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Fission track and nannofossil ages from a Paleocene bentonite in the Schlieren Flysch (Central Alps, Switzerland)

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Abstract

A bentonite layer contained in the Schlieren Flysch series has been dated by calcareous nannofossils and by radiometric fission track analysis of volcanic zircon grains. The nannofossil assemblage belongs to NP5 zone and the mean fission track age is 57.8 ± 2.7 Ma. This new age constrains the poorly documented Paleocene part of the geological time scale.

Keywords: Bentonite, zircon, fission track, calcareous nannofossils, Schlieren Flysch, Central Alps, Switzerland.

Introduction

The presence of bentonite layers in the Voirons, Gurnigel, Schlieren and Wägital Flysch was reported by WINKLER (1983) and WINKLER et al. (1985 a, b). The volcanic origin of these thin, yellow and white altered layers was deduced from the clay mineral and heavy mineral composition, and by the presence of recrystallized pyroclastic debris in some layers. Chemical analysis and theoretical correction for diagenetic modifications point generally to partly andesitic and partly alkali basaltic (trachybasaltic) sources for these bentonites.

The record of synorogenic volcanism is generally very poor in the Alps. The occurrence of the altered ash layers thus may be due to distant volcanic activity not directly related to the Alpine orogeny. However, palaeogeographic, sedimentologic and textural considerations make it probable that they were derived from subduction related arc or back-arc volcanic centers situated to the south of the Alpine orogen (WINKLER, 1983; WINKLER et al., 1985b).

The host rock of the bentonites is a 1500–1800 m thick turbiditic and hemipelagic Late Cretaceous to Eocene flysch series forming a more or less continuous belt from Lake Geneva to Central Switzerland. From sedimentologic, petrographic and structural evidence it appears that the 300 km long flysch sequence was deposited in a remnant South Penninic, periodically convergent deep-sea trench basin with a source area composed of both basement and sedimentary cover rocks (WINKLER, 1983, 1984b). The lack of carbonate material in the hemipelagic layers points to a depositional environment below the local CCD (e.g. WINKLER, 1984a).

We have observed 14 nearly uncontaminated bentonite layers in Late Maastrichtian, Paleocene and Early Eocene flysch series and, particularly in the Tertiary, they are closely related to the Tonstein-Schichten facies representing diachronous abyssal plain/oceanic slope deposits, comparatively rich in lime-free hemipelagic shales (WINKLER, 1983, 1984b). Their occurrence is also closely linked to the presence of iron- and manganese-bearing layers (WINKLER et al., 1985b).

The bentonite layers consist of a few millimeter to 2 centimeter thin yellow and white clay layers with high contents of montmorillonite in free phase (up to 100%) or in the mixed-layer phase montmorillonite/illite (up to 80%). As an important test of

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purity, in individual layers the total heavy mineral content was recorded. The assemblages consist nearly exclusively of euhedral apatite, zircon and a few pseudo-hexagonal biotites and thus represent uncontaminated volcanic ash layers. Additional tourmaline, rutile, anatase, brookite and garnet were considered as terrigeneous impurities (WINKLER et al., 1985b).

One of these layers (sample WW 1948) of early Late Paleocene age revealed a very rich heavy mineral content with abundant and well preserved euhedral zircon grains. Together with the generally good calcareous nannofossil control in the flysch series (e.g. WINKLER, 1983) it was considered valuable to combine fission track dating of zircon with current nannofossil zonation. In spite of the occurrence of the ash layer WW 1948 in a very lime-poor facies, by repeated sampling we were successful in finding good nannofossil assemblages allowing a first hand correlation of biostratigraphy with the fission track dates.

Specification of bentonite WW 1948

The analysed ash layer occurs in the Änggenlouenen section in the Entlebuch area ca. 30 km SW of Lucerne (section locality, Swiss topographic map 1 : 25.000 "Schüpfheim", coord. 647.760 / 194.020). The samples were taken from the Lower Tonstein-Schichten Fm. at the foot of the Fürstein Mt. chain (see Figs 1 and 2).

The Lower Tonstein-Schichten Fm. at this location belongs to the outer facies belt of the Schlieren flysch basin, characterized by thick abyssal

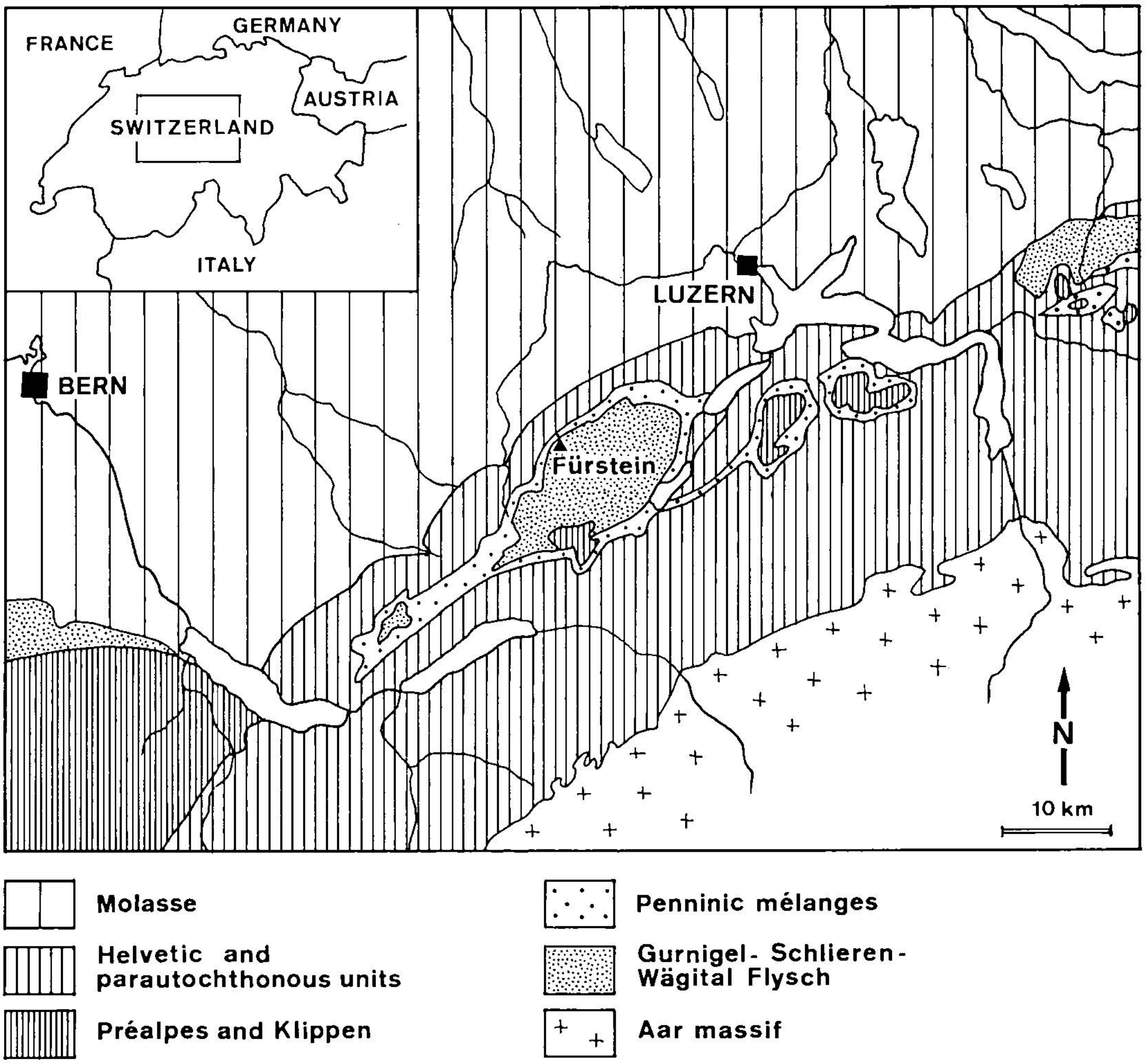

Fig. 1 Simplified geological map of Central Switzerland with location of the Fürstein mountain.

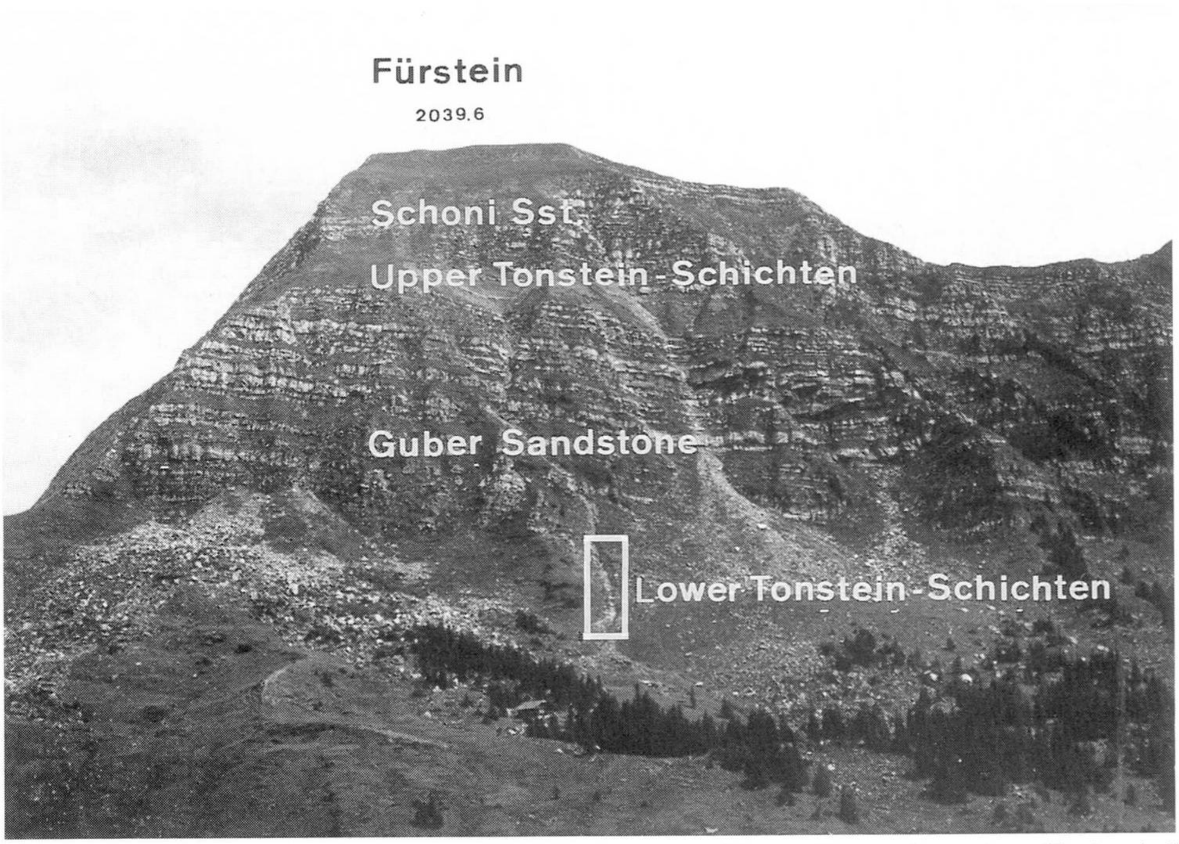

Fig. 2 View of the northern slope of the Fürstein with Paleocene and Lower Eocene formations. The box indicates the position of section A in Fig. 3 with the bentonite in the lowermost part (detailed section B).

plain/oceanic slope deposits, reaching a younger age (earliest Late Paleocene) in its top than in the inner facies belt (NP4 or latest Early Paleocene, WINKLER, 1983, 1984b). They consist of a generally thin-bedded repetition of fine-grained turbiditic sandstones and shales intercalated with comparatively thick and well developed greyish-green hemipelagic claystones (see Fig. 3). In contrast to other formations of the Schlieren Flysch series, the turbiditic shales in the Tonstein-Schichten facies are always poor in carbonate material. In addition to this, the Lower Tonstein-Schichten Fm. is characterized by the occurrence of greenish, well sorted, quartzitic turbidite beds, referred to as "Öl-quarzite" by the pioneers of Swiss geology.

The clay fraction of the bentonite is composed of 67% montmorillonite and 29% illite in the mixed-layer phase; kaolinite amounts to 4% (semiquantitative estimates). From statistically counted heavy mineral grains (enriched by bromoform separation technique) 68% are apatite, 30% zircon, 2% titanite, 1% chromite and 3% contaminating non-volcanic minerals (2% tourmaline, 1% brookite). The typology of zircon (PUPIN, 1980) was evaluated on 150 individual grains and the homogeneous distribution in the diagram indicates a primary calc-alkaline magma source. The observed homogeneous typology of the zircon grains proves that the layer is the product of a single and not reworked volcanic event. The assumed diagenesis corrected chemical composition of the bentonite points to the presence of a basaltic or phonolitic volcanic ash, depending on which correction factors are applied (see WINKLER et al., 1985b).

There is good control on the maximum temperature reached during burial of the bentonites. From illite crystallinity measurements, clay mineral assemblage and feldspar preservation it is assumed that the series was affected by low to medium grade diagenetic overprint of approximatively 70–100 °C (WINKLER, 1983). Therefore apatite fission track dating is not recommended.

Calcareous nannofossil biostratigraphy

The nannofossil samples were mostly taken at the turbiditic sand-shale transition, because this is in the present formation the most favourable place to obtain carbonate-bearing and sufficiently soft samples. Six samples were studied for calcareous nannofossils in simple smear-slides and examined with an optical microscope. Five of them contained quite rich assemblages (Tab. 1). The preservation is

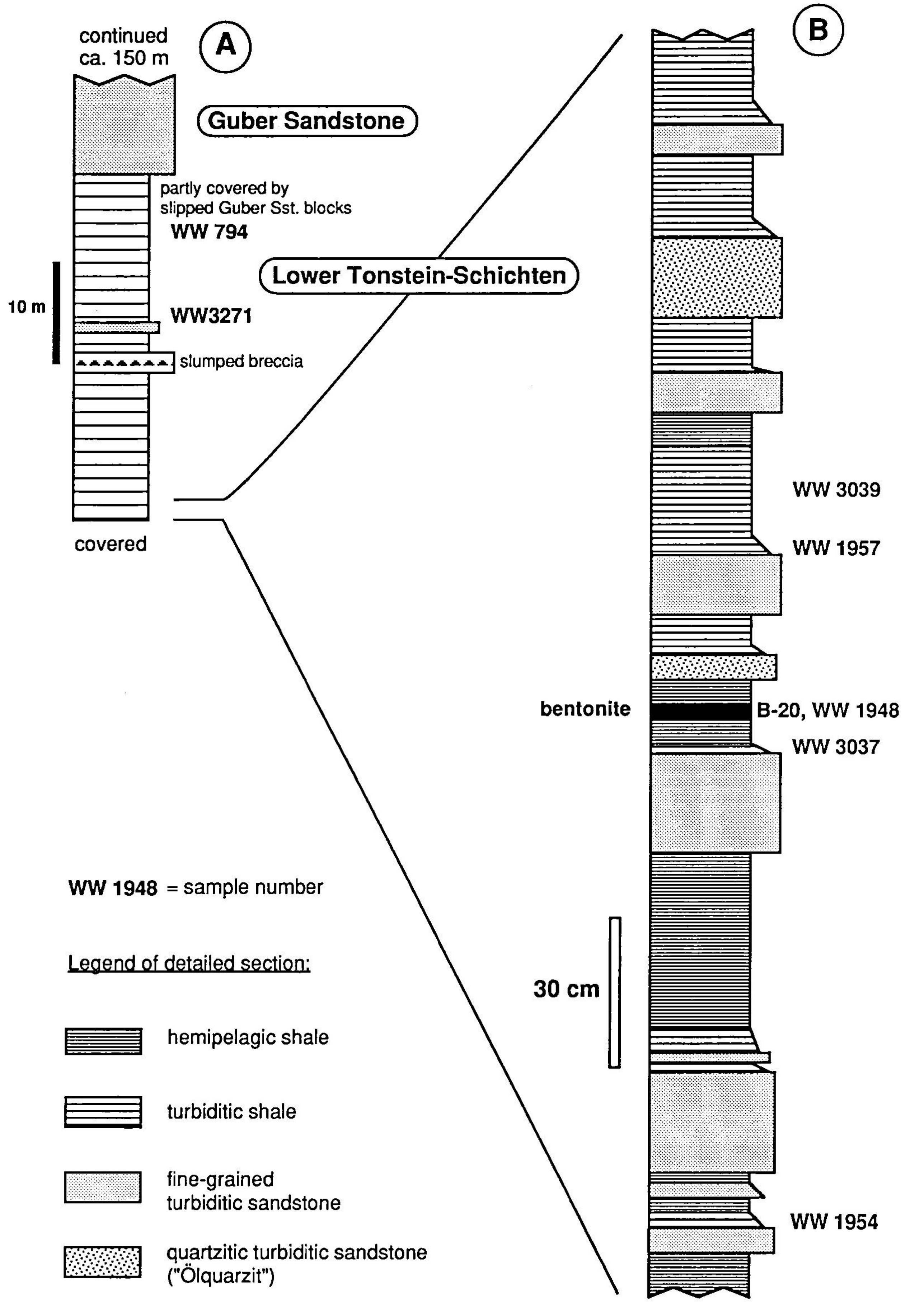

Fig. 3 Composite (A) and detailed (B) section of the Änggenlouenen outcrop in the Lower Tonstein-Schichten Formation.

Tab. 1 Calcareous nannofossil biostratigraphy below and above the bentonite layer in the Schlieren Flysch. Abbreviations: vR, + = very rare, present, R = rare, Rf = rare to few, C = common. Preservation: vP = very poor, P = poor, Pm = poor to moderate, M = moderate. For complete citations of authors of species see PERCH-NIELSEN (1985 a, b).

Sample	WW 1954	WW 3037	WW 1957	WW3039	WW 3271	WW 794
Nannofossil abundance & preservation	C, Pm	vR, vP	R, Pm	R, Pm	R, M	C, Pm
Palaeocene nannofossils						
Chiasmolithus sp.	+					
C. edentulus	+		+			
Coccolithus pelagicus s.a.	+	+	Rf	+	R	R
Fasciculithus billii	?	+	?	?	?	
F. janii	+		+	+		
F. tympaniformis	+	+	+	+	+	Rf
F. ulii	+		+			
F. sp. cf. F. magnus	+			+		
Markalius inversus	+		+			
Neochiastozygus sp.	+					
Neocrepidolithus sp.	+					
Placozygus sigmoides	+	+	+	+	+	+
Prinsius martinii	+		+	+	R	
Sphenolithus primus	C	+	+	+	+	Rf
Thoracosphaera sp.	+			+	R	+
Toweius craticulus	+		+	+	+	+
T. eminens	+		+	+	+	R
Chiasmolithus danicus			+			
C. inconspicuus			+	+		
Cruciplacolithus tenuis s.a.			+			
Ericsonia subpertusa				+		
Ericsonia sp. cf. E. robusta			+			
Fasciculithus pileatus			+	+		
Neochiastozygus perfectus			+	+	+	
Prinsius bisulcus			+	+		+
Chiasmolithus bidens				+	+	+
C. frequens				+		
Braarudosphaera bigelowii		bentonite		+		
Ellipsolithus distichus				+		
Neochiastozygus digitosus				+		
Lanternitus duocavus				+		
Ellipsolithus macellus					+	
Pontosphaera sp.					+	
Heliolithus cantabriae					+	+
H. kleinpellii					+	Rf
Sphenolithus anarrhopus						+
Nannofossil - Zone	NP 5				NP 6	
Mesozoic nannofossils (reworked)						
Arkhangelskiella cymbiformis	+		+	+	+	
Ceratolithus aculeus					+	
Chiastozygus sp.					+	
Chiastozygus fessus				+		
Eiffellithus eximius			+			+
E. turriseiffelii					+	
Ellipsagelosphaera communis				+	+	
Eprolithus floralis						+
Lucianorhabdus sp.	+		+			
Micula decussata	+	+	+	+	R	+
Nannoconus steinmannii					+	
Prediscosphaera cretacea			+			
Reinhardtites anthophorus				+		
Stephanolithion bigotii					+	
Stradneria crenulata			+			
Watznaueria barnesae	+	+	+	+	R	+

very poor in one sample and poor to moderate in the others. The poorly preserved assemblages are affected heavily by dissolution. This has affected the diversity of the assemblages, in that fragile species have been removed or broken and are no longer determinable. The biostratigraphic marker species of the Late Paleocene are, however, relatively solution resistant and thus the zonal assignments are judged to be realistic.

The two samples below and the two samples above the bentonite layer (see Fig. 3, Tab. 1) feature assemblages typical of NP5, the *Fasciculithus tympaniformis* Zone of MARTINI (1971), including *F. tympaniformis* but no *Heliolithus kleinpellii*. The latter appears very rare in sample WW 3271. It reaches rare to few in the uppermost sample studied and assigns these two samples to NP6, the *Heliolithus kleinpellii* Zone, since the marker of NP7, *Discoaster mohleri*, was not found. No calcareous nannofossils indicative of younger zones were observed.

VAROL (1989) subdivided both NP5 and NP6, a subdivision that was not feasible in our material. He noticed an overlap of *H. kleinpellii* with *Fasciculithus janii* and *F. pileatus*, an interval that should fall between samples WW 3039 and WW 3271. Its absence might indicate slow sedimentation or a hiatus between those two samples.

Reworked Mesozoic coccoliths were found in all samples. Most species have a Late Cretaceous range but sample WW 3271 also contains species with a Late Jurassic range *(Stephanolithion bigotii)* and some with an early Cretaceous distribution *(Nannoconus steinmannii)* – an expression of deeper erosion during the regression around the NP 5/6 boundary (HAQ et al., 1988)?

Fission track ages

The clayey bentonite samples (totally approx. 1.5 kg) were disaggregated by repeated soaking in cold Désogéne (CIBA-GEIGY, Basel) and short treatments in the ultra-sound bath. Heavy minerals (including zircons) were separated from the sandy residue by conventional heavy liquid (bromoform) techniques. Fission track ages were measured for two independant zircon samples (B-20 and WW 1948) using the external detector method approach (GLEADOW, 1981). ^{238}U spontaneous fission tracks were etched in the polished zircon crystals using a eutectic of KOH–NaOH at 220 °C for 15 hrs (GLEADOW et al., 1976). ^{235}U induced fission tracks were recorded in an external detector of low-uranium mica, held against the zircons during irradiation with thermal neutrons. These micas were subsequently etched using 40% HF at 20 °C for 45 mins. Sample B-20 (see preliminary presentation by HURFORD et al., 1987) was irradiated in the J1 thermal facility of the HERALD reactor, Aldermaston, UK, and sample WW 1948 in the thermal column of the PLUTO reactor, Harwell, UK. Track counting utilised a ZEISS Axioplan microscope (100× oil objective, total magnification 1250×) equipped with a Stagemover computerised stage system to locate the zircon crystals and their mirror image mica impressions. Neutron fluences were monitored by including wafers of uranium dosimeter glass CN1 (HURFORD and GREEN, 1983) at either end of the sample stack and counting the induced tracks recorded in a mica detector held against the glass.

Sample ages (Tab. 2) were calculated using the zeta calibration approach (FLEISCHER and HART, 1972) using a value of 113.0 ± 2.6 for ζ_{CN1} determined by repeated analysis of age standards (HURFORD and GREEN, 1983). As a control of calibration, aliquots of zircon age standards from the Fish Canyon tuff (San Juan, Colorado, see HURFORD and HAMMERSCHMIDT, 1985) and the Buluk Member tuff (northern Kenya, see HURFORD and WATKINS, 1987) were included in each irradiation. Analytical results are given in Tab. 2. Analyses were subjected to a χ^2-test (GALBRAITH, 1981) to determine whether any extra-Poissonian error might be present. Each data set passed the test at > 5% level, indicating the Poissonian error (the conventional error of GREEN, 1981) derived from counting statistics to be a reasonable estimator of experimental error.

The results for the two samples are identical within their errors with a mean of 57.8 ± 2.7 (1 σ) Ma (or a weighted mean of 57.8 ± 1.9 [1 σ] Ma).

Discussion and conclusions

Our data indicate that the bentonite, embedded in sediments biostratigraphically correlated with NP5 zone (early Late Paleocene) contains volcanic zircons which yield a mean fission track age of 57.8 ± 2.7 Ma. Biostratigraphic dating had to be carried out on turbiditic shales. The first occurrences of nannofossil marker species were considered for zonal assignments. Both the reworked nature and possible postdepositional dissolution could represent a probable source of error. However, the zonal markers for NP5 *(Fasciculithus tympaniformis)* and NP6 *(Heliolithus kleinpellii)* are rather solution resistant forms and they occur in our section in an obviously undisturbed succession. In addition, this biostratigraphic correlation fits well with other nannofossil dates in adjacent areas (WINKLER, 1983).

Tab. 2 Zircon fission track data measured on the bentonite samples B-20 and WW 1948 and standards.

Samples and Standards	Mineral and No. Crystals	Spontaneous ρ_s (N_s)	Induced ρ_i (N_i)	$P\chi^2$	Dosimeter ρ_d (N_d)	Age Ma ± 1 σ
Schlieren Flysch						
B-20	zircon 20	6.728 (2122)	4.305 (1358)	70%	0.66 (4700)	58.0 ± 2.5
Wi 1948	zircon 10	8.181 (1167)	4.893 (698)	20%	0.611 (3880)	57.5 ± 2.9
Age Standards						
Fish Canyon	zircon 20	5.535 (2778)	8.395 (4213)	55%	0.749 (4700)	27.8 ± 1.1
Fish Canyon	zircon 14	6.31 (2910)	8.127 (3748)	45%	0.611 (3880)	26.8 ± 0.8
Buluk Member	zircon 20	1.149 (1433)	2.869 (3579)	65%	0.742 (4700)	16.8 ± 0.7

Notes:
(i). track densities (ρ) are as measured and are ($\times 10^6$tr cm^{-2}); numbers of tracks counted (N) shown in brackets;
(ii). analyses by external detector method using 0.5 for the 4π/2π geometry correction factor;
(iii). ages calculated using dosimeter glass CN-1 with $\zeta_{CN1} = 113 \pm 3$; other constants as defined in HURFORD and GREEN (1983);
(iv). $P\chi^2$ is probability of obtaining χ^2 value for v degrees of freedom, where v = no. crystals - 1;
(v). independent ages of standards: Fish Canyon Tuff 27.8 ± 0.7 Ma; Buluk Member Tuff 16.2 ± 0.2 Ma (see HURFORD and GREEN, 1983; HURFORD and WATKINS, 1987).

Preliminary radiometric $^{238}U/^{206}Pb$ dating of two zircon samples from the same bentonite layer was provided by FISCHER (1988) revealing ages of 52.57 ± 0.22 and 54.78 ± 0.50 (2 σ) Ma. These quite similar and young dates certainly confirm the synsedimentary volcanic derivation of the zircon grains. However, in comparison with current chronostratigraphic calibrations as CURRY and ODIN (1982) these radiometric ages correlate with NP zones 8–10 at about the Paleocene-Eocene boundary. From palaentologic evidence the fission track ages are preferred to the U–Pb ages since the transition from Late Paleocene to Early Eocene corresponding with the U–Pb ages occurs in the same section higher up in the series at the boundary between NP 9 and NP 10 which coincides with the transition from the Guber Sandstone to the Upper Tonstein-Schichten Formation in Fig. 2.

The present fission track age of 57.8 ± 2.7 Ma corresponds better with most existing chronostratigraphic and biostratigraphic correlations. It coincides with NP5 in CURRY and ODIN (1982), approximatively with the transition from NP5 to NP6 in HARLAND et al. (1982; but not with HARLAND et al., 1990) and lowermost NP6 in HAQ et al. (1988). Because of the poor outcrop conditions at the base of the Fürstein mountain chain the position of the bentonite inside the NP5 zone cannot be more precisely assessed at the present time.

The mean fission track age of 57.8 ± 2.7 Ma is a new constraint for calibrating the Palaeogene time scale at a place where very few results are available.

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