonation is based on the occurrence of *Transversopontis pygmaeus* which is considered as a marker of NP 23–24. Blooms of *Reticulofenestra lockerii* are characteristic. In the upper part, NP 24 is determined by the occurrence of *Sphenolithus distentus, Dictyococcites bisectus, Helicosphaera recta, Cyclicargolithus abisectus*, together with blooms of *Reticulofenestra lockerii* and *Dictyococcites hesslandii.*

In planktic foraminifera assemblages, the absence of *Globigerina? ampliapertura* and *Tenuitella? danvillensis* are remarkable. There are still very rare *Pseudohastigerina.* The occurrence of *Paragloborotalia opima opima* together with *Chiloguembelina* indicates an age not younger than P 21a in the Ottenthal sections.

Stratigraphic range in the Ottenthal sections: Lower to Middle Oligocene, Upper Kiscellian, upper NP 23–NP 24, planktic foraminifera P 19/20–P 21a.

An overview of important events and stratigraphic results of the sections at Ottenthal are given in Figs. 2 and 4. Biostratigraphically and paleoecologically important planktic foraminifera as well as various bio-events characterise the lithostratigraphic units. The investigated sections and formations comprise the Upper Eocene? to Lower Oligocene, corresponding to the Upper Priabonian?, Rupelian, and Lower Chattian. In the regional

Central Paratethys stage system (comp. RÖGL, 1998) the Ottenthal Formation belongs to the Upper Priabonian? and Lower Kiscellian (nannoplankton zones: NP 21 to NP 23; planktic foraminifera: Eocene?, P 18 to P 19); the Thomasl Formation has a range from Upper Kiscellian to Lower Egerian. In the Ottenthal sections the range of the Thomasl Formation is restricted to upper NP 23–NP 24, P 19/20–P 21a, whereas the total range of the formation extends up to NP 25, lower P 22? (FUCHS et al., this volume)

8. PALEOENVIRONMENTAL INTERPRETATION

8.1. Ottenthal Formation

In the definition of the "Ottenthaler Schichten" (SEEIFERT, 1982) a deposition on the inner shelf and littoral region of the Bohemian Massif with some input of crystalline rocks and Cretaceous sediments was considered. The coaly layers, brackish diatomites, nannofloras, gypsum growth were interpreted as nearshore lagunal deposits in a quiet environment. The nannoplankton assemblages with strong changes between normal marine and brackish, indicated by blooms of *Braarudosphaera bigelowii*, the fish remains, few ostracods, sponge spicules, and poor assemblages of globigerinas in distinct layers were interpreted to characterise extreme environmental conditions. Sedimentation and environment of the "Ottenthal Beds" are re-interpreted according to the different lithologic units.

8.1.1. Ottenthal Member

The lower part of the Ottenthal Member with a *Globigerina*-marl facies shows high diversity assemblages of calcareous nannoplankton and euhaline foraminifera with rich plankton and diverse benthos of outer shelf to upper slope. The benthic assemblages, with a greater percentage of agglutinated deep-water species in Altruppersdorf, are interpreted as deposited on the upper slope.

In the upper part of the member, connected with the changing lithology of laminated and banded marls and clays a distinct change in microfossils occurs. Abundant calcareous nannofossils in the light coloured marls of NP 22 suggest normal hemipelagic conditions. Otherwise the complete absence of discoasters, helicospherids, chiasmoliths, sphenoliths, *Cyclicargolithus floridanus*, and *Dictyococcites hesslandii* show ecological stress. The beginning restriction of the Paratethys from open ocean circulations in Early Kiscellian/Pshekian time, together with the influx of boreal waters and/or seasonal fluctuations in salinity are considered as the cause of the change. Planktic foraminifera are similarly influenced by palecological conditions, most probably also cold water, and show blooms of single or only few small species (*Globigerina officinalis, G. ouachitanesis, G. praebulloides*). The floods of *Tenuitella? danvillensis* is of special interest, as it was considered primarily as a Late Eocene element in the southern hemisphere (described by JENKINS, 1971, as *Globorotalia aculeata*). The mass occurrences of pteropods (*"Spiratella"= Limacina*) has been interpreted as influx of cold boreal waters (SEIFERT et al., 1991, p. 119). Restricted bottom circulation and low oxygen are evidenced by the absence of bioturbation in laminated sediments, and by benthic foraminiferal assemblages of small size (mainly below 150 µm) of predominantly *Bolivina, Uvigerina, Trifarina*. In low numbers constantly are present cassidulinids, *Escornebovina, Biapertorbis, Heronallenia*. Strongest ecologic stress can be supposed at time of deposition of low calcareous to non-calcareous, dark brown bituminous clays. Only poor assemblages of dissolution resistant coccoliths occur there (e.g., *Coccolithus pelagicus, Dictyococcites bisectus, Pontosphaera multipora, Reticulofenestra umbilicus, Isthmolithus recurvus*). Secondary gypsum in brown clays suggests selective dissolution of coccoliths. Quantitative differences in thanatocoenoses of lithologically distinct 1–2 mm thick laminae are presented in Tab. 3. In the upper part of the Ottenthal Member, the deposition of banded marls with a regular repetition of dark bituminous clay is considered to be caused by orbital cycles, and to express an increase of seasonality and cooling in the Lower Oligocene (comp. KRHOVSKY, 1995).

8.1.2. Galgenberg Member

In the shales near the base of the Galgenberg Member thin layers with calcareous nannoplankton and planktic foraminifera show short normal marine episodes. The benthic assemblage is still rather small but diversified, additionally with rare larger forms, e.g., *Anomalinoides granosus, Cibicidoides mexicanus, Uvigerina moravia*. In the basal Galgenberg Member radiolaria (nasselariids) occur in a non-calcareous shale layer. In a similar position of alternating calcareous shales and diatomites, radiolaria (*Nasselaria*) have been reported from the top of the Pouzdrany Formation (KUCERA, 1994).

In the stratigraphically older part of the laminated diatomites, marine diatoms and silicoflagellates occur, e.g., *Chaetoceros* bristles, *Pyxilla, Actinoptychus, Stephanopyxis, Hemiaulax*. In the upper part blooms of *Aulacoseira praeislandica* show lowered salinity, with a gradual transistion of marine to brackish diatomites. Similar results of reduced salinity show the archaeomonads in diatomites with yellowish intercalations, with *Archaeomonas dangeardium, A. heteroptera, A. lefeburei, A. pachyceros, A. scrabulata*. The occurrence of a monospecific flora of *Braarudosphaera bigelowii* in shales of the Ottenthal type section may correspond to such an event of reduced salinity.

The general absence of calcareous fossils in this member is interpreted as a reduction of salinity below the tolerance level of calcareous nannoplankton and foraminifera. Beside the disconnection of the Paratethys from open ocean circulation, an increase in precipitation and high run-off may have caused a freshwater overflow, stratification of water masses, and intensive supply of land-derived silica (KRHOVSKY et al., 1993). This resulted in a bloom of diatoms, a continuously decreasing salinity at the surface, and anoxic bottom conditions with laminated sediments.

8.1.3. Dynow Marlstone

Reduced salinity and high nutrient content are inferred for low diversity calcareous nannoplankton assemblages characterised by blooms of *Dictyococcites ornatus* and the occurrence of *Transversopontis fibula* (KRHOVSKY, 1981; NAGYMAROSY, 1991). Foraminifera are absent in this unit, demonstrating abnormal probably dysaerobic bottom conditions and surface salinity below the tolerance of globigerinids. The deposition of the Dynow Marlstone marks the time of strongest Oligocene Paratethys isolation with small endemic bivalves and ostracodes from the Austrian Molasse Basin to Transcaucasia, the so-called Solenovian horizon (Popov et al., 1993).

8.2. Thomasl Formation

A distinct environmental change occurred between the deposition of the Dynow marlstone and of the Thomasl Formation, with a return of normal marine conditions. In the lower part of the Thomasl Formation, calcareous nannoplankton of laminated shales shows blooms of *Reticulofenestra lockerii* and *Pontosphaera latelliptica*, deposited during short dry periods with low run-off and almost normal marine salinity. Horizons with predominantly small plankton occur, and gradually normal growth size and large species become common (e.g., *Globigerina wagneri, Globigerinella megaperta, Paragloborotalia opima opima, Beella rohiensis, Globorotaloides, Catapsydrax*). In the upper part of the "Waldweg" section three thicker layers of nannofossil-chalk occur, which have similarities with such layers in South Moravia and with the Jaslo/Zagorz Limestones in the Polish-Rumanian Carpathians (Krhovsky & Djurasinovic, 1993; Haczewski, 1989). Foraminifera are similarly restricted to some horizons, but sometimes the occurrence is depending on dissolution processes, with the preservation of agglutinated benthics. Size of benthic foraminifera is still smaller in comparison with time-equivalent faunas of the Molasse Basin but assemblages are of high diversity. The common occurrence of *Lenticulina, Neugeborina, Nodosaria, Stilostomella, Pleurostomella, Gyroidinoides, Cibicidoides* shows better oxygenated bottom conditions. Otherwise the high content of *Bulimina, Bolivina,* small uvigerinas, and in other samples agglutinated *Miliammina* and *Repmanina* indicate further existing conditions of oxygen deficiency. Deposition depth is outer shelf to upper slope. A similar increase of faunal diversity and oxygenated bottom waters has been observed in the Kiscell Clay in Hungary and in the lower Vima Formation in Transylvania (Upper Kiscellian).

9. CORRELATION WITH SOUTHERN MORAVIA AND THE MOLASSE BASIN

The Pouzdrany and Zdanice Units in South Moravia were deposited on the continental slope of the southeastern margin of the Bohemian Massif, and sheared off from the basement similarly as the Waschberg Unit. An exact correlation of the different formations is hindered by facies changes within the same basin (Fig. 7).

The lower part of the Ottenthal Member (NP 21) is similar in facies to the lower and middle part of the Pouzdrany Formation and to the Sheshory Marl of the Nemcice Formation of the the Zdanice Unit. The banded marls of the Ottenthal Member (NP 22) are present in the "Subchert member" of the "Menilitic formation" of the Zdanice Unit, where the upper part is silicified. In the Pouzdrany Unit the correlative part of the Pouzdrany Marl (Upper Pouzdrany Formation) shows a rapid change from banded marls to brown marls and diatomaceous clays. The pteropod horizon presents a good correlation level in the banded marls of all units.

The Galgenberg Member begins with non-calcareous shales with thin layers of silicified claystone, which correlate with both south Moravian units, at the beginning of the Uhercice Formation and at the base of the "Chert member". On top of the

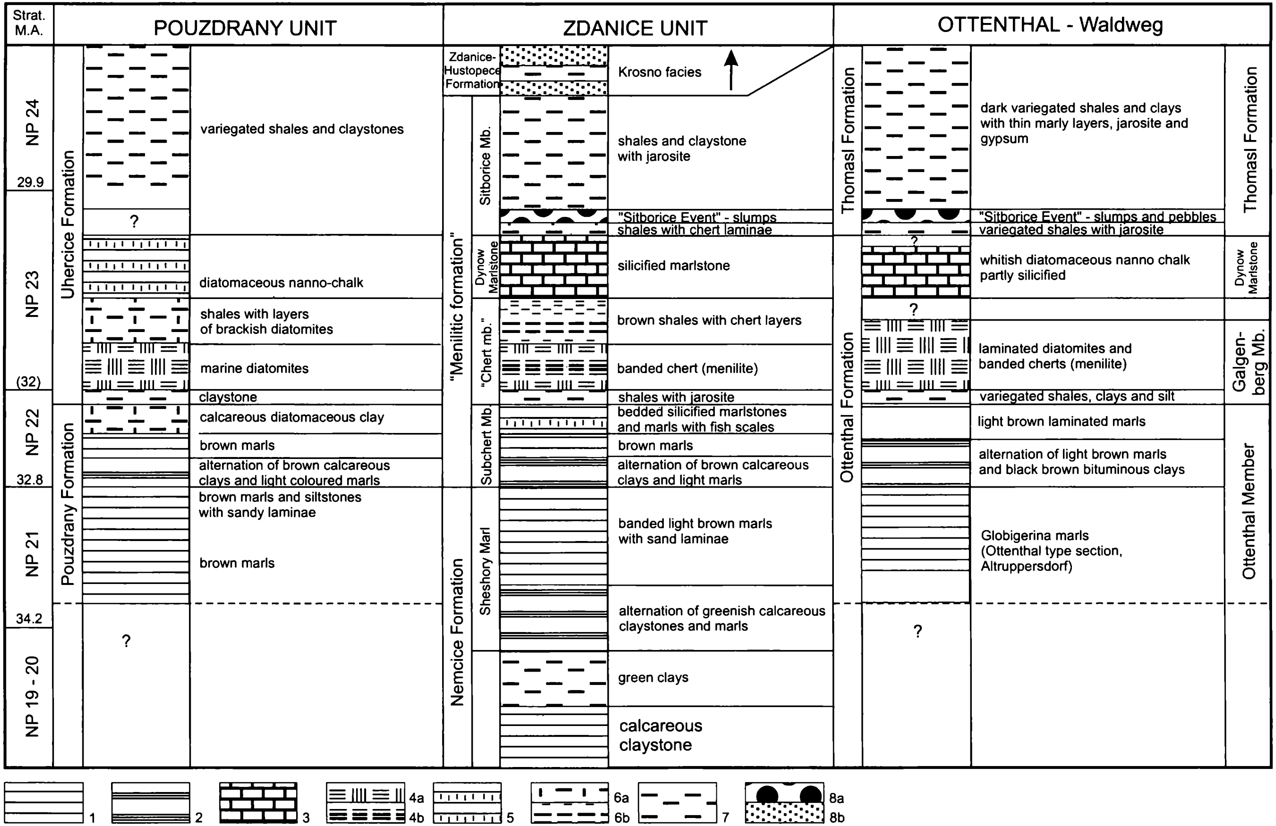


Fig. 7: Lithostratigraphic correlation between the Pouzdrany and Zdanice Units and the Ottenthal – "Waldweg" section. Explanations: 1. marl and calcareous shales; 2. alternation of banded marl and bituminous clay; 3. nannofossil-chalk; 4a. diatomite; 4b. chert/menilite; 5. diatomaceous chalk and silicified marl; 6a. diatomaceous shales and claystone; 6b. shales with chert layers; 7. shales, claystone and clay; 8a. slumps and pebble layers; 8b. sandstones and sand.

claystones follow diatomites which are diagenetically altered to cherts (menilites) in the Zdanice Unit. In the Ottenthal sections the contact between diatomites and the superimposed nannofossil-chalk of Dynow Marlstone (NP 23) is tectonic. This member is silicified in the Zdanice Unit, whereas in the Uhercice Formation of the Pouzdrany Unit almost pure nannofossil-chalk and diatomaceous chalk are developed. Also the upper boundary of the Dynow Marlstone is bordered by faults in the Ottenthal sections. Therefore an erosional surface as in the Zdanice Unit has not been observed. An erosion of the Dynow Marlstone is documented by pebble layers within the lower Thomasl Formation (Sitborice Event). Up-section the sedimentation in all areas is more pelitic, the basal part of the Thomasl Formation and the Sitborice Member are characterised by slumps and pebble layers. The variegated shales are predominantly non-calcareous, with thin laminae of calcareous nannoplankton (uppermost NP 23–NP 24), and with diatomaceous shales and cherts (menilite). Three beds of nannoplankton have been observed in the "Ottenthal-Waldweg" section, similar to such layers in the Sitborice Member (Krhovsky & Djurasinovic, 1993). The contact to the Upper Oligocene, probably Michelstetten Formation has not been recorded. In the Zdanice Unit, locally exists a gradual transition to the flyschoid Zdanice-Hustopece Formation, in other places slumps, sands, and conglomerate horizons are developed.

In comparison with the Molasse Basin (comp. Wagner, 1998) the occurrence of Dynow Marlstone is of the most striking similarity which comprises there a thickness up to 15 m. The basal Oligocene of the Schöneck Formation (NP 21–22) consists of black shales and marlstones with fish remnants ("Fischschiefer"). Foraminifera are restricted to distinct horizons, and laminated shales indicate the absence of bioturbation and dysaerobic bottom conditions in some parts. Diatomites and menilites below the Dynow Marlstone are missing in the Molasse Basin. On top of the Dynow Marlstone follow with interfingering lithology the banded and laminated shales and marls of the Eggerding Formation. Also here nannoplankton blooms of few species in thin laminae are common (e.g., *Cyclicargolithus floridanus, C. abisectus;* NP 23–24). The hemipelagites and distal turbidites of the Zupfing Formation (NP 23–24) in the south have an increasing content of nannoplankton cemented in limestone layers. In the shallower Ebelsberg- and Eferding Formations (NP 25) the pelitic content predominates, bioturbation is common, indicating a better aeration of the sea bottom. Rich planktic and benthic assemblages, comparable to those of the Kiscell Clay in Hungary are present. Along the active slope of the Molasse Basin coarse sediments with turbidites, contourites and mass flows occur (Deutenhausen and Puchkirchen Formations), not to compare with the sedimentation of the Waschberg Unit. The Oligocene development of the Waschberg Unit demonstrates a strong relation to the Outer Carpathian Flysch. The position of the Waschberg Unit as an allochthonous Molasse unit should be re-considered.

A comparison of the Ottenthal section with comparative sequences in northern Hungary was presented by Seifert et al. (1991). In the Hungarian Paleogene basin a reduction of salinity occurred already during NP 22 at the time of deposition of the Tard Clay. The "*Spiratella*"-horizon and the *Cardium lipoldi*-fauna are recorded in the sections of the Tard Clay. The Thomasl Formation is time equivalent with the uppermost Tard Clay and with the Kiscell Clay, but of different lithology.

10. CONCLUSIONS

The present research of sections at Ottenthal has demonstrated, that it is necessary to revise and subdivide the "Ottenthaler Schichten" of SEIFERT (1982). The new section "Ottenthal-Waldweg" resolved some problems encountered along the type section. All sequences are strongly tectonized, thereby presenting the lithologically different facies types faulted in small wedges, and in tectonical contact, also partly overturned. By detailed micropaleontological investigation and by comparison of the facies types with the Pouzdrany and Zdanice Units in southern Moravia a differentiation of distinct formations and members was possible.

The former Ottenthal Beds are subdivided in the Ottenthal and Thomasl Formations. Within the Ottenthal Formation three members are distinguished. The Ottenthal Member consists of two lithologically different parts. The lower part consists of massive or bedded *Globigerina*-marls (NP 21) with rich euhaline nanno- and microfossil assemblages. In the upper part laminated and banded marls with dark bituminous clay layers are developed (NP 22). The microfossils demonstrate a distinct change from open marine conditions to a semi-enclosed Paratethys basin, with blooms of only few species of planktic foraminifera, and with stress resistent calcareous nannoplankton. The bottom conditions are partly dysaerobic with a strong reduction of benthic foraminifera. A Paratethys wide horizon of pteropods (*"Spiratella"* = *Limacina*) was recorded within the laminated sequence in both sections.

A gradual change from calcareous to siliceous bioproductivity is observed in the basal shales (upper NP 22) of the Galgenberg Member. The deposition of marine diatomites follows which is gradually replaced by low salinity diatomites. Silicification into bedded cherts is rare in the Ottenthal sections. Lamination and absence of calcareous fossils is interpreted by restricted open marine circulation and simultaneous climatic deterioration with strong precipitation, stratification of the water column, low salinity surface waters, and dysaerobic bottom conditions. The salinity of surface waters was still reduced during the production of the nannofossil-chalk of the Dynow Marlstone. The sediment was produced by blooms of *Dictyococcites ornatus* and *Transversopontis fibula* (NP 23). The characteristic horizon of small endemic Paratethys bivalves (*Cardium lipoldi*-fauna, Solenovian horizon) was found in the Dynow Marlstone of the Ottenthal type section.

Within the Ottenthal sections a sedimentary contact with the overlying Thomasl Formation is not recorded. At the base, slumps, sands and gravels mark the "Sitborice Event" (KRHOVSKY & DJURASINOVIC, 1993). The mineralogical research showed a distinct change of heavy mineral composition between the Ottenthal and the Thomasl Formations. The tourmaline-zircon-garnet dominance in the Ottenthal Formation was replaced by a dominance of garnet. And the zeolithe mineral clinoptilite is only present in the Ottenthal Formation.

The dark variegated shales of the Thomasl Formation have some calcareous layers, mainly thin nannoplankton laminae with blooms of few species, e.g., *Reticulofenestra lockerii, Dictyococcites hesslandii* (upper NP 23 to NP 24). Also thicker marl layers (3 to 10 cm) rich in calcareous nannofossils are present. Alternations of calcareous and non-calcareous layers show the sensitivity of the ecosystem to small climatic fluctuations. Planktic assemblages consist of alternating small and large sized species. Benthic foraminifera are present in some layers, and show a return to nearly normal marine conditions. The environment is interpreted as outer shelf to upper bathyal. Compared with the Thomasl type section, the latter reflects a deeper, upper to middle bathyal deposition depth.

Summarizing, the environmental conditions of the Oligocene of the Waschberg Unit are influenced by the restriction of open oceanic communication of the Paratethys caused by tectonic acitivities and sealevel changes. There is also a strong influence of orbital cycles and climatic changes (KRHOVSKY, 1995). In the upper part of the Ottenthal Member, the sequence of more or less regularly alternating marls and bituminous clays seems to be influenced by productivity changes. In the case of influence by orbital cyclicity, the marl layers are deposited during drier periods with stronger seasonality, increased oceanic circulation, higher nutrient content in the photic zone, and higher productivity. Floods of small planktic foraminifera point to lower temperatures and seasonally fluctuating ecological stress. The bituminous and dark brown laminated clays in contrast are considered as deposits of wetter climate periods with slightly lowered seasonality. Higher run-off led to an estuarine circulation type, decreased surface salinity, stratified water column, and dysaerobic bottom conditions. Productivity of calcareous nanno- und microfossils decreased, CCD was in a higher position. In dry phases of the climatic cycle with higher seasonality, increased silica supply caused a high production of diatoms.

The Dynow Marlstone may be deposited during a next drier period, but in the upper diatomaceous part of the nannofossil-marls increased run-off and reduced surface salinity happened again. The "Sitborice Event" in the lower Thomasl Formation may be a consequence of the sea-level fall at the TA 4.4–TA 4.5 boundary (HAQ et al., 1988).

In a comparison of lithology and fossil assemblages a correlation with the Pouzdrany and Zdanice Units in South Moravia was possible. Some similarities with both or one of those units show different deposition areas in the same Outer West Carpathian Flysch Sea. A correlation with the Austrian Molasse Basin is possible by biostratigraphy, but sedimentary sequences are different. Only the extreme environment of the Dynow Marlstone extended over both sedimentary regimes.

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