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^{230}TH/U DATING RESULTS FROM OPENCAST MINE SCHÖNINGEN

Middle and Late Pleistocene deposits are exposed in the Schöningen lignite mine in Eastern Lower Saxony. The Pleistocene sediment succession consists of various interglacial and interstadial peat and limnic sediments, travertine tuff, soils, glacial tills and fluvioglacial as well as loess deposits. At least three interglacials postdating the Elsterian glaciation and predating the Holocene were established according to Thieme et al. (1987), Urban et al. (1988; 1991a; 1991b) and Urban (1999; 2007).
Due to deposition in different cycles (Thieme / Mania 1993), later named channels (Mania 1998), the Pleistocene sediment succession in Schöningen is complex. Six major channels termed I to VI from the oldest to the youngest containing interglacial and early glacial deposits were identified. The sediment succession begins with the Late Elsterian glacial and interstadial deposits preceding the Holsteinian channel (I), followed by the Reinsdorf Interglacial (II). The Schöningen Interglacial (III) represents a warm episode of the pre-Drenthe (Early Saalian Stadial) period. The pedocomplex (IV) developed in alluvial loess overlying Drenthe Stadial till of the Saalian glaciation and was covered by a succession of soft travertine and peat representing the Eemian channel (V). Overlying sediments provide environmental information of the Weichselian Late Glacial and the Holocene (VI) (summarised in Urban 2007).
The stratigraphic position of the classical Holsteinian deposits, especially in relation to the Reinsdorf sediment succession (Urban 2007) and their correlation with other pollen records and the marine isotope stratigraphy are still under debate. The age and stratigraphic position of the upper Middle Pleistocene Reinsdorf sediment succession which contains archaeological horizons with the famous wooden throwing spears (Thieme 1996; 1997; 1998; 1999; 2007) are of particular interest.
During the past decades profile series have been saved by Hartmut Thieme and the excavation team from the ongoing mining process and are successively analysed sedimentologically and palynologically (Urban / Sierralta, this volume).
In 2003, the profile of Schöningen 13-II x662 y2 (**fig. 1**) was sampled using 25 cm long steel boxes (Thieme 2007). The lowermost part of this sediment succession consists of two aggradation series that contain peat and gyttja layers. This study reviews several radiometric and thermal ionisation mass spectrometric studies on Schöningen deposits using the ^{230}Th/U method that have been undertaken since the early 1990s.

METHOD

Uranium-series dating is a commonly used method for dating speleothems (e. g. Richards / Dorale 2003), corals (see Edwards et al. 2003; Scholz / Hoffmann 2008), and lacustrine carbonates (Edwards et al. 2003; Sierralta et al. 2010). Since Vogel / Kronfeld (1980) demonstrated that ^{230}Th/U dating can be applied to peat, this method has been used to a variety of deposits (Heijnis 1992; Heijnis / van der Plicht 1992; Geyh / Techmer 1997; Geyh et al. 1997; Rowe et al. 1997; Frechen et al. 2007).
The ^{230}Th/U dating method is based on the radioactive disequilibrium in the ^{238}U decay series. The ^{230}Th/U disequilibrium dating method (Ivanovich / Harmon 1992; for a comprehensive overview see Bourdon et

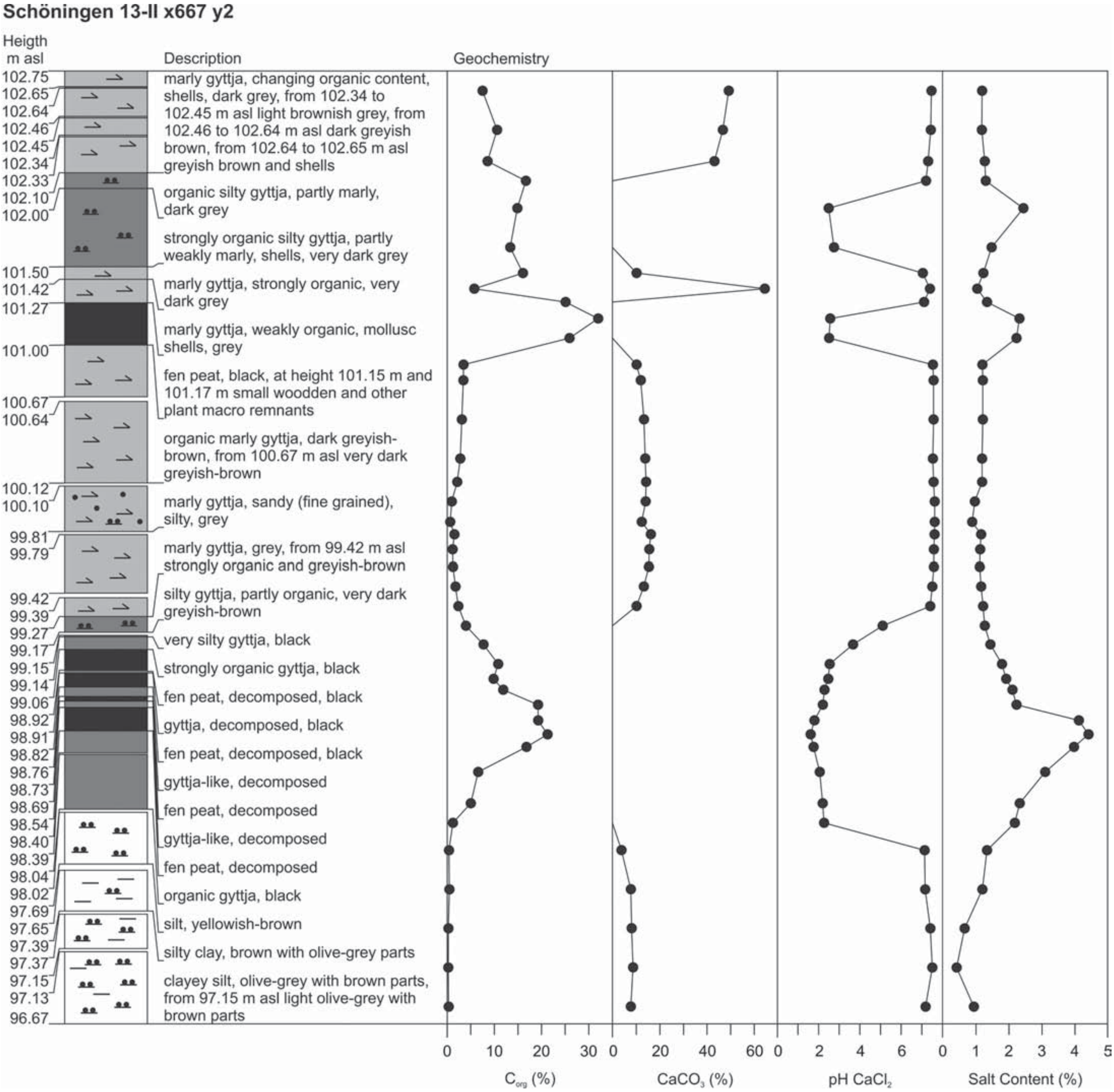


Fig. 1 Altitude and lithology of the part of the profile Schöningen 13-II that contains the peat layers that were sampled for ^{230}Th/U dating in 2003. – (Modified after Urban et al. 2011).

al. 2003) is based on the two daughter nuclides ^{234}U and ^{230}Th with the half lives of 245,250 ± 490 years and 75,690 ± 230 years, respectively (Cheng et al. 2000). Radioactive disequilibrium evolves following geochemical transitions, e. g. weathering. By weathering of host rock, uranium is leached from uranium-bearing minerals and dissolved in groundwater as uranyl ions or as uranyl carbonate complexes under oxidizing conditions, while thorium is almost insoluble in groundwater and tends to adsorption onto clay minerals. ^{230}Th formes by radioactive decay of ^{234}U when uranium is deposited from groundwater.

Precise ages are obtained by the $^{230}Th/U$ method if (1) initially thorium was absent during the formation of fen peat and (2) the deposits have experienced no migration of uranium and thorium since its formation. However, most of such peat formations are impure and gained various amounts of detrital material, e.g. windblown dust containing natural quantities of thorium. Detrital contamination is identified by the presence of significant levels of ^{232}Th in the samples which is the most abundant, extremely long-lived isotope of Th. $^{230}Th^{232}Th$ activity ratios of <10 indicate a high detrital contamination which considerably falsifies the $^{230}Th/U$ ages.

To correct for admixed ^{230}Th from detritus with a uniform initial [$^{230}Th/^{232}Th$] activity ratio at the time of formation, the isochron method was developed (Kaufman / Broecker 1965) and applied (e.g. Osmond et al. 1970; Kaufman 1971; Ku / Liang 1984; Schwarcz / Latham 1989; Luo / Ku 1991). Schwarcz / Latham (1989) showed that measured ^{230}Th activities for age calculation can be corrected for the admixed detrital ^{230}Th by analysing leachates of several coeval sub-samples with differing detrital contents (L/L-method). The present-day initial $^{230}Th/^{232}Th$ value which is the correction factor f of the measured ^{230}Th activity is given by the interception of the regression line to the data points with the Y axis in a Rosholt-I plot ($^{230}Th/^{232}Th$ vs. $^{234}U/^{232}Th$; **fig. 2**). It is used to correct the measured ^{230}Th activity of each coeval subsample individually according to Kaufman / Broecker (1965).

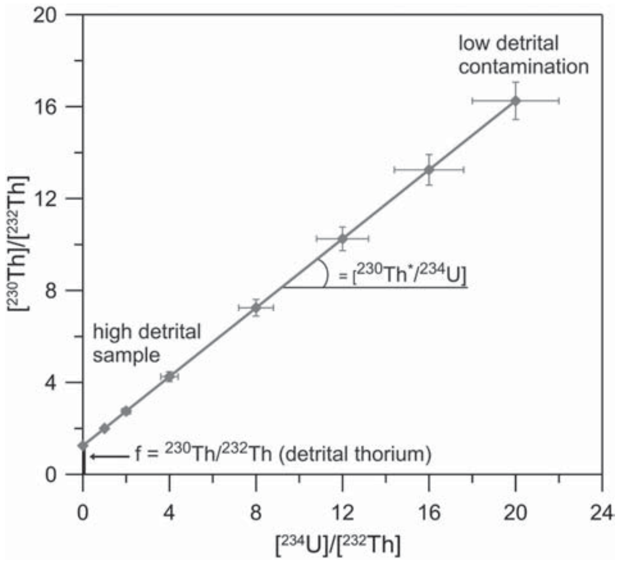


Fig. 2 Rosholt-I plot and explanaition of the impact of detrital contamination. The slope of the regression line of the data increases with age. The y-intercept of this line determines the detritus correction factor. – (Illustration M. Sierralta).

The second prerequisite of the $^{230}Th/U$ method is that the dated system behaved under closed system conditions with respect to all uranium and thorium isotopes. Humic acids from decomposed plants and organic material such as fen peat take up uranium from the groundwater (Titayeva 1966; Vogel / Kronfeld, 1980). Organic decomposition products like humic and fulvic acids have a large absorption capacity for uranium in the form (Szalay 1958; Yliruokanen 1980). Very stable uranyl organic complexes are formed by aromatic ring structures with hydroxyl and carboxyl groups (Szalay 1958). Therefore, high uranium concentrations in peat ranging from 1 to 100 ppm have been observed. The mobility of uranium in humic sediments or peat depends on the mobility of humic and fulvic acids (Szalay 1958).

Percolating ground water in buried organic-rich sediments causes further uranium uptake or loss. Most of the uranium dissolved in groundwater is fixed and adsorbed in the upper and lower rim of peat layers. Experience shows that usually 10 cm thick peat protects its central part from further uranium import (Geyh / Techmer 1997). A post-sedimentary uptake of thorium is unlikely as it is almost insoluble in groundwater. It was found that the inner part of a 20-30 cm thick undisturbed peat layer might be considered as closed system (Heijnis / van der Plicht 1992; Geyh / Techmer 1997). However, also this part might have behaved as open system with regard to uranium if thin sand layers or sand lenses are present and act as pathway for unhindered groundwater access. Loss of uranium owing to dissolution in oxygenated water, e.g. rain water, may change the uranium isotopic composition and may be identified by the isotope evolution plot (**fig. 3**; Osmond / Ivanovich 1992).

The chemical extraction of uranium and thorium for TIMS $^{230}Th/U$ dating from the ash of the samples was adapted from the leachate/leachate technique (e.g. Schwarcz / Latham 1989; Kaufman 1993). To meet the

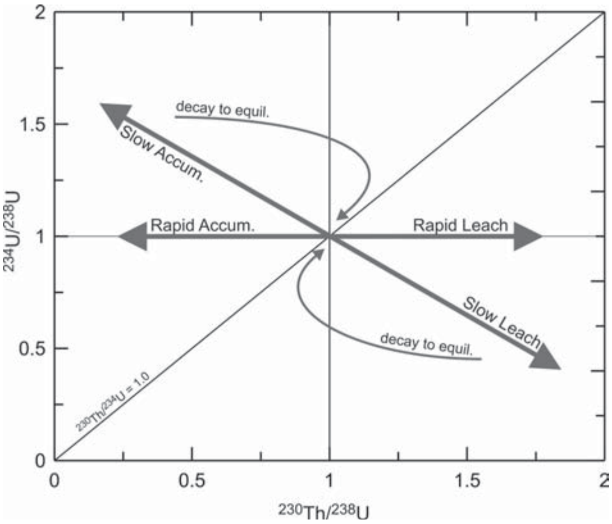


Fig. 3 Isotope ratio evolution plot after Osmond / Ivanovich (1992). – Curved lines show the development of both isotope ratio ratios with time. The effect of slow and rapid uranium mobilisation on the isotope ratios results in straight-line vectors demonstrated by arrows. The point (1,1) is equilibrium for both activity ratios. – (Illustration M. Sierralta).

isochron requirements at least three coeval dry peat samples of about 0.3-0.5 g each were crushed gently and combusted in an O_2 flow at a temperature of about 800 °C for 15 h. The remaining ashes were treated with NaOH to remove remaining humic acids and dissolved slowly in a concentrated HNO_3/HCl mixture and afterwards processed as described by Frechen et al. (2007). All samples were run with total procedural blanks.

The isotopic ratios were measured by thermal ionisation mass spectrometry (TIMS; Finnigan MAT262 RPQ) applying the double filament technique. The external reproducibility was determined by measurements of standard solution of NBL-112A (New Brunswick Laboratories Certified Reference Material) and yields a value of ± 0.3% (1σ SD). Age calculation of the isochron age was performed as described by Geyh (2001) and Sierralta et al. (2010).

RESULTS

Early dates on Schöningen deposits by alpha spectrometry

First absolute dating attempts using the ^{230}Th/U method with alpha spectrometry were performed by Heijnis (1992). He published two preliminary, uncorrected ages on intra-Saalian interglacial deposits, nowadays assigned to Schöningen cycle/channel III (**tab. 1**) to sort out whether the Holsteinian interglacial should be correlated with MIS 7 or even older MIS. He concluded that the so-far uncorrected ages for the Schöningen interglacial deposits of 180 and 227 ka confirm an older age for Holsteinian interglacial deposits.

Further unpublished ^{230}Th/U dating attempts within the 1990s have been performed on Schöningen interglacial deposits at the LIAG laboratory (former NLfB) in Hannover by alpha spectrometry. The radiometric results are given in **table 2**. Low ^{230}Th/^{232}Th values indicate high detrital contamination of the samples and the need for ^{230}Th corrections. Unfortunately, the correction of measured ^{230}Th activities by the isochron method failed. The data points plot widespread in the Rosholt-I plot (^{230}Th/^{232}Th vs. ^{234}U/^{232}Th; **fig. 4a**) which inhibits the determination of the correction factor. Furthermore, the isotope evolution plot after Osmond and Ivanovich (1992) does not show a narrow data point cluster, but follow one isotope evolution line indicating that these samples could be of different age.

Mass spectrometric ^{230}Th/U-dating of peat samples of the Reinsdorf sediment succession

The Reinsdorf sediment succession at Schöningen 13-II x667 y2 (2003) contains two fen peat layers between 98.54 and 99.27 m asl, and 101.00 and 101.27 m asl (**fig. 1**). Both layers were sampled for ^{230}Th/U-dating. According to the sampling in the opencast mine the lower organic rich layer of 90 cm thickness was sampled in four steel boxes of 25 cm length (Thieme 2007). Therefore, the lower peat layer was

sample	UTD code	U (ppm)	$^{234}U/^{238}U$*	$^{230}Th/^{234}U$*	$^{230}Th/^{232}Th$*	age (ka)
Schöningen 882/Sla	91-179	6.632	1.104 ± 0.029	0.821 ± 0.138	4.959 ± 0.777	180 $^{+125}_{-57}$
Schöningen 882/Sla	91-180	7.518	1.092 ± 0.043	0.904 ± 0.167	3.296 ± 0.362	227 $^{+2379}_{-96}$

Tab. 1 Alpha spectrometric isotope results from Schöningen intra-Saalian deposits taken from Heijnis (1992). – UTD denotes uranium thorium disequilibrium. * All values are taken from Heijnis (1992). It remains unclear if given errors are 1σ or 2σ, as it is not mentioned in the thesis.

HV-No	sample	U	Th [ppm]	$^{230}Th/^{234}U$ [ppm]	$^{230}Th/^{232}Th$ 1SE	$^{230}Th/^{238}U$ 1SE	$^{234}U/^{238}U$ 1SE	$age_{uncorrected}$ 1SE [ka]
999α	13-A	12.45	4.590	0.897 ± 0.043	8.197 ± 0.036	0.993 ± 0.043	1.108 ± 0.052	226 ± 24
998α	13-A	4.575	2.419	0.653 ± 0.038	4.274 ± 0.031	0.743 ± 0.038	1.137 ± 0.047	112 ± 5
997α	13-A	36.46	3.310	0.046 ± 0.062	1.838 ± 0.091	0.055 ± 0.063	1.185 ± 0.037	5.1 ± 0.2
994α	12-B	7.535	3.155	0.204 ± 0.078	1.832 ± 0.093	0.252 ± 0.078	1.237 ± 0.065	24.5 ± 1.5

Tab. 2 Alpha spectrometric $^{230}Th/U$ results from Schöningen deposits by LIAG (unpublished).

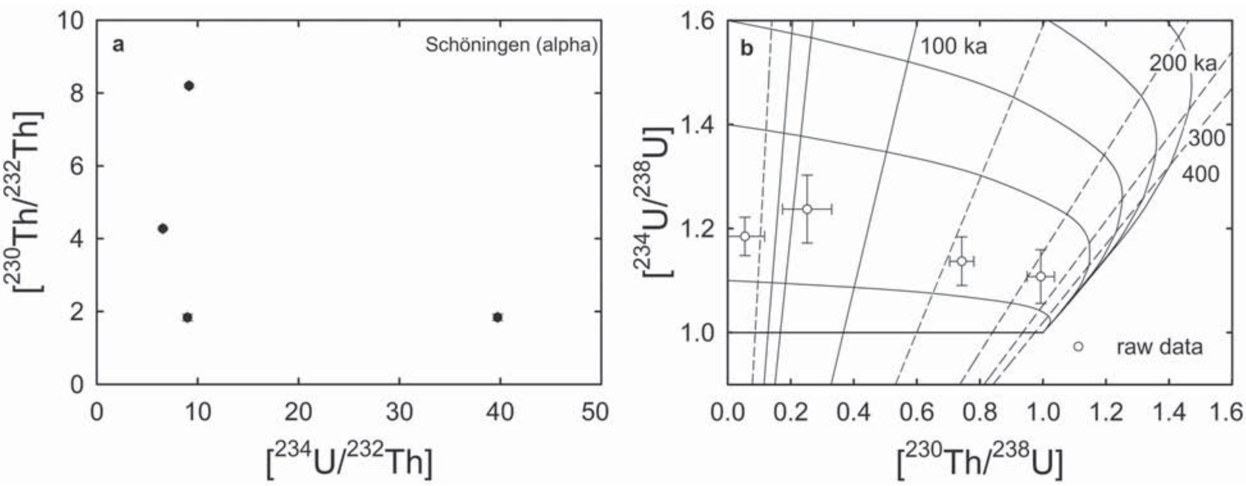


Fig. 4 Rosholt-I plot (**a**) and isotope evolution plot (**b**) from alpha spectrometric results by LIAG laboratory (unpublished). – Solid curved lines in **b** demonstrate developments of isotope ratios with time, dashed lines represent lines of equal age (isochrons). – (Illustration M. Sierralta).

subdivided into three sections from bottom to top: section I) 98.47-98.54m asl, section II) 98.74-98.84 m asl, section III) 98.92-99.06 m asl.

Three samples represent section I from 98.47 to 98.54 m asl (**fig. 5a-b**). Section II from the lower central part is represented by seven samples from four fen peat layers (98.74-98.84 m asl; **fig. 6a-b**), and Section III from the upper central part by seven samples from four layers (98.92-99.06 m asl; **fig. 7a-b**). These three Sections are not more than 15 cm thick and intercalated by decomposed gyttja layers of up to 3 cm thickness. These are not ideal conditions to guarantee closed system conditions. Six samples were analysed from the upper fen peat from three layers (101.075-101.20 m asl; **fig. 8a-b**). Also this section has only 7 cm distance from the upper and lower thick gyttja layer.

The measured isotopic ratios, standard deviations, and uncorrected and corrected $^{230}Th/U$ ages are compiled in **table 3**. The activity ratios $^{230}Th/^{232}Th$ range from 0.8 to 19 indicating a high detrital contam-

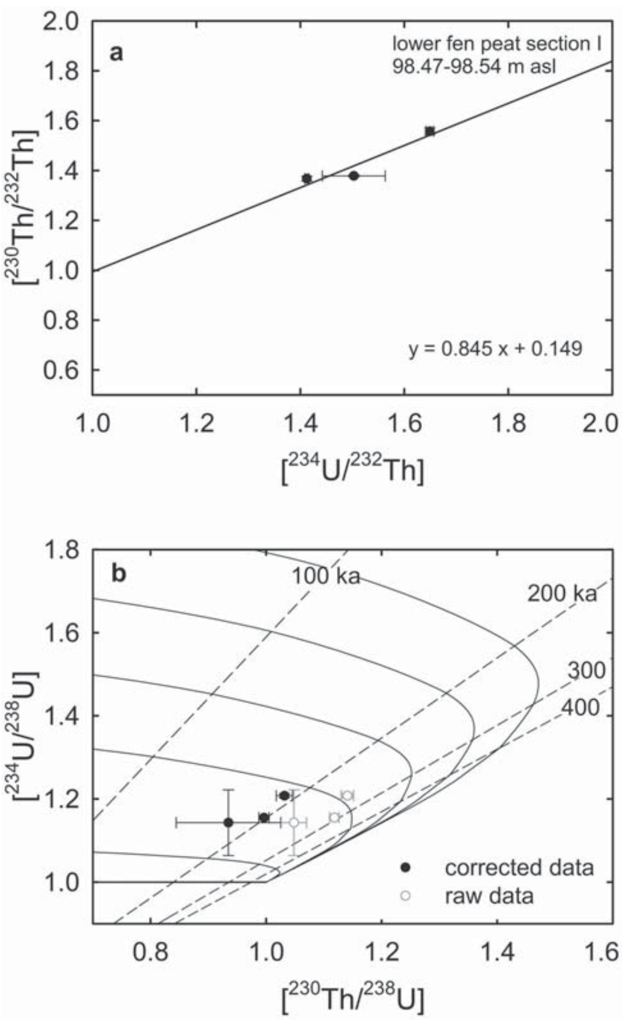


Fig. 5 Rosholt-I plot (**a**) and isotope evolution plot (**b**) for isotopic results from the lower fen peat layer section I (98.47-98.54 m asl) measured by TIMS. For explanation see fig. 4. – (Illustration M. Sierralta).

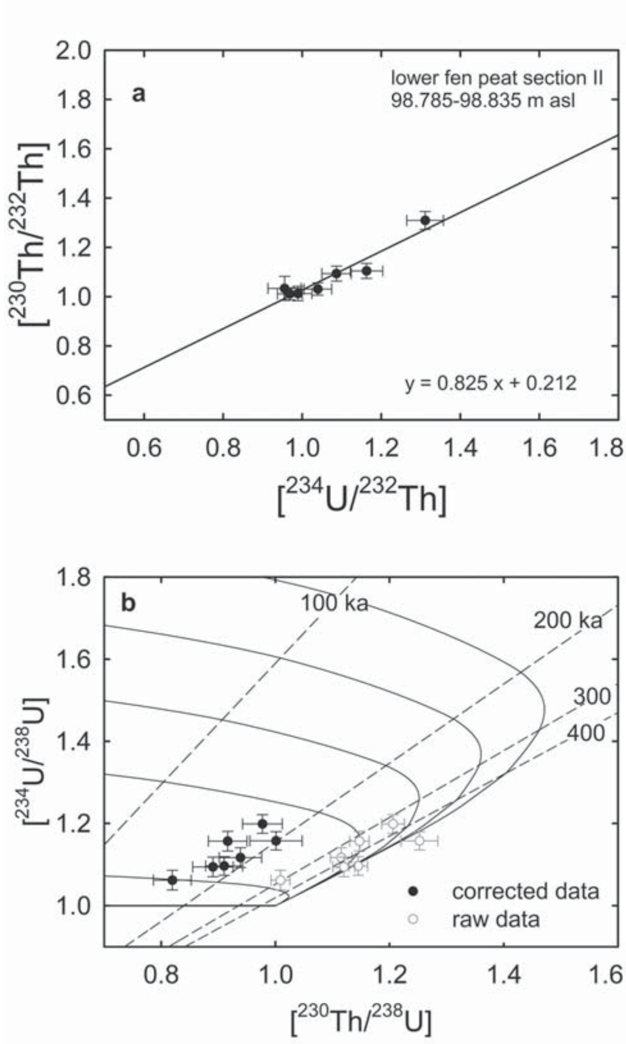


Fig. 6 Rosholt-I plot (**a**) and isotope evolution plot (**b**) for isotopic results from the lower fen peat layer section II (98.74-98.84 m asl) measured by TIMS. For explanation see fig. 4. – (Illustration M. Sierralta).

ination. Consequently detrital correction of the measured ^{230}Th activity had to be applied with individual correction factors determined by the isochron method. The check of closed system behaviour was performed by the isotope evolution plots ^{234}U/^{238}U vs. ^{230}Th/^{238}U (Osmond / Ivanovich 1992), the Rosholt-I plots (figs 5-7), and the Osmond-I plots (^{230}Th/^{238}U vs.^{232}Th/^{238}U and ^{234}U/^{238}U vs. ^{232}Th/^{238}U; fig. 9).

DISCUSSION

The key issues for ^{230}Th/U dating are the detritus correction of the raw ^{230}Th/U ages and the check for open-system conditions with regard to uranium. The extent of detritus contamination of the ^{232}Th activity is obtained by the Rosholt-I plot (^{230}Th/^{232}Th vs. ^{234}U/^{232}Th) which yields the detritus correction factor. Furthermore, outliers cannot be easily determined as the plot uses a common nominator. Due to zero correlation

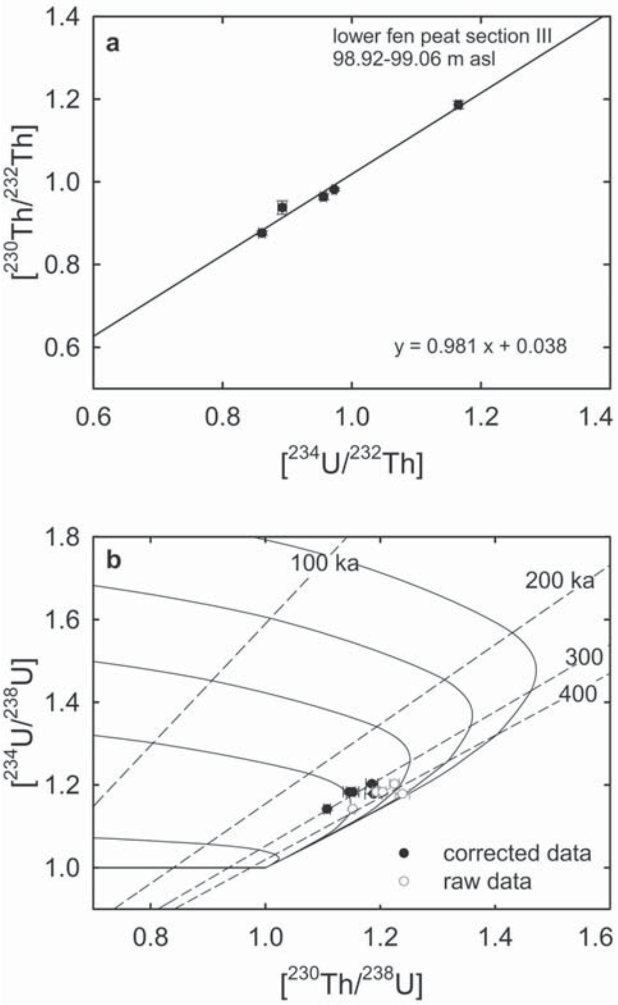


Fig. 7 Rosholt-I plot (a) and isotope evolution plot (b) for isotopic results from the lower fen peat layer section III (98.92-99.06 m asl) measured by TIMS. One outlier (TIMS-No 846) was excluded from the data set and is not shown in the diagrams. For explanation see fig. 4. – (Illustration M. Sierralta).

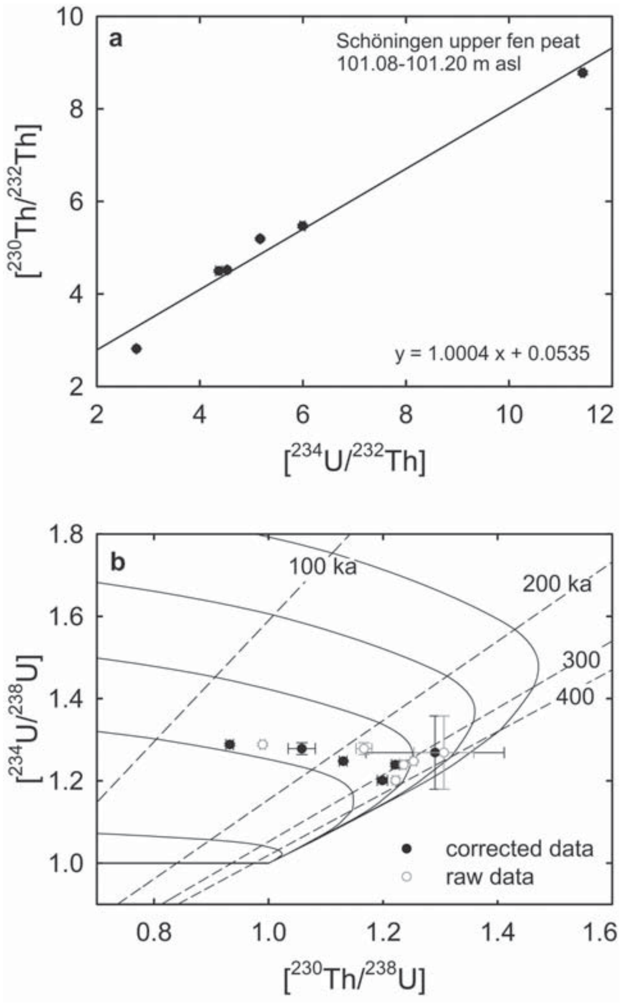


Fig. 8 Rosholt-I plot (a) and isotope evolution plot (b) for isotopic results from the upper fen peat layer 101.08-101.20 m asl measured by TIMS. For explanation see fig. 4. – (Illustration M. Sierralta).

effects all sample data of samples that contained detritus from the same source have to lie on straight lines in any of the possible isotope ratio plots (Ludwig 2003; Geyh 2008). Ludwig (2003) emphasizes that the use of both Osmond diagrams (Osmond et al. 1970) with the common denominator ^{238}U has several advantages in both visualization and identification of the strengths and weakness of data sets for their use in $^{230}Th/U$ dating. We used the Osmond-I plots ($^{230}Th/^{238}U$ vs. $^{232}Th/^{238}U$ and $^{234}U/^{238}U$ vs. $^{232}Th/^{238}U$; **fig. 9**) to check the quality of each data set for open-system conditions and to discard outliers.

One outlier (TIMS No. 846) in the data set was determined in section III of the lower fen peat layer (98.92-99.06 m asl). The reason was a very low ion intensity of ^{232}Th during the data acquisition. This data point was excluded from the isochron plot.

During sampling for $^{230}Th/U$ and pollen analysis it was impossible to distinguish between decomposed fen peat and gyttja layers. The latter were identified by investigations on the organic carbon content (Urban et al. 2011). We avoided to sample the lowermost and uppermost 10 cm of the organic-rich layers of dark brown to black colour at 98.04-98.14 and 99.05-15 m asl. Unfortunately, these layers turned to be gyttja

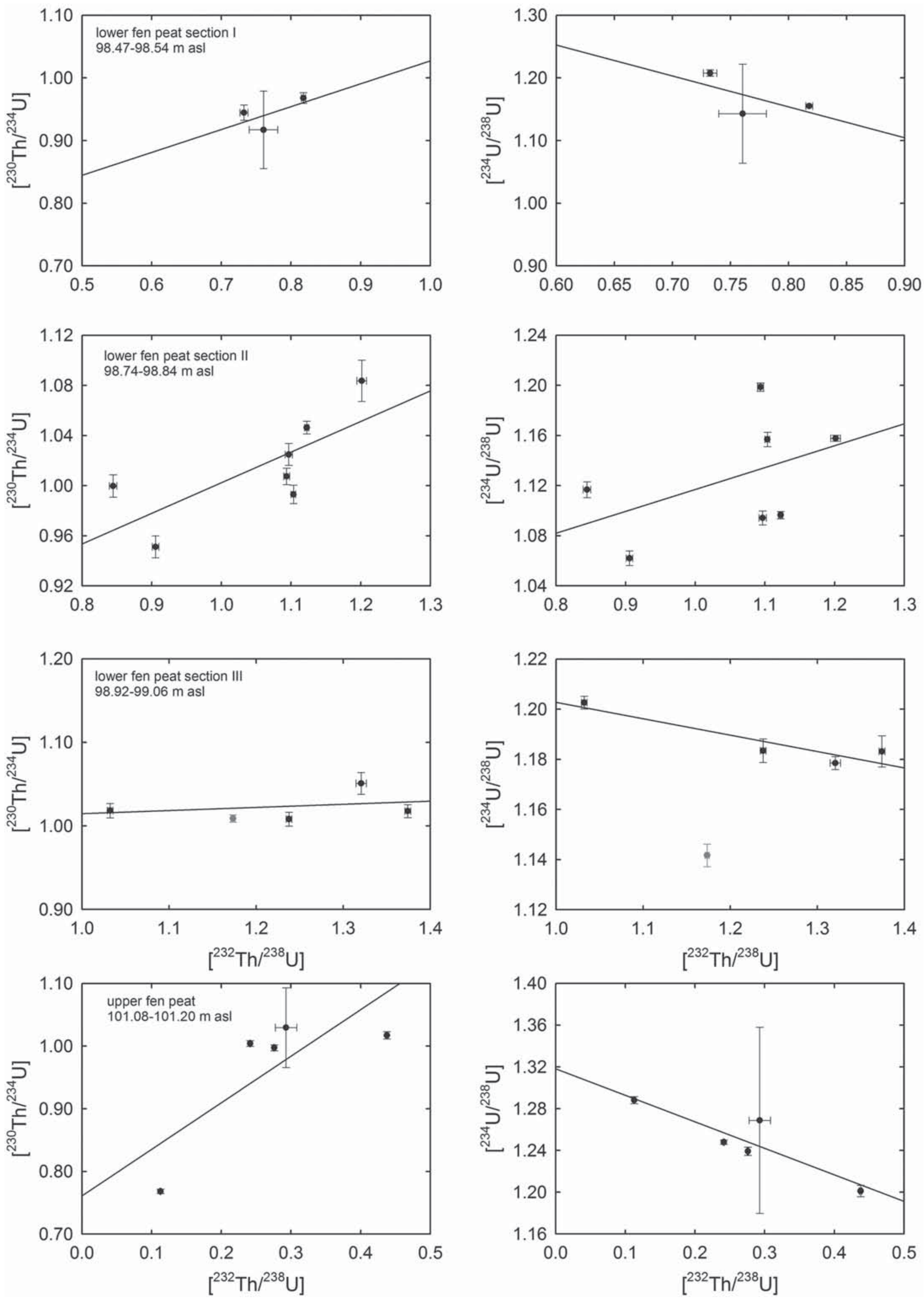
TIMS No	depth [m asl]	U [ppm]	Th [ppm]	$^{230}Th/^{234}U$ $2\sigma_{SD}$	$^{230}Th/^{232}Th$ $2\sigma_{SD}$	$^{230}Th/^{238}U$ $2\sigma_{SD}$	$^{234}U/^{238}U$ $2\sigma_{SD}$	$age_{uncorrected}$ [ka]	$age_{corrected}$ [ka]
lower peat section I									
849	98.47–98.48	0.91	2.03	0.945 ± 0.012	1.558 ± 0.013	1.141 ± 0.011	1.208 ± 0.005	253 ± 10	
850	98.50–98.52	0.83	2.07	0.968 ± 0.009	1.367 ± 0.010	1.118 ± 0.008	1.155 ± 0.002	290 ± 10	
851	98.53–98.54	0.85	1.96	0.917 ± 0.062	1.378 ± 0.003	1.048 ± 0.022	1.143 ± 0.079	238 ± 90	
lower peat section II									
765	98.74–98.75	1.93	4.94	1.000 ± 0.009	1.322 ± 0.008	1.117 ± 0.008	1.117 ± 0.006	363 ± 22	
766	98.76–98.78	1.05	3.58	1.046 ± 0.005	1.022 ± 0.005	1.147 ± 0.005	1.096 ± 0.003	> 650	
839	98.76–98.78	1.13	4.12	1.084 ± 0.016	1.044 ± 0.021	1.255 ± 0.016	1.158 ± 0.002	> 650	
840	98.76–98.78	1.48	4.97	0.993 ± 0.007	1.041 ± 0.005	1.149 ± 0.006	1.157 ± 0.006	328 ± 12	
841	98.76–98.78	1.56	5.18	1.007 ± 0.007	1.104 ± 0.008	1.208 ± 0.007	1.199 ± 0.003	337 ± 12	
767	98.80–98.81	1.56	5.20	1.025 ± 0.009	1.023 ± 0.009	1.121 ± 0.008	1.094 ± 0.006	maximum age	
768	98.82–98.84	1.85	5.10	0.951 ± 0.009	1.116 ± 0.008	1.010 ± 0.007	1.062 ± 0.006	297 ± 12	
lower peat section III									
843	98.92–98.94	1.37	4.30	1.018 ± 0.009	1.186 ± 0.009	1.225 ± 0.008	1.203 ± 0.003	357 ± 19	300 ± 13
844	98.95–98.96	0.98	3.94	1.051 ± 0.013	0.938 ± 0.016	1.239 ± 0.012	1.179 ± 0.003	maximum age	348 ± 31
845	98.98–99.00	0.96	3.60	1.008 ± 0.008	0.964 ± 0.007	1.193 ± 0.007	1.183 ± 0.005	345 ± 15	n.d.
852	98.98–99.00	1.24	4.40	1.009 ± 0.004	0.982 ± 0.004	1.152 ± 0.004	1.142 ± 0.003	371 ± 11	296 ± 7
847	99.04–99.06	0.91	3.80	1.018 ± 0.008	0.876 ± 0.005	1.204 ± 0.006	1.183 ± 0.006	367 ± 18	289 ± 12
846*	99.04–99.06	1.01	0.19	1.002 ± 0.009	19.164 ± 0.068	1.167 ± 0.008	1.166 ± 0.002	340 ± 16	n.d.
upper peat layer									
770	101.08–101.09	1.82	2.40	1.017 ± 0.006	2.816 ± 0.005	1.222 ± 0.005	1.201 ± 0.005	356 ± 13	
1123	101.08–101.09	2.54	0.87	0.768 ± 0.005	8.780 ± 0.004	0.990 ± 0.005	1.288 ± 0.003	146 ± 2	
771	101.12–101.13	1.68	1.48	1.030 ± 0.064	4.498 ± 0.027	1.306 ± 0.052	1.269 ± 0.089	maximum age	
1124	101.12–101.13	1.76	1.29	1.004 ± 0.004	5.192 ± 0.005	1.253 ± 0.004	1.248 ± 0.002	314 ± 6	
772	101.18–101.20	1.66	1.37	0.997 ± 0.005	4.519 ± 0.004	1.236 ± 0.004	1.239 ± 0.004	305 ± 6	
1125	101.18–101.20	1.87	1.21	0.913 ± 0.011	5.468 ± 0.006	1.167 ± 0.012	1.278 ± 0.014	219 ± 6	

Tab. 3 Derived isotopic ratios, and $^{230}Th/U$ ages of peat samples from profile Schöningen 13-II (2003), all uncertainties are given as 2σ standard deviations of the mean. – n.d. = not determined.

and not the decomposed fen peat which would be the appropriate material to work as a barrier for uranium uptake. Therefore, gyttja layers have been investigated that were presumed to be fen peat layers. Gyttja is not an ideal material for $^{230}Th/U$ dating as closed system conditions cannot always be assured. The higher mineral content of gyttja may offer pathways for oxygenated groundwater that can transport, leach or supply uranium. However, Gaigalas et al. (2007) successfully dated a gyttja layer from Mardasavas section in Lithuania. Furthermore, Müller et al. (2005) were the first to succeed in dating the fine-detritus mud from Jammertal (near Biberach/D) by $^{230}Th/U$. The silicate content of an organic rich deposit seems to be not always a criterion for the success of the dating method.

The data from Section I of the lower fen peat layer was obtained from the lowermost gyttja layer and indicate open system behaviour (**fig. 5**). It could be caused by ascending groundwater through the intercalated gyttja layers. Higher salt contents of these layers may be a further indicator for processes such as halokinesis.

Fig. 9 Osmond-I diagrams for all samples investigated by TIMS from four sections of the profile Schöningen 13-II. Samples fulfilling the prerequisites of the $^{230}Th/U$ dating method must build straight regression lines. Scatter from regression line indicates open-system behavior. One outlier from the lower fen peat section III is marked in grey. – (Illustration M. Sierralta).



lower fen peat section I
98.47-98.54 m asl
lower fen peat section II
98.74-98.84 m asl
lower fen peat section III
98.92-99.06 m asl
upper fen peat
101.08-101.20 m asl
[230Th/234U]
[234U/238U]
[232Th/238U]

The isotope ratios from section II of the lower central part scatter widely in the Rosholt I plot (**fig. 6a**) which does not allow to draw a regression line. The scatter in the isotopic evolution plot (**fig. 6b**) does also support the assumption of open-system conditions with regard to uranium. This section consists of two peat layers of 3 and 8 cm thickness intercalated by a 5 cm thick gyttja layer which may not fulfil closed-system conditions.

The uranium isotope ratios of section III of the lower fen peat (98.92-99.06 m asl) behaved as closed system (**fig. 7a-b**) as also shown by a more or less constant uranium concentration. The Osmond-I plot (**fig. 9**) shows one additional outlier (TIMS No 845; shown in grey) that falls of the regression line. The data was excluded from further calculation.

The Rosholt-I plot yielded a detritus correction factor of 0.041 and an isochron ^{230}Th/U age of 290 ± 5 ka (n = 4) with a reasonable $\chi^2 = 3.45$.

The data of the upper peat layer demonstrates open system conditions (**figs 8-9**). The scatter in the Osmond-I plot is widely distributed also shown in the Rosholt-I plot and the isotope evolution plot. A reliable detritus correction was impossible and the prerequisites of the dating method are not fulfilled.

The pollen spectra of the lower fen peat intercalated by gyttja layers that yielded a mean isochron age of 290 ± 5 ka ^{230}Th/U reveal late phases of the Reinsdorf interglacial sensu Urban (1995) and are correlated with LPAZ 3b and R4/(R5), when *Pterocarya* and *Fagus* are present by occasional grains (Urban et al. 2011; Urban / Sierralta, this volume). The upper fen peat of the Reinsdorf sediment cycle represents a vegetation succession occurring after a severe climatic deterioration characterised by a newly spread of *Betula* and *Pinus* accompanied by some *Juniperus*, *Alnus*, *Picea* and *Larix*, which most probably corresponds to the Reinsdorf interstadial A/B (sensu Urban 1995; 2007) comprising cycles II-3 and II-4, respectively.

CONCLUSION

The uranium series dating of fen peat deposits from the Schöningen deposits remains a difficult task as the peat layers have not an ideal thickness as they are super- and underlain or intercalated by gyttja layers. We are still convinced on a successful ^{230}Th/U dating for parts of the Reinsdorf interglacial. The corresponding isochron ^{230}Th/U dates correlated the Reinsdorf succession with MIS 9 corresponding to the Holsteinian interglacial at the type site at Bossel, Lkr. Stade/D (Geyh / Müller 2007). This finding implies that the Reinsdorf sediment succession may represent an exceptional and regionally deviating type of the Holsteinian interglacial sensu strictu.

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ZUSAMMENFASSUNG / ABSTRACT

^{230}Th/U Altersbestimmungen im Tagebau Schöningen

Sediment- und Torfabfolgen bieten die Möglichkeit der Rekonstruktion von Klima- und Paläoumweltbedingungen. Ohne verlässliche geochronologische Untersuchungen kommen die stratigraphischen Interpretationen jedoch nicht aus. Jenseits der Altersgrenze von ^{14}C-Datierungen bieten meist nur Optisch Stimulierte Lumineszenz (OSL) an kalt- und warmzeitlichen Sedimenten und ^{230}Th/U-Datierungen an warmzeitlichen Torfabfolgen die Möglichkeit zur Bestimmung des geochronologischen Rahmens. Folgende Datierungsvoraussetzungen müssen für eine zuverlässige ^{230}Th/U-Datierung erfüllt sein: (1) während der Genese wird ausschließlich Uran in Torf akkumuliert und (2) das System muss anschließend isotopenchemisch geschlossen bleiben, d. h. Uran- und Thoriumisotope werden nicht mobilisiert, also weder zu- oder abgeführt. Erste Datierungsversuche mit der ^{230}Th/U-Ungleichgewichtsmethode unter Anwendung der Alphaspektrometrie an Torfen des Schöningen Interglazials führten zu keinen zufriedenstellenden Ergebnissen. Neuere Untersuchungen mit der Thermionen-Massenspektrometrie (TIMS) an zwei Torflagen, die palynologisch dem Reinsdorf-Interglazial zugeordnet werden, lieferten Alter zwischen 280-350 ka und erlauben eine Korrelation des Reinsdorf-Interglazials mit MIS 9. Infolgedessen wird das Reinsdorf-Interglazial neuerlich auch als ein möglicher regionaler Sondertyp des Holstein-Interglazials diskutiert.

^{230}Th/U dating results from opencast mine Schöningen

Sediment and peat successions offer the opportunity for reconstructions of climate and palaeoenvironment by various methods including stratigraphy and palynology. In many cases they lack a robust chronology. Beyond the age range of the ^{14}C method, optical stimulated luminescence and ^{230}Th/U disequilibrium dating are the most commonly used numerical methods (besides e. g. electron spin resonance, amino acid racemisation) to date glacial and interglacial deposits, respectively. The uranium series dating method has two main prerequisites: (1) a complete chemical fractionation between uranium and thorium during formation of the deposit, and (2) closed system behaviour of the nuclides since the formation of the deposit. First dating attempts of uranium series investigations on peat deposits from Schöningen by alpha spectrometry failed for unspecified reasons. Recently, ^{230}Th/U investigations on two layers from Reinsdorf interglacial deposits were performed by thermal ionisation mass spectrometry (TIMS). The ^{230}Th/U ages ranging from of 280-350 ka suggest the correlation of the Reinsdorf sediment succession with MIS 9. Thereupon the palynological record of the Reinsdorf sediment succession is newly discussed as a potentially unusual regional type of the Holsteinian interglacial.