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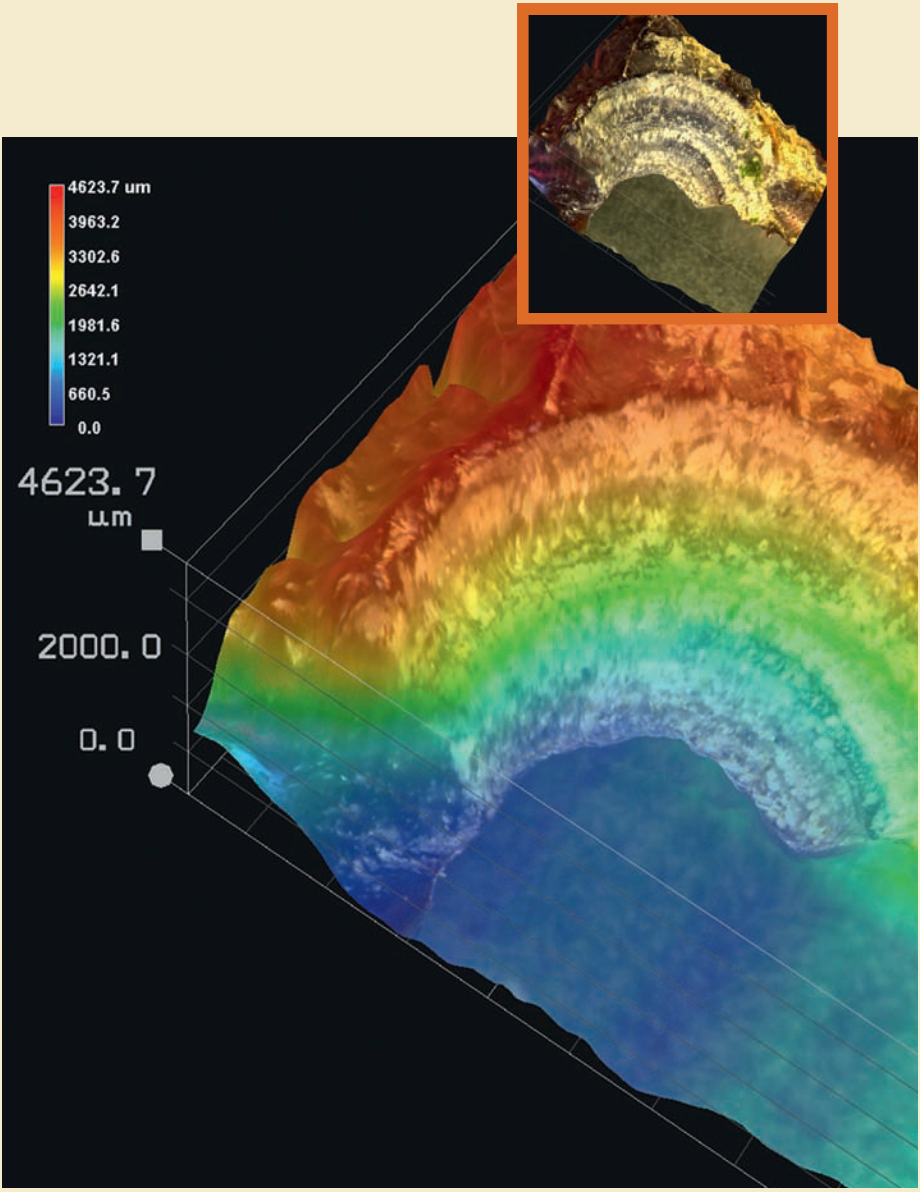

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Bernsteinbruchstück 18/48-266 eines durchbohrten Perlenrohlings (Aufn. U. Bohnhorst)
aus Grabow 15, Ldkr. Lüchow-Dannenberg, mit kolorierter Höhenschichtaufnahme
(Aufn. Di Maida) am Digitalmikroskop Keyence (vgl. Beitrag G. Di Maida/S. Veil in diesem Band).

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„Das baltische Gold – Bernsteinverwendung in der Steinzeit“
„The Baltic Gold – Use of Amber in the Stone Age“
16.11.2013

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Discovery of tephra on the Grabow 15 floodplain site, northern Germany

Die Entdeckung von Tephra im Bereich der Flussniederungsfundstelle Grabow 15 in Norddeutschland

Rupert A. Housley, Falko Turner, Johann Friedrich Tolksdorf and Stephan Veil

Schlüsselwörter: *Niedersachsen, Elbe-Jeetzel Niederung, Spätpaläolithikum, Spätglazial, vulkanische Asche, Spätholozän, Askja, Island*

Keywords: *Lower Saxony, Elbe-Jeetzel valley, late Palaeolithic, Late Glacial, volcanic ash, late Holocene, Askja, Iceland*

Zusammenfassung: *Tephrostratigraphie und Tephrochronologie sind für die Untersuchung archäologischer und paläoökologischer Sedimentfolgen von großer Bedeutung (*Davies *et al. 2002;* Turney *et al. 2004, 2006;* Balascio *et al. 2011). Schichten vulkanischen Glases oder Tephra haben das Potential – insofern sie sicher identifiziert und charakterisiert werden können – verschiedenste Sedimentsequenzen mit deren Funktion als paläoklimatische oder menschheitsgeschichtliche Archive exakt, zeitlich hochaufgelöst und zweifelsfrei miteinander zu korrelieren und synchronisieren (*Lowe *et al. 2011). Die Identifizierung einer bestimmten Tephra kann dabei auf im Gelände sichtbaren Eigenschaften, auf diversen physikalischen und geochemischen Laboranalysen in Kombination mit dem paläoökologischen oder -klimatischen Kontext beruhen. Ist eine Tephra einmal durch radiometrische, historische oder andere Methoden gut datiert, so lässt sich dieses Alter wegen der relativen Kurzlebigkeit vulkanischer Asche in der Atmosphäre (Tage bis Monate) auf andere Fundorte und -schichten mit Präsenz der Aschelage übertragen, aus Tephrostratigraphie wird Tephrochronologie (*Sarna-Wojcicki *2000). Die Tephrochronologie liefert damit als altersgleichwertige Datierungsmethode eine Event-Stratigraphie von außergewöhnlicher Präzision (*Westgate/Gorton *1981).*

*Die Anwendung der Tephrostratigraphie auf limnische und terrestrische Sedimente wird dabei allerdings durch einige Einflussfaktoren wie mögliche Redeposition und Streuung von Tephralagen über einige Zentimeter, Sedimentationsvariabilität innerhalb eines Sedimentarchivs sowie dem Auftreten widerholter Eruptionen eines Vulkans mit nahezu identischer (geochemischer) Zusammensetzung der Tephra verkompliziert (*Larsen/Eiríksson *2007;* Lane *et al. 2012). Neue Entwicklungen in der Detektion, Isolierung und geochemischen Charakterisierung nicht sichtbarer Lagen von ‚Mikro- oder Kryptotephra' ermöglichen es jedoch, Tephrostratigraphie und -chronologie in weitaus größeren Gebieten und vielfältigeren Situationen durchzuführen als zuvor (*Turney *1998;* Blockley *et al. 2005;* Davies *et al. 2012). Die Zielsetzung dieses Artikels besteht in der Anwendung dieser tephrostratigraphischer Methoden auf Sedimente im Umfeld des in der Elbe-Jeetzel-Niederung gelegenen Fundplatzes Grabow 15 (Abb. 1). Die Analysen wurden durchgeführt im Rahmen der vom Briti-*

schen NERC (Natural Environment Research Council) geförderten RESET-Forschungsinitiative, in welcher Archäologen, Vulkanologen, Tephrochronologen und Geologen gemeinsam die Chronologie wesentlicher Phasen der menschlicher Expansion der letzten 100.000 Jahre und deren Zusammenhang zu abrupten Umweltveränderungen untersuchen (http://c14.arch.ox.ac.uk/reset/).

Archäologischer, geowissenschaftlicher und biostratigraphischer Kontext

Seit etwa zwei Jahrzehnten laufende intensive archäologische Untersuchungen haben zur Entdeckung einer Vielzahl von Fundplätzen der spätpaläolithischen Federmesser-Kultur am westlichen Rand des Elbe-Urstromtals in der Elbe-Jeetzel-Niederung geführt. Alleinstellungsmerkmal der Fundplätze sind außergewöhnliche Bernsteinartefakte, unter anderem die Figur eines Elchs, welche stilistisch zwischen dem vorhergehenden Magdalénien und späteren mesolithischen Kulturphasen einzuordnen sind (Veil/Breest 1995, 2000; Street et al. 2001; Veil/Terberger 2009; Veil et al. 2012). Seit 2007 steht sowohl der Fundplatz Grabow 15 (53°00'N/11°07'E, c. 13.5 m NN) mit in situ gelagerten Artefakten in späteiszeitlichen Hochflutlehmen der Jeetzel als auch das weitere Untersuchungsgebiet mit seinem geomorphologischem Inventar aus Talsand, verlandeten Flussrinnen verschiedener Generation, Dünen und Hochflutsedimenten im Fokus der Arbeiten (Abb. 1). Interdisziplinäre Untersuchungen (Pollen, pflanzliche Makrofossilien, Diatomeen, Ostrakoden, Geochemie, Radiokarbon- und OSL-Datierungen) der Grabungssedimente und späteiszeitlicher Rinnenfüllungen ermöglichen sowohl die Einordnung der Siedlungsphase in ein lokales biostratigraphisches Konzept (Abb. 2), die Korrelation der einzelnen untersuchten Profilsequenzen und die Rekonstruktion der späteiszeitlichen Umweltbedingungen als auch grobe Parallelisierungen und Vergleiche zu anderen europäischen Fundstellen (Tolksdorf et al. 2013; Turner et al. 2013). Der Nachweis von späteiszeitlichen Aschelagen wie der allerødzeitlichen Laacher See-Tephra (Boogard/Schmincke 1985) und der Vedde-Tephra aus der Jüngeren Dryas (Blockley et al. 2007) in Sedimenten der Jeetzel-Niederung würde diese Parallelisierungen validieren und damit die überregionale Bedeutung der interdisziplinären Studien erhöhen.

Vier Profile im Umfeld des Fundplatzes Grabow 15 wurden tephrostratigraphisch untersucht: Das Referenzprofil und Nordprofil in den Hochflutsedimenten der Grabungsfläche (Abb. 1D) sowie die Pollenprofile W.VI und W.VIII in Füllungen späteiszeitlicher Flussrinnen (Abb. 1C). Die Proben wurden mit der nicht-destruktiven physikalischen Dichtetrennungsmethode nach Blockley et al. (2005) aufbereitet. Dabei wurden zunächst kontinuierlich 5-10 cm-Abschnitte untersucht. Tephrapartikel wurden lichtmikroskopisch identifiziert, gezählt und anschließend dem entsprechenden Abschnitt Proben in 1 cm-Abschnitten entnommen. Der Probe mit maximaler Anzahl an Tephrapartikeln wurden diese zur geochemischen Analyse entnommen.

Die geochemische Zusammensetzung der Hauptbestandteile des vulkanischen Glases wurde mit wellenlängendispersiver Elektronenstrahlmikroanalyse (WDS-ESMA) an der Universität Oxford bestimmt. Neben einer Reihe mineralischer und oxidischer Standards wurden sekundäre vulkanische Standards der MPI-DING Sammlung (Jochum et al. 2006) in den Messreihen verwendet, um die analytische Präzision der Messungen zu kontrollieren.

Ergebnisse und Diskussion

Die Analyse das Profils W.VIII erbrachte keine Tephra-Partikel. Die Untersuchung des Nordprofils ergab eine sehr geringe Anzahl detektierter Tephrapartikel, welche aufgrund des Fehlens vulkanischen Glases geochemisch nicht analysiert werden konnten.

Das Pollenprofil W.VI zeigte ebenfalls eine sehr geringe Konzentration an Tephrapartikeln, welche allerdings über einen Bereich von 2.5 m zu streuen scheinen und ebenfalls nicht genügend Material für geochemische Analysen ergaben (Abb. 3). Auf Basis der Biostratigraphie – dem Fehlen thermophiler Baumarten (Corylus, Quercus, Ulmus) sowie hoher Anteile lichtliebender Pflanzen (Juniperus, Artemisia und Empetrum) – und zweier Radiokarbondaten lässt sich das Auftreten des deutlichsten Tephra-Peaks in einer Tiefe von 240-241 cm in die Mitte der jüngeren Dryas einordnen. Ein wichtiger vulkanischer Marker dieses Zeitabschnitts, der eine Parallelisierung von europäischen Sedimentprofilen mit grönländischen Eisbohrkernen ermöglicht, ist die Vedde-Asche (Abb. 2, Blockley *et al. 2007;* Davies *et al. 2012). Leider erlaubt das Fehlen einer geochemischen Signatur keine eindeutige und zweifelsfreie Zuordnung der Tephrapartikel aus Profil W.VI.*

*Tephrapartikel wurden im obersten Teil des Referenzprofils gefunden und streuen – vermutlich durch Flugaktivität – über einen Bereich von 9 cm (Abb. 4). Wegen der geringen Konzentration an Partikeln wurden nur zwei Proben geochemisch analysiert, welche eine rhyolithische Zusammensetzung aufweisen und die Tephra in die größere Gruppe isländischer Herkunft einordnen (Abb. 5A). Verglichen mit den Aschen isländischer Ausbrüche zeigt die Grabow 15-Tephra in Bezug auf Magnesium- und Eisenoxidgehalt größte Übereinstimmungen zu der Gruppe der Askja-Tephra (Abb. 5B und 5C). Aufgrund der Stratigraphie des Referenzprofils und der geochemischen Signatur der Tephra erscheint sowohl die Zuordnung zum Askja AD 1875 Ausbruch (*Sigurdsson/Sparks *1978;* Oldfield *et al. 1997) als auch der nur distal bekannten Glen Garry-Tephra, welche nach kalibrierten Radiokarbondaten auf 2210-1996 cal. BP (Kalendarjahre vor 1950) datiert wurde (*Barber *et al. 2008), plausibel. Die bisher nachgewiesenen Ausdehnungen der Aschefahnen beider Ausbrüche überlappen in Norddeutschland (Abb. 6,* Bogaard *et al. 1994, 2002;* Bogaard/ Schmincke *2002), so dass auch insgesamt keine eindeutige Zuordnung der Grabow 15-Tephra zu einem der beiden Ausbrüche möglich ist.*

Schlussfolgerungen

*Das prinzipielle Ziel der hier vorgestellten Studie bestand darin, festzustellen, ob sich zur überregionalen Korrelation verschiedener Profile wichtige Aschehorizonte wie die Laacher See Tephra (LST) oder die Vedde-Asche in späteiszeitlichen Sedimenten im Umfeld des Fundplatzes Grabow 15 nachweisen ließen. Obwohl allerødzeitliche Sedimente sowohl in den Fundplatz-Profilen als auch im Paläorinnen-Profil W.VIII erhalten waren, wurde die LST als bedeutender Aschemarker des späten Allerød (*Bogaard/Schmincke *1985;* Schmincke *et al. 1999;* Baales *et al. 2002) nicht nachgewiesen. Aufgrund der Lage des Fundplatzes am äußeren westlichen Rand der bekannten Ausdehnung der LST-Aschefahne (*Riede *et al. 2011) kann nicht entschieden werden, ob die LST nicht konserviert wurde oder das Untersuchungsgebiet gerade außerhalb des Depositionsbereichs blieb. Ebenso konnte trotz der stratigraphischen Korrelation mit einer sehr geringen Tephraanreicherung im Profil W.VI kein eindeutiger Nachweis der Vedde-Asche aus der jüngeren Dryas erbracht werden. Dagegen wurde überraschend die Tephra eines spätholozänen Ausbruchs des Askja-Vulkans entdeckt, welche für die Erstellung eines europäischen tephrostratigraphischen Netzes zur Verknüpfung von Fundstellen von gewisser Bedeutung ist. Die Untersuchungen im Umfeld des Fundplatzes Grabow 15 zeigen damit eindrucksvoll die Probleme, aber auch das Potential tephrostratigraphischer Analysemethoden.*

Abstract: *An investigation of the late Palaeolithic 'Federmesser' Grabow 15 site reveals the presence of 'cryptotephra' (invisible volcanic ash) in a disturbed Holocene deposit which overlies the late-glacial archaeological strata that are embedded in late Glacial floodplain sediments. Geochemical analyses demonstrate that the tephra originates from Iceland; most likely froman eruption of the volcano of Askja. In the lateHolocene there are two known eruptions of Askja: the historical eruption of AD 1875 and the earlier 'Glen Garry'tephra, which is only known as a horizon outside Iceland. Although similarity of composition prevents these contenders being distinguished on their geochemistry alone, nevertheless, the presence of such volcanic glass at the Grabow site demonstrates the potential for applying tephrostratigraphy in an archaeological setting, especially in regions where multiple ash footprintsare known to be present. The presence of a very low numbers of volcanic glass shards in an adjacent river palaeochannel suggests the presence of another, potentially important, tephra in the region. However, failure to obtain a geochemical signature leaves the origin of the ash open and questions whether it constitutes a primary fall event.*

Introduction

Tephrostratigraphy and tephrochronology have the potential to be of major significance to the study of past archaeological and palaeo-environmental sequences (Davies et al. 2002; Turney et al. 2004; 2006; Balascio et al. 2011). Layers of volcanic glass or tephra, once securely identified, provide the means to accurately link and synchronize diverse sedimentary records with their archives of palaeoclimate and past human behaviour (Lowe 2011). Tephrostratigraphy is an age-equivalent dating method that provides an exceptionally precise volcanic-event stratigraphy (Westgate/Gorton 1981). Where the tephra have been dated by radiometric, incremental, historical, or other methods, the presence of volcanic ash layers allow ages to be transferred between sedimentary records (Sarna-Wojcicki 2000). Such transfers are valid because the primary tephra from an eruption essentially have the same short-lived age everywhere the ash falls, forming isochron layers very soon after the event (of the order of days, weeks or months). Furthermore, sequential tephra layers provide key information on the geochemistry and eruption frequency of volcanoes and the spatial and temporal interrelationships of eruptions (e.g. Juvigné et al. 1996; Haflidason et al. 2000; Smith et al. 2011). Developments in the detection, isolation and characterisation of non-visible 'microtephra' or 'cryptotephra' have allowed tephrochronology to be applied to many more situations and larger geographical areas than hitherto was the case (Davies et al. 2002). The new contexts open up interesting developments, but as this paper demonstrates, do not come without attendant complexities; the taphonomy of the depositional layers have an important influence. Recovery of trustworthy data is not always simple.

The focus of this paper is the application of tephrostratigraphy to the floodplain archaeological site of Grabow 15 in the Elbe-Jeetzel valley, Lower Saxony. During the last two decades, intensive archaeological research in this area has revealed a multitude of sites dating to the late Palaeolithic period that have yielded, among others, exceptional artistic amber artefacts (Veil/Breest 1995; 2000; Street et al. 2001; Veil/Breest 2006). Archaeological investigations at Weitsche and Grabow have shown the first evidence of amber processing and the stylistic development of art between the preceding Magdalenian and the succeeding Mesolithic period (Veil/Breest 2006; Veil /Terberger 2009; Veil et al. 2012). The sites belong to the earliest phase of the Federmesser culture (Riede/Edinborough 2012). Since 2007, Grabow site 15 has been in the focus of interdisciplinary research, which aims to place the site in its stratigraphical and palaeo-environmental context (Tolksdorf et al. 2013; Turner et al. 2013). The tephrostratigraphy is one component of this programme of investigation.

The Principles of Tephrostratigraphy and Tephrochronology

Tephrostratigraphy is a method for correlating diverse sedimentary sequences, whether they are palaeo-environmental, geological or archaeological in nature. It has the advantage over many other chronological tools in that the precision is commonly significantly better (Lowe 2011). The use of tephra is grounded in the principle that layers are deposited in a stratigraphic sequence and the position is governed by the Law of Superposition (Feibel 1999). If a tephra layer can be identified and characterised, it can be correlated to another tephra layer in another locality and this links the two spatial loci in time (Westgate/Gorton 1981). Matching of tephra layers can be done by physical properties in the field or from diverse analyses in the laboratory. In some instances the palaeo-environmental or palaeoclimatic context of a tephra may be significant. Where an existing age for the tephra is known, be it from historical records, radiometric dating (e.g. ^{14}C or $^{39}Ar/^{40}Ar$; Sarna-Wojcicki 2000), or an incremental archive (e.g., varves or ice core layers; Grönvold et al. 1995), the age may be transferred from one locality to another provided compositional properties, e.g. chemical characteristics, are the same. In such situations tephrostratigraphy becomes tephrochronology, a powerful tool for dating.

There are many factors that potentially limit the application of tephrostratigraphy (Lowe 2011); those of relevance in the context of this investigation include:

I The possibility of tephra being reworked leading to the remobilisation of glass shards. This can significantly influence whether correlation is feasible. Remobilised tephra will form diachronous rather than isochronous surfaces. Their use tephrochronologically is fundamentally compromised unless reworking is very localised and near-contemporaneous with the primary depositional event. The non-reworked part of a tephra deposit does provide an isochron of maximum age (the date of the tephra eruption and primary deposition) but any reworked components are always younger.

II The vertical spread (dissemination) of shards over distances of some centimetres through soft sediments may occur. This leads to the stratigraphic difficulty of identifying the exact point in the sediments where tephra layer was deposited at the time of eruption.

III Sampling of different profiles will sometimes document periods of non-deposition, erosion and reworking, revealing differential effects. This can occur even when distances between sampling locations are small. Hence within-site variability is a factor, suggesting that local geographic and taphonomic processes may sometimes be complex.

IV Repeated eruptions may sometimes result in chemically-similar geochemical datasets. Indeed many Icelandic tephra produced by different eruptions have very similar major element geochemistry (Larsen/Eiríksson 2007; Lane et al. 2012). If on the sampling site the tephra zone is poorly dated, the alternate potential correlates may not be resolvable on geochemistry alone and an ambiguous outcome may be the result (e.g. Housley et al. 2012).

Tephra detection alone, albeit the crucial starting point in a tephrostratigraphical study, is therefore not sufficient on its own; there are many ancillary requirements if the presence of tephra is to give a good age marker.

Visible volcanic ash on archaeological sites has long been recognised. Historical examples include the Roman towns of Pompeii and Herculaneum, preserved by the AD 79 eruption of Vesuvius. Prehistoric examples include the early Bronze Age settlement of Akrotiri on the island of Santorini (Hardy 1990), and the early Upper Palaeolithic sites of Kostienki-Borshchevo (Anikovich 2005; Anikovich et al. 2007; Melekestsev et al. 1984; Pyle et al. 2006; Sinitsyn 2001). The focus of this study concerns non-visible cryptotephra.

Non-visible volcanic layers – the context of this research

In the last two decades there has been a realisation that non-visible 'microtephra' or 'cryptotephra' layers may preserve in sedimentary sequences. In distal localities removed from the eruptive vent, recognition of tephra by the naked eye is rarely possible. However, the development of laboratory processing methods (TURNEY 1998; BLOCKLEY et al. 2005) has allowed systematic screening for such ephemeral volcanic ash layers so that the ash 'footprints' of eruptions have been significantly extended over larger geographical regions. Tephrostratigraphy can be now applied to many more sedimentary settings than was hitherto the case.

The research reported here was undertaken within the context of the RESET research initiative, a 5-year Consortium funded by the UK's Natural Environment Research Council (NERC) that brings together archaeologists, volcanologists, tephrochronologists and stratigraphers to investigate the chronology of major phases of human dispersal and development in Europe during the past 100 000 years, and to examine the degree to which these were influenced by abrupt environmental transitions (http://c14.arch.ox.ac.uk/reset/). The late-glacial archaeology of northern Europe formed one component of this project, with other parts of the Consortium focusing on earlier archaeological periods in southern Europe and northern Africa, on natural environmental sequences from terrestrial and marine settings, and on better chemical characterisation of the proximal deposits in the immediate vicinity of the volcanoes.

The principle objective of this investigation is to test whether specific supra-regionally occurring tephra horizons, such as the Laacher See tephra (LST) of the late Allerød age (BOOGARD/SCHMINCKE 1985) or the Vedde Ash from the mid Younger Dryas (BLOCKLEY et al. 2007), are present within the sediments. If these tephra are preserved in association with the archaeological layers of Grabow site 15, they would provide independent chronological markers for the late Palaeolithic human activity. If the tephra layers were to be found in sediments around Grabow and Weitsche they would form an independent check for the biostratigraphical correlations, thereby enhancing the result of any associated palaeoenvironmental research.

Geographical and Biostratigraphical Setting

The Grabow site 15 (53°00'N/11°07'E, c. 13.5 m asl) is located on the Jeetzel river, which is a small tributary flowing through the broadened Elbe river valley (Wendland area, Lower Saxony; *Fig. 1A&B*). Situated at the western edge of the glacial Elbe spillway, fluvial dynamics have been the main agent acting in the Jeetzel river plain in the past until regional drainage and river canalisation in the 20th century (TURNER et al. 2013). 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. Detailed geomorphological mapping in the Jeetzel valley has revealed several generations of palaeochannels of Late-glacial and Holocene age, as well as large areas covered by silty floodplain sediments (Fig. 1C). Multidisciplinary analysis (pollen, plant macrofossils, diatom and ostracod analyses, soil geochemistry, ^{14}C and OSL-dating) of these palaeochannel and floodplain sediments has produced a local biostratigraphical framework (*Fig. 2*; TURNER et al. 2013). By applying this framework, records of different sites in the Jeetzel valley can be correlated robustly, whilst also providing for more tentative correlation with other sites in northwest Europe and their associated proxy records. Sediments in Grabow site 15, where Paleolithic artefacts are located in situ within floodplain loam, and adjoining paleochannel fills have been shown to cover the late-glacial Allerød and Younger Dryas periods (*Fig. 2*; TOLKSDORF et al. 2013; TURNER et al. 2013).

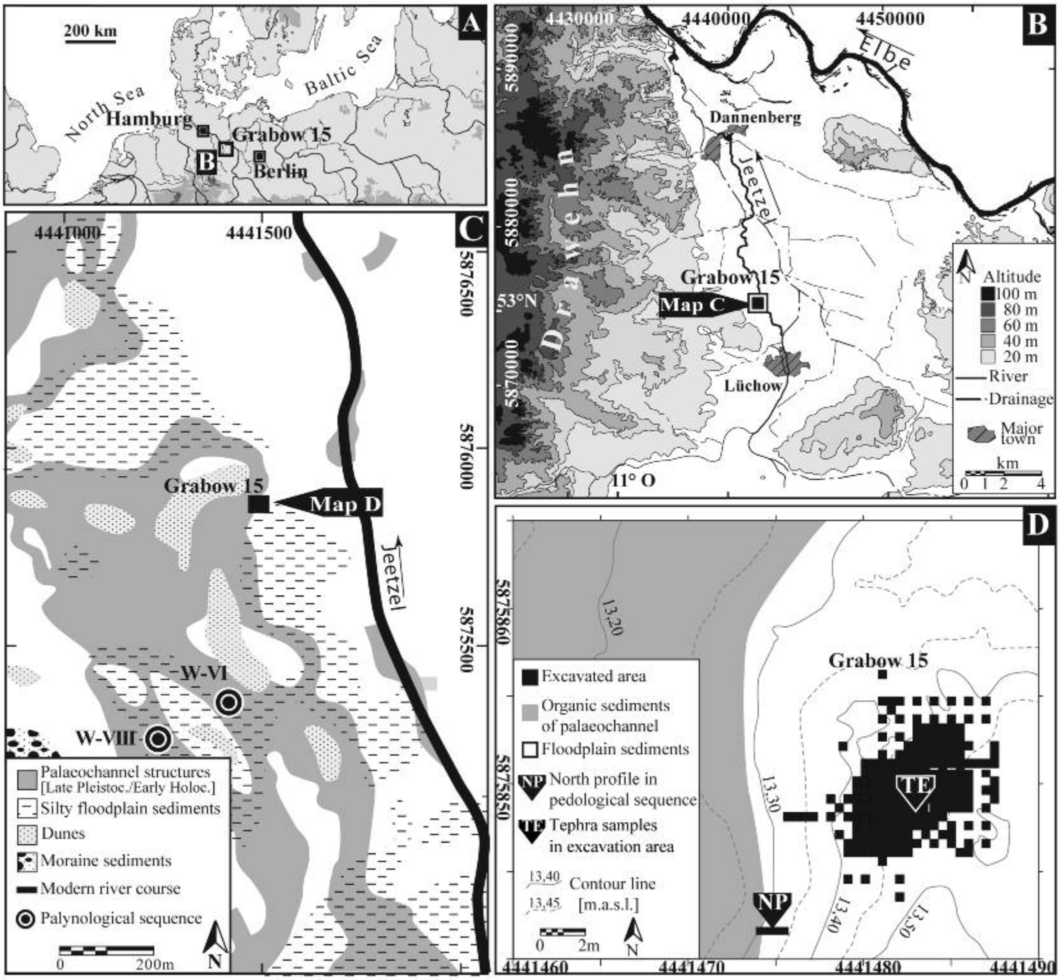

Fig. 1
A: Location of Grabow site 15 within the Northern European Plain;
B: Location of Grabow site 15 and topographic situation of the broadened Elbe river valley;
C: Distribution of palaeochannel structures, floodplain sediments and tephra analysed pollen cores W–VI and W–VIII in the vicinity of Grabow site 15;
D: Plan of excavation area showing position of two of the tephra analysed sequences – RP (pedological reference profile, see also Tolksdorf et al. 2013) and TE (tephra samples from excavation profile).

Abb. 1
A: Lage des Fundplatzes Grabow 15 in der Nordeuropäischen Tiefebene;
B: Topographische Situation im Elbe-Urstromtal; C: Paläorinnen, Hochflutsedimente und Dünen im Umfeld das Fundplatzes Grabow 15, mit Lage der tephrostratigraphisch analysierten Profile W.VI und W.VIII; D: Grabungsplan des Fundplatzes Grabow 15 mit Position der tephrostratigraphisch analysierten Sequenzen RP (Referenzprofil) und NP (Nordprofil).

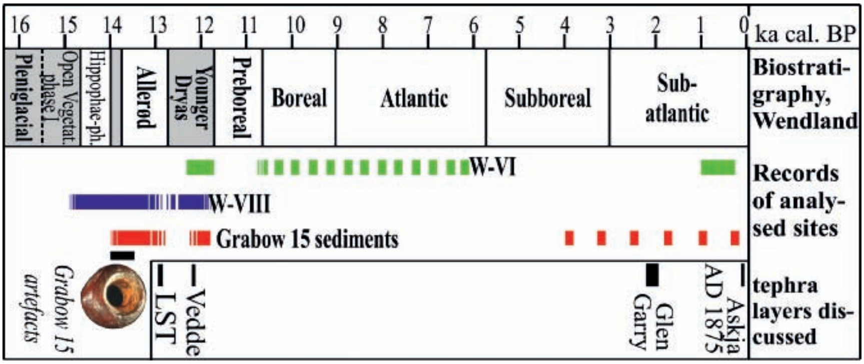

Fig. 2
Biostratigraphic framework for the Grabow / Weitsche region (after Turner 2012) showing the relevant volcanic eruptions and the main periods of sedimentation in the studied profiles. An amber bead from Grabow 15's amber workshop illustrates the chronological position of the site.

Abb. 2
Biostratigraphie des Hannoverschen Wendlands (nach Turner 2012), unter Angabe der in den analysierten Profilen erfassten Abschnitte und im Text erwähnter Vulkanausbrüche.

Sampling and Methods

Tephrostratigraphical samples were taken from four profiles around the Grabow site 15: the RP pedological sequence and from a profile within the 2008 main excavation area (TE) within floodplain sediments (*Fig. 1D*), the W–VIII and W–VI pollen sequences located within palaeochannels (*Fig. 1C*).

The samples were prepared using the non-destructive physical separation methods of Blockley et al. (2005). Initial processing involved the examination of contiguous 5-10 cm samples to determine presence/absence of cryptotephra. Sub-samples were sieved and dried before separation by specific gravity heavy liquids. Where tephra was detected, the shards were identified and counted using optical microscopy, and a further series of contiguous 1 cm samples are prepared to precisely define the position of the tephra peak. Identified tephra peaks are then re-extracted and prepared for geochemical analysis.

Volcanic glass is typically analysed using micro-analytical techniques. Major element compositions were measured using wavelength-dispersive JEOL electron microprobe analysis (WDS-EPMA) at the University of Oxford. The instrument is calibrated using a suite of mineral and oxide standards. A range of fused volcanic glass secondary standards from the MPI-DING collection (Jochum et al. 2006) were analysed between and within WDS-EPMA analytical runs to monitor precision and accuracy. Based upon reproduction of these secondary standards, major element precision was shown to lie between <1 to <10% (at 2σ).

Results

Scanning of pollen core W–VIII produced no tephra and so no further analysis was undertaken. Scan samples from the north profile excavation trench of Grabow site 15 revealed very low absolute numbers of tephra shards. An attempt to characterise a possible minor peak of 4 tephra shards failed because the subsequent samples contained no volcanic glass. For this reason it proved impossible to continue studying this profile.

Pollen core W–VI also had only a very low concentration of shards, scattered down almost 2.5 m of sediment (*Fig. 3*). Again this proved too low a concentration to obtain major element geochemistry. However the position of the tephra is potentially important and so this core is discussed below.

Examination of the RP pedological sequence revealed a slightly more encouraging result. Tephra was detected in low concentrations (maximum of 7 shards/g dry weight) in the uppermost samples of RP, but scattered over a vertical distribution of 9 cm (*Fig. 4*). The wide vertical distribution of tephra shards – an original layering should be expected in a range of

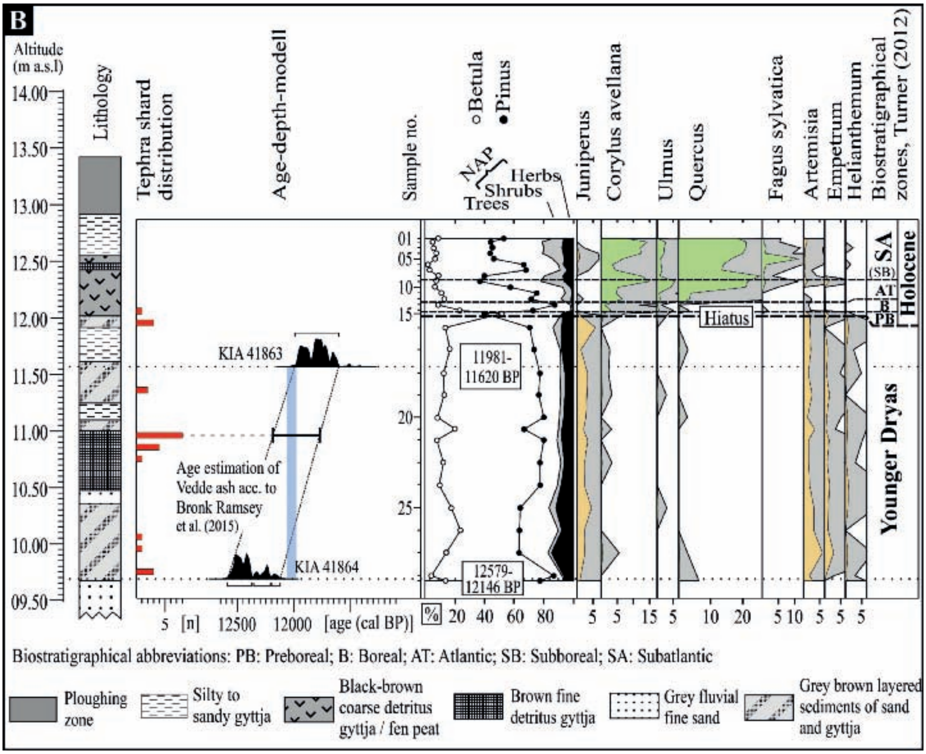

Fig. 3
Distribution of the tephra shards in pollen core W–VI and their relationship to sedimentary lithology, age (based on radiocarbon) and vegetation phases (Turner 2012).

Abb. 3
Streuung von Tephrapartikeln im Pollenprofil W.VI, im Vergleich zu Lithologie, Sedimentalter (nach Radiokarbondaten) und biostratigraphischen Zeitabschnitten (nach Turner 2012).

Grabow	SiO_2	TiO_2	Al_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	Total
OxT2631_1	73.1	0.76	13.7	2.65	0.09	0.41	2.53	3.86	2.29	99.44
OxT2631_2	71.3	0.95	13.1	4.30	0.07	0.82	2.76	3.72	2.33	99.39
ATHO	**SiO_2**	**TiO_2**	**Al_2O_3**	**FeO**	**MnO**	**MgO**	**CaO**	**Na_2O**	**K_2O**	**Totals**
Average (n=6)	75.26	0.25	12.33	3.29	0.1	0.11	1.72	3.47	2.6	99.12
2stdv	3.84	0.06	0.15	0.08	0.04	0.03	0.06	2.27	0.14	3.58
StHs6/80										
Average (n=6)	62.53	0.69	17.9	4.38	0.07	1.92	5.26	4.42	1.24	98.41
2stdv	2.17	0.6	0.31	0.31	0.06	0.19	0.34	0.22	0.13	2.65
Preferred values										
Atho-G	*75.6*	*0.26*	*12.2*	*3.27*	*0.11*	*0.1*	*1.7*	*3.8*	*2.64*	
95% cl	*0.7*	*0.02*	*0.2*	*0.1*	*0.01*	*0.01*	*0.03*	*0.3*	*0.09*	
StHs6/80-G	*63.7*	*0.7*	*17.8*	*4.37*	*0.08*	*1.97*	*5.28*	*4.4*	*1.29*	
95% cl	*0.5*	*0.02*	*0.2*	*0.07*	*0*	*0.04*	*0.09*	*0.1*	*0.02*	

Tab. 1
WDS-EPMA major element chemical data for cryptotephra sample OxT2631. Data are presented as non-normalized weight percent oxide (wt %) values. Atho-G and StHs6/80-G secondary glass standards provide an assessment of analytical precision achieved by WDS-EPMA. Preferred values for the secondary glass standards are from the GeoRem database (Jochum et al. 2006).

Tab. 1
Geochemische Zusammensetzung der Hauptelemente in Tephraprobe OxT2631 (WDS-ESMA Messverfahren). Angabe in nicht-normalisierten prozentualen Massenanteilen der Oxide (wt %). Die zusätzliche Verwendung von Atho-G and StHs6/80-G Glas Standards ermöglicht die Einschätzung der analytischen Genauigkeit der Messungen. Normwerte der Standards aus der GeoRem-Datenbank (Jochum et al. 2006).

sub-millimetres to millimetres – is due to historic ploughing of the topsoil (unit 4) of the site. Due to the low shard concentration, only two analyses of major elements were obtained (OxT2631). Both analysed shards exhibit a rhyolitic composition that fits well into the broad chemical group assigned to tephra delivered from Icelandic sources (*Table 1, Fig. 5*). No tephra was detected in samples taken from the profile TE.

Discussion

If the MgO and FeO content of the glass shards from the RP pedological sequence at Grabow site 15 are compared to tephra from Holocene Icelandic eruptions, it appears that the Grabow analyses best match the chemical grouping from the volcano of Askja. There are two confirmed late-Holocene eruptions of Askja: the AD 1875 event (Sigurdsson/Sparks 1978; Oldfield et al. 1997) and the distal-only Glen Garry tephra, which is dated by radiocarbon to c.2210-1966 cal BP (Barber et al. 2008). On stratigraphic and geochemical grounds, either eruption is plausible. The fact that the tephra in profile RP has been disturbed means it should be viewed as a diachronous rather than isochronous surface.

Geographically, the ash fall footprints show that the AD 1875 eruption has been documented in Scandinavia, whilst the Glen Garry has been observed in the north of Britain (*Fig.*

6). Previous research has demonstrated that the respective ash fall zones overlap in northern Germany. Tephra of the Glen Garry eruption is present in three peat bogs in Schleswig-Holstein: Dosenmoor, Grambower Moor and Jardelunder Moor, and the Askja AD 1875 eruption is known from Grambower Moor (Bogaard et al. 1994, 2002; Bogaard/Schmincke 2002). Since the Grabow site lies 100 km south of Grambower Moor, only a small extension of the respective ash fall envelopes are required to accommodate either eruption.

On the basis of the biostratigraphy – the absence of thermophilous trees (*Corylus*, *Quercus*, *Ulmus*) plus high amounts of heliophilous elements like *Juniperus*, *Artemisia* and especially *Empetrum* – and two radiocarbon dates (KIA-41863 and KIA-41864) the minor concentration of shards in pollen core W–VI at a depth of 2.40-2.41 m would appear to centre on the mid Younger Dryas Stadial (*Fig. 3*; Turner 2012). An important tephra chronological marker, known as the Vedde Ash, has been widely recognised in Europe at this time (Blockley et al. 2007; Davies et al. 2012). However, the lack of geochemistry precludes definitive assignation to a given volcanic centre and eruptive event. Furthermore, the presence of the shards in brown fine detritus gyttja / fen peat raises questions whether the volcanic glass is in situ or re-worked from an earlier deposit. For these reasons a firm correlation is impossible – further research would be needed to confirm such a finding.

Conclusions

The principle objectives of this investigation were to test whether specific supra-regionally occurring tephra horizons, such as the Laacher See tephra (LST) or the Vedde Ash, are present within the sediments. If present they could provide independent chronological markers for the Federmesser archaeology. Although sediments from the Allerød are preserved both in Grabow site 15 and pollen core W.VIII (*Fig. 2*), no Laacher See tephra as a characteristic central European marker horizon of the late Allerød (Bogaard/Schmincke 1985; Schmincke et al. 1999; Baales et al. 2002) was detected. With respect to the fallout zone mapped by means of the known occurrence sites of this tephra (Riede et al. 2011), Grabow site 15 is located close to the western edge of the suggested fallout zone. We are therefore unable to decide if the Laacher See tephra was not deposited or if the conditions of (periodic) floodplain and palaeochannel sedimentation prevented preservation. The same is true for the sediments dated to the Younger Dryas, where despite a tantalising suggestion no clear layer of the expected Vedde Ash (Blockley et al. 2007) was identified.

However, an unexpected late-Holocene eruption was discovered, albeit situated within a sedimentary unit disturbed by modern ploughing. Discovery of the products of an eruption of Askja are contributing to the construction of a pan-European tephra lattice which is seeking to join different localities using age-specific tephra marker horizons. The unanticipated by-product of a late Palaeolithic study which did not find the LST or the Vedde Ash has instead produced data that are relevant to the study of a more recent time period. This is a demonstration of how research can lead to unexpected discoveries.

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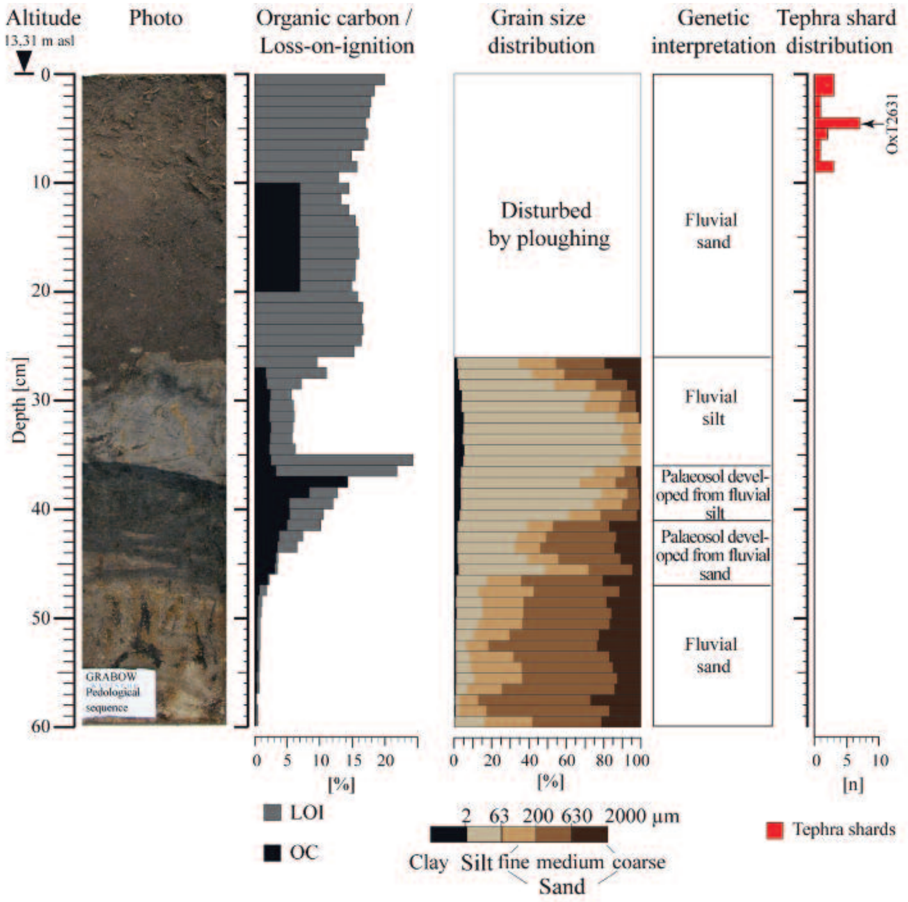

Fig. 4
Distribution of tephra shards in the RP pedological sequence. OxT2631 marks the location where the major element geochemistry was measured.

Abb. 4
Streuung von Tephrapartikeln im Referenzprofil (RP) der Grabung Grabow 15.
Der Pfeil markiert die Probe (OxT2631), an der die geochemische Zusammensetzung der Hauptbestandteile gemessen wurde.

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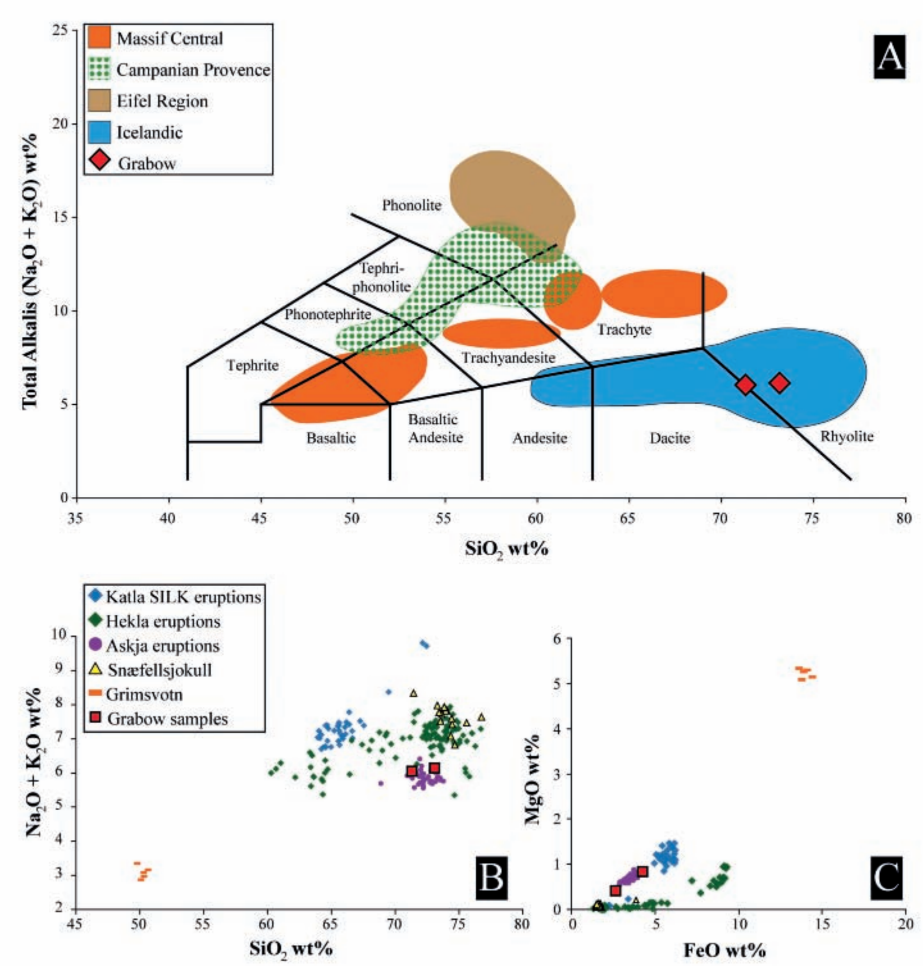

Fig. 5
Chemical analysis of the tephra shards detected in profile RP (cf. Fig 1D) and reconstruction of possible source areas. A: Total Alkali Silica (TAS) plot after LE-MAITRE et al. (1998), showing the general chemical grouping for each volcanic region that could have potentially deposited tephra within Grabow site 15. Areas defined with data from various authors (VERNET et al. 1998; MIALLIER et al. 2004; TURNEY et al. 2008; HARMS & SCHMINCKE 2000; HAFLIDASON et al. 2000);
B: TAS plot comparing the Grabow 15 samples to some other known Holocene eruptions from a range of Icelandic geologies; C: MgO and FeO wt% plot comparing the Grabow 15 samples to selected known Holocene eruptions from a range of Icelandic geologies (Katla SILK: LARSEN et al. 2001; Hekla: DUGMORE & NEWTON 1992; DUGMORE et al. 1992; Askja: OLDFIELD et al. 1997; LARSEN et al. 2001; Snæfellsjökull: BOYGLE 1994; Grimsvotn: HAFLIDASON et al. 2000).

Abb. 5
Chemische Zusammensetzung der Tephrapartikel aus Probe OxT2631 mit Rekonstruktion möglicher Herkunftsgebiete. A: Gesamtalkalie- und Silizium-Gehalt (Grafik nach LE-MAITRE et al. 1998), im Vergleich zur chemischen Zusammensetzung von Vulkanaschen aller in Betracht kommenden Liefergebiete (nach VERNET et al. 1998; MIALLIER et al. 2004; TURNEY et al. 2008; HARMS/SCHMINCKE 2000; HAFLIDASON et al. 2000); B: Gesamtalkalie- und Silizium-Gehalt der Grabow 15-Probe OxT2631 im Vergleich zu anderen holozänen Aschen bekannter isländischer Eruptionen; C: MgO and FeO-Gehalt (Massenanteil wt%) der Grabow 15-Probe OxT2631 im Vergleich zu anderen holozänen Aschen bekannter isländischer Eruptionen (Katla SILK: LARSEN et al. 2001; Hekla: DUGMORE/NEWTON 1992; DUGMORE et al. 1992; Askja: OLDFIELD et al. 1997; LARSEN et al. 2001; Snæfellsjökull: BOYGLE 1994; Grimsvotn: HAFLIDASON et al. 2000).

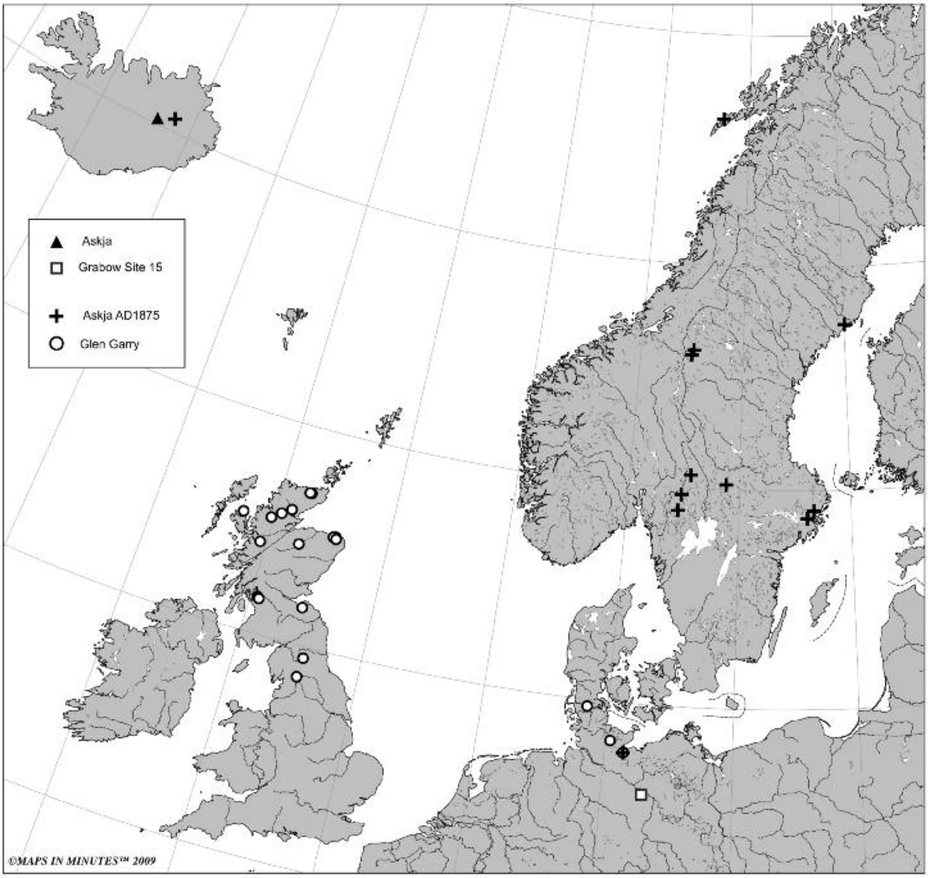

Fig. 6
Map showing Grabow site 15 in relation to previous find localities for the Askja AD 1875 and Glen Garry tephra. Data from BERGMAN et al. 2004; BLUNDELL et al. 2005; BOGAARD & SCHMINCKE 2002; BOYGLE 2004; DAVIES et al. 2007; DUGMORE et al.,1995; LANGDON & BARBER 2004; LARSEN et al. 1999; OLDFIELD et al. 1997; PILCHER & HALL 1996; PILCHER et al. 2005; and WASTEGÅRD 2005.

Abb. 6
Lage des Fundplatzes Grabow 15 in Relation zu bisherigen Fundorten der Askja AD 1875 und Glen Garry Tephra. Daten aus BERGMAN et al. 2004; BLUNDELL et al. 2005; BOGAARD/SCHMINCKE 2002; BOYGLE 2004; DAVIES et al. 2007; DUGMORE et al. 1995; LANGDON/BARBER 2004; LARSEN et al. 1999; OLDFIELD et al. 1997; PILCHER/HALL 1996; PILCHER et al. 2005; WASTEGÅRD 2005.

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