Mikromorphologische Untersuchungen zur Fundplatzgenese an den Fundstellen Schöningen, Grabow und Blätterhöhle, Deutschland, und der Fundstelle Varsche Rivier 003, Südafrika

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Inhaltsverzeichnis

1. Zusammenfassung

Die mikromorphologischen Untersuchungen an altpaläolithischen Fundplätzen in Schöningen, spätpaläolithischen Fundplätzen in Grabow, dem mesolithischem Fundplatz Blätterhöhle, und dem *Middle Stone Age* Fundplatz Varsche Rivier 003 haben zum Ziel die Entstehung der Fundplätze, die Genese der Schichten und der Befunde zu rekonstruieren. Diese Rekonstruktionen wurden dann in Bezug auf das menschliche Verhalten interpretiert.

Als Untersuchungsmethode wurde die Mikromorphologie verwendet, die anhand der mikroskopischen Bestimmung von Komponenten, aber vor allem anhand der Untersuchung der Mikrostruktur von Sedimenten und Böden Formationsprozesse identifizieren und interpretieren kann. Dies gilt insbesondere für die Untersuchungen von Feuerstellen, die als Befunde eine eigene Ablagerung darstellen.

In Schöningen 13 II-4, Schöninen13 II Obere Berme und Schöningen 12 II-4 wurde das unmittelbare Ablagerungsmilieu der archäologischen Hinterlassenschaften untersucht. Eine entscheidende Frage war hierbei der *in situ* Charakter der archäologischen Hinterlassenschaften, der mikromorphologisch nicht nachgewiesen worden konnten. Vielmehr konnte nachgewiesen werden, dass die fundführenden Schichten unter Wasser abgelagert wurden. Folglich werden alternative Formationsmodelle zu einer *in situ* Ablagerung diskutiert (z.B. Abfallentsorgung in den See, Jagen und *Caching* auf der gefrorenen Seeoberfläche, oder eine geogene Verlagerung der Materialien in den See durch Wellenaktivität oder Rutschungen).

Eine ähnliche Frage bezüglich des primären oder sekundären Kontextes der archäologischen Funde stellte sich an dem Abri Varsche Rivier 003, wo zwischen verlagerten und bioturbierten Schichten am Hang und weniger gestörten Schichten innerhalb des Abris unterschieden werden konnte. Dies hat Auswirkungen auf räumliche Verhaltensinterpretationen und die ausgeführten OSL-Datierungen.

In Grabow konnten die mikromorphologischen Untersuchungen Einzelheiten zu der Bodenbildung eines Fluvisols, in dem die archäologischen Fundplätze erhalten waren, beitragen und somit zur Umweltrekonstruktion.

In Schöningen 13 II-4, der Blätterhöhle und Grabow waren im Feld mögliche Feuerstellen identifiziert worden und mikromorphologische Untersuchungen konnten diese wiederlegen (Schöningen), belegen (Grabow) und ihre Überprägung durch Bioturbation (Blätterhöhle) aufzeigen.

2. Summary

Micromorphological analyses at Lower Paleolithic sites at Schöningen, Late Paleolithic sites at Grabow, the Mesolithic site Blätterhöhle, and the Middle Stone Age Site Varsche Rivier 003 are primarily intended to understand the formation of the sites, the layers and specific features. These reconstructions are then used to evaluate human behavior. To this aim, micromorphological analyses were conducted. Micromorphology can identify sedimentary components and most importantly the microstructure of depositional units, and is therefore a powerful tool to detect, analyze and interpret site formation processes. This is especially true for the analysis of hearth features, which represent a distinct depositional unit.

Micromorphological analyses at Schöningen 13 II-4, Schöningen 13 II Upper Berm, and Schöningen 12 II-4 were directed at reconstructing the depositional environment of the archaeological remains. One of the key questions is whether the archaeological remains are in a primary context. The micromorphological analyses found no evidence that the deposits are in a primary context and instead revealed a subaqueous deposition of the find-bearing layers. Consequently, alternative site formation models are discussed (e.g. anthropogenic disposal of materials into the lake, a geological relocation of the artifacts by wave action or slumping, and hunting or caching on lake-ice).

Similarly, at the abri Varsche Rivier 003 micromorphological analyses were able to differentiate between a secondary context on the slope and a more primary, less turbated context inside the abri. This has implications for behavioral interpretations and OSL dating.

Micromorphological analyses on the fluvisol at Grabow, which contains the archaeological sites, confirmed and expanded data on soil formation and environmental reconstruction.

At Schöningen 13 II-4, Blätterhöhle, and Grabow field observations of purported hearths were corrected (Schöningen), verified (Grabow) and their bioturbated character identified (Blätterhöhle) by micromorphological analyses.

3. Liste der Publikationen der kumulativen Dissertation

3.1. Akzeptierte Publikationen

Serangeli, J., Bigga, G., Böhner, U., Julien, M.A., Lang, J. & **Stahlschmidt, M**. (2012). Ein Fenster ins Altpaläolithikum. Archäologie in Deutschland 4, 2012, 6-12.

Erklärung Eigenanteil: ca. 15%

Tolksdorf, J. F., Turner, F., Kaiser, K., Eckmeier, E., **Stahlschmidt, M**., Housley, R. A., Breest, K., Veil, St. (2013). Multiproxy Analyses of Stratigraphy and Palaeoenvironment of the Late Palaeolithic Grabow Floodplain Site, Northern Germany. Geoarchaeology 28, 1, 50-65.

Erklärung Eigenanteil: ca. 8%

3.2. Eingereichte Publikationen

Stahlschmidt, M.C., Miller, C.E., Ligouis, B., Goldberg, P., Urban, B., Serangeli, J. & Conard, N.J. (eingereicht a). The depositional environments of Schöningen 13 II-4 and their archaeological implications. Journal of Human Evolution: Special issue Schöningen.

Erklärung Eigenanteil: ca. 82%

Stahlschmidt, M.C., Miller, C.E., Ligouis, B., Hambach, U., Goldberg, P., Berna, F., Richter, D., Urban, B., Serangeli, J. & Conard, N.J. (eingereicht b). On the evidence for human use and control of fire at Schöningen. Journal of Human Evolution: Special issue Schöningen.

Erklärung Eigenanteil: 71%

3.3. Manuskripte

Stahlschmidt, **M.C**., Report on the micromorphological analyses at Schöningen 12 II- 4, Germany - 2013.

Erklärung Eigenanteil: 100%

Stahlschmidt, **M.C**, Bericht über die mikromorphologischen Untersuchungen an der Fundstelle Grabow 19, Deutschland - 2013.

Erklärung Eigenanteil: 100%

Stahlschmidt, **M.C**, Report on the geoarchaeological field work and micromorphology at Varsche Rivier 003, South Africa - 2012.

Erklärung Eigenanteil: 100%

Stahlschmidt, **M.C**, Miller. C.E., Bericht über die mikromorphologischen Untersuchungen an der Feuerstelle 2 Blätterhöhle, Deutschland - 2011

Erklärung Eigenanteil: 80%

4. Einleitung

4.1. Geoarchäologie und Fundplatzgenese

Die Rekonstruktion der Entstehung von Fundplätzen, Ablagerungen und von Befunden als eigene Ablagerung (Stein, 1987) beschäftigt sich mit dem direkten Kontext der archäologischen Hinterlassenschaften in Gestalt von Sedimenten und Böden (Goldberg und Berna, 2010). Dieser Kontext kann durch eine Analyse der kulturellen und nicht-kulturellen Formationsprozesse einer Fundstelle, einer Schicht oder eines Befundes untersucht werden (Schiffer, 1983). Es werden dabei mit folgende Fragen gestellt:

- Was ist vorhanden?
- Woher stammt es?
- Wie wurde es an den Fundplatz, Schicht, Befund transportiert?
- Wie wurde es abgelagert?
- Wie wurde es post depositional verändert?

Die Methodik dieser Arbeit zur Analyse von Formationsprozessen teilt sich in die Feld- und Laborarbeit auf. Die Feldarbeit bestand aus einer Feldbegehung mit Landschaftsbeobachtungen (Geomorphologie, Gesteine, tektonische Spuren, anthropogener Landschaftseinfluss, Bewuchs etc.) inklusive Probenahme für eine Referenzkollektion und stratigraphischen Untersuchungen sowie Probenahmen am Fundplatz. Die Laborarbeit bestand aus mikromorphologischen Untersuchungen.

4.2. Mikromorphologie

Die Mikromorphologie ist eine kontextuelle, mikroskopische Sedimentanalyse und untersucht intakte Blöcke von Sedimenten und Böden in Dünnschliffen mithilfe von petrographischen Mikroskopen (Courty *et al.*, 1989). Mikromorphologische Untersuchungen ermöglichen die Identifikation der Komposition, der Textur, der Struktur und des Gefüges einer Ablagerung neben anthropogenen und pedogenetischen Befunden. Die Mikromorphologie ermöglicht so die Rekonstruktion der Formation von Fundstellen, Schichten und einzelnen Befunden als auch ihre nachträglichen Transformationen.

Im Feld wurden befestigte, orientierte Proben genommen und im Geoarchäologischen Labor, Universität Tübingen, weiter behandelt. Die Proben wurden für 24 Stunden bei 40°C getrocknet und anschließend mit einer 7:3 Mischung aus Kunstharz und Styrol mit Methyl Ethyl Ketone Peroxide (MEKP) Härter als Katalysator imprägniert. Nach 5-10 Tage wurden die Proben erneut bei 50°C bis zu ihrer vollständigen Aushärtung erhitzt. Folgend wurden kleine Blöcke aus den Proben herausgesägt. Aus diesen Blöcken wurden von P. Kritikakis, Universität Tübingen, Th. Beckmann, Braunschweig, Germany, und von *Spectrum Petrographics*, Inc. in Vancouver, Washington, U.S.A., Dünnschliffe hergestellt.

Die Analyse der Dünnschliffe erfolgte mit einem *Zeiss Axio Imager petrographic microscope* unter Durchlicht mit parallelen und gekreuzten Polarisationsfiltern sowie unter blauem Fluoreszenzlicht bei 25-, 50-, 100-, 200- und 500-facher Vergrößerung. Die Beschreibung und Analyse der Dünnschliffe folgt Courty *et al.* (1989), Stoops (2003) und Stoops *et al.* (2010).

In Bezug auf die geoarchäologischen Fragestellungen dieser Arbeit und der einzelnen Fundplätze haben mikromorphologischen Untersuchungen in ähnlichen Kontexten vielversprechende Ergebnisse geliefert. Mikromorphologischen Untersuchungen von Feuerstellen können mikroskopische Feuerrückstände wie Asche (siehe z.B., Berna *et al.*, 2012) und Phytolithen (siehe z. B. Schiegl *et al.*, 1994) identifizieren, *in situ* Feuerstellen anhand ihrer Mikrostruktur ausmachen (siehe z.B. Goldberg *et al.*, 2009), mehrfach Nutzung feststellen (siehe z.B. Shahack-Gross *et al.*, 2014), ihrer Erhaltung in Freilandfundplätzen (siehe z.B., Friesem *et al.*, 2013) und in Höhlen und Abris (Goldberg and Bar-Yosef, 1998) belegen, und makroskopische Interpretationen von Feuerstellen berichtigen (siehe z.B. Goldberg *et al.*, 2001).

Des Weiteren haben mikromorphologische Analysen Ablagerungsbedingungen und post-depositionale Überprägungen von archäologischen Fundplätzen in Höhlen (Goldberg und Sherwood, 2006), Abris (Courty *et al.*, 1989), in Hanglagen (siehe z.B. Karkanas und Goldberg, 2008), in Freilandfundstellen wie Seen (siehe z.B. Karkanas *et al.*, 2011) und Auenlandschaften (siehe z.B. Audouze, 1997) rekonstruieren können sowie ihre Bedeutung für die archäologischen Hinterlassenschaften diskutiert.

5. Mikromorphologische Untersuchungen - Schöningen

5.1. Schöningen

Lage und Geologie

Die Fundstelle Schöningen liegt an der Grenze der Norddeutschen Tiefebene zum Harz am Fuße des Elms, der nordwestlich von Schöningen liegt. Geologisch befindet sich Schöningen an der südwestlichen Synkline der Offleben Salzmauer und in der Helmstedt-Staßfurt Salzstruktur (Mania, 1995). Heute befindet sich der Fundkomplex innerhalb eines Braunkohle-Tagebaus, in dem Mittelpleistozäne Ablagerungen zwischen Elster- und Saalezeitlichen Ablagerungen erhalten sind (Mania, 1995). Die Mittelpleistozänen Ablagerungen sind innerhalb von Rinnenstrukturen enthalten, deren Entstehung und generelle Verfüllungen unterschiedlich interpretiert werden (siehe Mania, 1995; Lang *et al.*, 2012).

Die Fundplätze und -schichten, die in dieser Arbeit behandelt werden (Schöningen 13 II-4, Schöningen 13 II- Obere Berme, Schöningen 13 II-2/3, Schöningen 12 II-4, Schöningen 12B), stammen aus einer sedimentären Serie von lakustrinen Schichten, die sich in Verbindung mit einem Paläosee innerhalb der Rinnenstruktur abgelagert haben (Mania, 1995; Urban, 2007; Lang *et al.*, 2012). Urban (1995, 2007) stellt diese Serie von lakustrinen Ablagerungen anhand von palynologischen Untersuchungen in das Reinsdorf Interglazial, eine mögliche Unterform des Holstein Interglazials, und damit in das *Marine Isotope Stage* 9 (siehe auch Urban *et al.*, in Vorb.). Die lakustrine Abfolge besteht aus fünf Serien von grauen, sandigen bis tonigen Kalkmudden, die in eine braune, organische Mudde übergehen (Böhner *et al.*, 2005; Thieme, 2007a; Urban, 2007; Stahlschmidt *et al.*, eingereicht a). Diese Wechselfolge von Kalkmudden und organischen Mudde wird als eine Folge von Seewasserspiegelschwankungen interpretiert (Mania, 2007; Urban, 2007; Lang *et al.*, 2012).

Archäologie

Der Archäologe H. Thieme vom Niedersächsischen Amt für Denkmalpflege (NLD) hat 1992 die ersten paläolithischen Funden innerhalb des Tagebaus entdeckt und erste Ausgrabungen begonnen (Thieme, 1997). Bis heute sind 28 paläolithische Fundhorizonte und -plätze bekannt (Serangeli *et al.*, 2012b), von denen die meisten als Rettungsgrabung ausgegraben worden sind. Die Fundschichten enthalten Steinartefakte, Tierknochen, und Holzartefakte. Der wassergesättigte Zustand der Ablagerungen bis Beginn des Tagebaus hat eine einzigartige Erhaltung von Holzartefakten aus der Altsteinzeit gewährleistet.

Fundplätze

<u>Schöningen 13 II-4</u> Ausgrabungen in Schöningen 13 II-4 haben 1994 begonnen und dauern noch an. Die archäologischen Hinterlassenschaften datieren ins Altpaläolithikum und

stammen vorwiegend von dem Kontaktbereich einer Kalkmudde (Schicht 4b/c) und einer braunen, organischen Mudde (Schicht 4b), und bestehen aus Steinartefakten, Tierknochenresten von geschlachteten Pferden und Holzspeeren (Thieme, 2005; Voormolen, 2008; van Kolfschoten, 2014; Terberger *et al.*, eingereicht). Des Weiteren wurden Belege für menschliche Feuernutzung von der dieser Fundschicht berichtet, mit vier Feuerstellen und einem gebrannten Holzartefakt (Thieme, 2005).

Schöningen 13 II Obere Berme Eine neue Ausgrabungsfläche, 13 II Obere Berme oder auch Speerhorizont Süd, wurde 2011 geöffnet. Diese Fundschicht gab bisher altpaläolithische Steinartefakte und Tierknochenreste frei und sie stellt vermutlich eine südliche Verlängerung der Fundschicht 13 II-4 dar (Serangeli et al., 2012; Serangeli et al., in Vor.)

Schöningen 13 II-3 und 13 II-2 Die Fundschichtkomplexe Schöningen 13 II-3 und 13 II-2 liegen stratigraphisch unterhalb der Schicht 13 II-4 und Grabungen hier dauern noch an. Hier wurden bisher altpaläolithische Tierknochen, Steinartefakte und ein Holzartefakt ausgegraben (Thieme 2002; 2007d; Serangeli *et al.*, 2012). Die jetzige Grabungsmannschaft hat eine vertikale Spalte durch die beiden Schichtkomplexe mit dunkel verfärbtem Sediment identifiziert und als mögliche Brandspur angesprochen.

Schöningen 12B Der Fundplatz Schöningen 12 B stellt eine Rettungsgrabung dar, enthielt zwei Fundhorizonte und datiert ins Altpaläolithikum (Serangeli *et al.*, 2012). Fundhorizont 1 bestand aus einer sandigen Mudde, Fundhorizont 2 aus einer detritischen Mudde und beide Schichten enthielten Steinartefakte und Tierknochen (Thieme und Maier, 1995). Zusätzlich haben Mania (1995) und Thieme (2007c) gebrannte Hölzer von der Fundschicht 2 berichtet, darunter auch der sogenannten Fackelkopf.

Schöningen 12 II-4 Der Fundplatz Schöningen 12 II-4 wurde 2007 bis 2009 gegraben und stellte eine Rettungsgrabung dar. Es konnte hier ein fast komplettes Skelett eines Auerochsen, andere Tierknochenreste, Elfenbein, Steinartefakte und mögliche Holzartefakte aus dem Altpaläolithikum geborgen werden. Die Funde stammen vorwiegend aus einer Kalkmudde (Schicht 4c) und wenige Funde aus der aufliegenden braunen, organischen Mudde (Schicht 4b) (Serangeli *et al.*, 2010; Serangeli *et al.*, 2012).

5.2. Fragestellung - Ablagerungsmilieus und Feuernutzung

5.2.1. Ablagerungsmilieu in Schöningen 13 II-4, Schöningen 13 II Obere Berme und Schöningen 12 II-4 (Stahlschmidt *et al.*, eingereicht a; Stahlschmidt a)

Geoarchäologische Analysen in Schöningen befassen sich mit der Analyse des unmittelbaren sedimentären Kontextes der archäologischen Hinterlassenschaften. Das Ziel der Analysen ist die Rekonstruktion des Ablagerungsmilieus und damit der Ablagerungskontext des menschlichen Verhaltens.

Im Fall von Schöningen 13 II-4 (Stahlschmidt *et al.*, eingereicht a) befinden sich die archäologischen Funde am Kontakt zwischen einer Kalkmudde (Schicht 4c) und einer organische Mudde (Schicht 4b). Thieme (1999, 2005, 2007a,b) hat die These aufgestellt, dass es hier um ein einzelnes Ereignis menschlicher Aktivität auf der Kalkmudde, die eine typische limnische Ablagerung darstellt (Flügel 2010), während eines Trockenfalls dieser Schicht durch Seespiegelschwankungen handelt. Mit steigendem Seespiegel wurden die archäologischen Hinterlassenschaften *in situ* in der organischen Mudde einsedimentiert (Thieme, 1999, 2005).

Stahlschmidt *et al.* (eingereicht a) haben diese Hypothese durch Feldanalysen und mikromorphologische Analyse zusammen mit organischen Petrologie-Analysen durch B. Ligouis (Universität Tübingen) untersucht und folgende Fragen untersucht:

1) Ist ein Trockenfallen der Kalkmudde und der organischen Schicht mikromorphologisch zu identifizieren, zum Beispiel durch bodenbildende Prozesse, wie Bioturbation, Trockenrisse und Humifizierung?

2) Handelt es sich bei den fundführenden Schichten 4b/c und 4b um terrestrische, litorale oder limnische Ablagerungen? Was bedeutet dies für die archäologische Hinterlassenschaften und assoziiertes menschliches Verhalten? Handelt es sich bei den Schichten um *in situ* Ablagerungen oder Verlagerungen?

3) Ist ein einzelnes Ereignis (siehe z.B. Thieme 1999) geoarchäologisch durch komplexe Bodenbildungen, zeitliche Tiefe der Ablagerungen oder Laufhorizonte nachvollziehbar?

Die archäologischen Funde der Fundstelle 12 II-4, Tierknochen und Steinartefakte, stammen ebenso aus einer Kalkmudde und auch hier wurde menschliche Aktivität und Ablagerung der Funde am Ufer des Paläosees postuliert (Serangeli *et al.*, 2012a, b). Julien *et al.* (in Vorb.) hingegen weisen auf eine komplexe taphonomische Ablagerung der Knochen und der Sedimente hin. Mikromorphologische Untersuchungen in Schöningen 12 II-4 haben, wie in Schöningen 13 II-4, das Ziel, das Ablagerungsmilieu der Funde zu bestimmen und folgende Fragen zu beantworten: Handelt es sich um eine terrestrische, litorale oder limnische Ablagerungen? Was kann der sedimentäre Kontext über die Ablagerung der archäologischen Funde und demnach über menschliches Verhalten aussagen?

5.2.2. Schöningen - Feuernutzung (Stahlschmidt *et al.*, eingereicht b)

Wann der Mensch Feuer zu nutzen, zu kontrollieren und herzustellen angefangen hat, ist einer der größten Diskussionspunkte in der paläolithischen Archäologie (siehe z. B. James *et al.*, 1989; Roebroeks und Villa, 2011, Stahlschmidt *et al.*, eingereicht b). Feuernutzung und -kontrolle beinhaltet eine Vielzahl an Vorteilen, da es eine externe Licht- und Wärmequelle ist (Oakley, 1955), zum Schutz vor Raubtieren dient (Brain, 1991), Bearbeitung und Veränderung von Werkmaterialien ermöglicht (Ahlers, 1983) sowie die effektivere Nutzung von Nahrungsquellen (Wrangham, 2009). Speziell für die erste Besiedlung nördlicher Breiten wird die Fähigkeit zur Feuernutzung und -kontrolle oft vorausgesetzt (siehe z.B. Oakley, 1955; Gowlett, 2006; Wrangham, 2009). Angebliche Feuerstellen, gebrannte Steine und Hölzer (Thieme, 2005) in Schöningen werden weitläufig (siehe z.B. Gowlett, 2006; Wrangham, 2009; Roebroeks und Villa, 2011) als die besten Belege für frühe Feuernutzung im Altpaläolithikum Nordeuropas interpretiert. Diese angeblichen Belege für Feuernutzung beruhen allerdings bisher fast allein auf makroskopischen Beobachtungen, abgesehen von vorläufigen, unklaren mikromorphologischen Untersuchungen (Schiegl und Thieme, 2007) und einigen Feuersteinen, die mit Thermolumineszenz-Analysen als gebrannt identifiziert wurden (Richter, 1998; Richter und Thieme, 2012).

Viele Studien (James *et al.*, 1989; Laville 1970; Rottländer 1989; Hahn 1991; Goldberg *et al.*, 2001; Roebroeks und Villa, 2011) weisen zu einem darauf hin, dass eine makroskopische Bestimmung von gebrannten Material Schwächen hat, und zum anderen, dass allein das Vorkommen von gebranntem Material nicht auf menschliche Feuernutzung schließen lässt, hierfür sei eine mikrokontextuelle Analyse nötig. Stahlschmidt *et al.* (eingereicht b) stellen eine multianalytische, mikrokontextuelle Untersuchung der angeblichen Belege von menschliche Feuernutzung in Schöningen vor. Diese Studie hat erstens zum Ziel zu bestimmen, ob die angeblich gebrannten Materialien tatsächlich Feuer ausgesetzt waren, und zweitens um zu untersuchen, ob diese Feuereinwirkung mit menschlicher Aktivität in Zusammenhang steht.

5.3. Ergebnisse und Diskussion

5.3.1. Analyse der Ablagerungsmilieus in Schöningen 13 II-4 und Schöningen 13 II Obere Berme

Stahlschmidt *et al.* (eingereicht a) präsentieren Feldanalysen, mikromorphologische Analysen, organische Petrologie Untersuchungen, sedimentologische und Pollenanalyse zum Ablagerungsmilieu der fundführenden Schichten in Schöningen 13 II-4 und 13 II Obere

Berme. B. Ligouis hat organische Petrologie Untersuchungen an den Schichten 4b/c und 4b an einer Sedimentsäule in Schöningen 13 II-4 vorgenommen und B. Urban hat sedimentologische und Pollenanalyse an den Schichten 4c, 4b/c und 4b an derselben Sedimentsäule vorgenommen. M. Stahlschmidt und C. Miller haben Feldanalysen und mikromorphologische Untersuchungen an den Schichten 4c, 4 b/c, 4b, 4a, und 5d an fünf Sedimentsäulen, einer zusätzlichen Blockprobe von Schöningen 13 II-4, drei Profilen in Schöningen 13 II Obere Berme vorgenommen und die Ergebnisse aller Untersuchungen korreliert.

5.3.1.1. Eigene Ergebnisse

Schöningen 13 II-4 (Stahlschmidt *et al.*, eingereicht a)

Im Folgenden wird eine Zusammenfassung der makroskopischen und mikromorphologischen Analysen präsentiert. Für die Analyse des Ablagerungsmilieus in Schöningen 13 II-4 wurden 13 Blockproben genommen und aus diesen 35 Dünnschliffe gewonnen.

<u>Schicht 4c</u> Schicht 4c ist eine Kalkmudde, die mikroskopisch aus mikrokristallinen Kalzit mit geringem Tonanteil besteht. An gröberen (>10 µm) Komponenten sind fragmentierte Pflanzengewebe in Sand- bis Schluffgröße, Quarzkörner in Sand- bis Schluff-Größe, Pyrit, Ostrakoden- und Molluskenschalen, Reste von Armleuchteralgen, Diatomeen und Schwammnadeln vorhanden. Die Mikrostruktur zeigt einen einfachen Porenraum und die c/f-Relativverteilung ist porphyrisch. Längliche Pflanzengewebe sind meist horizontal ausgerichtet und es wurden keine Belege für Bioturbation beobachtet.

<u>Schicht 4b/c</u> Schicht 4b/c ist ca. 5-15 cm mächtig und durch einen Anstieg in organischem Material und Weich-Sediment-Deformationen gekennzeichnet. Das organische Material besteht aus sand- bis schluffgroßen Pflanzengewebe, die vereinzelt in der Matrix auftreten oder in gerundeten, transportierten Aggregaten. Post-depositionale Befunde wie Gipsformationen und Eisenoxidation treten vermehrt in Gesellschaft von Pflanzengeweben auf. Zudem war eine massive, laminierte Eisenoxidation am Kontakt zur aufliegenden Schicht 4b zu beobachten (siehe 6.2.1). Der Kontakt zur aufliegenden Schicht 4b ist sehr klar.

Als gröbere Komponenten treten wie in Schicht 4c Quarzkörner in der selber Größenordnung (Sand- bis Schluff-Größe), Pyrit, Ostrakoden- und Molluskenschalen, Reste von Armleuchteralgen, Diatomeen und Schwammnadeln auf. Weder Aggregierung noch Bioturbation konnten beobachtet werden. Trockenrissen sind rezent.

Schicht 4b Schicht 4b ist eine organische, braune Mudde. Makroskopisch tritt die Schicht massiv und lokal laminiert auf. Die Mächtigkeit der Schicht beträgt maximal 35 cm und ihre größte Mächtigkeit korreliert mit der höchsten Fundkonzentration (Lang *et al.*, 2012). Mikroskopisch ist erkenntlich, dass die Schicht hauptsächlich aus sand- bis schluffgroßen Pflanzengewebe besteht. Das Pflanzengewebe liegt fragmentiert vor, keine vollständigen Wurzeln wurden beobachtet, und längliche Pflanzengewebe sind horizontal ausgerichtet. Als weitere Grobkomponenten liegen schluff- bis sandgroße Quarzkörner und Glimmer, Gipskristalle und Pyrite vor und in geringer Anzahl treten weiterhin Diatomeen und Schwammnadeln auf. Als Feinmaterial ist Ton vorhanden und die Matrix ist sehr kalkarm. Die beobachteten Laminae zeichnen sich durch gestiegenen Quarz- und Tonanteil aus. Weder Aggregierung noch Bioturbation wurden beobachtet und beobachtete Trockenrisse sind rezent. Der Kontakt zur aufliegenden Schicht 4a ist graduell.

Schicht 4a Schicht 4 ist ebenso eine organische Mudde mit einem gestiegenem Tonanteil im Vergleich zur Schicht 4b. Makroskopisch konnten im Gegensatz zu vorherigen Beobachtungen keine einzelnen Pflanzengewebe erkannt werden (Böhner *et al.*, 2005; Thieme, 2007b). Mikroskopisch war ein leichter Anstieg in der Größe der Pflanzengewebe zu vermerken (max. 1,5 mm; generell 0,5 mm bis 0,2 mm). Vereinzelte amorphe, humifizierte Pflanzengewebe und verrundete Aggregate treten auf. Quarzkörner und Glimmer treten als weitere Grobkomponenten auf neben wenigen Schwammnadeln. Diatomeen sind nicht beobachtet worden. Der Kontakt zur aufliegenden Schicht 5d ist messerscharf und irregulär.

Schicht 5d Schicht 5d besteht aus einem grauen Schluff mit Laminierungen aus bläulich-grauen Ton. Mikroskopisch ist erkennbar, dass das Feinmaterial vorwiegend aus Ton mit einem leichten Kalkanteil besteht. Sand- bis schluffgroße Quarzkörner treten häufig auf. Tonige, verrundete Bodenaggregate, organische Aggregate und Pflanzengewebe treten vereinzelt auf, während humifizierte organische Aggregate regelmäßig auftreten.

Schöningen 13 II Obere Berme

Im Folgenden wird eine Zusammenfassung der makroskopischen und mikromorphologischen Analysen präsentiert. Für die Analyse des Ablagerungsmilieus in Schöningen 13 II Obere Berme wurden 3 Blockproben untersucht aus denen 3 Dünnschliffe hergestellt wurden.

Die Schichten 4b/c und 4b an der Oberen Berme sind durch Weich-Sediment-Deformation und Sedimentrutschungen überprägt. Dies trifft vor allem auf den Kontaktbereich zwischen den Schichten 4b/c und 4b zu. Zudem durchziehen einige Verwerfungen die Schichtabfolge. Die Schicht 4b/c unterscheidet sich nicht durch ihre Komponenten von 13 II-4 (Quarzkörner, Pflanzengewebe, Reste von Armleuchteralgen, Ostrakoden- und Molluskenschalen, Pyrit, Diatomeen und Schwammnadeln in einer kalkreichen Matrix), aber leicht in ihrer Mikrostruktur. Verrundete, organische Aggregate treten sehr häufig auf. Dies setzt sich auch in der aufliegenden Schicht 4b fort. Der Kontakt zwischen den beiden Schichten ist lokal durch Weich-Sediment-Deformationen und Rutschungen überprägt. Die Matrix von Schicht 4b ist lokal kalkhaltiger und enthält Molluskenschalen und Reste von Armleuchteralgen im Gegensatz zur fast kalkfreien Schicht 4b in Schöningen 13 II-4. Zusätzlich treten auch hier verrundete, organische Aggregate auf, wie in Schicht 4b/c.

5.3.1.2. Ergebnisse Anderer Forscher

*Organische Petrologie in Schöningen 13 II-4 (*B. Ligouis in Stahlschmidt *et al.*, eingereicht a)
Die Pflanzengewebe in Schicht 4b/c und 4b zeigen alle niedrige Reflexionswerte, die auf eine geringe Humifizierung hinweisen. Stärker humifizierte Horizonte konnten nicht beobachtet werden. Die Pflanzengewebe stammen hauptsächlich von krautigen Pflanzen und zwar von terrestrischen, litoralen und limnischen Pflanzen. So konnten zum Beispiel *Botryococcus* Algen bestimmt werden. Wenige transportierte Torfaggregate wurden beobachtet und keine *in situ* wachsenden Wurzeln.

Sedimentologische und Pollenanalysen in Schöningen 13 II-4 (B. Urban in Stahlschmidt *et al.*, eingereicht a)

Schicht 4c und 4b/c Der Karbonatanteil schwankt in diesen beiden Schichten zwischen 58% und 81% und der Anteil des organischen Kohlenstoffs schwankt zwischen 2% und 5,4%. Die Pollenerhaltung nicht sehr gut, aber der Großteil der Pollen stammt von aquatischen Pflanzen, was auf ein offenes Gewässer hindeutet. Terrestrischen Pflanzen sind im Vergleich seltener.

Schicht 4b Schicht 4b ist fast karbonatfrei und der Anteil des organischen Kohlenstoffs beträgt bis zu 21%. Pollendaten zeigen eine Abnahme von aquatischen Pollen und eine Zunahme von terrestrischen Pollen, wie zum Beispiel *Cerealia* type, *Asteraceae* and *Artemisia* and *Pinus* Pollen.

5.3.1.3. Diskussion

Ablagerungsmilieu 13 II-4 Die Komponenten (Diatomeen, Schwammnadeln, Reste von Armleuchteralgen, Ostrakoden- und Molluskenschalen), ihre Form (verrundete Aggregate, fragmentierte Pflanzengewebe) und die Mikrostruktur (Laminierungen, die Vergesellschaftung von terrestrischen, litoralen und limnischen Pflanzen, Fehlen von Bioturbation und altenTrockenrissen) der Schichten 4c, 4b/c, 4b und 4a weisen auf eine Unterwasserablagerung dieser Schichten (siehe z.B., Stach, 1975; Bouma *et al.*, 1990;

Retallack und Wright, 1990; Taylor *et al*., 1998; Flügel, 2010) in einer mosaischen Sumpf-Ufer-Landschaft am See (siehe auch Urban, 2007; Urban *et al*., in Vorb.) hin. Die Schichten unterscheiden sich in ihrer Nähe zum Ufer, mit den Schichten 4b und 4a in größerer Ufernähe als die Schichten 4b/c und 4c. Dies spiegelt vermutlich Seewasserspiegelschwankungen wieder (siehe Lang *et al*., 2012). In Schöningen 13 II Obere Berme ist ein höherer Einfluss von Deformationen und Sedimentrutschungen zu beobachten gewesen, was eventuell auf einer größeren Nähe zu einem Einfluss in den See schließen lässt.

Ein Trockenfallen der Schichten, evident durch Bioturbation, *in situ* Pflanzenwachstum, Krustenbildung, Karbonatlösung und -rekristallisierung, Fäkalienrest (siehe z.B., McSweeney and Fastovsky, 1987; Retallack and Wright, 1990; Alonso-Zansa *et al*., 2009; Flügel, 2010; Karkanas *et al*., 2011), konnten nicht nachgewiesen werden. Stattdessen stellen diese Schichten Ansammlungen von transportiertem Material unter Wasser dar. Die Ablagerung der archäologischen Funde in diesen Unterwasserablagerungen hat zu verschiedenen Zeitpunkten stattgefunden, wie die Verteilung der Funde durch die verschiedenen Schichten zeigt. Dies stimmt mitden zooarchäologischen Untersuchungen überein (Musil, 2007; Voormolen, 2008; Julien *et al*., eingereicht; Rival *et al.,* eingereicht).

Diese Interpretation einer Unterwasserablagerung der fundführenden Schichten wirft die Frage auf, durch welche/-n Prozess/-e die archäologischen Materialien hier zur Ablagerung kamen. Mögliche alternative Formationsmodelle zum Trockenfallen der Kalkmudde und einer *in situ* Ablagerung sind: 1) Abfallentsorgung in den See; 2) kleinräumige, geogene Verlagerungen in den See (im Fall von Schöningen 13 II Obere Berme durch Sedimentrutschungen); 3) Menschliche Aktivität auf der gefrorenen Seeoberfläche.

5.3.2. Analyse des Ablagerungsmilieus in Schöningen 12II-4

Für die Analyse des Ablagerungsmilieus in Schöningen 12 II-4 wurden 3 Blockproben in je zwei Dünnschliffen untersucht.

5.3.2.1. Ergebnisse

<u>Schicht 4c2</u> Schicht 4c2 besteht vorwiegend aus schluffgroßen Quarzkörnern in einer massiven Mikrostruktur. Andere Grobkomponenten sind Glimmer, Pflanzengewebe, Ostrakoden- und Molluskenschalen, Reste von Armleuchteralgen und sandgroße Quarzkörner. Längliches Pflanzgewebe ist horizontal gebettet. Tonlamina und Erosions-Kontakte wurden beobachtet. Die Anzahl an Resten von Armleuchteralgen steigt aufwärts und markiert den graduellen Kontakt zur aufliegenden Schicht 4c1.

Schicht 4c1 Die stratigraphisch höhere Schicht 4c1 weist eine massive karbonatreiche Mikrostruktur mit einer Vielzahl von gut erhalten Armleuchteralgen, Ostrakoden- und Molluskenschalenfragmenten auf. Als weitere Grobkomponenten treten Pflanzengewebe, schluff- bis sandgroße Quarzkörner auf. Längliches Pflanzgewebe ist horizontal gebettet. Linsen aus sandgroßen Quarzkörnern, Variationen im Anteil des Feinmateriales und ein Erosions-Kontakte treten auf. Der Anteil an Pflanzenmaterial steigt aufwärts.

5.3.2.2. Diskussion

Die Komponenten und Mikrostruktur (Tonlamina, Armleuchteralgen Ostrakoden- und Molluskenschalen, horizontale Ausrichtung von länglichem Pflanzengewebe, Karbonatausfällungen) weisen auf eine Unterwasserablagerung der fundführenden Schichten hin (Bouma *et al.*, 1990; Treese, 1982; Tucker und Wright, 1990; Wallace 1999). Die sedimentäre Veränderung von Schicht 4c2 zu 4c1 deutet auf einen Wechsel von höherer zu niedrigerer Energie hin. Die verstärkte Schluffkomponente in Schicht 4c2 geht vermutlich auf eine größere Nähe zu einem deltaischen Einfluss in den See zurück (siehe Lang *et al.*, 2012). Der steigende Anteil an Pflanzenmaterial wiederum deutet auf größere Nähe zum Ufer (Dobrowolski, 2001) und damit einen niedrigen Seewasserspiegel hin. Die Erosions-Kontakte, Sandlinsen und lokale Veränderungen im Feinmaterialanteil könnten auf episodischen Wellenaktivitäten hinweisen. Dieser letzte Punkt lässt eine Verlagerung der archäologischen Materialien durch Wellenschlag vom Ufer in den See hinein vermuten.

5.3.3. Analyse der Hinweise auf Feuernutzung in Schöningen (Stahlschmidt *et al.*, eingereicht b)

Stahlschmidt *et al.* (eingereicht b) präsentieren Untersuchungen an angeblichen Feuerstellen, angeblich gebrannten Sediment und Holz. B. Ligouis (Universität Tübingen) hat organische Petrologie-Untersuchungen an organischen Resten (einer Feuerstelle, Holz und Sediment) durchgeführt; U. Hambach (Universität Bayreuth) hat magnetische Gesteinsparameter an einer der angeblichen Feuerstelle und Sediment des Brennexperiments untersucht; D. Richter (Universität Bayreuth) hat Thermolumineszenz-Untersuchungen an einer der angeblichen Feuerstelle und Sediment des Brennexperimentes durchgeführt; F. Berna (Simon-Fraser Universität) hat FTIR-Spektroskopie an einer der angeblichen Feuerstelle und Sediment des Brennexperimentes durchgeführt; Stahlschmidt, Miller, Goldberg und Berna haben mikromorphologische Untersuchungen an den vier angeblichen Feuerstellen durchgeführt;

Stahlschmidt und Miller haben Feldanalysen und das Brennexperiment durchgeführt und alle Ergebnisse kontextualisiert.

5.3.3.1. Ergebnisse des Brennexperimentes

Für das Brennexperiment wurde Sediment von der Schicht 4b/c von außerhalb der Feuerstellen verwendet und in einem Muffelofen zu 100°C, 200°C, 300°C, 400°C, 500°C, 700°C, 800°C, 900°C, 1000°C und 1100°C erhitzt. Im Folgenden wird eine Zusammenfassung der Ergebnisse des Brennexperimentes vorgestellt. Ergebnisse von anderen Spezialisten sind als solche gekennzeichnet.

100°C- 300°C: Zerstörung von ferromagnetischen Eisen-Sulphiden und Neoformation von Para- und Supermagnetischen Phasen (Hambach).

400°C: Abwesenheit von Kaolinit (Berna); Formation von Magnetite/Maghemite (Hambach); Veränderung der TL-Messungskurve (Richter); mikromorphologisch: verkohlte Pflanzengewebe, wenige rote Aggregate.

500°C: makroskopischer Farbwechsel zu leicht braun; mikromorphologisch: Graufärbung von Schalenfragmenten und einige rote Aggregate, verkohlte Pflanzengewebe.

700°C: makroskopischer Farbwechsel zu rötlich gelb; mikromorphologisch: Karbonatabbau, viele rote und einige orange Aggregate, Neoformation von rosa Mineral/Hämatite (siehe Hambach); Zerstörung Magnetite/Maghemite + Hämatite Formation (Hambach); Portlandite Formation (Berna); Veränderung der TL-Messungskurve (Richter).

800°C: makroskopischer Farbwechsel zu rötlich gelb; mikromorphologisch: fortgesetzter Karbonatabbau, Schwarzfärbung von Schalenfragmenten, viele rote und einige orange Aggregate, rosa Mineral/Hämatite (siehe Hambach); Zerstörung Magnetite/Maghemite + Hämatite Formation (Hambach); Portlandite Formation (Berna).

900°C: makroskopischer Farbwechsel zu leicht grau; mikromorphologisch: Schwarzfärbung von Schalenfragmenten, Karbonatabbau abgeschlossen, viele rote und einige orange Aggregate, rosa Mineral/Hämatite (siehe Hambach); Zerstörung Magnetite/Maghemite + Hämatite Formation (Hambach); Portlandite Formation (Berna); Veränderung der TL-Messungskurve (Richter).

1000°C-1100°C: alle Eisen-Phasen sind zu Magnetite/Maghemite (Hambach) transformiert; mikromorphologisch: viele rote und einige orange Aggregate, rosa Mineral/Hämatite und Neoformation Schwarzes Mineral/ Magnetite/Maghemite (siehe Hambach).

5.3.3.2. Eigene Ergebnisse Feuerstellen

Im Folgenden werden die makroskopischen und mikromorphologischen Ergebnisse der Rotverfärbung (Feuerstellen) am Kontakt der Schichten 4b/c und 4b und die lokale, leicht rötliche Verfärbung der Schicht 4b/c unterhalb der vier Feuerstellen zusammenfassend vorgestellt. Der geologische Kontext der Rotverfärbung, Schichten 4b/c und 4b, wurde in 5.3.1.präsentiert.

Es wurden 12 Blockproben von den Feuerstellen Schöningen 13 II4 und eine Kontrollprobe von außerhalb der Feuerstellen genommen. Aus diesen Proben wurden 16 Dünnschliffe gewonnen, die die Schicht 4b/c enthielten, und 14 Dünnschliffe die die Rotfärbung des Kontaktbereiches 4b zu 4b/c enthielten.

<u>Schicht 4b/c</u> Makroskopisch wurde lokal eine leicht rötlichere Färbung der Schicht 4b/c an den vier Feuerstellen beobachtet. Mikromorphologisch ist zu erkennen, dass die makroskopische Verfärbung aus lokalen Variationen der Pyrit und Eisenoxidation (siehe 5.1.1.) resultiert. Die hier beobachtete Eisenoxidation (zerstreut, in Verbindung mit Pflanzengewebe) ähneln nicht denen des Brennexperiments (aggregiert, orange und rot). Auch die anderen Hitzebefunde des Brennexperiments konnten nicht identifiziert werden (keine Veränderung an den Schalenfragmenten, kein Verkohlen von Pflanzengewebe, kein Kalkabbau, kein Hämatite oder Magnetit/Maghemit- Bildung).

Die Dünnschliffe der Feuerstellen und einer Kontrollprobe von außerhalb der Feuerstellen unterscheiden sich allein durch das Fehlen der Eisenoxidation am Kontakt der Schichten 4b/c und 4c (siehe unten).

<u>Feuerstellen - Rotverfärbter Schichtkontakt 4b/c zu 4b</u> Die Rotverfärbung an den angeblichen Feuerstellen schwanken in ihrer Größe zwischen 1-3 m² und ist ca. 2-3 cm mächtig. Mikroskopisch ist ersichtlich, dass die Rotverfärbung aus mehreren horizontalen Laminae aufgebaut ist und aus einem massiven Auftreten von amorphen, oxidierten Eisen besteht, das die Matrix von den Schichten 4b/c und 4b durchdringt.

Die mikromorphologischen Untersuchungen konnten weder typische Komponenten von Feuerstellen (Ascherhomben, Phytolithen, Holzkohle) identifizieren noch haben sie die Ergebnisse des Brennexperimentes (keine Veränderung an den Schalenfragmenten; kein Verkohlen von Pflanzengewebe; kein Kalkabbau; kein Hämatite oder Magnetite/Maghemite) wiedergespiegelt.

5.3.3.3. Ergebnisse Anderer Forscher

Organische Petrologie (Ligouis in Stahlschmidt *et al.*, eingereicht b) Reflexionsmessungen an den Pflanzengeweben der angeblichen Feuerstelle 1 und in den Schichten 4b/c haben niedrige Werte (0.17 %Rr bis 0.22 %Rr) ergeben, die einer leichten Humifizierungen entsprechen und nicht einer Verkohlung. Es konnten nur sehr wenige, verrundete, krautige Pflanzengewebe mit Verkohlungsspuren identifiziert werden. Diese resultieren vermutlich von einem natürlichen Torfbrand in der Nähe.

Ähnliches gilt für das angeblich verbrannte Holzfragment von der Fundstelle 12 B und angeblich gebranntes Sediment von der Fundschicht 13 II-3/2. In beiden Fällen weisen die Reflexionsmessungen auf Humifizierung und nicht auf eine Verkohlung hin.

Thermolumineszenz (Richter in Stahlschmidt *et al.*, eingereicht b) Die Glowkurve der Thermolumineszenz-Untersuchung unterscheidet sich nicht zwischen der Schicht 4/c von der Feuerstelle 1 und einer Probe von außerhalb der Feuerstellen. Bei dem Brennexperiment hingegen waren Unterschiede in der Ausprägung und Intensität der Glowkurve als Reaktion auf die Laborerhitzung erkennbar.

FTIR (Berna in Stahlschmidt *et al.*, eingereicht b) Die FTIR-Spektroskopie hat Kaolinit innerhalb der Rotfärbung der Feuerstelle 1 identifizieren können. Dieses Tonmineral ist bei Temperaturen über 400°C nicht stabil (siehe auch Brennexperiment).

5.3.3.4. Diskussion

Die Untersuchungen der unterschiedlichen Belege für Feuernutzung in Schöningen haben ergeben, dass diese entweder keine oder kaum Brandspuren aufzeigen und dass die wenigen Belege von Feuer nicht mit menschlicher Aktivität in Verbindung gebracht werden können. Makroskopische Bestimmung von Feuerstellen und anderem gebrannten Material in Schöningen hat sich als nicht zuverlässig erwiesen.

Die Rotverfärbungen am Kontakt der Schichten 4b/c und 4b in Schöningen 13 II-4 resultieren vermutlich von den rezenten, künstlichen Grundwassersenkungen durch den Tagebau. An dem Kontakt der beiden Schichten ist wegen des unterschiedlichen Porenraums dieser ein Redoxpotential vorhanden. Dieses hat in Verbindung mit sauerstoffreichem Wasser zu einer massiven Oxidation von Eisen geführt. Dass es sich bei der Rotfärbung um einen rezenten Prozess handelt, entspricht auch Beobachtungen der Ausgräber, die bemerkten, dass die Rotfärbung sich über die Jahre verstärkte und anwuchs. Zudem konnte im Feld an entsprechenden Sedimentkontakten eine ähnliche Eisenoxidation beobachtet werden.

Die schwarze Färbung an der Sedimentspalte in 13 II-3 wurde durch Humifizierung verursacht und gleiches gilt für das Holzfragment von 12B.

Folglich zeigt Schöningen bisher noch keine eindeutigen Hinweise auf Feuernutzung oder Feuerkontrolle durch den Menschen. Der Fundkomplex Schöningen dient daher nicht als Beispiel für menschliche Feuernutzung in der Altsteinzeit Nordeuropas. Stattdessen lassen die Ergebnisse ähnliche, makroskopische Belege für frühe Feuernutzung fraglich wirken [siehe z.B. Beeches Pit (Gowlett, 2006) oder der sogenannte Bratspieß von Schöningen 13 II-4 (Thieme, 2005)]. Vielmehr unterstützt diese Studie die These von Roebroeks und Villa (2011), dass die erste Besiedlung nördlicher Breiten ohne Feuerkontrolle erfolgte. Alternative Adaptionsmöglichkeiten für Hominiden bei der Erstbesiedlung nördlicher Breiten sind der Gebrauch von Hütten, Migrationen, verstärkte tierische Ernährung, Kleidung und physische Anpassung (Gilligan, 2010; Stahlschmidt *et al.*, eingereicht b).

6. Mikromorphologische Untersuchungen - Grabow

6.1. Grabow

Der Fundkomplex Grabow liegt in Norddeutschland in der Auenlandschaft des Jeetzel Flusses, ein Zufluss der Elbe. Neben der Flussdynamik des Jeetzel Fluss ist diese Landschaft durch Moränenreste der Saale Eiszeit geprägt (Tolksdorf *et al.*, 2013). Die beiden Fundplätze Grabow 15 und 19 liegen im gleichen Areal (Grabow) und weisen den gleichen sedimentären Kontext auf. Die Stratigraphie in Grabow besteht aus fluvialen Sanden überlagert von fluvialen Schluffen. Der Kontakt der beiden Schichten ist durch eine stark organische Anreicherung charakterisiert und hierin befinden sich die archäologischen Funde. Tolksdorf und Kollegen (2013) interpretieren diesen stark organischen Kontaktbereich als einen Paläoboden (siehe folgend).

S. Veil hat eine Vielzahl spätpaläolithischer Fundplätze in der Auenlandschaft des Jeetzel entdeckt und ausgraben, u.a. Bernsteinwerkstätten (Veil *et al.*, 2012). Die hier untersuchten Fundplätze Grabow 15 und 19 werden zeitlich dem Allerød zugeordnet und archäologisch den Federmessergruppen (Veil *et al.*, 2012).

6.2. Fragestellung - Umweltrekonstruktion und Feuerstellen in Grabow 15 und 19 (Tolksdorf *et al.*, 2013; Stahlschmidt b)

6.2.1 Umweltrekonstruktion in Grabow 15

Tolksdorf *et al.* (2013) haben eine multianalytische Untersuchung an dem Paläoboden der Fundstelle Grabow 15 durchgeführt, die das Ziel hat die Paläoumwelt zu rekonstruieren und somit die menschliche Aktivität zu kontextualisieren. Die mikromorphologischen Untersuchungen innerhalb dieser Studie hatten das Ziel die unterschiedlichen bodenbildenden Prozesse und rezenten, post-depositionalen Überprägungen des Paläobodens zu identifizieren.

6.2.2. Feuerstellen in Grabow 19

An der Fundstelle Grabow 19 wurden lokale, gräuliche Sedimentverfärbungen als mögliche Feuerstellen identifiziert. Die mikromorphologischen Analysen haben hier zum Ziel die Genese und Erhaltung der möglichen Feuerstellenbefunde und das dazugehörige menschliche Verhalten zu rekonstruieren und zu analysieren: Handelt es sich um *in situ* Feuerstellen? Abfallbefunde? Welches Brennmaterial wurde benutzt? (Stahlschmidt b)

6.3. Ergebnisse und Diskussion

6.3.1. Umweltrekonstruktion - Grabow 19

6.3.1.1. Ergebnisse und Interpretation Anderer Forscher in Grabow 15

Tolksdorf und Kollegen (2013) stellen ein Formationsmodel für den Fundplatz Grabow 15 in Zusammenhang mit Paläoumweltveränderungen (speziell der Flussgeschichte) anhand von pedologischen und archäologischen Daten, Chrono, -Tephra- und Palynologie-Stratigraphie (für eine Übersicht der Daten siehe Tolksdorf *et al*, 2013, Seite 55) vor. Aus ihren Daten schlussfolgern Tolksdorf und Kollegen, dass die Schicht 1 fluviale Sande des frühen Allerød darstellen, die durch periodische Überflutung durch den nahegelegenen Fluss abgelagert wurden. Darauf folgend hat sich ein fluvialer Schluff während des Jüngeren Dryas abgelagert (Schicht 3). In einer Periode von Oberflächenstabilität wurden diesen fluviale Schluffe und die unterliegenden fluvialen Sande pedogen überprägt (Schicht 2b und 2a).

Menschliche Aktivität der Federmesser-Gruppe hat sich auf diesen Auensedimenten abgespielt und zu archäologischen Ablagerungen geführt. Die menschliche Aktivität ist verknüpft mit Perioden von Oberflächenstabilität (Schichten 2a und 2b).

6.3.1.2. Eigene Ergebnisse Grabow 15

Im Folgenden wird eine Zusammenfassung der mikromorphologischen Analysen präsentiert. Für die Analyse in Grabow 15 wurden drei Dünnschliffe untersucht.

<u>Schicht 1</u> Schicht 1 besteht fast ausschließlich aus verrundeten, sand-großen Quarzkörnern in einer massiven Mikrostruktur mit einfachem Kornzwischenraum. Als weitere Komponenten treten einige wenige Glimmer, Ton und amorphes organisches Material auf. Das Feinmaterial, Ton und amorphes organisches Material tritt in Aggregaten zwischen den Quarzkörner oder in leichten Hüllen auf. Wenige Kotpillen und eine rezente Wurzel weisen auf Bioturbation hin. Des Weiteren wurden Eisenausfällungen beobachtet. Der Kontakt zur aufliegenden Schicht 2a ist graduell und durch einen starken Anstieg an organischem Material gekennzeichnet.

<u>Schicht 2a</u> Schicht 2a weist einen starken Anstieg an amorphen, organischen Material auf. Des Weiteren treten größere Pflanzengewebe auf, die lokal mit Kotpillen vergesellschaftet sind. Längliche Pflanzengewebe zeigen eine Tendenz zur horizontalen Orientierung. Quarzkörner und Glimmer treten mit den gleichen Charakteristika wie in Schicht 1 auf. Das Feinmaterial besteht aus amorphem, organischem Material und tritt in Aggregaten oder in Hüllen auf. Es sind mehr Poren vorhanden als in Schicht 1, die in der Form von Kanälen und Kammern auftreten und oft organisches Material beinhalten. Eisenausfällungen treten

vergesellschaftet mit Poren und organischem Material auf. Der Kontakt zur aufliegenden Schicht 2b ist graduell.

Schicht 2b Die Schicht 2b ist der Schicht 2a in den meisten Charakteristika ähnlich (gesteigerter Anteil an organischem Material, Vorkommen von einigen Glimmer-Mineralen, Bioturbation, Eisenausfällung). Quarzkörnern treten hier allerdings vermehrt in der Schluffgröße auf. Der Anteil an organischem Material nimmt aufwärts weiter zu und der Tonanteil sinkt gegensätzlich leicht. Der Ton zeigt leichte Tendenzen zu einem kreuz- und kornstreifigen b-Gefüge. Die Schicht 2b zeichnet sich vor allem durch ihre geschichtete Oberkante aus, mit dunkelbraunem organischem Material und Quarz-reichen Laminae. Der Kontakt zur aufliegenden Schicht 3 ist irregulär und lokal sehr scharf bis graduell.

Schicht 3 Die Schicht besteht aus Quarzkörnern (vorwiegend in Schluffgröße) in einer tonigen Matrix mit dichter Mikrostruktur und wenig Porenraum. Das tonige Feinmaterial weist ein kreuz- und kornstreifiges b-Gefüge auf. Als weitere Komponenten treten amorphes, organisches Material und Glimmer auf.

6.3.1.3. Diskussion Grabow 15

Die mikromorphologischen Beobachtungen (Dominanz der Sandgröße bei Quarzkörner, horizontale Ausrichtung von länglichen Pflanzengewebe) an der Schicht 1 stimmt mit der Interpretation von fluvialen Sanden überein (FitzPatrick, 1984; Stoops, 2003).

Schichten 2b und 2a zeigen eine Vielzahl von mikromorphologischen Belegen für eine schwach entwickelte Bodenbildung (Bioturbation, Wurzeln, absteigende Abnahme an organischem Material, redoximorphische Merkmale, keine Aggregatbildung) (Retallack, 1981; Bouma et al 1990; Lindbo et al 2010). Die Schichten 2a und 2b unterscheiden sich leicht durch die Größe der Quarzkörner von einander, was der transitionalen Phase zwischen den fluvialen Sanden (Schicht 2a) und Schluffen (Schicht 2b) entspricht. Der laminierte Charakter der Oberkante der Schicht 2b lässt auf einen fluvialen Einfluss bei der Entstehung des Fluvisols schließen.

Die fluvialen Schluffe der Schicht 3 sind von dem Wechsel von Trocken- und Feuchtphasen überprägt, wie das b-Gefüge des Tones aufzeigt (Brewer, 1976; McSweeney und Fastovsky, 1987). Dies ist aber vermutlich ein rezenter Prozess.

Die mikromorphologischen Untersuchungen stimmen mit den Interpretationen von Tolksdorf und Kollegen (2013) überein und ergänzen diese mit Details der Bodenbildung.

6.3.2. Feuerstelle Grabow 19

6.3.2.1. Ergebnisse

An der Fundstelle Grabow 19 wurde der Feuerstellenbefund 101 beprobt, der sich in der dortigen Schicht GS 3 befindet, was in Bezug auf Grabow 15 und Tolksdorf *et al*. (2013) in die Schicht 2b ist (siehe Veil *et al*., in Vorb.). Es wurden hier 4 Dünnschliffe untersucht.

Die mikromorphologischen Beobachtungen an der Schicht GS 3 (hoher Anteil amorphes, organisches Materials, das mit Tiefe abnimmt; Bioturbation-Merkmale; Quarzkörner verrundet, in Schluff bis Sandgröße; Tonanteil mit leichten Tendenzen zu einem kreuz- und kornstreifigem b-Gefüge; Eisenausfällungen; Laminae an der Oberkante) entsprechen der Beschreibung von Schicht 2b in Punkt 6.3.1.2.. Zusätzlich konnten einige Holzkohleflitter, wenige Feuersteine und Knochen im Dünnschliff identifiziert werden.

Der Befund 101 zeichnet sich durch eine räumlich klar begrenzte Ansammlung von Mikroholzkohle aus, die hier bis zu 50% der groben Fraktion ausmacht. Diese Holzkohlepartikel sind nicht kantenverrundet und weisen eine Größenvariation von wenigen Mikrometer bis zu 5 mm auf. Ascherhomben oder Phytolithen wurden nicht beobachtet und der Befund ist vergesellschaftet mit einigen Knochenfragmenten und Glaukonitkörnern.

6.3.2.2. Diskussion

Die mikromorphologische Untersuchung bestätigt, dass das Ablagerungsmilieu an der Fundstelle Grabow 19 dem Ablagerungsmilieu in Grabow 15 entspricht.

Der Befund 101 stellt mit großer Wahrscheinlichkeit einen *in situ* Feuerstellenbefund dar. Die Abwesenheit von Ascherhomben ist hier nicht weiter verwunderlich, da der tonig-sandige Schluff kein geeignetes Milieu für die Erhaltung von Asche darstellt und der Befund zudem durch Verwitterung und Bioturbation überprägt ist. Die klare Begrenzung des Befundes, die gute Erhaltung der Holzkohle und die hohe Konzentration der Holzkohle macht einen Transport des Materials unwahrscheinlich und weist auf einen *in situ* Befund hin. Weitere Untersuchungen bezüglich einer Hitzeveränderung der vergesellschafteten Glaukonitkörner und Knochen könnten Klarheit verschaffen. Die Erhaltung des Befundes trotz Überprägung durch die Bodenbildung des Fluvisols stellt einen exzeptionellen Befund einer Feuerstelle innerhalb eines Bodens dar.

7. Mikromorphologische Untersuchungen - Varsche Rivier 003

7.1. Varsche Rivier 003

Lage und Geologie

Der Fundplatz Varsche Rivier 003 liegt in der Knersvlakte Landschaft im nordwestlichen Südafrika. Die Knersvlakte ist eine leicht hügelige Küstenebene gekennzeichnet durch ein reiches Vorkommen an Quarz und von Sukkulenten-Pflanzen. Die Knersvlakte ist im Westen begrenzt durch den Atlantischen Ozean, im Süden durch den Olifants Fluss, im Süden durch die quarztische Granite-Gneis Übergruppe und im Norden durch den Hardeveld (Cowgill *et al.*, 1999). Die Knersvlakte ist von Schiefer, Phylliten und Kalkstein unterlegen. Die Fundstelle Varsche Rivier 003 liegt am Südufer des Varsche Flusses, der hier eine Schlucht durch eine Kalksteinformation schneidet. Die Fundstelle liegt am oberen Ende eines Abhangs, der von der Kante des anstehenden Kalksteins zum Fluss führt, in einem Abri.

Archäologie

Die Fundstelle wurde 2009 entdeckt und - nach Testgrabungen im gleichen Jahr- 2010 erstmalig gegraben (Steele *et al.*, 2012). Es wurden zwei Ausgrabungsflächen geöffnet, eine am Abhang und eine im Abri selber. Während die obersten Schichten vor allem *Late Stone Age* (LSA) und einige wenige *Middle Stone Age* (MSA) Artefakte enthielten, wurden in den unteren Schichten Howiesons Poort und Still Bay (beide MSA) Funde gemacht (Steele *et al.*, 2012) (für eine stratigraphische Übersicht siehe 7.3.1.). Die Howiesons Poort und Still Bay Industrien - mit ihrer Standarisierung von Steinartefakten und Innovationen wie Ornamenten und Gravierungen - spielen eine zentrale Rolle in der Diskussion um die Entstehung des modernen, menschlichen Verhaltens im MSA in Südafrika (siehe z.B., McBrearty und Brooks, 2000; Henshilwood und Marean, 2003).

7.2. Fragestellung - Fundplatzgenese (Stahlschmidt c)

Die geoarchäologische Analyse an dem Abri Varsche Rivier 003 hat zum Ziel die Genese des Fundplatzes zu analysieren, die stratigraphische Abfolge zu dokumentieren, die Integrität der archäologischen Schichten zu untersuchen, und den Fundplatz in die Paläolandschaft einzuordnen (Stahlschmidt c.). Ein Hauptproblem der Fundstelle ist die unterschiedliche Ablagerung innerhalb des Abris und auf dem Abhang des Vorplatzes, woraus sich folgende Fragen ergeben: Welche Ablagerungsprozesse sind innerhalb und außerhalb des Abris zu unterscheiden? Wie sind die Schichten innerhalb und außerhalb des Abris zu verbinden? Was für unterschiedliche Prozesse haben auf die archäologischen Hinterlassenschaften gewirkt?

Kann ein primärer Kontext oder sekundären Kontext in den Ablagerungen unterschieden werden? Wie unterscheidet sich der Kontext innerhalb und außerhalb des Abris?

7.3. Ergebnisse und Diskussion

7.3.1. Makroskopische Beobachtungen

In der Grabungskampagne 2011 wurde eine Feldbegehung der unmittelbaren Landschaft des Fundplatzes inklusive Probenahme für eine Referenzkollektion durchgeführt. Weiterhin wurde eine stratigraphische Beschreibung der Schichten am Fundplatz vorgenommen, und es wurden Locker- und Blockproben am Fundplatz genommen. Die Ausgrabung 2011 bestand aus zwei Ausgrabungsflächen, eine innerhalb des Abris - Abri-Ausgrabungsfläche - und eine weitere auf dem Abhang vor dem Abri - Abhang-Ausgrabungsfläche. Für die mikromorphologische Analyse in Varsche Rivier 003 wurden 12 Dünnschliffe untersucht.

<u>Abhang-Ausgrabungsfläche</u> Die geologischen Horizonte (GH) 1-3 bestehen aus Kalksteinen (unsortiert, kantig) in einer schluffig, leicht sandigen Matrix. Bioturbation mit Wurzeln, Kanälen und humifizierten organischen Material ist in allen drei Horizonten mit abnehmender Intensität von GH 1 zu GH 3 vorhanden. In der Mitte der Ausgrabungsfläche befand sich ein großer Kalksteinblock, der die GH 4-5 in eine hangaufwärtige Schicht, mit vermehrt horizontal orientierten Kalksteinen, und eine hangabwärtige Schicht mit vermehrt hangabwärts orientierten Kalksteinen, unterteilte.

GH 4 und 5 enthalten weniger Kalksteine als die Schichten GH 1-3 und sind zudem durch horizontale (mit leichter Hangneigung) karbonatische Krusten charakterisiert.

GH 6 besteht aus braunem Schluff mit einem geringen Anteil an Kalksteinen.

Alle geologischen Schichten am Abhang zeigen eine Hangneigung parallel zur rezenten Oberfläche.

<u>Abri-Ausgrabungsfläche</u> Die sedimentäre Abfolge innerhalb des Abris konnte in einen obere, anthropogenen (vorwiegend LSA; GH 1-5) und einen unteren, geogenen Part (MSA; GH 6-9) unterteilt werden. GH 1 ist ein bioturbierter, braun-grauer Schluff. GH 2 ist zu einem geringeren Maße als GH 1 von Bioturbation geprägt und ebenso ein grau-brauner Schluff mit vielen Knochen- und Schalenfragmenten. GH 3 ist durch eine braune, organische Pflanzenbettung charakterisiert. Bei dem folgenden GH 4 handelt es sich um eine gelblich-grauen Schluff mit weißen, karbonatischen *Nodules*. GH5 ist ebenso ein gelblich-grauer Schluff mit einer hohen Anzahl an Holzkohlefragmenten und möglichen Aschelinsen. Eine horizontale Schicht mit Landschneckenschalen trennt den oberen LSA Part von dem unteren MSA Part der Abfolge.

Die GH 6-8 bestehen vorwiegend aus geblichen-grauem Schluff mit einigen Kalksteinfragmenten in Kies-Größe. GH 7 weist eine größere Kompaktheit als GH 6 auf und GH 8 ist leicht bräunlich mit weniger Kalksteinfragmenten als zuvor. GH 9 ist ein bräunlicher, toniger Schluff.

7.3.2. Mikromorphologische Analysen

Dünnschliffen von GH 2 bis GH 6 von der Abhang-Ausgrabungsfläche und von GH 6 bis GH 9 von der Abri-Ausgrabungsfläche wurden analysiert.

<u>Abhang-Ausgrabungsfläche</u> Alle GHs am Abhang weisen eine karbonatische Matrix mit einem geringen Tonanteil auf, der in GH 6 leicht verstärkt ist. Als Grobkomponenten treten sand-große Kalzitkristalle, schluff- bis sandgroße Quarzkörner, Knochenfragmente, Straußeneierschalen und einige Mikrodebitage-Stücke auf. GH 4 bis 6 enthalten eine Vielzahl gebrannter Knochenfragmente und einige wenige Holzkohlefragmente. GH 6 zeigt einen verstärkten Anteil an sand-großen Knochenfragmenten.

Die Mikrostruktur zeigt ein Schwammgefüge auf und ist granular mit vielschichtigen Hüllen an den Grobkomponenten. Die vielschichtigen Hüllen sind in GH 6 weniger stark ausgeprägt. Mikrodebitage-Stücke sind nicht bzw. kaum von Hüllenbildung betroffen, während Knochenfragmente eine durchschnittliche Hüllenbildung aufweisen. Bioturbation ist in allen Horizonten evident mit Grabgängen, Kanälen, Rhizolithen, Redoxbefunden und transportierten Bodenaggregaten.

Es wurden keine mikromorphologischen Unterschiede in dem hangaufwärtigen und hangabwärtigen Teil der GHs 4 und 5 festgestellt. Die karbonatische Krusten in GH 4 und 5 zeichnen sich durch eine mikritische Mikrostruktur mit eingehüllten Grobkomponenten, Knochenfragmenten, Pflanzen-*Pseudomorphen* aus und sind durch Grabgänge und Kanäle unterbrochen.

<u>Abri-Ausgrabungsfläche</u> Die Matrix der GHs 6-8 ist karbonatisch und weniger von einem Schwammgefüge geprägt und auch weniger granular als in den GHs vom Abhang. Hüllen wurden an wenigen Grobkomponenten festgestellt und diese sind nur dünn. Zudem ist Bioturbation in geringem Maße vorhanden, während transportierte Bodenaggregate in einem erhöhten Maße auftreten.

Die Grobkomponenten bestehen aus sand-große Kalzitkristallen, schluff- bis sandgroße Quarzkörner, Knochenfragmente, Straußeneierschale, und einige Mikrodebitage-Stücke und zudem konnte hier Gipsformation beobachtet werden.

GH 9 zeichnet sich durch eine tonige, leicht organische Matrix aus und zeigt einen größeren Anteil von sand-großen, gebrannten Knochenfragmenten auf.

7.3.3. Diskussion

Die mikromorphologischen Untersuchungen haben unterschiedliche Formations- und post-depositionale Prozesse auf dem Abhang und innerhalb des Abris feststellen können. Dies sind kolluviale Prozesse, verstärkte Bioturbation, feuchtere Bedingungen auf dem Abhang im Gegensatz zu weniger post-depositionalen Störungen und trockeneren Bedingungen innerhalb des Abris.

Die Hüllen an den Grobkomponenten in den GHs des Abhanges resultiert wahrscheinlich aus kolluvialen Prozessen in Verbindung mit einer feuchten Umgebung (siehe z.B. Hay und Reeder, 1978; Bertran und Texier, 1999; Rose *et al.*, 2000). Die Krustenbildung in GH 4 und 5 resultiert vermutlich aus einer unterirdischen Karbonatverteilung unter Wassereinfluss mit folglich schneller Evaporation und stellt einen post-depositionalen Prozess dar (Rabenhorst und Wilding, 1986; Wright und Tucker, 1990). Der tonige und organisch-reiche GH 6 weist auf feuchtere Bedingungen hin. Es kann hier also ein Wechsel von feuchteren Bedingungen (Ton und organisches Material in GH 6, Schwammgefüge und granulare Mikrostruktur in GH 6-2) zu post-depositionalen Prozessen unter trockeneren Bedingungen (Krustenbildung) nachvollzogen werden.

Innerhalb des Abris sind geschütztere Bedingungen (Gipsbildung) und weniger Turbation der Schichten reflektiert. Die Bodenaggregate stammen von der Hochfläche und sind durch den Deckenspalt eingespült worden.

Der braune Schluff innerhalb des Abris und auf dem Abhang weist einige Ähnlichkeiten auf, wie der gestiegene Tonanteil und die verstärkte Präsenz von gebrannten, sand-großen Knochenfragmenten. Letzteres ist ein typisches Merkmal für paläolithische Schichten (Miller, im Druck). Es konnten aber auch Unterschiede festgestellt werden, wie der kolluviale Charakter und die vermehrte Bioturbation am Abhang.

In Bezug auf den primären oder sekundären Kontext der geologischen Schichten und der archäologischen Hinterlassenschaften in diesen, ist zu vermuten, dass die Materialien auf dem Abhang verlagert wurden (evtl. nicht auf Mikrodebitage zutreffend) und durch Bioturbation post-depositional vermischt wurden. Letzteres hat eine negative Bedeutung für die vorgenommen OSL-Datierungen und muss bei den gewonnenen Daten in Betracht gezogen werden. Des Weiteren wurde die Empfehlung ausgesprochen sich in den zukünftige Grabungen auf den Abri zu konzentrieren.

8. Mikromorphologische Untersuchungen - Blätterhöhle

8.1. Blätterhöhle

Der Fundplatz der Blätterhöhle liegt in Westdeutschland im Gebiet des südwestfälischen Massenkalkes in einem Seitental der Lenne. Geologisch gesehen ist dieser Massenkalk Teil des Schwelmer Kalks in der Struktur des Remscheid-Altenaer Sattels (Orschiedt, 2010). Die Blätterhöhle ist eine Höhle innerhalb des Weißensteins bei Hagen-Holthausen. Archäologische Ausgrabungen auf dem Höhlen-Vorplatz begannen 2006, nachdem innerhalb der Höhle mittel- und jungsteinzeitliche Menschenreste entdeckt worden waren. Hier wurde neben Knochen und Steinwerkzeugen aus dem Spätpaläolithikum und Mesolithikum auch ein Fragment eines menschlichen Schädeldaches entdeckt, das in das Mesolithikum datiert. Auf dem Vorplatz wurde 2006 eine erste Feuerstelle im Feld identifiziert, 2008 eine weitere und eine dritte während der Grabungskampagne 2009 (Orschiedt, 2010).

8.2. Fragestellung - Feuerstelle (Stahlschmidt, Miller)

An dem Abri Blätterhöhle wurde auf dem Vorplatz eine lokale, großräumige (ca. 20 cm hoch und 90 cm lang), dunkelgräuliche Verfärbung des Sediments dokumentiert und als mögliche Feuerstelle interpretiert, Feuerstelle 2 (Orschiedt *et al.*, 2010). Mikromorphologische Untersuchungen sollten dazu dienen festzustellen, ob die Sedimentverfärbung durch eine oder mehrere Feuerstellen verursacht wurde, ob es sich um eine/mehrere *in situ* Feuerstelle/-n oder Abfallgrube/-n handelt und ob der Befund post-depositional überprägt ist/sind.

8.3. Ergebnisse und Diskussion

Es wurden im Feld zwei Proben für mikromorphologische Untersuchungen genommen und daraus vier Dünnschliffe gewonnen, die die Schichten 4a, die Feuerstellen 2/Schicht 4b und die aufliegende Schicht 3 beinhalten.

8.3.1. Ergebnisse

<u>Schicht 4a</u> Die Schicht 4a zeichnet sich durch ihren Hauptanteil an schluff- bis feinsand-großen Quarzkörner in einer karbonatisch-tonigen bis leicht organischen Matrix aus. Als weitere Grobkomponenten sind kantige Kalksteinfragmenten, Knochen- und Schalenfragmenten, sowie Sandstein und Tonsteine und vereinzelte Holzkohlesplitter vorhanden. Die Mikrostruktur ist sehr kompakt und Poren treten selten in Form von Rissen, Kanäle und Kammern auf. Weiterhin waren Tonhüllen, Tonverlagerungen,

Rhizokonkretionen und andere Kalkanreicherungen zu beobachten. Eine Schichtung oder Sortierung des Sediments konnte nicht beobachtet werden.

Die Feuerstelle 2 - Schicht 4b Die Feuerstelle 2 zeichnet sich mikromorphologisch durch einen erhöhten Anteil an Holzkohle (wenige µm bis zu 1 cm) und einen leicht erhöhten karbonatischen Anteil im Feinmaterial aus. Zudem treten hier vereinzelt Ascherhomben und gebrannte Knochen auf. Des Weiteren unterscheidet sich die Feuerstelle 2 nicht von der Schicht 4a und ist ebenso von Bioturbation stark überprägt.

Schicht 3 Die Schicht 3 entspricht größtenteils der Schicht 4a und zeigt eine Dominanz von schluff- bis feinsand-großen Quarzkörner in einer karbonatisch-tonigen Matrix, die hier aber stärker organisch ist. Als weitere Grobkomponenten treten wie zuvor gerundete, kleine Sandsteine, Knochen-, Schalen- und Molluskenfragmente neben einigen wenigen Holzkohlesplittern auf. Der Porenraum ist hier in einem größeren Ausmaß von Bioturbation geprägt als in der Schicht 4a und es konnten einige rezente Wurzeln beobachtet werden.

8.3.2. Diskussion

Die Charakteristika der Quarzkörner lassen auf eine äolische Ablagerung der Quarzkörner in den Schichten 4 und 3 schließen, während die Kalkkomponente in der Grob- und Feinfraktion von dem anstehenden Kalksteinmassiv stammt. Die Mikrostruktur mit Rissen, Kanälen, Kammern, Wurzeln und Rhizokonkretionen lässt auf Bioturbation und post-depositionale Überprägungen mit Kalkanreicherungen und Tonverlagerung schließen.

Die makroskopisch gräulichere Färbung der Feuerstelle 2 resultiert vorwiegend aus der feinen Verteilung von Holzkohlesplittern, Ascherhomben, gebrannten Knochen und dem erhöhten Karbonatgehalt der Feinfraktion. Es konnte keine stratifizierte Feuerstelle, die idealerweise aus einem rot verfärbtem, oxidiertes Sediment unter einer Holzkohle-Schicht unter Ascheschicht besteht (siehe z.B. Mentzer, 2012), identifiziert werden. Vielmehr treten die unterschiedlichen Kategorien von gebranntem Material vermischt miteinander und vermischt mit nicht gebranntem Material auf. Die Feuerstelle/-n ist/sind durch Bioturbation überprägt.

9. Schlussbetrachtung

Die mikromorphologischen Untersuchungen an den Fundstellen Schöningen, Grabow, Varsche Rivier 003 und der Blätterhöhle haben detaillierte Einblicke in die Genese der Fundplätze, ihrer Schichten und Befunde erlaubt.

An der Fundstelle Schöningen konnte ein Trockenfallen der fundführenden Seesedimente, postuliert von Thieme (2005), mikromorphologisch nicht nachgewiesen werden. Stattdessen weisen die Komponenten, die Erscheinungsform der Komponenten und die Mikrostruktur auf eine ständige Unterwasserablagerung hin. Die mikromorphologischen Analysen stellen daher eine einmalige *in situ* Ablagerung der Funde in Frage und alternative Ablagerungsprozesse, wie eine anthropogene oder geogene Verlagerung der Funde, müssen in Betracht gezogen werden (Stahlschmidt *et al.*, eingereicht a). Des Weiteren hat die mikrokontextuelle-Analyse die Belege für eine Feuernutzung in Schöningen widerlegt (Stahlschmidt *et al.*, eingereicht b) und die Studie betont die Notwenigkeit der Durchführung von mikrokontextuellen-Analysen von Belegen für Feuernutzung vor der Erstellung von Modellen zu früher Feuernutzung.

Die mikromorphologischen Analysen in Grabow 15 stimmen mit den anderen pedologischen Untersuchungen, den archäologischen Daten und der Chrono-, Tephra- und Palynologie-Stratigraphie in dem Formationsmodel einer Ablagerung von fluvialen Schluffen über fluvialen Sande und einer Bodenbildung an ihrem Kontaktbereich überein. Zudem konnte die mikromorphologische Untersuchung die makroskopische Bestimmung von Feuerstellenbefunden in der Freilandfundstelle Grabow 19 bestätigen.

An dem Abri Varsche Rivier 003 konnten unterschiedliche Ablagerungsprozesse innerhalb des Abris und am Abhang vor dem Abri festgehalten werden, was sowohl für die archäologische Integrität der Ablagerung als auch für die OSL-Datierungen Auswirkungen hat und diskutiert wird.

Die mikromorphologische Untersuchung einer Feuerstelle auf dem Vorplatz der Blätterhöhle konnte keine stratifizierte Feuerstelle identifizieren, aber ließ dennoch auf mindestens eine lokal bioturbierte Feuerstelle schließen.

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Anhänge

1. Serangeli, J., Bigga, G., Böhner, U., Julien, M.A., Lang, J., Stahlschmidt, M. (*2*012). Ein Fenster ins Altpaläolithikum. Archäologie in Deutschland 4, 2012, 6-12.
2. Tolksdorf, J. F., Turner, F., Kaiser, K., Eckmeier, E., Stahlschmidt, M., Housley, R. A., Breest, K., Veil, St. (2013). Multiproxy Analyses of Stratigraphy and Palaeoenvironment of the Late Palaeolithic Grabow Floodplain Site, Northern Germany. Geoarchaeology 28, 1, 50-65.
3. Stahlschmidt, M.C., Miller, C.E., Ligouis, B., Goldberg, P., Berna, F., Urban, B., Serangeli, J., Conard, N.J. (eingereicht a). The depositional environments of Schöningen 13 II-4 and their archaeological implications. Journal of Human Evolution. Special issue Schöningen.
4. Stahlschmidt, M.C., Miller, C.E., Ligouis, B., Hambach, U., Goldberg, P., Berna, F., Richter, D., Urban, B., Serangeli, J., Conard, N.J. (eingereicht b). On the evidence for fire at Schöningen. Journal of Human Evolution. Special issue Schöningen.
5. Stahlschmidt, M. C., Report on the micromorphological analyses at Schöningen 12 II-4, Germany - 2013.
6. Stahlschmidt, M. C., Bericht über die mikromorphologischen Untersuchungen an der Fundstelle Grabow 19, Deutschland - 2013.
7. Stahlschmidt, M. C, Report on the geoarchaeological field work and micromorphology at Varsche Rivier 003, South Africa - 2012.
8. Stahlschmidt, M. C, Miller, C.E., Bericht über die mikromorphologischen Untersuchungen an der Feuerstelle 2 Blätterhöhle, Deutschland - 2011.

Anhang 1

Serangeli, J., Bigga, G., Böhner, U., Julien, M.A., Lang, J., Stahlschmidt, M. (*2*012). Ein Fenster ins Altpaläolithikum. Archäologie in Deutschland 4, 2012, 6-12.

Ein Fenster ins Altpaläolithikum

Seit Mitte der 1990er-Jahre stehen die altpaläolithischen Fundstellen in Schöningen im Zentrum der Aufmerksamkeit. Zugleich lösten sie Diskussionen darüber aus, wie die Hominiden in Mitteleuropa damals lebten. Dank Schöningen und der hier entdeckten Speere wissen wir, dass die Menschen vor etwa 300 000 Jahren geschickte und opportunistische Jäger waren und über Planungstiefe, Abstraktionsvermögen und reiche Erfahrungen verfügten.

Von **Jordi Serangeli, Gerlinde Bigga, Utz Böhner, Marie-Anne Julien, Jörg Lang** und **Mareike Stahlschmidt**

Der Landkreis Helmstedt befindet sich im östlichen Niedersachsen, zwischen dem Harz im Süden und der norddeutschen Tiefebene. Schöningen selbst (ca. 114 m ü.NN) liegt am Fuße des Elms, eines ca. 25 km langen und bis 8 km breiten Höhenzugs aus Muschelkalk (bis 323 m ü.NN). Fruchtbare Lössböden, Salzvorkommen und die verkehrsgünstige Lage an den Ost-West-Verbindungen machten die Region schon früh für Menschen attraktiv (siehe auch AiD 3/2010, S. 28–31; 3/2011, S. 53; 4/2011, S. 8–13; 2/2012, S. 47). Seit 140 Jahren hat der Braunkohleabbau großflächig in die Landschaft eingegriffen. Diese bis zu 140 m tiefen Einschnitte konnten sich Archäologen, Geologen, Paläobotaniker und Paläontologen in den letzten 30 Jahren zunutze machen, um 50 bis 30 Millionen Jahre alte Schichten des Tertiärs und bis 400 000 Jahre alte Schichten des Quartärs zu untersuchen.

Geologie und Klima

Der Tagebau Schöningen befindet sich in der westlichen Randsenke der Helmstedt-Staßfurter Salzmauer. Seit 2009 hat man sowohl die tertiäre Randsenkenfüllung als auch die quartären Sedimente mit modernen geologischen Methoden neu untersucht. Dabei wurde sowohl die Scherwellenseismik, eine geophysikalische Methode, die einen Blick bis in 80 m Tiefe ermöglichte, als auch über 700 Bohrdaten verwendet. Daraus entstand eine 3D-Modellierung des Untergrundes.

Die Basis des Tagebaus bilden unverfestigte, ca. 50 Millionen Jahre alte Sedimente. Es handelt sich im Wesentlichen um alternierende Schichtpakete aus Braunkohle und Sand, die eine Gesamtmächtigkeit von 366 m erreichen. Während der Elster-Eiszeit (ca. 400 000 bis 320 000 Jahre vor heute) wurde die Region von einem einige Hundert Meter mächtigen Gletscher komplett überfahren, der bis zum Harz reichte. Das Schmelzwasser unter diesen gewaltigen Eismassen stand unter hohem Druck und schnitt sich einen Weg in die darunterliegenden Sedimente. Dadurch entstand eine bis zu 850 m breite und 40 m tiefe subglaziale Rinne. Diese Rinnensysteme sind typisch für die Elster-Eiszeit in Norddeutschland. Der untere Teil der subglazialen Rinne in Schöningen ist mit Schmelzwasserablagerungen und Grundmoräne verfüllt.

Vor ca. 320 000 Jahren änderte sich das Klima und eine neue Warmzeit begann, das Holstein-Interglazial. In Schöningen wird diese Zeit aufgrund der speziellen paläobotanischen Befunde auch als Reinsdorf-Interglazial bezeichnet. Als sich die Gletscher der Elster-Eiszeit nach Norden zurückzogen, verblieb ein langgestrecktes Becken, in dem sich ein See bildete. In dieser Zeit hatte der verbliebene See eine Länge von etwa 2,5 km, eine Breite von 200 bis 400 m und eine Wassertiefe von bis zu 7,5 m. Gespeist wurde er durch Zuflüsse aus dem Elm, die kleine Deltasysteme am Westufer des Sees aufschütteten. Die Ablagerungen des Sees sind durch zyklische Seespiegelschwankungen geprägt und bestehen aus oganik-reichem Schlamm und Torf der Uferzone und Ablagerungen des Seebeckens. Im Uferbereich weisen kleine, sandgefüllte Kanäle auf die ehemaligen Zuflüsse des Sees hin. Diese Abfolge von Sedimenten mit zahlreichen feinen Wechseln erreicht lokal eine Mächtigkeit von über 6 m. Beim Absinken des Seespiegels fielen die Ufer trocken, und es kam zur teilweisen Erosion älterer Ablagerungen. Seespiegelanstiege führten zu verstärktem Torfwachstum an den Rändern des Sees und begünstigten so die Erhaltung der Sedimente. Die Seespiegelschwankungen wurden durch klimatisch

Satellitenbild der Region: Tagebau und Fundstelle von Schöningen.

Grabungssituation in Oktober 2011. Man erkennt sehr deutlich die durch Seespiegelschwankungen entstandenen vier Verlandungsfolgen. Zu jeder Folge gehören graue, meist muschelreiche Kalkmudden des Seebeckens und darüber Torf bzw. organogener Schlamm im Uferbereich.

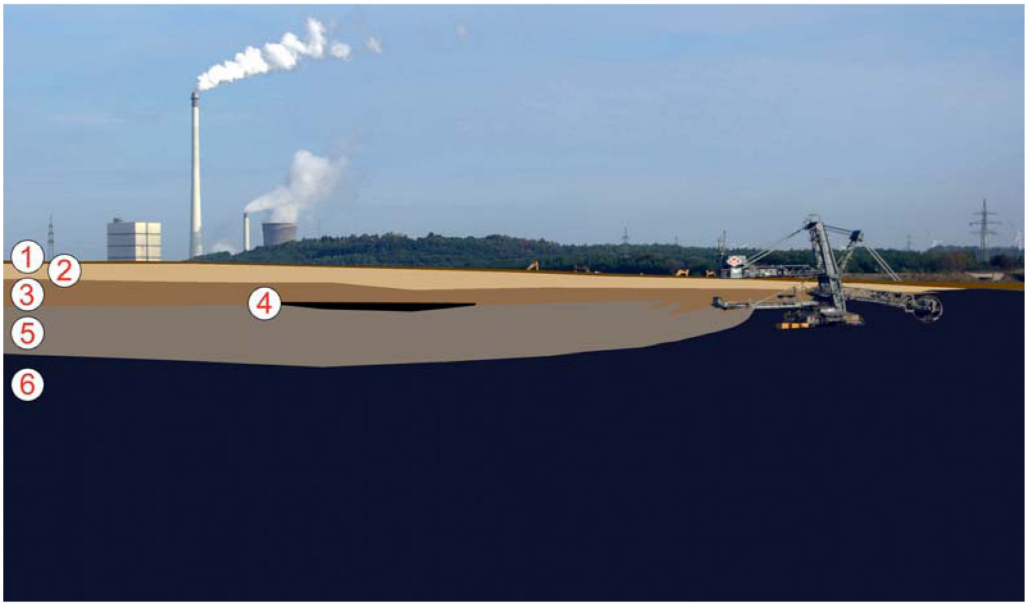
bedingte Veränderungen der Niederschlagsmenge und damit des Oberflächenabflusses sowie des Grundwasserspiegels gesteuert.

Insbesondere während der klimatisch trockeneren Perioden zogen der See und die Feuchtgebiete am Ufer Tiere und somit auch den Menschen an. Aufgrund der Datierung von ca. 300 000 Jahren kann man davon ausgehen, dass hier der »Homo heidelbergensis« lebte. Artefakte und Faunenreste blieben nach erfolgreicher Jagd am Seeufer zurück und wurden beim Anstieg des Seespiegels im Sediment eingebettet. Die genauen Ablagerungsprozesse an den Fundplätzen sind allerdings noch nicht abschließend geklärt. Laufende mikroskopische Sedimentanalysen an der Fundstelle der Speere und auf deren stratigrafischer Fortsetzung weisen auf eine direkte Vergesellschaftung der Funde mit ufernahen Seesedimenten hin. Der See bildete die Grundlage für die hervorragende Erhaltung von organischen Materialien.

Dem Holstein-Interglazial folgte die Saale-Eiszeit bzw. der Saale-Komplex (ca. 300 000 bis 130 000 Jahre vor heute), in dem mehrere Eisvorstöße und Klimaschwankungen beinhaltet sind. Auch in dieser Phase wurde Schöningen von einem einige Hundert Meter mächtigen Gletscher überfahren. Dieser Gletscher

paläon – Forschungs- und Erlebniszentrum Schöninger Speere

Am Rande des Tagebaus in nächster Nähe zu den noch laufenden Ausgrabungen entsteht derzeit das paläon, ein modernes Forschungs- und Erlebniszentrum mit großem Landschaftspark. Ab Frühjahr 2013 wird man hier die sensationellen Originalfunde in einer spannenden Ausstellung sehen und aktuelle Forschung hautnah miterleben.



Unter dem bereits abgetragenen Humushorizont (1) erkennt man die Lössablagerungen der Weichsel-Eiszeit (2), Sand- und Geröllschichten der Saale-Eiszeit (3), die organogenen Sedimente von Schöningen, in denen die archäologischen Funde eingebettet sind (4), die Grundmoräne der Elster-Eiszeit (5) und die tertiären Sande und Braunkohlenflöze (6).

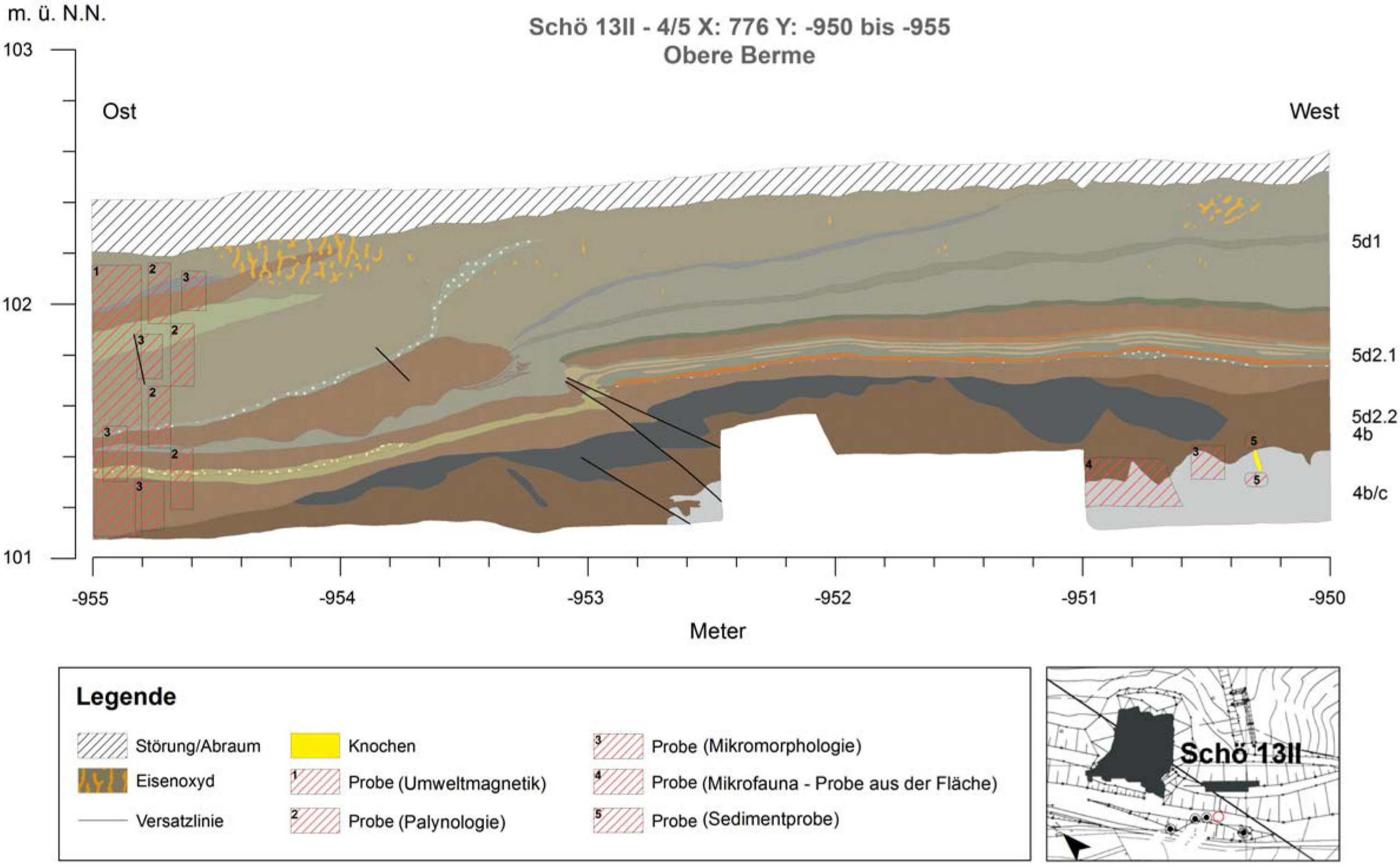
Die Schöninger Funde entdeckte man am Übergang der grauen Kalkmudde zum aufliegenden dunkelbraunen organogenen Schlamm des Uferbereichs.

Schöninger Speer im Sediment (Juni 1997), (siehe Seite 9).

verursachte eine weiträumige Erosion. Nur die Sedimente, die tief genug in der subglazialen Rinne der vorherigen Eiszeit lagen, blieben erhalten. Schmelzwasserablagerungen und Grundmoräne der Saale-Eiszeit sind im Tagebau weit verbreitet. Das der Saale-Eiszeit folgende Eem-Interglazial (ca. 130 000 bis 115 000 Jahre vor heute) ist nur an einigen Stellen erhalten. Auf Ablagerungen der Weichsel-Eiszeit (ca. 115 000 bis 12 000 Jahre vor heute), zumeist einige Meter Lösse aus dem Hochglazial, sind in Senken gute Aufschlüsse aus dem Holozän (ab ca. 12 000 Jahre vor heute bis jetzt) erhalten.

Der Mensch und seine Spuren

Sowohl die Dimensionen des Tagebaus mit ca. 6 km^2 als auch die Geschwindigkeit des Abbaus – ein Schaufelradbagger baut bis zu 40 000 m^3 bzw. 80 000 t am Tag ab – machen aus der archäologischen Arbeit einen ständigen Kampf gegen die Zeit. Umso mehr Anerkennung verdient die Arbeit von Hartmut Thieme, der von 1982 bis 2008 das Projekt »Archäologische Schwerpunktuntersuchungen im Helmstedter Braunkohlerevier« (ASHB) am Niedersächsischen Landesamt für Denkmalpflege koordinierte und leitete. Dank dieses Projekts konnten im Vorfeld des Abbaus großflächige Rettungsgrabungen durchgeführt und zahlreiche holozäne Fundstellen gerettet werden. 1992 wurde die erste von mehreren paläolithischen Stätten entdeckt. Anzahl und Bedeutung der paläolithischen Befunde und Funde, darunter Holzartefakte, sind so groß, dass die Grabungen, die wissenschaftliche Auswertung und die Versorgung der teils höchst sensiblen Objekte ununterbrochen bis heute andauern. Seit Juni 2008 wird das Projekt als Kooperation zwischen dem Niedersächsischen Landesamt für Denkmalpflege und der Universität Tübingen geführt (seit 2010 im Rahmen eines DFG-Projektes). Qualität und die größere Anzahl an Freilandfundstellen erlauben es, in Schöningen neue Akzente bei der Erforschung des Altpaläolithikums zu setzen. Hier können soziale und ökonomische Verhaltensformen am Ende des Altpaläolithikums untersucht sowie die Siedlungsdynamik vor Ort analysiert werden. Schöningen mit seinen zahlreichen Fundstellen aus verschiedenen Perioden des Holstein-Interglazials kann weiter als Fallbeispiel herangezogen werden, um die Besiedlungsgeschichte im nördlichen Mitteleuropa besser zu verstehen.



Profil der Fundstelle Schöningen: Schicht 5d1, 5d21, 5d2.2: Wechsellagerung von Schluffen und Sande mit unterschiedlicher Korngröße und Anteil an organischem Material; Schicht 4b: Fundschicht mit hohem Anteil an organischem Material (u.a. Käferflügeldecken); Schicht 4b/c: Übergang zwischen der Fundschicht und der darunter liegenden Kalkmudde.


SCHÖNINGEN 13/07
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Mit einem Alter von ca. 300 000 bis 320 000 Jahren zählt Schöningen zu den ältesten Fundorten in Deutschland. Diverse archäologische Stätten (zumindest sieben seit 2008, insgesamt wahrscheinlich mehr als 20) belegen eine wiederholte Anwesenheit des Menschen während der gesamten Holstein-Warmzeit. Hinweise für Aufenthalte in Schöningen finden sich sowohl für die Zeit des Wärmemaximums, aus dem u.a. Wasserbüffel, Waldelefant und Erlen belegt sind, als auch für das Ende der Warmzeit, als das Pferd als Großsäuger stark vertreten war und sich eine offene Steppe ausgebreitet hatte.

Die Existenz des Menschen in so unterschiedlichen Klimaten setzt die Fähigkeit voraus, sich gegen Kälte schützen zu können. Art und Lage der Schnittspuren an Pferdeknochen aus Schöningen weisen auf das Enthäuten der Tiere hin. Wozu? Nur um an das Fleisch zu kommen? Schnittspuren an Bärenknochen z.B. aus Biache-Saint-Vaast in Frankreich oder aus Taubach scheinen zu zeigen, dass der Mensch zumindest seit dem Mittelpaläolithikum Tierfelle zu nutzen wusste. Ob und in welcher Form in Schöningen Feuer verwendet wurde, ist eine der wichtigsten Fragestellungen der neuen Grabung und des laufenden DFG-Projekts. Auch hierzu finden derzeit geoarchäologische Untersuchungen statt.

Sensation Schöninger Speere

Unter den vielen Funden sind ohne Zweifel die acht Schöninger Speere eine Weltsensation. Nicht nur, weil es sich um einzigartige Objekte handelt, sondern wegen der Vielzahl an Erkenntnissen, die sie uns über die Fähigkeiten unseren Vorfahren verraten.

Die Speere sind keine »einfachen« Werkzeuge. Ihre Herstellung benötigte Planungstiefe, Abstraktionsvermögen und Erfahrung. Von den acht publizierten Speeren sind sieben so gut erhalten, dass sich ihre Maße ermitteln ließen. Sie weisen Längen zwischen 1,80 m und 2,50 m sowie ein Gewicht von ca. 500 g auf. Moderne olympische Speere messen bei den Herren zwischen 2,60 m und 2,70 m und wiegen etwa 800 g; Speere der Damen sind 2,20 m bis 2,30 m lang und ca. 600 g schwer.

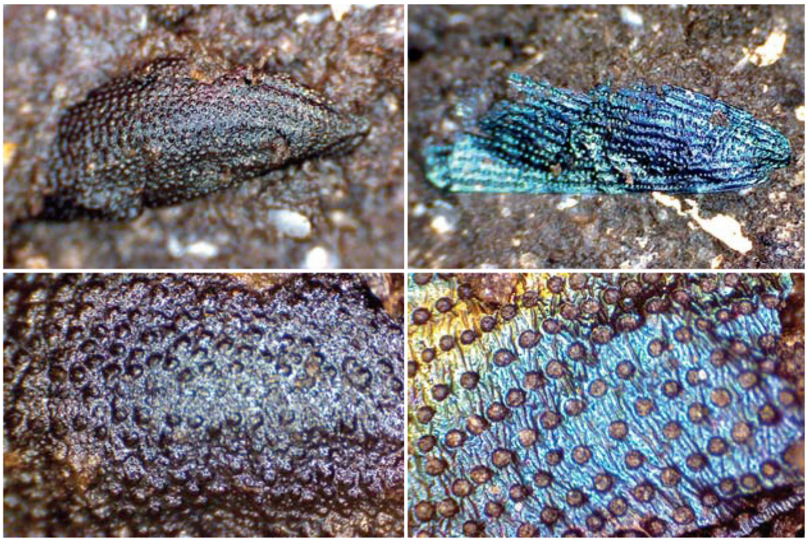
Messerartiges Gerät aus Schöningen.

1 Fichtenzapfen (Picea sp.);
2 Laubmoos (Bryophyt), Blätter und Stamm;
3 Krauses Laichkraut (Potamogeton crispus), Samen;
4 Gänsefuß (Chenopodium sp.), Samen;
5 Gewöhnlicher Wasserhahnenfuß (Ranunculus aquatilis), Samen;
6 Armleuchteralge (Chara sp.), Gametangien.

Der Schwerpunkt der Schöninger Speere liegt auf dem vorderen Drittel. Durch den Vergleich mit heutigen Speeren weiß man: Dies ist optimal, um Durchschlagskraft und Treffsicherheit zu gewährleisten. Somit lassen sich die paläolithischen Speere aus Schöningen in ihren Maßen und Details sehr gut mit unseren Wurfspeeren vergleichen, was bedeutet, dass auch die damaligen Menschen ähnliche motorische Fähigkeiten besaßen wie wir. Experimentelle Versuche anhand eines nachgebildeten Speers haben die Interpretation als Wurfspeere untermauert. Dabei ließ sich ohne großen Kraftaufwand eine Wurfweite von über 65 m erreichen. Weiterhin konnte die Treffsicherheit einer solchen Waffe über eine Distanz von 20 bis 30 m aufgezeigt werden.

Einfache Steinartefakte

Während die Speere fein bearbeitet und als Indiz für komplexes Handeln zu betrachten sind, scheinen die Steinartefakte bislang eher mit geringem Aufwand bzw. mit wenigen Schlägen und für eine sofortige Anwendung hergestellt worden zu sein. Zahlreiche Feuersteinabsplisse zeigen, dass die Steinwerkzeuge intensiv verwendet wurden und dadurch wiederholt und regelmäßig überarbeitet werden mussten. Bei den derzeitigen Grabungen des Niedersächsischen Landesamtes für Denkmalpflege und der Universität Tübingen wurden hervorragende Schaber, gezähnte und gebuchtete Geräte entdeckt, die jedoch scheinbar nicht aus genormten Abschlägen gefertigt wurden. Bei manchen Silices handelt es sich um natürliche



Käferflügeldecken aus Schöningen.

Frostscherben, die anscheinend absichtlich und ohne Veränderung vom Menschen an die Fundplätze gebracht wurden. Alle Steinartefakte bestehen aus lokalem baltischem Feuerstein, der durch Gletscher der Elster-Eiszeit nach Norddeutschland gelangte. Die Levallois-Methode, die typische Abbautechnik des Mittelpaläolithikums, ist bisher nicht belegt. Zudem scheinen auch Faustkeile zu fehlen. Diese markanten Eigenheiten lassen Schöningen aus den bekannten Schemata herausfallen.

Einer der ältesten Auerochsen

Wie bereits erwähnt, wurden in Schöningen mehrere Fundorte entdeckt. Meistens handelt es sich um kleine Plätze, bei denen manchmal nur einzelne Knochen und ebenfalls nur wenige Spuren menschlicher Anwesenheit auszumachen sind. Manchmal findet sich nur ein Abschlag oder ein Knochen mit Schnittspuren.

Ein besonderer Fund ist ein annähernd vollständiger, sieben bis acht Jahre alter männlicher Auerochse. Ein solcher Bulle wäre weder für Mensch noch Tier eine leichte Beute gewesen. Ob der Auerochse vom Menschen bei der Jagd getötet und anschließend zerlegt wurde oder aus anderen Gründen hier verendet ist, muss noch geklärt werden. Ein einfacher Abschlag unweit des Befundes zeigt, dass der Mensch zur selben Zeit in der Umgebung gelebt hat. Auerochsen kamen wahrscheinlich erst ab dem Holstein-Interglazial nach Mitteleuropa. Somit ist dieses Individuum mit seinen zahlreichen, größtenteils sehr gut erhaltenen Knochen als Referenz für die Art »Bos primigenius« zu betrachten.

Befundsituation mit den sehr gut erhaltenen Knochen eines ca. 300 000 Jahre alten Auerochsens (2009).

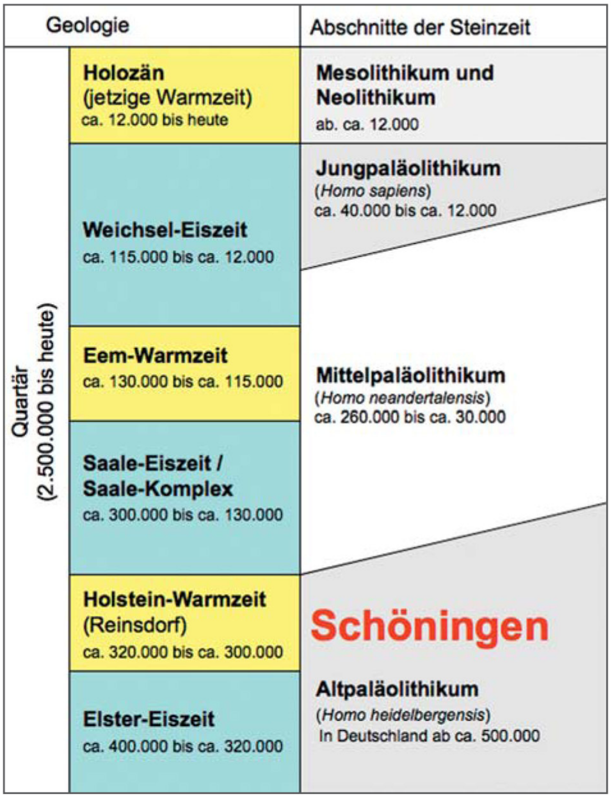
Schädel eines ca. 300 000 Jahre alten Auerochsens (2009).

Unterwasserarchäologie ohne Wasser

Dank des feuchten Milieus sind die Erhaltungsbedingungen hervorragend. Man muss bedenken, dass alle diese Funde bis vor 30 Jahren unter dem Grundwasserspiegel lagen. Erst mit der Eröffnung des Tagebaus wurde der Grundwasserspiegel gesenkt. Somit machen wir Unterwasserarchäologie, ohne Wasser. Unter Luftabschluss blieben Pflanzenreste hervorragend erhalten, ohne dass eine Verkohlung für die Konservierung notwendig gewesen wäre. Zudem sind

Visualisierung des Forschungs- und Erlebniszentrums in der natürlichen Landschaft mit Weiden für Wildpferde.

nicht nur Knochen großer Säugetiere wie Elefanten, Nashörner, Wasserbüffel und Pferde, sondern auch zahlreiche Reste von kleinen und kleinsten Tieren überliefert, etwa von Mäusen, Vögeln, Amphibien und Reptilien. Zugleich sind Wirbel und Schuppen von Fischen, vollständige Muscheln, Schnecken und sogar Käferflügelpanzer erhalten. Dies alles spiegelt ein umfassendes Bild der damaligen Tierwelt wider.



	Geologie	Abschnitte der Steinzeit
Quartär (2.500.000 bis heute)	**Holozän** (jetzige Warmzeit) ca. 12.000 bis heute	**Mesolithikum und Neolithikum** ab. ca. 12.000
	Weichsel-Eiszeit ca. 115.000 bis ca. 12.000	**Jungpaläolithikum** (*Homo sapiens*) ca. 40.000 bis ca. 12.000
	Eem-Warmzeit ca. 130.000 bis ca. 115.000	**Mittelpaläolithikum** (*Homo neandertalensis*) ca. 260.000 bis ca. 30.000
	Saale-Eiszeit / Saale-Komplex ca. 300.000 bis ca. 130.000	
	Holstein-Warmzeit (Reinsdorf) ca. 320.000 bis ca. 300.000	**Schöningen**
	Elster-Eiszeit ca. 400.000 bis ca. 320.000	**Altpaläolithikum** (*Homo heidelbergensis*) In Deutschland ab ca. 500.000

Ähnliches gilt für die Flora, von der nicht nur 300 000 Jahre alte Hölzer, sondern auch Zapfen, Blätter, Pollen und Samen in bester Qualität zeugen. Dadurch kann die lokale und regionale Umwelt zuverlässig rekonstruiert werden. Die lange Stratigrafie mit ihrem Reichtum an Flora und Fauna ist von besonderer Bedeutung für das Holstein-Interglazial.

»Homo heidelbergensis« – uns gar nicht so fern

Der Mensch vor 300 000 Jahren, höchstwahrscheinlich »Homo heidelbergensis«, war uns in vielem sehr ähnlich. Die Schöninger Speere belegen handwerkliche Geschicklichkeit, Planungstiefe und Abstraktionsvermögen. Da die Speere unseren heutigen bis in Details sehr ähnlich sind, muss auch die Geschicklichkeit des »Homo heidelbergensis« beim Herstellen und Anwenden der Waffen mit unserer vergleichbar gewesen sein. Weiterhin wissen wir dank zahlreicher Hinweise, dass »Homo heidelbergensis« schon in der offenen Steppe leben konnte; also war er bereits in der Lage, der Kälte zu trotzen. Schnittspuren an Tierknochen belegen, dass er die Felle der Beute abgezogen hat. Ebenso ist davon auszugehen, dass er als opportunistischer Jäger und Sammler auch die Pflanzen seiner Umwelt zu nutzen wusste.

Den ständig weitergeführten Grabungen in Schöningen, der ausgezeichneten Zusammenarbeit der vielen involvierten Institute und den zahlreichen Analysemethoden verdanken wir sehr detaillierte Einblicke in die Lebenswelt früher Menschen im nördlichen Mitteleuropa. Dank der Schöninger Funde und Befunde ist das Bild auf einmal klarer. Diese Zeit erscheint uns nicht mehr so fremd und fern, wir können uns mit den damaligen Menschen vergleichen und dadurch etwas mehr über uns selbst lernen. Ψ

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Anhang 2

Tolksdorf, J. F., Turner, F., Kaiser, K., Eckmeier, E., Stahlschmidt, M., Housley, R. A., Breest, K., Veil, St. (2013). Multiproxy Analyses of Stratigraphy and Palaeoenvironment of the Late Palaeolithic Grabow Floodplain Site, Northern Germany. Geoarchaeology 28, 1, 50-65.

Research Article

Multiproxy Analyses of Stratigraphy and Palaeoenvironment of the Late Palaeolithic Grabow Floodplain Site, Northern Germany

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Changing river courses and fluctuations of the water table were some of the most fundamental environmental changes that humans faced during the Late Glacial, particularly as these changes affected areas intensively used for settlement and resource exploitation. Unfortunately, only a few stratigraphies have been documented in the North European plain that show the interaction between river development, vegetation history, and occupation by Late Palaeolithic humans. Here, we present the results of detailed stratigraphical studies (pedology, archaeology, chrono-, tephra-, and palynostratigraphy) at the Federmesser site Grabow 15 located in the broad Elbe River valley. The research aimed to produce a model of site formation based on a multiproxy approach, relating the local evidence to the palaeoenvironmental and settlement history of the wider region. After deposition of fluvial sands during the Late Pleniglacial in a braided setting, the river course developed locally toward a meandering system at the transition from the Older Dryas to the Allerød, while periodic flooding led to the deposition of floodplain sediments during the early Allerød. The floodplain was settled by people of the earliest "Federmessergruppen," who are believed to have chosen this open floodplain area along the river for collecting and processing amber of local origin. Their artifacts became embedded in the aggrading floodplain sediments. In the late Allerød, floodplain sedimentation ceased and a Fluvisol-type soil developed, indicating a trend toward geomorphic stability. The Fluvisol was then covered by silty floodplain sediments due to a rising water level during the late Younger Dryas resulting in the cessation of human occupation in the area. Subsequent organic-rich Late Glacial/Holocene sediments preserved the settlement remains to the present.

INTRODUCTION

The main challenge to human cultures during the Late Glacial in northern Europe was the adaptation to rapid and fundamental changes in their environment. Although knowledge about general trends in vegetation and economy has improved in recent decades, still little is known about adaptation to the hydrological changes (relocation of river courses, fluctuations of water table) of this time period. One of the main drawbacks in understanding these processes is the small number of records on the environmental history of central European river valleys during the Late Glacial and their strong disturbance by later processes (e.g., Hiller, Litt, & Eißmann, 1991; Hagedorn, 1995; Starkel, 2003; Kaiser et al., 2012). Consequently, knowledge about the effects of climatic and hydrological changes during this period in fluvial systems is still rather limited and sites with the potential to link these environmental reconstructions to human settlement history are exceptionally rare. The Grabow 15 site therefore provides a rare insight into the relation between vegetation, hydrology, and humans shedding light on the adaptation of Late Glacial hunter-gatherers to a changing environment.

Since 2007, the site of Grabow 15 site has been the focus of interdisciplinary research which aims to investigate archaeological features ascribed to the Federmessergruppen revealing their stratigraphical and palaeoenvironmental context. While the history of the Late Glacial channel system (Turner et al., 2012) and the detailed description and interpretation of the archaeological assemblage will be addressed by forthcoming publications, we here focus on the site stratigraphy and the palaeoenvironmental record. Situated on the bank of an abandoned river channel, the artifacts of the site are embedded in a complex stratigraphy of fluvial origin.

Due to its specific sedimentary and archaeological setting, the Grabow 15 site therefore offers the rare opportunity to study local fluvial and environmental dynamics by a multiproxy analysis while relating these results to vegetation history and human environment. To link the sedimentological units and to build a chronological framework, palynological analysis, ^{14}C-dating, and tephrostratigraphy were performed. High-resolution pedological analysis included micromorphology and the analysis of a fire-derived chemical marker (Black Carbon [BC]). By combining these results and linking them to the results of the archaeological record, we attempt (i) to reconstruct the environmental setting in which the human occupation took place, (ii) to investigate whether traces of local human impact on the environment are visible, and (iii) to analyze whether post-depositional processes might have affected the integrity of the archaeological record.

GEOGRAPHICAL SETTING

The Grabow 15 site (53°00′N/11°07′E, c. 13.5 m a.s.l.) is located on the Jeetzel River, which is a small tributary flowing through the broad Elbe River valley (Wendland area; Figures 1A, 1B, 2A). Situated at the western edge of the glacial Elbe spillway, fluvial dynamics have been the main agent in the Jeetzel River plain below 20 m a.s.l. in the past until regional drainage and river canalization in the 20th century limited fluvial influence. Late Glacial fluvial sands and low dunes are prevalent in the low-lying areas of the Jeetzel valley while moraines of Saalian age are present as partly isolated hills around the site (Figure 1B). Detailed geomorphological mapping revealed several generations of palaeochannels of Late Glacial and Holocene age in the immediate vicinity of the site (Figure 1C). Today the area is used for intensive crop farming and most palaeochannels have been leveled. During the last two decades, intensive archaeological research in this area has revealed a multitude of sites dating to the Late Palaeolithic period that yielded, among others, exceptional artistic amber artifacts (Veil & Breest, 1995, 2000; Street et al., 2001; Veil & Breest, 2006; Veil et al., 2012). Generally, the high density of Late Palaeolithic floodplain sites in that area is an exceptional feature for northern Germany. Two intensively investigated sites, Weitsche and Grabow 15, are of special interest as they not only provide the first evidence of amber processing and the stylistic development of art between the preceding Magdalenian and the subsequent Mesolithic (Veil & Breest, 2006; Veil & Terberger, 2009; Veil et al., 2012), but they also belong to the earliest phase of the hunter-gatherer groups of the Allerød known as the "Federmessergruppen" in archaeological terms (Schwabedissen, 1954; Riede & Edinborough, 2012).

METHODS

Fieldwork was conducted between 2007 and 2009. During a first survey, the distribution and thickness of sedimentological units was recorded and the microtopography was mapped using a differential GPS. Based on these results, four profiles, representative of the site and lying in the abandoned river channel and in the excavated area, were selected for sampling (Figures 1D, 2A). Sediments from the channel fill were retrieved using the "palaeochannel core" (profile PC) for palynological and sedimentological analyses. The adjacent floodplain sediments were sampled in a trench "reference profile" (RP pedological sequence) for pedological analyses including grain-size distribution, organic content, micromorphology, tephrostratigraphy, and the measurement of "BC" as a proxy for the occurrence of fire. A series of samples was taken from two separate profiles in the excavation area and combined into a composite profile for palynological analysis (Excavation Profile [EP] pollen sequence). During excavation, the exact vertical and horizontal position of all flint or amber artifacts, charcoal and bone/antler fragments down to a size of at least 10 mm were recorded *in situ*. These data were used to illustrate the vertical scattering of the artifacts within the sediment units.

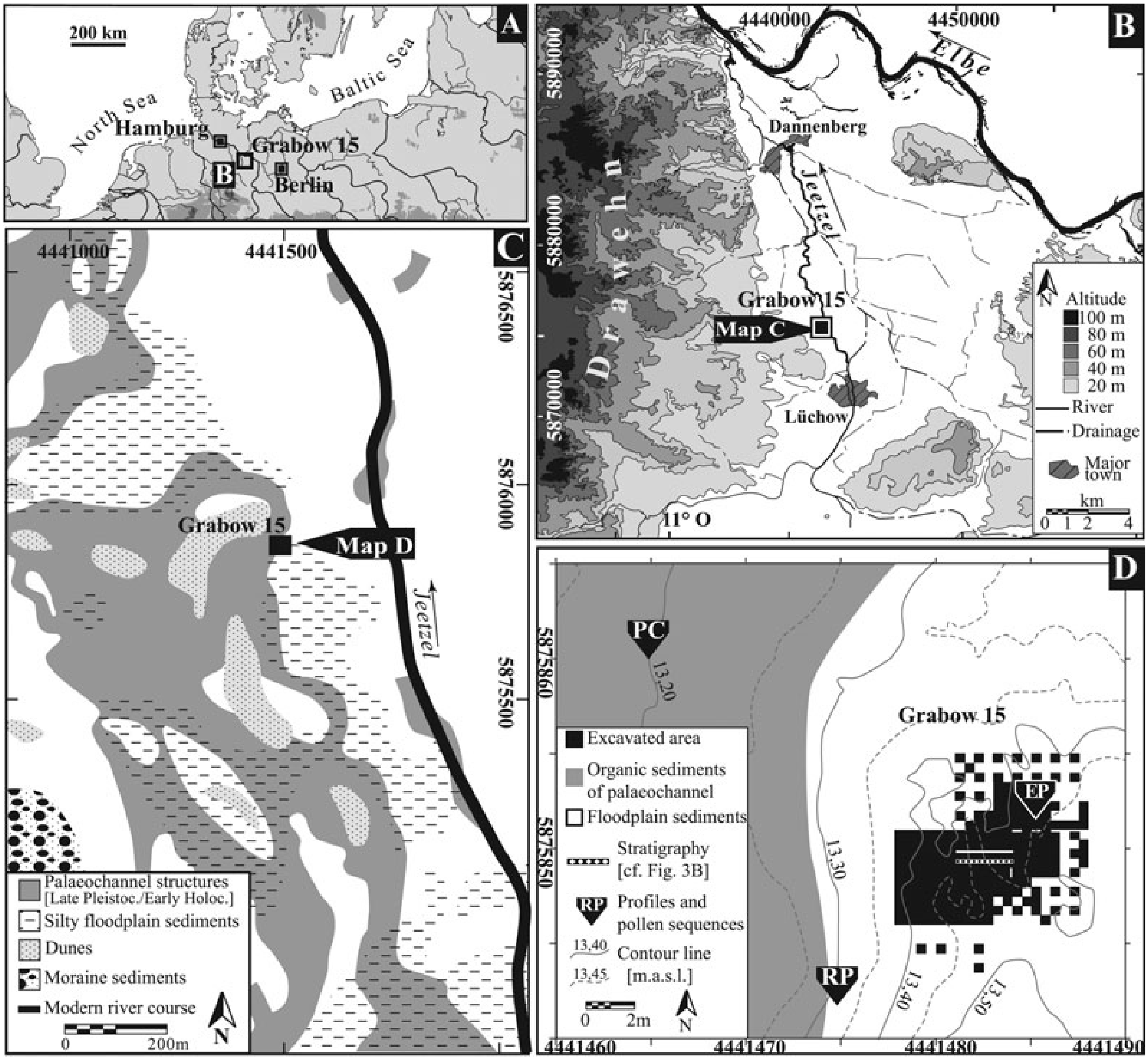

Figure 1 (A) Location of the Grabow 15 site within the northern European plain; (B) location of the Grabow 15 site and topographic situation of the Elbe River valley; (C) distribution of palaeochannel structures and floodplain sediments in the vicinity of the Grabow 15 site; (D) plan of the excavation area showing the position of the analyzed sequences.

Samples for palynological analyses were taken each 3–5 cm within PC pollen sequence and each 1–2 cm within the EP pollen sequence. Adding *Lycopodium* as a marker of pollen density (Stockmarr, 1971), the pollen samples were prepared by acetolysis according to standard procedures (Berglund & Ralska-Jasiewiczowa, 1986). Pollen identification and nomenclature followed Beug (2004). Samples were counted up to at least 500 pollen grains of terrestrial plants. Percentages were calculated with reference to a terrestrial pollen sum, while *Alnus*, Poaceae, Cyperaceae, and other taxa of wet habitats were excluded (following de Klerk, 2002). The diagrams were grouped into site pollen zones (SPZ) based on common trends in arboreal (AP)/nonarboreal pollen (NAP)-ratio and percentages of taxa that are assumed to be synchronous. Biostratigraphical phases were defined according to existing high-resolution pollen sequences for northern Germany (Usinger, 1985; Merkt & Müller, 1999; de Klerk, 2002, 2008).

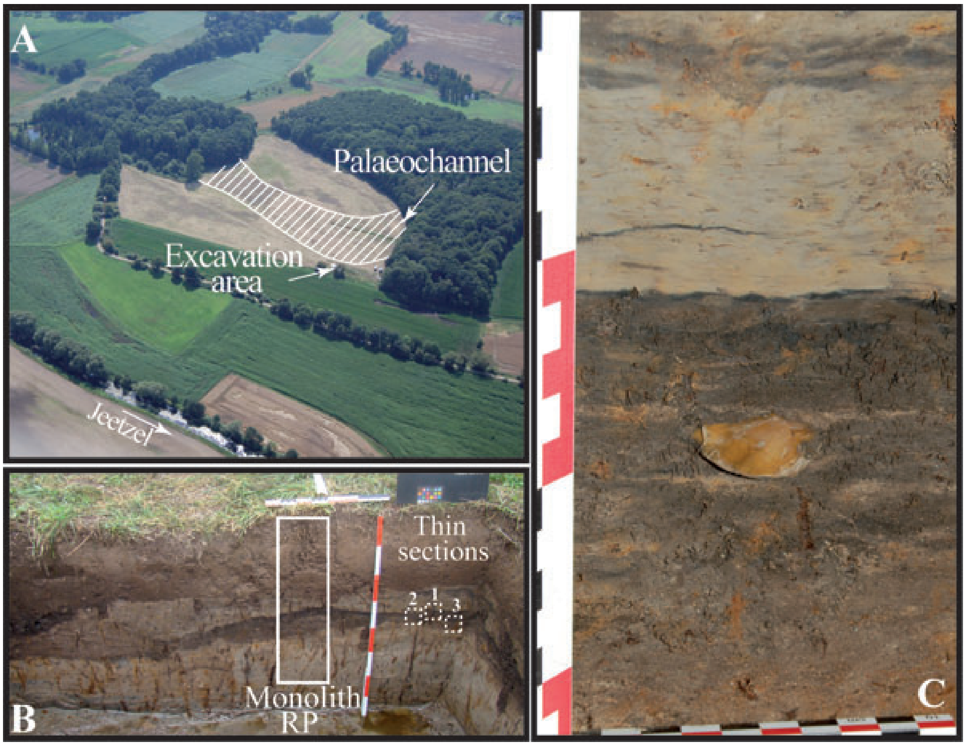

Figure 2 (A) Aerial view of the Grabow 15 site (view to southwest); (B) profile RP (pedological sequence) with micromorphological samples (thin sections) and soil monolith; (C) position of an *in situ* artifact in a profile of the excavation area.

Sedimentological and pedological analyses were performed in the RP sequence. The profiles were described according to both a German soil science standard (AG Boden, 2005) and an international pedological standard (FAO, 2006). Designations of soil horizons and soil types are given using both the German standard (AG Boden, 2005) and the "World Reference Base for Soil Resources" (IUSS-ISRIC-FAO, 2006). Soil color in the RP pedological sequence was determined using the "Munsell Soil Color Charts" under moist conditions. From the RP pedological sequence, a soil monolith was extracted using a steel box, which was later sampled in the laboratory (Figure 2B). Grain-size distribution was determined in the RP pedological sequence in 1 cm increments by laser diffraction (Fritsch Analysette 22). The content of organic matter was estimated both by the analysis of loss on ignition at 550°C (Heiri, Lotter, & Lemcke, 2001). Carbonate content was tested by reaction with HCl acid but was shown to be absent in all samples from the RP pedological and EP palynological sequences. Total element composition (main and trace elements) was determined by X-ray-fluorescence (XRF) analysis. After crushing to silt-size with a pebble mill and ignition of the ground samples at 975°C, the samples were measured using a MagixPro analyzer (Panalytical). The content of "BC" in the RP pedological sequence was determined as benzene polycarboxylic acids (BPCAs) according to the method described by Brodowksi et al. (2005). BC comprises a range of chemical compounds that derive from incomplete combustion of organic material. As they are relatively resistant to decomposition over long periods of time they provide a proxy for biomass burning within sediments. The samples (two replicates) were first treated with trifluoroacetic acid to remove polyvalent cations and then digested with HNO_3 at 170°C for 8 hours. The sum of BPCAs in each sample was analyzed after derivatization in a gas chromatograph equipped with a flame ionization detector. We used a conversion factor of 2.27 to estimate BC contents from BPCA-C contents. This factor provides a conservative minimum estimate of the true BC contents in soils (Glaser et al., 1998; Brodowksi et al., 2005).

For micromorphological analysis, three oriented and intact block samples from the RP pedological sequence (Figure 2B) were collected, encompassing three sediment units and their contacts, which were then processed into thin sections (by T. Beckmann, Braunschweig-Schwülper). Analysis was conducted with a petrographic microscope using plane- and cross-polarized light at different magnifications to identify the organic and minerogenic components of the deposits as well as their related

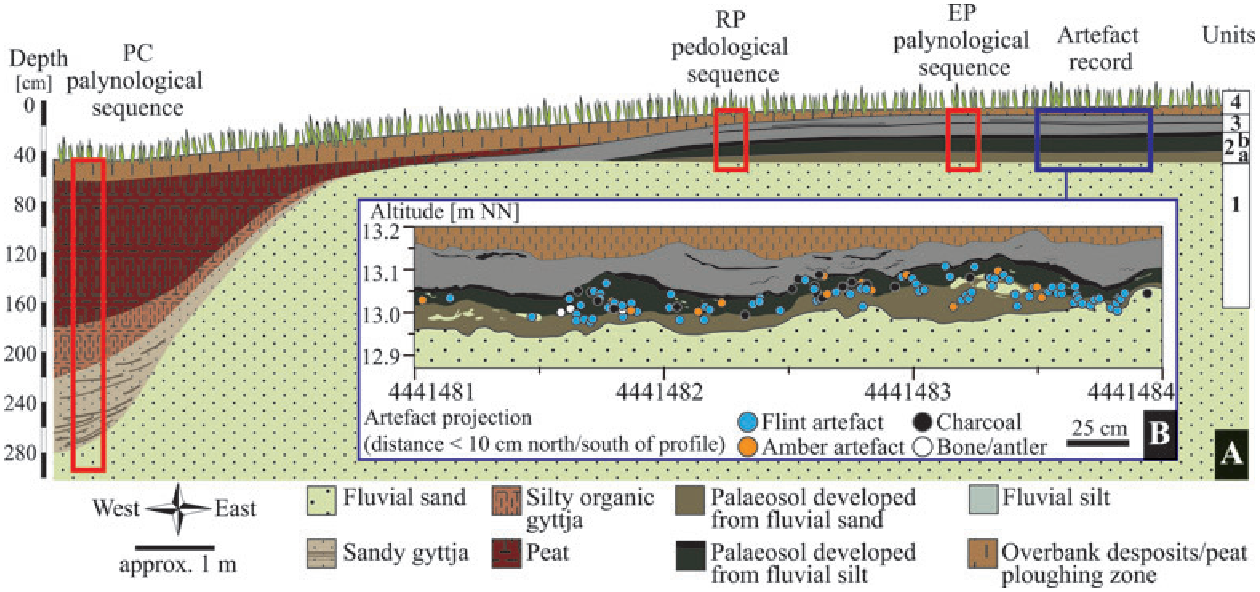

Figure 3 (A) Diagrammatic representation of the analyzed sequences. (B) West-east running trench recorded in the excavation area (see Figure 1D for location) with artifact projections showing the vertical distribution of the artifacts.

appearance to infer formation processes. The micromorphological description follows Stoops (2003) and Stoops, Marcelino, and Mees (2010). Samples were taken from the RP pedological sequence and the EP pollen sequence and processed according to Blockley et al. (2005) to ascertain if tephra particles were present. The main objective of this analysis was to test whether specific supra-regionally occurring tephra horizons, such as the Laacher See tephra (LST) from the late Allerød age or the Vedde ash from the Younger Dryas are present within the sediments to provide another independent chronological marker (Davies et al., 2012). Radiocarbon dating of organic material from the PC sequence and macroscopic charcoal from the excavation area was conducted by the Leibniz-Laboratory for Radiometric Dating and Isotope Research in Kiel. The ages were calibrated using Calib 6.0 (Stuiver & Reimer, 1993) and the IntCal09-database (Reimer et al., 2009).

RESULTS

Archaeo-, Litho-, and Pedostratigraphy of the RP Pedological Sequence

The excavation area is characterized by a sequence of relatively coarse-grained fluvial sands (sediment unit 1) that are overlain by fluvial fine sands and silts (units 2a, 2b, 3), with sharp transitions between the layers (Figure 3A). It was observed that the uppermost part of the sequence (unit 4) had been disturbed by ploughing. The documentation of the artifacts in the excavation area showed that their vertical distribution is limited to units 2a and 2b (Figure 3B). Thus, the period of human occupation of the site and the phase of fine-grained overbank sedimentation would seem to be contemporaneous (Figure 2). Concentrations of charcoal, cremated bones, and heated flint, indicating a hearth structure, were observed on the transition from units 1 to 2 and suggest that this was a main horizon of human occupation. Profile RP is subdivided into four main sediment units analogous to the excavation area (Figure 4). Units 1a and 1b at the base consist mainly of relatively coarse-grained fluvial sands. Only a few microscopic scatters of organic matter were observed and few channels are present toward its upper limit. At a depth of 46 cm below ground surface, the percentage of silt and the organic content distinctly increased, marking the transition to unit 2, which generally is attributed to low-energy fluvial processes and soil formation. Unit 2 can be subdivided into subunit 2a, representing the lower part of a palaeosol developed from fluvial sand (overbank deposit) with lower organic content, and subunit 2b, which represents the upper part of this palaeosol with higher organic content (soil type according to IUSS-ISRIC-FAO, 2006: "Gleyic Fluvisol"; according to AG Boden, 2005: "Gley-Paternia"). Examination of thin sections revealed *in situ* bioturbation-like channels, chambers, the presence of excrements and roots. These features are more apparent in subunit 2b and represent firm evidence of pedogenesis (Retallack, 1981). The presence of water lain laminae and the horizontal layering

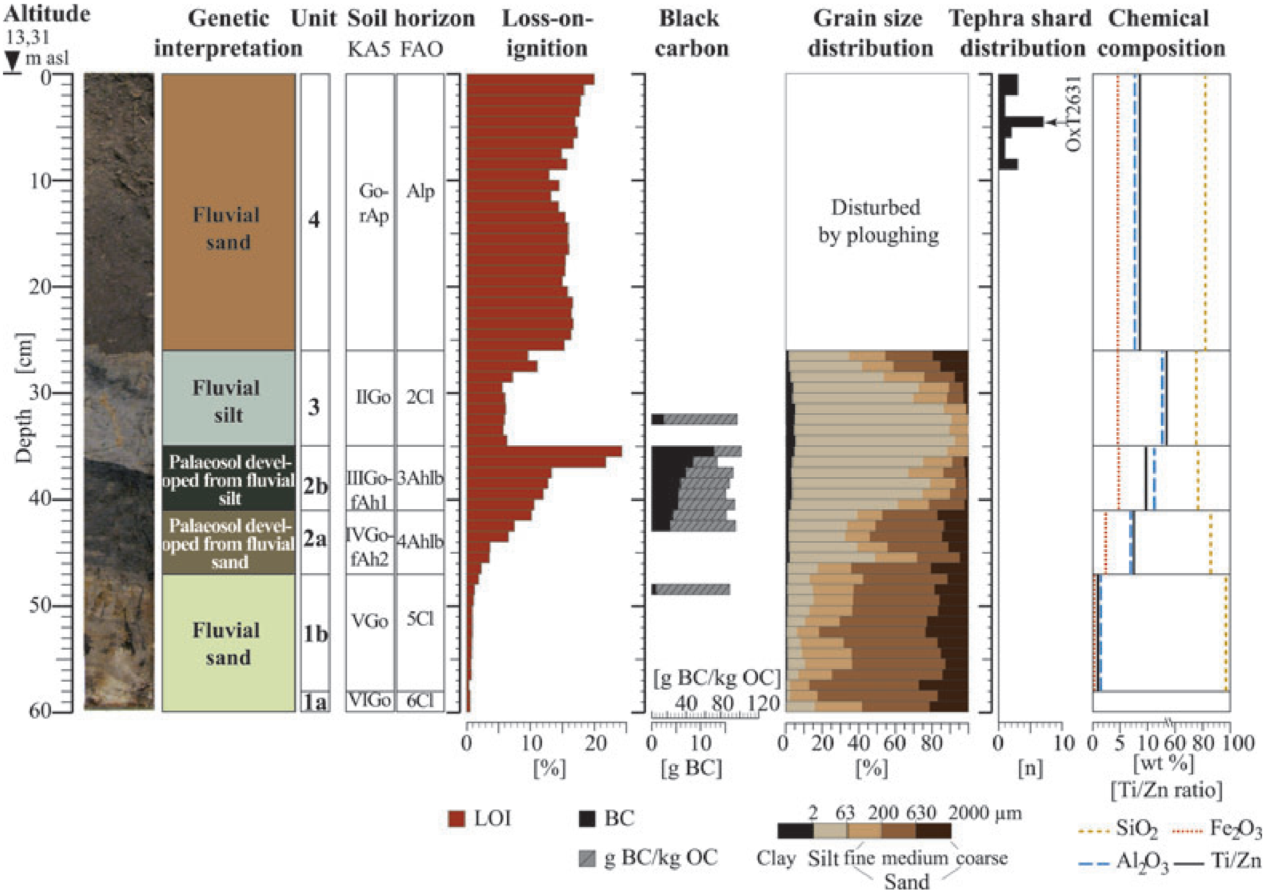

Figure 4 Stratigraphy of the RP pedological sequence with pedological data used to delimit the pedological horizonation/sedimentary units (see Figure 1D for location).The content of "Black Carbon" BC was recorded as a marker of fire intensity.

of organic residues (Figure 5A) confirm sedimentation under low-energy conditions (FitzPatrick, 1984; Stoops, 2003), while the occurrence of the palaeosol generally indicates surface stabilization.

The organic content is very high (OC = 8–14%) in the upper two centimeters of the palaeosol (subunit 2b), and therefore only this small portion of the palaeosol could be described as "strongly humic" (in German: "anmoorig"). Although the ratio of BC to OC remains constant within unit 2, the absolute concentration of BC rises significantly toward the palaeosurface. Two interpretations may be proposed. On the one hand, there may have been a distinct rise in fire frequency or a change in fire intensity. On the other hand, assuming a constant input of charred particles, unit 2b represents accumulation over a longer time period than unit 2a. However, as the artifacts are distributed within the lower part of subunit 2b as well as in the upper part of the subunit 2a (Figure 3), no synchronous rise of BC with the local human occupation of the site is apparent. Moreover, the upwardly decreasing amount of microscopic charcoal, visible in the pollen diagram (Figure 7) in subunit 2b, as proxy of local and sub-regional burning, support the idea that the increasing amounts of BC and the human occupation are not necessarily connected. The micromorphological analyses show that the very top of unit 2b is not so much the result of *in situ* growing plants and their decay products (humus), but of fluvial sedimentation of relocated humified material derived from the wider catchment. Based on this we would argue that the BC signal does not only reflect on-site burning but also a continuous fire regime in the extended environment.

The palaeosol is covered by unit 3, which can be interpreted as silty overbank sediment deposited under standing water conditions during periodic flood ing. The grano- and cross-striated b-fabric of the slightly clayish silty groundmass (Figure 5B) provides firm evidence of successive wetting and drying cycles (Brewer, 1976). The uppermost unit 4 results from modern drainage and ploughing that has mixed Late Glacial/Holocene

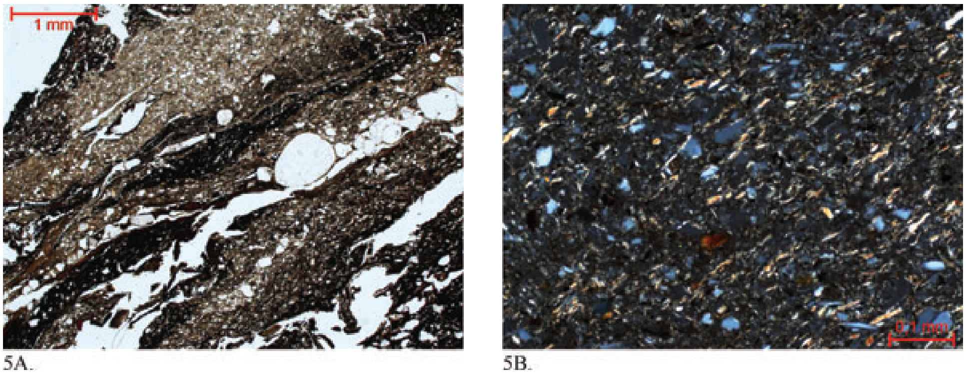

Figure 5 (A) The top of unit 2b (palaeosol) with organic rich brown to black layers, silty yellowish-gray laminae and several lines of quartz grain in-wash. Plane-polarized light (PPL), scale at top left 1 mm. (B) Dense microstructure of unit 3 (fluvial silt). Note the orientation pattern of mica minerals and clay representing a cross-striated b-fabric. Cross-polarized light, scale at bottom right 0.1 mm.

sandy-loamy overbank deposits and—probably—Holocene decomposed peat.

The XRF analyses corroborate by means of clearly different elemental concentrations (particularly reflected by the Ti/Zr-ratio) the designation of certain sediment layers/units (Figure 4; Table I). The values result from different mineralogical properties depending on different particle sizes during the changing sedimentation process. They do not result from a change in the source area caused by changes in the catchment. The high SiO_2 content of the lowermost unit (97%) indicates that it consists mainly of quartz grains with no pedogenic signal. Throughout sediment units 2a–3, the percentage representation of Fe_2O_3 and Al_2O_3 increases up the profile, which might be a result of weathering processes that affected these horizons. The increase of Pb in unit 1 may indicate a certain imprint of industrial emissions and provides further evidence for the recent age of these sediments.

Palynostratigraphy

The sediments at the base of the profile PC below 290 cm are fine- to medium-grained sands of fluvial origin. These were not suitable for the preservation of pollen or other organic matter (Figure 6). These inorganic fluvial deposits are overlain by sands with intercalating organic layers up to 230 cm. Based on the remains of algae and aquatic macrophytes, these partly organic sediments derive from lacustrine sedimentation following the abandonment of the river channel. Pollen analyses reveal high percentages of NAP, especially pollen of light-demanding taxa such as *Juniperus*, *Helianthemum*, *Artemisia*, *Cerastium*-type, and *Selaginella* (Figure 6, SPZ C). Due to the occurrence of these light-demanding taxa and the high proportion of *Empetrum*, SPZ C can be correlated with records of the second part of the Younger Dryas in NW Europe (e.g., Hoek, 1997; Merkt & Müller, 1999; de Klerk, 2008; Theuerkauf & Joosten, 2012) thereby covering the latest part of this period, which lasted from approximately 12,300 to 11,600 cal. BP.

The onset of SPZ D is marked palynologically by the rise of *Betula* and *Filipendula* and lithologically by an increase in both OC and $CaCO_3$ content. While the NAP-sum remains comparably high in the lower part of SPZ D, it decreases gradually in the upper part of the zone where *Betula* reaches high values accompanied by low amounts of light-demanding taxa. SPZ D is assigned to the Pre-Boreal (c. 11,600–10,700 cal. BP). SPZ E, assigned to the Boreal period (c. 10,700–9600 cal. BP), is characterized by the dominance of *Pinus*, the presence of *Corylus* to about 5% and increasing values of *Alnus* and other taxa of a "mixed deciduous forest" (*Ulmus*, *Quercus*, *Tilia*, and *Hedera*). Meanwhile, light-demanding taxa such as *Helianthemum*, *Empetrum*, and *Selaginella* have disappeared from the pollen assemblages. As the lower boundary of SPZ E is marked by a break in pollen trends and the onset of peat growth, we infer a hiatus in pollen sedimentation between SPZ D and E. While the trend of decreasing *Pinus* and increasing *Ulmus*, *Quercus*, *Tilia*, and *Fraxinus* prevails during the younger sediments, the appearance of *Fagus* in SPZ F supports an attribution to the late Atlantic (c. 7000–5900 cal. BP). The decline of *Ulmus* at the onset of SPZ G is characteristic of the Sub-Boreal period (c. 5700–2900 cal. BP).

As the fluvial sands at the base of the EP pollen sequence yielded nearly no pollen, this record starts with SPZ A in the lower parts of the sandy-silty alluvial sediments of unit 2a (Figure 7). NAP-pollen values prevail here, especially *Artemisia*, *Helianthemum*, Rosaceae, and *Thalictrum*, but a high percentage of Poaceae, Cyperaceae,

Table I Results of the pedological and XRF analyses. Designation of soil horizons and texture classification are given according to both AG Boden (2005) and FAO (2006).

Depth [cm]			0–26	26–36	36–41	41–47	47–58	58–78	78–180
Horizon [KA5]			Go-rAp	II Go	III Go-fAh1	IV Go-fAh2	V Go	VI Go	Gr
Horizon [FAO]			Alp	2Cl	3Ahlb	4Ahlb	5Cl	6Cl	6Cr
Sedimentary unit			4	3	2b	2a	1b	1a	1a
Excavation layer			GS1	GS2	GS3	GS3	GS4	GS4	GS4
Genetic interpretation			Fluvial sand	Fluvial silt (overbank deposit)	Palaeosol developed (overbank deposit)	Palaeosol developed from fluvial silt (overbank deposit)	Fluvial sand from fluvial sand (overbank deposit)	Fluvial sand	Fluvial sand
Color		[Munsell]	7.5YR2.5/1 (black)	2.5Y4/2 (dark grayish brown)	10YR2/1 (black)	10YR4/1 (dark gray)	2.5Y5/3 (light olive brown)	2.5Y6/3 (light yellowish brown)	5Y4/2 (olive gray)
Granulometry	Clay	[%]	1.7–2.0	2.8–5.3	3.0–3.5	1.6–2.3	0.6–1.0	0.5	–
	Silt	[%]	32.9–39.7	50.9–87.2	58.3–75.4	30.9–46.6	5.7–16.4	1.9	–
	Fine sand	[%]	17.2–19.9	7.5–22.2	14.0–17.0	13.5–23.0	11.9–18.4	14.9	–
	Medium sand	[%]	25.6–26.0	0.0–16.7	12.0–19.5	23.5–39.6	43.5–58.3	65.7	–
	Coarse sand	[%]	15.4–19.6	0.0–7.6	1.1–2.2	4.7–14.4	20.7–23.5	17	–
	Texture class	[KA5]	Su3-Su4	Us-Uu	Us	Su3-Su4	Ss-Su2	Ss	Ss
	Texture class	[FAO]	Sandy loam	Silt loam-silt	Silt loam	Sandy loam	Sand-loamy sand	Sand	Sand
Main elements	SiO_2	[%]	82.8	75.9	77.6	86.4	97	–	–
	Al_2O_3	[%]	7.7	12.9	11.2	7	1.6	–	–
	Fe_2O_3	[%]	4.8	4.8	4.9	2.4	0.2	–	–
	MnO	[%]	0.1	0.0	0.0	0.0	0	–	–
	MgO	[%]	0.5	1.1	0.7	0.5	0.1	–	–
	CaO	[%]	1.1	1.0	1.7	0.7	0.1	–	–
	Na_2O	[%]	0.7	0.9	0.9	0.7	0.3	–	–
	K_2O	[%]	1.6	2.4	2.0	1.7	0.7	–	–
	TiO_2	[%]	0.6	0.9	0.7	0.6	0.1	–	–
	P_2O_5	[%]	0.3	0.1	0.2	0.1	0.0	–	–
	SO_3	[%]	0.0	0.0	0.1	0.0	0.0	–	–
Trace elements (selection)	Pb	[ppm]	45	18	18	10	6	–	–
	Sr	[ppm]	71	100	108	74	26	–	–
	Zr	[ppm]	315	337	313	404	314	–	–
Ti/Zr-ratio [molar]		8.6	13.7	9.8	7.6	1.0	–	–	

and *Selaginella selaginoides* is also noteworthy. The transition to the subsequent SPZ B is marked by decreasing terrestrial NAP-values, notably declines in Poaceae, Cyperaceae, and *Selaginella*. The uppermost samples of this zone show a dominance of *Pinus*-pollen.

The transition to SPZ C coincides with the lower boundary of the silty overbank sediments of unit 3 (Figure 7) and is marked by a sharp increase of NAP-values, especially *Artemisia*, *Empetrum*, *Cerastium*-type, Poaceae, and Cyperaceae. The high amounts of *Pediastrum* algae at the end of SPZ C indicate the (temporary) existence of still water conditions and may derive from a phase of higher water levels during that time.

Both the break in pollen trends and the sedimentological change make a hiatus between SPZ B and C very likely. As the pollen values of SPZ C in the PC pollen sequence and SPZ C in the EP pollen sequence are very similar, we have correlated both pollen zones with one chronological phase. Based on the palynology, SPZ C represents the second part of the Younger Dryas and SPZ B can be identified as an Allerød (c. 13,800–12,700 cal. BP) pollen spectrum. SPZ A may be equivalent to the Older

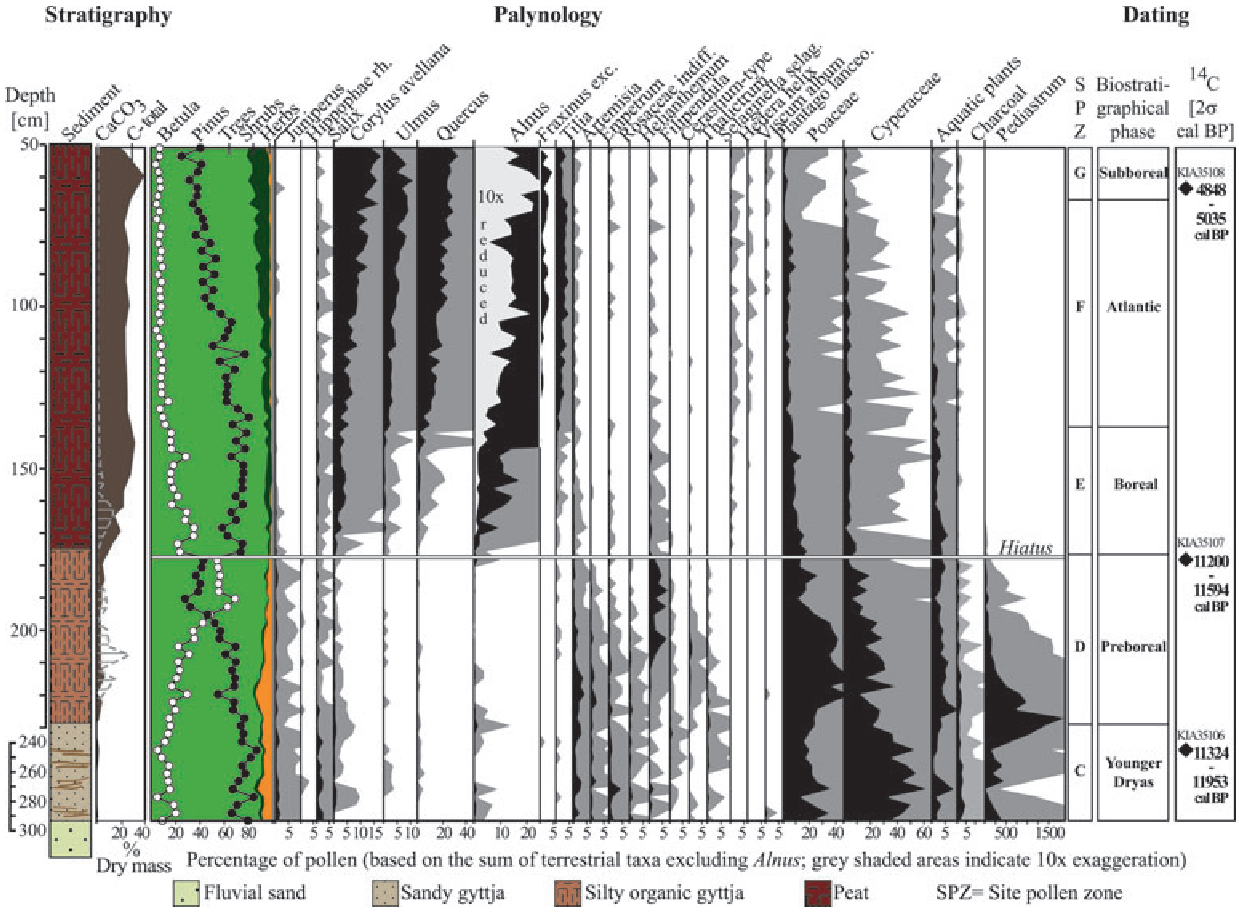

Figure 6 Pollen diagram from the PC palynological sequence taken from the palaeochannel (see Figure 1D for location).

Dryas according to Hoek (1997) (c. 14,000–13,800 cal. BP).

Archaeo-, Chrono-, and Tephrostratigraphy of the RP Pedological Sequence and of the Excavation Area

The entire artifact assemblage can be attributed to an early stage of the Federmesser techno complex (FMG) by means of typology and the technology of blade production. Based on ^{14}C-data from other sites, the FMG in the European plain is traditionally assigned to the Allerød (e.g., Bokelmann, Heinrich, & Menke, 1983; Terberger et al., 2004; Riede & Edinborough, 2012). The occurrence of some technological features which are more typical of the Magdalenian (e.g., fine long borers, use of burin spalls as blanks for borers) may indicate that this assemblage can be placed at the very beginning of the known FMG tradition or even before. An early Allerød age (sensu Hoek, 1997) of the site is confirmed by two ^{14}C dates (Table II) of material from archaeological features from the lowermost part of subunit 2b. These yielded ages of 14,137–13,815 yr cal. BP and 14,185–13,703 yr cal. BP. The stratigraphic position of the artifacts within the lower part of unit 2 therefore provides evidence to date the start of sandy-silty overbank sedimentation to the end of the Older Dryas or to the beginning of the Allerød. This is in good accordance with the palynological analysis from this stratigraphical unit.

Wood from the base of the palaeochannel infill in the PC palynological sequence yielded a ^{14}C-age of 11,953–11,342 yr cal. BP (Table II) and confirmed the palynological interpretation of the lowermost sediments (SPZ C) as Younger Dryas. The beginning of sedimentation during the Younger Dryas means that fluvial transport energy must have declined in this period. Further ^{14}C-ages from the PC palynological sequence confirm that the SPZ D sediments date to the Pre-Boreal (11,594–11,200 yr cal. BP) and that SPZ G can be ascribed to the Sub-Boreal (5035–4848 yr cal. BP).

Tephra shards were only detected in low concentration (1–7 shards/g dry weight) in the uppermost samples of

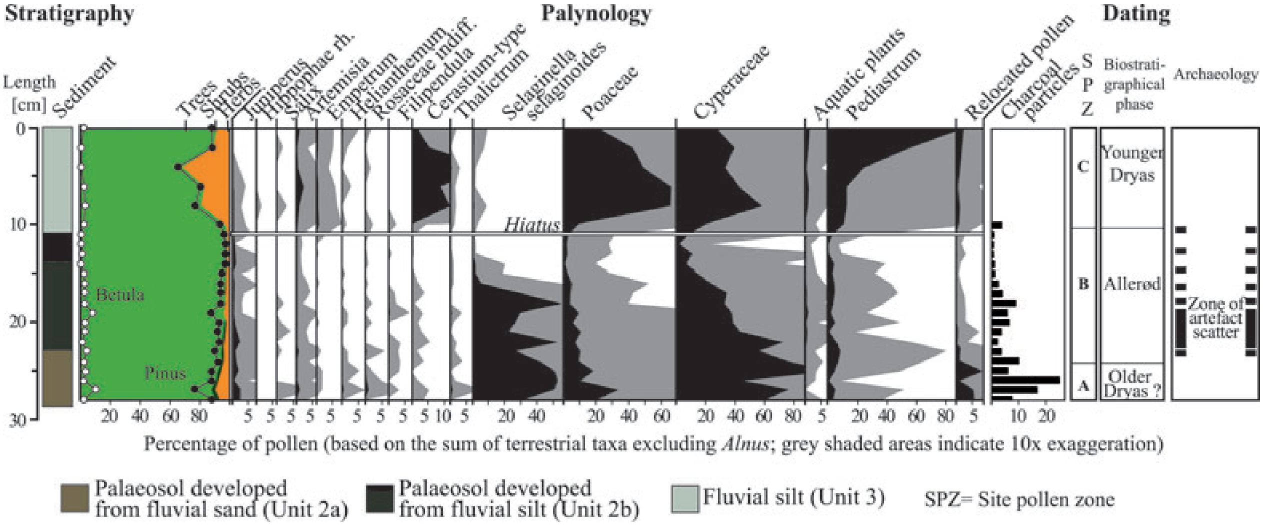

Figure 7 Composite pollen diagram from the EP palynological sequence taken from the excavation area (see Figure 1D for location).

RP, spread over a vertical distribution of 9 cm (OxT2631) probably as a result of historic ploughing. Based on their chemical properties, they either derive from the A.D. 1875 eruption of Askja (Oldfield et al., 1997; Haflidason, Eiriksson, & Kreveld, 2000) or from the 2210–1966 yr cal. BP Garry tephra (Barber, Langdon, & Blundell, 2008).

DISCUSSION

Site Development

The results allow us to establish a model of local landscape development beginning in the Late Glacial (Figure 8). After deposition of fluvial sands in the Late Pleniglacial, a deeper river channel incised into the floodplain, probably during the Bølling or Older Dryas (prior to 13,800 cal. BP). Episodic sedimentation in the floodplain during flood events started around the onset of the Allerød. In this period, the river bank was inhabited by people with cultural affinities to the early Federmesser-gruppen whose artifacts became embedded in aggrading fine-grained fluvial sediments (^{14}C-ages cover the time span from 14,200 to 13,700 cal. BP). Because amber may still be found today on erosional banks of the River Jeetzel and such pieces are present in different stages of processing within the archaeological record, it seems very likely that collecting and processing of amber from the sediments was an important local activity during human occupation. This may explain the decision to settle in this open and rather unsheltered area. During the Allerød, in general, fluvial sedimentation shifted toward a finer particle size indicating decreased transportation energy

Table II Radiocarbon ages from the PC palynological sequence and from the archaeological record (excavation area). Calibration was performed using Calib 6.0.1 software (Stuiver & Reimer, 1993) with the IntCal 09 database (Reimer et al., 2009).

Lab. No.	Profile/Context	Material	Depth [cm]	^{14}C age [years BP]	^{14}C cal. Age [years cal. BP (2σ)] [IntCal09]	δ^{13}C [‰]
KIA-35106	PC palynological sequence	Wood	246	10,065 ± 45	11,953–11,928; 11,824–11,383; 11,379–11,342	− 28.3
KIA-35107	PC palynological sequence	Organic material [indet.]	178	9885 ± 50	11,594–11,562; 11,467–11,456; 11,405–11,200	− 27.7
KIA-35108	PC palynological sequence	Wood	65	4355 ± 35	5035–5011; 4978–4848	− 26.5
KIA-41862	Archaeological feature	Charcoal (*Betula*)		12,125 ± 50	14,137–13,815	− 27.7
KIA-41861	Archaeological feature	Bone fragments (calcined; one fragment unburnt)		12,070 ± 100	14,185–13,703	− 23.8

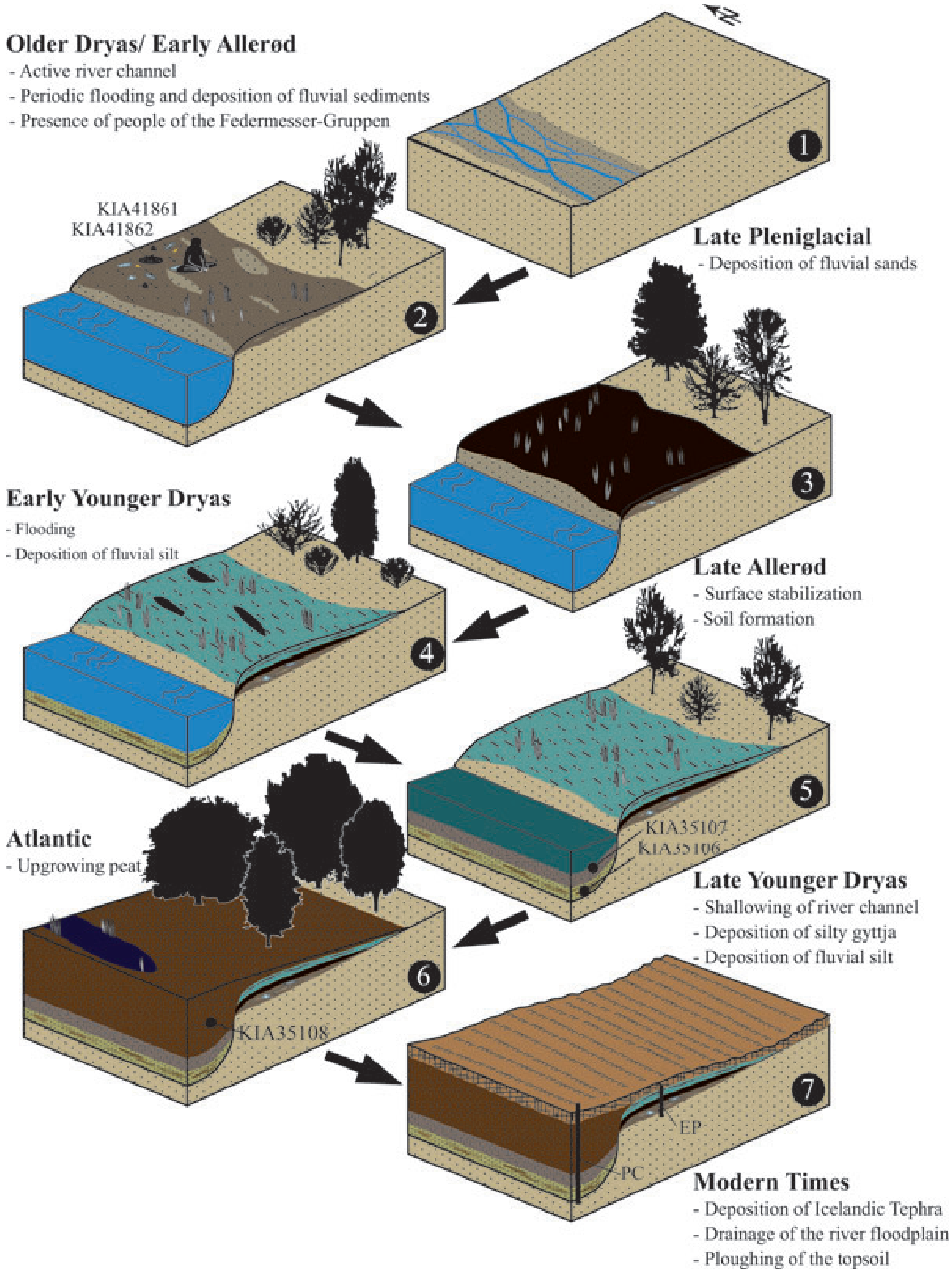

Figure 8 Model of Late Quaternary site formation at Grabow 15 illustrated by seven time slices.

at the site. Fluvial sedimentation diminished in the late Allerød, initiating the formation of a (semi-) terrestrial soil (palaeosol of Fluvisol-type).

Floods in the Younger Dryas caused the deposition of silty overbank sediments, thereby protecting and preserving the Late Palaeolithic features to the modern day.

The Holocene record in the abandoned river channel is characterized by the aggradation of organic sediments (gyttja and peat). Subsequently, mire development spread into the surrounding areas due to rising water levels during the mid-Holocene. The Younger Dryas-Pre-Boreal boundary (c. 11,600 cal. BP) is marked by both a general rise in pollen concentration and in percentages of *Filipendula* pollen (cf. Usinger, 2004). A peak of NAP in the pollen record, most notably of *Artemisia*, *Empetrum*, and *Thalictrum*, indicates a short delay in forest development during the early Pre-Boreal. Later in the Pre-Boreal, a birch-pine-forest developed replaced by a pine-birch forest in the late Boreal. It is characterized by a paucity of hazel, which is typical on nutrient-poor sites located on Saalian till sediment and soils of the so-called lower terrace (Late Glacial fluvial sands) in the wider region (e.g., Speier, 1994). The pollen record shows a typical Holocene vegetation sequence for northern Germany, with the spread of more thermophilic deciduous trees, and a remarkable early expansion of alder forests in fens around the Grabow 15 site. Many archaeological sites of Mesolithic (c. 11,600–6000 cal. BP) and early Neolithic age (c. 6000–5000 cal. BP) along the Holocene channel system of the Jeetzel River attest to the attraction of the area for hunting and farming groups during the early and mid-Holocene. Draining and ploughing during modern times caused an admixture of the uppermost sediments that received late Holocene tephra shards.

Regional Palaeoenvironmental Implications

Comparably well-investigated Late Glacial stratigraphies in floodplains and basins are rare in central and western Europe (e.g., Niers-Rhine/NW Germany: Kasse et al., 2005; Barthe river and Endinger Bruch basin/NE Germany: Kaiser, 2004a; Wierzyca and Wda rivers/NW Poland: Błaszkiewicz, 2010; Paris basin/France: Pastre et al., 2003; Selle river/France: Antoine et al., 2003). Some of these records suffer from a lack of preservation, low chronological resolution or limited analytical approach. Thus, by avoiding such constraints, our results significantly improve our understanding of this period.

Although only a few pollen sequences from late Quaternary floodplain sediments in northern and central Germany have been used for environmental reconstruction (e.g., Willerding, 1960; Litt, 1992; Caspers, 1993, 2000), our cross-check of sediments from a palaeochannel and an adjacent floodplain site demonstrate that these sediments offer considerable potential as reliable records of vegetation change. Nonetheless, we do not expect that floodplain sediments represent the same level of palynostratigraphical precision as sediments from lakes and peats (Prentice, 1985; Sugita, 1994; Gaillard et al., 2008). The contribution of far-traveled fluvially transported pollen to the pollen assemblage may be high and may have undergone considerable fluctuations. Together with the local deposition of pollen from plants in the immediate proximity, this may explain why the share of floatable saccate *Pinus*-pollen and local elements (*Cerastium*, *Selaginella*) in the EP is higher than in sequences from nearby lakes and peatlands. In contrast, the share of *Betula* seems relatively diminished in comparison with nearby pollen diagrams (Lesemann, 1969; Röhrig et al., 2004; Christiansen, 2008).

In general, the palynological results from the Grabow 15 site support the findings from sites in the wider region (Usinger, 1985; Hoek, 1997; Merkt & Müller, 1999). The relative maximum of NAP is in the Older Dryas–Allerød transition, especially of *Helianthemum* and *Thalictrum*, followed by a *Juniperus* maximum and decreased values of terrestrial NAP, Poaceae, Cyperaceae, and *Selaginella*. For the Younger Dryas, the palynological record indicates the presence of open forest vegetation with scattered tree stands which is often characterized as "park tundra" (Lang, 1994; Usinger, 2004). Typical for this period are the light-demanding taxa such as *Juniperus*, *Helianthemum*, *Artemisia*, *Thalictrum*, and *Selaginella*. Based on the occurrence of high amounts of *Pinus*-pollen and *Pinus sylvestris*-needles in the sediments, the Grabow 15 site represents one of the most north-westerly sites in central Europe where the persistence of *P. sylvestris* is proven during the Younger Dryas (Spurk, Kromer, & Peschke, 1999; Theuerkauf & Joosten, 2012). Further records for the persistence of pine trees in central Europe have been reported, for example, from the German Uplands (Rhine valley: Hölzer & Hölzer, 1994; Neckar valley: Bos et al., 2008; Amöneburger basin: Bos, 2001) and from northeast Germany (Theuerkauf & Joosten, 2012). It therefore seems that river valleys in central Europe may have provided microrefugia for pine trees during the Younger Dryas.

The peak of NAP and the delayed establishment of forest development observed at Grabow 15 during the Pre-Boreal may be another local demonstration of the Pre-Boreal oscillation, a cold and dry phase, frequently detected in records from NW Europe (Usinger, 2004; Bohncke & Hoek, 2007; Bos et al., 2007).

A palaeosol of Allerød age occurring in a fluvial sequence is a feature hitherto rarely detected, indicating that a previously active environment stabilized successively during the Allerød probably under the influence of denser vegetation. Comparable processes can be identified at dry site of aeolian sands in the wider region where the formation of the frequently detected so-called "Usselo and Finow soils" (Albic and Brunic Arenosols, respectively) started synchronously (Kaiser et al., 2009).

Although sediments from the Allerød are preserved at this site, no LST as a characteristic central European marker horizon of the late Allerød (Schmincke, Park, & Harms, 1999; Baales et al., 2002) was detected. With respect to the fallout zone mapped by means of the known localities of this tephra (Riede et al., 2011), Grabow 15 site is located close to the western edge of the suggested fallout zone. We are therefore unable to decide if the LST did not fall in the local area or if the conditions of periodic floodplain sedimentation prevented preservation. The same is true for the sediments dated to the Younger Dryas, where no layer of the expected Vedde ash (Blockley et al., 2007) was identified.

Concerning hydrological changes during the Late Glacial, our results indicate a relative high water level at this site during the Younger Dryas, which resulted in the widespread deposition of silty floodplain sediments. This (seasonal?) local increase of the water level might be caused, on the one hand, locally by a nearby active river channel of the Jeetzel or Elbe River, or, on the other hand, regionally by an increasing water level in the broadened Elbe valley. The latter—a general increase of water levels in rivers and lakes probably during the second half of the Younger Dryas—has been demonstrated previously by several records in nearby northeastern Germany (e.g., Helbig & de Klerk, 2002; Kaiser, 2004b; Terberger et al., 2004; Kaiser et al., 2007, 2012). Perhaps regular flooding is responsible for the lack of archaeological evidence for human occupation in this area during this period, that is, by people of the Tanged Point (Ahrensburgian) culture.

CONCLUSIONS

The results presented in this paper show that floodplain sediments are suitable archives to analyze the interactions between climate, hydrology, vegetation, and human activities from the Late Glacial with relatively high resolution. The following conclusions can be drawn:

1. *Older Dryas/early Allerød:* Sandy and silty overbank sediments were deposited along an active meandering river channel, providing the parent material for subsequent pedogenesis.
2. *Allerød:* Fluvial sedimentation diminished and pedogenic processes started. A soil of Fluvisol-type rich in organic matter developed. In general, this hydrological stabilization phase probably favored (periodic?) human occupation of the river banks during dry seasons. Amber was collected from local fluvial sediments and was processed into artistic objects.
3. *Late Younger Dryas:* The river water level rose, which led to the deposition of silty overbank deposits during floods while the river channel became abandoned. This protected the archaeological record from later disturbances. The overall trend of rising water tables during this period probably forced humans out of the low-lying localities (river valleys, lake basins) in northern central Europe.
4. *Holocene:* The abandoned river channel was filled with lacustrine sediments and peat growth started. Paludification spread out into the surroundings. The uppermost sediment layer was disturbed by modern human drainage and ploughing.

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Anhang 3

Stahlschmidt, M.C., Miller, C.E., Ligouis, B., Goldberg, P., Berna, F., Urban, B., Serangeli, J., Conard, N.J. (eingereicht a). The depositional environments of Schöningen 13 II-4 and their archaeological implications. Journal of Human Evolution. Special issue Schöningen (55 pages)

The depositional environments of Schöningen 13 II-4 and their archaeological implications

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ABSTRACT

Geoarchaeological research at Schöningen 13 II-4, often referred to as the *Speerhorizont,* has focused on describing and evaluating the depositional contexts of the well-known wooden spears, butchered horses, and stone tools. These finds were recovered from the transitional contact between a lacustrine marl and an overlying organic mud, originally thought to be an intermittently wetted *in situ* growing peat. The original excavators proposed that hominin activity, including hunting and butchery, occurred on a dry lake shore and was followed by a rapid sedimentation of organic deposits that embedded and preserved the artifacts. Our geoarchaeological analysis challenges this model. Here, we present evidence that the sediments of Schöningen 13 II-4 were deposited in a constantly submerged area of a paleolake. Although we cannot exclude the possibility that the artifacts were deposited during a short, extreme drying event, there are no sedimentary features indicative of surface exposure in the sediments. Accordingly, this paper explores three main alternative models of site formation: anthropogenic disposal of materials into the lake, a geological relocation of the artifacts, and hunting or caching on lake-ice. These models have different behavioral ramifications concerning hominin knowledge and exploitation of the landscape and their subsistence strategies.

Keywords

Geoarchaeology; Lower Paleolithic; Site Formation; Lake sites; Schöningen

Introduction

Artifacts are embedded within a sedimentary matrix that provides the ultimate context for the interpretation of an archaeological site (Goldberg and Berna, 2010). Archaeological sediments can provide valuable information on past environments (French, 2003), past human behavior (Stein, 1987), and help in evaluating the integrity of the archaeological record (Schiffer, 1983). Generally, Paleolithic open-air sites are viewed as being more exposed to subaerial weathering and geological reworking when compared to cave or rock shelter sites (Goldberg and Sherwood, 2006). However, Paleolithic sites found in lakes, floodplains, and estuaries seem to present an exception to the general pattern of poor open-air preservation because of rapid, low-energy deposition found in these settings. Archaeological remains found in these settings are often interpreted as *in situ* assemblages that accurately portray life in the past (e.g., Bar-Yosef and Tchernov, 1972; Feibel, 2001). Previous researchers (Thieme, 1999, 2005; Voormolen, 2008; Lang *et al.*, 2012a) have suggested that the remains found within Schöningen 13 II-4 were directly deposited by hominins on a dry surface that was subsequently submerged under rising lake levels and that the archaeological remains were preserved directly in place. This “Pompeii-like” interpretation is based solely on field, macroscopic observations. Here, we employ a micro-contextual approach using micromorphology combined with organic petrology, and Fourier transform infrared (FTIR) spectroscopy to study in detail the depositional environments and formation processes of the find-bearing horizons at Schöningen 13 II-4 and investigate the archaeological ramifications of these processes. The techniques employed here have demonstrated their value in the study of archaeological sediments in wetland and lacustrine environments (Macphail, 1999; Wallace, 1999; Tsatskin and Nadel, 2003; Mallol, 2006; Boschian and Sacca, 2010; Macphail *et al.*, 2010; Karkanas *et al.*, 2011; Ismail-Meyer *et al.*, 2013).

Geographical and geological setting of Schöningen 13 II-4

The Middle Pleistocene site of Schöningen 13 II is located in an active open-cast lignite mine in northern Germany, about 100 km east of Hannover, Lower Saxony at the border of the northern German Plain to the north and the Harz Mountains to the southeast. The mine is set in the south-western syncline of the Offleben salt wall. The syncline is filled with 360 m of paralic to marine Paleogene sediments (Mania, 1995; Brandes *et al*., 2012), which are exploited for lignite. The Paleogene sediments are overlain by Pleistocene glacial and interglacial sediments. The Elster and Saalian glacial advances both transgressed this area, whereas the Weichsel glacial advances did not reach this far south (Eissmann, 2002; Ehlers *et al*., 2004; Litt *et al*., 2007).

The Middle Pleistocene sediments are preserved in an elongated NNW-SSE trending trough, which is 3.5 km long and typically 300-400 m wide (Lang *et al.*, 2012a). Lang *et al.* (2012a) interpret the trough as an ice tunnel valley formed underneath the Elsterian ice shield and reject former formation models proposed by Mania (1995) who suggested that the trough was formed by fluvial activity as dissolution of the underlying salt structure lowered local base level. The Middle Pleistocene sedimentary sequence in the trough consists of Elsterian subglacial meltwater deposits, subglacial till and glaciolacustrine deposits at its base. Holsteinian interglacial lacustrine-deltaic sediments follow the Elsterian glaciogenic deposits, which in turn are covered by Saalian glaciolacustrine and glaciofluvial deposits, and subglacial till. The Middle Pleistocene sequence is topped by Weichselian loess (see Fig. 1) (Urban, 1991, 2007; Mania, 1995; Thieme, 2005; Lang *et al*., 2012a, b). The interglacial Middle Pleistocene sequence, which contains 28 Pleistocene find horizons (see Serangeli *et al*., 2012), comprises three major episodes of deltaic-lacustrine sedimentation (Lang *et al*., 2012a). Lang and colleagues (2012) linked these three episodes of deltaic sedimentation to Holsteinian intra-interglacial cooling events and sea level changes. The second episode of deltaic sedimentation contains the spear horizon, Schöningen 13 II-4, and belongs to the Reinsdorf interglacial (Urban 1995), which was most recently dated to MIS 9 (Urban *et al*., 2011; Urban and Sierralta, 2012) and based on biostratigraphical correlation therefore interpreted as a regional form of the Holsteinian (Bittmann 2012; Litt *et al*., 2007). This correlation is still in debate. New evidence supports the biostratigraphical subdivision of Urban (1995, 2007) of the occurrence of two palynologically distinguishable interglacials Schöningen 13 I (Holstein) and Schöningen 13 II (Reinsdorf) which are stratigraphically clearly separated from one another (Urban *et al*., this issue.; Lang *et al*., 2012a).

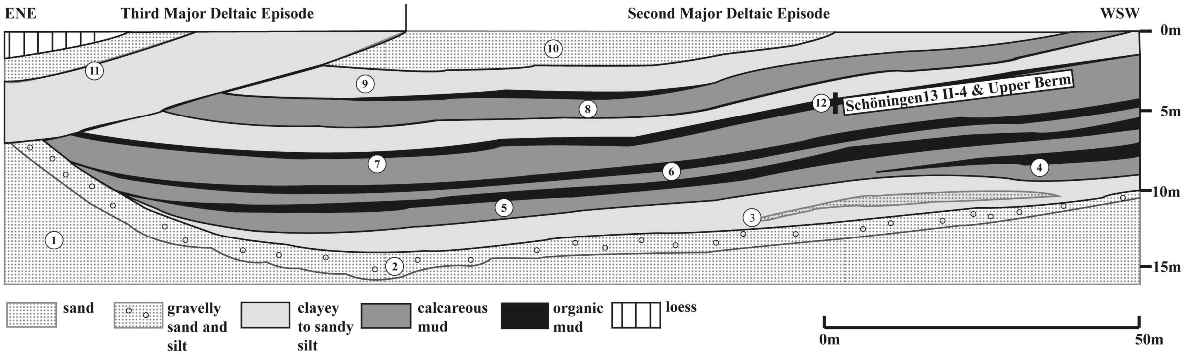
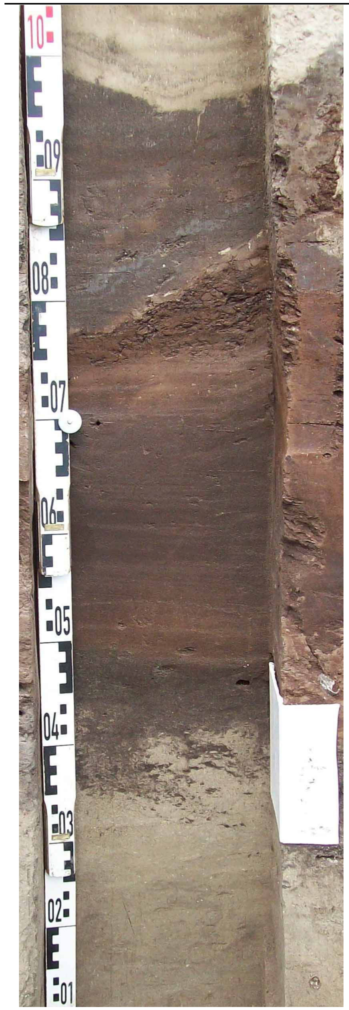


Fig. 1.Simplified, schematic sequence at Schöningen 13 II (after Mania in Thieme, 1999, p463, and Urban, 2007, modified according to Lang and colleagues, 2012a, b). 1 and 2. Glaciolacustrine deposits 3. Reinsdorf/Holsteinian Interglacial lacustrine deposits; 4.-7. Reinsdorf/Holsteinian Interglacial shallowing cycles of the lake 1 to 4 with calcareous mud grading into a dark organic mud; 8. 5th shallowing cycle, composed of sandy silt and a dark organic mud; 9 and 10. glaciolacustrine deposits; 11. Interglacial lacustrine deposits and loess; 12. Vertical line showing approximate location of the sequence at Schöningen 13 II-4 illustrated in Table 1.

The second episode of major deltaic lacustrine deposition comprises five sedimentary cycles (Mania, 1995; Urban, 2007; Lang *et al.*, 2012a), with each cycle consisting of calcareous to clayey muds that grade into a dark brown organic mud (Table 1); each cycle is capped by an erosional surface (Urban, 2007; Lang *et al.*, 2012a). These cycles are interpreted as a repeated shallowing of the lake as a result of relative lake level lowering (Mania, 1995; Thieme, 1999, 2005; Lang *et al.*, 2012a, b). Schöningen 13 II-4 is set in the fourth shallowing cycle of the lake. Based on palynological data, Urban (1995, 2007) and Urban *et al.* (2011, this issue.) report progressive climate deterioration from the first to the fifth cycle. The vegetation succession based on palynological data of the Reinsdorf sequence is described (Urban *et al.*, this issue) using the reference profile 13 II described by Thieme (2007a, c) and Böhner *et al.* (2005) and previous results (Urban, 1995). Levels II-1 to 2c5, the latter consisting of the oldest archaeological horizon (Urban and Sierralta, 2012; Urban *et al.*, 2011, Urban *et al.*, this issue), reflect warm but already terminal interglacial conditions. Sublevel 2c4 marks the onset of a climatic cooling reflected by an increase of moisture and the expansion of boreal woodland and peat formation. The zonal vegetation of sublevels 2b to 2c3 suggests an opening of the landscape as indicated by a strong increase of grasses and terrestrial herbs though under relative high lake level. Sublevels 2a(b) to 4c show a steppic character with patches of open wood land. Increasing dryness is recognizable in level 4a and 4b, indicating an open steppe environment dominated by grassland, stocks of pine and birch,



Layer	Lithology	Color (Munsell)	Components and structures
5d	Clayey silt	grey (2.5YR 5/1)	Laminations of bluish clay and brown silt; sand lenses; no archaeological finds
contact sharp, erosional			
4a	Organic silt	dark brown (7.5YR 3/2)	homogenous, clayey, locally fissural; very few archaeological finds
contact gradual			
4b	Organic silt	brown to dark and very dark brown (7.5YR 3/2 to 2.5/2, 7.5YR 4/2 to 2.5/2)	locally clayey and laminated; some archaeological finds
contact clear, most archaeological finds located here			
4b/c	Calcareous silt	light yellowish to olive brown and light olive brown and light brownish grey (2.5YR 5/3, 6/3, 5/4, 6/1), yellowish brown to dark yellowish brown (10YR 5/8 to 4/6)	Increased content in organic silt in compared to layer 4c; few small-scale slumping features some archaeological finds
Contact gradual			
4c	Calcareous silt	light grey (10YR7/2) to light olive brown to olive brown (2.5YR 5/4- 4/4),	Homogenous, locally clayey and sand lenses; shell fragments, local white and dark brown domains, some iron staining; few archaeological finds

Table 1. Sequence at Schöningen 13 II-4 witness block. Finds were encountered in layer 4c, 4 b/c and 4b. Note the tooth fragment above the white sample box, the gradual contact from layer 4c to layer 4b/c, the laminated nature of layer 4b, and the sharp erosional contact from layer 4a to the fifth cycle of lacustrine deposition.

scattered larch and spruce, and very few elder and juniper (Urban *et al*., this issue). The palynological observations are reflecting the terrestrial, lake shore and aquatic vegetational and climatic conditions of the surrounding landscape.

The paleolake associated with the archaeological remains had a maximal extension of 1 km² and a maximal depth of 6-7.5 m (Lang *et al*., 2012a). The paleolake has been described as hydrologically open during high water levels with a southern outlet and as hydrologically closed at low lake level (Böhme, 2000; Mania, 2007; Urban, 2007; Lang *et al*., 2012a). When it was hydrologically open, the paleolake was fed by streams coming from the southwest. The archaeological site Schöningen 13 II is located at the western side of the lake, where several palaeo-streams were likely flowing into the lake (Lang *et al*., 2012a). According to Thieme (2007a) the prevailing wind direction today is from the northwest and north, meaning that wave action was most pronounced at the south-eastern end of the lake and less so at Schöningen 13 II.

Following Thieme (2007a) and Böhner *et al.* (2005), the find-bearing sequence at Schöningen 13 II-4 consists of four sedimentary layers (Fig 1, Table 1). A grey calcareous marl (layer 4c) at the base exhibits a gradual but clear contact with layer 4b. This gradual transition from layer 4c to layer 4b was defined as distinct layer, layer 4b/c (see e.g., Voormolen, 2008; J. Serangeli personal communication) and accordingly is used as a distinct layer here. The overlying layer 4b was previously described as a dark brown peat or organic mud (Mania, 1995; Thieme, 2005, 2007a). Layer 4b is locally overlain by layer 4a, which was also called a peat (Thieme, 2005). The top of layer 4a is marked by an erosional contact with deposits of the fifth depositional cycle (Lang *et al.,* 2012a). These deposits include 5d, a laterally discontinuous layer of dark grayish silt and 5c, a laterally extensive layer of yellowish grey sand.

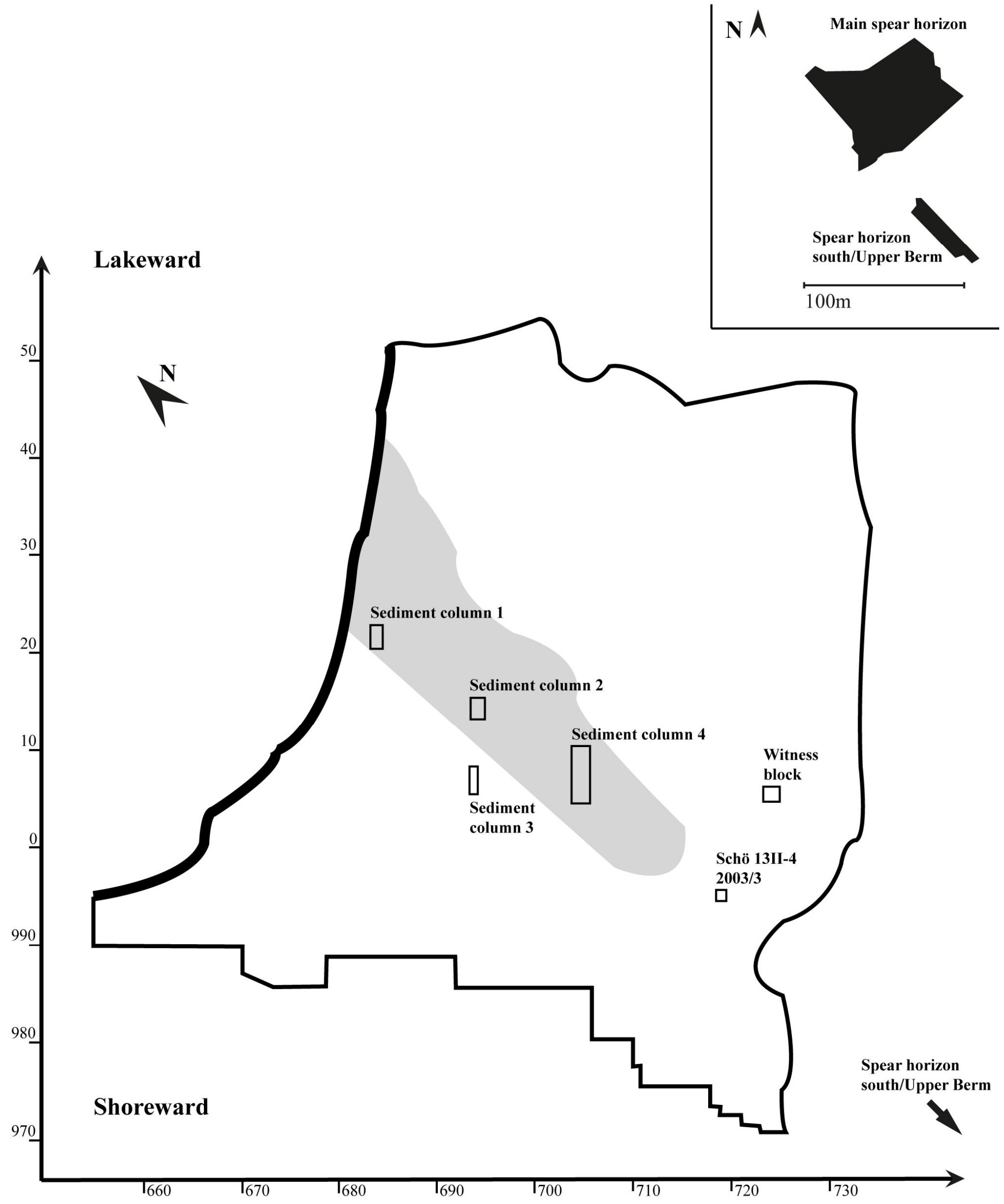


Fig.2. Schematic map of Schöningen 13 II-4 (after Thieme, 2007, p 173), and the location of 13 II Upper Berm in relation to Schöningen 13 II-4 (after Serangeli *et al.*, 2012, p 7) in the upper right. The excavation area Schöningen 13 II-4 is cut by mining activities to the north, east and south and the actual size dimension of the find horizon is therefore not known. The find horizon seems to continue in the excavation area Schöningen 13 II Upper Berm, which is also cut by mining activities. The schematic map of Schöningen 13 II-4 shows the locations of the four sediment columns, the witness block and the frozen block sample Schö 13II-4 2003/3. Colored in grey is the area of densest find concentration, whereas to the east and south finds are present in low concentration and only very few were found to the west (see Thieme, 2007). The profile depicted in Figure 1 was taken at the northern edge of the excavation area Schöningen 13 II-4 (thick line).

The finds at Schöningen 13 II-4 consist of flint artifacts, wooden spears, and bone remains (see below), which are vertically distributed through 30-40 cm of the calcareous marl (layer 4c), the transitional layer 4b/c to the overlying organic mud (layer 4b); only a few finds occurred in the overlying peat (layer 4a) (Thieme 2005, 2007c; Voormolen 2008). Most finds are located at the direct contact between layers 4b/c and 4b (Thieme 2005, 2007a). Schöningen 13 II-4 is particularly noteworthy for its preservation of Middle Pleistocene organic artifacts. This excellent preservation is a result of the continuous water-logging of the site since burial. Schöningen 13 II-4 was located about 10 m below the current ground surface and about 8 m below the historic groundwater table. In order to facilitate mining operations, the groundwater table was artificially lowered in the 1970s by the mining company, E.ON. They constructed additional wells in the vicinity of the site specifically to preserve the site after discovery of the first wooden spear by Thieme in 1994 (pers. com. P. Mutzbauer).

Archaeological research at Schöningen 13 II-4

A team from the Lower Saxony Heritage Office (*Niedersächsisches Landesamt für Denkmalpflege)* under the direction of Hartmut Thieme first reported the discovery of a Middle Pleistocene wooden spear from Schöningen 13 II-4 in 1994 (Thieme, 1997). This discovery was followed by the excavation of seven more wooden spears (Thieme, 2005) found in association with the remains of three dozen butchered horses (van Kolfschoten, 2014, this issue), stone tools, and four purported hearths (Thieme, 2005). The team excavated the majority of the sediments from the fourth depositional cycle (*Speerhorizont*), leaving four sediment columns with remains of purported hearths and two witness columns for future research (Fig. 2). These sediment columns have been partially disturbed by recent bioturbation and desiccation fractures. Following the discovery of Pleistocene artifacts at Schöningen, mining operations continued but left a 3900m^2 area that is currently under excavation by a team from the University of Tübingen. A new excavation area, Schöningen 13 II Upper Berm (see Fig. 2), was recently opened and is thought to represent a southern extension of Schöningen 13 II-4 (Serangeli *et al.*, 2012; Serangeli *et al.*, this issue).

In addition to publications on the spears (Thieme, 2007b), other work has been reported on the faunal remains, lithic artifacts, and the purported hearth features. In his dissertation Voormolen (2008) analyzed 20% of the bones from Schöningen 13 II-4 recovered prior to 2001. He reported that horse remains dominate the assemblage at over 94.8 % by NISP (Number of identified specimen) of all determined bone remains, followed by deer and bovid remains (see Table 2). Furthermore, he reported that of the horse elements, 23% show marks of human impact and 16% show carnivore damage. Larger elements are more common than smaller skeletal elements. Voormolen (2008) also observed striations and rounding by sedimentary transport, albeit in very low numbers, with 1.5% of the horse remains showing striations and 2.8 % exhibiting rounding. The number of traces of human activity, carnivore action and sediment abrasion on the deer and bovid remains differ slightly from the pattern of the horse remains (see Table 2). Voormolen (2008) suggested that the deer and bovid remains were deposited by more natural processes, relative to the horse remains. However, he noted that all bone remains were generally very well preserved and concluded that the bone remains could not have been exposed on the surface for a long period of time. He was also able to refit some bones over a maximum horizontal distance of 75 cm and from layer 4a to 4c (Voormolen, 2008). Musil (2007) and Voormolen (2008) also report that some skeletal elements were found in articulation; however, details on these articulations, along with information on orientation patterns, and size distribution, remain unpublished.

	Horse (2809 NISP)	Bovid (92 NISP)	Deer (60 NISP)
Human butchery marks	23 % cutmarks 15 % marrow extraction marks	30 % cutmarks 34.7%	18 % cutmarks 6 % marrow extraction marks
Carnivore marks	16 %	8.7 %	22 %
Sediment abrasion	1.5 % striations 2.8 % rounding	4.4 % rounding	1.5 % striations 3 % rounding

Table 2. Overview on the traces of human, carnivore and sediment modification on the bone remains separated by taxon after Voormolen (2008, p. 123).

Serangeli and Böhner (2012) reported more than 1500 lithic artifacts from Schöningen 13 II-4. Lithic artifacts are generally well-preserved and show sharp edges (J. Serangeli pers. communication). The lithic artifacts were made from the locally available flint (Thieme, 2005) and 90% of the lithic assemblage are chips, the remaining 10% are flakes, retouched scrappers and points. Handaxes and any evidence of Levallois technology are noticeably absent (Serangeli and Böhner, 2012; Thieme, 2005). Serangeli and Böhner (2012) interpret the lithic assemblage as suggestive of a terminal Lower Paleolithic.

Thieme (1997, 2005) observed four reddened, circular features at the contact of layer 4b/c with layer 4b. He interpreted these as possible hearths. A preliminary micromorphological analysis of the formation and use of the purported hearth features remained inconclusive

(Schiegl and Thieme, 2007). Stahlschmidt and colleagues (this issue.) conducted a multiproxy geoarchaeological analysis of the features employing micromorphology, organic petrology, FTIR, mineral magnetic parameters study, luminescence studies and heating experiments. The results of this analysis demonstrated that the purported hearths and their associated deposits do not show any signs of being heated. Instead, the reddening observed in the field was formed by natural post-depositional processes related to the lowering of the groundwater by the mining company (Stahlschmidt *et al.*, this issue.).

Different researchers have proposed varying site formation models for Schöningen 13 II-4. Thieme (1999, 2005, and 2007a) suggested that the assemblage of bones, spears, stone tools and hearths was the result of one single event of hunting and butchery. He set the scenario on a dry shore that was vegetated with sedge grassland in late summer to winter. He argued that the artifacts were buried in place in spring by rising water levels. His interpretation of a dry surface on which the hunting and butchery occurred is based on the presence of hearths, black surface impregnations on bones by humic acids, and the observation of channel structures (Thieme, 2005). Voormolen (2008) and Musil (2007) suggested that the faunal assemblage is the result of several events. Voormolen (2008) argued that the hominins drove the animals into the soft mud at the lake shore and killed the horses in this natural trap. He argues that the low representation of smaller skeletal elements is not a result of water action but a result of human selection, thereby suggesting a primary context for the faunal assemblage. Similarly, Lang and colleagues (2012) assume that the archaeological assemblage accumulated on exposed deltaic plain based on “the complete preservation of the spears” (Lang *et al.*, 2012a, p 17).

Lacustrine settings

Lakes can be divided into the aphotic lake basin, where sunlight is absent, and the vegetated photic lake margin, reached by sunlight (Fig 3.). The aphotic lake basin - the profundal zone - is characterized by a fine-grained sediment containing remains of diatoms, algae, mollusks, ostracods, and ejecta from fish; these deposits often exhibit fine laminations (Bouma *et al.*, 1990; Platt and Wright, 1991; Flügel, 2010). The detrital plant material in the profundal zone is often degraded by bacterial activity in the water column (Teichmüller and Teichmüller, 1982).

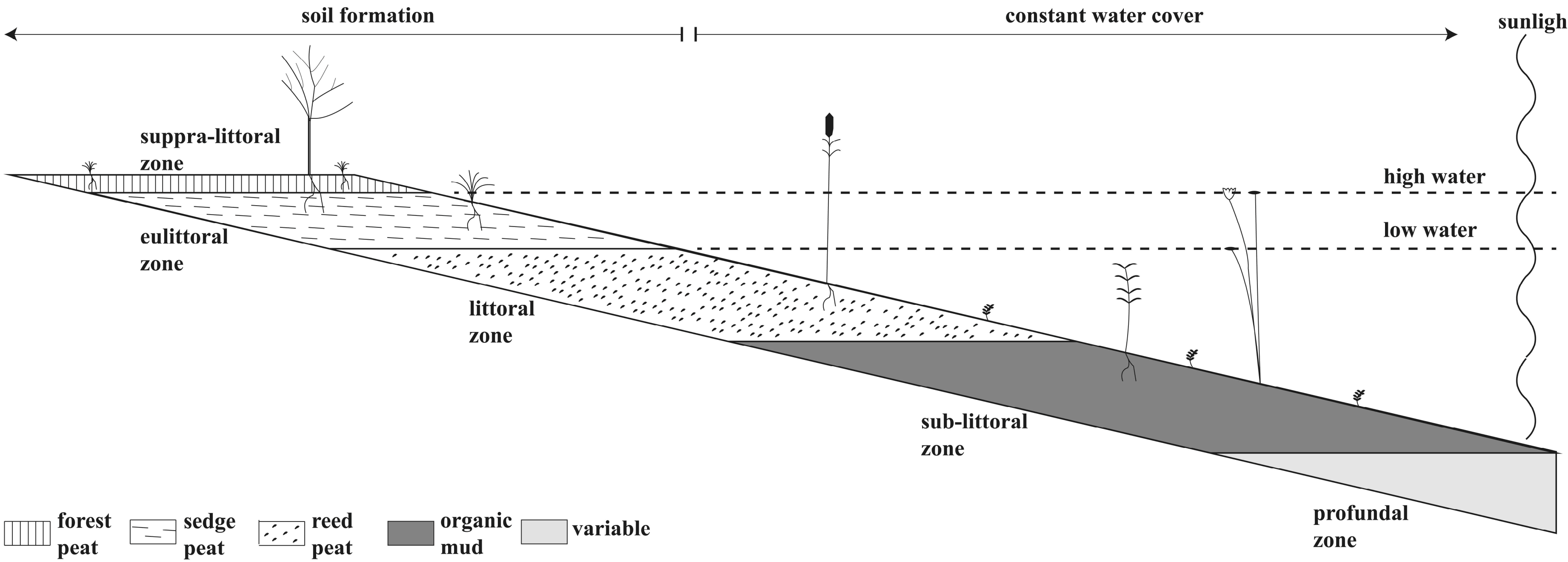


Fig. 3. Simplified schematic sedimentary sequence at lake margins (figure after Overbeck 1950, p.15, following nomenclature of Wright 1990). Deposits of the profundal zone vary, but are often characterized by laminated clay facies. The adjacent sublittoral zone is composed of coarse to fine detrital muds and represents a constantly submerged deposit. Floating and submerged plants grow here, but other plant residues can be transported here as well. The overlying littoral zone is vegetated by floating, submerged, and emergent plants and also represents a constantly submerged zone. Plant residues present a mix of transported and *in situ* grown vegetation. The adjacent eulittoral zone is defined as the zone between the highest and lowest water stand and is regularly flooded. At low water levels desiccation and some weak soil formation can occur here. Present plant residues are mostly grown *in situ*. Above the highest lake level is the suppralittoral zone. Soil formation can be observed here in the form of bioturbation, horizonation, clay illuviation, formation of hydromorphic features and desiccation structures (see e.g., Forsaith, 1917; Plaziat and Freytet, 1978; Bouma *et al*., 1990; Schnurrenberger *et al*. 2003; McSweeney and Fastovsky, 1987; Wright, 1990; Mallol, 2006; Flügel, 2010). Note that the spatial relation, extent and presence of these zones differ greatly from lake to lake and even within the same lake. Therefore, most lake shorelines present mosaic environments.

The lake margin can be divided into several subzones depending on the direct depositional environments (Fig. 3). The classification of these zones is dependent on water depth, water flow, tides, temperature, ground morphology, and plant communities (Overbeck, 1950; Göttlich, 1976; Stach *et al.*, 1975; Talbot and Allen, 1996; Taylor *et al.*, 1998). These zones include the lowermost sub-littoral zone and the adjacent littoral zone, both of which are constantly submerged and composed of detrital mud and peat, respectively. The eulittoral zone is located between the highest and lowest water level stand and consists of *in situ* growing peat. Here, weak pedogenesis can occur (Bouma *et al.*, 1990; Wright, 1990; Alonso-Zansa *et al.*, 2009; Flügel, 2010). The suppralittoral subzone is located on the terrestrial shore and can be occasionally flooded, allowing for the formation of wetlands (Overbeck, 1950; Stach *et al.*, 1975; Göttlich, 1976; Teichmüller and Teichmüller, 1982; Wright 1990; Flügel 2010). Lake margin zones differ in their plant community and depositional characteristics (Fig. 3). The farther from the shore, the lower the terrestrial sedimentary input and the larger the impact of transportation on the sedimentary grains and aggregates. Lake margin deposits can form *in situ*, through sedimentary transport, or they can be formed by both *in situ* and transport processes (Feibel, 2001), depending on their depositional character and history.

Paleolithic sites in lacustrine settings

A number of Middle Pleistocene archaeological sites are found in lacustrine settings (see below). The occurrence of archaeological remains along the shores of lakes may reflect hominin exploitation of these rich environments; however, these same environments may preferentially preserve archaeological remains because of their low-energy sedimentation and anoxic conditions (Brochier, 1983; Wymer, 1999; Gaudzinski and Roebroeks, 2000; Feibel, 2001; Goldberg and Macphail, 2006). Several researchers have interpreted Middle Pleistocene assemblages found in lacustrine and similar depositional environments as representing *in situ* assemblages not significantly influenced by post-depositional reworking. These sites include Dmanisi (Gabunia *et al.*, 2000), Gesher Benot Ya-aqov (Alperson-Afil and Goren-Inbar, 2010), 'Ubeidiya (Bar-Yosef and Tchernov, 1972; Villa, 1976), Boxgrove (Roberts, 1999), and in Olorgesailie and Olduvai Gorge (Leakey, 1971; Feibel 2001). At all of these sites, researchers argued that the archaeological assemblages were deposited by humans on a dry surface that was subsequently covered by low-energy sediments as a result of rising water levels. For instance, the archaeological remains at the sites of Boxgrove, Olduvai FLK Zinjanthropus floor, and at Olorgesailie were found in waterlain sediments in association with paleosols (Leakey, 1971; Macphail, 1999; Feibel 2001) implying the presence of a stable, terrestrial surface on which hominin occupation took place. Lacustrine sediments are often too soft to provide a stable surface for walking or extensive settlement. However, Petrequin (1991), in the context of experimental Neolithic lake-dwellings, observed that a calcareous crust formed on top of an exposed lake marl after a few months of exposure.

The properties of the archaeological remains themselves can also be informative about depositional history, like any other sedimentary particle (Schiffer, 1983; Stein, 1987; Dibble *et al.*, 1997; Thayer Morton, 2004). Therefore, artifacts not only bear cultural, but also environmental information. Orientation, size sorting, abrasion, and surface marks on the archaeological material, in concert with an analysis of the hydrological environment and architecture of the sedimentary matrix, can provide further insights into site formation processes. For instance, at ‘Ubeidiya, the fluvial reworking of the archaeological remains was evident in the sedimentary structures as well as in the archaeological objects themselves, of which many showed abrasion and some exhibited breakage patterns typical of sediment compression (Bar-Yosef and Goren-Inbar, 1993; Shea, 1999; Mallol, 2006). These observations led researchers to reject the hypothesis of *in situ* living floors at the site (Shea, 1999; Gaudzinski, 2004; Mallol, 2006). Other commonly employed arguments exist for the presence of a walkable surface. For example, Feibel (2001) argued that at Gesher Benot Ya’aqov in some instances the presence of artifacts in layer III was the only clue for exposure of the lacustrine mud.

Research goals

The present geoarchaeological study aims at identifying the depositional environments of Schöningen 13II-4 based on a micro-contextual analysis (Goldberg and Berna, 2010). The micro-contextual analysis examines the deposits at mm to cm scale and employs the methods of micromorphology, organic petrology, FTIR and mFTIR, as these have proven very valuable in deciphering depositional and post-depositional processes in lacustrine settings (Retallack, 1981; Texier, 2000; Courty, 2001). We additionally include palynological and sedimentological analysis for small- and large-scale environmental reconstruction.

Here, we address the following questions about the site’s depositional history: What are the depositional environments associated with the artifacts? Is the archaeological assemblage in primary context? How many depositional events of archaeological remains are represented? Is there evidence of former surfaces in the archaeological layers? What hominin behavior could explain the depositional history?

Methods and materials

For this study we used the methods of micromorphology, coupled with organic petrology, FTIR, µFTIR (micro Fourier-Transform Infrared Spectrometry), sedimentological (see below) and palynological investigation all integrated with detailed field description and recording of sampling location and observation.

Micromorphology, FTIR and µFTIR

Micromorphology is a method to analyze formation processes of soils and sediments through the study of intact blocks of sediment that have been indurated with a polyester resin, sliced and made into petrographic thin sections (Courty *et al.*, 1989). This method allows us not only to identify sedimentary components, but also to identify the sedimentary structures, pedogenetic features, and their spatial and temporal relationships. For this study, oriented blocks were collected in stabilized containers in the field. The samples were dried in the Geoarchaeology Laboratory at the University of Tübingen and impregnated with a 7:3 part mixture of unpromoted polyester resin and styrene and catalyzed with Methylethylketone peroxide (MEKP) under vacuum. After 5-10 days the samples were again heated and then sliced into blocks of 50x75x10mm. The sliced blocks were glued onto glass slides and ground to a thickness of about 30µm. The thin sections were produced by Th. Beckmann (Schwülper-Lagesbüttel, Germany), Spectrum Petrographics, Inc. (Vancouver, Washington, U.S.A.), and by P. Kritikakis (Geoarchaeological Laboratory, University of Tübingen). Analysis was conducted with a petrographic microscope under plane-polarized, cross-polarized, and UV-light at magnifications of 20x to 500x. The descriptions follow nomenclature in Courty *et al.* (1989), Stoops (2003), and Stoops *et al.* (2010).

Micromorphology has proven valuable in deciphering formation processes in lacustrine settings in various contexts (see e.g., Forsaith, 1917; Retallack, 1981; Tyson, 1995; McSweeney and Fastovsky, 1997; Macphail and Goldberg, 1999; Taylor *et al.* 1998; Texier 2000; Freytet and Verrecchia 2002; Flügel 2010). In particular, McSweeney and Fastovsky (1997), and Freytet and Verrecchia (2002) were able to demonstrate short-termed exposure of lacustrine sediments, that resulted in pedogenesis and which left micromorphologically visible traces. Micromorphology has also been successfully applied to investigate changing lake levels in association with archaeological sites (Karkanas *et al*., 2011; Tsatskin and Nadel, 2003; Ismail-Meyer and Rentzel, 2013).

In addition to the micromorphological investigation, FTIR was performed on loose samples and on the thin sections (µFTIR). These techniques are used to identify and characterize organic and inorganic materials based on their characteristic molecular absorption of Infrared radiation (Farmer, 1974). FTIR and µFTIR were carried out at the Laboratory of MicroStratigraphy in Boston University. Loose sediments were prepared by grinding a few tens of micrograms of homogenized sample with an agate mortar and pestle. About 0.1 mg or less of the sample was mixed with about 80 mg of KBr (IR-grade) and a 7 mm pellet was made using a hand press (Qwik Handi-Press, Spectra-Tech Industries Corporation) without evacuation. FTIR spectroscopy and microspectroscopy were conducted using a Thermo-Nicolet Nexus 470 IR spectrometer coupled to Spectra-tech Continuum FTIR microscope. The spectra were collected between 4000 and 400 cm^{-1} at 4 to 8 cm^{-1} resolution. Organic and inorganic phases were identified and characterized by using in-house and ad hoc FTIR spectral libraries (see e.g. Weiner, 2010).

Organic Petrology

Organic petrology is a branch of coal petrology, whose main application is the study of the properties of peat, brown coal and hard coal by reflected light microscopy. Methods of organic petrology include the measurement of reflectance and fluorescence of organic particles, known as macerals (see Tabl. 3 for Organic Petrology terms). The investigation is carried out on well-polished surfaces of impregnated block- samples in reflected white light and in fluorescence mode.

Sample preparation was conducted at the Laboratories for Applied Organic Petrology, University of Tübingen. A microscope photometer equipped for reflected light and for visual fluorescence examination was used with oil immersion objectives (20x to 60x). Random reflectance in oil (mean %Rr) of the telohuminites (textinite B and ulminite B) was measured according to standard procedure (Taylor *et al*., 1998). Description and classification of the organic micro-components (macerals) is based on the nomenclature of macerals in brown coal and coal (ICCP, 1971, 1998; Taylor *et al*., 1998; ICCP, 2001; Sýkorová *et al*., 2005). Fluorescence examination was done to identify and classify the macerals of the liptinite group (pollen, spores, algae, cuticules, cortical tissues, resin bodies) and to recognize their alteration by oxidation through transportation or desiccation, and by burning.

Maceral Group	Maceral Subgroup	Maceral	Maceral Type
Huminite: humified plant tissues	Telohuminite: humified plant tissue	Textinite: ungelified tissue with visible cell structure	
		Ulminite: more or less gelified tissue	
Liptinite : hydrogen-rich and lipid-rich plant remains (spores, cuticles, resins, algae…)		Alginite: algae	Telalginite: large colonial algae or structured thick-walled unicellular algae (as opposed to filamentous)
		Liptodetrinite: fine detrital (<10µm) fragments of liptinite macerals, therefore not assignable to sporinite (spores), cutinite (cuticles), resinite (resinous bodies) or alginite (algae) macerals	
Inertinite: Carbon-rich and oxidized macerals		Fusinite: product of incomplete combustion of tissues (high reflecting charcoal); biodegraded, dehydrated or weathered tissues	
		Semifusinite: product of incomplete combustion of tissues (low reflecting charcoal); weak humified, oxidized or dehydrated tissues	
		Inertodetrinite: fine detrital (<10µm) fragments of fusinite and semifusinite	

Table 3. Glossary of Organic Petrology terms. Description of maceral groups, macerals, and macerals subgroups only as mentioned in text. The presented macerals, the non-crystalline components of brown coal, are divided into three groups: Huminite, intertinite, and liptinite. The division of these groups is based on chemical composition, origin, conservation, volatile-matter content, morphology, structure, and macerals reflectance (for more information see *Stach et al*., 1975; Taylor *et al*., 1998; ICCP 2001, 1998; Sýkorová *et al*., 2005).

Sedimentological and palynological investigation

Sedimentological and palynological sample preparation was carried out in the laboratories of the Institute of Ecology, Subject Area Landscape Change of Leuphana University Lüneburg for geochemical and botanical analysis. Samples were analyzed for Carbon and Nitrogen using a Perkin Elmer 2400 Series II CHNS/O Elemental Analyzer, for their carbonate content following gasometric determination with the Scheibler apparatus and for soluble salts (Electrical Conductivity, EC) according to VDLUFA (1991). For palynological analysis, including charcoal particles (<100 µm), 10-20 g samples were treated by standard palynological methods (Faegri and Iversen, 1989; Moore *et al*., 1991). Pollen calculation and diagram construction were performed with the software package Tilia, Tiliagraph and Tiliaview (Grimm, 1990). The pollen sum used for calculating the diagram is based on the terrestrial phanerogams. Taxa belonging to the cryptogams, aquatic plants, Ericaceae, Cyperaceae and charcoal particles were percentaged outside the pollen sum. For each sample the total sum of all palynomorphs was based on the counting of at least one microscope slide (24 x 32 mm).

Materials

We collected and studied a total of thirteen block samples from four of the remaining sediment columns in addition to a block sample from the Thieme excavation and three from the new excavation area, Schöningen 13 II Upper Berm (Fig. 2 and SI 1). The witness block was studied only through field observations. The four sediment columns were located in areas with varying find densities. At the four sediment columns, all find horizons and preserved overlying layers were sampled. We produced a total of 38 thin sections for micromorphological analysis. Eight of which were additionally studied by µFTIR; nineteen loose samples were studied by FTIR. For organic petrologic analyses, four block samples from sediment column 1 were studied. Sub-sampling for petrographic thin sectioning, FTIR analyses and organic petrology was carried out on the same block samples to insure contextual continuity among the techniques.

Additional sampling (30 subsamples from block samples) for sedimentological and palynological investigation was carried out on Profile Schöningen 13 II-4, x 683, y 21 (2010) between 101.90 m and 102.65 m above sea level (a.s.l.) using three 25 x 7 x 5 cm sized steel boxes during the excavation campaign of 2010 in the laboratories of the Institute of Ecology, Subject Area Landscape Change of Leuphana University Lüneburg for geochemical and botanical analysis.

Results

The following presents a summary of the micromorphological, mFTIR, FTIR, organic petrology data, palynological and other sedimentological investigation (for more detailed results broken down by method, see SI 2 to SI 4, Table 1).

Schöningen 13 II-4

Layer 4c The grey calcareous mud of layer 4c (Table 1) is present over the entire excavation area and in four thin sections from sediment column 1 and 4 (SI 2). Fine material in this homogenous layer is composed of microcrystalline calcite with a minor proportion of clay (Fig. 4 and 5). Silt- and sand -sized quartz, plant residues, ostracods and mollusk shell fragments, chara remains, pyrite framboids, diatoms and sponge spicules are common components (Fig. 4a and 4b). Some diatom species could be tentatively identified morphologically as *Cymbella aspera* and pinnate diatoms, which are both shallow water species (N. Cameron personal communication). It is interesting to note that plant residues are dominantly fragmented and fall in the silt- to sand-sized range. No *in situ* growing roots were observed. Pollen content and preservation is generally poor in all layers.

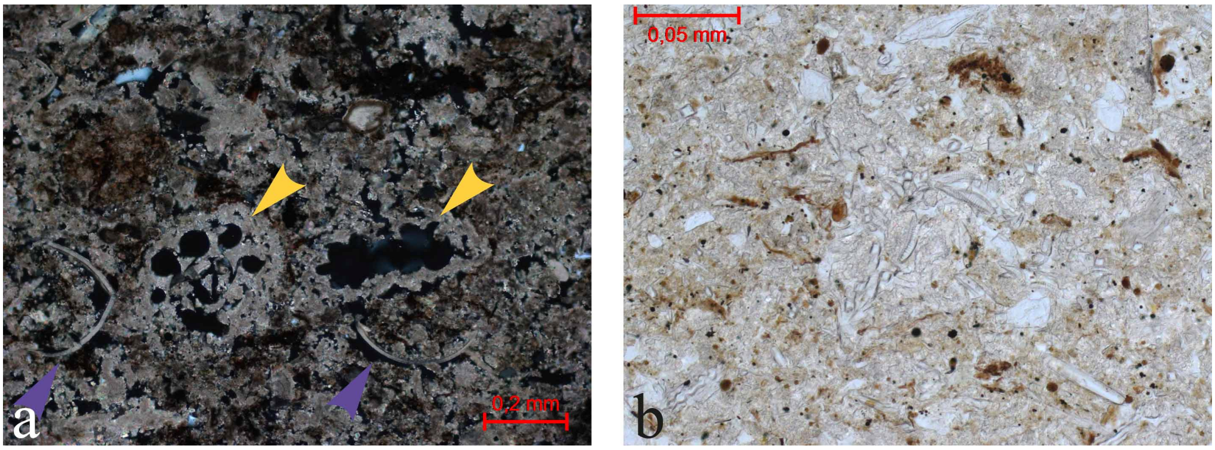


Fig. 4 Microphotographs of layer 4c. (a). Layer 4c with well preserved chara remains (yellow arrows) and ostracod shells (purple arrows) in a calcareous groundmass. XPL, scale at lower right, 0.2mm. (b) Layer 4c with many diatoms next to amorphous organic remains (brown dots), plant residues and pyrite framboids (black dots). Plane-polarized light (PPL), scale at upper left, 0.05mm.

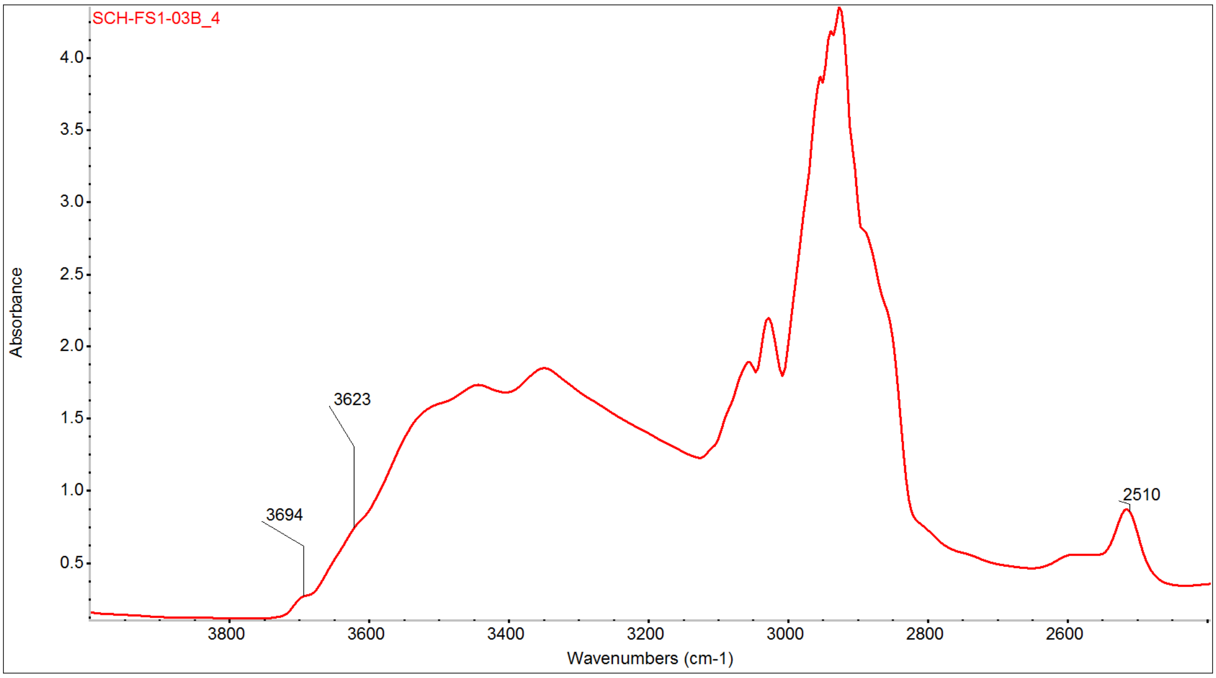


Fig. 5. Representative transmission FTIR spectrum of marl-like sediment processed in petrographic thin section showing the IR absorptions of calcite (at 2510 cm^{-1}) and kaolinite (weak at 3695 and 3623 cm-1).

The carbonate content amounts to 58%, organic carbon is 2 % and organic matter content (calculated as C% x 1.72) amounts to 3.4 % (Fig. 6 and 7.). Mean C/N ratio amounts to 9.8 and soluble salt content of the calcareous mud to about 1.2%. The present pollen derive mainly from aquatic plants, e.g. Ranunculacae (cf. *Ranunculus aquatilis*, *Ranunculus acris, Ranunculus sceleratus*). Pollen findings of *Myriophyllum verticillatum, M. spicatum*, cells of *Pediastrum duplex, Potamogeton* pollen as well as a rich variety of fruits of *Potamogeton spec*. (Jechorek, 1997, 2007 Bigga *et al*., this issue) among others, indicate open water conditions. Pollen from more terrestrials stands such as reed belts and bogs are present in lower numbers, e.g. *Typha cf. latifolia, Phragmites, Cyperaceae and Sphagnum spores* (Fig. 8).

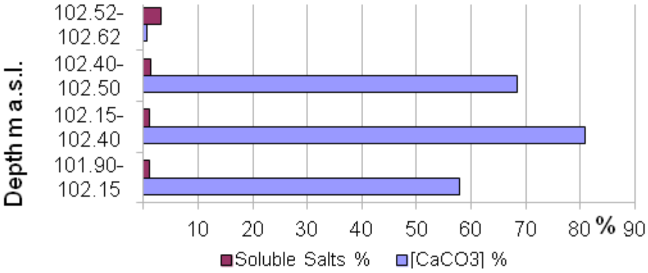


Fig. 6. Soluble salts and calcium carbonate content at Schöningen 13II-4 2010 (x 638 y 21).

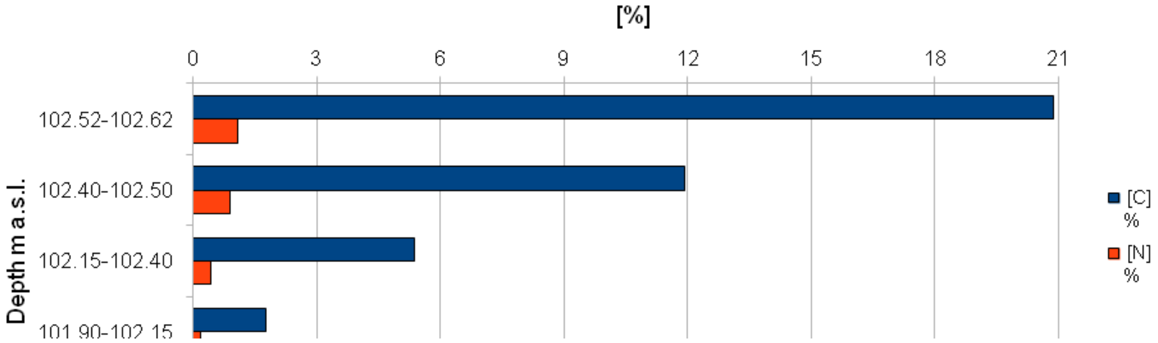


Fig. 7. Carbon and Nitrogen content at Schöningen 13 II-4 2010 (x 638 y 21).

Layer 4b/c Layer 4b/c has a thickness of 5-15 cm and is characterized by an increase in plant residues (Table 1, SI 2 to 4). Twelve thin sections were produced from this layer and three block samples for organic petrologic study. Plant residues occur mostly as rounded aggregates and less frequently as isolated fragments in the calcareous matrix (Fig. 9a). Plant residues are principally represented by fine fragments of huminite (see Table 3 for Organic Petrology terms) tissues almost exclusively derived from herbaceous plants. Liptinite plant residues, which consist mainly of spores and highly fragmented bark- or cork-derived tissues, are very dispersed in the mineral matrix. Microstratified peat clasts (Fig. 9a) are rich in inertodetrinite and show a higher gelification grade than plant residues elsewhere in the matrix. Pollen data do not vary from unit 4c (see above). Accumulations of plant residues are often microstratigraphically associated with post-depositional features, such as gypsum crystal intergrowths and iron oxide precipitation. Chara remains, telalginite of Botryococcus-type algae (Fig. 9b), ostracods, sponge spicules and diatoms are also present. The latter were notably absent in thin sections from sediment column 3. The carbonate content varies between 68% and 81% and amounts of organic carbon are 5.4%. Organic matter content amounts to 9.3 % (Fig. 6 and 7). Mean C/N ratio amounts to 12.8 and soluble salt content of the calcareous mud to about 1.2%. The contact with the overlying layer 4b is sharp and locally overprinted by iron precipitation with a maximal vertical extent of 3 cm. Iron oxide precipitation at the contact with the upper layer 4b takes the form of amorphous, impregnative

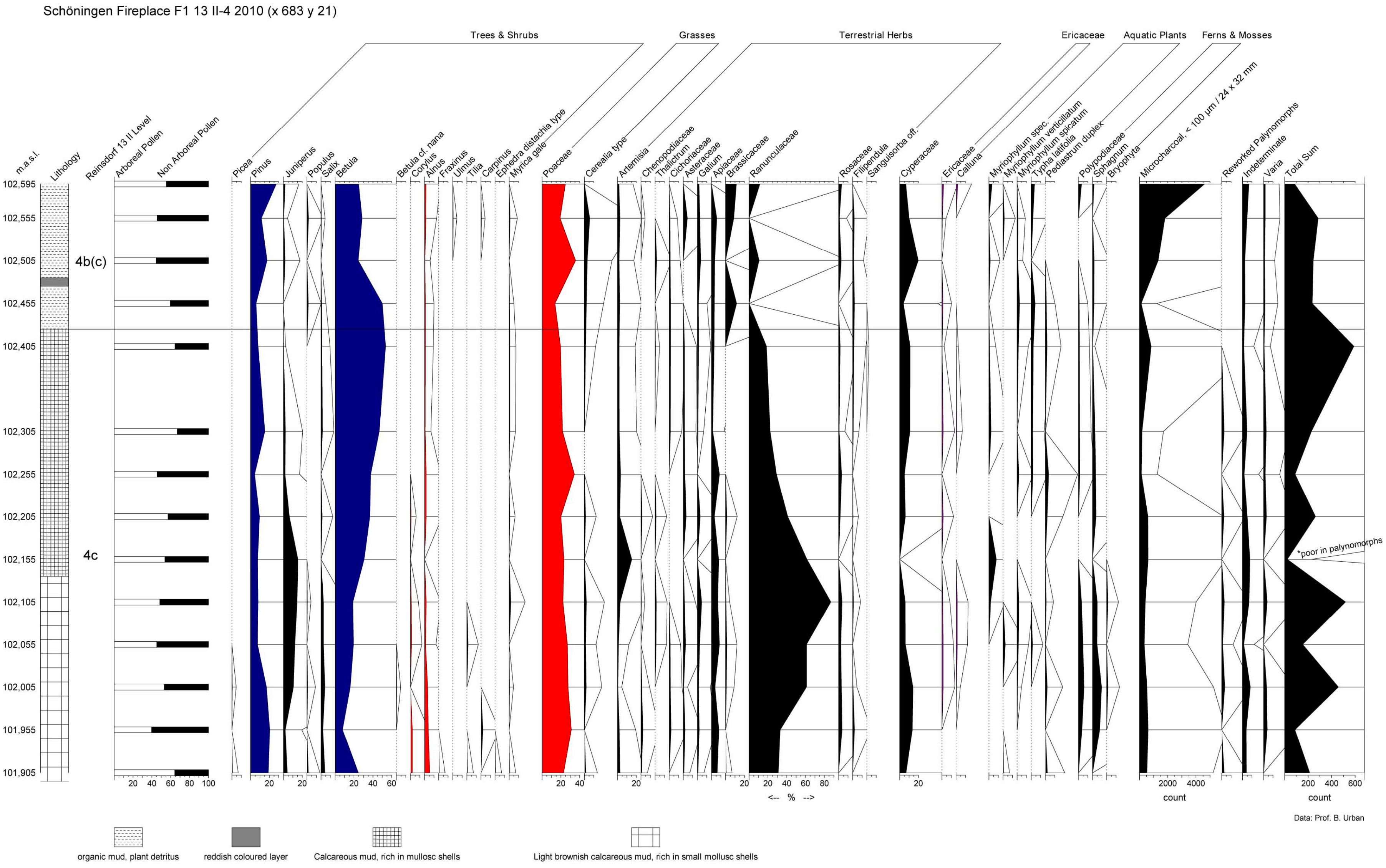


Fig. 8. Pollen diagram of Schöningen 13 II-4 2010 (x 683, y 21).

features that exhibit a laminated structure, indicating several episodes of formation (see Stahlschmidt *et al.*,this issue.).

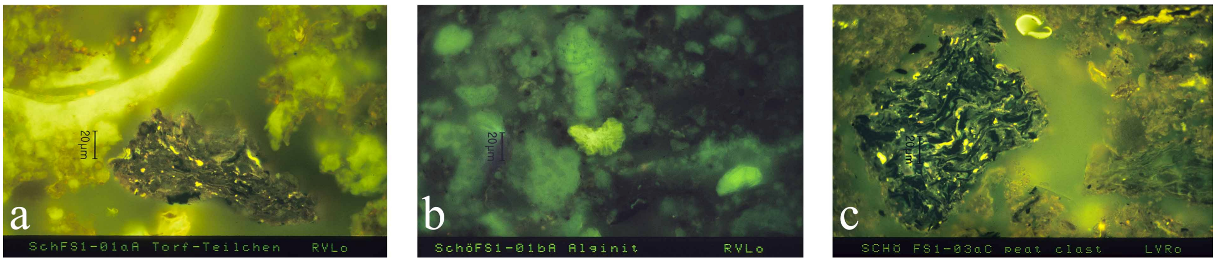


Fig. 9. Microphotographs of block samples in Fluorescence mode, oil immersion. (a) Layer 4b/c with peat clast and yellowish fluorescing ostracod shell fragment. (b) Telalginite of Botryococcus-type algae in layer 4b/c, scale to its left, 20µm. (c) Microstratified peat clasts in layer 4b containing yellow fluorescing liptodetrinite and inertodetrinite (black non-fluorescing plant detritus). The weak greenish-yellow fluorescing calcareous clayey matrix contains sporinite, bright green fluorescing suberinite (bottom right) and liptodetrinite.

Layer 4b Layer 4b is a brown organic mud (Table 1, SI 2 to 4, Fig. 10a) and present in ten thin sections and three block samples for organic petrologic study. It is homogenous and locally exhibits a laminated structure (Fig. 10d). Layer 4b has a maximum thickness of 35 cm, but it is variable across the site. The thickest occurrence of layer 4b correlates with the highest density of finds, and the overall distribution of 4b mirrors the spatial distribution of the finds (Lang *et al.*, 2012a). Layer 4b is nearly carbonate-free and consists of an increasing Carbon content of up to 21% and consists by 20.5% to 36% of organic matter. Mean C/N ratio is 17 (13.4 at 102.40 – 102.50 m and 21 at 102.52 – 102.62 m). Soluble salt content of the calcareous mud amounts to about 3.2%.

Layer 4b consists principally of plant residues (Fig. 10a). Only very few carbonates are represented in the mineral matrix, which mostly consists of minor amounts of clay (Fig. 6 and11). Few silt- and sand- sized grains of quartz, mica (Fig. 10b), and very few rounded sand-sized grains of glauconite are present. Laminations are formed by different contents of clay and quartz grains (Fig. 10d) and an amorphous, unidentified mineral. A higher amount of plant residues in 4b relative to layer 4b/c is a result of the increase in textinite and liptodetrinite (SI 4). Huminite tissues present in layer 4b are derived from herbaceous plants and exhibit a variable size, but rarely larger than 0.3 mm. Inertinite, including small, rounded charcoal particles, is present in very low numbers and no pattern or concentration was observed. Some telalginite derived from *Botryococcus*-type algae and a few rounded peat clasts cemented by a clayey and calcareous matrix were observed (Fig. 9c). Plant residue composition of the peat clasts is different from the other plant residues found in layer 4b. They are rich in inertodetrinite, their gelification grade is higher than of the other plant residues and they are generally well microlaminated (Fig. 9c). Apart from the peat clasts no aggregation of material was observed. The general appearance of the plant residues is fragmented. We observed very few complete plant bodies and no evidence for *in situ* growth of plants. Diatoms and sponge spicules also appear regularly but in lower numbers than that found in 4b/c and 4c (Fig. 10c). Pollen data show a distinctive decrease of aquatic pollen, e.g. *Ranunculacae* and in *Betula* pollen. An increase was observed in *Cyperaceae* (sedges), grasses, e.g. *Cerealia* type, *Asteraceae* and *Artemisia* and *Pinus* pollen (Fig. 8).

Fractures within the deposit appear generally fresh, and are likely recent in age (Fig. 10b).

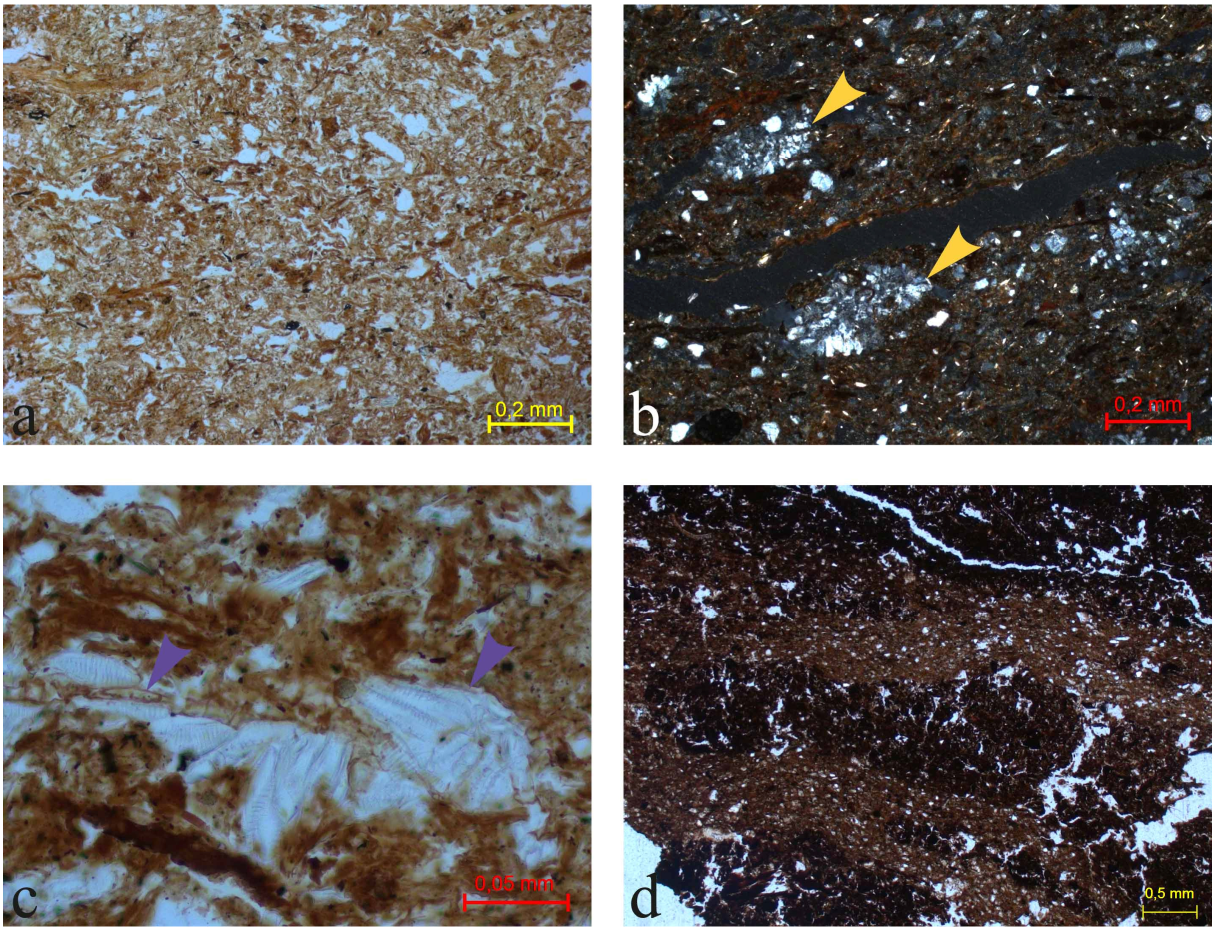


Fig. 10. Microphotographs of layer 4b. (a) Layer 4b consists dominantly of plant residues. Elongated plant tissues show a tendency for horizontal alignment. PPL, scale at lower right 0.2mm. (b) Layer 4b has a clayey fine mass and shows gypsum neoformation (yellow arrows). XPL, scale at lower right, 0.2mm. (c) Layer 4b contains diatoms (purple arrows) and sponge spicules. PPL, scale at lower right, 0.05mm. (d). Laminations of variable quartz, plant residue and clay content in layer 4b. PPL, scale at lower right, 0.5mm.

Some fractures exhibit dusty clay infillings, which formed after exposure following excavation. Secondary gypsum crystal intergrowths and framboidal pyrite were also observed. Some secondary, undetermined phosphate is present and associated with a larger fracture.

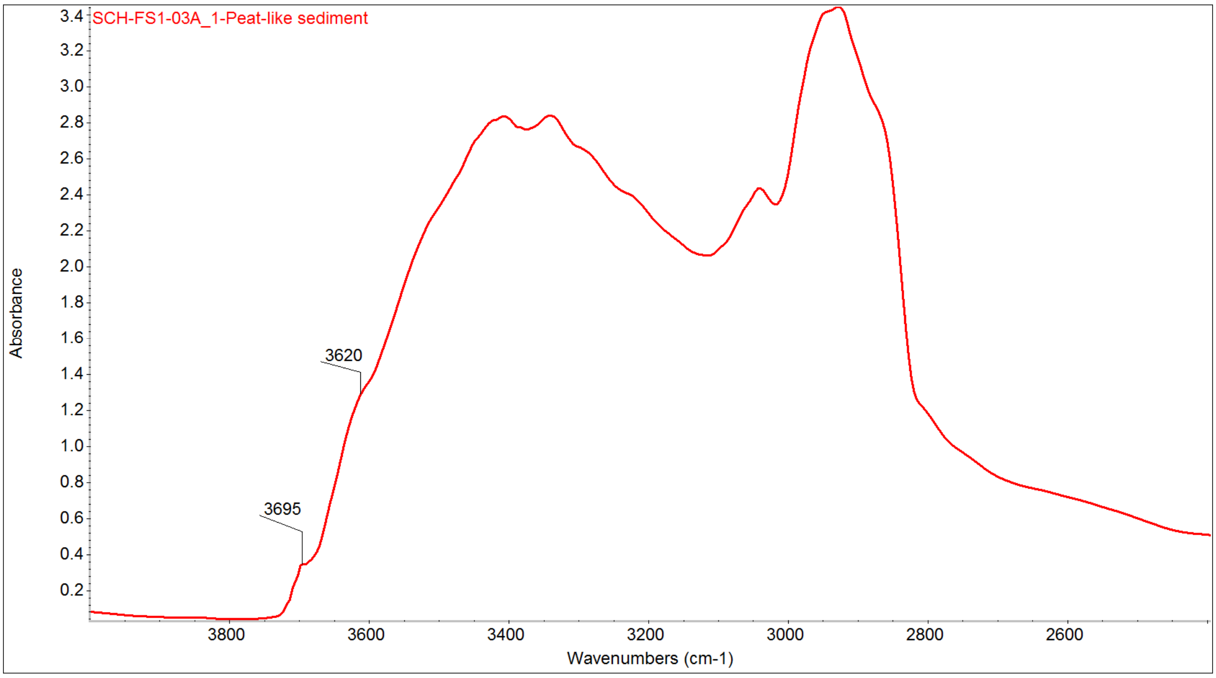


Fig. 11 Representative FTIR spectrum of layer 4b processed in petrographic thin section showing weak IR absorptions of kaolinite (weak at 3695 and 3620 cm-1) and no calcite.

<u>Layer 4a</u> The overlying layer 4a is also an organic mud (Table 1). No macroscopically visible plant fragments were observed by us in the field or laboratory, contrary to former observations (Böhner *et al.*, 2005; Thieme, 2007a). Layer 4a is represented in four thin sections from a single block sample collected in sediment column 4 (SI 2). In this sample we did not observe a significant difference between layer 4a and 4b, apart from a slight increase in clay. We also noted an increase in the size of plant residues in 4a compared to 4b. We observed rare occurrences of fragments 1.5 mm in size, but most plant remains were 0.5 mm to 0.2 mm. Furthermore, dark, humified plant residues that we did not observe in layer 4c, 4b/c and 4b, appear in layer 4a, in low numbers, varying in size from 0.35 to 0.1 mm. Complete plant bodies are very rarely observed and we noted no evidence for *in-situ* growing roots. Diatoms were not found in layer 4a. The contact with the fifth cycle, in the form of layer 5c and 5d, is sharp and locally has a layered appearance (Fig. 12). Pollen data from reference profile Schöningen 13 II (2003) among others and of site Schöningen 12 II (2009) point to a strong

increase of terrestrial herbs versus a decrease of tree pollen and local water logging enhancing raised bog growth (Urban *et al.*, this issue.).

Fig. 12. Thin section Schö 13 II-4 2010/24B containing layer 4a, 5d and their contact. The brown 4a is present in two laminations and is dissected by grey silt and clay laminations of layer 5d. Note the sharp contact between layer 4a and 5d. Size of slide 5x7.5 cm.

Layer 5c Layer 5c consists of a yellowish grey, sandy silt with some lamina of dark brown silt (see also Böhner *et al.*, 2005). Locally, this layer is underlain by layer 5d, consisting of a grey silt with laminations of bluish grey clay, brown organic silt and lenses of sand (Table 1, Fig. 12). In thin section, only layer 5d2 is present within three slides. Layer 5d2 consists of several discrete laminations varying in their content of fine material, clay, plant residues and quartz grains. The fine mass is clayey and slightly calcareous. Fine sand- to silt-sized quartz grains appear frequently, in contrast to few sand- and silt-sized grains of quartz in layers 4c to 4a. We observed few rounded clay soil aggregates and also small aggregates of humified organic material; however, plant residues here are very few and small, ranging from 0.04 mm to 0.02 mm. In layer 5c (Urban *et al.*, this issue) an increasing inflow of reworked pollen and a further increase of open landscape indicators is observed.

Schöningen 13 II Upper Berm

The contact of layer 4b/c with 4b was studied at three different profiles from Schöningen 13 II Upper Berm and four thin sections were available for this analysis (SI 1, Fig. 13, 14a). Layer 4b/c at Upper Berm does not differ significantly from its expression at Schöningen 13 II-4 and has the same components but within a different fabric (SI 2). Rounded aggregates of plant residues with a size range from 0.1 to 2 mm are present in both layers 4b/c and 4b (Fig. 14b and 14d). The sedimentary sequence at Schöningen 13 II Upper Berm exhibits some slumping structures, which distorted the previously homogenous structure of layer 4b/c and the contact with layer 4b (Fig. 13, 14a). One thin section exhibits a fault (Fig. 14a). In two areas the contact and layer 4b differ from each other at Upper Berm. Samples Schö 13 II Upper Berm 2011/23 and 2011/38 show a distorted contact produced by slumping, as well as a calcareous component in layer 4b, in the form of ostracod shells and chara (Fig. 14d); it exhibits a strong presence of diatoms compared to layer 4b at Schöningen 13 II-4. Additionally, a fissural microstructure was observed between layer 4b/c and 4b that continues upwards in 4b in sample Schö 13 II Upper Berm 2011/23 (Fig. 14c). In contrast to samples Schö 13 II Upper Berm 2011/23 and 2011/38, sample Schö 13 II Upper Berm 2011/43 exhibits a sharp contact from layer 4b/c to 4b; there was no calcareous component observed in layer 4b, similar to layer 4b at Schöningen 13 II-4.

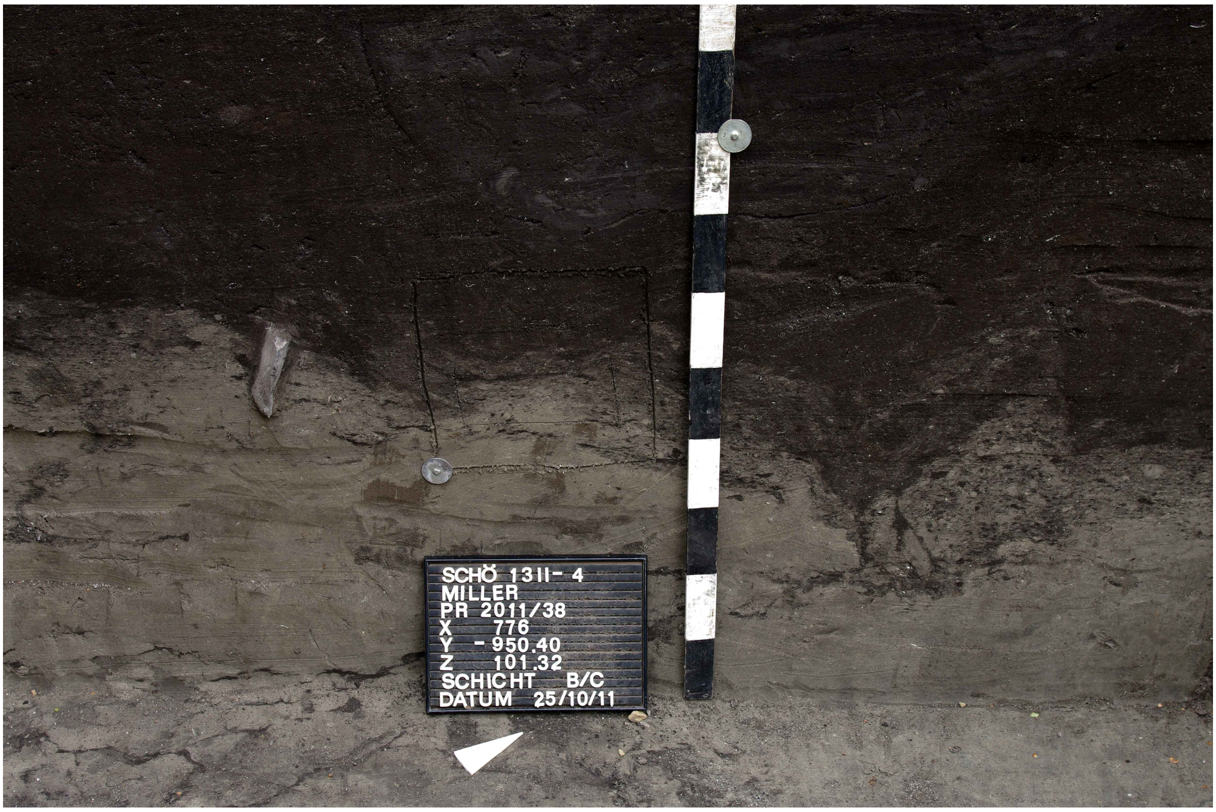


Fig. 13. Profile photo of Schöningen 13II Upper Berm showing the contact of layer 4b/c to 4b. The sedimentary sequence is affected by slumping. Note the bone fragment to the left of the outline of the sample at the direct contact of layer 4b/c to 4b (Photo Julian Bega).

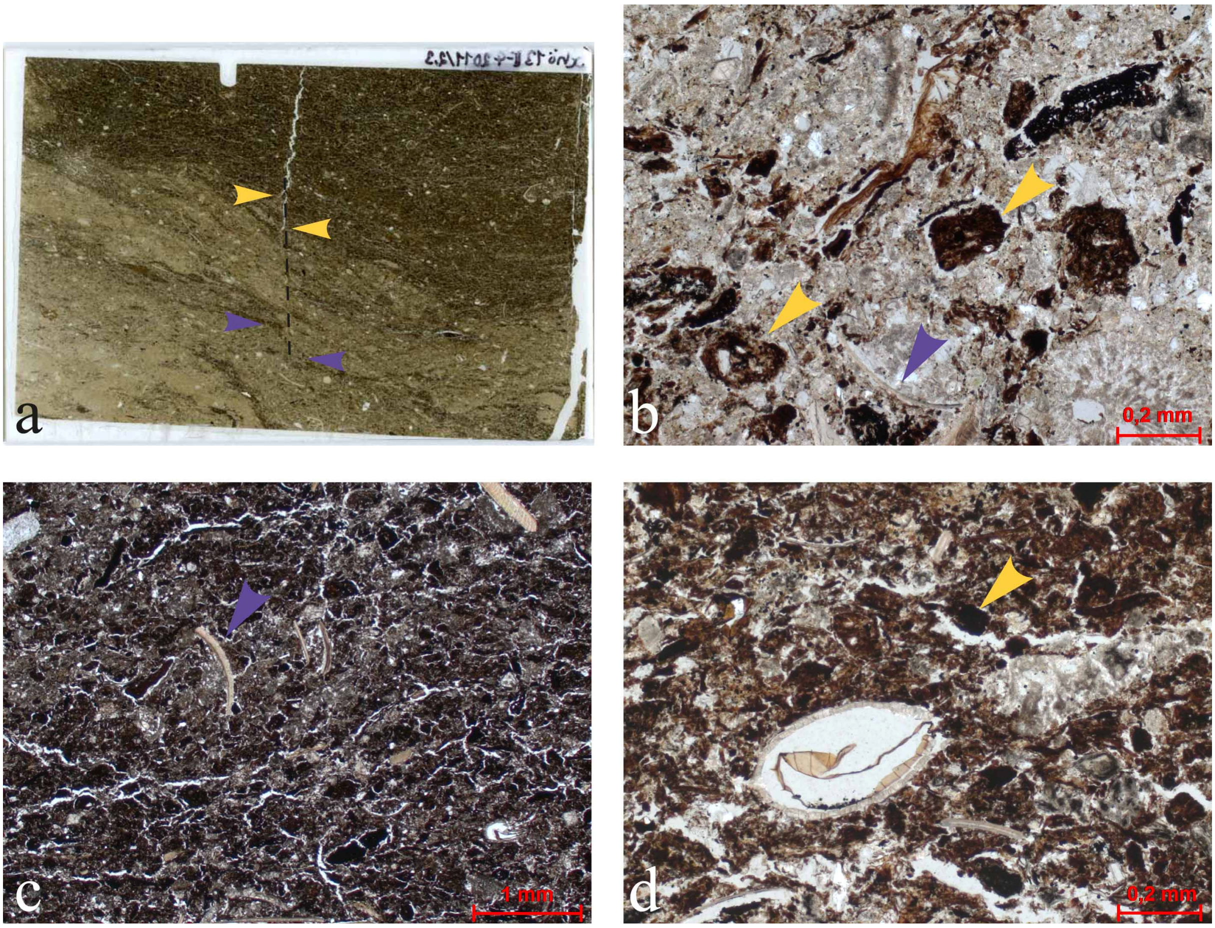


Fig. 14. Microphotographs at Schöningen 13 II Upper Berm. (a) Thin section Schö 13 II Upper Berm 2011/23 exhibiting a distorted contact of layer 4b to 4c with slumping and a fault structure (yellow and purple arrows matching up). (b) Layer 4b/c at Upper Berm with rounded organic clasts (yellow arrows) and ostracods (purple arrow) in a calcareous matrix. PPL, scale at lower right, 0.2mm. (c) Gradual and distorted contact of layer 4b/c to 4b at Sch 13II Upper Berm. Note the fissural structure and the ostracods (purple arrow). PPL, scale at lower left, 0.2mm. (d) Layer 4b with a fissural structure, round aggregates of plant residues (yellow arrow) and calcareous components such as shell fragments and chara. PPL, scale at lower right, 1mm.

Discussion

Depositional environments

The micromorphological, FTIR, and organic petrology results of the investigated profiles indicate that all three sedimentary layers associated with archaeological remains - layers 4c, 4b/c, and 4b - formed under permanent water coverage. Our findings comprise elements indicative of a sublittoral depositional environment as well as those characteristic of a mosaic swamp environment. Carbonate content decreases and organic content increases from layers 4c, 4b/c to layers 4b and 4a. This diachronic variation most likely reflects a lowering of lake level (see also Lang *et al.*, 2012a). The variation in sediments between Schöningen 13 II-4 and Upper Berm most likely reflect different energy settings, with the latter showing a higher energy setting. Our interpretation of a subaqueous nature of these deposits is based on three key observations: first, the identification of environmentally diagnostic components such as diatoms, sponge spicules, chara remains, and ostracods; second, the appearance, and association of sedimentary components, e.g., the rounded and fragmented morphology of plant residues, the association of terrestrial, littoral and subaqueous plant residues; and thirdly, microstratigraphic observations, e.g., the intact nature of fine laminations and the lack of evidence of pedogenesis or desiccation structures, which would have modified the original sedimentary features.

<u>Depositional environments - Schöningen 13 II-4</u> Layer 4c and layer 4 b/c are lacustrine, calcareous marls. The calcareous groundmass of layer 4c and 4b/c is the result of biochemically precipitated and bioturbated carbonates, representing a typical lacustrine process (Wright, 1990; Platt and Wright, 1991; Freytet and Verrecchia, 2002; Flügel, 2010). Diatoms, sponge spicules, chara remains, ostracod, and mollusk fragments and telalginite derived from the *Botryococcus*-type algae all indicate a sublittoral to open water lacustrine environment (Bouma *et al.*, 1990; Retallack and Wright, 1990; Freytet and Verrecchia, 2002). Furthermore, the consistently fragmented state of the plant tissue and size sorting indicate transport by water (Stach, 1975; Taylor *et al.*, 1998) whereas the small size of all sediment particles indicates a low energy setting. The occurrence of pyrite framboids reflects the presence of anoxic bottom water with moderate to high bacterial activity under reducing conditions, and a moderately high water-table in fresh-water peat-forming environments (Bouma *et al.*, 1990; Tang *et al.*, 2001; Roberts and Sneider, 2003). The macroscopic color variations in the calcareous marls are related to varying content and distribution of pyrite and iron oxides associated with the plant residues. The increase in plant residues in layer 4b/c might indicate a greater proximity to the shore, possibly as a result of lower lake levels (Dobrowolski, 2001). Furthermore, the pollen composition point to a lake level fall from layer 4c over 4b/c to 4b and the change in C/N ratio also points to increased terrestrial input (Meyers and Lallier-Vergés, 1999).

Layer 4b consists of a detrital mud of fragmented plant tissues, and is typical of a transported, subaqueous deposit (Overbeck, 1950; Stach *et al.*, 1975; Taylor *et al.*, 1998). The abundant evidence strongly suggests that layer 4b, like layer 4c and 4b/c, was deposited subaqueously: laminations, horizontal layering of elongated plant tissues, the repeated presence of reworked peat clasts, pyrite framboids, pyrite replacement of organic matter, and the presence of sponge spicules, diatoms, and telalginite derived from *Botryococcus*-type algae. Moreover, the various sources for the plant residues - terrestrial, littoral, subaqueous vegetation and peat - suggest that layer 4b was deposited in the open water zone of a lake. The fine size of the plant residues (< 0.3 mm) and the presence of silt and clay indicate that deposition of layer 4b occurred in a very low energy setting (Gastaldo and Demko, 2011). Furthermore, the very low humification of plant residues indicates short transport distance and rapid deposition as bacterial activity in the water column, leading to humification of the plant residues, is enhanced in carbonate-rich waters (Teichmüller and Teichmüller, 1982), and would otherwise have altered the plant residues more extensively. Rapid deposition could also be linked to lower water depth. The absence of *in situ* growing roots and the presence of well preserved *Botryococcus*-type algae indicate open water conditions (Wake and Hillen, 1980; Tyson, 1995; Jankosvská and Komárek, 2000).

Layer 4a is similar to layer 4b and is predominantly composed of fragments of plant residues. The similarities between these layers suggest that both represent detrital mud with a restricted transport and a subaqueous deposition. The only remarkable difference between layer 4b and 4a in the studied samples is the occurrence of dark, strongly humified plant tissues in 4a and the absence of diatoms, which might indicate decreased transport distance and thereby an increased shore proximity and decreased water depth. Based on the results of our study we agree with the previous designation of this layer as a "peat" as a descriptive term for a deposit very rich in organic matter (Stach *et al.*, 1975; Göttlich, 1976; Taylor *et al.*, 1998; Succow and Joosten, 2001) but not as a genetic term for an accumulation of organic material formed by *in situ* growth of plants. However, field observations of macroscopically visible plant remains made during the original excavation of Schöningen 13 II-4 (Thieme, 1999, 2005; Böhner, 2005) and botanical investigations of layer 4c and 4b (Urban *et al.*, this issue) do suggest a locally variable environment with some zones of *in situ* peat formation (see below).

The irregular and sharp contact with the overlying layer 5d2 represents an erosional contact, implying a higher energy environment. Layer 5d2 was deposited in a profundal lacustrine setting and displays intact laminations (see also Lang *et al.*, 2012a).

<u>Depositional environments - Schöningen 13 II Upper Berm</u> The investigated sedimentary sequence at Schöningen 13 II Upper Berm shows a slightly different picture from that at Schöningen 13 II-4: slumping, the intrusion of components from layer 4c into 4b, the

presence of round aggregates of plant residues in 4b/c and 4b. We interpret these aspects of the deposits as the result of a slightly higher and more variable energy setting than that at Schöningen 13 II-4, suggesting post-depositional disturbances of the archaeological record in the Upper Berm locality. The fissural structure of the organic mud in 4b at Schöningen 13 II Upper Berm is possibly related to physical stress as this excavation area is located 1.5 m underneath a road used by large vehicles of the mining company.

Depositional environments - Conclusion Based on our results, the deposits of Schöningen 13 II-4 and Schöningen 13 II Upper Berm can be envisioned as having formed within a mosaic environment of a swamp (see also Urban, 2007; Urban *et al.*, this issue). In this environment, deposition of archaeological materials occurred in subaqueous sediments and at different moments in time as their vertical distribution over at least two distinct geological units indicates (see also Voormolen, 2008; Musil, 2007). The herbaceous part of the plant detritus at Schöningen 13 II-4 originated from reed-like and sedge vegetation growing in the littoral and eulittoral zone that was permanently covered with shallow water. The deposition of the herbaceous part of the plant detritus occurred in a nearby open water setting. Furthermore, local topographic variation could have created small reed-covered islands in close association with the archaeological finds. Transported peat clasts, which show higher oxidation and also gelification, originate from adjacent *in situ* growing peat in the eulittoral zone, which was occasionally exposed and weathered (Teichmüller and Teichmüller, 1982; Meyer and Ishiwatari, 1993; Gastaldo and Demko, 2011). Birch and pine stands were present at some distance from the site, growing in the eu- and suppra-littoral zone. Sediments at Schöningen 13 II Upper Berm possibly reflect greater proximity to a water inflow source. During times of high rain fall and increased lake level, the increased inflow could have caused slumping of soft sediments, and, at the same, could have eroded aggregates of plant residues from elsewhere and transported them into the lake.

However, the sediments directly associated with the archaeological finds - 4c, 4b/c, 4b, and 4a - show no signs of ancient pedogenesis or desiccation, and were deposited subaqueously. Features that we would expect to find if these deposits were subaerially exposed would include slaking crusts and rip-up clasts, refilled channels, dissolved and recrystallized carbonates, truncated, *in situ* growing roots, root casts and fecal pellets (McSweeney and Fastovsky, 1987; Platt and Wright, 1991; Freytet and Verrecchia, 2002; Alonso-Zansa *et al.*, 2009; Flügel, 2010; Karkanas *et al.*, 2011). Instead, the sediments were preserved under water in their original structure until recent times. Due to groundwater lowering by EON in the 1970s and exposure of the sediment columns following excavation, some minor post-depositional processes have influenced the deposits: gypsum formation, fractures, burrowing, iron precipitation, and clay illuviation. We interpret these post-depositional features as recently formed phenomena.

Our results support interpretation of Lang and colleagues (2012a), that the sequences at Schöningen 13 II-4 and the Upper Berm result from lowering lake level superimposed by a profundal deposit of the fifth shallowing cycle (layer 5c) associated with rising lake level. Sedimentary layers 4c, 4b/c, 4b, and 4a all are sublittoral layers, but reflect different lake level stands. If the artifacts found within these layers were deposited contemporaneously with these sediments, they most likely represent deposition at different moments in time (see also Musil, 2007; Voormolen, 2008; Julien *et al.,* this issue a).

Implications for archaeological site formation

Seasonally dry surface Our interpretation of a depositional environment for Schöningen 13 II-4 that was constantly under water stands in contrast to former interpretations of the depositional environment of the archaeological assemblage. Thieme's site formation model (1999, 2005) argues for the presence of a dry surface on which the hominin activities occurred. However, we did not find any evidence for the presence of a previously dry surface in the sediments at Schöningen 13 II-4. Furthermore, much of the evidence used to argue for the presence of a dry surface have other, more likely explanations in light of the present study. For example, the observed reddening of the purported hearths, which was used to argue for the presence of a dry surface, is the result of recent, post-depositional precipitation of iron oxide along a redox gradient (see Stahlschmidt *et al*., this issue) and therefore does not present evidence for a dry surface. The black surface marks on some of the bones, which were interpreted as the result of root activity by Thieme (2005), might either be humification traces or manganese staining associated with water and not biological agents. The identification of these traces can be done only by the application of detailed analysis and only their morphological form can differentiate between specific plant parts. Instead, within our study, we found no evidence for the *in situ* growth of roots in the sediments which contain the bones. Although Thieme (2005) reported the presence of rills at the contact between the marl and the organic mud, we did not find any geological evidence for an erosive surface. Rather, the presence of a transitional layer (4b/c) between the calcareous marl (4c) and the organic mud (4b) suggests that deposition was constant and gradual under subaqueous conditions.

We cannot rule out a small-term variation of the water table that would not have left behind evidence of aerobic exposure of the organic material or mineral sediment. However, repeated water table fluctuations, as would be implied by the isotopic evidence for multiple kill events (Julien *et al.*, this issue a), should have left structural traces in the form of slaking crusts, desiccation fractures, or aggregate formation, and would have caused occasional oxidation of sedimentary organic matter. None of these desiccation indicators were observed in the sediments of Schöningen 13 II-4 or Schöningen 13 II Upper Berm.

Similarly, our results pose some problems for Voormolen's kill site model for Schöningen 13 II-4. Voormolen (2008) suggested that early hominins repeatedly drove horses into the wet and soft lacustrine mud, where they were easy to kill. Our data do not thoroughly support such a depositional environment but instead show that the find horizons were under constant water cover and most likely not accessible for human butchery practices. Frison and Stanley (1982) and Frison (1989) believe that the use of muddy lake shores to trap animals is unlikely and argue that it is difficult if not impossible to butcher and remove meat from a bog. Furthermore, no vertically articulated lower limbs, which provided highly suggestive evidence for such behavior at Olduvai (Leakey, 1971) and the Paleoindian Big Lake Bison Kill site in North America (Turpin *et al.*, 1997), have been reported for Schöningen. Therefore, further mechanisms for the formation of Schöningen 13 II-4 need to be considered.

The results of our study present an apparent contradiction in the geoarchaeological record at Schöningen: the site contains coarse-grained anthropogenic components within a fine-grained, subaqueous deposit. In geology, the occurrence of coarse-grained components in subaqueous, fine-grained sediments is often interpreted as dropstones, which are explained by short term, single events of deposition, e.g., stones drifting on lake ice or being projected (e.g., through volcanic eruption) into the lake (see e.g., Bennett *et al.*, 2009). Based on this analogy, comparisons with other archaeological sites, and ethnographic parallels, we present and discuss three alternative site formation models: first, the archaeological material was displaced by geogenic processes; second, the archaeological material was placed into the lake by human activities; third, human activity took place on a frozen lake surface.

<u>Geogenic displacement of the assemblage</u> Geogenic processes of fluvial activity, wave movement, and floatation could have displaced the archaeological assemblage from a nearby

location of hominin activity into the lacustrine sediments. Evidence for fluvial activity of such a magnitude to transport the archaeological remains into the lake was not observed in the sedimentary sequence. Supporting this observation is the fact that no naturally occurring, coarser grained materials in the size range of the archaeological remains have been reported from the find horizons. The very low occurrence of sediment abrasion and rounding of the bones and artifacts suggests that fluvial reworking had only a minor impact on the archaeological remains. However, the low amount of sediment abrasion and rounding on the bones is not surprising given the fine-grained nature of the sediments. Furthermore, the lack of size sorting does not necessarily exclude water transport (Isaac, 1977; Schick, 1986; but see Thayer Morton, 2004). Evidence for wave action was not observed in the sediments from Schöningen 13 II-4 and the intact laminations in layer 4b suggest absence of wave action (but see Julien *et al.*, this issue b for evidence of wave action at Schöningen 12 II-4). However, no orientation pattern and spatial analysis have so far been published for the archaeological remains at Schöningen 13 II-4.

Paleontological sites in lacustrine settings have been explained as the result of animals dying at the lake margin and washing into the lake by floatation, e.g. at Messel lake, Germany (Koenigswald *et al.*, 2004). However, the archaeological assemblage at Schöningen 13 II-4 is comprised of objects with different sizes and densities, as well as transport properties: dry wood implements could have ultimately floated, whereas flint artifacts, fresh bone, and water soaked wood (see below) would have to have been transported by traction. In any case, their mutual deposition in the same place by natural processes would have required a very short transport distance combined with a low energy setting. The setting of the site in a mosaic environment with close association of open water, vegetated islands, and solid ground makes small-scale displacement of the assemblage into subaqueous deposits a plausible scenario. If the formation of Schöningen 13 II-4 is a result of such small-scale displacement, it leaves open the possibility that the spatial association of the archaeological remains may have some behavioral significance (Thayer Morton, 2004).

Anthropogenic displacement of the assemblage Another scenario that may explain the formation of Schöningen 13 II-4 is human disposal of materials into the lake. This activity could have included two different behaviors: waste disposal and storage of wooden tools in wet environments. Waste disposal into the lake could have been a type of site maintenance activity, aimed at avoiding attraction of predators in a highly competitive ecosystem.

Considering the evidence for repetitive hunting of horses in the same location (Julien *et al.,* this issue a), it is possible that the hominins chose to dispose of butchery waste to keep away insects and to avoid scaring off future prey (see e.g., Grønnow, 1985). Waste disposal into lakes has ethnographic parallels. For example, Taylor and Turner (1969) observed Inuit disposing whole carcasses into lakes after mass kills. Furthermore, waste disposal behavior has been suggested for Mesolithic (see e.g., Street, 1989), Neolithic and lake sites of younger periods (see e.g. Menotti, 2004). To our knowledge, this type of behavior has not been suggested for any other Paleolithic site.

Storage and caching of resources could also explain the formation processes at Schöningen 13 II-4. Such behavior has been documented in the ethnographic literature. Pohlhausen (1953) reports that Inuit store carcasses in cold lake water. Sharp (1981) notes similar behavior among the Chipewyan people, who store reindeer carcasses in ice-cold lake water. Archaeological parallels are reported by Fisher (1995, 2009), who interpreted finds of mastodon remains with butchery marks in North American lake sites as evidence for subaqueous storage of meat. Experiments that he conducted demonstrated good preservation conditions using this method (Fischer, 1995). Similarly, Pohlhausen (1953) suggested that storage behavior was responsible for the accumulation of reindeer remains at the late Paleolithic lake site of Stellmoor. Grønnow (1985) suggested similar lake-water storage behavior for caches of worked antler blanks found in lake sediments at the same site.

<u>Frozen lake surface</u> Another possible scenario is that human activity occurred on the frozen surface of the lake. This model is based on the geological concept of dropstones. One could also imagine flints, bone remains and wooden spears that were rafted on ice and were eventually deposited in subaqueous deposits. This scenario would suggest that human activity took place on a frozen lake surface, which subsequently melted away. Using frozen lake and river surfaces as activity areas, including for hunting, butchery and also for storage, is a common practice in northern latitudes (McHugh, 1972; Landals, 1990; Fisher, 1995; Helm, 2000; Brink, 2008; Fisher, 2009). The animals are driven onto lake or river ice, where the slippery surface works as trap decreasing the animal's mobility. We did not observe sedimentary signatures that would indicate the former presence of a frozen lake surface (see e.g., Squyres *et al*., 1991). However, such evidence is rarely encountered in sediments located in the submerged zone of the lake. Furthermore, the model of a frozen lake surface is partially contradicted by isotopic data (Julien *et al*., this issue a) that shows that the horses died in multiple events between summer and early winter.

Conclusion

The multidisciplinary approach taken here presents a novelty in the analysis of lacustrine Middle Pleistocene sites. Using the methods of micromorphology, organic petrology, FTIR, palynology and sedimentology we were able to produce some robust inferences on the depositional history of the water body and its relationship to associated human occupation. Our evidence shows that the deposits of Schöningen 13 II-4 and Schöningen 13 II Upper Berm investigated in this study formed within the environment of a mosaic swamp landscape where the dry shore, the various lake margin zones, and open water zone were in close spatial association. However, the archaeological assemblage was preserved only in an aqueous setting. The depositional environment of the archaeological remains makes in-place hominin activity highly unlikely. This being said, the possibility of waste disposal and storage in the lake suggests novel behaviors related to subsistence in the Middle Pleistocene. The two alternative site formation models of small-scale geological reworking and a frozen lake surface both imply a secondary context of the archaeological assemblage. As none of the models explains every property of the archaeological assemblage so far, it seems that the archaeological assemblage presents a palimpsest of different behaviors that occurred in a restricted, localized area at different points in time. Our results suggest that Middle Pleistocene subsistence behavior may have involved more complex associated behaviors than previously assumed. Furthermore, the archaeological remains from Schöningen show that these early hominins had a range of behaviors that allowed them to successfully cope with the cold climate in northern latitudes, and that they systematically and successfully exploited this landscape.

High resolution spatial analysis of the horizontal and vertical distribution and orientation pattern of the finds in relation to find category, suspension capability, size, density, and refittings in relation to the geoarchaeological data (see e.g., Boschian and Sacca, 2010) and the continued excavation at Schöningen 13 II Upper Berm will eventually provide a clearer site formation model for Schöningen 13 II-4. This study has highlighted the importance and potential of contextual studies of the sediments associated with archaeological remains and calls for caution in the interpretation of hominin behavior at sites in similar settings without similar contextual analysis.

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Supplementary Information

Supplementary Information 1 Sample list

Sample No	Square	Z-value*	Affiliation	Layer	Employed method
Schö 13 II-4 Sch FS1 1	683/21	102.56	Sediment column 1	4b/c-4b	Micromorphology, mFTIR, Organic Petrology
Schö 13 II-4 Sch FS1 2	682/21	102.40	Sediment column 1	4b/c-4b	Micromorphology, mFTIR
Schö 13 II-4 Sch FS1 3	683/21	102.80	Sediment column 1	4b/c-4b	Micromorphology, mFTIR, Organic Petrology
Schö 13 II-4 Sch FS1 4	682/21	102.42	Sediment column 1	4c	Micromorphology, mFTIR
Schö 13 II-4 Sch FS1 5	684/22	102.17	Sediment column 1	4c	Micromorphology, mFTIR
Schö 13 II-4 2010/29	693/14	102.42	Sediment column 2	4b/c-4b	Micromorphology, FTIR
Schö 13 II-4 2010/30	693/13	102.46	Sediment column 2	4b/c -4b	Micromorphology, FTIR
Schö 13 II-4 2011/01	695/8	102.99-102.74	Sediment column 3	4b/c -4b	Micromorphology
Schö 13 II-4 2011/5	694/6	102.73	Sediment column 3	4b/c-4b	Micromorphology
Schö 13 II-4 2011/08	695/7	103.00	Sediment column 3	4b/c-4b	Micromorphology
Schö 13 II-4 2010/23	704/9	101.65-102.05	Sediment column 4	4c-4b/c-4b	Micromorphology, FTIR
Schö 13 II-4 2010/24	705/9	101.51-102.15	Sediment column 4	4c-4b/c-4b-4a-5d	Micromorphology, FTIR
Schö 13 II-4 2003/3.1	719/-995	102,16	Frozen block sample	4b-4b/c	Micromorphology
Schö 13 II-4 2010/9.1	683/21	101.90	Sediment column 1	4c	Palynology and Sedimentology
Schö 13 II-4 2010/9.2	683/21	102.42	Sediment column 1	4c-4b/c	Palynology and Sedimentology
Schö 13 II-4 2010/9.3	683/21	102.65	Sediment column 1	4b/c	Palynology and Sedimentology

Schö 13 II Berme 2011/23	776/-949	101.26	Upper Berm	4b/c-4b	Micromorphology
Schö 13 II Berme 2011/38	776/950	101.32	Upper Berm	4b/c-4b	Micromorphology
Schö 13 II Berme 2011/43	778/963	100.59	Upper Berm	4b/c-4b	Micromorphology

*Z-value relate to block sample

Supplementary Information 2. Micromorphological description of the layers.

	Unit	Microstructure, aggregates, voids & ratio coarse to fine fraction	mFTIR & FTIR	Fine fraction*	Coarse fraction*	Comments
Schö 13 II-4 sediment column 4	5d	Laminations, rounded aggregates	Quartz, clay (smectite, kaolinite)	Clay to slightly calcareous (micritic)	Quartz (rounded, fine sand to silt sized, all fragments, light to dark brown in color), plant residue (0.04 to 0.02 mm), rounded glauconite	Laminations varying in content of fine material, plant residues and quartz grains
Schö 13 II-4 sediment column 4	4a	Homogenous, elongated plant tissue with a tendency for horizontal alignment	Gypsum, quartz, clay (smectite, kaolinite), organic matter	Clay and amorphous organic fine material	Plant residues (1.5 to 0.002 mm, dominantly 0.5 mm to 0.2 mm, all fragments, light to dark brown in color), quartz (rounded, fine sand to silt sized), mica, pyrite framboids, sponge spicules, rounded glauconite, very few rounded charcoal particles	Regular appearance of humified plant residues Contact with layer 5d sharp and layered No *in-situ* growing roots observed
Schö 13 II-4	4b	Homogenous to locally laminated;	Quartz, clay	Clay and amorphous	Plant residues (0.1 to 0.002 mm, but predominantly ~0.5 to 0.1 mm; all fragments,	Contact with unit 4a gradual to

sediment column 1 -4		elongated plant tissue with a tendency for horizontal alignment, large fractures, lens structure in one TS	(smectite, kaolinite), organic matter, gypsum	organic fine material	light brown to brown in color), gypsum, quartz (rounded, fine sand to silt sized), mica, framboidal pyrite, sponge spicules, diatoms, very few rounded charcoal particles	indiscernible Lowermost centimeters with laminations No *in-situ* growing roots observed
Schö 13 II-4 sediment column 1 -4	4b/c	Water escape structures elongated plant tissue with a tendency for horizontal alignment, simple packing voids, some large fractures	Calcite, quartz, clay (smectite, kaolinite), organic matter	Dominantly micritic to rarely rhombohedral calcite to clayey and amorphous organic fine material	Plant residues(0.02 to 0.001 mm, but predominantly around 0.5 to 0.1mm all fragments, light brown to brown in color), quartz (rounded, fine sand to silt sized), framboidal pyrite, ostracods and mollusk fragments, chara, gypsum sponge, spicules, diatoms, bone fragments (angular, ~0.5 mm)	Contact with unit 4b clear and with intense iron precipitation No *in-situ* growing roots observed Diffuse iron precipitation
Schö 13 II-4 sediment column 1, 4	4c	Homogenous, elongated plant tissues with tendency for horizontal	Calcite, gypsum, quartz, few clay (smectite,	Dominantly micritic to rarely rhombohedral calcite to slightly clayey	Quartz (rounded, fine sand to silt sized), plant residues (0.01 to 0.2 mm, all fragments, light brown to brown in color) framboidal pyrite, gypsum, ostracod and mollusk fragments, chara, diatoms sponge spicules	Contact with unit 4b/c gradual No *in-situ* growing roots observed Diffuse iron

		alignment, simple packing voids, few larger fractures	kaolinite)			precipitation
Schö 13 II-4 2003/3.1	4b	Elongated plant tissue with a tendency for horizontal alignment, large vertical fractures slightly fissural	-	Clayey	Plant residues (around 0.5 to 0.1 mm; all fragments, light brown to brown in color), gypsum, quartz (rounded, fine sand to sit sized), mica, framboidal pyrite, diatoms, sponge spicules	Contact with 4b/c clear but fractured Fracture and fissure probably related to recent freezing and defrosting
Schö 13 II-4 2003/3.1	4b/c	Elongated plant tissue with a tendency for horizontal alignment, simple packing voids, some large fractures	-	Dominantly micritic to rarely rhombohedral calcite to clayey and amorphous organic fine material	Plant residues(0.5 to 0.1 mm all fragments, light brown to brown in color), quartz (rounded, fine sand to silt sized), framboidal pyrite, ostracods and mollusk fragments, chara, gypsum, sponge spicules, diatoms, bone fragments (angular, ~0.5 mm)	Fractures probably related to recent freezing and defrosting
Schö 13 II Upper	4b	Elongated plant tissue with a	-	Clayey and micritic calcite	Plant residues (around 0.5 to 0.1 mm; all fragments, light brown to brown in color),	Contact with 4b/c distorted by soft

Berm, Samples 2011/23 and 2011/38		tendency for horizontal alignment, large vertical fractures fissural		and amorphous organic fine material	rounded aggregates of plant residue (0.1 to 2mm, dark brown), gypsum, quartz (rounded, fine sand to sit sized), mica, framboidal pyrite, ostracod and mollusk shells, chara, diatoms, sponge spicules	sediment deformation
Schö 13 II Upper Berm Samples 2011/43	4b	Elongated plant tissue with a tendency for horizontal alignment, large vertical fractures	-	Clayey and amorphous organic fine material	Plant residues (around 0.5 to 0.1 mm; all fragments, light brown to brown in color), rounded aggregates of plant residue (0.1 to 2mm, dark brown), gypsum, quartz (rounded, fine sand to sit sized), mica, framboidal pyrite, diatoms, sponge spicules	Contact with unit 4b/c clear and with intense iron precipitation
Schö 13 II Upper Berm 2011/23, 2011/38 and 2011/43	4b/c	Elongated plant tissue with a tendency for horizontal alignment, simple packing voids, some large fractures	-	Micritic calcite to clayey and amorphous organic fine material	Plant residues(0.5 to 0.1mm all fragments, light brown to brown in color), rounded aggregates of plant residue (0.1 to 2mm, dark brown), quartz (rounded, fine sand to silt sized), framboidal pyrite, ostracods and mollusk fragments, chara, gypsum, sponge spicules, diatoms, bone fragments (angular, ~0.5mm)	

* limit fine to coarse fraction at 0.01µm

Supplementary Information 3. Reflectance Results.

Samples Schö 13 II-4 Sch FS1 1 & 3

Lithological units	Huminite reflectance (telohuminite)			Fluorescence properties of organic particles		Palaeo-environmental indicators	
	Mean value %Rr	Std	N	Huminite	Liptinite	faunal relics; algae	sedimentary features
4b	0,17 and 0,21	0,028 and 0,039	200	non-fluorescing to brown fluorescing	brightly yellow to yellow and green to bright green fluorescing	rare to few ostracod cuticles; few sponge spicules; very rare Botryococcus-typ algae	randomly oriented plant residues; high degree of fragmentation (sporinite, suberinite); peat clasts: <150µm (reworked peat)
upper contact	0,13 and 0,19	0,031 and 0,048	63	non-fluorescing to brown fluorescing	brightly yellow to yellow and brightly green fluorescing	few to rare ostracod cuticles; very rare sponge spicules and very rare Botryococcus-typ algae	high degree of fragmentation (sporinite, suberinite); peat clasts: <150µm (reworked peat)
lower contact	0,15 and 0,17	0,042 and 0,054	57	non-fluorescing to brown fluorescing	yellow and brightly green to green fluorescing	Variable amounts of ostracod shell and cuticles; rare sponge spicules; rare Botryococcus-typ algae	high degree of fragmentation (sporinite, suberinite); peat clasts: 30-60 µm (reworked peat)

4c	0,15 and 0,22	0,051 and 0,030	54	non-fluorescing to brown fluorescing	brightly yellow to yellow and green to bright green fluorescing	Frequent to few ostracod shells and cuticles; few diatoms and sponge spicules; rare Botryococcus-typ algae	high degree of fragmentation (sporinite); peat clasts: 100-250µm (reworked peat); facies strongly bioclastic

Supplementary Information 4.

SEMI-QUANTITATIVE PETROGRAPHIC ANALYSIS

Samples Schö 13 II-4 Sch FS1 1 & 3

Preparation: two polished blocks

Maceral group	**Maceral**	**Reflected light** (oil immersion)	**Fluorescence** (uv-light + violet-light excitation; oil immersion)	**Petrographic composition**															
			Facies :	**4b/c**				**lower contact**				**upper contact**				**4b**			
				rare	few	common	abundant	rare	few	common	abundant	rare	few	common	abundant	rare	few	common	abundant
Huminite	Textinite	fine fragments (10-300µm) of ungelified or partly gelified tissues, almost exclusively derived from herbaceous plants, dark grey with reddish internal reflections; rare fragments (150-250 µm) of root tissues (facies 03aB)	weak dark brown and yellow-brown fluorescence	▨	▨			▨	▨	▒		▨	▨	▒		▨	▨	▨	▒
	Ulminite	fine fragments of gelified tissues (size: up to 400 µm), almost exclusively derived from herbaceous plants, dark grey with reddish internal reflections	weak dark brown to non-fluorescing	▨				▨				▨	▒			▨	▒		
	Attrinite	mixture of ungelified fine humic detritus (<10µm) and porous amorphous humic matter: mostly associated to the peat clasts (clasts size: 60 to 250µm)	weak brown	▨				▨				▨				▨			
	Densinite	mixture of gelified fine humic detritus (<10µm) and porous amorphous humic matter	weak brown to non-fluorescing																
	Corpohuminite	homogeneous humic cell excretions	weak brown to non-fluorescing	▨	▒			▨	▒			▨				▒			
	Gelinite	homogeneous or porous amorphous humic gels	non-fluorescing													▒			
Liptinite	Sporinite	dark grey to orange-brown microspores (spores, pollen grains) and sporongia; often fragmented and frequent in the peat clasts	moderately intense yellow, yellow-green	▨				▨	▨			▨	▨			▨	▨		
	Cutinite	leaf cuticles	moderately intense brown, yellow																
	Resinite	intra-/extra-cellular resin and waxes bodies	intense brown, yellow, green	▒															
	Fluorinite	small intra-cellular granules in leaf tissues (lipid secretions)	intense green, yellow					▒				▒				▒			
	Suberinite	thin fragments of folded thin tissues, orange-brown, more or less translucent: bark- or cork-derived tissues	intense yellow	▨				▨	▨			▨	▒			▨	▨		
	Alginite	alginite (telalginite) derived from *Botryococcus* -type algae (20-80µm)	intense yellow and yellowish-green	▨				▨	▒			▒				▨	▒		
	Liptodetrinite	small fragments of liptinite macerals less than 7-5µm in size; mostly associated to the peat clasts	moderately intense to intense yellow to yellowish-green	▨				▨	▨	▒		▨	▨	▒		▨	▨	▨	
	Chlorophyllinite	occurs sporadically as small particles (1-5µm) in peat clasts	intense blood-red	▨															
	Bituminite	finely granular amorphous groundmass, dark grey with reddish internal reflections	weak to moderately intense, brown to yellow-brown																
Inertinite	Fusinite	fragments of well-preserved tissues (80-400µm), white, high reflecting, mostly derived from herbaceous plant tissues: product of wild fire (charcoal)		▨				▨				▨				▨			
	Semifusinite	light grey, low reflecting tissues (20µm): product of aerobic biodegradation or wild fire (charcoal)		▨								▨				▨	▒		
	Funginite	middle grey to light grey sclerotia (20-50 µm in size) often fragmented and other fungal remains		▨				▒				▨				▒			
	Secretinite	grey, white, vesicular and non-vesicular bodies, various morphology: oxidation or combustion products of resin or humic gels																	
	Macrinite	light grey or white amorphous matrix or discrete structureless bodies: product of dehydratation of humic matrix substances; metabolic product of fungi and bacteria																	
	Inertodetrinite	isolated cell-wall fragments of fusinite and semifusinite tissues (2-5 to 10µm), homogeneous, white (high reflecting) and light grey (moderately reflecting): product of wild fire (strongly fragmented charcoal); mostly as inclusions in the peat clasts		▨				▨				▨				▨			
Natural char		fragmented, low reflecting spheroidal carbon particles (30-80 µm), with porous spherical morphology : influence of heat from fire on peat (product of ground fire or surface fire)		▒				▒								▨			
Faunal relics	Ostracods	fragments of shells and well preserved cuticles (dark grey)	shells: moderately intense greenish; cuticles: non-fluorescing	▨	▨	▒		▨	▨			▨	▒			▨	▒		
	Sponge spicules	siliceous spicules with rod-like morphology in longitudinal sections and circular morphology in transverse sections	non-fluorescing	▒				▒				▒				▨	▒		
	Other bioclasts	few diatoms and highly fragmented shells (?)	bright green or yellowish-green	▨	▨	▒		▨				▨				▨			
Mineral matter	Clay minerals	finely dispersed inclusions in carbonate matrix and as matrix in huminit-rich clayey aggregates	weak to moderately intense brownish	▨	▨			▨	▨			▨	▨			▨	▨	▨	▒
	Carbonates	major component of the matrix : mixture of carbonate mud, pellets and sparry calcite; rare rhombohedral dolomite crystals with fluorescence zonation	weak to moderately intense greenish to dark brown	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨	▨		
	Gypsum	isolated crystals of very variable size and radiating aggregates (80-250 µm)	weak dark greenish	▨				▨	▨			▨				▨	▨		
	Quartz	mostly well rounded quartz grains (10-140µm in size)	non-fluorescing	▒				▨				▨	▒			▨			
	Pyrite	single crystals, framboids (up to 20 µm in diameter and some strongly weathered) and aggregates; greyish concretions (spongy pyrite?) with anisotropic mineral inclusions (marcasite?) near the top of unit 4c	non-fluorescing	▨	▨	▨		▨	▨	▨		▨	▒			▨	▨	▒	
	Metal oxides	iron oxides and hydroxides (?) showing colloform textures; rare plant tissues (textinite, fusinite, funginite) are permineralized by ferriferous (?) reddish-grey minerals; in unit 4c : only near the top	non-fluorescing	▒				▨	▨			▨							
	Other minerals	epigenetic heterogeneous and anisotropic mineral concretions, and detritic minerals?	non-fluorescing	▨	▒			▒											

Note that concerning the liptinite group and the inertinite group, the table shows only the macerals encountered in the samples, and not the entire classification

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Anhang 4

Stahlschmidt, M.C., Miller, C.E., Ligouis, B., Hambach, U., Goldberg, P., Berna, F., Richter, D., Urban, B., Serangeli, J., Conard, N.J. (eingereicht b). On the evidence for human use and control of fire at Schöningen. Journal of Human Evolution. Special issue Schöningen (57 pages)

On the evidence for human use and control of fire at Schöningen

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When and how humans began to control fire has been a central debate in Paleolithic archeology for decades. Fire plays an important role in technology, social organization, subsistence, and manipulation of the environment and is widely seen as a necessary adaptation for the colonization of northern latitudes. Many researches view purported hearths, burnt wooden implements, and heated flints from Schöningen as providing the best evidence for the control of fire in the Middle Pleistocene of Northern Europe. Here we present results of a multianalytical study of the purported hearths along with a critical examination of other possible evidence of human use or control of fire at Schöningen. We conclude that the analyzed features and artifacts present no convincing evidence for human use or control of fire. Our study also shows that a multianalytical, micro-contextual approach is the best methodology for evaluating claims of early evidence of human-controlled fire. We advise caution with macroscopic, qualitative identification of combustion features, burnt flint, and burnt wood without the application of such techniques as micromorphology, Fourier transform infrared (FTIR) spectroscopy, organic petrology, luminescence, and analysis of mineral magnetic parameters. The lack of evidence for the human control of fire at Schöningen raises the possibility that fire control was not a necessary adaptation for the human settlement of northern latitudes in the Lower Paleolithic.

Keywords: Early fire - northern latitudes - human behavior - Paleolithic archaeology - Schöningen -micromorphology

Introduction

The origins of the use and control of fire is one of the central and most debated topics in Paleolithic archaeology and human evolution (see e.g., Goudsblom, 1986; James, 1989; de Lumley, 2006; Gowlett, 2006; Wrangham, 2009; Alperson-Afil and Goren-Inbar, 2010; Roebroeks and Villa, 2011a; Sandgathe *et al.*, 2011a; Gowlett and Wrangham, 2013). Fire use and control would have provided several crucial advantages to early humans: it can serve as a light and heating source (Oakley, 1955; Bellomo, 1994; Gilligan, 2010), as a hunting aid (Goudsblom, 1986; Mallol *et al.*, 2007), can be used for cleaning occupation surfaces (Wadley *et al.*, 2009; Wadley *et al.*, 2011), as protection from predators (Goudsblom, 1986; Brain; 1991), as a means to improve tool technology (Ahlers, 1983; Brown *et al.*, 2009; Mallol *et al.*, 2007), and as a way to increase food range, its nutritional value, and preservation (Stahl *et al.*, 1984; Bellomo, 1994; Wrangham *et al.*, 1999; Wrangham, 2003; Mallol *et al.*, 2007; Wrangham, 2009) (or see Clark and Harris, 1985, for an overview). Because of these advantages, archaeologists assign fire use and control an important role in human evolution. Brain (1991) suggests that fire use and control could have increased early humans' competiveness (Brain, 1991), and Gowlett (2006) and Wrangham (2009) amongst others (Rolland, 2004; Pruetz and LaDuke, 2010) suggest that fire use and control impacted the evolution of biological traits, including brain size and cognition.

Furthermore, several researchers see the use and control of fire as a precondition for the first settlement of northern latitudes (Oakley, 1955; Binford, 1985; Brace *et al.*, 1987; Straus, 1989; Weiner *et al.*, 1998; Wrangham *et al.*, 1999; Klein, 2002; Rolland, 2004; Gowlett, 2006; Preece *et al.*, 2006). The sites at Schöningen are referenced as among the earliest such examples (Thieme, 1997; Mania, 1995; Klein, 2002; Goren-Inbar *et al.*, 2004; Thieme 2005; Alperson-Afil and Goren-Inbar, 2006; Gowlett, 2006; Preece *et al.*, 2006; Thieme 2007a-d;

Berna and Goldberg, 2008; Klein, 2009; Wrangham, 2009; Daniau *et al.*, 2010; Roebroeks and Villa, 2011a; Gowlett and Wrangham, 2013; Shahack-Gross *et al.*, 2014). Northern latitudes present several challenges to their occupants, having shorter duration of daylight in winter, severely cold winters, a variety of large predators, and a scarcity of edible plants during winter, consequently demanding a stronger reliance on animal resources. According to Gilligan (2010) these challenges can be answered through seasonal migration, physical adaptation, or technological improvement in the form of new hunting weaponry, clothing, use of shelters, and use of fire.

Most evidence for early use of fire relies on macroscopic, qualitative identification of residues and objects that appear to have been affected by fire, often described as a change in color (see e.g., Purdy, 1971, 1974; Shipman *et al.*, 1984). However, macroscopic observations of burning are often misleading and need to be confirmed by specific analyses, e.g. micromorphology, FTIR, organic petrology, analysis of mineral magnetic parameters and thermoluminescence measurements (see e.g., James *et al.*, 1989; Stiner *et al.*, 1995; Shahack-Gross *et al.*, 1997; Richter, 1998; Goldberg, *et al.*, 2001; Ligouis, 2006; Hanson and Cain, 2007; Roebroeks and Villa, 2011). In short, human control of fire is best investigated by employing a micro-contextual approach (see e.g., Karkanas *et al.*, 2007).

Several researchers cite hearths, burnt wood, bone, and flint from different localities and find horizons as providing evidence for human use and control of fire at Schöningen (see e.g., Klein, 2002; Alperson-Afil and Goren-Inbar, 2006; Berna and Goldberg, 2008; Voormolen, 2008; Wrangham, 2009; Weiner, 2010; Roebroeks and Villa, 2011a). However, apart from a preliminary and inconclusive micromorphological investigation of one of the purported hearths (Schiegl and Thieme, 2007) only macroscopic, qualitative observations of fire use and control have been reported at Schöningen (Thieme 1997, 1999, 2005, 2007; Schiegl and Thieme, 2007). Here we present the first contextualized, multianalytical study of deposits, materials and purported hearths at Schöningen and show that claims for human use and control of fire are highly dubious.

Schöningen

Setting and Geology Schöningen lies between the North German Plain to the north and the Harz Mountains to the southeast and is situated at the southeastern foot of the Elm, a limestone ridge 25 km long and up to 8 km wide (Elsner 2003) - at an altitude of 114m above mean sea level.

Schöningen is located on the southwestern syncline of the Offleben salt wall and in the Helmstedt Staßfurt salt structure (Mania, 1995; Brandes *et al.*, 2012). Today the site complex of Schöningen is located in an open-cast lignite mine, which exposes Middle Pleistocene sites sandwiched between glaciogenic deposits of the Elsterian and Saalian glaciations (Urban, 1991a; Mania, 1995; Elsner, 2003; Ehlers *et al.*, 2004). The Paleolithic site complex of Schöningen is preserved in an elongated trough, which dissects the underlying Paleogene marine bedrock. Lang and colleagues (2012) recently interpreted the trough as a tunnel valley that formed underneath the Elsterian ice shield. Mania (1995, 2007) interpreted the formation of the trough as a result of salt dome solution, which resulted in lowering of the basin. He suggested that recurring fluvial activity at the onset of a warm period which would have eroded and infilled the trough during the interglacial following the Elsterian.

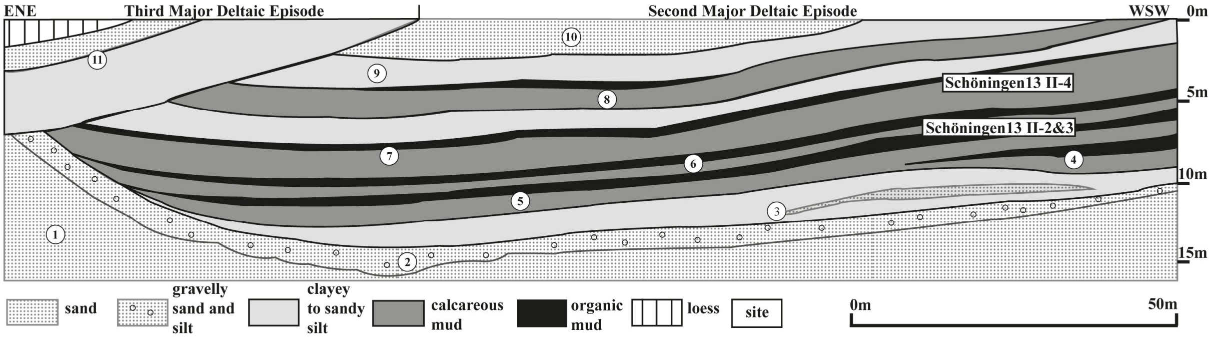


Fig.1. Simplified, schematic sequence at Schöningen 13 II in the second episode of major infill of the trough (after Mania in Thieme 1999, p463, and Urban 2007, modified according to Lang and colleagues, 2012a, b). 1 and 2. Elsterian Glaciolacustrine deposits 3. Holstein/Reinsdorf Interglacial lacustrine deposits; 4.-7. Holstein/Reinsdorf Interglacial shallowing lake cycles 1 to 4, with calcareous mud grading into a dark organic mud; they include the sites Schöningen 13 II-4 and 13 II-3. Site 12B is located in the northern equivalent of 4.; 8. 5th shallowing cycle, composed of sandy silt and a dark organic mud; 9 and 10. Glaciolacustrine deposits; 11. Interglacial lacustrine deposits and loess. See Fig. 2 for the position of the profile.

Stratigraphy In the southern mining area of the mine the trough is filled with Elsterian glaciogenic deposits that are overlain by a sequence of Holstein/Reinsdorf interglacial deltaic and lacustrine deposits. These deposits are in turn capped by Saalian glaciogenic deposits and Weichselian loess. The interglacial Middle Pleistocene sedimentary sequence, which contains the numerous Paleolithic layers, consists of three major superimposed deltaic systems (Lang *et al.*, 2012). The first major infill was assigned to the Holsteinian based on palynological analyses (Urban, 1995). The materials analyzed in this study come from sites Schöningen 12B and Schöningen 13 II, which are situated in the second major deltaic system within a series of lacustrine deposits (Lang *et al*., 2012) (Fig. 2) exposed in the southern area of the mine (Fig. 1) and were assigned to the Reinsdorf as a possible subset of the Holsteinian and recently dated to MIS 9 (Urban *et al*., 2011; Urban and Sierralta, 2012). In the northern mining area Urban *et al*. (1991a) report telmatic sediments of the Middle Pleistocene Schöningen Interglacial, which they interpret as an equivalent of marine isotope stage 7 (MIS 7). The same authors (Urban *et al*., 1991a) also report travertine and peat in the same area, which they correlate with Eemian MIS 5e and substages 5d and 5c.

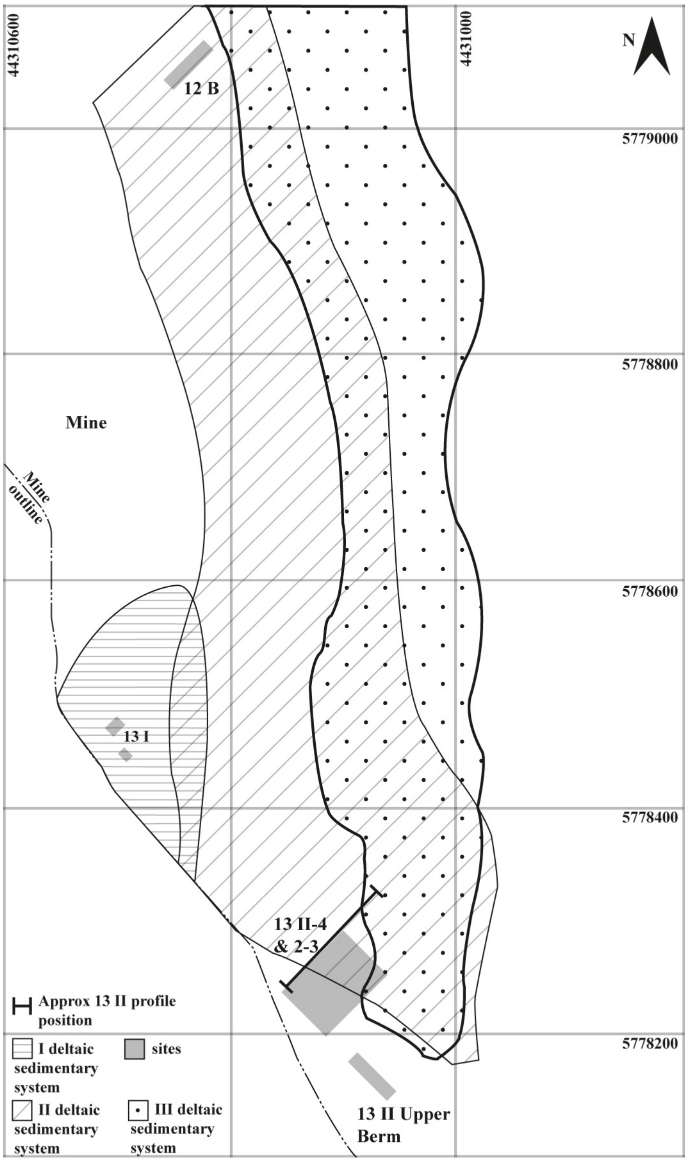


Fig. 2. Map of Schöningen sites discussed here. The Schöningen sites are located in an open-cast mine and the sites Schöningen 13II-4, 13 II Upper Berm and 12 B are associated with sediments from the second major cycle of lacustrine deposition. The approximate 13 II profile position refers to Fig. 1 (after Mania in Thieme 1999, p. 457 and Serangeli *et al*., 2012, p. 14).

Researches assign Schöningen 13 II and 12B to the Reinsdorf interglacial, which is a possible equivalent subset of the Holsteinian interglacial (Urban, 1995, 2007; Bittmann, 2012; Urban and Sierralta, 2012; but see Urban *et al.*, this issue). The sedimentary sequence at Schöningen 13 II consists of five lacustrine cycles of grey calcareous mud that grade upward into dark brown organic muds (Thieme, 2007c; Urban, 2007; Stahlschmidt *et al.*, this issue). Geological studies (Mania, 2007; Urban, 2007; Lang *et al.*, 2012) interpret the alternation between marl and organic mud as a result of lake-level fluctuations related to variations in climate.

Archaeology During the course of mining, which began at Schöningen in the 1970s, the miners artificially lowered the groundwater table through the construction of several deep well. Starting in1983 state archaeologist H. Thieme monitored operations at the lignite mine and discovered the first Paleolithic artifacts in 1992 (Thieme, 1997). Additional wells were then constructed to facilitate subsequent archaeological excavation. Twenty-eight Paleolithic sites and find horizons were discovered in association with the mine (Serangeli *et al.*, 2012a), most of which were excavated as salvage operations. The sites contain lithics, bone remains and wooden artifacts, the latter being excellently preserved due to the waterlogged state of the sites.

Evidence for fire Thieme (1997, 1999, 2002, 2005, 2007a, b) and Mania (1995) reported evidence for anthropogenic fire from six sites and find horizons at Schöningen (Table 1). Most of the evidence was based on qualitative, macroscopic observations; however, Richter (1998, 2007) conducted a thermoluminescence study of burnt flint pieces from Schöningen 13 I and Schiegl and Thieme (2007) conducted an inconclusive micromorphological study of hearth 1 from Schöningen 13 II-4. Most of the arguments for the anthropogenic origin for the fire evidence at Schöningen were based on the association of this evidence with archaeological remains (see e.g., Thieme 2005).

Site/locality	Archaeological remains	Fire evidence	Publication of fire evidence	References of fire evidence	Performed analysis	Results	Interpretation: anthropogenic fire
Schöningen 13I	Lithics, bone remains	Burnt flint –natural pieces	Richter, 1998, 2007, 2012	Alperson-Afil & Goren-Inbar 2006; Wrangham 2009; Roebroeks and Villa 2011	Thermoluminescence	Burnt	Fire use: unknown Fire control: no Fire making: no
Schöningen 13 II-1	Bone remains with cutmarks	Burnt wood	Thieme, 2002				
Schöningen 13 II-2/3	Bone remains, lithics, one wood artefact	Black sediment	-	-	Organic petrology	Not burnt	-
Schöningen 13 II-2 Berme	Bone remains, two lithics	Accumulation of burnt wood (termed hearth)	Thieme, 2007d	-	No	-	-
Schöningen 13 II-4	Lithics, wooden tools, bone remains with cutmarks	Hearths	Thieme, 1997, 1999, 2005, 2007b; Schiegl & Thieme, 2007	Gaudzinski & Roebroeks 2000; Alperson-Afil & Goren-Inbar 2006; Preece et al 2006; Klein 2009; Wrangham 2009; Roebroeks and Villa 2011	Micromorphology, FTIR, mFTIR, organic petrology, thermoluminescence, mineral magnetic parameters	Not burnt	-
	Lithics, wooden tools, bone remains with cutmarks	Burnt bone	-	Voormolen 2008	-	-	-
	Lithics, wooden tools,	charred wood-	Thieme, 1997, 1999,	Preece et al. 2006; Wrangham	No	-	-

	bone remains with cutmarks	roasting stick (*Bratspieß*)	2005, 2007a	2009; Roebroeks and Villa 2011			
	Lithics, wooden tools, bone remains with cutmarks	Burnt wood - Fire-hardened spears	-	Rice 2007; Berna and Goldberg 2008; Coolidge and Wynn 2009; Alperson-Afil, Richter and Goren-Inbar 2010; Weiner 2010	-	-	-
Schöningen 12 A - find horizon 2	-	Accumulation of burnt wood (termed hearth)	Thieme and Maier 1995	-	No	-	-
Schöningen 12B-find horizon2	Bone remains, lithics	Burnt wood	Mania, 1995; Thieme 2007c	-	Organic petrology	Not burnt	-

Table 1. Overview of the Lower Paleolithic purported evidence for anthropogenic fire at Schöningen. Note that only in one instance (burnt lithics 13 I) analyses were able to confirm the burnt state of the material, while at the same time an anthropogenic involvement is doubtful.

Evidence for fire - hearths Thieme (1997, 1999, 2005, 2007) interpreted four features at Schöningen as hearths. His interpretation was based on macroscopic observations of localized reddening of the calcareous marl, layer 4b/c, at the contact with the organic mud, layer 4b, and on cracks in the sediment at this contact (Thieme, 1997, 1999, 2005, 2007) (Fig. 3). Thieme excavated the features only partially and preserved the remaining sediment columns in wooden cases for future analysis. The recent excavation team reopened and excavated the hearth features between 2010 and 2012, noting that they had been affected by bioturbation and drying (Fig. 3). No charcoal, burnt bone, or ash was recovered from the features. Thieme reported that the hearths had a dimension of 1 m², whereas upon reopening the wooden cases, the reddened area was up to 3m², thus presenting what would be unusually large hearths (but see Shahack-Gross *et al.*, 2014 for similarly large hearths). Preliminary micromorphological analysis by S. Schiegl on thin sections from hearth 1 detected the presence of quartz grains with surface cracks that she suggested could have been caused by heating. However, Schiegl and Thieme (2007) also pointed out that the mollusk shells within the sediment from hearth 1 did not appear altered by heat. The authors reported these results as inconclusive (Schiegl and Thieme, 2007).

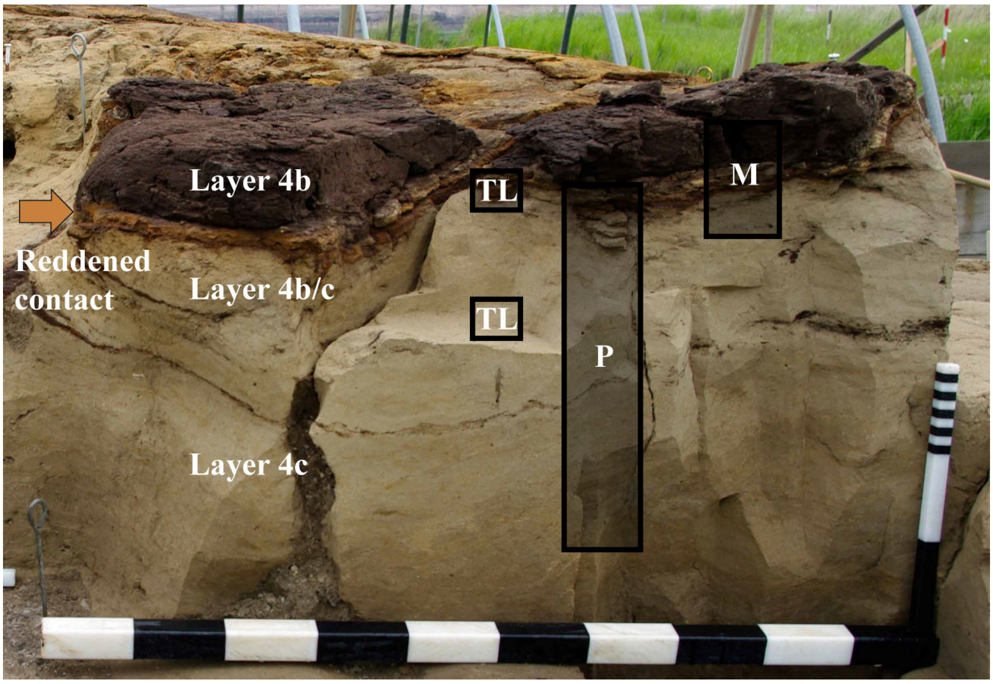


Fig. 3. The sedimentary sequence at fireplace 1 at Schöningen 13 II-4. Layer 4c is a calcareous marl and shows an increase in organic matter in its upper part, layer 4b/c. The contact between layer 4b/c and the organic mud of layer 4b is overprinted by a indurated, reddened crust, which was interpreted as the result of heat alteration (Thieme 1997, 2005). The squares show the approximate locations of samples for micromorphology, FTIR, and

organic petrology (all “M”), study of mineral magnetic parameters (“P”), and thermoluminescence analysis (“TL”). Note the recent bioturbation (refilled channel) and drying features (cracks). Photo by J. Lehmann ©NLD.

Evidence for fire - burnt wood Excavators have described fragments of burnt wood from Schöningen 13 II-1, 13 II-2 Berme, 13 II-4, 12 A find horizon 2, and 12B (Mania, 1995; Thieme and Mania, 1995; Thieme, 1997, 1999, 2002, 2005, 2007a-d; pers. comm.. W. Schoch) (Table 1). Two accumulations of burnt wood in Schöningen 13 II-2 Berme and 12 A find horizon 2 were reported as hearths, but no details were provided. Thieme (2005) also reported a piece of wood that appeared to be worked by humans and also possibly burnt. He interpreted this as a roasting stick, or *Bratspieß*.

Evidence for fire - burnt flint Richter (1998, 2007), Richter and Thieme (2012), and Richter and Krbetschek (this issue) reported 13 burnt pieces of flint from Schöningen 13 I, which was confirmed with thermoluminescence and recently dated to 321 ± 16ka (Richter and Krbetscheck, this issue), whereas none of these pieces shows clear characteristics of having been worked or modified by humans.

Since its discovery and the reporting of evidence for fire, Schöningen has been cited in almost all the major reviews of early evidence for fire (Gowlett, 2006; Klein, 2009; Wrangham, 2009; Alperson-Afil and Goren-Inbar, 2010; Daniau *et al.*, 2010; Roebroeks and Villa, 2011a; Gowlett and Wrangham, 2013). Several studies mention fire-hardening of the wooden spears from Schöningen as evidence for human use of fire (Rice, 2007; Berna and Goldberg, 2008; Coolidge and Wynn, 2009; Alperson-Afil and Goren-Inbar, 2010; Weiner, 2010). Neither Thieme (1997, 2005), nor any subsequent studies (Terberger *et al.*, this issue) described the spears as exhibiting evidence for heating.

Sites Excavations began at Schöningen 13 II in 1994 and are ongoing. Archaeological artifacts at Schöningen 13 II-4 are mostly found at the contact of layer 4b/c, a calcareous marl, with layer 4b, an organic mud (see e.g., Stahlschmidt *et al.*, this issue), and consist of butchered horse remains, wooden spears, and numerous flint artifacts in addition to purported evidence for anthropogenic fire (Thieme, 1997, 2005, 2007; Voormolen, 2008; Serangeli and Böhner, 2012; Kolfschoten, 2013; Terberger *et al.*, this issue). Cited evidence for anthropogenic fire at Schöningen 13 II-4 consists of purported hearths and a roasting stick (Thieme, 2005).

At Schöningen 13 II-3 and 13 II-2 bone remains, lithics and one wooden artifact lithic were discovered (Thieme 2002; 2007d; Serangeli *et al.*, 2012a), and the recent excavation team observed an additional case of possible heat-altered sediment here. They noted a vertical crack several meters long through the calcareous marl of 13 II-3 and across layers 13 II-2 that was filled with black sediment (Fig. 4).

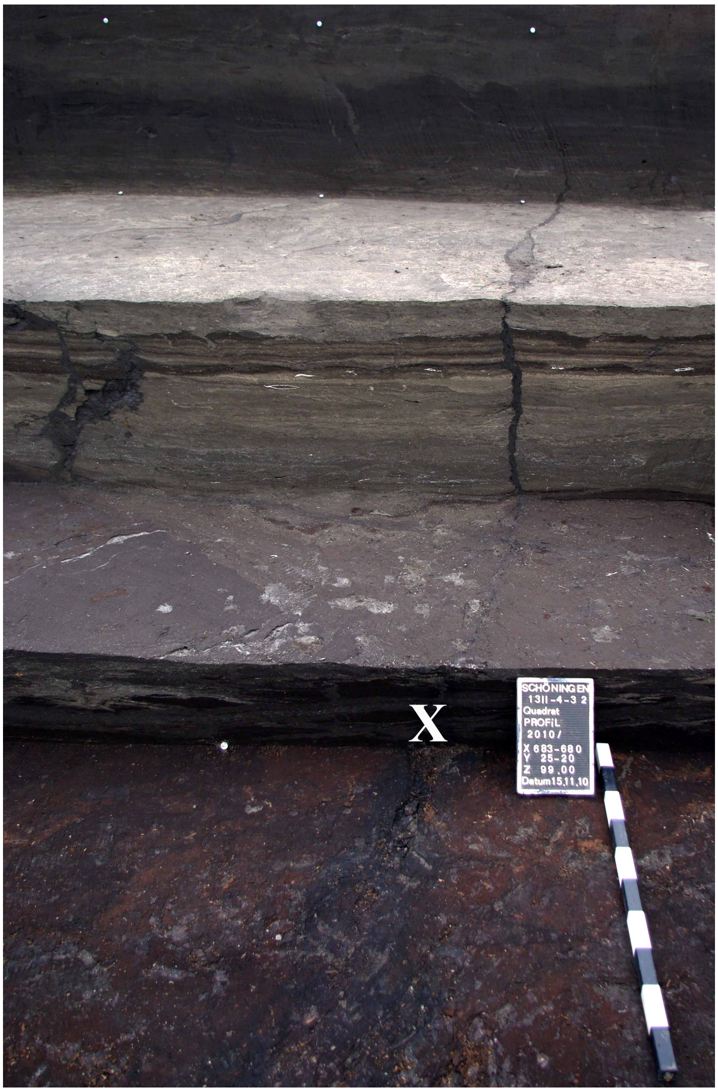


Fig. 4. Photo of the crack running through Schöningen 13 II-3 and 13 II-2. Samples were taken at the contact of Schöningen 13 II-w with 13 II-3 and the "X" illustrates the approximate location of the samples. Photo by W. Mertens ©NLD.

Schöningen 12B was a rescue excavation, and the locality contains two find horizons. Find horizon 1 consists of a sandy mud and find horizon 2 of coarse detrital mud, both containing bone remains and lithics (Thieme and Maier, 1995). Mania (1995) and Thieme (2007c) reported an accumulation of burnt wood in find horizon 2 and interpreted this accumulation of burnt wood as a possible hearth. The find horizon contained an additional fragment of supposed burnt wood, the so-called *Fackelkopf* (ID 13325).

Early evidence for human use of fire

Evidence for fire in the archaeological record can be the result of either human action or natural fire, and it is commonly difficult to separate the two. Therefore, the burden of proof rests on the archaeologists to demonstrate that the evidence for fire clearly represents human action, and not a natural process. Identification of human use of fire is further complicated by the possible human exploitation of natural fire. Archaeologists generally differentiated three stages of anthropogenic fire: the use, control, and production of fire (see e.g., Frazer, 1930; Pruetz and LaDuke, 2010; Sandgathe *et al.*, 2011a). Roebroeks and Villa (2011a) and Sandgathe and colleagues (2011a, b) further differentiate between observations of sporadic fire use - including the use and controlled use of fire from natural, more unreliable sources - and habitual fire use, which infers the production of fire, in the archaeological record (see also Shahack-Gross *et al.*, 2014). In many cases, the stages of fire use can be differentiated from each other and from natural fire by a contextual analysis (see e.g., Bellomo, 1994; Weiner *et al.*, 1998; Goldberg *et al.*, 2001; Gowlett *et al.*, 2005; Karkanas *et al.*, 2007; Roebroeks and Villa, 2011a; Berna *et al.*, 2012; Shahack-Gross *et al.*, 2014).

<u>Natural fire</u>. The earliest evidence for naturally occurring fire occurs as fragments of charcoal found in rocks dating to the Devonian (Scott 2000). Fires can be caused by lightning strikes (which are the source for the majority of natural fires), volcanic activity, sparks from rock falls, spontaneous combustion, and meteorite impacts (Batchelder, 1967; Tutin *et al.*, 1996; Jones and Lim, 2000; Scott, 2000). Tree-crown fires, volcanic eruptions and lightning strikes can produce temperatures over 700°C, and tree stumps, burning humus or peat fires can burn over elongated periods (Davis, 1959; Stach, 1975; Isaac, 1982; James, 1989; Scott, 1989; Pyne *et al.*, 1996; DeBano *et al.*, 1998; Scott, 2000; Buenger, 2003; Christian *et al.*, 2003; Fessler, 2006). Lightning strikes and burning tree stumps can produce local heat-alterations of

sediments that mimic anthropogenic combustion features (see also Isaac, 1982; Clark and Harris, 1997; Isaac and Harris, 1997; Scott, 2000).
Evidence that archaeologists assume to be indicative of anthropogenic fire - such as burnt bone or heated flint or sediment - can also be produced naturally. For example, Hendey (1976) reported Miocene burnt bone from the fossil bone bed of Langebaanweg, whereas Avery and colleagues (2004) mention burnt tortoise bones caused by bush fires in South Africa; Bordes (1957) reported Miocene burnt flint from Thenay, France. Clark and colleagues (1984) and Clark and Harris (1985) reported Pliocene burnt sediment at Middle Awash, Ethiopia.

Human use of fire. Human use or opportunistic use (Clark and Harris, 1985) of fire includes both conceptualization of fire and its collection from natural sources (Pruetz and LaDuke, 2010). Fire use does not represent a unique human behavior, since chimpanzees have been observed to show predictive behavior towards fire, and other species are known to exploit wild fires for warmth and food (Goudsblom, 1986; Wrangham, 2009; Pruetz and LaDuke, 2010). Human knowledge of fire is difficult to identify in the archaeological record, and most hypotheses regarding early human-fire interaction are based on inferences or indirect data (see e.g., Berna *et al*., 2012; Gowlett and Wrangham, 2013). Some of the earliest evidence for knowledge of fire comes from the ca. 1.0Mya site of Wonderwerk in South Africa. Here, Berna and colleagues (2012) described ash remains and burnt bone, as identified by micromorphological and FTIR analysis, inside the cave, arguing that one would not expect natural fire in this setting. Gowlett and Wrangham (2013), using observations of changes in human morphology, argue that humans used fire use as early as 1.5Mya, despite the lack of direct archaeological evidence.

Human control of fire. Control of fire or predetermined use (Clark and Harris, 1985) means the maintenance of a fire via fuel provisioning and restraint. The control of fire includes preservation and transport of fire from natural sources of ignition and represents a much more complex and unique human behavior, excluding the observation of rehabilitated chimpanzees in Senegal managing campfires (Brewer, 1978). Some researchers have argued for indirect evidence for the control of fire, such as selective burning of materials (Gowlett and Wrangham) and materials heated to high temperatures at archaeological sites (see e.g., Brain and Sillen, 1988; Bellomo, 1993, 1994; Preece *et al*., 2006; Backhouse and Johnson, 2007).

The latter arguments assume that high temperatures are only reached within campfires and not by natural fires and exhibit a shorter burning time; however, this assumption is questionable (see above and Gowlett and Wrangham, 2013).

Combustion features, in the form of structured hearths, provide the most direct evidence for human control of fire; however, they can be difficult to identify since they are often ephemeral features subject to post-depositional alteration. Microcontextual analysis has proven useful in the analysis of archaeological combustion features (Courty *et al*., 1989; Goldberg *et al*., 2001; Karkanas *et al*., 2007; Roebroeks and Villa 2011a; Wadley *et al*., 2011; Mentzer, 2012; Shahack-Gross *et al*., 2014). Localized features consisting of heat-altered sediments, that excavators interpreted as the remains of hearths, have been reported and criticized at the Lower Paleolithic sites of Chesowanja (Gowlett *et al*., 1981, 1982; Isaac, 1982), Gadeb (Clark and Kurashina, 1979; Barbetti *et al*., 1986), Koobi Fora (Isaac, 1984; Clark and Harris, 1985; Barbetti, 1986), Olorgesailie (Isaac, 1977, 1984) in Africa, and Zhoukoudian (Wu, 1985; Weiner *et al*., 1998; Goldberg, *et al*., 2001) in Asia (see James *et al*., 1989, for a critical overview). Alperson-Afil (2008) and Alperson-Afil and colleagues (2006, 2007) proposed indirect evidence of hearths at Gesher Benot Ya'aqov, dated to 800.000BP. They inferred the former presence of hearths using spatial analysis of burnt flint, as verified by thermoluminescence analysis. However, in their discussion of burning by natural fire they only refute the possibility of an *in situ* natural fire. Similarly, they do not discuss the possibility that nodules of raw material had been heat altered before human use. In Europe, burnt sediment at the Lower Paleolithic sites of Vértesszöllös (Vertes and Dobosi, 1990), Menez-Dregan (Monnier *et al*., 1994, 2001), Terra Amata (Villa, 1982, 1983), and an accumulation of supposed burnt wood at Bilzingsleben (Mania, 1991; Mania and Mania, 2002; but see Steguweit, 2003) have been reported as human control of fire. However, the researchers at these sites do not demonstrate that the purported heat-altered materials are anthropogenic (see also James *et al*., 1989; Roebroeks and Villa, 2011a), and the dating of Menez-Dregan is still unclear (Mercier *et al*., 2004). Gowlett (2006) and Preece and colleagues (2007) reported on scatters of burnt flint and bone next to possible hearths at Beeches Pit, UK. To date, no data have been published to demonstrate that the supposed hearths were formed through heating, and it is not clear if the heated bones and lithics were produced by human activities or natural fires (see also Preece *et al*., 2007).

The most direct and unambiguous evidence for the control of fire and of habitual fire use in the form of hearths and reused hearths comes from Qesem Cave in Israel, dated to 400.000

and 300.000 BP respectively (Karkanas *et al.*, 2007; Shahack-Gross *et al.*, 2014). In the Middle Paleolithic and Middle Stone Age, evidence for control of fire with discrete hearths is known in Africa from Sibudu (Wadley *et al.*, 2011), Asia from e.g., Tabun, Kebara, Hayonim (Goldberg, 2003), and in Europe from e.g., Pech-de-l'Azé, Roc de Marsal (Goldberg, 2004; Goldberg *et al.*, 2010), and Abric Romani (Vallverdu *et al.*, 2010).

Human production of fire Fire can be artificially produced by wood-on-wood friction or stone-on-stone percussion in addition to a tinder source (Hough, 1926; Weiner, 2003). Direct evidence for this behavior is rare, and so far reported only from the Upper Paleolithic (see e.g., Weiner and Floss, 2005; Sorensen *et al.*, 2014), with one possible exception from the Middle Paleolithic site of Bettencourt, France (Rots, 2011, in press). Habitual fire use, manifested in the archaeological record as a repetitive pattern of fire control, is often seen as a prelude to the production of fire (Frazer, 1930; Goudsblom, 1986, Gowlett, 2006; Pruetz and LaDuke, 2010). Sandgathe and colleagues (2011a, b) maintain that habitual fire use presents only indirect evidence for fire production. They further argue, based on a lack of evidence for habitual fire use at the sites of Roc de Marsal and Pech-de-l'Azé, that Middle Paleolithic humans in Europe still relied on scarce, natural sources of ignition and that Neanderthals lacked the ability to make fire (Sandgathe *et al.*, 2011a; but see Roebroeks and Villa, 2011b).

Material and Methods

Materials

Table 2 contains an overview of all samples and the performed analyses.

Hearths All four purported hearths from Schöningen 13 II-4 were sampled in blocks from various locations that encompass the sediments of layer 4b/c, layer 4b, and their contact, where the purported hearths are located (Fig.3). Hearth 1 was analyzed by all methods whereas the remaining hearths were investigated only with micromorphology. One bulk sample from layer 4b, two blocks and one bulk sample from layer 4b/c and one block sample encompassing the contact of layer 4b/c with the overlying sediments, layer 4b, with no reddening in between, were additionally taken outside the hearths to serve as control samples (Table 2). The control bulk samples were used for a heating experiment, studied by micromorphology, mineral magnetic parameters and thermoluminescence, and the control block samples were studied by micromorphology and thermoluminescence.

Site	Sample No/ID	Sample type	Square	Z-value*	Feature	Layer	Employed method
Schöningen 13 II-4	Schö 13 II-4 Sch FS1 1A	Sediment block sample	683/21	102.44-102.56	hearth 1	4b-red layer-4c	Micromorphology/mFTIR
	Schö 13 II-4 FS1 1a	Sediment block sample	683/21	102.44-102.56	hearth 1	4c	Organic Petrology
	Schö 13 II-4 FS1 1b	Sediment block sample	683/21	102.44-102.56	hearth 1	4b-red layer-4c	Organic Petrology
	Schö 13 II-4 Sch FS1 1B	Sediment block sample	683/21	102.44-102.56	hearth 1	4b-red layer-4c	Micromorphology/mFTIR
	Schö 13 II-4 Sch FS1 1C	Sediment block sample	683/21	102.44-102.56	hearth 1	4b-red layer-4c	Micromorphology/mFTIR
	Schö 13 II-4 Sch FS1 2	Sediment block sample	682/21	102.29-102.40	hearth 1	4b-red layer-4c	Micromorphology/mFTIR
	Schö 13 II-4 FS1 3a	Sediment block sample	683/21	102.54-102.80	hearth 1	4b-red layer-4c	Organic Petrology
	Schö 13 II-4 FS1 3b	Sediment block sample	683/21	102.54-102.80	hearth 1	4b	Organic Petrology
	Schö 13 II-4 Sch FS1 3B	Sediment block sample	683/21	102.54-102.80	hearth 1	4b-red layer-4c	Micromorphology/mFTIR
	Schö 13 II-4 Sch FS1 4	Sediment block sample	682/21	102.37-102.42	hearth 1	4c	Micromorphology/mFTIR
	Schö 13 II FS1 2010/21.1 BT 1079	Sediment block sample	683/22	102.61-102.05	hearth 1	4c	Thermoluminescence
	Schö 13 II-4 FS 1 2010/22.1	Sediment bulk sample	683/22	102.05 - 102.62	hearth 1	4c	Mineral Magnetic Parameters
	Schö 13II-4 FS 1 2010/16	Sediment bulk sample	682/22	102.54	hearth 1	4c	Mineral Magnetic Parameters
	Schö 13 II-4 2010/29	Sediment bulk sample	693/14	102.42	hearth 2	4b-red layer-4c	FTIR
	Schö 13 II-4 2010/29A	Sediment block sample	693/14	102.42	hearth 2	4b-red layer-4c	Micromorphology
	Schö 13 II-4 2010/30	Sediment bulk sample	693/13	102.46	hearth 2	4b-red layer-4c	FTIR
	Schö 13 II-4 2010/30A	Sediment block sample	693/13	102.46	hearth 2	4b-red layer-4c	Micromorphology
	Schö 13 II-4 2010/30B	Sediment block sample	693/13	102.46	hearth 2	4b-red layer-4c	Micromorphology
	Schö 13 II-4 2011/5	Sediment block sample	694/6	102.73	hearth 3	4c-red layer-4c	Micromorphology
	Schö 13 II-4 2011/08	Sediment block sample	695/7	103.00	hearth 3	4b-red layer-4c	Micromorphology

	Schö 13 II-4 2011/01A	Sediment block sample	695/8	102.99-102.74	hearth 3	4b-red layer-4c	Micromorphology
	Schö 13 II-4 2010/23	Sediment bulk sample	704/9	101.65-102.05	hearth 4	4b-red layer-4c	FTIR
	Schö 13 II-4 2010/23C	Sediment block sample	704/9	101.65-102.05	hearth 4	4b-red layer-4c	Micromorphology
	Schö 13 II-4 2010/23D	Sediment block sample	704/9	101.65-102.05	hearth 4	4b-red layer-4c	Micromorphology
	Schö 13 II-4 2010/24	Sediment bulk sample	705/9	101.51-102.15	hearth 4	4b-red layer-4c	FTIR
	Schö 13 II-4 2010/24F	Sediment block sample	705/9	101.51-102.15	hearth 4	4b-red layer-4c	Micromorphology
	Schö 13II-4 2010/24G	Sediment block sample	705/9	101.51-102.15	hearth 4	4b-red layer-4c	Micromorphology
	Schö 13 II-4 FS1 5	Sediment block sample	684/22	102.17		4c	Micromorphology/mFTIR
	Schö 13 II-4 2003/3.1	Sediment block sample	719/-995	102,16		4b-4c	Micromorphology
	Schö 13II-4 BT-2011/25 BT 1077	Sediment block sample	776/-949	101.26		4c	Thermoluminescence
	Schö 13 II-4 BrEx 4b/c	Sediment bulk sample			off site marl	4b/c	Heating Experiment
	Schö 13 II-4 BrEx 4b	Sediment bulk sample			off site marl	4b	Heating Experiment
Schöningen 13 II-3/2	Schöningen 13 II-3/2 2010/35	sediment bulk sample	681/21	98.95		2a	Organic Petrology
Schöningen 13 II-3/2	Schöningen 13 II-3/2 2010/36	sediment bulk sample	682/21	98.95		2a	Organic Petrology
Schöningen 12 B	ID13325	Wood and sediment	7/10	Not specified		Not specified	Organic Petrology

Table 2. Sample list.

Burnt sediment Two bulk samples from the black, purportedly burnt sediment from the crack running through Schöningen 13 II-3 and 13 II-2 were taken at the contact of a organic mud from 13 II-2 and studied by organic petrology.

Burnt wood A piece (2 mm³) of purported carbonized wood from a supposed wooden artifact from Schöningen 12B and the attached sediment were studied by organic petrology. Sampling here was conducted by the Department of State Heritage Lower Saxony

Methods

Micromorphology Micromorphology is the study of intact blocks of sediment and soils in thin section using a petrographic microscope. It permits identification of the composition, texture, structure, and fabric of the deposits, as well as the observation of pedogenic and anthropogenic features; since the original integrity of the sediment is conserved it is possible to determine the relative spatial and temporal relationships among materials and voids in the sample (see e.g., Courty *et al.*, 1989). The technique of micromorphology has proven to be a powerful tool for detecting early fire by revealing the presence of ash and the *in situ* character of hearth-related features [see e.g. at Sibudu (Goldberg *et al.*, 2009), Qesem Cave (Karkanas *et al.*, 2007; Shahack-Gross *et al.*, 2014), Wonderwerk Cave (Berna *et al.*, 2012), Kebara, Hayonim Cave (Goldberg and Bar-Yosef, 1998)]; it was also successfully applied to the correction of claims of fire at Zhoukoudian (Goldberg *et al.*, 2001).

For the micromorphological study, oriented blocks of sediment were collected in the field and stabilized by plaster of Paris or wooden containers. Sample preparation was conducted at the Geoarchaeology Laboratory, University of Tübingen. Samples were oven dried at 40°C for 1 day and then impregnated under a vacuum with a 7:3 part mixture of unpromoted polyester resin and styrene, catalyzed with methyl ethyl ketone peroxide (MEKP). After 5-10 days the samples were again heated at 50°C until they had hardened completely. The hardened blocks were then sliced into tiles of 50x75x10mm. Thin sections were produced by Spectrum Petrographics, Inc. in Vancouver, Washington, U.S.A., and Th. Beckmann, Braunschweig, Germany. Analysis of the resulting thin sections was conducted with a Zeiss Axio Imager petrographic microscopes under plane-polarized, cross-polarized, and blue fluorescence, at magnifications of 20x to 500x. Description and analysis follows Courty and colleagues (1989), Stoops (2003), and Stoops and colleagues (2010).

FTIR Fourier-Transform Infrared Spectrometric analysis was performed on the thin sections and loose samples. Fourier-Transform Infrared (FTIR) spectroscopy is used in order to determine the characteristic molecular absorptions of infrared radiation by organic and inorganic material. The resulting infrared absorbance spectra are used to understand the composition of archaeological sediments and materials. Furthermore, FTIR spectroscopy is very sensitive to variations in composition (substitutions) and crystallography (atomic order) that result from diagenetic processes such as heat alteration (see e.g., Weiner 2010).

Sample preparation was performed at the MicroStratigraphy Laboratory at Boston University. Powdered aliquots of experimental and archaeological samples were analyzed by FTIR spectroscopy using a Thermo-Nicolet Nexus 470 IR spectrometer. Representative FTIR spectra were obtained by grinding a few tens of micrograms of sample with an agate mortar and pestle. About 0.1 mg or less of the sample was mixed with about 80 mg of KBr (IR-grade). A 7 mm pellet was made using a hand press (Qwik Handi-Press, Spectra-Tech Industries Corporation) without evacuation. The spectra were collected between 4000 and 400 cm^{-1} at 4 cm^{-1} resolution. The presence of FTIR absorption of organic and inorganic phases was identified by using in-house or ad hoc spectral libraries (i.e., Weiner, 2010).

Organic Petrology Organic petrology is a branch of coal petrology and its main application is the study of peat, brown coal, and hard coal properties with reflected light microscopy (Taylor *et al.*, 1998). The study of the reflectance and fluorescence of organic residues can be informative about the presence of charred plant material (wood, seeds, tissues etc.), which constitutes important evidence for fuel use and combustion conditions (see e.g. Schiegl *et al.*, 2004; Ligouis, 2006; Goldberg *et al.*, 2009; Clark and Ligouis, 2010).

Organic petrological investigations are carried out on well-polished surfaces of particulate- or block- samples in reflected white light and in fluorescence mode. Sample preparation for organic petrology was conducted at the Laboratory for Applied Organic Petrology (LAOP) at the University of Tübingen. Polarized light is used to assess the properties (anisotropy, mosaic structure) of the carbon forms especially if they result from coal carbonization (coke) and from incomplete combustion of fossil fuels (nonburnt carbon in the form of char) (Taylor *et al.*, 1998). Analyses was conducted with a Leitz DMRX-MPVSP microscope photometer equipped for reflected white-light and blue-light illumination, and is set up with oil immersion objectives (20x to 50x).

Mineral magnetic parameters Mineral magnetic properties can reflect changes in iron mineralogy in soils, soft sediments and hard rocks that result from diagenetic redox-processes, pedogenesis and also thermal alteration. Thermal alteration leads to an enhancement of mineral magnetic parameters caused firstly by the thermal degradation of plant tissues and secondly by the transformation of para- and/or antiferromagnetic iron minerals to ferrimagnetics. This enhancement of mineral magnetic parameters can be identified by low field susceptibility and concentration of independent interparametric ratios derived from laboratory induced remanences (Dalan, 1998; Evans and Heller, 2003)).

Sample preparation was conducted at the Laboratory for Palaeo- and Environmental Magnetism, Bayreuth University, Germany. The low field magnetic susceptibility was determined with a MAGNON Susceptibility Bridge (MAGNON, Dassel, Germany) at AC-fields of 300 A/m at 0.3 and 3 kHz, respectively, and is given as mass specific susceptibility (χ). The frequency dependence of susceptibility (χfd) (χfd% = [χ(0.3 kHz) - χ(3kHz)] / χ(0.3 kHz) x 100 in %) is a measure of the relative contribution of SP-ferrimagnetica close to the SP-SD threshold. χ reflects concentration of ferrimagnetic minerals and also grain size distribution. Fine-grained superparamagnetic (SP) ferrimagnetica (<0.03 µm) have a 2-3 times higher χ than stable single-domain, pseudosingle-domain (SSD, PSD; ~ 0.03-10µm) and multidomain ferrimagnetica (MD, > ~10µm) (Evans and Heller, 2003). Induced isothermal remanent magnetizations (IRMs) were determined after exposing the samples to a pulsed field of 2000 and 200 mT (back field), respectively, along one spatial axis. Magnetization was produced using a MAGNON PM II pulse magnetizer and measured via an AGICO JR6-spinner magnetometer (AGICO, Brno, Czech Republic). The IRM acquired in the 2 T field is regarded as saturation isothermal remanent magnetization (SIRM). As the SP-size fraction is defined by the absence of magnetic remanence under room temperature, IRMs are essentially controlled by the concentration of SSD to MD-ferrimagnetica. Furthermore, IRMs depend on the mineralogical composition with ferrimagnetica (magnetite, maghemite) being more easily magnetised than antiferromagnetica (goethite, hematite) (Maher, 1986). Therefore, the modified S-ratio (= ((IRM200mT / IRM2000mT) + 1) / 2) is indicative of the relative abundance of ferrimagnetica to antiferromagnetica and a concentration-independent proxy (Walden *et al.*, 1999; Velzen and Deckers, 1999).

Anhysteretic remanent magnetizations (ARMs) were induced with a 50 µT static field and 100 mT alternating field (AF) amplitude using a Magnon AFD 300 demagnetizer. The ARM was produced along one spatial axis and remanent magnetization was measured via the

AGICO JR6-spinner magnetometer. Similar to the IRM, the ARM reflects the concentration of remanence carrying magnetic phases. However, the ARM decreases more strongly from the SSD to the MD-fraction than does the SIRM. Therefore, the IRM/ARM ratio is a useful concentration-independent proxy for detecting changes in the ratio of SSD-MD fraction vs. SSD fraction (Evans and Heller 2003; Maher, 1986).

Thermoluminescence Thermoluminescence analysis can determine if sediment has been exposed to heating in the past by analysing the TL glow curve shapes and TL sensitivities. Luminescence has been frequently used to examine the presence of temperature-induced changes in sediment and subsequently to determine the age of heated sediment from archaeological contexts (Aitken, 1985; Alperson *et al.*, 2007). Verification of prehistoric heating is usually done by the heating plateau test (Aitken, 1985), where a flat ratio of TL induced by artificial irradiation versus the natural TL signal provides evidence of the heating in the past. However, the material under study here is sediment, and bleaching of the signal during deposition or sampling could induce results comparable to heating. Therefore the heating plateau test alone is not proof of a prehistoric firing event. However, heating of minerals change the sensitivity of the TL-signal and results in different shapes of the TL-glow curves, which can indicate prehistoric heating.

Sample preparation was conducted at the Max Planck Institute for Evolutionary Anthropology in Leipzig, Germany. TL measurements were performed on a Risø Da-15 luminescence reader at 5 K s^{-1} to 450°C with immediate background subtraction. Luminescence detection with an EMI 9236QA photomultiplier was restricted to the UV-blue wavelength range by Corning 5-58 and KG-5 glass filters. Irradiations were performed with a calibrated external ^{90}Sr/^{90}Y -source, and samples were stored at 50°C for one week before measurement. Prior to the luminescence study, the organic and carbonate content of this fine grained sediment was removed and the fine grain fraction (4-11 µm) was extracted according Stokes law.

Heating Experiment Sample preparation and the heating experiment itself were performed at the Geoarchaeology Laboratory, Tübingen University. Sediment samples from layer 4b/c and layer 4b from Schöningen 13 II-4 were subjected to a stepwise heating experiment. The samples were heated for 4 hours in a muffle furnace to temperatures of100°C, 200°C, 300°C, 400°C, 500°C, 700°C, 800°C, 900°C, 1000°C, and 1100°C, and subsequently cooled down for at least 24 hours in a desiccator. In a second run, no desiccator was employed to account for possible variance, but none was observed and only some test analyses of the mineral magnetic parameters were carried out on these. Color change and weight loss were recorded and further analyses were chosen based on these observations. The samples of layer 4b were only studied macroscopically. For the samples of layer 4b/c, study of the mineral magnetic parameters was conducted on the whole temperature range. Micromorphological analyses and FTIR spectroscopy were performed on the samples from layer 4b/c between temperatures of 400°C to 1100°C. Thermoluminescence analyses were conducted on samples from layer 4b/c samples heated to 400°C, 700°C, and 900°C. A non-heated sample from layer 4b/c was analyzed with micromorphology, FTIR, by study of the mineral magnetic parameters, and by Thermoluminescence analyses.

Results

Hearths at Schöningen 13 II-4

Stahlschmidt and colleagues (this issue) present a detailed analysis of the geological context of the purported hearth features and the following includes a short review of the geological context.

<u>Geological context - Layer 4b</u> Layer 4b is composed of dark brown (Munsell Soil Color Chart 7.5YR 3/2) organic silt, which locally exhibits laminations. Layer 4b has a variable but maximal thickness of 35 cm. Under the microscope layer 4b is composed mostly of small (< 0.3 mm), slightly humified fragments of plant tissues, with a minor portion of rounded, sand- to silt-sized grains of quartz and mica (Table 3, 4a, b). Framboidal pyrite, diatoms, sponge spicules, and secondary nodules of gypsum were additionally noted in thin section. The microstructure is massive with some lamina distinguished by increased silt-sand-sized quartz and clay content. No evidence for heat alteration was found in this layer (Table 3).

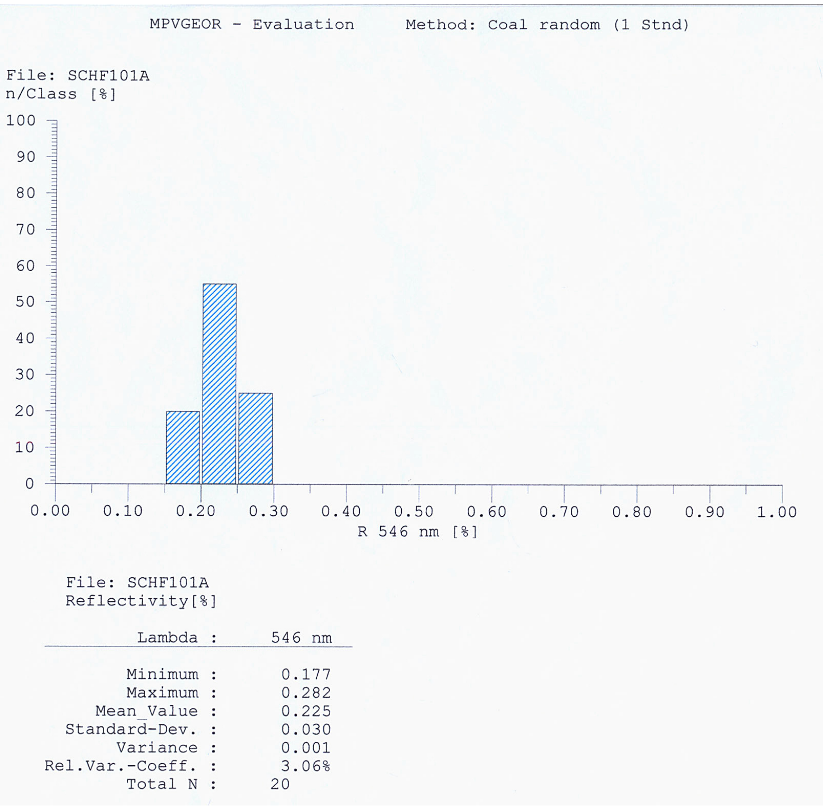
Sample No.	Layer	Microstructure, aggregates, voids & ratio coarse to fine fraction	Fine fraction*	Coarse fraction*	Comments
Schö 13 II-4 sediment hearth 1 -4	4b	Homogenous to locally laminated; elongated plant tissue with a tendency for horizontal alignment, large fractures, lens structure in one TS	Clay and amorphous organic fine material	Plant residues (0.1 to 0.002 mm, but predominantly ~0.5 to 0.1 mm; all fragments, light brown to brown in color), gypsum, quartz (rounded, fine sand to silt sized), mica, framboidal pyrite, sponge spicules, diatoms, very few rounded charcoal particles	Contact with unit 4a gradual to indiscernible Lowermost centimeters with laminations No *in-situ* growing roots observed
Schö 13 II-4 sediment hearth 1 -4	4b/c	Water escape structures elongated plant tissue with a tendency for horizontal alignment, simple packing voids, some large fractures	Dominantly micritic to rarely rhombohedral calcite to clayey and amorphous organic fine material	Plant residues (0.02 to 0.001 mm, but predominantly around 0.5 to 0.1mm all fragments, light brown to brown in color), quartz (rounded, fine sand to silt sized), framboidal pyrite, ostracods and mollusk fragments, chara, gypsum sponge, spicules, diatoms, bone fragments (angular, ~0.5 mm)	Contact with unit 4b clear and with intense iron precipitation No *in-situ* growing roots observed Diffuse iron precipitation
Schö 13 II-4 sediment hearth 1, 4	4c	Homogenous, elongated plant tissues with tendency for horizontal alignment, simple packing voids, few larger	Dominantly micritic to rarely rhombohedral calcite to slightly clayey	Quartz (rounded, fine sand to silt sized), plant residues (0.01 to 0.2 mm, all fragments, light brown to brown in color) framboidal pyrite, gypsum, ostracod and mollusk fragments, chara,	Contact with unit 4b/c gradual No *in-situ* growing roots

		fractures		diatoms sponge spicules	observed Diffuse iron precipitation
Schö 13 II-4 2003/3.1	4b	Elongated plant tissue with a tendency for horizontal alignment, large vertical fractures slightly fissural	Clayey	Plant residues (around 0.5 to 0.1 mm; all fragments, light brown to brown in color), gypsum, quartz (rounded, fine sand to sit sized), mica, framboidal pyrite, diatoms, sponge spicules	Contact with 4b/c clear but fractured Fracture and fissure probably related to recent freezing and defrosting
Schö 13 II-4 2003/3.1	4b/c	Elongated plant tissue with a tendency for horizontal alignment, simple packing voids, some large fractures	Dominantly micritic to rarely rhombohedral calcite to clayey and amorphous organic fine material	Plant residues(0.5 to 0.1 mm all fragments, light brown to brown in color), quartz (rounded, fine sand to silt sized), framboidal pyrite, ostracods and mollusk fragments, chara, gypsum, sponge spicules, diatoms, bone fragments (angular, ~0.5 mm)	Fractures probably related to recent freezing and defrosting

Table 3. Micromorphological description of layers 4b and layer 4b/c at the four hearths and the control sample (Schö 13 II-4 2003/3.1). The variation between the 4 hearths is insignificant and they are therefore described as one.

	Schö 13II-4 FS1 1a&b					Schö 13II-4 FS1 3a&b					
Lithological units and thickness (cm)	**Huminite (telohuminite) reflectance**			**Fluorescence properties of organic particles**		**Lithological units and thickness (cm)**	**Huminite (telohuminite) reflectance**			**Fluorescence properties of organic particles**	
	Mean value %Rr	**Standard deviation**	**Number of measurements**	**Huminite**	**Liptinite**		**Mean value %Rr**	**Standard deviation**	**Number of measurements**	**Lithological units and thickness (cm)**	**Huminite (telohuminite) reflectance**
4b >1,8	0,21	0,039	100	non-fluorescing to brown fluorescing	brightly yellow and green fluorescing	**4b** >6,3	0,17	0,028	100	non-fluorescing to brown fluorescing	yellow and brightly green fluorescing
Red contact upper part 0,4 – 0,8	0,19	0,048	23	non-fluorescing to brown fluorescing	brightly yellow and brightly green fluorescing	**Red contact upper part** 0,3 – 0,5	0,13	0,031	40	non-fluorescing to brown fluorescing	yellow and brightly green fluorescing
Red contact lower part 1,0 – 1,5	0,17	0,054	10	non-fluorescing to brown fluorescing	yellow and brightly green fluorescing	**Red contact lower part** 2,0 – 2,5	0,15	0,042	47	non-fluorescing to brown fluorescing	yellow and green fluorescing
4c >5,8	0,22	0,030	20	non-fluorescing to brown fluorescing	yellow and green fluorescing	**4c** >1,3	0,15	0,051	34	non-fluorescing to brown fluorescing	brightly yellow and brightly green fluorescing

Table 4a. Optical properties of plant tissues of the liptinite group (spores, pollen, algae, bark- or cork-derived tissue) in the samples Schö 13 II-4 FS 1 1a&b and 3a&b.



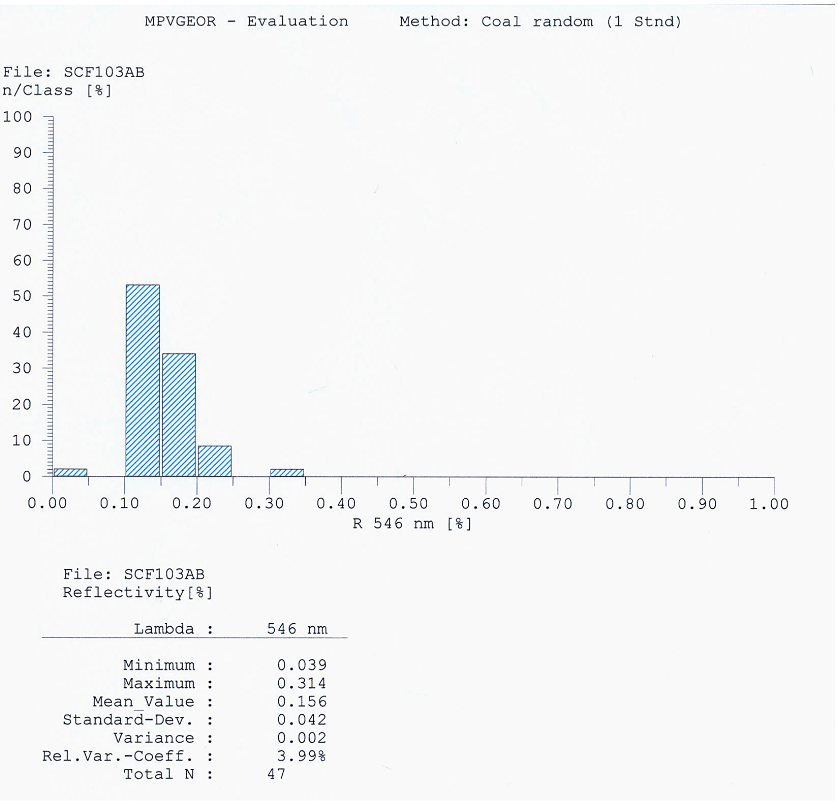
```
MPVGEOR - Evaluation      Method: Coal random (1 Stnd)

File: SCHF101A

    File: SCHF101A
    Reflectivity[%]

           Lambda :      546 nm
   ________________________________
          Minimum :       0.177
          Maximum :       0.282
       Mean_Value :       0.225
    Standard-Dev. :       0.030
         Variance :       0.001
   Rel.Var.-Coeff. :       3.06%
          Total N :      20
```

Table 4b. Huminite reflectance histogram of layer 4c/b in sample Schö 13 II-4 FS11a&b.



```
MPVGEOR - Evaluation      Method: Coal random (1 Stnd)

File: SCF103AB

    File: SCF103AB
    Reflectivity[%]

           Lambda :      546 nm
   ________________________________
          Minimum :       0.039
          Maximum :       0.314
       Mean_Value :       0.156
    Standard-Dev. :       0.042
         Variance :       0.002
   Rel.Var.-Coeff. :       3.99%
          Total N :      47
```

Table 4c. Huminite reflectance histogram of the reddening in sample Schö 13 II-4 FS 13a&b.

Geological context- Layer 4b/c Macroscopically, layer 4b/c is a calcareous mud with some mollusks that represent the only macroscopically identifiable materials in addition to the archaeological remains. Layer 4b/c exhibits minor soft sediment deformation, and it varies in color from brownish gray to gray (Munsell Soil Color Chart 2.5YR 6/3, 5/4, 6/1, and 10YR 5/8 to 4/6), which results from variable content of organic tissue, pyrite, and iron precipitations (see Stahlschmidt *et al.*, this issue). Microscopically, layer 4b/c consists of plant tissue, pyrite, silt- to sand-sized quartz grains, diatoms and shell fragments in a calcareous matrix (Fig. 5b, c, Table 3).

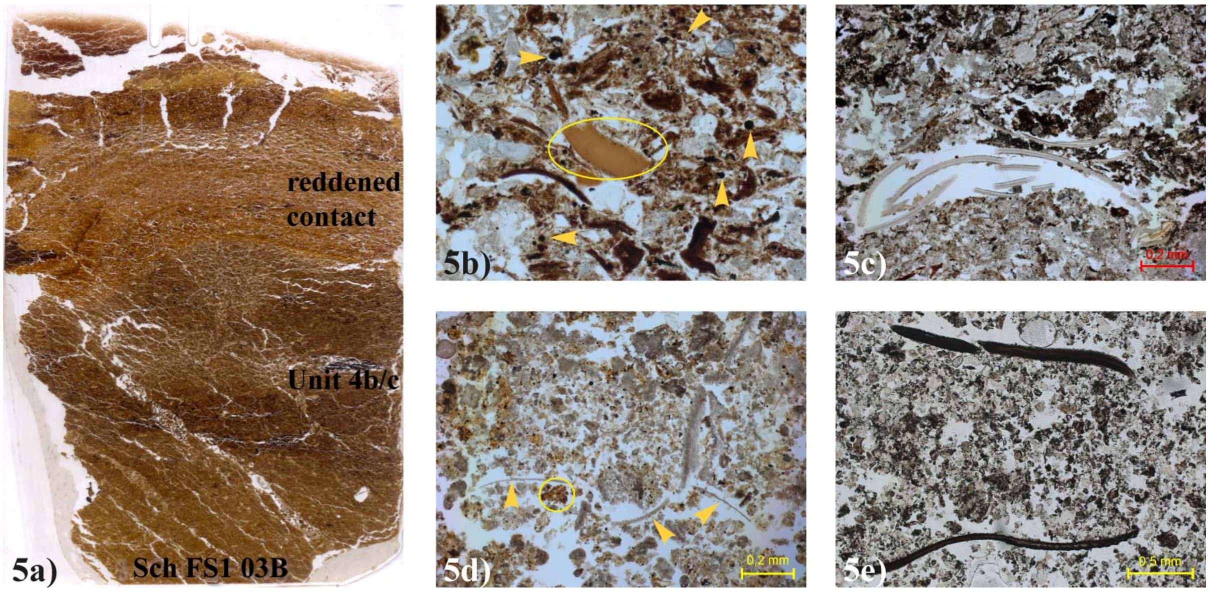


Fig. 5. Micromorphology at the reddening at the top of layer 4b/c and the heating experiment. Fig. 5a. Scan of thin section Sch FS 1 03B showing the reddened crust, which is composed of several lamina, scale 7.5cm x 5cm. Fig. 5b. Microphotograph of layer 4b/c just below the reddening. Note the abundance of pyrite (yellow arrows), brown organic tissues and a bone fragment (yellow circle), none of them showing evidence for heat alteration. Plane-polarized light (PPL), scale at lower right 0.1 mm. Fig. 5c. Microphotograph of layer 4b/c just below the reddened layer. Note the well preserved shell fragments, which show no evidence for heat alteration as replicated by the burning experiment. PPL, scale at lower right 0.2 mm. Fig. 5d. Microphotograph of the calcareous marl heated to 500°C. Note the grey coloring of the shell fragments (yellow arrows) and the localized red staining (yellow circle). PPL, scale at lower right, 0.2 mm. Fig. 5e. Microphotograph of the calcareous marl heated to 800°C. Calcite depletion is visible here and hematite (pinkish) formation. Note also the black color of the two shell fragments. PPL, scale at lower right 0.5 mm.

Below the strongly reddened features interpreted as hearths, layer 4b/c appears slightly more red than the marls outside the purported hearth areas (Munsell Soil Color Chart 2.5YR 5/3).

Excavators initially thought that this was also a result of heat alteration. However, the micromorphological analyses revealed the reddish colorations to result from localized iron oxidation associated with microscopic plant tissues and oxidation of the ubiquitous pyrite (see above). The general reflectance value of the plant tissue from layer 4b/c (0.17 %Rr to 0.22%Rr) indicates humification and gelification, not charring (Table 4b). Only very few, dispersed pieces of charred plant tissue were observed (Fig. 6). The recorded fluorescence color and intensity of the organic tissue are typical for the peat stage of plant tissue and corroborate the reflectance values. Micromorphological analyses on layer 4b/c from outside the hearths showed no difference in components or structures from within the four hearths. Similarly, thermoluminescence analysis with a heating plateau test showed no difference in the glow curve shape and sensitivity in the sample from layer 4b/c from hearth 1 and that from outside the purported hearths (Fig. 7a-d). This suggests that these samples did not experience different temperatures. However, when exposing the samples to sunlight bleachability of the TL signal was detected, which revokes the heating plateau result.

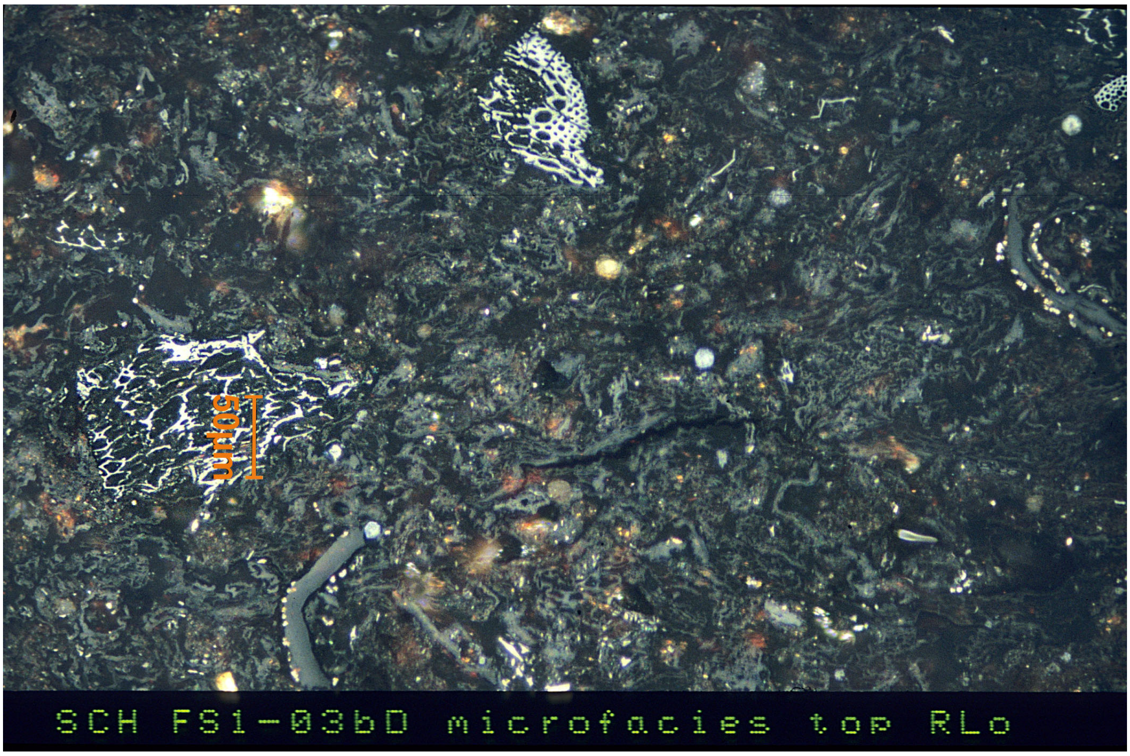
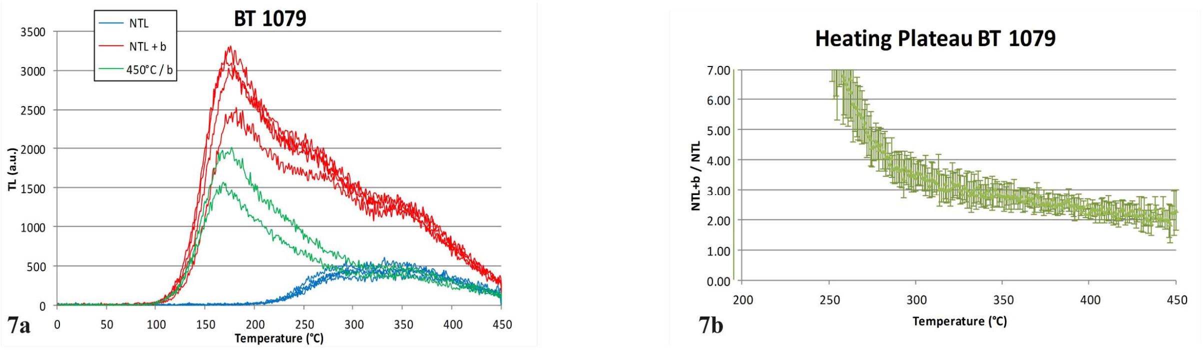


Fig. 6. Microphotograph in reflected light of a polished block from layer 4b at hearth 1. Two fragments of charred herbaceous-derived tissue (white) occur next to numerous fragments of mixed huminitic herbaceous-derived tissues. Scale at the left 50µm.



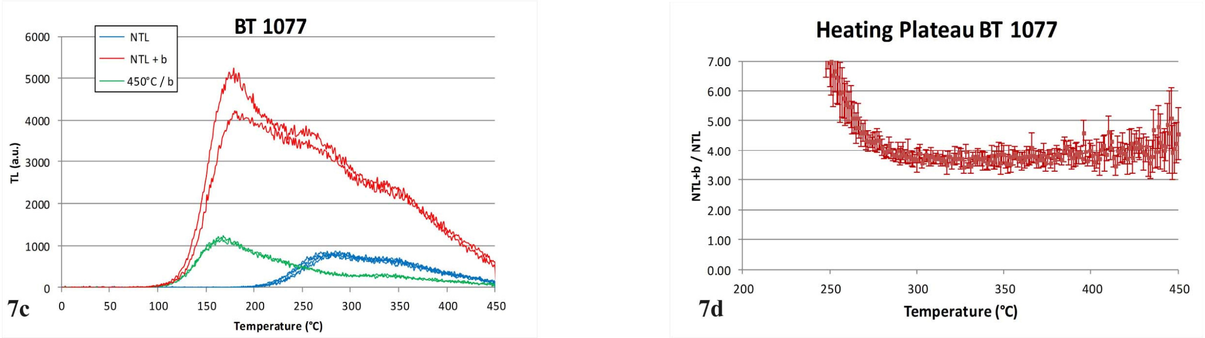


Fig. 7a & b. TL glow curves of sample Schö 13-II FS1 201/21.1 (BT-1078). 7a. The blue curves (NTL) show the natural TL, the red lines (NTL+b) the TL signal produced by an additional artificial irradiation (200 Gy), and the green lines (450°C /b) he TL-signal after identical irradiation of the sample after measurement of the NTL.7b. Ratio of NTL+b over NTL (heating plateau test).

Fig. 7c & d. TL glow curves of sample Schö 13II-4 (BT-1077). 7a. The blue curves (NTL) show the natural TL, the red lines (NTL+b) the TL signal produced by an additional artificial irradiation (200 Gy), and the green lines (450°C / b) the TL-signal after identical irradiation of the sample after measurement of the NTL; 7b. the ratio of NTL+b over NTL (heating plateau test).

Results of the heating experiment (see Table 5 for an overview) The heated samples from layer 4b/c show a range of reactions starting from 100° to 300°, at which point destruction of ferromagnetic Fe-sulfides occurs and neo-formation of para- and supermagnetic phases (SP) takes place (Fig. 9). Stable single domain (SSD) magnetite/maghemite forms at 400°C (Fig. 9). A macroscopic color change from grayish brown to pale brown was first observed at 500°C (Fig. 5d). The color change continues to reddish yellow (7.5YR 7/4-6/4) from 700 to 800°C and to light gray (10YR 7/2) at 900°C. The change in color noticed in our experiments is likely a result of 1) gray shell fragments and first orange staining by iron oxidation at 500°C, 2) blackened shell fragments and an increase in dark red and orange staining from 800°C onwards, 3) calcite depletion from 700 to 800°C, 4) destruction of magnetite/maghemite from 700-900°C with hematite formation at 800°C and 900°C (Fig. 5e, 9).

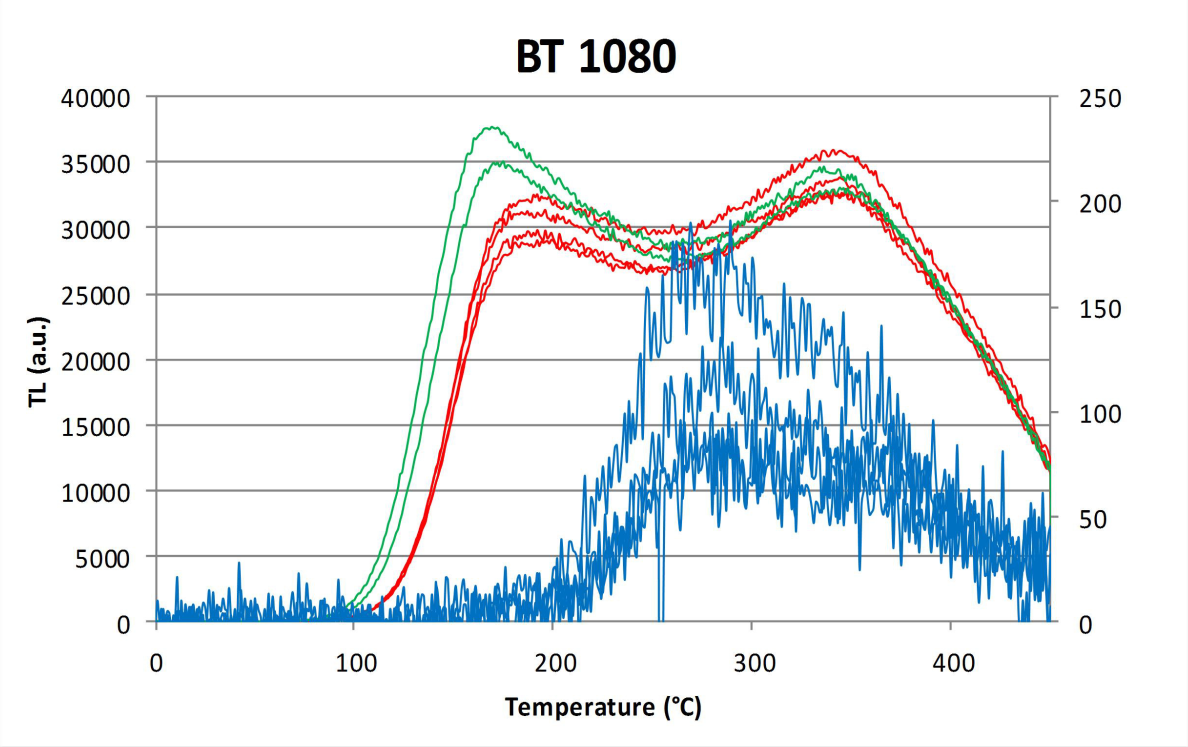


Fig. 7e. TL glow curves of sample Schö 13-II FS1 Lab 46 (BT- 1081). The blue curves (400°C) shows the residual TL after heating, the red lines (400°C+b) show the TL signal produced by an artificial irradiation (200 Gy), and the green lines the TL-signal after identical irradiation of the sample after measurement of the residual.

Furthermore, we observed that kaolinite is absent from samples heated to 400°C, and that portlandite first appears at 700°C (Fig. 8) as a result of CaO re-hydration (Weiner, 2010). Finally, at 1000°C all Fe-bearing phases are transformed to magnetite/maghemite (Fig. 9). The shape of the TL signal changes as a result of laboratory heating as observed in the samples heated to 400°C, 700°C, and 900°C (Fig.7e). Additionally, for an identical dose the sensitivity is raised by a factor of seven compared to the regeneration of the sample supposedly having been fired in antiquity.

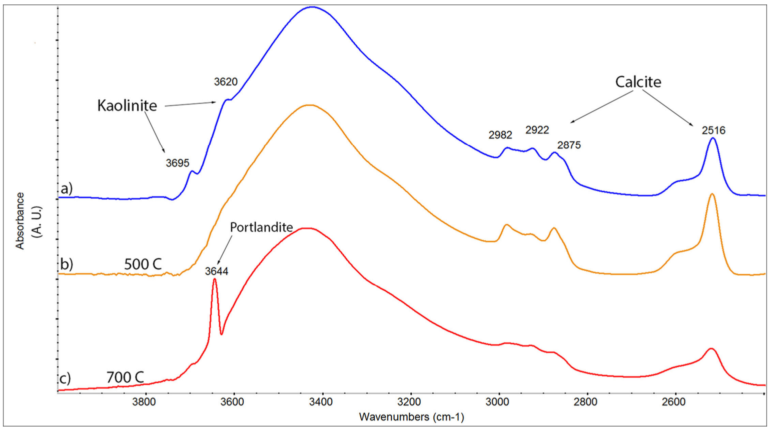


Fig. 8. a) Representative FTIR spectrum of local marl sediment showing the IR absorptions of kaolinite (3620 and 3695 cm^{-1}) and calcite (2516 and 2875-2982cm^{-1}); b) Representative FTIR spectrum of local marl sediment heated to 500 C showing the abatement of kaolinite IR absorptions (3620 and 3695 cm^{-1}); c) Representative FTIR spectrum of local marl sediment heated to 700 C showing the IR absorption of portlandite [Ca(OH)2](3644 cm^{-1}) and the abatement of kaolinite IR absorptions (3620 and 3695 cm^{-1}).

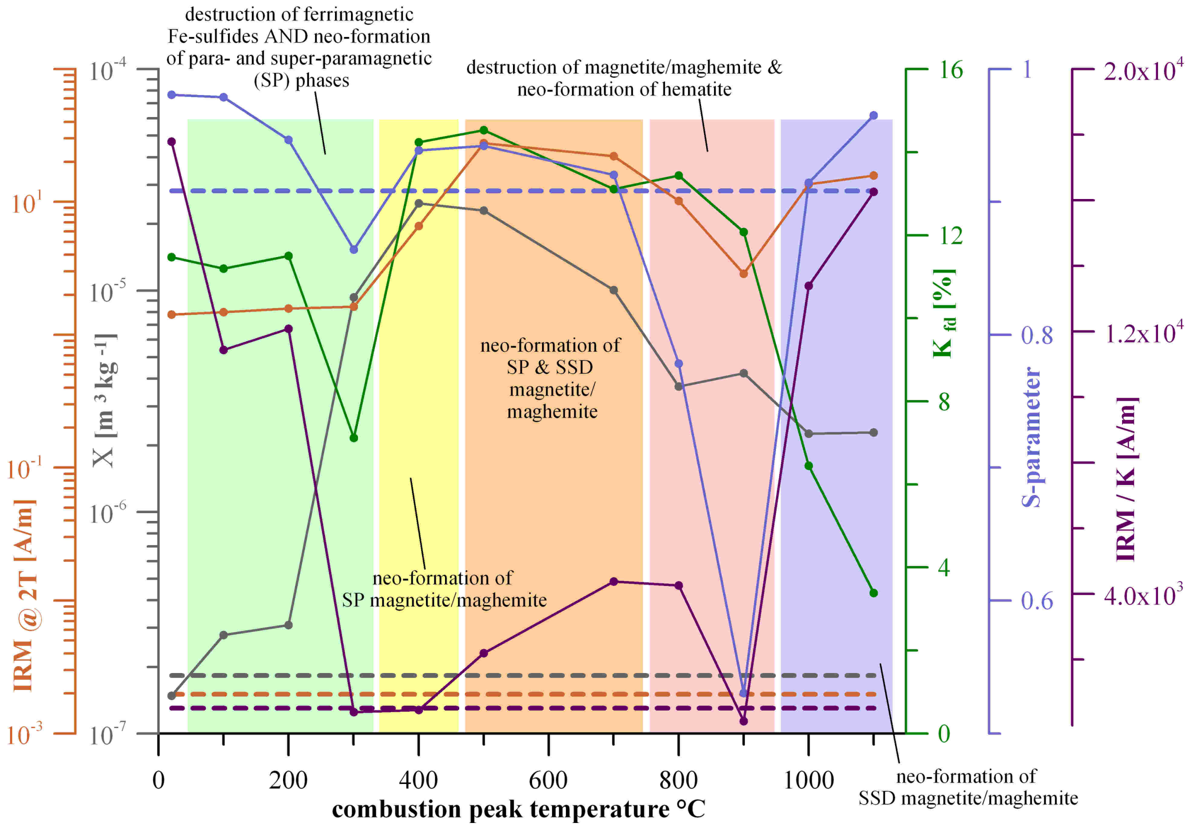


Fig. 9. Changes of mineral magnetic parameters with heating up to 1100°C. Concentration-dependent-parameters are plotted at the left and mineral and grain size indicative inter-parametric ratios are shown at the right. The dashed lines mark the respective values of the reddened layer at the purported fireplaces. Note that there is no temperature interval where the magnetic characteristics of the reddened layer correspond to the experimental results.

Temperature	Color Macroscopic (Munsell color Chart)	Microstructure	Components and their alterations	Red staining	Mineral phases (present after cooling-down to ambient temperatures)
0°C	10YR 5/2 grayish brown	Massive	shells, diatoms, quartz grains, plant residues, bone, calcite, clay	none	Calcitic crystallitic b-fabric, Kaolinite present
up to 300°C	10YR 5/2 grayish brown	-	shells, diatoms, quartz grains, plant residues, calcite, clay	-	destruction of ferrimagnetic Fe- sulfides, neo-formation of para- and super-paramagnetic (SP) (Fe-oxide?) phases
400°C	10YR 5/2 grayish brown	Massive to granular	shells grayish, diatoms and quartz unaltered, charred plant residues, calcite, clay	many dark red spots	Calcitic crystallitic b-fabric, no Kaolinite, neo-formation of SP Fe-oxide-phases and of stable single domain (SSD) magnetite/maghemite
500°C	10YR 6/3 pale brown	Granular to dense massive	shells grayish, diatoms and quartz unaltered, calcite, clay	many dark red spots	Calcitic crystallitic b-fabric, magnetic phases as above, no Kaolinite
700°C	7.5YR 7/4-6/4 reddish yellow	Granular to dense massive	shells dark grey to black, diatoms and quartz unaltered¸ calcite, clay altered, portlandite	many dark red spots and some orange red staining	Calcite depletion zones visible, beginning hematite formation, destruction of magnetite/maghemite, no Kaolinite
800°C	7.5YR 7/4-6/4 reddish yellow	Dense massive, locally granular	Very few diatoms and few brown to black colored shells observed, quartz grains unaltered, portlandite	many dark red spots and some orange red staining	Calcite dissolved, increasing hematite formation, destruction of magnetite/maghemite continues, no Kaolinite
900°C	10YR 7/2 light	Dense	Very few diatoms and brown shells,	many dark red spots	Hematite present

	gray	massive, locally granular	quartz grains unaltered, portlandite	and some orange red staining	no Kaolinite
1000°C	10YR 7/2 -7/3 light gray to very pale brown	Dense massive	Very few diatoms and no shells observed, quartz grains unaltered, portlandite	many dark red spots and some orange red staining	Transformation of all Fe-bearing phases to magnetite/maghemite, no Kaolinite
1100°C	10YR 7/2 light gray	Granular to massive	No diatoms observed neither shells, quartz grains unaltered, portlandite	Locally dark red spots	Magnetite/Maghemite no Kaolinite

Table 5. Overview of all results from analyses of the heating experiment.

The reddening/purported hearth features. The reddened contact between the layers 4b/c and 4b occupied horizontal spaces of 1 to 3 m³, varying between the 4 hearths. The reddened contact consists of a consolidated hard crust with a thickness of 2-3cm and a brownish yellow to reddish yellow color (Munsell Soil Color 10YR 6/8- 7.5YR 6/6). Microscopically, the reddening is composed of amorphous iron impregnating the groundmass of layers 4b and 4b/c. This reddening is in fact composed of several microlayers, which indicates multiple episodes of formation (Fig. 5a). The reddening most likely results from groundwater lowering activities of the mine in recent times. Oxygen-rich water in combination with a redox potential at the contact of the two layers resulting from their differing capacities to hold water, brought about the massive precipitation of iron at the contact. Other spatially extensive iron oxidation features at similar sedimentary contacts were observed in the excavation area at Schöningen 13 II (Fig 10). Moreover, the observation by the excavators that the reddened contact has grown vertically and horizontally over the years supports the assumption that the reddening represents a recent, on-going process.

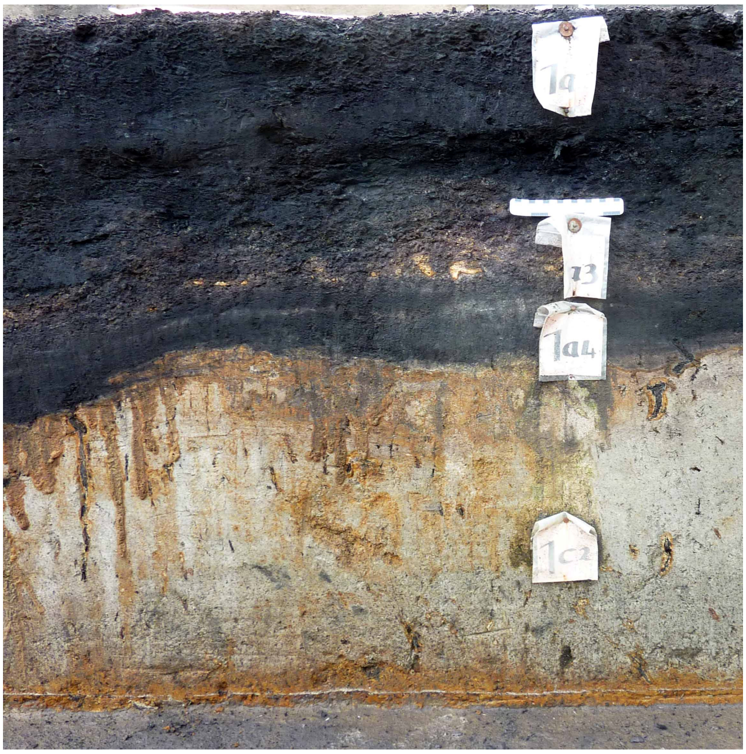
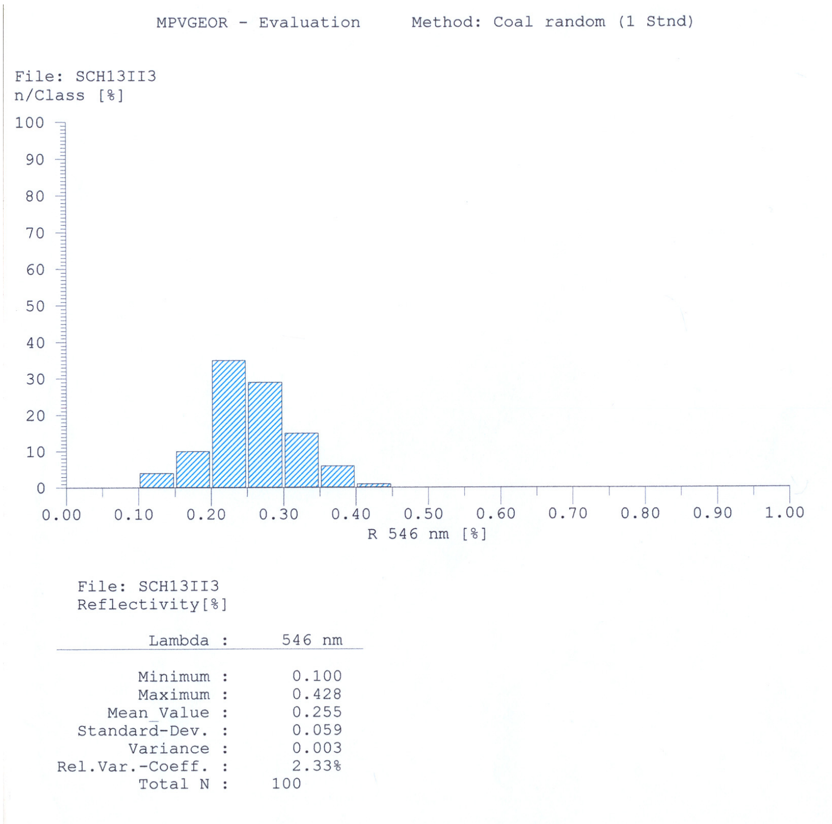


Fig. 10. Photograph of the contact of calcareous marl with an organic mud/peat deposit at Schöningen 13 II-1. Note the iron precipitation at this contact, which is similar to the purported hearth features in 13 II-4.

Micromorphological analyses did not detect ash remains or phytoliths associated with the reddening, and revealed only a few, isolated charcoal fragments. Organic petrologic analysis showed that the charred plant tissues are herbaceous, and the reflectance values indicate low humification and hardly any charred particles (Table 4a,c), which most likely originate from natural peat fires. Ostracod and mollusk shell fragments and bone fragments in thin section show no evidence for heat alteration (Fig. 5b, c; Table 3). Furthermore, FTIR analyses demonstrated the presence of kaolinite, which is not stable above temperature of 400°C (Fig. 8). None of the experimentally produced heat alterations (charring of plant tissue, color change of shell fragments, formation of portlandite, hematite, magnetite, or calcite depletion) were observed on the material obtained from the purported hearths, and the local red staining observed in the heating experiment is unlike the reddening at the purported hearths (see above).

Burnt sediment from Schöningen 13 II-3

The reflectance values of the two sediment samples show a mean value of 0.25%Rr and a range from 0.10%Rr to 0.45%Rr (Table 6). These reflectance values are indicative of humification and not carbonization (which results in values greater than ~0.6%Rr). Charred plant tissues (fusinites) are a rare occurrence in the sediment sample and are dominantly herbaceous and highly fragmented.



```
              MPVGEOR - Evaluation      Method: Coal random (1 Stnd)

File: SCH13II3
n/Class [%]
```

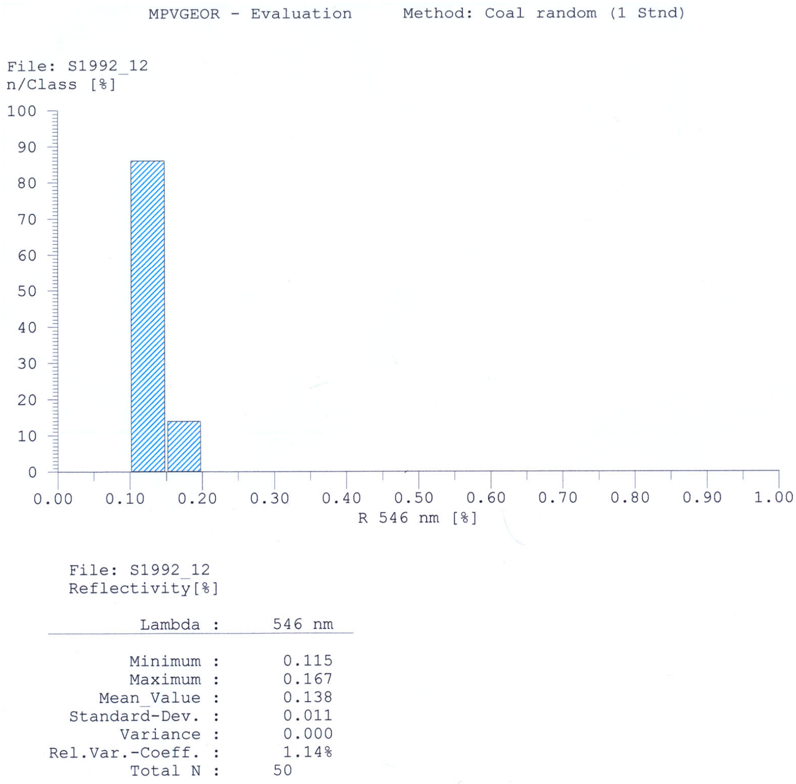
```
File: SCH13II3
Reflectivity[%]

          Lambda :      546 nm
---------------------------------
         Minimum :       0.100
         Maximum :       0.428
      Mean_Value :       0.255
   Standard-Dev. :       0.059
        Variance :       0.003
 Rel.Var.-Coeff. :       2.33%
         Total N :     100
```

Table 6. Huminite reflectance histogram of the purported burnt sediment Schö 13 II-2/3 2010/35&36.

Burnt wood and sediment from Schöningen 12 B

The presumed burnt piece of wood is very well preserved and shows low reflectance values, 0.11%Rr to 0.16%Rr (Table 7), which are indicative of humification and not carbonization. No part of the wood piece showed reflectance values that indicate combustion (which would be > 0.6%Rr). Brown fluorescence of the cell walls shows that the wood sample is composed of humic substances in addition to lignin and cellulose.



```
File: S1992_12
Reflectivity[%]

       Lambda :      546 nm

      Minimum :       0.115
      Maximum :       0.167
   Mean_Value :       0.138
Standard-Dev. :       0.011
     Variance :       0.000
Rel.Var.-Coeff. :     1.14%
      Total N :      50
```

Table 7. Huminite reflectance histogram of the purported burnt wood ID 13325.

Discussion

No evidence for human use or control of fire at Schöningen

Our results show that the reddening at the purported hearths at Schöningen 13 II-4 did not result from heating, but instead represents a natural, recent post-depositional process of iron precipitation and oxidation. Such reddened contacts of two overlying sedimentary layers are widely known features in lacustrine sequences (see e.g., Deike *et al.*, 1997; Kaczorek and Sommer, 2003). A few transported, charred plant tissues probably resulting from natural fires are the only evidence for fire at Schöningen 13 II (see also Urban *et al.*, this issue). Palynological analysis (Urban *et al.*, this issue and Stahlschmidt *et al.*, this issue) documents an increase in microcharcoal at several erosional contacts in the profile section 12 II and 13 II. This observation might primarily be interpreted as a result of natural fires arising under changing seasonality of a shifting climate causing drought stress to the vegetation and an unstable landscape; there is no lack of organic matter to burn in this peaty environment. Furthermore, the organic petrology analyses show that the presumably burnt sediment from Schöningen 13 II-3 and purported burnt wood from Schöningen 12 B have not been exposed to heat. These results highlight the difficulty of using macroscopic identification of burnt sediment and charcoal without further verification, and call into question other burnt wood claimed as evidence for fire at Schöningen, e.g. the *Bratspieß* (see e.g., Thieme, 2005; Terberger *et al*., this issue).

Lithics from Schöningen 13 I had been exposed to fire as demonstrated by thermoluminescence analysis (Richter, 1998). This being said, the association of burnt, possibly natural pieces of flint with archaeological remains does not demonstrate human use of fire (see e.g., James *et al*., 1989; Roebroeks and Villa, 2011). This is more true for burnt wood, which occurs naturally and is likely to be preserved in lacustrine deposits (see e.g., Power, 2010).

Implications for the archaeological record in northern latitudes

Schöningen does not contain evidence for controlled or habitual use of fire. The results of our study on the reddened and black sediments at Schöningen call into question similar claims for human control of fire solely based on visual identification of reddened or dark-colored sediments and other materials without further analysis. At Beeches Pit, hearths have been identified based on spatial clustering of burnt flint and bone associated with oxidized sediments, overlain by dark sediments interpreted as hearths associated with pond margin and possible spring deposits (Gowlett *et al*., 2005). However, the inferred temperature of 350 to 800°C for the bones and lithics does not exclude natural fires, and no analysis of the purported hearth sediments has yet been presented. A detailed micro-contextual analysis of the purported hearths, as also proposed by Gowlett and colleagues (2005), would potentially be able to differentiate between natural and anthropogenic fire.

The lack of evidence for human induced fire at Schöningen, and the questionable evidence at Beeches Pit, leaves archaeologists with no conclusive evidence for human control of fire in northern latitudes during the Lower Paleolithic. This lack of evidence could be either a result of poor preservation, human behavior, or both.

<u>Preservation</u> Surovell and Brantingham (2007) argue that the archaeological record is subject to taphonomic biases, which cause overrepresentation of younger periods relative to older periods (but see Surovell *et al*., 2009). The lack of early evidence for human use and control of fire in northern latitudes might also be a result of taphonomic processes erasing the evidence (Sandgathe *et al*, 2011b). Hearths and burnt materials can be subject to destructive processes, such as bioturbation, erosion, and chemical alterations (see e.g., Sergant *et al*.,

2006; Mallol *et al*., 2007; Braadbaart *et al*., 2009; Mentzer, 2012). Combustion features can also be influenced by geochemical conditions and modifications of the depositional environment (see e.g., Shahack-Gross *et al*., 2004; Shahack-Gross *et al*., 2014). For example, in northern latitudes acidic soils predominate (see e.g., Jones *et al*., 2010), which negatively effects ash preservation. However, charcoal shows better preservation under acidic, rather than alkaline ones (Braadbaart *et al*., 2009). Caves and rockshelters exhibit very good preservation properties, as shown by the rich record of well-preserved hearth features in Middle Paleolithic sites in Europe and the Near East (see e.g., Goldberg and Bar-Yosef, 1998; Goldberg *et al*., 2009; Wadley *et al*., 2011). However, Lower Paleolithic sites in caves and rock shelters in Europe have not been reported to hold any evidence for fire, see e.g. Atapuerca Gran Dolina and Sima del Elefante, Arago, Treugol'naya , and Visogliano (Roebroeks and Villa 2011).

Many early sites in northern latitudes are located in open-air settings, e.g. Pakefield, Boxgrove, Happisburgh, Schöningen, Bilzingsleben, and sites in open-air settings are subject to more pronounced post-depositional alterations, such as bioturbation, erosion, and weathering (Goldberg and Sherwood, 2006). Sergant and colleagues (2006) in their investigation of a lack of Mesolithic hearths in the NW European plain, argue that unstructured hearths rarely preserve in this type of setting, since they are erased by bioturbation and erosion. Mallol and colleagues (2007) in an ethnographic study on the use of fire by the Hadza observed that taphonomic processes, such as root invasion and erosion, can erase hearths in open-air settings, but that microscopic traces are often preserved depending on sedimentation rate. Supporting Mallol's observations, Friesem and colleagues (2013) report on a Middle Paleolithic hearth in an open-air setting, noting that it was likely preserved because of rapid burial.

Human behavior Gowlett and Wrangham (2013) argue that a lack of natural fire in northern latitudes presented a limiting factor for human settlement there. However, whereas most of the Lower Paleolithic sites in Europe date to interglacials, (e.g., Boxgrove, Bilzingsleben, Pakefield, Schöningen), there are sites occupied during unfavorable climatic conditions, like Happisburgh (Parfitt *et al*., 2010). Sandgathe and colleagues (2011a, b) claim that Neanderthals did not practice habitual fire use and that they depended on naturals sources of fire. However, contradicting Sandgathe *et al*.'s claim, Rots (2011, in press) presents evidence for ignition activities on a Levallois lithic at the site of Bettencourt, France. The current state of evidence suggests that the first inhabitants of northern Europe did not habitually use and control fire (Roebroeks and Villa, 2011a). Consequently, other strategies for cold adaptation, such as seasonal migration, physical adaptation, or technological improvement in the form of new hunting weaponry, clothing, or use of shelters (Gilligan, 2010), need to be investigated. An independence from fire seems odd in the face of data indicating that modern humans cannot survive, even if fully acclimatized, to temperatures below -5°C without some kind of protection against the cold in form of clothing, fire or shelter (Hardy *et al.*, 1971; Gilligan, 2010); it is possible though that archaic humans might have had a different temperature tolerance. In this context, providing warmth seems the most important application of fire next to providing nutritional improvement and light, especially as the loss of body hair occurred long before the expansion into northern latitudes (Rogers *et al.*, 2004; Reed *et al.*, 2007). Use of shelters, seasonal migration, a stronger reliance on animal food resource, clothing, and physical and nutritional adaptation present further strategies to cope with a colder environment (Gilligan, 2010).

Many Lower Paleolithic sites in Europe are situated in rock shelters and caves that could have provided protection. The analysis of sites in open-air settings have not yet yielded reliable evidence for the construction of shelters in the Lower and Middle Paleolithic [cf. the controversial case of Terra Amata (de Lumley, 1969), Chichibu (Hadfield, 2000) and Bilzingsleben (Mania and Mania 2000)]. Shelters become a common feature of archaeological sites only in the Upper Paleolithic (Iakovleva and Djindjian, 2005; Svoboda *et al.*, 2005). Seasonal migration in winter to areas with less harsh climate presents a plausible model to deal with cold, but so far this option has been discussed in detail only from the later Middle Paleolithic onward (see e.g. Féblot-Augustins, 1993), and the archaeological data of the Lower Paleolithic is as of yet too sparse to infer such behavior. Similarly, the fossil record of the Lower Paleolithic in northern latitudes is too sparse to ascertain a physical adaptation to colder climates, whereas with the Middle Paleolithic a cold-adapted species - the Neanderthals - appears in Europe (Sergi, 1944; Churchill, 1998; Steegmann *et al.*, 2002; Snodgrass, 2009; but see Rae *et al.*, 2011).

Some researchers suggest that an increase in the consumption of animal resources is a necessary adaptation in order to maintain a high metabolic rate when confronted with the rarity of plant food in northern latitudes (Snodgrass, 2009; but see Speth, 2010). However, more detailed studies of edible plants in northern latitudes are still in progress (Bigga *et al.*, this issue). The lack of vitamin C caused by the scarcity of plant food could have been answered with an increase of raw - not cooked meat - especially liver, as is done by the Inuit (Höygaard, 1940; Draper, 1977). The spears from Schöningen are an excellent example of an improved hunting technology, and the richness of butchery remains at the site shows good access to animal resources. Horsehide might also have been exploited as protection against the cold (Voormolen, 2008), and it is generally assumed that Neanderthals (see e.g., Wales, 2012) depended on clothing to survive winter. The origin of clothing is still an open question since its preservation in Paleolithic context is very improbable. However, studies of needles, depictions, textile impressions, and the evolution of lice have been provided some indirect evidence for Paleolithic clothing (see e.g., Adovasio *et al.*, 1996; Soffer *et al.*, 1998; Soffer, 2004). For example, genetic studies of lice evolution show that clothing lice evolved from head lice possibly as early as 170 000 (Kittler, 2003, 2004; Toups *et al.*, 2011). This date is interestingly close in age to the appearance of modern humans and evolutionary studies on lice from other, more archaic hominins are not possible.

Conclusion

Since James' (1989) early critic on the various claims for human use and control of fire in the Paleolithic literature, the evaluation of evidence for fire has been approached in a much more circumspect manner and the associated human behavior is carefully classified into fire use, control, sporadic use and control, habitual use and control, and fire production. However, many claims for early use of fire still rest on unsubstantiated assumptions and "intuitive" claims. Our multianalytical contextualized study at Schöningen is an example of a refutation of such types of unsupported claims. Our analysis on purported hearths, burnt sediment, wood, and lithics and a critical reassessment of other claims for fire at Schöningen show clearly that the site complex does not in fact serve as an example of human use, let alone control of fire in the Lower Paleolithic.

Fire is a natural process, which goes back until at least the Devonian (Scott, 2000). In a first step of identifying human use of fire, macroscopic observations of fire need to be verified with specific methods. In a second step, human use of fire can only be inferred by a contextual analysis; a micro-contextual approach presents the most promising tool.

The lack of direct evidence for human use and control of fire in northern latitudes does not serve as evidence for absence of such behavior, and it is still debated if this lack of evidence is a preservation issue or related to by human behavior. Accepting the null hypothesis would here mean, that unless material is proven to be burnt, it is not burnt, and that unless human fire use can be proven, humans did not use fire. Accordingly, the present dataset in Europe suggests the absence of fire use and control in the Lower Paleolithic. More in depth research along the lines used in this study is needed to find and evaluate evidence for early fire use in northern latitudes. Furthermore, the ramifications of the lack of human fire use are not well investigated and alternative survival strategies by hominins such as seasonal migration, physical adaptation, or technological improvement in the form of new hunting weaponry, clothing, use of shelters need to be explored.

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Anhang 5

Mareike C. Stahlschmidt, Report on the micromorphological analyses at Schöningen 12 II-4, Germany - 2013. (11 pages)

Bericht über die mikromorphologischen Untersuchungen in Schöningen 12 II-4 - 2013

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Methods

A standard sedimentary description was carried out and carbonate content was tested with HCL. Color was determined with the Munsell Soil Color Chart.

Micromorphological studies were performed in order to understand the structure and formation of the sedimentary units at this part of the site. Micromorphology is the study of undisturbed sediments and soils primarily through the use of petrographic thin sections. This technique allows for the identification of the mineral and organic components of the sediment and their structural arrangement. These observations in turn can be used to reconstruct the depositional and post-depositional environments of the sediment. Oriented and stabilized intact samples are collected in the field as individual blocks, which are then taken to the laborаratory, where they are impregnated with a mixture of unpromoted polyester resin, styrene and Methyl ethyl ketone peroxide (MEKP). After hardening for several days, they are cut into blocks, which are then glued onto glass slides and ground to a thickness of about 30 µm. Analysis was conducted with a petrographic microscope under plane-polarized, cross-polarized, and UV-light at magnifications of 20x to 500x. Terminology follows Courty *et al.* (1989), Stoops (2003), and Stoops *et al.* (2010).

Materials

In 2009 five block samples (x 899, y 615, z 102.05-103.25), stabilized by wooden and metal jackets, were collected at Schöningen 12 II-4, encompassing units 4c and 4b (Fig. 1 and table 1). Subsampling for palynological, sedimentological and micromorphological investigations was conducted at the Institute of Ecology, Subject Area Landscape Change of Leuphana University Lüneburg.

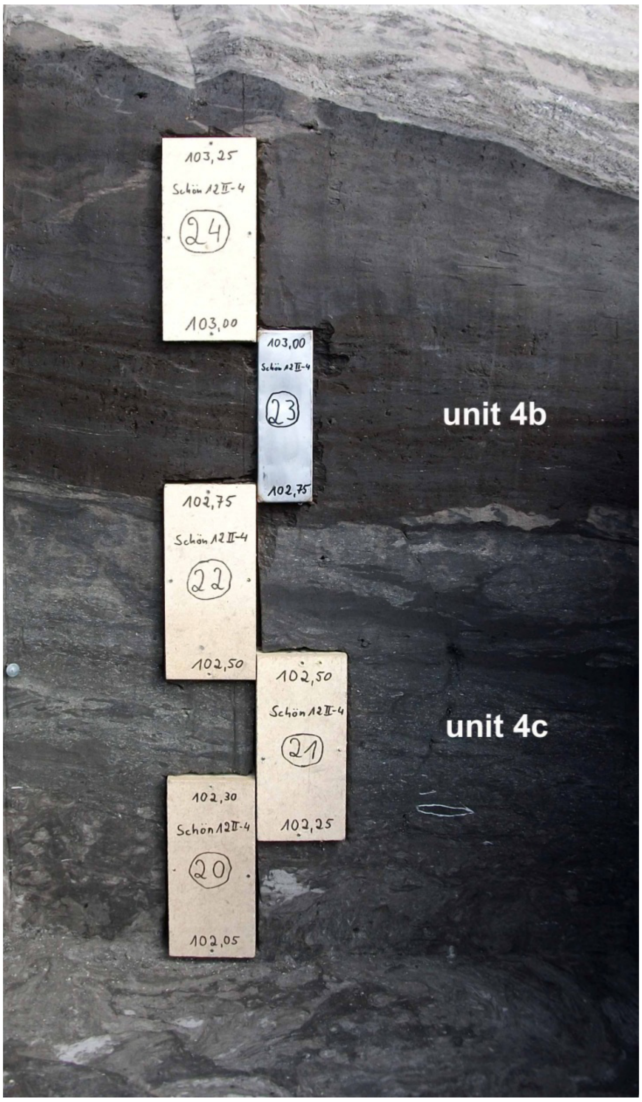


Fig.1. Profile photo at Schöningen 12 II-4 with the block samples Schö 12 II-4 2009/20 to 24. ©NLD.

For micromorphological studies the remaining blocks were transferred to the Geoarchaeological Laboratory, Institute for Archaeological Sciences, University of Tübingen, Germany; here impregnation occurred and P. Kritikakis manufactured the thin sections. Additionally one thin section of an encrusted bone sample Schö 12II ID 17897 from unit 4c3 was produced. Including the crust sample, seven thin sections were available for this study with two thin sections produced from each block sample Schö 12 II-4 2009/20, Schö 12 II-4 2009/21 and Schö 12 II-4 2009/22. The petrographic thin sections come from unit 4c1 and 4c2, which contain archaeological material.

Results

Macroscopic description (Urban, Stahlschmidt)

The sedimentary sequence at Schöningen 12 II-4 comprises a sequence of grey clay, sand and marl topped by a dark organic rich layer (Böhner *et al.* 2005, Lange *et al.* 2012, Urban 2007). Unit 4c at Schöningen 12 II-4 presents a calcareous mud, which was subdivided in the field into 4c1, 4c2 and 4c3. 4c3 has a gravelly to sandy component and 4c2 and 4c1 were noted as sandy. As the excavation of 12II-4 was a recue excavation, the available sedimentary description is limited and the following description is restricted to the block samples. In the block samples the lowermost part is a dark grayish brown to light brownish grey (2.5Y 4/2 to 2.5Y 6/2) calcareous silt. Some remains of mollusks are visible. This unit corresponds to unit 4c2. From z=102.14 to 102.72 the sediment is a very dark grayish brown, to very dark gray to dark gray (2.5Y 3/2 to 2.5Y 3/1 to 2.5Y 4/1) calcareous mud. Upwards it shows an increased content of mollusk remains. This unit corresponds to unit 4c1.The overlying unit 4b is black (2.5Y2.5/1) fine organic silt. It did not show any reaction to treatment with HCl.

Results Micromorphology (Stahlschmidt)

The following presents a summary of the micromorphological data, for more detailed results see Table 2.

The two thin sections from the lower most block sample Schö 12 II-4 2009/20, unit 4c2 to 4c1, display a dense grain supported groundmass of silty quartz grains (Fig.2.). Other coarse components are mica, plant residues, shell fragments, ostracods, and sand-sized quartz grains. The fine material comprises clay and amorphous organic fine material. There are areas with less fine material than the general composition and erosional contacts (Fig.3). Plant residues are mainly amorphous organic fine material; elongated larger plant tissue residues mostly show a tendency of horizontal alignment. Localized domains of calcareous fine material were observed in low density, as well as some clay. The number of calcareous localized domains increases upwards and they mainly represent chara and shell remains. On the other hand the amount of clay decreases in this direction as does the amount of silty quartz grains.

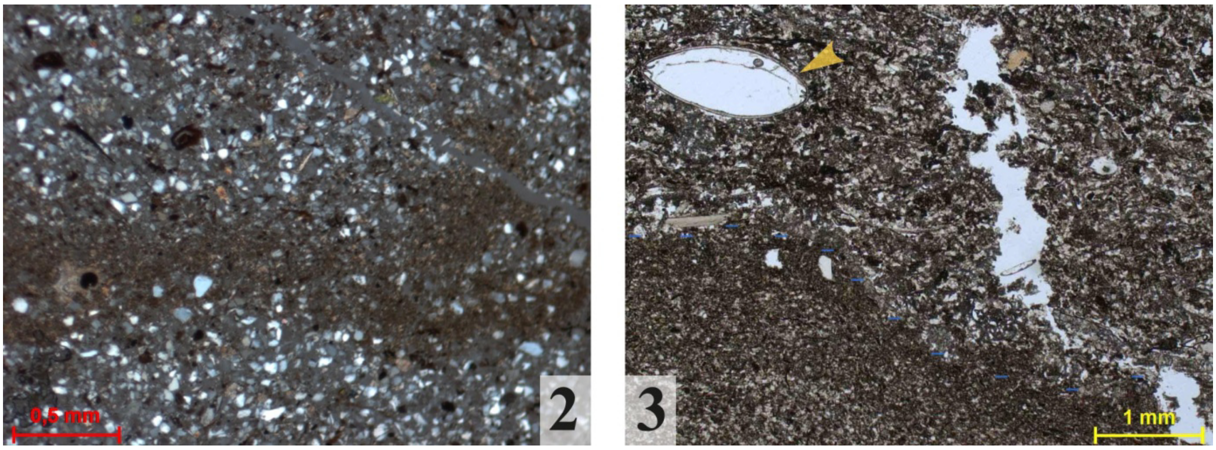
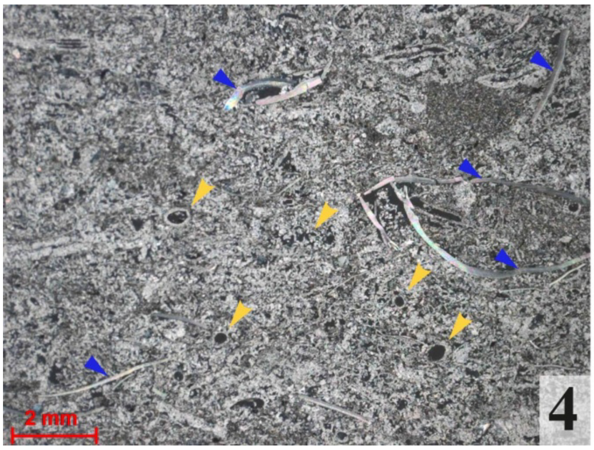


Fig.2. Dense silty quartz-rich groundmass with plant residues in Schö 12II-4 2009/20B. Note the horizontal clay lamina in the middle of the picture with a calcareous chara remain (yellow arrow). Crossed-polarized light (XPL), scale at lower left 0.5 mm. Fig.3. Erosional contact in unit 4c2. Fine material increases upwards with a sharp contact in the middle of the photo (blue lines). Well preserved ostracod remains (yellow arrow) are present. Plane-polarized light, scale at right bottom 1 mm.

The two thin sections from the block sample Schö 12 II-4 2009/21, unit 4c1, show a very different picture. Here the groundmass is calcareous, dominantly consisting of chara remains and shell fragments (Fig.4. and 5). Plant residues are as below and mainly present as amorphous organic fine material and few larger, well preserved plant tissue residues are present; elongated plant tissue residues show a tendency for horizontal alignment. Silty quartz grains are present only in lower density than below. In thin section Schö 12 II-4 2009/21B local areas of pure silty quartz were observed and an erosional contact. The number of plant residues gradually increases with height. The increase in plant residues continues in the two overlying thin sections from Schö 12 II-4 2009/22 (Fig. 3), which otherwise do not differ from Schö 12 II-4 2009/21.



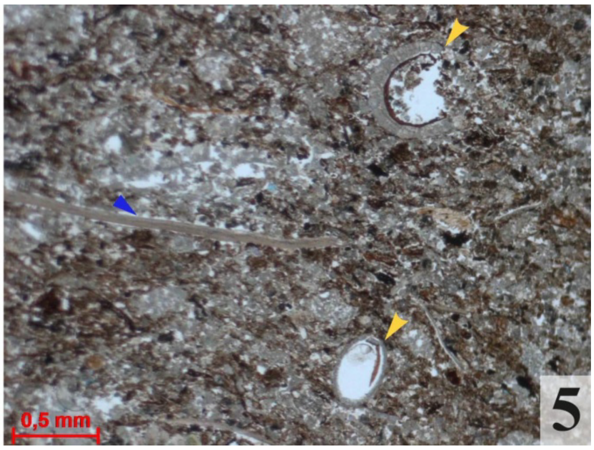


Fig.4. Calcareous groundmass of unit 4c, sample Schö 12II-4 21B, with many chara remains (yellow arrows) and shell fragments (blue arrows). XPL, scale at lower left 2 mm. Fig.5. Schö 12II-4 2009/22C calcareous groundmass with preserved shell fragments (blue arrow) and chara remains (yellow arrows), which still contain plant tissue. Note the high amount of amorphous plant residues in the matrix. Plane-polarized light (PPL), scale at lower left 0.5 mm.

The thin section of the hard crust from the bone sample (Schö 12 II-4 ID 17897) is composed of a dense black matrix of pyrite, which attached and incorporated coarse grains in the form of silty quartz and to well rounded sand-sized grains. In incident light the crust is slightly yellow. The crust mainly consists of fine crystalline aggregates of pyrite, some framboids are present. Areas of hematite formation were visible.

Conclusion and Discussion

The results of the thin section analysis indicate lacustrine deposition for unit 4c. The horizontal clay and plant residue lamina, the horizontal bedding of elongated plant residues, shell and well preserved chara remains in unit 4c are characteristic of a shallow, open water lacustrine deposition under constant water cover (Bouma *et al.* 1990, Treese 1982, Tucker and Wright 1990, Wallace 1999). The sedimentary change from Schö 12II-4 2009/20, unit 4c2 to 4c1, to Schö 12II-4 2009/21 and 22, unit 4c1, reflects a shift from relative higher to lower energy setting. The strong quartz silt component in unit 4c2 (thin section Schö 12II-4 2009/20A) suggests that this unit is closer to the deltaic source of the paleolake (see Lang *et al.* 2012) than is the upper unit 4c1. There as the presence of clay lamina in unit 4c2 suggests episodes of low energy deposition. Erosional contacts, local absence of fine material and the presence of slumps of silty quartz in thin sections Schö 12 II-4 2009/A and B indicate wave action. In conclusion, unit 4c2 was most likely deposited in the constantly water covered, sub-littoral zone of the paleolake subjected to episodic wave action.

Thin section Schö 12II-4 2009/20B reflects a gradual change from unit 4c2 to 4c1 with a decrease in silty quartz and an increase in plant residues and calcareous sedimentation.

The dominantly calcareous groundmass of unit 4c1, mainly composed of chara remains and shell fragments, reveals lower energy sedimentation than unit 4c2 and little post depositional disturbances (Flügel 2010). Unit 4c1 was most likely deposited in the sub-littoral zone of the paleolake. The upward increase of plant residue in unit 4c1 and its dominance in unit 4b possibly indicate a greater proximity to the shore (Dobrowski 2001). Similarly the absence of calcite precipitation in unit 4b might reflect decreased water coverage (Brochier 1983, Dean 1981).

The pyrite crust on the bone sample (Schö 12II ID 17897) of unit 4c3 reflects anoxic conditions for the formation of the crust (Berner 1970, Marnette *et al.* 1993, Suits & Wilkins 1998). The formation of hematite presents a recent feature of the weathering of the pyrite due to exposure (Challis 1975). Unit 4c3 was noted as sandy by the excavators, matching the presence of sandy grains in the crust.

Tables

Table 1. Sample list

Sample	Square	z-value	units
Schö 12II-4 ID 17897	-864/656	100.34	4c3
Schö 12II-4 2009/20	-899/ 615	102.05-102.3	4c2 to 4c1
Schö 12II-4 2009/21	-899/ 615	102.25-102.5	4c1
Schö 12II-4 2009/22	-899/ 615	102.5-102.75	4c1

Table 2. Overview micromorphological description of the thin sections

Sample	Geological unit	Groundmass	Other components	Microstructure
Schö 12II-4 2009/20B	4c2	Silty quartz	Mica, plant residues, sandy quartz, clay, local calcareous domains (mostly chara), few molluscs and ostracods	Grain supported, some laminae of clay, mostly horizontal orientation of elongated plant particles
Schö 12II-4 2009/20A	4c2-4c1	Silty quartz	Mica, plant residues, sandy quartz, clay, local calcareous domains (mostly chara), few molluscs and ostracods	Grain supported, some laminae of clay, horizontal orientation of elongated plant particles, erosional contacts, slumps of silty quartz, increase in calcareous domains, decrease in silty quartz and clay, areas devoid of fine material
Schö 12II-4 2009/21B	4c1	Calcareous, biogenic	Quartz grains (silt sized), plant residues, molluscs and ostracods	Fine mass dominated by encrusted chara, horizontal orientation of elongated plant particles, amount of plant residues increasing upwards
Schö 12II-4 2009/21A	4c1	Calcareous, biogenic	Quartz grains (silt sized), plant residues, molluscs and ostracods	by encrusted chara, horizontal orientation of elongated plant particles, amount of plant residues increasing upwards
Schö 12II-4 2009/22C	4c1	Calcareous, biogenic, and	Quartz grains (silt sized), molluscs and ostracods	dominated by encrusted chara and plant residues, horizontal orientation of elongated plant particles, amount

		plant residues		of plant residues increasing upwards
Schö 12II-4 2009/22B	4c1	Calcareous, biogenic, and plant residues	Quartz grains (silt sized), molluscs and ostracods	Fine mass dominated by encrusted chara and plant residues, horizontal orientation of elongated plant particles, amount of plant residues increasing upwards
Schö 12II-4 ID 17897	4c3	Pyrite, amorphous, microcrystalline	Quartz grains, hematite, framboid pyrite	Dense crust with adhering coarser particles on bone Locally hematite present

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Anhang 6

Mareike C. Stahlschmidt, Bericht über die mikromorphologischen Untersuchungen an der Fundstelle Grabow 19, Deutschland - 2013. (4 Seiten)

Bericht über die mikromorphologischen Untersuchungen in Grabow 19 - 2013

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Methode

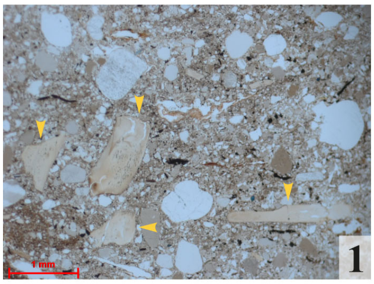
Die Mikromorphologie ist eine kontextuelle, mikroskopische Sedimentanalyse. Sedimente, Böden und archäologische Befunde werden dafür in ihrer ursprünglichen Struktur und Textur untersucht. Sie informiert über die abgelaufenen sedimentären, pedogenen, anthropogenen und post-depositionalen Prozesse. Damit ermöglicht die Mikromorphologie eine Rekonstruktion der Formation von Fundstellen, Befunden und einzelnen Schichten als auch ihre nachträglichen Transformationen. Im Feld werden hierfür befestigte Proben genommen, die dann im Labor mit einer Mischung aus Kunstharz, Styrol und Härter imprägniert werden. Nach der Aushärtung werden kleine Blöcke aus den Proben herausgesägt, diese werden dann auf Glasplatten aufgeklebt und im letzten Schritt auf eine Dicke von 30 µm herunter geschliffen. Die Analyse der Dünnschliffe erfolgt mit einem petrographischen Mikroskop unter 25-, 50-, 100-, 200- und 500-facher Vergrößerung unter Durchlicht mit parallelen und gekreuzten Polarisationsfiltern sowie unter UV-Licht. Die Beschreibung folgt Courty *et al.* (1989), Stoops (2003; 1990) und Stoops *et al.* (2010).

Ergebnisse

Vier Dünnschliffe standen für die folgende Untersuchung zur Verfügung, hergestellt von Th. Beckmann, Schwülper-Lagesbüttel. Die Dünnschliffe umfassen die Grabungsschichten GS 3 und GS 4 sowie den Feuerstellenbefund 101.

Die fundführende Grabungsschicht 3, GS 3, ist in drei Dünnschliffen vorhanden. Das Feinmaterial dieser Schicht besteht aus Ton, der leichte Tendenzen zu einem kreuzstreifigen b-Gefüge aufweist, und amorphen, organischen Material. In der gröberen Kategorie, bei einer Größe über 10 µm, überwiegen gerundete bis leicht kantige Quarzkörner in Sand- und Schluffgröße. Weiterhin sind Glimmer vorhanden und Pflanzenreste in unterschiedlicher

Größenordnung. Größere Pflanzenreste weisen verschiedene Zellenformen auf. Der Anteil an Pflanzenmaterial nimmt mit steigender Tiefe ab. Vereinzelt sind Schwammnadeln sowie Diatomeen. Knochenfragmente, Holzkohleflitter und einige wenige Feuersteine, vermutlich Artefakte, vorhanden (siehe Abbildung 1). Die Schicht beinhaltet einige Hinweise auf Bioturbation, in Form von rezenten Wurzeln, sowie Gängen und Kammern als der Hauptanteil des Porenvolumens (siehe Abbildung 2). Weiterhin sind Eisenausfällungen vorhanden, vor allem in Bezug auf Poren. Der oberste Zentimeter dieser Schicht ist durch Laminae mit dunkelschwarzem und braunem amorphen organischen Material geprägt.



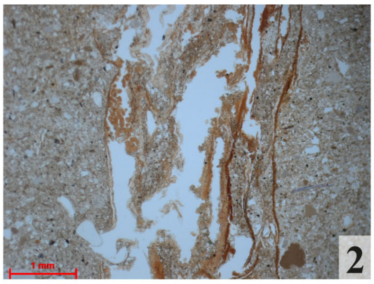
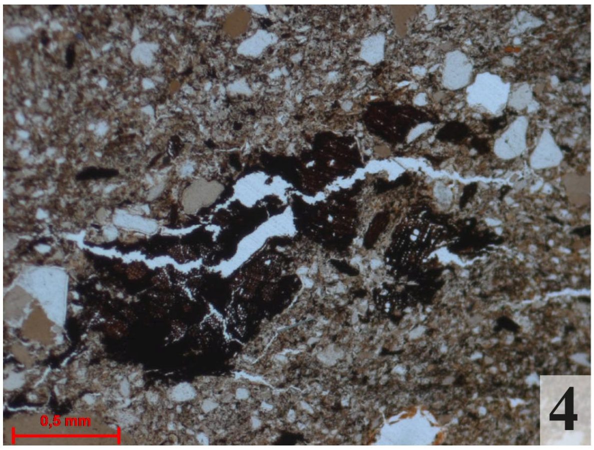


Abbildung 1. GS 3 mit Knochenfragmenten (gelbe Pfeile), sand- bis schluffgroßen Quarzkörnern und einigen vereinzelten Holzkohlepartikeln. Parallele Polarisationsfiltern (PPL), Maßstab links unten 1 mm. Abbildung 2. Rezenter Wurzelgang in GS 3 mit erhaltenen Pflanzenzellen. PPL, Maßstab links unten 1 mm. Abbildung 3. Scan von Dünnschliff Grabow 19 – 2A. Der Feuerstellenbefund 101 ist durch seine graue Färbung erkenntlich (roter Pfeil). Dünnschliffmaße 5x7,5 cm.

Innerhalb dieser Schicht befindet sich der Befund 101, vertreten in einem der Dünnschliffe. Dieser ist bereits makroskopisch im Dünnschliff durch eine lokale Graufärbung erkenntlich (siehe Abbildung 3). Mikroskopisch wird ersichtlich, dass die Graufärbung durch eine Vielzahl von Holzkohlepartikeln, bis 50% der groben Fraktion, verursacht wird. Diese Holzkohlepartikel sind nicht kantenverrundet und weisen eine Größenvariation von wenigen Mikrometer bis zu 5 mm auf (siehe Abbildung 4 und 5). Weiterhin enthält der Befund schluffgroße Quarzkörner, Glimmer, einige Knochenfragmente und Glaukonit.



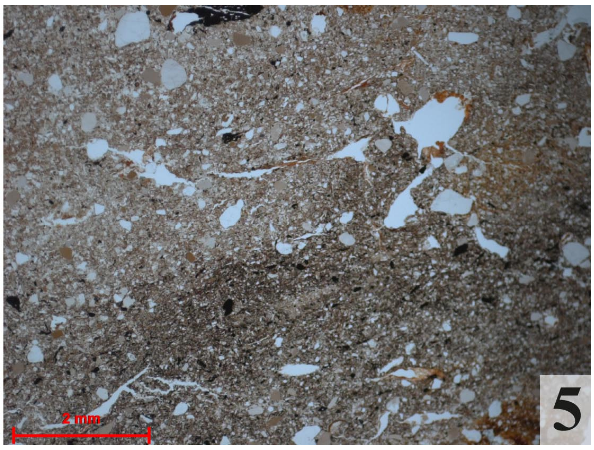


Abbildung 4. Gut erhaltenes Holzkohlefragment in Befund 101. PPL, Maßstab links unten 0,5 mm. Abbildung 5. Feuerstellenbefund in unterer Bildhälfte, gekennzeichnet durch eine dunklere Färbung, verursacht durch eine Vielzahl kleiner Holzkohleflitter. PPL, Maßstab links unten 2 mm.

Die aufliegende Grabungsschicht 2, GS 2, ist geprägt durch einen erhöhten Anteil an Feinmaterial, in der Form von kreuzstreifigem Ton und amorphen organischem Material. In der gröberen Kategorie dominieren wieder gerundete Quarzkörner in Sand- bis Schluffgröße. Weiterhin ist Glimmer vorhanden, der in seiner Orientierung dem kreuzstreifigen b-Gefüge des Tones entspricht. Größere Fragmente an Pflanzenmaterial sind seltener als in GS 3 und vor allem in der Form von rezenten Wurzeln vorhanden. Eisenausfällungen treten auf, speziell in Verbindung mit Poren. Das Porenvolumen ist vor allem durch einige wenige Gänge und Kammern geprägt. Ansonsten ist die Mikrostruktur massiv.

Diskussion

GS 3 stellt einen tonig-sandigen Schluff dar, der durch Bioturbation überprägt ist. Diese Bioturbation ist sowohl rezenten als auch älteren Ursprungs. Die organischen Laminae an der Oberkante dieser Schicht weisen darauf hin, dass diese als Paläoboden interpretierte Schicht (Tolksdorf *et al*. 2013) das Resultat von eingeschwemmtem Material mit anschließender Bodenbildung ist. Der in dieser Schicht enthalten Befund 101 stellt mit großer Wahrscheinlichkeit einen *in situ* Feuerstellenbefund dar. Die Abwesenheit von Ascherhomben ist hier nicht weiter verwunderlich, da der tonig-sandige Schluff kein geeignetes Milieu für die Präservation von Asche darstellt und zudem der Befund durch Verwitterung überprägt ist. Die klare Begrenzung des Befundes, die gute Erhaltung der Holzkohle und seine hohe Konzentration macht ein Transport des Materials unwahrscheinlich und weist auf einen *in situ*

Befund hin. Weitere Untersuchungen bezüglich einer Hitzeveränderung der vergesellschafteten Glaukonitkörner und Knochen könnten absolute Klarheit verschaffen.
Die Grabungsschicht 2 stellt einen tonigen, sandigen Schluff dar, der durch wiederholte Trocken- und Feuchtphasen überprägt ist. Die Bioturbation dieser Schicht ist vor allem rezenten Ursprungs.

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Anhang 7

Mareike C. Stahlschmidt, Report on the geoarchaeological field work and micromorphology at Varsche Rivier 003, South Africa - 2012. (17 pages)

Report on the geoarchaeological analyses at Varsche Rivier 003 - 2012

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Research questions

The geoarchaeological research at Varsche Rivier 003 is directed at understanding the formation of the site, documenting the stratigraphic succession, analyzing the integrity of the archaeological deposits and integrating the site into the landscape. For this aim in the 2011 field season a survey of the surrounding landscape was conducted, a standard stratigraphic description was carried out, loose samples were collected at the site and the surrounding area, and block samples were taken for micromorphological study. Several specific questions concerning the site formation came up during the excavation and stratigraphic discussion: How are the main excavation area and test pit III connected? Does the brown silt represent the same depositional episode inside and outside the shelter? Is archaeological material transported from inside the shelter to the slope or from the plateau above? What are the differences in upslope and downslope depositional processes and how are they influenced by the presence of the large boulder? Is the calcrete formation in geological horizon 4 and 5 groundwater related or does it present a pedogenic process linked to surface stabilization? What is the nature of the depositional change between the upper coarse-grained slope deposits and the lower, finer sediments? To address these questions, we applied the method of micromorphology, combined with grain-size analysis of loose samples.

Materials and Method

Geoarchaeological investigation by Mareike Stahlschmidt (University of Tübingen, Germany) during the 2011 field season at Varsche Rivier 003 was undertaken from July 24th to August 8th The geoarchaeological research consisted of two parts, an exploration of the surrounding landscape and one site study of the stratigraphy. Well-documented GPS points were taken at prominent points of the landscape and at different possible sediment sources to the site (see Fig. 1). Loose sediment samples and rock samples were collected as a reference collection for the site and landscape. Points were shot in with a total station for the preparation of a topographic profile from the tip of the limestone ridge above VR003 across the Varsche river bed to the north (see Fig. 2). Loose samples were collected on site, of which 8 were analyzed for grains size distribution analysis (see elsewhere). 11 block samples were collected for micromorphological studies, which was the main method used for analysis and interpretation of the site formation processes (Table 1, Fig. 3).

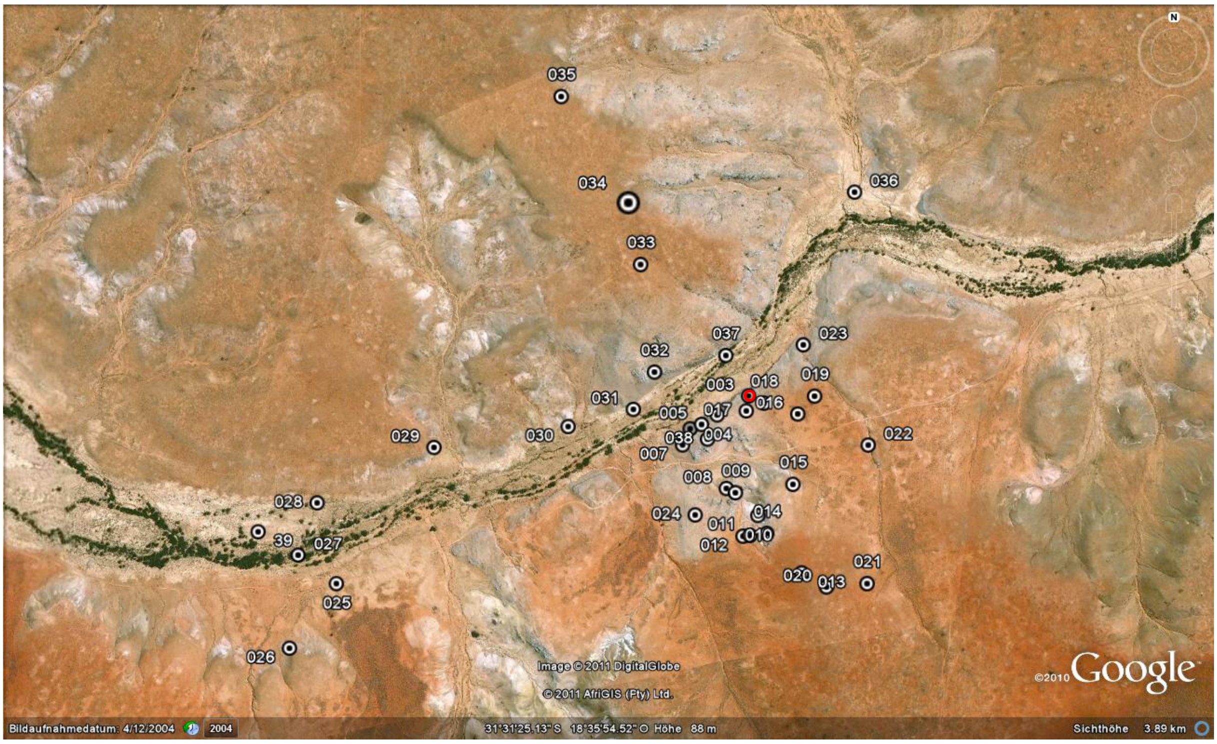

Fig. 1. Survey map of GPS points of the samples for a sediment reference collections of the survey study area. GPS point 3 (red circle) as the site VR003. Note the difference drainage system into the Varsche river exposing the limestone bedrock. The reddening color of the landscape is the result of iron coating quartz grains composing the dunes.

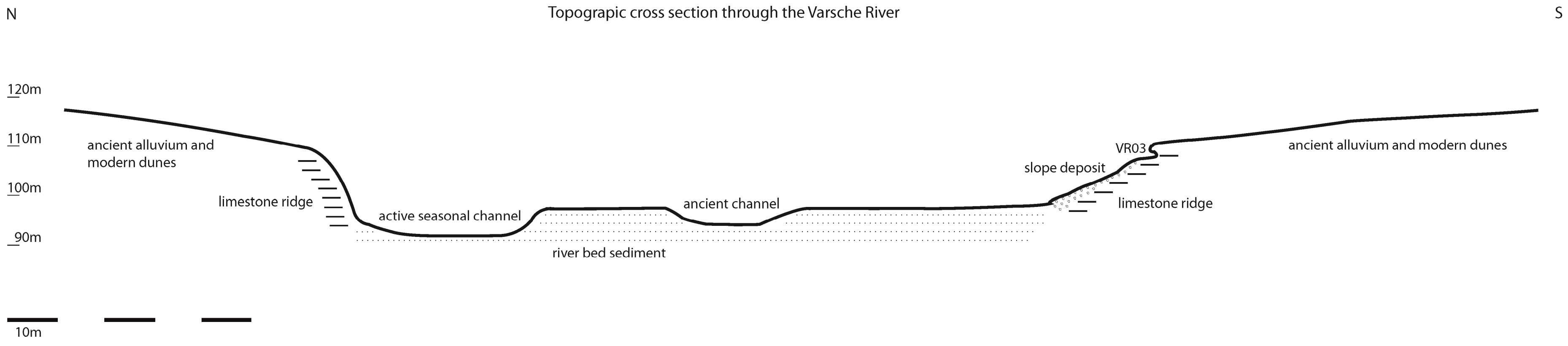

Fig. 2. Schematic topographic cross section through the Varsche river at the site location. The site VR003 is located about 8m above the present river bed elevation. The river is cut through the limestone bedrock and the riverbed is about 130m broad here. Further sediment sources are present on the plateau above the limestone with red sands, clays, soils, silcrete and quartz outcrops.

Micromorphology is the microscopic study of intact blocks of sediments (Courty *et al.* 1989). This provides insights into the formation of depositional units and their post-depositional alterations. Secured block samples were taken in the field and indurated with a mix of unpromoted polyester resin, styrene and Methylethylketone peroxide in the geoarchaeological laboratory in Tübingen. Small blocks were then cut off, glued onto glass slides and then ground to a thickness of 30 µm. The thin section production was conducted by T. Beckmann (Braunschweig, Germany) and P. Kritikakis (Tübingen, Germany). Analysis is performed with a standard petrographic microscope at magnifications of 25x, 50x, 100x, 200x and 500x using plane- and cross-polarized as well as blue-light fluorescence. Thin section description follows Courty *et al.* (1989), Stoops (2003) and Stoops *et al.* (2010).

Results

Macroscopic Analysis

The excavation area is divided into a main excavation area at the slope in front of the shelter and test pit III inside the entrance of the shelter. The stratigraphic succession at the main excavation and of test pit III is described in detail in Table X and Fig. Y. Starting from the top, geological horizons 1-3 contain a range of unsorted limestone rubble in grey sandy silt matrix. From geological horizon 1, the surface layer, over geological horizon 2 to geological layer 3 a decrease in bioturbation features, such as roots and other organic matter, is evident. A huge limestone boulder associated with numerous large limestone debris (see Fig. 3) divides the geological horizon 3 and following geological horizons 4 and 5, into an upper and a lower slope, but which only differ in a more horizontal orientation of limestone rubble in the upper slope part where the boulder served as a trap. Geological horizons 4 and 5 also consist of limestone rubble in a grey sandy silt matrix, but are characterized by horizontal calcareous crust structures. Geological horizon 5 presents one continuous hardpan structure, which coincides with the bottom of the large limestone boulder mentioned above. In the lower slope part, geological horizon 4 and 5 are less expressed. The lowermost geological horizon, 6, consists of fine brown silt with less limestone rubble than above. All geological units show a slight dip down the slope parallel to the modern surface.

Fig. 3. Eastern profile wall of the main excavation showing sampling locations of block samples for micromorphological study.

The sedimentary sequence inside the shelter is quite different and it can be divided into an upper, more anthropogenic part with LSA artifacts and a lower more geogenic part with a MSA signature. The upper LSA part of the sequence was separated into five geological horizons, geological horizon 1 to 5. Geological horizon 1 is the bioturbated surface. Below, geological horizon 2 is a grey to brown silt with many organic remains like modern roots, bones and shells. Geological horizon 3 is characterized a dark brown bedding features. Geological horizon 4 is defined by the presence of white calcareous nodules in the brownish grey silt matrix. Geological horizon 5 is characterized by numerous charcoal fragments and some white possible ash lenses. A horizontal layer of landsnail shells in the northern profile separates the upper LSA and lower MSA part of the stratigraphic sequence (see Table/Fig. Y). The lower MSA part was divided into four geological horizons, geological horizon 6 to 9. Geological horizon 6 and 7 both consist of pebble-sized limestone rubble in yellowish grey sandy silt with geological horizon 7 being compacter. Geological horizon 8 presents a transitional horizon to geological horizon 8 and shows a decrease in limestone rubble and a slightly brownish grey color. The lowermost horizon, geological horizon 9, consists of brown silt similar to the brown silt in the main excavation area, geological horizon 6, but only few centimeters of this layer were observable at the end of the field season 2011.

Micromorphological analysis

Micromorphological analyses were conducted on 12 thin sections, encompassing geological horizon 2 to 6 in the main excavation area and geological horizon 6 to 9 in test pit III, all presenting MSA bearing horizons. Geological horizons 5 to 6 of the main excavation area are represented in samples from the upslope and downslope part of the excavation area. No substantial difference was evident in the upslope and downslope part; therefore these are presented as one. Furthermore no micromorphological difference was observed from geological horizon 2 to geological horizon 3 from the main excavation area and from geological horizon 6 to geological horizon 7 in test pit III. Accordingly geological horizons 2 and 3 from the main excavation area are presented as one and geological horizons 6 and 7 in test pit III are presented as one. Table 2 shows the detailed results of the micromorphological analyses for each geological horizon and the following is a summary of the micromorphological highlights.

All analyzed horizons in the main excavation area have a calcareous groundmass with a lower clay component. Coarse components are sparry limestone rubble (Fig. 4a), sand-sized calcite crystals, sand to silt sized quartz, bone fragments, ostrich eggshell fragments and limestone pendant fragments. Possible microdebitage (Fig. 4c) and a few lenticular gypsum crystals are also present. The microstructure is micro-granular and spongy with thick, multilayered coatings of coarse grains by calcareous and clayey fine material (Fig. 4a-c, 5c). Coating of coarse grains is less expressed in the brown sandy silt of geological horizon 6 (Fig. 6a). Interestingly, only thin or no coatings were observed on angular quartz, quartzite and silcrete microdebitage (Fig. 4c). However, all observed bone fragments show thick coating. Bioturbation features are present in all horizons, e.g. in the form of burrows, channels, rhizoliths and redox features, and transported soil aggregates are of regular appearance (Fig. 7a-c).

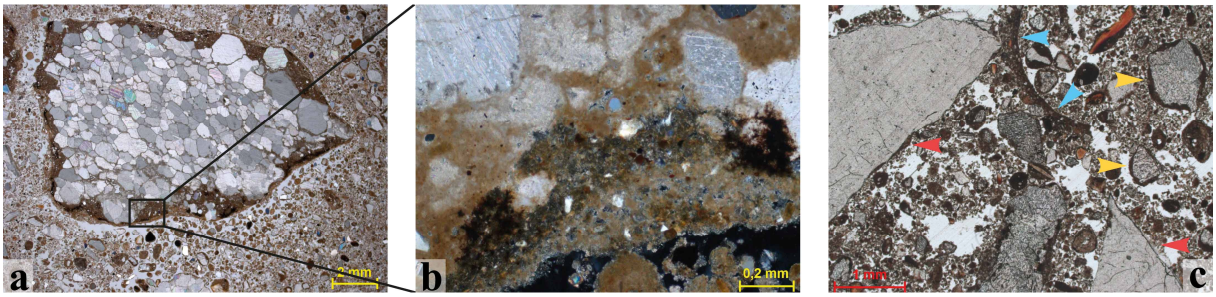

Fig. 4 Microphotographs of the coating on coarse grains in the main excavation area. 4a) Thick coating on coarse grains, here limestone rubble, by fine material in geological horizon 3. Note how all the fine material (>10 µm) is arranged in globular shape. Plane-polarized light (PPL), scale at right bottom 2 mm. 4b) Zoom onto the coating of the microphotograph 4a showing, that the coating often consists of several layers of coating, clayish and calcareous, and incorporates silt sized grains. Cross-polarized light (XPL), scale at right bottom 0.2 mm. 4c) Coating of all coarse grains (yellow arrows) in geological horizon 6, but microdebitage (red arrows) showing only thin to no coating. Note also a circular burrow (blue arrow) as a bioturbation feature. PPL, scale at lower left 1 mm.

Fig. 5 Microphotographs on the calcareous crust in geological horizon 4 and 5 in the main excavation area. 5a) The calcareous crust shows a dense microfacies dissected by channels with a more granular microstructure. PPL, scale at lower right 1 mm. 5b) The calcareous crust incorporates coated grains and coated bone fragments (yellow arrows). PPL, scale at upper right 1 mm. 5c) Zoom into the crust showing a calcitic crystallitic b-fabric, micritic calcite, a vughy microstructure (blue arrow) and some plant pseudomorphs (purple arrows). XPL, scale at lower right 0.1 mm.

Fig. 6 Brown silt in geological horizon 6 in the main excavation area and in geological horizon 9 in test pit III 6a) Brown silt in the main excavation area showing a speckled to calcitic crystallitic b-fabric with brownish organic staining. Note also the black bone char fragment in the middle of the photograph and the less intense coating on coarse grains. XPL, scale at lower right 0.2 mm. 6b) Abundant lenticular, secondary gypsum (yellow arrows) forming inside the shelter, test pit III. XPL, scale at lower right 1 mm. 6c) Brown silt inside the shelter, test pit III, shows a dominantly clayish matrix in GH 9 and lenticular gypsum. Note that the fine material is not arranged in coatings. XPL, scale at lower right 0.2 mm.

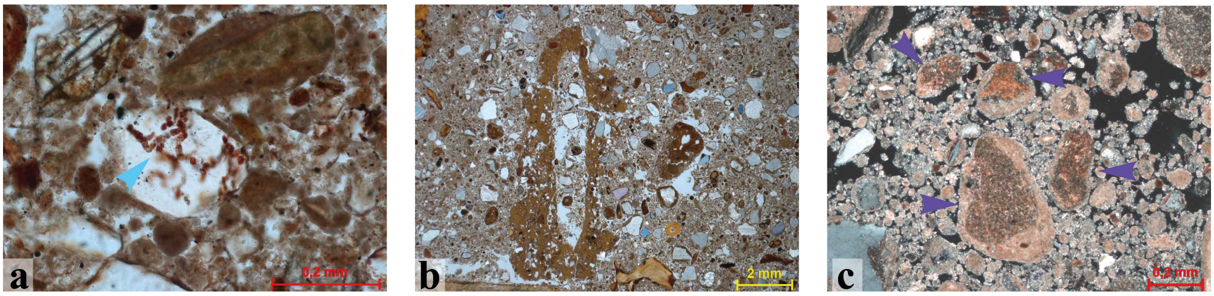

Fig. 7 Bioturbation features. 7a) Quartz grain with excrements (blue arrow) in the main excavation area. PPL, scale at lower right 0.2 mm 7b) Oxide feature in geological unit 6 of the main excavation area. Note the abundance of reddened bone (yellow arrows) and the absence of limestone rubble in this horizon. PPL, scale at lower left 2 mm. 7a) Transported soil aggregates in geological horizon 4 in the main excavation area. XPL, scale at lower right 0.2 mm.

In geological unit 4 und 5 dense calcareous areas were observed representing the calcareous crust as observed in the field. The calcareous crust is micritic, incorporates coated grains, bone fragments, plant pseudomorphs, and is dissected by some channels and vughs (Fig. 5a-c). No carbonate depletion was observed in the overlying geological horizon 4 and 3, while the lower geological horizon shows a lower carbonate content (see below). Burnt remains are present in geological horizon 4 to 6 in the form of reddened, dominantly sand sized bone fragments, few charcoal fragments, and bone char (Fig. 6a, 7b). Geological horizon 6 is characterized by an increased presence of reddened, sand-sized bone fragments, higher clay content in the matrix compared to the above horizons, and less limestone rubble (Fig. 6a, 7c), but shows the same micro-granular to spongy microstructure and coating, but less thick, as the upper horizons.
The picture is quite different inside the shelter, in test pit III. The microstructure here is dominantly spongy and less micro-granular. The fine material is generally not arranged in coatings (Fig. 6b, c). Bioturbation features are less frequent, while transported soil aggregates were regularly observed. Intense gypsum formation was observed in all analyzed horizons (Fig. 6b, c). Otherwise no difference in coarse components was observed. The groundmass is dominantly calcareous in geological horizon 6 to 8, but clayish in geological horizon 9 (Fig. 6c) and here only calcareous in association with a channel feature.

Discussion

The micromorphological analysis reveals differing formation processes and conditions on the slope, e.g. colluvial processes, bioturbation, moist conditions, from inside the shelter, e.g. few post-depositional alterations, dry conditions. Further, the micromorphology observations have different implications for the archaeological record with less post-depositional disturbances and a partial different depositional history of the archaeological materials inside the shelter than on the slope.
On the slope the most intriguing microfacies is the round coating of all coarse grains throughout the sequence. Coating on coarse grains can be produced by colluvial processes (see e.g. Bertran and Texier 1999), freeze and thaw (see e.g. Vliet-Lanoë 2010) or calcrete formation (see e.g. Braithwaite 1983; Wright and Tucker 1991; Candy *et al*. 2003). The round nature of the coating, its composition of several lamina and their position on the slope make a colluvial process combined with rolling on a wet surface the most likely explanation (Hay and

Reeder 1978; Bertran and Texier 1999; Rose *et al*. 2000). Concerning the calcareous crust, its formation is the result of subsurface redistribution of carbonates in these calcareous rich sediments (see e.g. Rabenhorst and Wilding 1986). The plant pseudomorphs indicate a bio-induction (Wright 1991 and Tucker) process of the carbonate redistribution while the micritic nature of the calcite indicates rapid evaporation (Braithwaite 1983) as a process. A combination of these processes is not unusual (Wright and Tucker 1990).

The calcareous crust incorporates coated grains and granules meaning that the colluvial deposition was followed by bioturbation and crust formation in geological unit 4 and 5 with the latter being a sign of drier conditions as also indicated by minor gypsum formation here. The formation of the crust was then again followed by bioturbation dissecting the crust. The more organic and clay-rich sediment of geological unit 6 indicate moister conditions than in the upper horizons. To summarize, we observe a change from moister conditions during the formation of the site to post-depositional alterations with dryer conditions.

Inside the shelter the conditions were generally much dryer and more sheltered as the intense formation of secondary gypsum and the absence of colluvial coating indicates. Nevertheless, soil aggregates are washed in through the chimney. The increased presence of clay inside the shelter could also present a result of more sheltered conditions, where in contrast to the slope small clay particles are not washed away by low energy water flow. This being said, the depositional change from a calcareous matrix to an almost carbonate depleted clay-rich matrix from geological horizon 6, 7 and 8 to geological horizon 9 is still unclear.

Another questions raised before was the connection between the brown silt inside and outside the shelter. While both horizons are characterized by a strong presence of burnt sand-sized bones, as is typical for paleolithic layers, and by an increased presence of clay compared to the upper horizons, some differences remained. Geological horizon 6 on the slope has a more colluvial characters and shows several bioturbation features whereas inside the shelter the sediments do not show a transported character.

Concerning the primary or secondary context of the archaeological materials on the slope and in the shelter several observations were made. Based on the sedimentary characteristics, sedimentary material Inside the Shelter presents mostly a primary context with minor bioturbation possibly caused post-depositional translocation of quartz grains. On the slope in the Main Area sedimentary material is in secondary, reworked and bioturbated context.

Bioturbation possibly caused post-depositional translocation of quartz grains. Colluvial processes might have influenced the archaeological assemblage, see e.g., the coating of small bone fragments. This being said the lack of coating of microdebitage points to a primary context for this sedimentary particle class.

The possible dislocation of quartz grains must be considered in regard to the OSL dating and a continuation of excavation inside the abri are recommended instead of excavations on the slope.

Tables

Table 1. Sample list

Sample No°	Excavation area	Square (X/Y)	Z-value	Layer	Employed method
VR3-11-1	Main exc. area	1016/1025	106.48	GH 2-3 (AH 3-4)	Micromorphology
VR3-11-3	Main exc. area	1016/1025	106.23	GH 4 (AH 4)	Micromorphology
VR3-11-4A	Main exc. area	1016/1025	106.08	GH 4-5 (AH 4, 5 & 7)	Micromorphology
VR3-11-4B	Main exc. area	1016/1025	106.06	GH 4-5 (AH 4, 5 & 7)	Micromorphology
VR3-11-5	Main exc. area	1016/1025	105.93	GH 6 (AH 7)	Micromorphology
VR3-11-6	Main exc. area	1016/1023	105.57	GH 5 (AH 5)	Micromorphology
VR3-11-7	Main exc. area	1016/1023	105.39	GH 6 (AH 6)	Micromorphology
VR3-11-8	Test pit III	1016/1029	106.53	GH 6-7 (AH 15-16)	Micromorphology
VR3-11-10	Test pit III	1016/1029	106.35	GH 8-9 (AH 17-20)	Micromorphology
VR3-11-11	Test pit III	1016/1029	106.2	GH 9 (AH 20)	Micromorphology
VR3-11-1017	Test pit III	1016/1029	106.25	GH 8 (AH 17)	Grain-size-analysis
VR3-11-1018	Test pit III	1016/1029	106.15	GH 9 (AH 18-20)	Grain-size-analysis
VR3-11-1019	Main exc. area	1016/1025	106.29	GH 3 (AH 3)	Grain-size-analysis
VR3-11-1020	Main exc. area	1016/1025	106.11	GH 4 (AH 4)	Grain-size-analysis
VR3-11-1022	Main exc. area	1016/1025	105.9	GH 4 (AH 6)	Grain-size-analysis
VR3-11-1023	Main exc. area	1016/1025	105.83	GH 6 (AH 7)	Grain-size-analysis
VR3-11-1025	Main exc. area	1016/1023	105.34	GH 6 (AH 7)	Grain-size-analysis
VR3-11-1026	Main exc. area	1016/1023	105.21	GH 6 (AH 7)	Grain-size-analysis

Table 2. Overview of the micromorphological data

GH	Samples	Microstructure	Coarse components*	Fine material
Main Excavation Area				
2 & 3	VR3-11-1	Typic, thick, globular coating of fine material on all coarse grains (thickness 10-140 µm but mainly ~30 µm; irregular pattern of coating, but often one side more heavily coated and elongated coarse grains with tendency for thicker coating on longer sides; clear borders) but quartz chips only with thin coating and gypsum without; fine material also in globular form (diameter 25-200 µm, but dominantly ~60 µm) but possibly coarse nuclei not visible; coating on coarse grains and fine material spheres homogenous, in some case with several lamina, clayish and calcareous, occasionally incorporating silt sized grains, red iron and amorphous organic staining Local areas with crust formation (dense, grayish dark brown to grey; calcareous; incorporating silt and sand sized grains), often associated with bones Thin dark red iron coating of all natural quartz grains Iron staining bone with recrystallisation and manganese staining complex packing voids micro-granular to spongy microstructure	Sparry limestone fragments (angular, not size sorted); calcite crystals (medium to very coarse sand sized); quartz grains (round to subangular, medium sand to coarse silt sized; dark red coating); bone fragments, angular (spongy and cortical); limestone pendants, angular, with clay component; lenticular gypsum (sand sized, single crystals in matrix and accumulations in voids); ostrich eggshell fragments; angular quartz chips (microdebitage?)	Calcareous, clayish calcitic crystallitic to speckled, sometimes cross-striated b-fabric; enaulic and chitonic; gray to brownish grey in PPL, grey to yellowish (iron staining) in XPL Crust calcitic crystallitic
4	VR3-11-3 VR3-11-4A VR3-11-	Typic, thick, globular coating of fine material on all coarse grains (thickness of coating 20-300 µm, but dominantly ~30 µm; coating mostly equally expressed on all side, but some fraction with more intense coating on two adjacent sides; clear borders) but gypsum; fine material also in globular form (diameter 10-	Sparry limestone fragments (angular, not size sorted); calcite crystals (medium to very coarse sand sized); quartz grains (round to subangular,	Calcareous, clayish Calcitic crystallitic to speckled, sometimes cross-striated b-fabric; enaulic and chitonic; gray to

	4B	115 µm, but dominantly 20-50 µm) but possibly coarse nuclei not visible); coating on coarse grains and fine material spheres homogenous, in some case with several lamina, clayish and calcareous, occasionally incorporating silt sized grains Thin dark red coating on quartz grains Round, transported soil aggregates, also coated Locally very dense in association/next to large bone fragments complex packing voids micro-granular to spongy microstructure bone with recrystallisation and manganese staining	medium sand to coarse silt sized, dark red coating); bone fragments (angular; some burnt?, different weathering stages; spongy and cortical); gypsum (single crystals in matrix and accumulations in voids); ostrich eggshell fragments; soil aggregates; limestone pendants, with clay component	brownish grey in PPL, grey to yellowish (iron staining) in XPL Soil aggregates with cross-striated b-fabric
5	VR3-11-4A VR3-11-4B VR3-11-6	Typic, thick, globular coating on all coarse grains (thickness of 15-200 µm , but dominantly ~30 µm; clear borders), but gypsum; fine material also in globular form (diameter 10-100 µm, but dominantly 20-40 µm) but possible coarse nuclei not visible; coating on coarse grains and fine material spheres homogenous, in some case with several lamina, clayish and calcareous, occasionally incorporating silt sized grains Thin dark red iron coating of quartz grains Dark grey to grey dense crust incorporating coated coarse grains, coated bones and globular fine material complex packing voids, vughs, channels micro-granular to spongy microstructure bone with recrystallisation and manganese staining	Sparry limestone fragments; calcite crystals (medium to very coarse sand sized); quartz grains (rounded to subangular; medium sand to coarse silt sized), bone fragments (many reddened with black edges; spongy and cortical); round soil aggregates; gypsum (single crystals in matrix and accumulations in voids); ostrich eggshell; quartz and quartzite microdebitage; charcoal	Calcareous, clayish Calcitic crystallitic to speckled, sometimes cross-striated b-fabric; enaulic and chitonic; gray to brownish grey in PPL, grey to yellowish (iron staining) in XPL Crust calcitic crystallitic b-fabric of the crust Grayish white soil aggregates with a striated to cross-striated b-fabric
6	VR3-11-4B, VR3-	Typic, thick, globular Coatings on all coarse grains (thickness of 10-150 µm, but dominantly 20-30 µm; borders less well-defined than in upper units), but	Calcite crystals (medium to very coarse sand sized); quartz grains (rounded to	Calcareous, clayish; Calcitic crystallitic to speckled,

	11-5 VR3-11-7	on microdebitage and gypsum; fine material also tending to be in globular form (diameter 10-125 µm, but dominantly 20 µm) but possible coarse nuclei not visible; coating on coarse grains and fine material spheres homogenous, in some case with several lamina, clayish and calcareous, occasionally incorporating silt sized grains Thin red iron coating of quartz grains Fine material denser than the above units Rounded pieces of calcareous crust Matrix with amorphous black spot and red iron local domains Iron oxide coating complex packing voids, vughs, channels, was burrow, rhizolith micro-granular to spongy microstructure bone with recrystallisation and manganese staining	subangular; medium sand to coarse silt sized), bone fragments (many reddened, black edges, other color changes and blackened cracks; spongy and cortical; mainly sand-sized); round soil aggregates; background gypsum? Very few lenticular gypsum; ostrich eggshell; quartzite, quartz, silcrete microdebitage; charcoal; mica; sparry limestone fragments; limestone pendants, with clay component; char	sometimes cross-striated b-fabric; enaulic and chitonic; gray to brownish grey in PPL, grayish white to light grayish brown (iron staining) in XPL Soil aggregates with cross-striated b-fabric
Inside Shelter - Pit III				
6 & 7	VR3-11-8	Passage feature Typic, thin coatings of some coarser grains (thickness 20-30 µm; calcareous und clayish; globular) Thin dark red coatings of quartz grains Many amorphous black spots and local red iron domains (less red iron domains than in the lower GH 8 and 9) Spongy to micro-granular microstructure, but some vughs and channels as well bone with recrystallisation and manganese staining	Sparry limestone fragments; single calcite crystals (medium to very coarse sand sized); quartz grains; gypsum (single crystals in matrix and accumulations in voids), bone fragments (spongy and cortical; mostly sand sized, many burnt); ostrich eggshell; char; round soil aggregates; mollusk fragment; charcoal; possible wood ash; clay-rich spelothem; halite	Calcareous, less so clayish Calcitic crystallitic b-fabric to speckled; porphyric to slightly chitonic; light yellowish brown to grayish brown to in PPL, yellowish to gray in XPL

8	VR3-11-10	Typic, thin coatings of most some coarse grains (bones, calcite crystals, quartz; thickness 20-30 µm; calcareous und clayish; globular) Thin dark red coatings of quartz grains Many amorphous black spots and local red iron domains Spongy to micro-granular microstructure Varying ration of fine to coarse material Passage feature bone with recrystallisation and manganese staining one quartz grains with calcite replacement	Sparry limestone fragments; single calcite crystals (medium to very coarse sand sized); lenticular gypsum (single crystals in matrix and accumulations in voids); quartz grains (round to subangular; medium sand to medium silt size); bone fragments (spongy and cortical; mostly sand sized; many burnt); limestone pendants, with clay component; round aggregates; charcoal; quartz microdebitage	Calcareous, less so clayish Calcitic crystallitic b-fabric to speckled; porphyric to slightly chitonic; light yellowish brown grayish brown in PPL, yellowish to gray in XPL Soil aggregates with striated to cross-striated b-fabric
9	VR3-11-11	Typic, thin coatings of most some coarse grains (bones, calcite crystals, quartz; thickness 20-30 µm; calcareous und clayish; globular) Thin dark red coatings of quartz grains Many amorphous black spots and local red iron domains Spongy to micro-granular microstructure bone with recrystallisation and manganese staining some plant tissue (spores associated with a degrading root)	Sparry limestone fragments; single calcite crystals (medium to very coarse sand sized); lenticular and epigranular gypsum (single crystals in matrix and accumulations in voids; very coarse sand to coarse silt size); quartz grains (round to subangular; medium sand to medium silt size); bone fragments (spongy and cortical; mostly sand sized; many burnt); clayish aggregates; oestrich eggshell; quartz and silcrete microdebitage; limestone pendants, with clay component	Clayish speckled and dotted, sometimes cross-striated b-fabric; in channel with calcareous component; porphyric, slightly chitonic; brownish gray to gray to in PPL, yellowish brown, grey and brown in XPL Soil aggregates with cross-striated b-fabric

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Anhang 8

Mareike C. Stahlschmidt, Christopher E. Miller. Bericht über die mikromorphologischen Untersuchungen an der Feuerstelle 2 Blätterhöhle, Deutschland - 2011. (11 Seiten)

Bericht über die mikromorphologischen Untersuchungen an der Feuerstelle 2 auf dem Vorplatz der Blätterhöhle, Hagen.

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Die Feuerstelle 2 auf dem Vorplatz der Blätterhöhle wurde zum Ende der Grabungskampagne 2008 entdeckt. Proben zur mikromorphologischen Analyse dieser Feuerstelle wurden im Mai 2009 durch Mareike Stahlschmidt, Universität Tübingen, genommen. Die Analyse der Dünnschliffe hatte das Ziel vertiefende Einblicke in die Genese des Befundes dieser Feuerstelle im Gesamtkontext der Fundstelle zu geben.

Die Blätterhöhle stellt eine Höhle innerhalb des Weißensteins bei Hagen-Holthausen dar. Der Fundplatz befindet sich somit im Gebiet des südwestfälischen Massenkalkes in einem Seitental der Lenne. Archäologische Ausgrabungen auf dem Vorplatz begannen 2006, nachdem innerhalb der Höhle mittel- und jungsteinzeitliche Menschenreste entdeckt worden waren. 2006 wurde eine erste Feuerstelle im Feld identifiziert, 2008 eine weitere und eine dritte während der Grabungskampagne 2009 (Orschiedt *et al*. 2007, 2008, 2010). Es wurde von Dr. Orschiedt und Juniorprofessor Dr. Miller, Universität Tübingen, entschieden für eine genauere Analyse der Feuerstelle 2 Proben dieses Befundes für eine mikromorphologische Untersuchung zu nehmen. Hierfür wurden zwei orientierte, mit Gips gefestigte Bodenproben, die sowohl den Befund (Schicht 4b) als auch das auf- (Schicht 3) und unterliegende Sediment (Schicht 4a) umfassten, genommen. Nach der Imprägnierung in Tübingen mit einer Mischung aus Kunstharz, Styrol und Härter wurden die Proben zu Spectrum Petrographics, Inc. in Vancouver, Washington, U.S.A., zur Herstellung der Dünnschliffe eingeschickt. Aus den Proben wurden je zwei Dünnschliffe hergestellt. Der Dünnschliff BL 1A beinhaltet den Schicht 3 oberhalb der Feuerstelle 2, BL 1B und BL 2A enthalten die Schicht 4a, den Befund der Feuerstelle 2, und der Dünnschliff BL 2B enthält die an die Feuerstelle angrenzenden und unterliegenden Schicht 4a (siehe Anhang 1). Die Dünnschliffe sind 7,5 cm x 5 cm groß und haben eine Dicke von 30 µm. Die Analyse der Dünnschliffe erfolgte mit einem gewöhnlichen petrographischen Mikroskop mit Auflicht, Durchlicht, parallelen (PPL) und gekreuzten Polarisatoren (XPL) und fluoreszierendem Licht unter 2,5- bis 50-facher Vergrößerung.

Ergebnisse

Makroskopische Untersuchung

Die Feuerstelle 2 wurde als eine solche makroskopisch aufgrund einer gräulichen Sedimentfärbung, dem Auftreten von Holzkohle, gebrannten Knochen, gebrannten Steinartefakten und Brandlehm angesprochen (Dr. Orschiedt pers. Mitteilung). *In-situ* Feuerstellen zeichnen sich im mikromorphologischen Befund durch eine Dreischichtung mit gebrannten, rötlichem Sediment an der ehemaligen Oberfläche als Unterkante, einer zwischenlagernden Schicht mit dem Brennmaterial, wie Holzkohle oder gebrannten Knochen, und einer abschließenden Schicht mit Asche aus. Die Rotfärbung des die Feuerstelle unterliegenden Sediments tritt nicht regelmäßig auf und hängt von den Eigenschaften des Sedimentes als auch des Feuers ab. Asche, als karbonatisches Material, ist bei einem pH unter 8 nicht mehr erhaltungsfähig und anfällig für Diagenese. Bei dem Sediment des Vorplatzes der Blätterhöhle handelt es sich um ein sehr kalkreiches Material (s.u.), das somit gute Bedingungen für eine Erhaltung von Asche darstellt. Die Unterscheidung von Asche zu Kalzit als Verwitterungsprodukt erfolgt anhand der Morphologie. Aschekristalle haben eine typische Rhombenform, wie sie im Dünnschliff erkennbar ist (Courty *et al.* 1989; Meignen *et al.* 2001; Miller *et al.* 2010; Weiner 2010).

Mikromorphologische Untersuchung

Es folgt eine zusammenfassende, mikromorphologische Beschreibung der Dünnschliffe und detaillierte Beschreibung der Dünnschliffe sind in Tabelle 1 zu finden. Die Grenze zwischen der Grob- und Feinfraktion liegt für alle Dünnschliffe bei 10 µm.

<u>BL 1A</u> Die Schicht 3 tritt im Dünnschliff sehr kompakt auf. Es ist kaum einfacher Kornzwischenraum und Packungshohlraum zu beobachten. Stattdessen ist der Porenraum von einer Vielzahl an Rissen, Kavernen und Kanälen bestimmt (Foto 1). Einige moderne Wurzel können in diesem Zusammenhang auch beobachtet werden. Es liegt keine Aggregierung von Feinmaterial und keine Sortierung vor. Das Verhältnis von der Grob- zur Feinfraktion liegt bei 2 zu 3. Die Relativverteilung ist einfach weit porphyrisch und lokal chitonisch. Die Grobfraktion besteht größtenteils aus Quarz mit 70% und Kalksteinfragmenten mit 15%. Quarz tritt mit einer Größenvariation von feinem Schluff bis sehr feinem Sand und der Hauptkomponente mittelgroßer Schluff auf. Der Kalkstein weist keine derartigen Tendenzen

in der Größenverteilung auf, sondern tritt in Größen von 3 cm bis wenige mm auf. Kalksteine treten kaum verrundet auf. Mit geringeren Anteilen konnten einige gerundete, kleine Sandsteine, Knochen-, Schalen- und Molluskenfragmente beobachtet werden (Foto 2 und 3). Auch einige wenige Holzkohlesplitter und Glimmer treten auf. Die Feinfraktion besteht aus Ton und karbonatischem Material. Die Grundmasse hat eine gelb-bräunliche Farbe bis hin zu gräulich. Vereinzelte schwarz getüpfelte Bereiche weisen auf organisches Material hin. Ton tritt meist unorientiert auf und der karbonatisches Material mit einem kalzitisch-kristallitischen b-Gefüge. Zudem sind einige Tonhüllen um Körner und in Poren zu beobachten sowie auch lokale Kalkanreicherungen (Foto 4). Als weitere Besonderheit treten vereinzelt Tonaggregate auf.

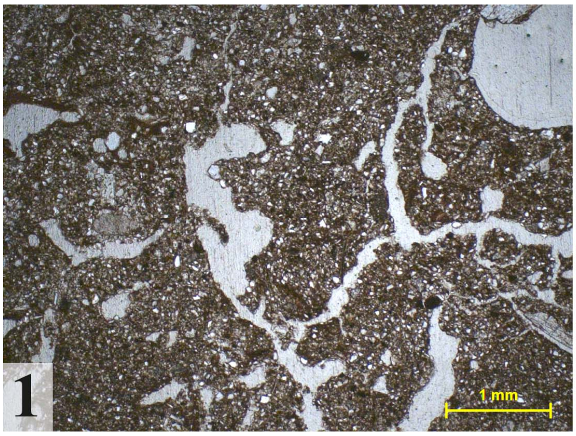
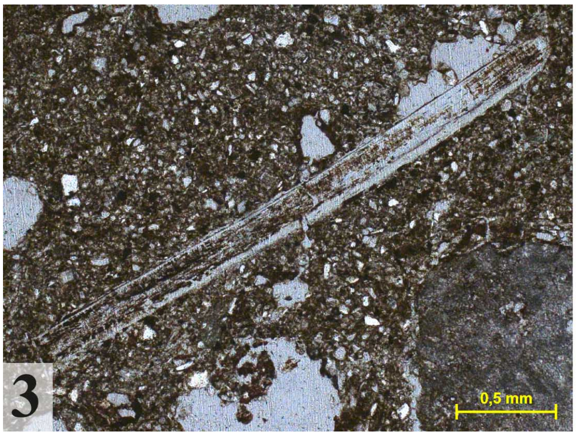


Foto 1. BL 1A mit kompakter rissiger Mikrostruktur mit Kanälen und Kaverne. Die Matrix ist sehr quarzreich PPL. Foto 2. Molluskenfragment in BL 1A. PPL.



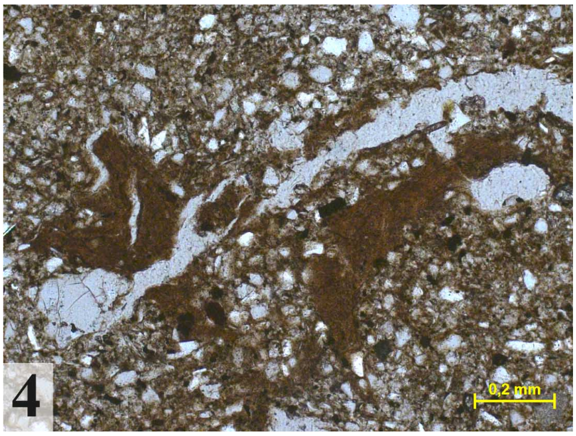
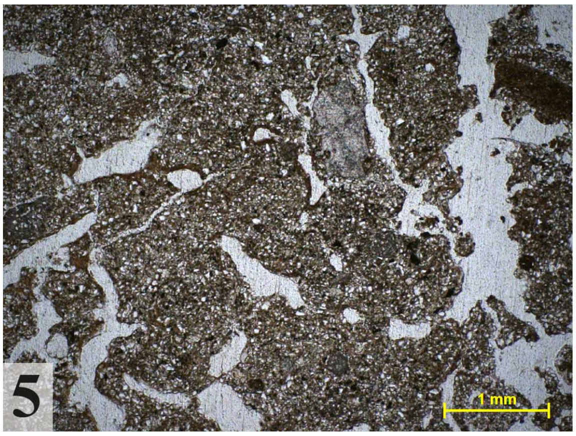


Foto 3. Knochenfragment in BL 1A. Die Matrix ist sehr kompakt und quarzhaltig. PPL. Foto 4. Tonanlagerungen in Poren, BL 1A. PPL.

BL 1B Dieser Dünnschliff enthält den Befund der Feuerstelle 2, die Schicht 4b. Auch hier weist das Sediment eine rissige Mikrostruktur mit vielen Kavernen und Kanäle auf, um dabei dennoch sehr kompakt aufzutreten (Foto 5). Es wurde keine Aggregierung von Feinmaterial beobachtet. Das Verhältnis der Grob- zu Feinfraktion liegt bei 1 zu 1, was einem erhöhten Anteil von Holzkohle, mit 10%, geschuldet ist. Die Relativ-Verteilung ist einfach weit porphyrisch mit chitonischen Tendenzen. Die Holzkohle tritt in einer Größenvariation von knapp 1 cm bis zu wenige µm große Splitter auf (Foto 6 und 9). Quarz und Kalksteinfragmente treten in gleicher Form und Anzahl wie zuvor in Schicht 3 auf. Neben diesen drei Hauptkomponenten der Grobfraktion treten zudem verrundete Sandsteine, Glimmer, Schiefer, Knochen-, Schalen- und Zahnfragmente auf (Foto 7 und 8). Hervorzuheben ist die Beobachtung von gebrannten Knochen, Holzkohle und einige Ascherhomben (Foto 9 und 10).

Das Feinmaterial besteht wiederum aus Ton und karbonatischem Material, wobei es eine verstärkte karbonatische Komponente aufweist (im Vergleich zu Schicht 3). Dieses drückt sich auch in der Vielzahl von Kalkanreicherung und Rhizokretionen aus, während Tonhüllen um größere Sedimentpartikel und in Poren weniger stark vertreten sind (Foto 11 und 12). Ansonsten unterscheidet sich die Feinfraktion in seinen Charakteristika nicht weiter. Ton tritt meist unorientiert und in Gelb- bis Orangetönen auf während Karbonat gräulich ist und als karbonatisch-kristallitisches b-Gefüge auftritt.

Weder in der Grob- noch Feinfraktion war eine Sortierung, abgesehen vom Quarz, oder Schichtung vorhanden.



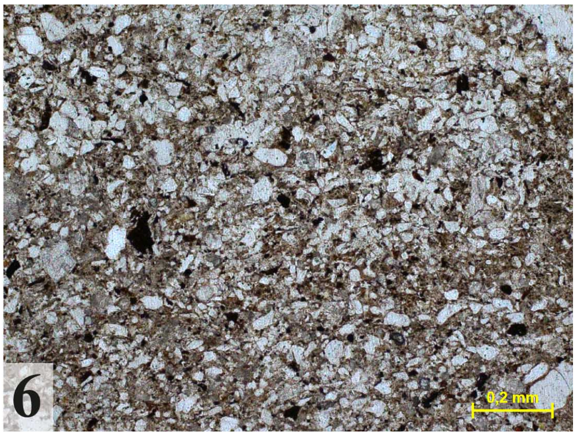


Foto 5. Mikrostruktur in BL 1B mit Rissen, Kavernen und Kanälen. Tonanlagerungen in den Poren sind sichtbar. PPL. Foto 6. Fein verteilte Holzkohle in BL 1B. PPL.

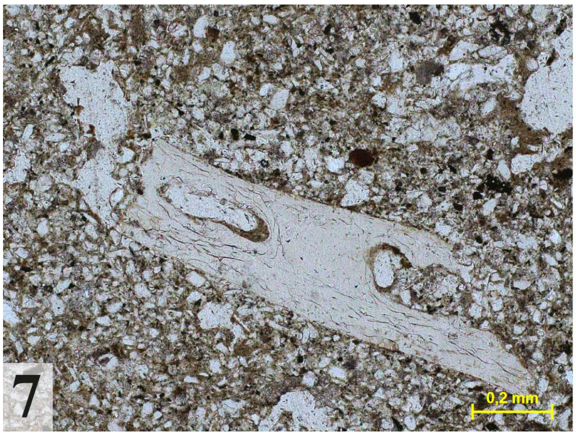
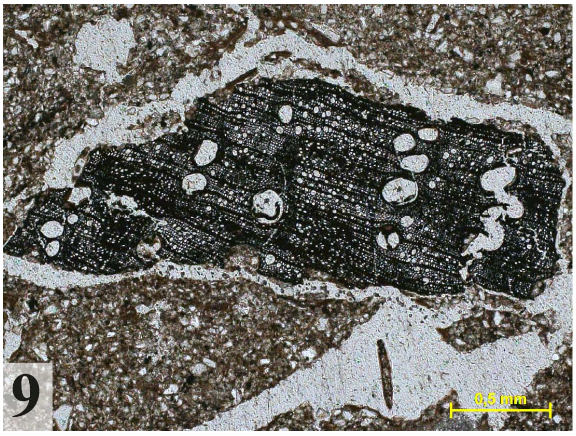


Foto 7. Knochenfragment in BL 1B. Haversche Kanäle und Krackelierungen, die auf Hitzeeinwirkung rückschließen lassen, auf der Oberfläche des Fragments erkennbar. PPL. Foto 8. Schalenfragment in BL 1B. XPL.



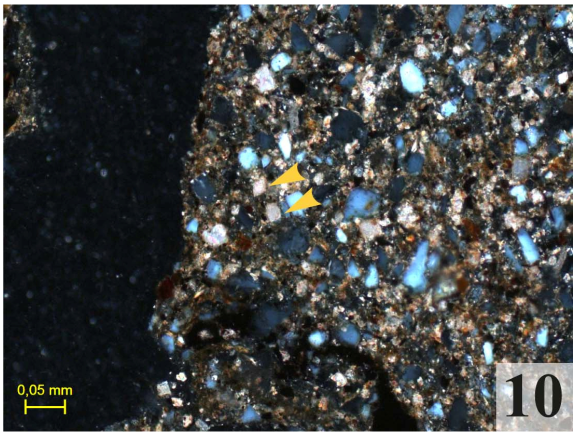
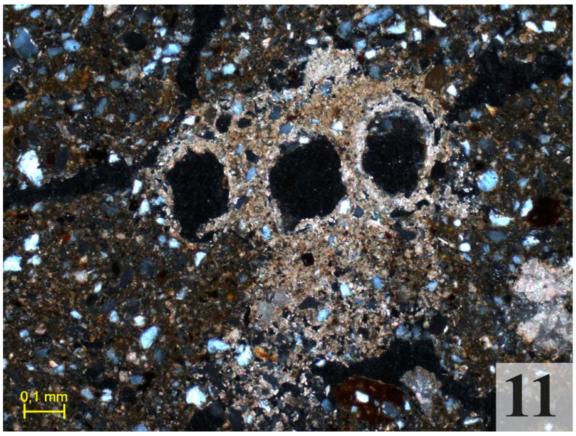


Foto 9. Holzkohlefragment in BL 1B. Tonanlagerungen in den Poren sichtbar. PPL. Foto 10. Ascherhomben (siehe Pfeile) in BL 1B. XPL.



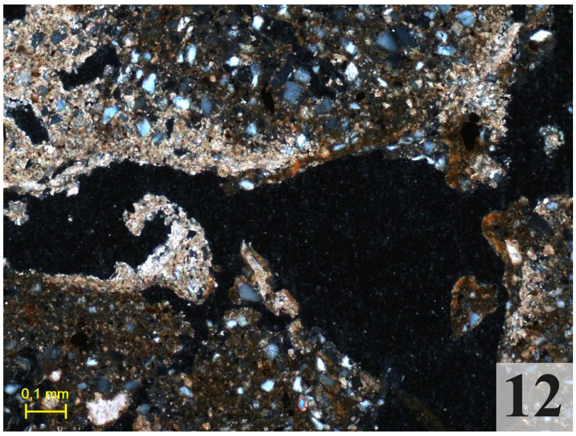
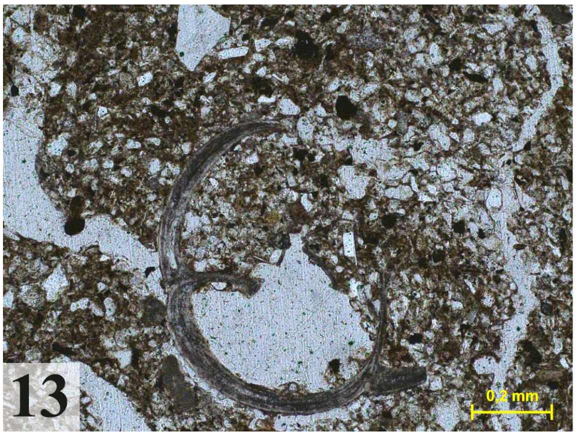


Foto 11. Rhizokretion in BL 1B. XPL. Foto 12. Tonanlagerungen und Kalkanreicherung in BL 1B. XPL.

BL 2A Dieser Dünnschliff enthält ebenso wie BL 1B den Befund der Feuerstelle 2 und zwar dessen Unterkante. Die Mikrostruktur ist vorwiegend rissig, aber ebenso auch von Kanälen und Kammern durchzogen, wobei es dennoch sehr kompakt ist. Ebenfalls wie BL 1B ist hier der Anteil an Holzkohle erhöht. Neben den beiden Hauptkomponenten Quarz und Kalksteinen, in gleichen Anteilen und Form wie in BL 1B, treten Knochenfragmente, Glimmer, Quarzite, Sandsteine und Schalenfragmente auf (Foto 13 und 14). Auch hier ist in der Feinfraktion ein verstärkter Anteil an karbonatischem Material in einem karbonatisch-kristallitischen b-Gefüge und mit einem gräulichen Farbton zu beobachten. Ton tritt unorientiert in gelb-orange auf. Sowohl Tonhüllen und Porenverfüllungen (Foto 15) sowie auch Kalkanreicherung sind vorhanden. Diese Befunde drücken sich in den leicht chitonischen Tendenzen der Relativ-Verteilung aus, die ansonsten einfach weit porphyrisch ist. In der Feinfraktion konnten zudem mehrere Ascherhomben beobachtet werden (Foto 16). Die Anzahl der Ascherhomben sowie auch der Kalkanreicherungen hat im Gegensatz zu BL 1B noch weiter zugenommen. Des Weiteren konnte auch Manganfleckung beobachtet werden.



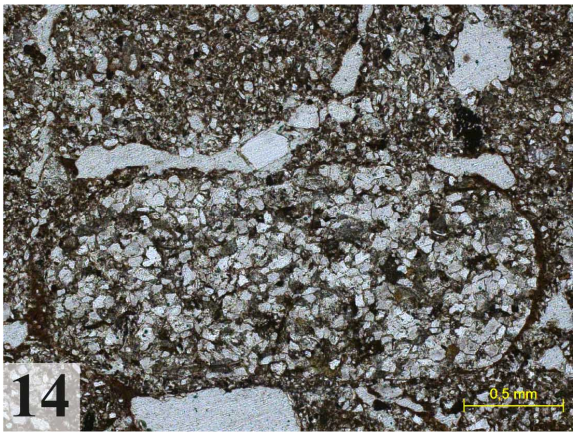
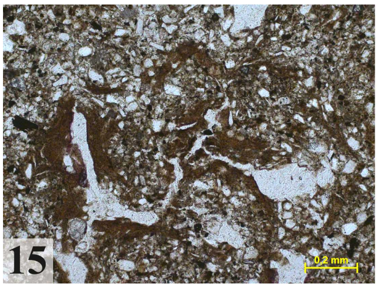


Foto 13. Molluskenfragment in kompakter Mikrostruktur mit Kanälen und Kavernen in BL 2A. PPL Foto 14. Gerundeter Sandstein in BL 2A. PPL.



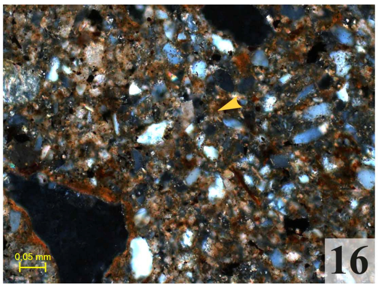


Foto 15. Tonanlagerungen in Poren in BL 2A. PPL. Foto 16: Ascherhomben (siehe Pfeil) in BL 2A. XPL. Foto 17. Kompakte Mikrostruktur mit Rissen, Kanälen und Kavernen in BL 2B. Schalenfragment mittig im Bild. PPL.

BL 2B Hierin ist die Schicht 4a vertreten, die sowohl an die Feuerstelle angrenzt also auch diese unterliegt. In diesem Dünnschliff hat der Anteil an Holzkohle wieder abgenommen. Nur vereinzelt können kleinere Holzkohlesplitter beobachtet werden. Quarz überwiegt wiederum in der Grobfraktion, gefolgt von kantigen Kalksteinfragmenten und in geringeren Anteilen, Knochen- und Schalenfragmenten, sowie Sandstein und Tonstein (Foto 17).

In der Feinfraktion entspricht der Anteil von Ton zu karbonatischem Material wieder dem in Schichte 3. Die Eigenschaften der Feinfraktion, mit einem karbonatisch-kristallitischen b-Gefüge des gräulichen karbonatischem Material und dem gelb-orangen Ton ohne Orientierung, abgesehen von den Tonhüllen, zeigen sich unverändert. Es treten wiederum auch Kalkanreicherungen auf. Das Verhältnis von Grob- zu Feinmaterial liegt wieder bei 2 zu 3. Die Relativverteilung ist einfach weit porphyrisch mit leicht chitonischen Tendenzen. Eine Schichtung oder Sortierung des Sediments konnte nicht beobachtet werden. Die Mikrostruktur ist wieder vorwiegend durch Risse, Kanäle und Kammern geprägt, wobei das Material sehr kompakt auftritt.

Diskussion und Zusammenfassung

Die vier Dünnschliffe des Vorplatzes der Blätterhöhle umfassen die Schichten A, B und C, den Befund der Feuerstelle 2. In ihren Hauptcharakteristika und Bestandteilen unterscheiden sie sich kaum, aber dennoch sind feine und bedeutsame Unterschiede zu beobachten.

Quarz in mittlerer Schluffgröße und kantige Kalksteine stellen die Hauptkomponenten der Grobfraktion hin. Sowohl Größe als auch Verrundungsgrad weisen auf eine Lössablagerung des Quarzes hin. Die Kalksteinfragmente stammen aus der Verwitterung des anstehenden Kalksteinmassives. Selbiges gilt für einen Großteil des karbonatischen Feinmaterials (siehe aber unten). Die Kalkanreicherungen, Rhizokretionen und Tonanlagerungen resultieren aus Wasserbewegungen und biologischen Aktivitäten und spiegeln damit post-depositionale Prozesse wieder. Die verrundeten Sandsteine sind möglicherweise als Magensteine von Vögeln auf den Fundplatz gelangt (siehe Miller 2009), was auch mit der Vielzahl an Schalenfragmenten übereinstimmt. Die Mikrostruktur ist in allen Dünnschliffen sehr rissig und weist eine Vielzahl an Kavernen und Kanälen auf. Diese Beobachtung in Verbindung mit dem Auftreten moderner Wurzel spricht für eine starke Bioturbation in allen 3 analysierten Schichten.

Die Dünnschliffe des Befundes der Feuerstelle 2, BL 1B und BL 2A, zeichnen sich durch einen hohen Beitrag an Holzkohle aus. Auch der erhöhte Anteil an karbonatischem Material, durch die Präsenz von Asche, in der Feinfraktion spricht für eine Feuereinwirkung. So resultiert dieser aus dem Vorkommen von Asche, wie es aus dem Auftreten von Ascherhomben ersichtlich wird. Ein weiteres Indiz ist die Beobachtung von gebrannten Knochen. Die makroskopisch gräulichere Färbung des Befundes, wie im Feld beobachtet als auch am Dünnschliff selber, im Vergleich zu den Schichten A und B resultiert vorwiegend aus der feinen Verteilung von Holzkohlesplittern und dem erhöhten Karbonatgehalt der Feinfraktion. Ein weiterer Faktor sind hier die in BL 2B beobachteten Manganflecken. Eine stratifizierte Feuerstelle ließ sich im Dünnschliff nicht nachweisen. Das gebrannte Material tritt ungeordnet vergesellschaftet mit ungebranntem Material auf. Die Ursache für diese Vermischung ist Bioturbation. Es gibt keine Hinweise darauf, dass das gebrannte Material angeschwemmt oder auf andere Art und Weise auf den Fundplatz verlagert wurde. Vielmehr ist von einer lokalen Feuerstelle auszugehen, deren *in-situ* Charakter zwar durch Bioturbation zerstört wurde, die aber dennoch, sowohl im Feld als auch mikroskopisch, als eine solche anzusprechen ist.

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Dünnschliff	Horizont und Feldbeschreibung	Microstruktur, Aggregate & Porenraum	c/f-Grenze, -Verhältnis u. -Relativ-Verteilung	Komponenten		Befunde und Bemerkungen
				Grob-Fraktion	Fein-Fraktion	
BL 1A	Schicht 3; Tonschluff mit Sandkomponente 10YR 4/3-3/3 massive Lagerung	Sehr kompakt, massive Mikrostruktur mit viele Poren (Pläne, Kavernen, Kammern und Gänge) nicht aggregiert, nicht sortiert	10µm, 2:3, chitonisch bis porphyrisch	Quarz (vornehmlich leicht kantig, teils auch kantig und gerundet, 0,18-0,01 mm, von sehr feinem Sund bis feiner Schluff, ca. 70%) Kalksteinfragmente (3 cm bis 1 mm, einige wenige größere, leicht kantig bist leicht gerundet, 15%), Sundsteinfragmente (stark verrundet, 90-100 µm, 5%), Knochen (bis zu 34 mm groß, 5%) Holzkohle-, Schalen- und Molluskenfragmente, (teils *in-situ* gebrochen), Glimmer	Vornehmlich Ton aber auch kalkhaltig; gelblich braun (makroskopisch orange erscheinend) bis grau mit schwarzen Flecken; hyalin, lokal gesprenkelt (feines organisches Material, in Schluffgröße); abnormale Interferenzfarben durch Fe-Verfärbung; kalzitisch-kristallitisches b-Gefüge, geflecktes b-Gefüge	- Tonhüllen um Quarzkörner und Porenverfüllungen - stark bioturbiert (rezente Wurzeln vorhanden) - Tonaggregat der Hochfläche vorhanden
BL 1B	Schicht 4b; Lehmschluff 10 YR 3/2-2/2 massive Lagerung Holzkohle	Sehr kompakt, massive Mikrostruktur mit viele Poren (Pläne, Kavernen, Kammern und Gänge) nicht aggregiert, nicht sortiert	10µm; 1:1, chitonisch bis einfach weit porphyrisch	Quarz (vornehmlich leicht kantig, teils auch kantig und gerundet; 0,01-0,44 mm, aber größtenteils mittelgroßer Schluff, 60%, mit fein bis mittelgroßer Sundkomponente, bis 10%, mittelgroßer Sand), Kalkstein (über 1 cm große Stücke bis wenige mm kleine, 40%), Holzkohle (10%), Glimmer (3%), Knochen (2%), gerundete Sundstein und Quarzite (2 mm bis 2 cm groß) Zahnfragment, Schiefer, Kalkanreicherungen (partiell sich zersetzend)	Vornehmlich Ton aber auch kalkhaltig; gelblich braun (makroskopisch orange erscheinend) bis grau mit schwarzen Flecken; hyalin, lokal gesprenkelt (feines organisches Material, in Schluffgröße); abnormale Interferenzefarben durch Fe-Verfärbung; kalzitisch-kristallitisches b-Gefüge, geflecktes b-Gefüge	- gebrannte Knochen - Kalkanreicherungen, inkl. Rhizokretionen/Rhizolithen, und Tonverlagerung - bioturbiert - mehr Kalkanreicherungen als in 1A - etwas weniger Porenvolumen und kalzitreichere Matrix -> Asche beobachtet

BL 2A	Schicht 4b; Lehmschluff 10 YR 3/2-2/2 massive Lagerung Holzkohle	Sehr kompakt, massive Mikrostruktur mit viele Poren (Pläne, Kavernen, Kammern und Gänge) nicht aggregiert, nicht sortiert	10µm, 1:1, chitonisch bis einfach weit porphyrisch	Quarz (vornehmlich leicht kantig, teils auch kantig und gerundet; 0,01-0,21 mm, aber vorallem mittelgroßer Schluff; 70%), Kalkstein (20%), Holzkohle (schwarze Punkte bis größer Stücke 2,5 mm, teils *in-situ* gebrochen, 10%), Knochen, Glimmer, Quarzite, Sandsteine, tonige Sandsteine	Vornehmlich Ton aber auch kalkhaltig; gelblich braun (makroskopisch orange erscheinend) bis grau mit schwarzen Flecken; hyalin, lokal gesprenkelt (feines organisches Material, in Schluffgröße); abnormale Interferenzfarben durch Fe-Verfärbung; kalzitisch-kristallitisches b-Gefüge, geflecktes b-Gefüge	- stärker entwickelte Pedofeatures als in 1A - höherer Anteil an Schiefer und Sandsteinen als in 1A -- bioturbiert - Manganflecken - aschiger als 1B
BL 2B	Schicht 3 Tonschluff mit Sundkomponente 10 YR 4/3-4/4 massive Lagerung	Sehr kompakt, massive Mikrostruktur mit viele Poren (Pläne, Kavernen, Kammern und Gänge) nicht aggregiert, nicht sortiert	10µm, 2:3, porphyrisch und chitonisch	Quarz (vornehmlich leicht kantig, aber auch kantig und leicht gerundet; 0,01-0,21 mm, aber vornehmlich mittelgroßer Schluff; 70%), Kalksteinfragmente (0,3 mm-1 cm, leicht kantig, 15%), Knochen und Schalenfragmente, Sandsteine (sehr wenige, gerundet), Kalzitkristalle, Tonsteine	Vornehmlich Ton aber auch kalkhaltig; gelblich braun (makroskopisch orange erscheinend) bis grau mit schwarzen Flecken; hyalin, lokal gesprenkelt (feines organisches Material, in Schluffgröße); abnormale Interferenzfarben durch Fe-Verfärbung; kalzitisch-kristallitisches b-Gefüge, geflecktes b-Gefüge	- Kalk- und Tonanreicherungen - bioturbiert - weniger kalzitisch als 1B und 2A