OBITUARY FOR THE WALSERBERG SERIES IN THE CRETACEOUS OF THE EASTERN ALPS (AUSTRIA, GERMANY)

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KEYWORDS

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ABSTRACT

New biostratigraphic investigations based on calcareous nannoplankton and dinoflagellates cysts indicate that the „Walserberg Series“ near Salzburg comprises deposits from the Upper Aptian to the Mid-Campanian. Generally, deposition took place below the CCD. The major part of the sedimentary succession displays no similarities with coeval deposits of the Northern Calcareous Alps, but can be readily correlated with the Rhenodanubian Group of the Penninic Basin (Rehbreingraben Formation, Lower Varicoloured Marlstone, Reiselsberg Formation, Seisenburg Formation, Kalkgraben Formation, Hällritz Formation). Only one outcrop containing glaucophane bearing sandstone cannot be integrated into the Rhenodanubian Group and might be an equivalent of the Branderfleck Formation of the Northern Calcareous Alps. In any case, the term “Walserberg Series” can be abandoned.

Neue biostratigraphische Untersuchungen mit kalkigem Nannoplankton und Dinoflagellatenzysten belegen, dass der stratigraphische Umfang der “Walserberg-Serie” bei Salzburg vom Ober-Aptium bis mindestens in das Mittel-Campanium reicht. Alle beprobten Sedimentgesteine wurden unterhalb der Kalzitkompensationstiefe abgelagert. Der Großteil der Schichtfolge hat keinerlei Ähnlichkeiten mit altersgleichen Ablagerungen der Nördlichen Kalkalpen, sondern zeigt gute Übereinstimmung mit den Formationen der penninischen Rhenodanubischen Gruppe (Rehbreingraben-Formation, Untere Bunte Mergel, Reiselsberg-Formation, Seisenburg-Formation, Kalkgraben-Formation, Hällritz-Formation). Lediglich Glaukophan-führende Sandsteine eines Aufschlusses passen nicht in die Schichtfolge der Rhenodanubischen Gruppe und könnten der kalkalpinen Branderfleck-Formation nahestehen. In jedem Fall kann der Name „Walserbergserie“ aufgegeben werden.

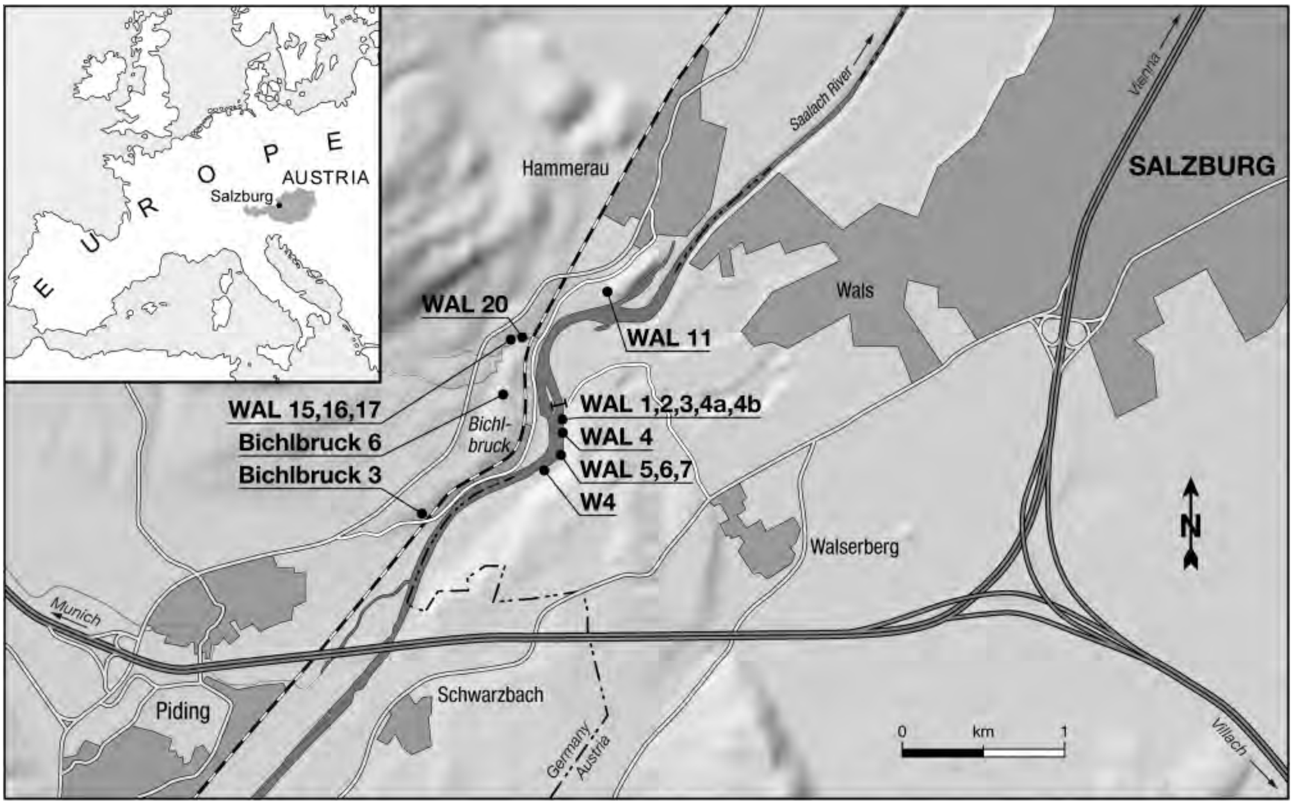


FIGURE 1: Sketch map showing the positions of sample locations. With the exception of samples WAL5, 6, 7 (Branderfleck Formation of the Northern Calcareous Alps?) all samples can be attributed to the Rhenodanubian Zone.

1. Introduction

The term “Walserberg Series” was introduced by Prey (1968) for a tectonically dismembered turbidite succession outcropping along the banks of the Saalach river in the Walserberg area near Salzburg (Fig. 1). The succession lies between the Northern Calcareous Alps to the south, and the Rhenodanubian Zone to the north. Prey (1969, 1980) assigned the “Walserberg Series” to the Albian to Turonian “Randcenoman” of the Northern Calcareous Alps (NCA). Faupl (1984) recognized the deep-water origin of these deposits and discussed their derivation from a more southerly part of the NCA, assuming them to be equivalent to the Branderfleck Formation. The interpretation of the “Walserberg Series” as an element of the NCA was also used in the geological map of Germany (Ganss et al., 1988) and the new geological map of the State of Salzburg (Braunstingl et al., 2005).

In other palinspastic reconstructions, the “Walserberg Series” is derived from the Lower Austroalpine realm (Woletz, 1967)

Figure 2: Sedimentary facies at some sample locations. 1) Upper Aptian (Wal 1,2,3,4a,4b); 2) Middle to lower Upper Cenomanian (Wal 20); 3) ? Upper Cenomanian to Turonian (Wal15,16,17); 4) Santonian (Bichlbruck 3/09); 5) Lower Campanian (Wal 4); 6) Lower Campanian (Bichlbruck 6/09).

or the South Penninic realm (Oberhauser, 1968). Apart from a few biostratigraphic data indicating the Albian to Turonian, the main argument for all paleogeographic assignments of the "Walserberg Series" are based on remarkable heavy mineral assem-

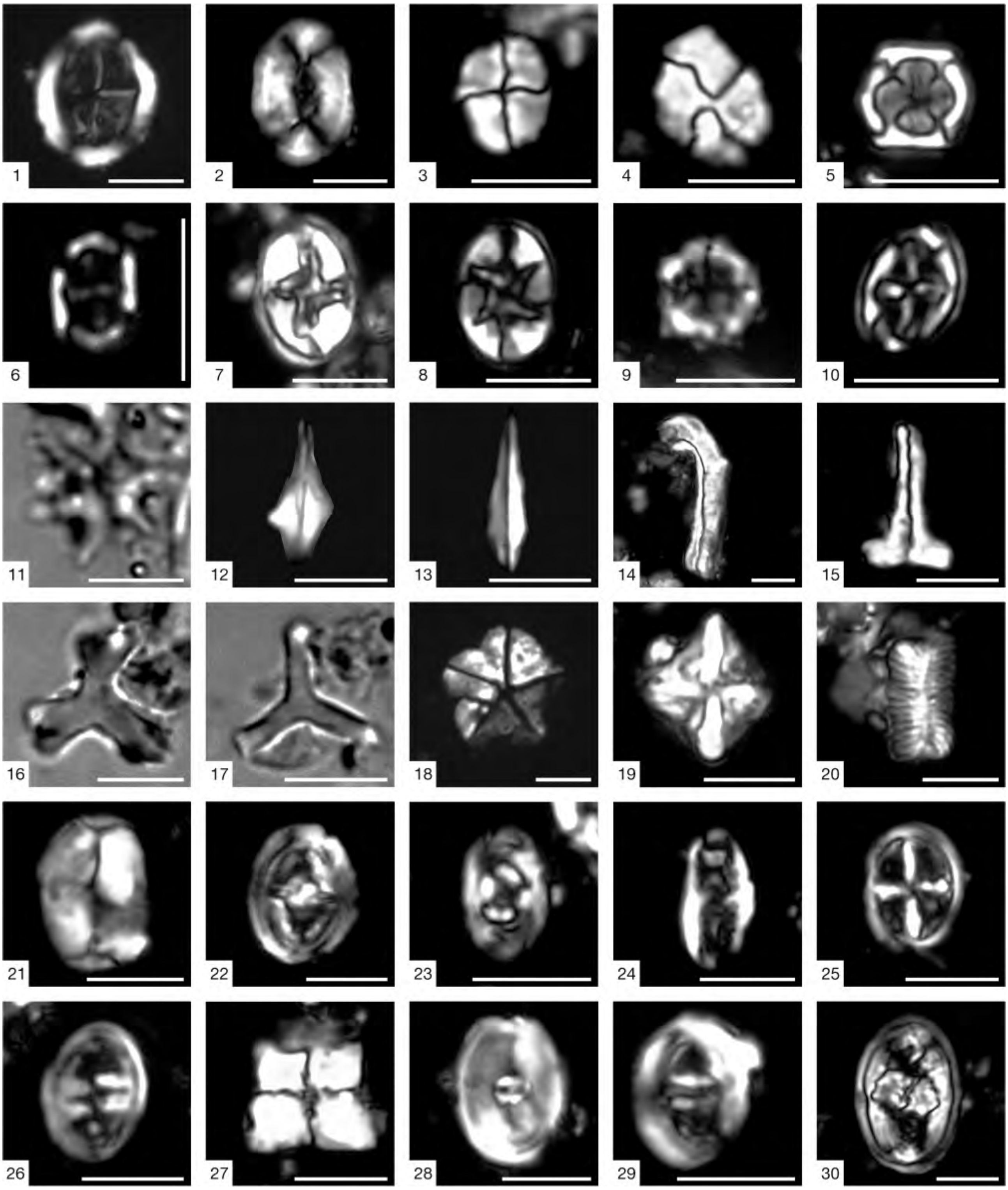
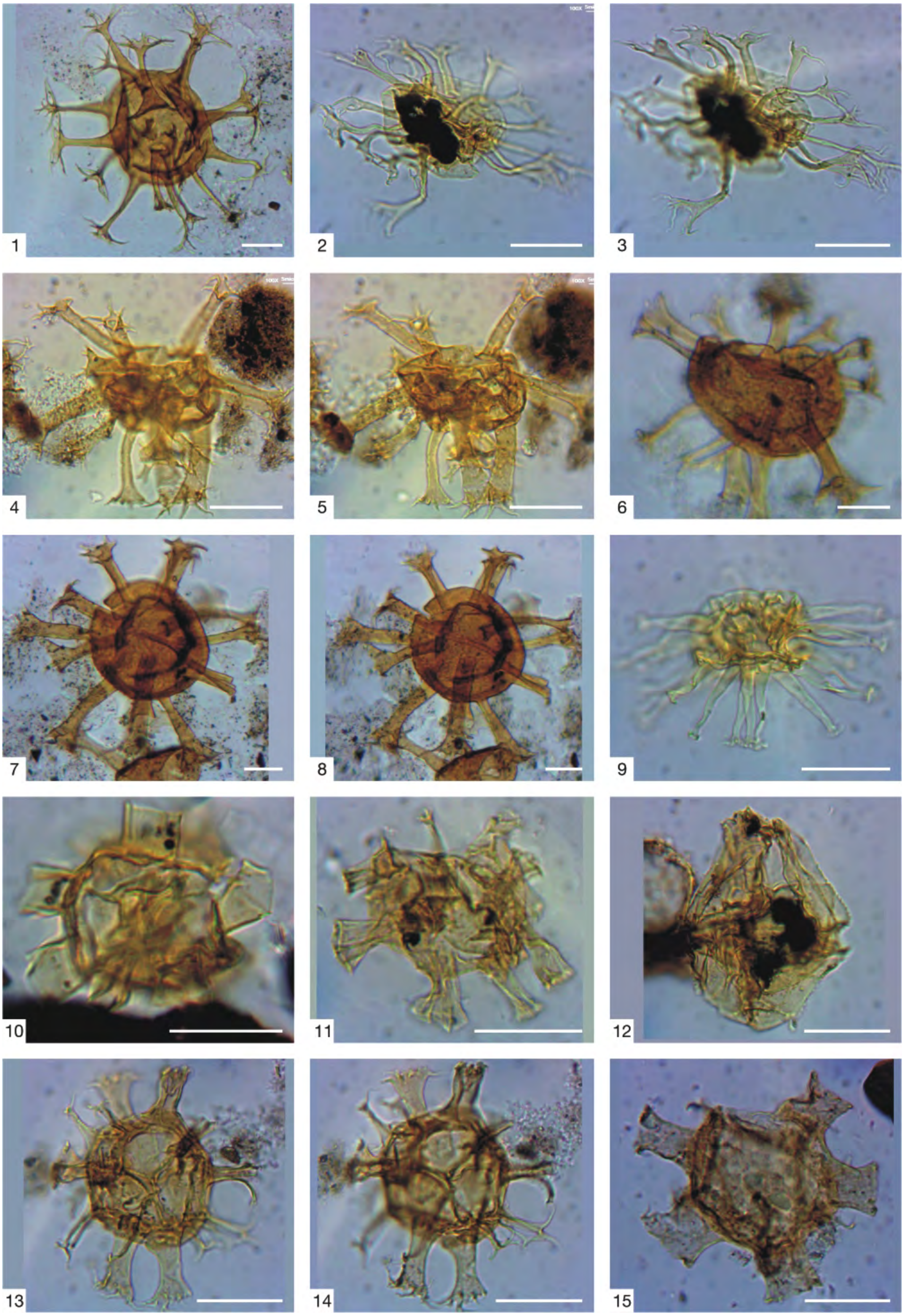


Figure 3: 1. *Arkhangelskiella cymbiformis* (Wal11/12), 2. *Broinsonia parca constricta* (Bichlbruck6), 3. *Calculites ovalis* (W4), 4. *Calculites obscurus* (Bichlbruck6), 5. *Corollithion kennedyi* (Wal20), 6. *Corollithion signum* (W4), 7. *Eiffellithus eximius* (Wal4), 8. *Eiffellithus turriseiffelii* (Wal20), 9. *Eprolithus floralis* (Wal20), 10. *Helicolithus compactus* (W4), 11. *Lithastrinus grillii* (W4), 12. *Lithraphidites acutus* (Wal20), 13. *Lithraphidites alatus* (Wal20), 14. *Lucianorhabdus cayeuxii* (W4), 15. *Lucianorhabdus maleformis* (W4), 16. *Marthasterites furcatus* (W4), 17. *Marthasterites simplex* (W4), 18. *Micrantholithus obtusus* (Wal4b), 19. *Micula staurophora* (Wal4), 20. *Nannoconus elongatus* (W4), 21. *Orastrum campanense* (Bichlbruck 6), 22. *Reinhardtites anthophorus* (Bichlbruck6), 23. *Rhagodiscus achylostaurion* (W4), 24. *Rhagodiscus angustus* (W4), 25. *Staurolithites crux* (Wal4), 26. *Tranolithus phacelosus* (Wal20), 27. *Uniplanarius gothicus* (Wal4), 28. *Zeugrhabdotus bicrescenticus* (W4), 29. *Zeugrhabdotus diplogrammus* (Wal20), 30. *Zeugrhabdotus embergeri* (Wal4). Scale bars = 5 µm.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blages at a few localities, containing significant amounts of chrome spinel, glaucophane and chloritoid (Woletz, 1967; Freimoser, 1972). Additionally, Faupl (1984) reported kaersutite.

However, Freimoser (1972) stressed that the outcrops to the west of the Saalach river show a strong similarity to the sedimentary succession of the Rhenodanubian Zone of the Penninic Basin.

The aim of this paper is to establish a stratigraphic framework for the “Walserberg Series” and to assess the tectonic assignment of these deposits.

2. Material and Methods

According to the map of Prey (1969), the “Walserberg Series” is exposed along the western and eastern banks of the Saalach river, which forms the boundary between Austria and Germany (Fig. 1). A major part of the area is covered by Quaternary sediments and so only small isolated outcrops of Cretaceous deposits occur. The whole area was remapped in detail by one of us (M.F.) and samples were taken from all pre-Quaternary outcrops and processed for biostratigraphic analysis using calcareous nannoplankton assemblages (H.E.). Additionally, dinoflagellate assemblages of samples from outcrops devoid of carbonate were studied (O.M.). In one sample, a relatively diverse terrestrial palynoflora was found; this has been analysed by Dr. Ilse Draxler (Geological Survey of Austria, Vienna).

Calcareous nannoplankton species were studied in smear slides with a Zeiss Axioplan lightmicroscope at a magnification of 1000x and were classified with the CC-zonal scheme of Sissingh (1977) and the BC and UC-schemes of Burnett (1998). The nannofossil assemblages originate from turbidites, because the hemipelagic claystones are devoid of carbonate. Consequently, heterochronous reworking of nannofossils cannot be ruled out. The slides are housed in the collection of the Geological Survey of Austria (Inv.Nr. 2012/049/0001 – 0040).

To obtain a better stratigraphic resolution, ten samples mainly from carbonate-free deposits were processed for palynological analysis following standard procedures. Between 30 and 100 g of dry sediment were crushed and treated by hydrochloric acid (Hcl 35%) to remove minor carbonate, and hydrofluoric acid (HF 40%) to remove silicates. The residue was sieved on 15 µm nylon sieves. The palynodebris was mounted in glycerin jelly on 2 microscope slides (A, B) after extensive mixing to obtain homogeneity and then covered by a slide cover (20 x 40 mm). Both slides of each sample were counted for dinocysts. The slides are stored at the Austrian Geological Survey in Vienna (Inv.Nr. 2012/017/0001-0007). With the exception of samples WAL5, WAL6, WAL15, WAL16, WAL17, the slides display good preservation and high abundances of dinoflagellate cysts. A total of 123 dinocyst species and subspecies were identified. The dinocysts assemblages show a high diversity with up to 64 species in the Lower Campanian sample WAL4/09.

Figure 4: The species name is followed by the sample number and England Finder coordinates (for localization of the specimen on the slide). 1. *Oligosphaeridium complex* (White, 1842) Davey and Williams, 1966b; 2/09B, X27; 2, 3. *Oligosphaeridium dividuum* Williams, 1978; 4/09B, M16; 4, 5. *Oligosphaeridium* spp.; 24 1/09A, E23; 6. *Hystrichosphaeridium salpingophorum* Deflandre, 1935a. ex Deflandre, 1937b. Emendation: Davey and Williams, 1966b; 2/09A, B10; 7, 8. *Hystrichosphaeridium salpingophorum* Deflandre, 1935a. ex Deflandre, 1937b. Emendation: Davey and Williams, 1966b; 2/09A, R34; 9. *Hystrichosphaeridium recurvatum* (White, 1842) Lejeune-Carpentier, 1940; 4/09A, T4; 10. *Litosphaeridium siphoniphorum* (Cookson and Eisenack 1958) Davey and Williams 1966. Emendation: Lucas-Clark, 1984; 7/09A, A11; 11. *Discorsia nannus* (Davey, 1974) Duxbury, 1977. Emendations: Duxbury, 1977; 3/09A, R28; 12. *Gonyaulacysta cretacea* (Neale and Sarjeant, 1962) Sarjeant, 1969; 4/09A, J19/2; 13, 14. *Callaiosphaeridium asymmetricum* (Deflandre and Courteville, 1939) Davey and Williams, 1966b. Emendation: Clarke and Verdier, 1967; 1/09B, H4; 15. *Callaiosphaeridium* spp.; 1/09A, O21; Scale bars = 20 µm.

3. Biostratigraphy and lithofacies of the studied outcrops

3.1 Upper Aptian

On the eastern bank of the Saalach river (coord. 47° 46´50” N, 012° 56´ 27” E) up to 0.7 m thick turbiditic sandstone beds alternating with green claystone and dark grey mudstones occur (Fig.2/1). Pelitic rocks are the dominant rock type by far in the succession. Beside dinoflagellate cysts, the dark grey mudstones also contain common terrigenous pollen and spores. Therefore, the mudstone is interpreted to be the upper part (Td) of the Bouma-cycle, whereas the green claystone is considered to be of hemipelagic origin deposited below the calcite compensation depth (CCD). The sandstone beds show parallel (Tb) and cross lamination (Tc). The greenish colour of these beds is due to glauconite.

Carbonate and calcareous nannoplankton were found in only two of the pelitic samples (WAL4a/12; WAL4b/12). The assemblage essentially consists of *Watznaueria barnesae*. Rare specimens of *Eprolithus floralis*, *Micrantolithus hoschulzii*, *Micrantolithus obtusus* and *Zeugrhabdotus embergeri* occur. Burnett (1998) noted that *Eprolithus floralis* has its lower occurrence (LO) in the lower Upper Aptian Zone BC21, whereas *Micrantolithus obtusus* (Fig.3/18) and *Micrantolithus hoschulzii* have their highest occurrence (HO) in this zone. In the zonation scheme of Sissingh (1977) this interval is part of Zone CC7.

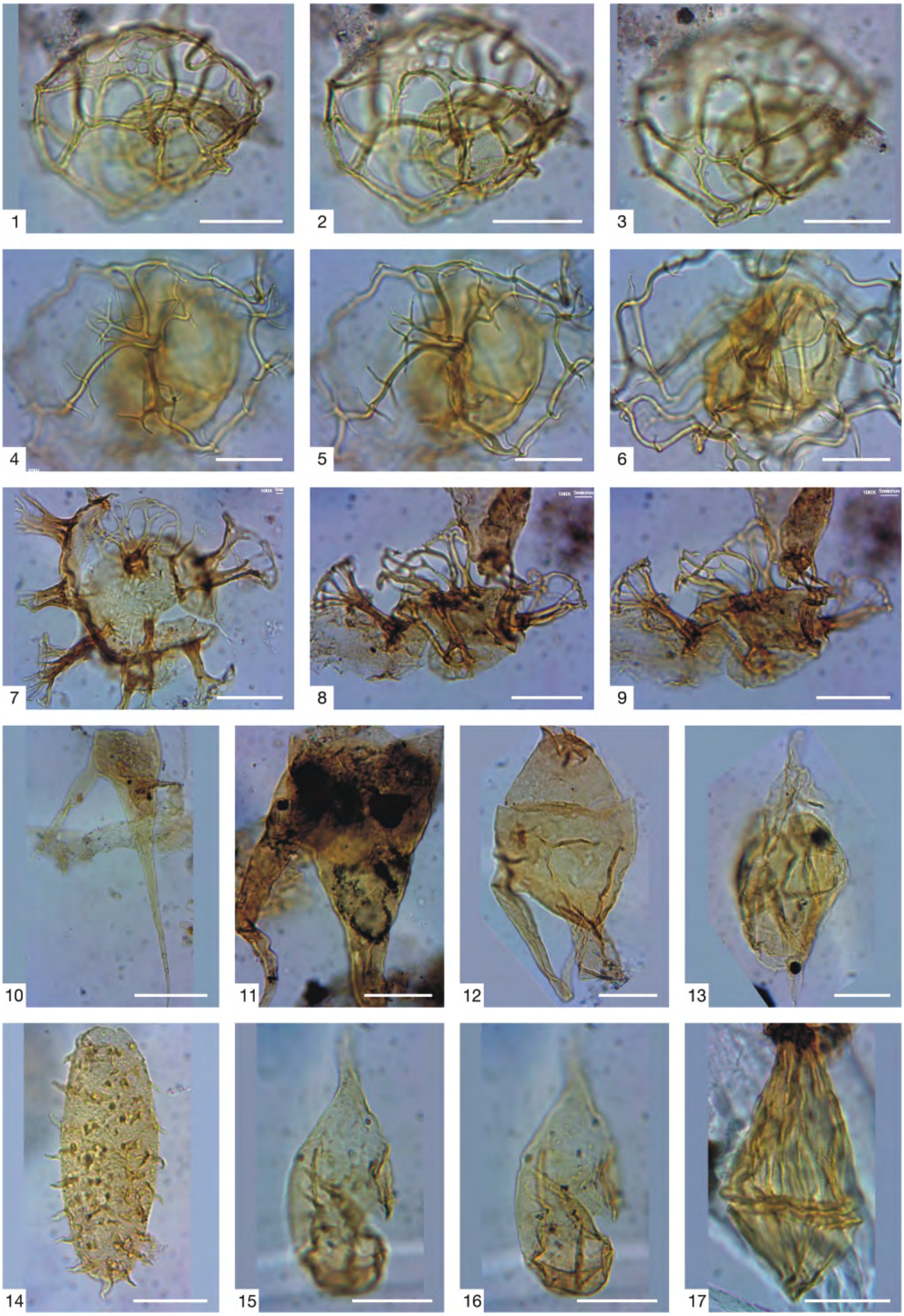
Dinoflagellate species from the samples from this outcrop (WAL1/09; WAL 2/09; WAL 3/09) are listed in Table 1. Sample 1/09 is characterized by high abundances (17% and 9.3% respectively) of *Oligosphaeridium complex* (Fig.4/1) and *Circulodinium distinctum* (Fig.6/5). In sample WAL2/09 the dinocyst diversity is relatively low (19 species/sample). *Hystrichosphaeridium salpingophorum* (Fig.4/6,7,8) has a high abundance and represents 88% of the dinocyst assemblage in this sample. Sample WAL3/09 displays relatively high abundances of *Oligosphaeridium complex* (26%), *Achomosphaera ramulifera* (14%), *Odontochitina operculata* (7.9%) and *Hystrichosphaerina schindewolfii* (6.6%).

The stratigraphically most important species found is *Hapsocysta peridictya* (Fig.5/1,2,3). In the Rhenodanubian Zone

Sample Numbers	1/09	2/09	3/09	4/09	5/09	6/09	7/09	15/11	16/11	17/11
Achomosphaera neptuni	1		2							
Achomosphaera ramulifera	11		42	2		1	2			
Aldorfia spp.	1									
Alterbidinium acutulum	1		2							
Alterbidinium spp.			2	1						
Apteodinium deflandrei	2		2	2						
Apteodinium vectense				1						
Areoligera coronata				2			1			
Areoligera spp.				4						
Batiacasphaera mica			2							
Batiacasphaera micropapillata	7		3	3		2	1			
Batiacasphaera spp.	2	2	3							
Batiacasphaera? reticulata			2	1						
Callaiosphaeridium asymmetricum	6		4							
Callaiosphaeridium spp.	1			1						
Callaiosphaeridium trycherium							1			
Canningia grandis	1		2	3						
Canningia spp.			1							
Cannosphaeropsis utinensis				3					1	
Cassiculosphaeridia reticulata			2							
Cerodinium diebelii				5			1			
Cerodinium spp.				2						
Chatangiella spp.				1						
Chatangiella? robusta				1						
Circulodinium distinctum	36	1	4				4	1		1
Cleistosphaeridium diversispinosum	20	3	8		20					
Cleistosphaeridium spp.	34	2	10	1	15		5			
Coronifera spp.	2		6	3						
Cribroperidinium cooksoniae							1			
Cribroperidinium spp.	1			1	1		1			
Cyclonephelium compactum		1								
Cyclonephelium spp.	9			2						
Dapsilidinium laminaspinosum	1									
Dinogymnium acuminatum				1						
Discorsia nannus			2							
Dissiliodinium spp.			2							
Downiesphaeridium? aciculare	4	2					1			
Endoscrinium campanula							1		2	
Endoscrinium spp.				1						
Exochosphaeridium bifidum				1			1			
Exochosphaeridium spp.				2						
Florentinia ferox				1						
Florintina laciniata	5								1	2
Glaphyrocysta semiticta	1									
Gonyaulacysta cretacea			2	1						
Gonyaulacysta spp.	1									
Hapsocysta peridictya		2	10							
Heterosphaeridium cordiforme	21		4	1	1		4	2		1
Heterosphaeridium spinaconjunctum							1			
Hystrichodinium pulchrum	10			4			3			
Hystrichokolpoma bulbosum	1									
Hystrichosphaeridium recurvatum			1	2						
Hystrichosphaeridium salpingophorum	5	273	2	1						
Hystrichosphaeridium tubiferum	2	3		2			3			
Hystrichosphaerina schindewolfii	10		20	2						
Hystrichosphaeropsis ovum							1			
Hystrichostrogylon membraniphorum	2			1						
Isabelidinium cooksoniae				1						
Isabelidinium spp.	20		2	1						
Kleithriasphaeridium loffrense				1			1			
Leberidocysta chlamydata	3		1	2						

Sample Numbers	1/09	2/09	3/09	4/09	5/09	6/09	7/09	15/11	16/11	17/11
Litosphaeridium siphoniphorum							2			
Manumiella spp.	6			1						
Manumiella? cf. *cretacea*	3									
Odontochitina operculata	2	7	24	1					2	
Odontochitina spp.		1	2							
Oligosphaeridium complex	66	2	80		1		3			
Oligosphaeridium dividuum				1						
Oligosphaeridium pulcherrimum	2		1							
Oligosphaeridium spp.	2	1					1			
Operculodinium centrocarpum				1						
Ovoidinium scabrosum					1					
Ovoidinium spp.			1							
Palaeoperidinium cretaceum	1		4	1	1					
Palaeoperidinium pyrophorum	2		2							
Paralecaniella indentata				2		1	1			
Pareodinia ceratophora				1						
Pervosphaeridium granaciculare							12			
Pervosphaeridium pseudhystrichodinium	2			2	1		3			
Pervosphaeridium spp.	4			1		1	2			
Phelodinium magnificum				1						
Prolixosphaeridium parvispinum			2							
Pseudoceratium pelliferum	1									
Pseudoceratium spp.	1									
Pterodinium aliferum			2							
Pterodinium cingulatum subsp. *cingulatum*	2	2	2	6	2	1	8	1	3	
Pterodinium cingulatum subsp. *polygonale*		1								
Pterodinium? *cornutum*			1							
Raetiaedinium truncigerum	2	3								
Riculacysta amplexa							1			
Rottnestia borussica				2		1				
Spinidinium echinoideum							1			
Spiniferites cf. *bulloideus*	2						2			
Spiniferites membranaceus	1		1	9						
Spiniferites multibrevis	1		4	8						
Spiniferites pseudofurcatus	1						8			
Spiniferites ramosus	34	1	10	170	2	1	17	2	4	2
Spiniferites ramosus subsp. *gracile*				2						
Spiniferites ramosus subsp. *granosus*				2						
Spiniferites scabrosus			1	6			1			
Spiniferites spp.		1	2	2			2			
Spongodinium delitiense				1						
Subtilisphaera spp.	1		4							
Subtilisphaera terrula	1									
Surculosphaeridium longifurcatum	4		4	1			2			
Surculosphaeridium? *basifurcatum*	6									
Systematophora spp.	1			1						
Tanyosphaeridium variecalamum	4									
Tanyosphaeridium xanthiopyxides	6		4	1						
Tenua hystrix				3						
Thalassiphora pelagica			2							
Thalassiphora spp.	2		1	1	1	1	1			
Trabeculidium quinquetrum							1			
Trichodinium ciliatum	2	1	6		1		1			
Trithyrodinium cf. *evittii*	1			5		1				
Trithyrodinium spp.				1						
Trithyrodinium suspectum	2			3			1			
Turnhosphaera hypoflata	2		1							
Wrevittia cassidata			1							
Xenascus gochtii					1					
Xenascus spp.				1	1					
Xiphophoridium alatum							1			
Total Dinocysts	**387**	**309**	**305**	**301**	**49**	**10**	**104**	**5**	**13**	**6**
Species number	**61**	**19**	**51**	**64**	**14**	**9**	**39**	**3**	**6**	**4**

Table 1: Inventory of dinoflagellate cysts of the studied WAL-samples.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of southern Bavaria, *H. peridictya* was used for the definition of the *Hapsocysta peridictya-Subtilisphaera terrula* Zone in the Upper Aptian and Lower Albian (Kirsch, 2003). A similar range is documented from the Western Carpathians in Slovakia (Skupien, 2003). At Walserberg, this species is recorded in two samples (WAL2/09, WAL3/09). *Pseudoceratium pelliferum* (Fig.6/4) is another important species in sample WAL1/09 of the same outcrop, which has its HO in the Upper Aptian of northern Germany (Below, 1982b; Prauss, 1990).

In both samples WAL1/09 and WAL3/09 *Hapsocysta peridictya* co-occurs with *Hystrichosphaerina schindewolfii* (Fig.5/7,8,9). This latter species was recorded in the Aptian of the Slovakian Carpathians (Skupien, 2003), in the Upper Barremian to Upper Aptian of Germany (Alberti, 1961) and in the Upper Hautervian to Lower Albian of Germany (Prauss, 1990). Williams and Bujak (1985) suggest that the stratigraphic range of this species comprises the Upper Hauterivian to Upper Albian.

In sample WAL3/09, *Prolixosphaeridium parvispinum* (Fig.5/14) occurs. This was previously recorded in the Barremian to Albian of Morocco (Below, 1982a) and in the Slovakian Carpathians (Skupien, 2003), and also in the Upper Barremian to Upper Aptian of northern Germany (Below, 1982b).

About 14% of the palynoflora in sample WAL3/09 consist of terrigenous species showing moderate to poor preservation. Angiosperm pollen are absent. The fern spores and Gymnosperm pollen indicate an Aptian to Albian age (personal communication Ilse Draxler): *Gleicheniidites senonicus*, *Gleicheniidites sp.*, *Clavifera triplex*, *Cicatricosisporites rersa*, *Cicatricosisporites sp.*, *Stereisporites europaeum*, *Lycopodiumsorites subrotundus*, *Cingutriletes clavus*, *Sestrosporites pseudoalveolatus*, *Vitreisporites pallidus*, *Pinuspollenites* sp., *Circulina* sp..

3.2 Upper Albian to Middle Cenomanian

Samples WAL5/09, WAL6/09, and WAL7/09 (coord.: 47° 46´43” N; 012° 56´26” E) were collected from the eastern bank of the Saalach river, immediately to the south of coarse grained sandstone beds (Fig.1). The samples originate from a small landslide in grey marlstone and red claystone.

In samples WAL5/09 and WAL6/09, *Watznaueria barnesae* is the only nannoplankton species found. Sample WAL7/09 has a stratigraphically more definitive assemblage, containing *Eiffellithus turriseiffelii*, the zonal marker for the Upper Albian to Lower Cenomanian Zone CC9 (Sissingh, 1977). In the zonation scheme of Burnett (1998) the presence of *Eiffellithus turriseiffelii* below the LO of *Corollithion kennedyi* indicates Zone UC0. Other species in this sample with LO in the Upper Albian are *Placozygus fibuliformis* and *Nannoconus regularis* (Perch-Nielsen, 1985).

This chronostratigraphic assignment is corroborated by the occurrence of the dinoflagellate species *Ovoidinium scabrosum* in sample WAL5/09 and of *Litosphaeridium siphoniphorum* (Fig.4/10) and *Xiphophoridium alatum* (Fig.6/10, 11) in sample WAL7/09. *Ovoidinium scabrosum* has a stratigraphic range from the Albian to the Lower Cenomanian (Millioud et al., 1975). *Litosphaeridium siphoniphorum* has a range from the Upper Albian to the Lower Turonian (Williams and Bujak, 1985) and is the index species for the *Litosphaeridium siphoniphorum* Zone. This zone was introduced by Herngreen (1978) for the Upper Albian to Lower Cenomanian in the Netherlands. In the northwestern Tethys region this dinoflagellate zone was described by Kirsch (2003) and Wagreich et al. (2006) from the Rhenodanubian Zone of the Eastern Alps. *Xiphophoridium alatum* was recorded in the Aptian to Albian of the Slovakian Western Carpathians (Skupien, 2003). This is in contrast to Williams et al. (2004) who assumed that the LO of this species to be in the Cenomanian. According to Williams and Bujak (1985) the stratigraphic range of *Xiphophoridium alatum* comprises the Upper Albian to Upper Santonian.

The best outcrop (coord.: 47° 47´07” N, 012° 56´11” E) in the Cenomanian (sample WAL20) was found to the north of Bichlbruck along the course of a small western tributary to the Saalach river (Fig. 1). There, up to 25 cm thick, soft silty marlstone beds alternate with brick red claystone (Fig.2/2). The latter are interpreted as hemipelagites deposited below the CCD, whereas the marlstone layers are seen as fine-grained mud turbidites. Smaller exposures of this unit occur up-stream (ca. 510 m altitude) in the southern branch of the creek.

Calcareous nannoplankton assemblages from the marlstone show moderate preservation and high abundances. The nannoflora is dominated by *Watznaueria barnesae*. The occurrences of *Corollithion kennedyi* (Fig.3/5), *Lithraphidites acutus* (Fig.3/12) and *Lithraphidites alatus* (Fig.3/13), which are marker species for the Cenomanian, are stratigraphically important. *Lithraphidites acutus* has its LO at the base of the Middle Cenomanian, *Corollithion kennedyi* has its HO in the lower Upper Cenomanian. This stratigraphic interval comprises Zone Uc3 of Burnett (1998), which correlates with the lower part of Zone CC10 of Sissingh (1977).

3.3 Upper Cenomanian to Turonian?

Along the river course north of Bichlbruck (coord. 47° 47´05” N, 012° 56´09” E) coarse grained, thick- to medium-bedded turbiditic sandstones occasionally with thin intercalations of green and grey claystones (Fig.2/3) border the above mentioned Cenomanian marlstone turbidites. The sand-rich succession is devoid of carbonate and, therefore, calcareous plankton species are absent. The palynological record of the three

Figure 5: 1-3. *Hapsocysta peridictya* (Eisenack and Cookson, 1960) Davey, 1979; 3/09A, U19; 4-6. *Cannosphaeropsis utinensis* Wetzel, 1933b. Emendations: May, 1980; 4/09B, F25; 7. *Hystrichosphaerina schindewolfii* Alberti, 1961; 1/09A, Z23; 8, 9. *Hystrichosphaerina schindewolfii* Alberti, 1961; 1/09A, H34; 10. *Odontochitina operculata* (Wetzel, 1933a) Deflandre and Cookson, 1955; 3/09A, P15; 11. *Odontochitina operculata* (Wetzel, 1933a) Deflandre and Cookson, 1955; 1/09A, W32; 12. *Odontochitina* spp.; 2/09A, F38; 13. *Chatangiella*? *robusta* (Benson, 1976) Stover and Evitt, 1978; 4/09A, B15/3; 14. *Prolixosphaeridium parvispinum* (Deflandre 1937) Davey et al 1969; 3/09B, J2; 15, 16. *Pareodinia ceratophora* Deflandre, 1947d. Emendation: Gocht, 1970b; 4/09B, C22; 17. *Dinogymnium acuminatum* Evitt et al., 1967; 4/09A, Q35;Scale bars = 20 µm.

samples investigated (WAL15, WAL16, WAL17) is very poor (Tab. 1) and does not give any relevant chronostratigraphic information. Heavy mineral assemblages of the psammitic rocks are strongly dominated by garnet (> 80%) and show low percentages of apatite, tourmaline, rutile and zircon (Freimoser, 1972).

Sandstone beds showing thicknesses up to 3 m are exposed at the eastern bank of the Saalach river. From the heavy mineral assemblages of this outcrop, Freimoser (1972) and Faupl (1984) described amphiboles (in particular glaucophane and kaersutite), chloritoid, and chrome spinel. Unfortunately, large limestone blocks were laid on the exposures a few years ago, during stream regulation works. Due to this, the pelitic intercalations could not be sampled during our survey and hence no reliable biostratigraphic information are available from the sandstone unit. Directly to the south, the sandstone borders Upper Albian to Lower Cenomanian varicoloured pelitic rocks (sample WAL7/09, see paragraph 3.2.) but it seems that this contact is tectonically overprinted. To the north, Campanian deposits (sample Wal4/04, see paragraph 3.5.) are tectonically squeezed between the sandstone and the above mentioned Upper Aptian rocks.

3.4 Santonian

To the south of Bichlbruck, red hemipelagic claystones and grey turbiditic siltstones (Fig.2/4) occur along a small forest road (coord.: 47° 46´ 31" N, 012° 55´ 45" E) immediately to the north of the railway crossing (Fig.1). Most of the outcropping rocks are devoid of carbonate. Calcareous nannoplankton was found in a thin marlstone layer (Bichlbruck 3) near the top of the outcrop.

The calcareous nannoplankton species *Reinhardtites anthophorus*, *Eiffellithus eximius*, *Lithastrinus grillii*, and *Marthasterites simplex* indicate the Lower Santonian Zone CC15. The same facies is poorly exposed along the eastern river bank. The nannoplankton assemblage of sample W4 (47° 46´ 39" N; 012° 56´21" E) is similar (see Figs.3/3,6,11,15,16,17,20, 23,24,28) but additionally contains *Lucianorhabdus cayeuxii* (Fig.3/14), the marker fossil for the Santonian Zone CC16.

3.5 Campanian

Along the eastern river bank, the above mentioned Upper Aptian succession is tectonically juxtaposed against varicoloured claystones and calcareous turbiditic marlstones in the south. Beside other calcareous nannoplankton species, the marlstone (WAL4/09) contains *Broinsonia parca constricta*, *Calculites obscurus*, and *Uniplanarius gothicus* (Fig.3/27), indicating the Lower Campanian Zone CC18.

In the dinoflagellate cyst assemblages (Tab.1) of sample WAL4/09 *Cerodinium diebelii* and *Phelodinium magnificum* (Fig.6/15) occur, both of which have their LO in the Campanian. According to Williams & Bujak (1985) *Cerodinium diebelii* has a range from the Upper Campanian to the Lower Paleocene. It was documented in the Maastrichtian of NW Germany by Marheinecke, (1992). *Phelodinium magnificum* has a range from the Lower Campanian to the Lower Paleocene (Williams and Bujak, 1985) and was recorded in the Upper Campanian to Upper Maastrichtian strata of Morocco (Rauscher and Doubinger, 1982) and from Maastrichtian to Danian in NW Tunisia (Brinkhuis and Leereveld, 1988). Reworking of older deposits is indicated by two specimens of *Hystrichosphaerina schindewolfii*.

To the west of the Saalach river (47° 46´46" N, 012° 56`03" E) graded beds from calcareous turbidites occur. The majority of these turbidites are marlstones (Fig.2/6), although sandstone and siltstone layers occur at the base of the turbidites (Tbc). Pelitic material is dominates the outcrops.

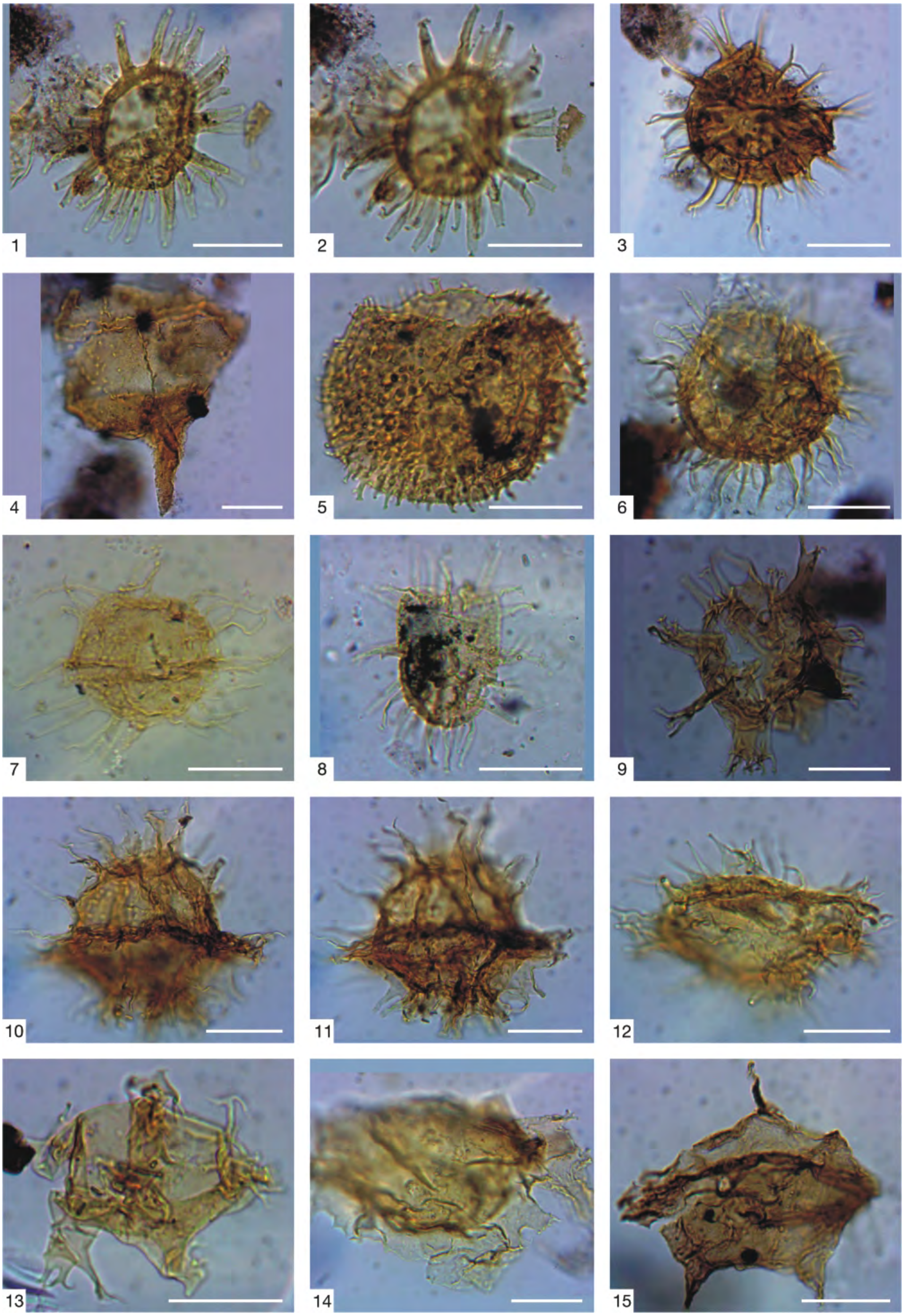
Calcareous nannoplankton assemblages (Bichlbruck 6/09) show moderate preservation and high abundances. The occurrences of *Broinsonia parca constricta* (Fig.3/2), *Broinsonia parca parca*, *Calculites obscurus* (Fig.3/4), *Calculites ovalis*, *Eiffellithus eximius*, *Eprolithus floralis*, *Lucianorhabdus cayeuxii*, *Lucianorhabdus maleformis*, and *Orastrum campanense* (Fig. 3/21) indicate the Lower Campanian. According to Burnett (1998), *Broinsonia parca constricta* and *Eprolithus floralis* occur together only in the lower Lower Campanian Sub-Zones Uc14b and 14c, which are correlated to Zone CC18 in the zonation scheme of Sissingh (1977).

Zeller Hill, south of Hammerau, is formed of thick bedded turbiditic calcareous sandstones and siltstones. Soft turbiditic marlstone and intercalating claystone are exceedingly rare. Sample WAL11 (coord. 47° 47´20" N; 012° 56´43" E) was taken in an old quarry in the southwestern part of Zeller Hill. Stratigraphically important species are *Arkhangelskiella cymbiformis* (Fig.3/1), *Broinsonia parca parca*, *B. parca constricta*, *Ceratolithoides* cf. *aculeus* (strongly overgrown), *Eiffellithus eximius* and *Uniplanarius gothicus*. This flora indicates the Mid-Campanian Zones CC20 and UC15.

4. Discussion

In the area assigned to the „Walserberg Series" by Prey (1969), Upper Aptian to Lower Campanian deposits are exposed. Maastrichtian strata were also reported by Freimoser (1972) but could not be found again during our survey. The majority of the encountered rocks are turbidites. Hemipelagic

Figure 6: 1, 2. *Dapsilidinium laminaspinosum* (Davey and Williams, 1966b) Lentin and Williams, 1981; 1/09B, M16; 3. *Pervosphaeridium pseudhystrichodinium* (Deflandre, 1937b) Yun Hyesu, 1981. Emendation: Davey, 1969a; 1/09A, H36; 4. *Pseudoceratium pelliferum* Gocht, 1957. Emendation: Dörhöfer and Davies, 1980; 1/09A, F9; 5. *Circulodinium distinctum* (Deflandre and Cookson, 1955) Jansonius, 1986; 1/09B, J10; 6. *Pervosphaeridium granaciculare* Fensome et al., 2009; 7/09B, W6; 7. *Hystrichodinium pulchrum* Deflandre, 1935; 1/09A, D17; 8. *Tanyosphaeridium xanthiopyxides* (Wetzel, 1933b ex Deflandre, 1937b) Stover and Evitt, 1978. Emendations: Sarjeant, 1985b; 3/09A, C4; 9. *Florintina laciniata* Davey and Verdier, 1973; 1/09A, H19; 10, 11. *Xiphophoridium alatum* (Cookson and Eisenack, 1962b) Sarjeant, 1966b. Emendation: Sarjeant, 1966b; 7/09B, W18; 12. *Florentinia ferox* (Deflandre, 1937b) Duxbury, 1980; 4/09B, B25/3; 13. *Xenascus gochtii* (Corradini, 1973) Stover and Evitt, 1978; 5/09B, P26; 14. *Xenascus* spp.; 4/09B, G24; 15. 1. *Phelodinium magnificum* (Stanley, 1965) Stover and Evitt, 1978; 4/09A, U16; Scale bars = 20 µm.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layers devoid of carbonate indicate that the entire succession was deposited below the CCD (see also Faupl, 1984). In the non metamorphic units of the northern Eastern Alps, deep-water deposits from the lower Upper Cretaceous are known from the Ultrahelvetic Zone, the Rhenodanubian Zone, and the Northern Calcareous Alps.

The Ultrahelvetic Zone is composed of detached deposits from the continental slope of the southern European Plate. The sedimentary record of the Upper Cretaceous is dominated by pelitic rocks (informally called "Buntmergelserie" in Austria and Eastern Bavaria), whereas turbidites are exceedingly rare. The lithofacies of the Buntmergelserie do not show any similarity to the turbidite rich succession in the Walserberg area.

The Rhenodanubian Zone is a detached part of the Penninic Basin to the south of the Ultrahelvetic slope. The sedimentary succession (Rhenodanubian Group, Egger and Schwerd, 2008) is strongly dominated by turbidites and comprises the Upper Barremian to Lower Eocene. The lithofacies and chronostratigraphic positions of most outcrops in the "Walserberg Series" can be reliably correlated with formations of the Rhenodanubian Group.

The glauconite-rich Upper Aptian rocks on the eastern bank of the Saalach river are similar to the Rehbreingraben Formation ("Gault Flysch") and the Upper Albian to Mid-Cenomanian turbiditic marlstone and red claystone can be assigned to the "Lower Varicoloured Marlstone" of the Rhenodanubian Group. In the Rhenodanubian Zone of Upper Austria (Oberaschau section) this unit accumulated during calcareous nannoplankton Biochron CC9 and the *Litosphaeridium siphoniphorum* dinoflagellate Biochron (Egger, 1992; Wagreich et al., 2006). In contrast to the "Walserberg Series", the top of "Lower Varicoloured Marlstone" at Oberaschau is within Zone CC9 whereas Zone CC10 is represented by grey marly mud-turbidites of the Ofterschwang Formation. These units are lateral equivalents (Egger and Schwerd, 2008). The Santonian thin-bedded siltstone turbidites alternating with red claystone layers look like the Seisenburg Formation, which has a stratigraphic range from the Coniacian to the Lower Campanian in the Rhenodanubian Zone (Egger, 1993). Lower Campanian calcareous turbidites showing thick marlstones in their upper parts correspond to the Kalkgraben Formation, and Mid-Campanian thick bedded calcareous turbidite beds to the Hällritz Formation.

Correlation of the coarse grained sandstones encountered near Bichlbruck and at the eastern river bank to the Rhenodanubian Group is more difficult. No relevant biostratigraphic information exits from these outcrops. The heavy mineral assemblages of the first mentioned outcrop are very similar to those of the Reiselsberg Formation (Freimoser 1972, Prey, 1980). Probably, this outcrop is in stratigraphic contact to the underlying "Lower Varicoloured Marlstone". In any case it can easily be integrated into the Rhenodanubian Group.

The sandstone outcrop on the eastern bank of the Saalach river is more problematic as the heavy mineral assemblages of these beds, containing glaucophane and kaersutite together with chloritoid and chrome spinel, are not characteristic of the Rhenodanubian Zone. However, in Cretaceous deposits of the northern Eastern Alps, glaucophane is especially well known from the Branderfleck Formation of the Northern Calcareous Alps (see Faupl and Wagreich, 1992 for a review). In the Branderfleck Formation, which was lithostratigraphically formalized by Gaupp (1982), the oldest deposits are Cenomanian neritic marlstone and calcilithites as well as breccias. Rapid subsidence caused a quick shift from this shallow water facies to bathyal and abyssal depositional conditions in the Turonian. Weidich (1984) documented a continuous sedimentary record from the Lower Cenomanian to the Lower Campanian in the tectonically lower units ("Randcenoman", Allgäu Nappe and northern Lechtal Nappe) in the western part of the Northern Calcareous Alps.

Winkler (1988) conducted sedimentological studies in the Branderfleck Formation. In the heavy mineral assemblages of the "Randcenoman", the Allgäu Nappe and the northernmost part of the Lechtal Nappe, glaucophane was commonly found (up to 25% of the assemblages). This mineral species occurs exclusively in the Albian to Coniacian of the northern margin of the Adriatic Plate but not in the South Penninic Arosa Zone. The chemistry of the amphiboles documents a high pressure/low temperature source area, which was assumed to be formed during Cretaceous convergence (Winkler, 1988). However, Von Eynatten et al. (1996) and Von Eynatten & Gaupp (1999) demonstrated that the source area of this high-P mineral assemblage is of Early Carboniferous age and lay in a Lower Austroalpine position near the transpressive plate margin that juxtaposes the Austroalpine and Penninic units.

At Walserberg, the abyssal deposits of the Upper Albian to Mid-Cenomanian do not show any similarity with the shallow water Cenomanian of the Branderfleck Formation. Further, the thin-bedded turbidite facies of the Santonian and the Campanian calcareous turbidites are not known from this formation. Glaucophane bearing heavy mineral assemblages from the sandstone on the eastern bank of the Saalach river are the only reason for correlating this outcrop with the Branderfleck Formation. However, Freimoser (1972) reported Maastrichtian ages from this outcrop, which are not known from the Branderfleck Formation elsewhere.

Thus, in summary, the major part of the sedimentary succession designated as "Walserberg Series" by Prey (1968) can be correlated without difficulty with the succession of the Rhenodanubian Group. The glaucophane bearing sandstone succession on the eastern bank of the Saalach river seems to be a tectonically isolated body within the southernmost part of the Rhenodanubian Zone. If it is really Maastrichtian in age, it cannot be correlated with any known sandstone in the northern Eastern Alps, in which case, a local source can be assumed for the derivation of the amphiboles. If it is Cenomanian or Turonian in age, it can be correlated with the Branderfleck Formation. In that case, it is a small tectonic slice between two branches of the large Innsbruck-Salzburg-Amstetten (ISAM)-fault system (Egger, 1997). This major sinistral strike-slip system runs sub-parallel to the northern margin of the Northern Calcareous Alps.

5. Conclusion

Most outcrops of the “Walserberg Series” can be readily attributed to lithostratigraphic units of the Rhenodanubian Group. Consequently, the term “Walserberg Series” is not necessary any more. Only the outcrop containing detrital glaucophane remains doubtful and needs further assessment to establish whether or not it is equivalent to the Branderfleck Formation of the Northern Calcareous Alps. In any case, the position of the northern margin of the Northern Calcareous Alps has to be shifted at least 1 km farther to the south compared to its position on published geological maps (Prey, 1969; Braunstingl, 2005).

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