The RITaK Conferences

2013–2014

edited by
Petra Eisenach, Thomas Stöllner, Arne Windler

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Raw Materials, Innovation, Technology of Ancient Cultures
RITaK 1

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The Ea-nasir-tablet BM 131236 (reproduced by courtesy of the Trustees of the British Museum); ensity map of Spondylus artefacts in Europe (Arne Windler); Slag Sample Pa-15-27. Polarized light microscope image (Stephen W. Merkel).

Frontispiece
Participants of the RITaK final conference, 27th–29th November 2014 (Photo: Gero Steffens)

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Content

Thomas Stöllner

Preface

Today, raw materials have become a major factor of global importance and play a significant role in international policy. The raw material markets of today are indisputably a driving force of the world's economy, but this has a long development. Acquisition and supply of raw materials dominate the agenda of modern states, confederations and coalitions. We constantly encounter the effects in our everyday-life, and we cannot escape the products of the modern raw material economy as well as the ongoing cycle of production and consumption. This situation has its negative but also positive consequences for us.

Discussions on the restricted access to rare resources is not only an issue of academic circles and the feuilletons of newspapers, they have become common in all parts of modern societies. The production of crude oil must end one day and we daily observe the growing demand for noble metals, rare earth elements or building materials. The world market and its volatile trading conditions and price fluctuations led to enormous price increases that has its consequences for our natural and cultural heritage. The destruction of the oldest gold mine of humankind, discovered in Georgia in the mountains of the Lesser Caucasus, is one of the sad results of such a sharp rise in price, or "*hausse*", and the financial voracity of the owners and shareholders.

Now mining exploitation is able to manage and work at larger depths and in more difficult deposits than ever before. At Chucquicamata, one of the largest copper mines in the world, the craterlike opencast has been expanded to 4.3 kilometers in length and a depth of more than 1000 meters. With the help of modern techniques, humans are able to exploit the poorest of ores and deposits in a profitable way.

When considering the history of raw-material exploitation through historical and archaeological perspectives, it can described also as a development of better extraction methods and the usage of ever decreasing grades of ores and raw material sources. What is exploited nowadays was not profitable more than 100 years ago! During antiquity and prehistoric times, humans only used the best and richest parts of deposits, especially when considering metal ores. Such comparisons allow us to recognize the history of raw material exploitation also as a history of an ongoing technical evolution that enabled the usage of remote and more complicated as well as new kinds of raw materials.

Yet, it would be one-sided to describe such a development *simply* as a continuous technical evolvement. Such would resemble the thinking of the 18th and 19th century, when Christian Jürgensen Thomsen (1788-1865) divided the early history of humankind into the ages of Stone, Bronze and Iron. Ideas such as these have imprinted our concepts, and still today we search for such material determinants within the discussions on early societies and cultural conditions. However, archaeologists have realized for a long time that such an angle of observation is inadequate and restricting: The material culture of ancient civilizations was based in varying degrees on their traditional heritage, which informed the use of materials and raw materials, but this was a complex, manifold and multifocal relationship.

Additionally, there is another aspect that hinders our perspectives in regard of raw materials in ancient societies: It is our own increasing distance to resources, both the regenerative and the non-renewable. This alienation seems to have evolved at a time when people realized the finite nature of many of their resources. We only can awaken our consciousness indirectly either by literary sources or by understanding historically the systems of shortage and surplus of raw materials. On the other hand, we observe a lack of consciousness in concern to the finiteness of resources in traditional societies. In some cases, their interaction with resources seems more integrated and holistic, which reflects a special relation to an animated or spiritually conceptualized nature. Resources are integrated and religiously embedded and thus part of a total system that ties humans with their own living environment. However, such relations are not necessarily harmonious and are not without conflict.

When describing a long-term change in our relation to raw materials, we have to accept that this relationship was complex at all times. There always were changes in exploitation modes, in producing objects and their trading and consumption. The role of societies to such processes has changed likewise and by this change such processes had an impact on cultures and conceptions of human beings. Therefore, it is important to investigate these relationships, and it is self-evident that not only technical aspects have to be discussed. It is an essential part of those questions to observe and consider the economic, cognitive and societal interplays over longer time periods. And this was and is one of the basic impetuses of the Bochum Graduate School "Raw materials, Innovation, Technology of Ancient Cultures" (Rohstoffe, Innovation, Technologie alter Kulturen) (RITaK) that was founded in 2011, after the Leibniz Association has granted three years of program funding in November 2010.

From the beginning onwards the Leibniz Graduate School RITaK has been focused on three essential aspects to be explored and discussed by the single empirical and methodological projects.

1. Technical knowledge was transferred between different societies through communication and interaction and by help of knowledgeable individuals, which induced the adoption of new raw material concepts (from production to consumption). Which pattern of implementation and mechanisms can be observed that were linked to the exploitation and exchange such goods and technological innovations?
2. Materials and objects saw various changes in the attribution of specific cultural, societal and economical values over time. Objects and materials can be regarded also as media/mediators of social representations and social constructions that amplified their role beyond a daily and ostentatious practicability. The social aspects and cognition behind the use of materials are to be explored.
3. The economical and societal factors that surround raw materials, such as applicability, efficiency and cultural practicality, that helped technologies and raw materials to be broadly introduced and accepted are to be explored.

The factors that were decisive during periods of change can only be investigated through a broader interdisciplinary framework in which archaeological, archaeometric and historical sources are investigated in unison.

This was one of our general aims of the Leibniz Graduate School RITaK. Eight PhD students as well as several associated colleagues participated in RITaK between June 2011 and the autumn of 2014. They came from various disciplines of the humanities and natural sciences. Most of them came as archaeologists, some as scientists and some as historians. All of the students were trained with the expertise of members of the graduate school and were therefore confronted with several other fields and points of view. In several case studies, our PhD candidates investigated innovation processes, raw material production, trade and markets in a broad period that spanned from the Neolithic to the Medieval and stretched from Central and Western Asia to Northern and Western Europe.

Seventeen partners from nine institutions encouraged our PhD-candidates to progress with their studies and thus greatly supported the Leibniz Graduate School RITaK. This is gratefully remembered especially in respect of the colleagues who accompanied the project as Advisory Board. Prof. Em. Dr. Barbara Ottaway, Exeter, and Dr. Béatrice Cauuet shall be mentioned especially as they continually provided the students with advice and gave access to their broad knowledge. Other colleagues joined meetings and discussions, helping to identify theoretical and logical inconsistencies and to synthesize some of the most probing question. Many of these colleagues took part in our annual Milestone-meetings and contributed with their experience.

The PhD group, but also the external and internal partners, have collaborated in an excellent way: There was always a good mood and a favoring atmosphere between the candidates – neither contention nor jealousy. They worked eagerly together and supported each other in the frame of profession but also in their personal relations. In the meanwhile, nearly all of the PhD-studies that have been begun in 2011 are finalized. The publication of the studies as monographies shall appear in the form of a RITaK series of *Der Anschnitt Beiheft*.

The Leibniz Graduate School RITaK found its foundation in a well-established collaboration between the Deutsches Bergbau-Museum Bochum (DBM) and the Ruhr-University Bochum (RUB). The collaboration between both institutions became closer in recent years: It spans from joint university teaching and lecture series to research projects that are carried out mutually and in a collegial atmosphere. In 2017 the foundation of the *House of Archaeologies*, an institute for archaeological research and learning is operated jointly by the RUB and the DBM, can be seen as a sign of the fruitfulness of this collaboration. This institute of research and learning is in immediate proximity to the laboratory and the exhibition buildings of the DBM.

Research, academic teaching and the transmission of research results to the broader public have found a home in the center of Bochum. This step induces the idea of Science-Campus that incorporates the RUB, DBM and the University of Technology Georg Agricola at a location where the academic world now can meet the general public in Bochum. It is an area where the discussion about the history and future of raw materials and their societal appropriations and exchange can be intensified and new concepts found.

It is therefore important to show my appreciation for the financial support that was granted by the Leibniz Association in the frame of their competitive SAW-program in 2010 that enabled the start of this collaborative program. I would like to thank furthermore the DMT-LB e.V. as well as the DBM, its directors Prof. Dr. Rainer Slotta and Prof. Dr. Stefan Brüggerhoff, as well as Rectorate of the RUB, for their constant and technical support.

Here we present the first volume of the RITaK monograph series that gives an overview about scientific contributions that were presented in Bochum during the RITaK project in 2013 and 2014. In 2013 (22th to 23rd of November) several scientists joined to discuss “Perspectives of an Economic Archaeology” in a broad interdisciplinary framework. Arne Windler, at that time one of the PhD-students of the RITaK-project, initiated and stimulated the workshop in Bochum. Michael Roos and I joined his initiative. During two days, we dealt with forms of trade and exchange, with resource-management and with social and economic structures. The basic question was if the “homo oeconomicus”-conception as a dominant notion of

macroeconomics and social studies still could be used as a central model to explain economic behavior.

This workshop originally was planned to be published separately but finally was joined with a second conference held at the end of 2014 in Bochum (27th to 29th of November). It was the final RITaK conference that was organized by the RITaK organizers, Petra Eisenach and Thomas Stöllner together with all PhD students from the Leibniz Graduate School RITaK: The conference followed a general theoretical section at the beginning and was then directed to the various fields the PhD students dealt with in their studies. Several colleagues from various European countries and the USA participated and enriched the discussions with their scientific expertise.

The volume “The RITaK-conferences” resembles some of the fruitful and collaborative work of the RITaK School between 2011 and 2015. I finally want to thank Petra Eisenach for her dedication, motivation and hard work that drove our Graduate School RITaK forward. She was invaluable for the program and always was a communicative partner for all of us. Thank you Petra!

Finally, I am looking forward to the response by the academic community of this volume and the ideas within. This response and impact will be the greatest outcome for us from all those years of mutual collaboration.

Volker Hilberg

The access to raw materials and its impact on Hedeby's development in the Viking period

ABSTRACT: All kinds of raw materials and mineral resources were imported and traded in changing quantities during the Viking period (c. from the end of 8th until the end of 11th century AD). The transport of these commodities primarily based on seafaring, which required rising infrastructure and support. A growing influence of kings, especially since the Christianization and the state formation processes (both are related with each other) is attested during the course of the 10th century. The Danish harbour of Hedeby played an important role due to its location between the North Sea and the Baltic Sea and its proximity to the Frankish and later the Ottonian and Salian realms. Further analytical and archaeological work is necessary to understand the changing use of different raw materials.

KEYWORDS: *EARLY MIDDLE AGES, VIKINGS, SCANDINAVIA, HEDEBY, EMPORIA, RAW MATERIALS, MINERAL RESOURCES, TRADE, PRODUCTION*

The early medieval silver economies, the coastal *emporia* and the socioeconomic development of society

From the later 7th century AD onward, the early medieval economy of Central and North Western Europe is characterized by two phenomena: In coinage and minting, the traditional gold standard based on the customs from late antiquity is abandoned in favour of a new silver value (Bompaire, 1997, pp.107-119; Grierson, Blackburn, 1986, pp.138-154; op den Velde, Klaassen, 2004, pp.65-67; Sarah, 2014). Most of these coins are not only found in coin hoards or graves from the Frankish or Anglo-Saxon realms, but are also registered more and more in settlement complexes of a new coastal type (cf. Domburg: op den Velde, Klaassen, 2004): the so-called *emporia* (Hodges, 2012; Kleingärtner, 2014, esp. pp.180-189; Kalmring, 2016). There is an enormous amount of publications dealing with these developments, especially with the phenomenon concerning the appearance and functioning of the new trading centres, which makes an up-to-date discussion and processing more and more complex. Projects dedicated to a modern research and investigation with regard to the archaeologically relevant materials are therefore very important to understand the development of the early medieval economy. It is not enough any longer just to rely on typochronological studies, rather, the invention of modern scientific analysis as being provided by recent archaeometric examination is of utmost importance. Some years ago for example, Guillaume Sarah has impressingly demonstrated how our knowledge and understanding of the Carolingian coinage could be improved through archaeometric analyses of the silver fineness and its development (Sarah et al. 2008; Sarah et al. 2009; Sarah, 2010).

The last decades have also seen a significant rise in archaeological excavations and complementary investigations, like geophysical prospections or systematic metal-detecting surveys – if possible – concerning these *emporia* dedicated to trade and handicraft production (**Fig. 1**). Much fieldwork has been done at places like London, Kaupang, Ribe, Hedeby, Groß Strömkendorf and Menzlin, Wolin, Truso, Birka, Staraja Ladoga or Novgorod. They are all nodes in a network of early urban trading centres which were connected by the sea or important riverine routes (Callmer, 1994; 2007; Sindbæk, 2007; Kleingärtner, 2014, pp.175-199). Their location is characterized by a very favoured position that allows combining several natural and economic areas (McCormick, 2007), and they are interrelated with several smaller trading centres which had a more regional significance but fulfilled central functions because they were situated along the coast or further in the inland (Callmer, 1994; Loveluck and Tys, 2006). As early as the middle of the 9th century, several *emporia* of the North Sea basin experienced an economic decline (Loveluck, 2013, pp.302-327), and since the middle of the 10th century there have been considerable changes in the structure of these places. A partial collapse of this old trading system is evident, without the reasons and causes being sufficiently

Fig. 1. Main emporia (red dots) of the Carolingian period in the North Sea and the Western Baltic. (Graphics: Jürgen Schüller, Schleswig).

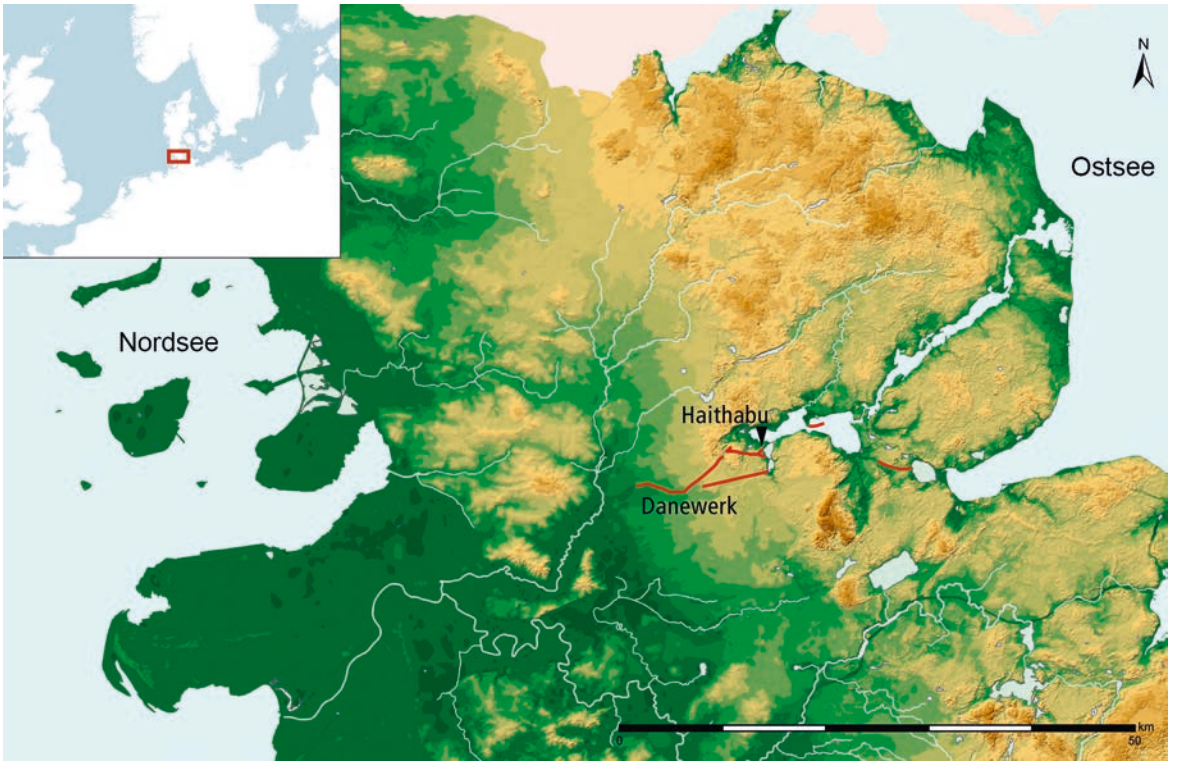

Fig. 2. The Schleswig isthmus with the Danevirke and the location of Hedeby. (Mapbasis: Landesvermessungsamt Schleswig-Holstein).

known (Callmer, 1994, pp.69-74), but J. Callmer has been thinking about political unrest and underlined that trade was becoming more regulated and controlled (ibid.; cf. Brather and Jagodziński, 2012, pp.316-326).

An important reason can also be seen in the changes resulting from Christianization of different areas north and east of the former Carolingian empire from the 10th century AD onward (Gelting, 2007; Samsonowicz, 2009). Through the progressing acceptance of Christianity by the ruling royal families and elites, radical sociopolitical changes of these societies are taking place: with the high clergy, a new population class is created assuming leading tasks in administration and government, the relationship between the king and his followers is redefined and also the power of government; the government of the king expanded, and the formation of a new hierarchical, Christian representation is necessary. These striking social developments also changed the stages that have been used so far to portray rule, power, and faith. In a long process lasting until the 13th century AD, monasteries and new cities, mostly named *civitates,* were founded, and churches were built for bishops and kings. For the pastoral care of the rural population, parish churches were required and built, the high clergy and new Christian rulers needed purposes palaces and courts for their new representation (Brink, 2013).

In his investigation of large cargo shipwrecks from about 1000 AD onward, Anton Englert (2015, pp.39-54) recently emphasized a growing specialization of merchant seafaring under royal protection as a process from the late Viking Age to the Hanseatic period. He specified decisive elements, so for example the existence of independent merchants living exclusively from trade, of co-operative merchant seafaring, and of a multiple ownership of ships or cargo, the codification of maritime law, a money-based economy and specific taxation of urban properties in connection with the accessibleness of coastal and inland towns. As a result, the societies who underwent these developments changed significantly from the early 11th century AD onward.

The *emporium* of Hedeby – geostrategic location and development of its functions

Crucial to the importance and development of these maritime trading centres are, as already mentioned, their favourable natural surroundings and their location (McCormick, 2007; Sindbæk, 2009, especially p.75). Hedeby, about 2 km south of medieval Schleswig in an inlet of the Schlei fjord directly connected to the Baltic Sea, is situated on the southern border of Denmark, in the transitional area of several cultural spheres (**Fig. 1+2**). Its immediate agricultural hinterland is represented by the fertile upper moraines of Angeln and Schwansen on either side of the Schlei fjord, inhabited by a Danish speaking population. On the west coast, in the area of the North Sea and the Wadden Sea, the settlement area of Frisian speaking tribes extended from the Schelde-Maas-Rhine estuary to the Danish area south of today's Ringkøbing fjord. South of the river Eider were the regions of old Lower German-speaking Saxon tribes, who were included in the Frankish kingdom by the Saxon wars of Charlemagne. In the south-east, along the east coast of Holstein, Slavs are living who can be attributed to an east-central European cultural area (Kalmring, 2010, pp.27-40).

Like no other early urban centre in Europe, the central importance of Hedeby is explained and recognized by its position at a unique junction between the North Sea and the Baltic Sea on the one hand and between Scandinavia and the continent on the other hand, situated at the narrowest point of the Jutland peninsula (Hilberg and Kalmring, 2014). This transit area is secured and controlled by the system of the Danevirke ramparts, which had been blocking the isthmus since the Germanic Iron Age and was massively expanded in 737 AD, representing the symbolic southern border of Denmark throughout the Middle Ages (Andersen, 1998; 2004; Dobat, 2008; Tummuscheit, 2012). The Danevirke has got a high symbolic significance, as it makes the reaching of a new dominion visible to the medieval traveller. In addition to the traffic control, it made the passage between the seas also easier and safer. This geostrategic situation also explains the Carolingian and Ottonian interest in Hedeby and the Schleswig isthmus. By this interface, the access to the Baltic Sea is provided and thus, links to the trading networks and their trade flows (mainly silver) to and from the east (Hilberg, 2014, pp.183188). Still in the southern forefront of the main rampart of the Danevirke and apparently already erected in the Germanic Iron Age (Andersen, 1998, pp.189-194; Tummuscheit, 2012, p.6), there was a settlement area with a favourable access to the fjords, located at the innermost part of the Schlei at the Haddebyer Noor, and protected by a 26 meter high elevation, the so-called *Hochburg* (Viberg and Kalmring, 2016). This settlement area is accessible from the west by land and from the east by the waterway of the Schlei. Since the middle of the 10th century AD at the latest, an approximately 1.3 km long semicircular rampart has been encompassing an area of roughly 25.5 ha, which in 1897 for the first time was identified as Hedeby, due to the rune stones found in the vicinity, and excavated during the following decades (Hilberg, 2008; von Carnap, Hilberg and Schultze, 2014). Since the entire area has never been inhabited since the end of the Viking Age, it offers excellent opportunities for archaeological excavations and prospections (**Fig. 3**). The settlement and burial finds are very well preserved and stand out in the vicinity of the small traversing river, because of an organic preservation in stratified layers (Schultze, 2008). Hedeby's function as a trading place developed in the early ninth century. In the 880s, an extensive building boom in the harbour (**Fig. 4**) resulted in the formation of large wooden jetties serving

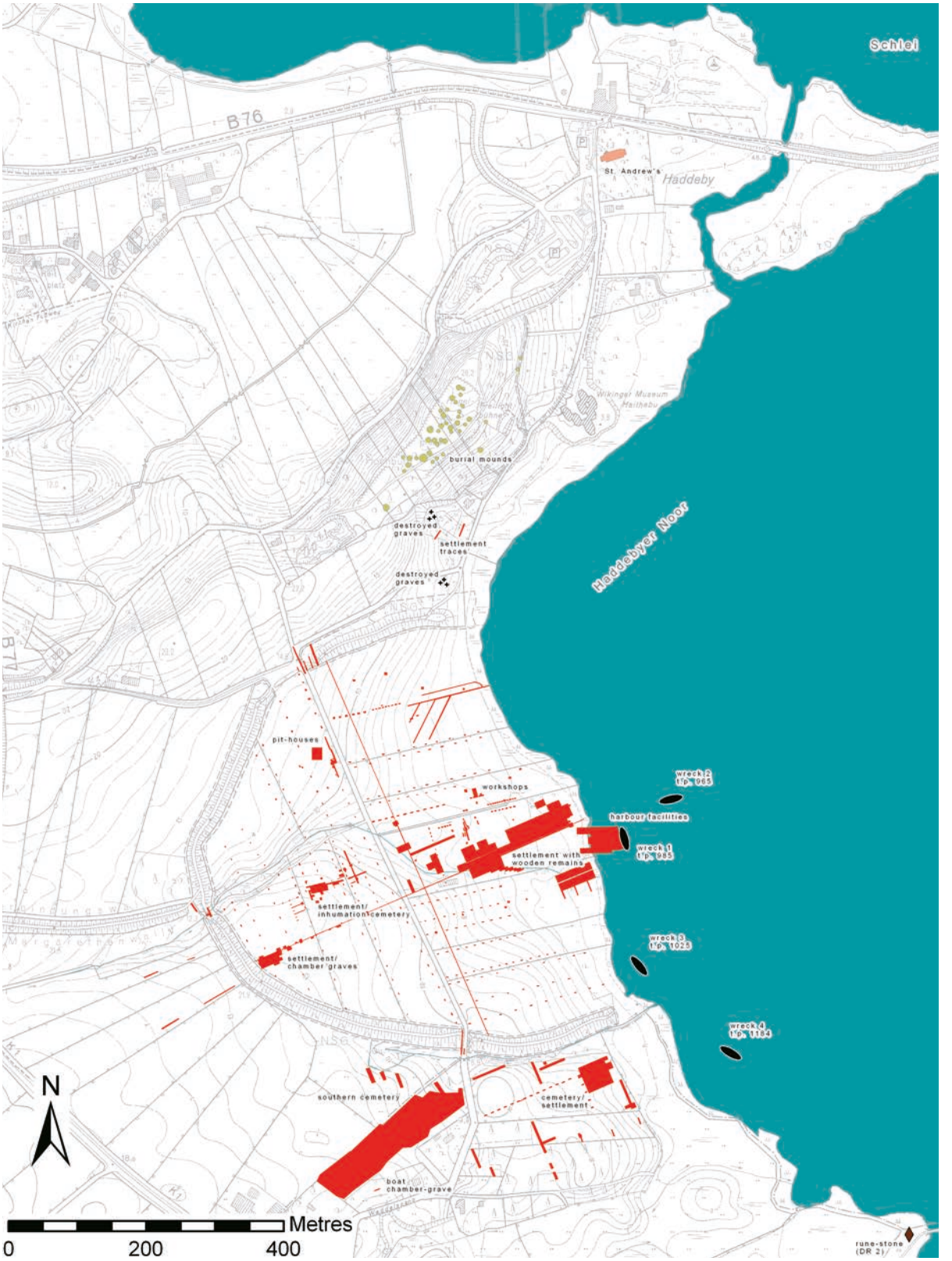

Fig. 3. Map of Hedeby and its entire region with excavation trenches since 1900 and known ship wrecks. (Graphics: Volker Hilberg).

as a mooring for ships and also as a marketplace (Kalmring, 2010). At this time, Hedeby was an international hub in a supraregional trade network with trade goods from far away and an innovative craft centre where all kinds of items and raw materials from all over the world could have been available (Sindbæk, 2012, esp. p.40, fig.2-3; Hilberg and Kalmring, 2014). Via Hedeby's harbour, the distribution and processing of goods with some luxury character

Fig. 4. Hedeby, 1979-1980 harbour excavation. Dating of the shipwreck and the harbour jetties. Scale 1:550 (KALMRING 2010a, Fig. 234; by courtesy of Sven Kalmring).

or commodities with specialized fabrication took place, such as wine and drinking vessels, textiles and skins, special raw materials (for example mill- or whetstones, metals such as silver, lead and tin, presumably salt, limestone and chalk, pitch and tar, antler, amber, and jet), and ceramics, jewelry, weapons, and slaves are distributed within the various kingdoms or dominions, whereby, on the one hand, the rising consumer demand of the elites is covered, and, on the other hand, important revenues and tolls are paid to the kings. In addition to the trade function, the significance of an extensive artisan production for the *emporia*, which largely depended on the state of archaeological investigations, was emphasized (Callmer, 2003; Skre, 2008; for Hedeby cf. Hilberg, 2009, pp.93-97). These products did not only circulate between the trade connections but also provided the hinterland. A wide range of handicraft products is attested by extensive excavations and field surveys (Schietzel, 2014, pp.322-467).

With the expansion of Scandinavian activities in the developing Old Rus' region, the influence of the Central Asian Islamic area, which in the meanwhile had also reached South Scandinavia via the Baltic Sea, had been growing decisively since the late 9th century. This trade, which is largely based on furs and slaves, is intensified. A system of bullion-based economy, relying on the use of fine balances and standard weights, was adopted for transactions, and huge amounts of late Abbasid and Samanid silver coins reached the Baltic Sea area (Kilger, 2007; Steuer, 2014). In the 930s, however, the southern Danish border area with Hedeby had become increasingly important for the Saxon kings of the Liudolfingian-Ottonian family, although the exact course can not reliably be reconstructed, because of the sparse historical records (Schlesinger, 1972, pp.80-91; Hoffmann, 1984; Sawyer and Sawyer, 2002, pp.171-173, 179-185; Stieldorf, 2012, pp.109-112, 432, 442, 487; different: Hybel, 2013). This pressure and impact of the Ottonian realm did not only lead to a form of tributary dependencies, but also to the establishment of the first Danish bishoprics in 948, and to the gradual state formation in Denmark under the leadership of the Jelling dynasty (Bagge, 2009, esp. p.148). The fact that Hedeby was also drawn into the changes and upheavals of the second half of the 10th century AD is marked by two rune stones placed in the immediate vicinity to the memory of high-ranking followers of king Svend Forkbeard (987-1014), who died in the fight for Hedeby (Jacobsen and Moltke, 1942, pp.5-10, no.1 and 3). The archaeological findings seemed to confirm this decline of Hedeby around the year 1000 (Jankuhn, 1986, pp.184-185, 222-223; Radtke, 2010): Apparently, there was no reliable evidence of building structures in the 11th century, the own coinage ended in the 980s, and the amount of late Viking period small finds or coins seemed to be very marginal and small. However, this image has fundamentally changed by the field research of recent years. Through systematic metal-detecting, it was possible for the first time to document the findings of the late Viking era in large numbers (**fig. 5**) (Hilberg, 2016). The last-mentioned assessment that the new late Viking find horizon could only be connected to a changed function of Hedeby in the 11th century must be contradicted, and also, that the

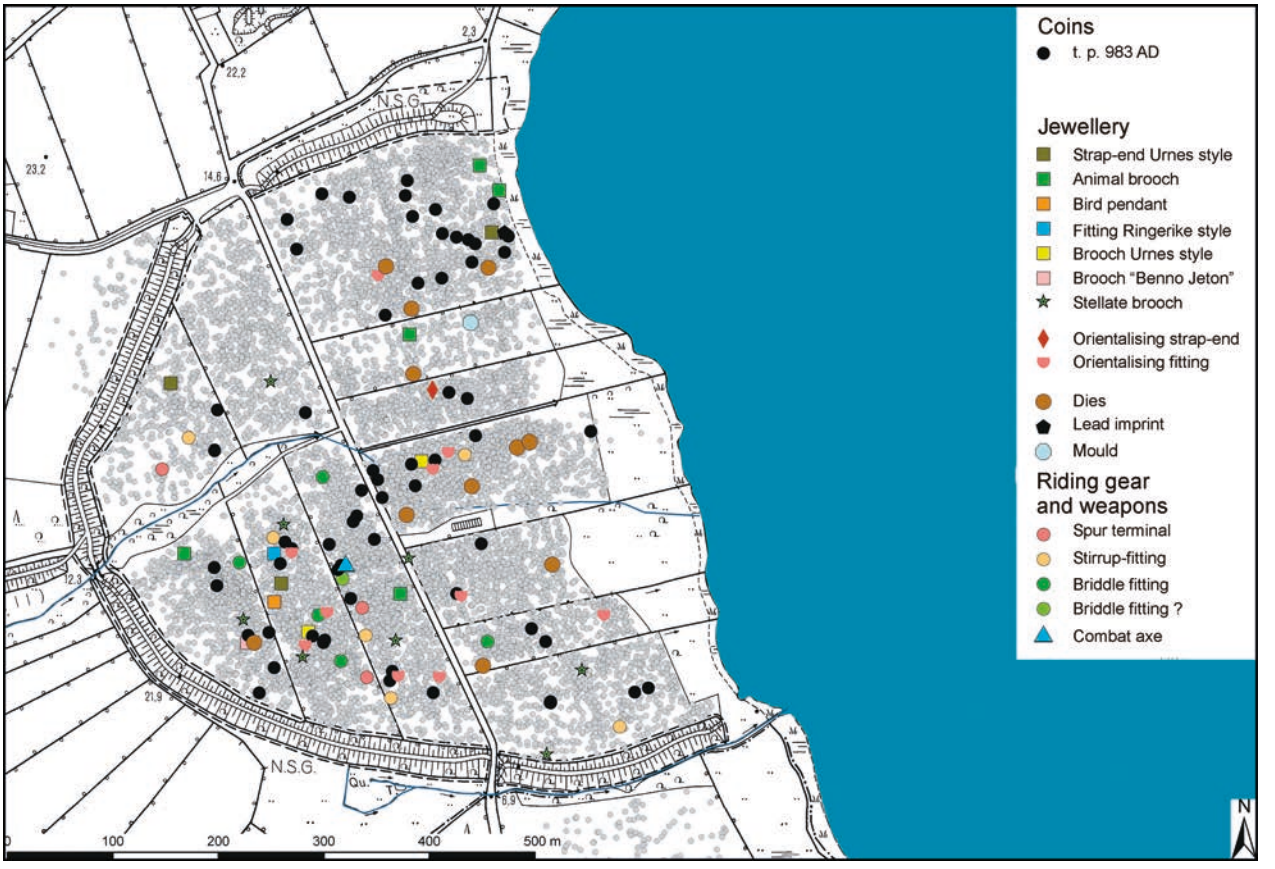

Fig. 5. Hedeby, metal-detected small finds of the late Viking period and coins struck after c. AD 983. (Map: Volker Hilberg).

place had no longer a long-distance trade function but was converted into a base of royal power. Not only the two rune stones erected by king Svend respectively by Thorulf, a high-ranking warrior of the royal retinue, but also the sources referring to the deployment of troops after the Danish conquest of England in 1013, and the new metal-detected small finds mainly consisting of riding accessories, would point in this direction (Radtke, 2009, pp.151-157; Lüdtke, 2013, p.89; Kleingärtner, 2014, p.180, footnote 389). In fact, the 11th century is characterized by a significant increase in riding equipment (cf. e.g. Graham-Campbell, 1991; Pedersen, 1996-97; Williams, 1997; Hinton, 2008, pp.82-83), but also women's dress accessories, semi-finished products and moulds are now much more numerous in Hedeby (Hilberg, 2016). For a recently considered "*flexible model of a gradual shift of individual functions from the southern bank* [Hedeby] *to the north shore* [Schleswig]" already in the first half of the 11th century (Radtke, 2010, p.157; Lüdtke, 2013, pp.89-90), however, archaeological finds have been missing so far, especially in Schleswig (cf. Rösch, 2015, esp. pp.241-253; 2016).

In particular, the high amount of single coin finds minted after 983 AD and the extensive number of standardized weights from the 11th century point out that Hedeby could not have lost its long-distance trade function and remained a trading and production centre until the middle of the 11th century. On a total of 92 single coins from former settlement contexts of the late Viking age after 983 AD, only 25 specimen were found before 2002 – an amount surpassing the contemporary leading Danish cities of Lund and Roskilde several times (Hilberg, 2016).

Traffic conditions and the access to raw materials

Most of the long-distance traffic in the Viking period was connected to the sea, using the water routes, and so realized by shipping (already Bugge, 1906; Borgolte, 2010, pp.508-511). However, even if maritime traffic was hampered by natural restrictions – the uncertainties of the weather, the changing of the seasons – it provided better possibilities as larger amounts of commodities could be transported easier, cheaper and faster. Martin Carver (1990) calculated a journey speed of 15 miles (à 1.609 km) per day on land and 82 nautical miles (à 1.852 km) for sea voyages. Furthermore, a safer trip with companions seemed to be more important than taking the shortest or best route (cf. Waßenhoven, 2006, p.88). For the Scandinavian area, the voyages of Ohthere and Wulfstan in the later 9th century AD (**fig. 6**) were recorded in king Alfred's *Orosius* report on traffic routes and the scheduled speed which seemed to be common in the Early Middle Ages (Bately and Englert, 2007; Englert and Trakadas, 2009). Ohthere sailed from *Sciringesheal*, most likely Kaupang

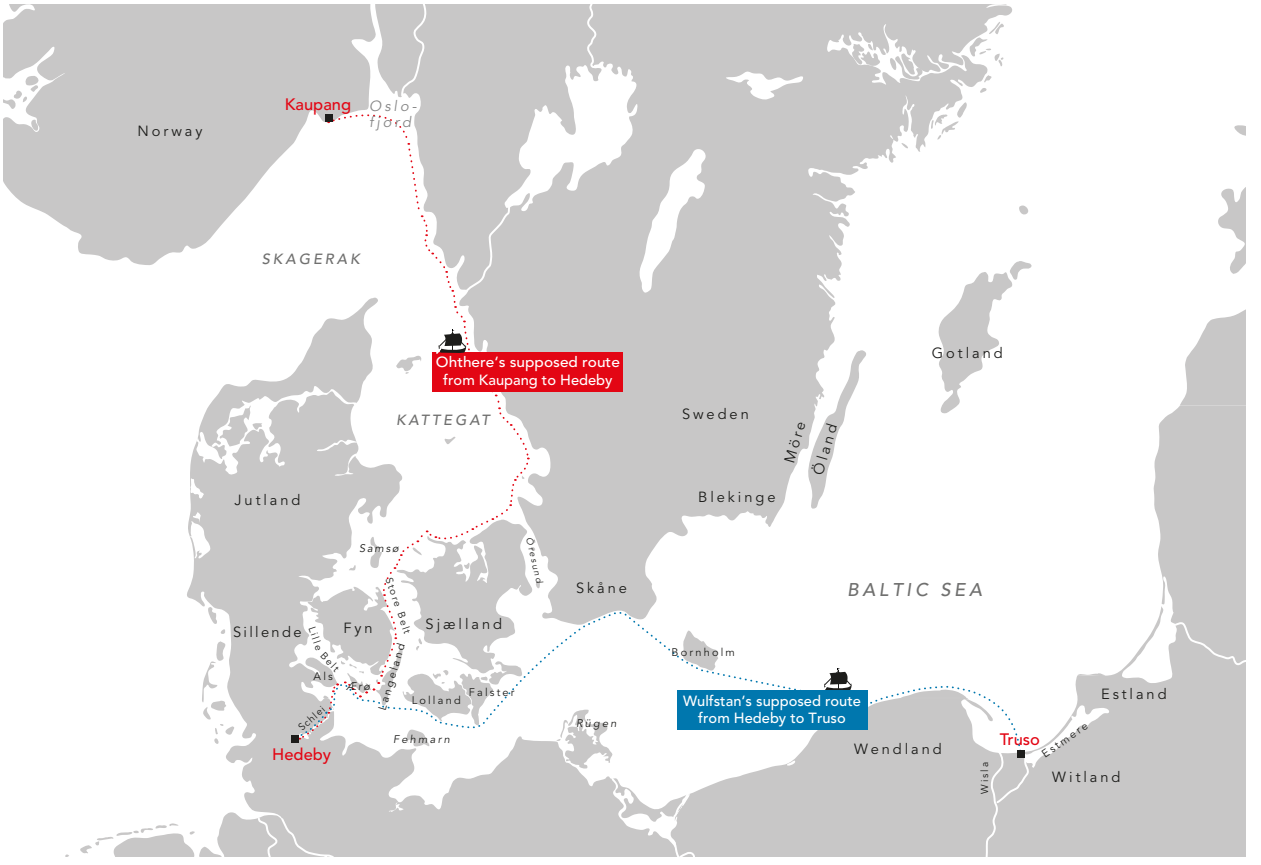

Fig. 6. The routes of Ohthere's and Wulfstan's voyages in the late 9th century AD. (Graphics: Jürgen Schüller, Schleswig).

in Vestfold/Norway, to Hedeby in five days, which means that he was sailing with 3.3 knots and covered the distance of about 400 nm while with an average of 80 nm every twenty-four hours. His contemporary Wulfstan had a lower average travel speed, between 2.3 and 2.45 knots, and was able to sail 55 or 59.3 nautical miles in a twenty-four hour period. For the journey from Hedeby to Truso in the mouth of the river Vistula, it took him seven days and nights (Englert and Ossowski, 2009, pp.268-269, with table 2).

Heavy bulk commodities from the continent, like lava quern stones from the Mayen region (**fig. 7**) which were very popular in Viking period of Denmark (Gabriel,1988, pp.157-161, 268 list 3; Feveile, 2010; Pohl, 2011; Parkhouse, 2014), were shipped downstream on the Rhine, passing Dorestad, the largest Frankish *emporium* and one of the most important toll stations. It seems plausible that the cargo was reloaded at Dorestad on sea-going ships and reached the Waddensea via the Oude Rijn or the Almere via the Vecht and arrived at Ribe or Hedeby after a journey of approximately 5–6 days (Dijkstra, 2011, pp.49-59). In Ribe, about 2.091 finds weighing at least 154 kilos and consisting of basalt have been found until 2000 (Feveile, 2010, p.133), whereas in Hedeby the amount of circa 5.700 objects weighing about 1.200 kilos was registered (Schietzel, 2014, pp.412-413). Kurt Schietzel (ibid.) assessed the low amount of garnet-mica schist quern stones from Hyllestad, Sogn og Fjordane, Norway (Baug, 2015), at approximately 1% of all quern stone finds from Hedeby, resulting from the extremely long transportation routes of 17-18 days at least according to Ohthere's report – or even much longer, when ships were heavily laden. With more than 3.400 objects weighing circa 540 kilos, also soapstone was very common in Hedeby used primarily for cooking vessels, but larger fragments had also been re-used after being reworked for several purposes (Resi, 1979). Due to trace element analysis, the sources of soapstone from fragments found in this south Danish *emporium* seem to be the nearest available deposits in western Sweden respectively eastern Norway, apparently avoiding longer transportation routes (**fig. 8**) (Alfsen and Christie, 1979; Resi, 1979, pp.123-131). Heid G. Resi also pointed out that the amount of soapstone vessel fragments in Hedeby decreased when the probably locally produced wheel-thrown pottery occurred in the 10th century. Apparently, this high quality pottery replaced the use of soapstone vessels by and by (Resi, 1979, pp.101-112).

Since in the Viking era no larger metal resources could be used in Scandinavia, apart from iron (Hybel and Poulsen, 2007, p.218), the supply of silver as a basis of economical transactions and wealth entirely depended on external procurement. This supply of raw materials was guaranteed by robbery and tribute payments on the one hand and by trade on the other (Coupland, 1999; Reuter, 1985; Williams, 2011). In the 8th and 9th centuries, silver

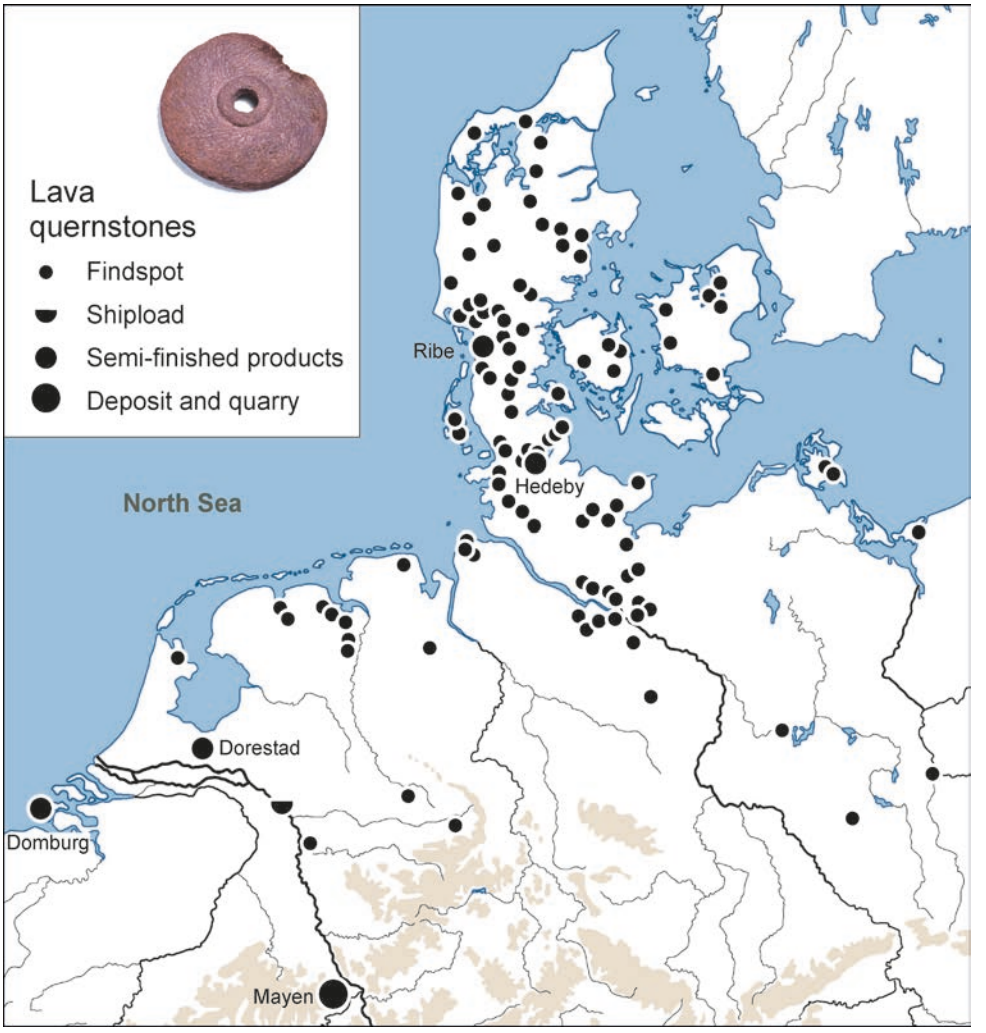

Fig. 7. The distribution of lava quernstones from Mayen in Northern Continental Europe and Denmark after Gabriel, 1991 and Feveile, 2010. (Graphics: Volker Hilberg).

predominantly came from the Carolingian Empire. In the course of the 9th century, the silver trade in form of Islamic dirhams continued growing (Kilger, 2007, pp.207-208, 228-246). Most of the silver circulating in Scandinavia in the 10th century may have come from molten dirhams (Hårdh, 2002, p.184).

Analytical research on Ottonian coins from the continent – especially the two most important coin groups of the so-called Saxon pennies and the Otto-Adelheid pennies (Kluge, 2001; 2005) – showed that Islamic silver was used for these coinages, too (Steuer, Stern and Goldenberg, 2002, pp.146-154; Steuer, 2004, pp.131-133). Christoph Bartels (1996, pp.235-236) assumes that the metal import for minting from the Islamic caliphate could not cover the demand for silver in Central Europe, and that a (re-)development of deposits started in Europe in the second half of the 10th century. The written record of these exploitations began for the Harz in 968, for the Vosges in 984, and for the Black Forest in 1028. This system of massive silver imports from Islamic Central Asia experienced a marked decline in the last decades of the 10th century, as is dramatically reflected in the changing composition of treasure finds in the Baltic Sea region (Leimus, 2007). The coin hoards deposited since the 970s were dominated by Western European denarii (Leimus, 2007), and the beginning of a massive silver influx from the East Frankish-German Ottonian Empire and late Anglo-Saxon England is also traditionally set during this period (Hatz, 1974, pp.47-51; Jonsson, 1990; Metcalf, 1998; Moesgaard, 2006). However, Danish hoards like Grisebjerggård (tp 942/3), Jyndevad (tp 954/5) and probably also Terslev (tp 940), in which early Saxon pennies are represented, show that this development had begun no later than in the middle of the 10th century (Jonsson, 1990, pp.139-141; Kilger and Moesgård, 2008) and thus, this influx started earlier than the hitherto supposed inflow of these Saxon pennies via the West Slavic area into the Baltic, due to Swedish coin finds from around 970 onward (Hatz, 1985). Such an early Saxon penny is also known as a settlement find from Hedeby (Wiechmann, 2007, p.260, cat.no.57)[2]. With the minting of the Otto-Adelheid-pennies after 983 (Ilisch, 2013), these coins reached Scandinavia and Hedeby in large numbers. In addition to the two old finds known so far (Wiechmann, 2007, p.260

Fig. 8. Scandinavian soapstone quarries versus quarries with petrographical correlation with soapstone remains from Hedeby, after Alfsen and Christie, 1979. (Graphics: Volker Hilberg).

cat.no.54-55), there are 19 Otto-Adelheid pennies recently found, which originate from a settlement excavation between 2005 and 2010 and from the systematic metal-detector surveys (**fig. 9**). In addition to the Otto-Adelheid-pennies and other Saxon coin types, Cologne's various S COLONIA-deniers and their imitations, and deniers from other Lower Lotharingian mints as well were used in Hedeby in the first half of the 11th century. They point to the economic relations between the Rhineland and southern Scandinavia, via the metropolis of Cologne (Hilberg, 2016, 74). Just as these coins are distributed all over Hedeby's settlement area, the standardized weights also occurring on a large scale refer to a broader trade function on-site. The late truncated spheres ("*Kugelzonengewichte* ") of types Steuer B1 middle, B2, B1 late, B3, and B4 clearly show that trade transactions were carried out on a large scale in the 11th century, too (ibid.).

The latest known building activities in Hedeby's harbour date back to the early 11th century (Kalmring, 2010, pp.237-239, 242-243, 454 fig. 324), the youngest coin from the harbour excavation is a penny struck by the Danish king Harthacnut (1035-1042) (Wiechmann, 2007, p.271, cat.no.131). In the harbour, the largest trading vessel of the Viking period sank, a huge cargo ship built after 1023, with a calculated water displacement of 75 tons, which would have achieved a loading capacity of approximately 60 tons (Kalmring, 2010, pp.122-125; Englert, 2015, p.60, fig.4.8).

Hedeby's transit function, its superior position in the trade traffic between the North Sea and Baltic Sea and between Scandinavia and the Central European continent, might be replaced after the planned transfer relocation during the reign of king Svend Estridsen (1047-1074) around 1066 without any interruption by its successor Schleswig (last: Rösch, 2016). The economic relations between Hedeby as a transit and marketplace and the Ottonian-Salian Empire have got, due to the dominating coin groups from the Harz area, Cologne and the Lower Lotharingian region, a considerable importance for the function and importance of this Danish harbour probably still in the first half of the 11th century.

As Harald Witthöft (2000, p.122; cf. e.g. Suhling, 1996, p.269) stressed a few years ago, the various metals served as the leading products of medieval economy:

Fig. 9. Hedeby, distribution of Otto-Adelheid-Pennies, types Hz III–IV, c. AD 990-1030/35. (Graphics: Volker Hilberg).

tools and weapons were made of iron, currency and coinage were based on gold and silver, and bronze and brass were among the most important commodity metals of which diverse equipment was manufactured. Like the Slavonic settlement areas in Central and Eastern Europe (Brather, 2008, pp.210-216), during the Viking age Scandinavia did not have or use own metallic resources, which had already been smelted at that time, except for different iron ore deposits (iron: Buchwald and Voss, 1992; Buchwald, 2005, esp. pp.292-335; Nørbach, 2003; Stenvik, 2003; Westphalen, 1989, pp.58-65; copper: Forshell, 1992; Stenvik, 2012; brass: Sindbæk, 2003). Mostly, less attention is drawn to the lack of existing ore deposits than to the role of metals in the long-distance trade or as booty. Where on the one hand metal scrap imports are considered (Roesdahl, 1980, pp.99-100), the Danish interest in Norway – visible with regard to a supremacy at different times – on the other hand is explained by the wealth of Norway concerning certain raw materials and commodities, such as walrus ivory, soapstone, various types of whetstones or iron (Roesdahl, 1980, p.99-100, 224; Buchwald, 2005, p.294). In addition to the recycling of scrap metal, the various metals were negotiated in ingot form: iron is forged into various forms (Westphalen, 1989, pp.65-67), silver and copper alloys are mostly cast into rod-shaped bars (Drescher, 1983, pp.175-178; Eiwanger, 1996; Sindbæk, 2001), silver is circulating not only in ingot form but also in form of coins, jewelry and chopped and cut pieces (Hårdh, 2002; Söderberg, 2011; Skre, 2011).

The nearest ore deposits available for South Scandinavia, which are not coming from Northern bog iron ores, are located at the northern edge of the German *Mittelgebirge* (**fig. 10**). They extend across the Rheinische Schiefergebirge from the Ardennes to the Sauerland and further to the Harz Mountains (Joris, 1993; Maus, 1993; Lammers, 2009, pp.74-75). Trading in these areas allowed access to silver and utility metals such as brass, bronze and other copper alloys, and lead as well. Besides, high-quality manganese and barium-rich iron played a role, such as from the Iberg near Bad Grund, where early Carolingian iron smelting could be proved (Bartels and Klappauf, 2012, pp.132, 142-143;Linke, Kriete and Klappauf, 2012), or further in the east from the Elbingeröder complex (Alper, 2016; Schnepp, 2016) which was smelted in the Harz and could have been transported from here to Southern Scandinavia, a thesis that has not yet been considered in research. The sparse historical sources only allow a few conclusions on the development of early medieval mining, but apparently there is an improvement in silver mining in the late 10th and 11th century – and in the extraction of lead – not only in the Harz Mountains, but also in the Vosges, in the Black Forest, and perhaps in Carinthia (Zotz, 1993, pp.189-190; Bartels and Klappauf, 2012, pp.128, 164-179). Successful research has shown,

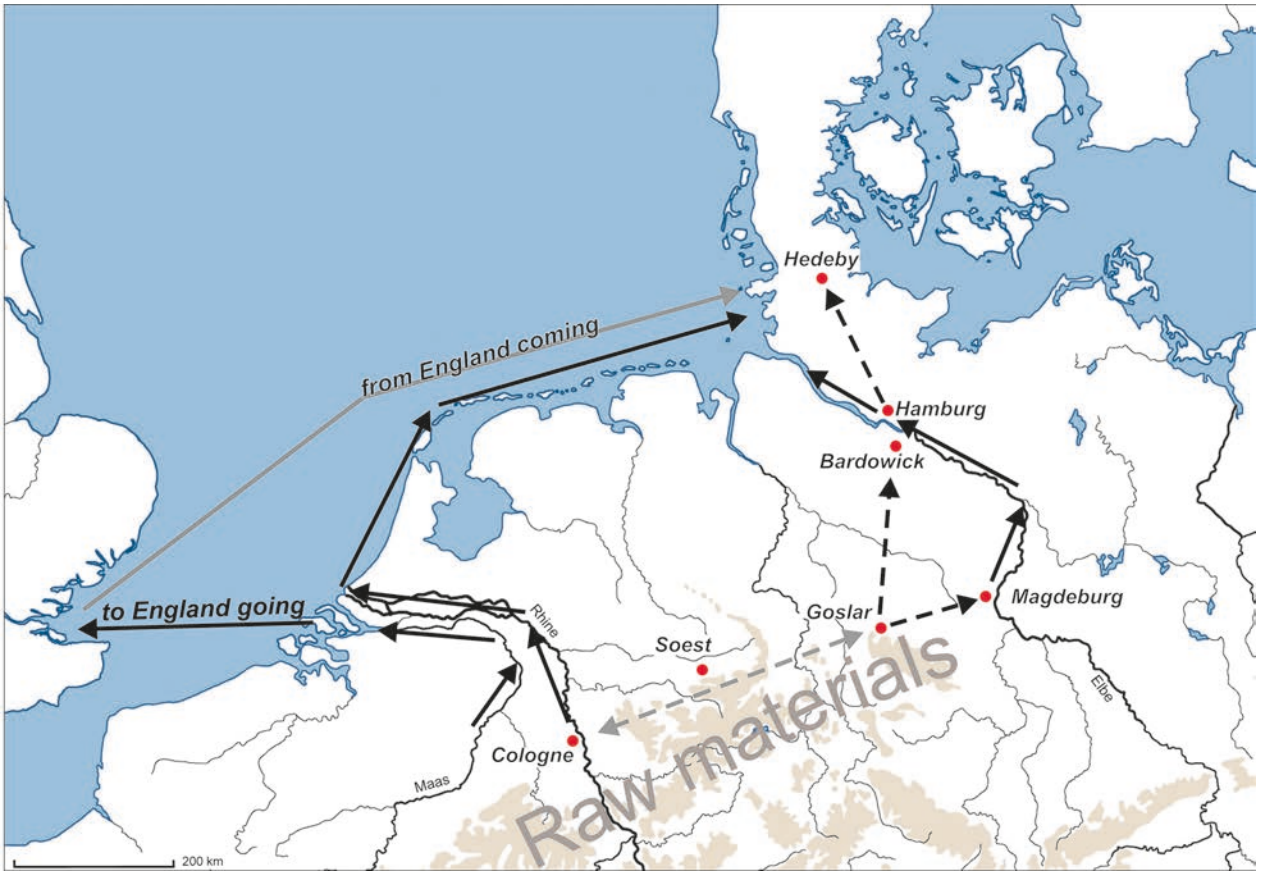

Fig. 10. The supply of various metals from the "Deutsche Mittelgebirge" to Hedeby in the Viking period via land routes (broken line) and by water (continuous line). An indirect supply (grey lines) is made possible in the context of manorial structures and by trade with England. (Graphics: Volker Hilberg).

however, that ore mining already took place earlier and that surface mining in opencast pits was invented. For the Roman Iron Age, the processing of gangue ore from the Upper Harz (silver-containing galena) and of copper ore from the Rammelsberg is attested at the site of Düna near Osterode at the western edge of the Harz (Brockner, Heimbruch and Koerfer, 1990; Brockner and Kaufmann, 2004, pp.152-154; Klappauf et al., 2008, p.66; Bartels and Klappauf, 2012, pp.121-123). The first melting sites in the Harz Mountains have been working since the 7th century AD (Klappauf, 2011, p.170; Bartels and Klappauf, 2012, pp.134-135).

Fig. 11. So-called "Benno-Jeton", brooch with the effigy of Henry III. (1039-56, emperor 1046), Goslar type, after AD 1047/48. Hedeby, excavation 2007, cultural layer, no. 8570, dm. 1.8 x 2 cm, leaded copper alloy.. (Photo: Claudia Janke).

Extraction or further processing of ores is also comprehensible where the written tradition is missing – attested in the meanwhile is the extensive brass production in Dortmund or in Soest, to the northwest of the Sauerland (Lammers, 2009, pp.48-75; Sicherl, 2011; Merkel, 2016b). However, these connections and production steps are best investigated in the Harz region and its surroundings (Klappauf, 2011). Archaeological features also suggest that the metals extracted in the Harz mountains in melting or smelting sites were then placed within the framework of the manorial organisation at locations directly in front of the deposits, where they were further processed or alloyed, then presumably put into the form of ingots to be better handled and traded (Klappauf et al., 2008, p.72, fig.4-6; Bartels and Klappauf, 2012, pp.134, 147; Blaich, 2012).

However, due to the lack of written sources for the 10th and 11th centuries, we know almost nothing about the organizational forms of metal production and processing in the ore districts and their surroundings. Because of the archaeological knowledge of smelting and cupellation in the settlement of Badenhausen (district of Osterode) during the 9th and 10th centuries AD, located in the immediate vicinity of the mint of Gittelde and supplied with raw

materials from contemporaneous smelteries in the mountains, Lothar Klappauf considered the Harz and its surrounding area be a well-organized and work-sharing mining region in the Early Middle Ages (Bartels and Klappauf, 2012, p.147). Whether the so-called "Benno me fecit" brooches found in Hedeby (**fig. 11**) and at various other places in Germany and Denmark (Emmerig, 2000) were used in their production area as jetons or tokens, thus assuming an organization of the mining system under the aegis of the later bishop of Osnabrück named Benno (1068-1088) – as was recently proposed (Bartels et al., 2007, pp.80-81; Klappauf et al., 2008, pp.68-69; Bartels and Klappauf, 2012, p.200) – is probably not further provable and so should not be overestimated.

In the course of the 10th century, the Harz developed into a central economic area and the most important dominion of the Ottonian royal house (Brachmann, 1992), with only about 300 km air-line distance to the south of Hedeby and the southern border of Denmark. This distance approximately corresponds to the distance from Hedeby/Schleswig to Ålborg at the Limfjord. In the 12th century, up to nine days were set for covering this distance, following the old route of the *Haervejen* or *Oxen Road* (Willroth, 1986, pp.9-10). By overland route, for example on the *Leiðarvísir*, historically attested in the High Middle Ages, which led through Gandersheim and Hildesheim in the vicinity of the Harz (Waßenhoven, 2006, pp.74-91, fig.3.1), but also by water along the river Elbe from Magdeburg[3], Denmark was comfortably accessible within a period of five to seven days (Carver, 1990, with fig. 15.3).

Not only to the new Ottonian centre of power and economy in Saxony, important and vivid trade relations were maintained, but to the Lower Lotharingian area and its metropolis Cologne comparable and even older relations existed, too, proven by the supply of lava quern stones (cf. above p. 7), wheel-thrown ceramics from the potteries in the Rhineland (Brorsson, 2010, pp.32-38; Pilø, 2011, pp.286-292; Keller, 2012), glass drinking vessels (Gaut, 2011, pp.179, 182-194, 248-253; Dodt,2016) or different kinds of metal (Merkel, 2016a, pp.56-58; 2016b). Recently conducted analysis of glass fragments from Hedeby pointed out that in the second half of the 9th century until the beginning of the 10th century, a special mixture of wood-ash glass and soda-lime glass was produced in the *emporium* which had been attested so far only in the Carolingian monasteries of Fulda and Lorsch (Kronz et al., 2016) in *Franconia*, which points to closer relations in handicraft production than the mere trading contacts hitherto expected and known.

Not only these direct links to the access of raw materials should be considered with regard to the Viking period of South Scandinavia. An indirect supply of mineral resources from these continental deposits could be possible via late Anglo-Saxon England, too, (**fig. 10**) which is supposed to have been an active consumer of mineral resources, especially silver, during the 8th and 9th centuries from the Frankish and in the 10th and 11th centuries from the Ottonian and Salian realms (Claughton, 2011). The English economy was more and more commercialized and the society underwent profound social changes (Fleming, 2001). It is supposed that most of the silver used in Anglo-Saxon England originated from continental sources in order to pay for English produce, especially wool and textiles or grain (Sawyer, 2013, pp.98-100; cf. also Fleming, 2001), only from the mid-12th century onward, the greatest part probably came from deposits in England and Wales (Claughton, 2011, pp.59-60). Clear documentary evidence for silver mining is not available before 1130, therefore it is assumed that the supply of silver to England was primarily linked with long distance and inter-regional trade in exchange with wool and textiles (Claughton, 2011, p.62). For the 11th century local sources of silver containing lead ores may have been used in the Mendips, Somerset, in Derbyshire, in the north Pennines and the Caldbeck Fells in Cumbria (Claughton, 2011, p.62; cf. Sawyer, 2013, pp.26-27; Merkel, 2016a, pp.55-56).

Large parts of the silver circulating and being used in Anglo-Saxon England was not only coming through direct trade links to Scandinavia but also for an important part by robbery and tribute payments, especially from 991 until 1041 AD, when the English had to make large payments of silver in form of tribute, *Danegeld* and later *Heregeld* to the Danes (Allen, 2006; Sawyer, 2013, pp.108-110). In 991, 10.000 pounds of silver, about 2.4 million pennies, had to be given to the Danes, in 1018, the large amount of 72.000 pounds, corresponding to the incredible sum of 17.28 million pennies, were paid (Allen, 2006, pp.497-498, table 7).

Results

The southern borderland of Denmark, the "Schleswig march" of the 10th and 11th centuries, with its main centre, the harbour town of Hedeby/*Sliaswich*, played a particularly important role in this area, thanks to its favourable access to Scandinavia and the Baltic Sea. The trading centre Ribe, 948 raised to a bishopric under Ottonian control, was located in the south of Denmark and had been participating in the North Sea trade through the Wadden Sea since the early 8th century (Feveile and Søvsø, 2010).These connections of the southern parts of Denmark to the East Frankish kingdom of the Ottonian and Salian kings and emperors find their notable expression not only in conflicts between their rulers but also in a correspondingly developed continental find horizon, consisting of metal finds such as dress accessories (Baastrup, 2005; 2014), coins (von Heijne, 2004, pp.109-113; Moesgaard, 2007, pp.122-124; Hilberg, 2014) or quern stones from the Mayen area (cf. above p. 7). From the later 11th century AD onward, easily worked tuffstone is imported from the Rhineland (from the southeastern Eifel area to Andernach) with several transshipping to the southern border area of Denmark where it was used for

churches and graves on Christian graveyards (Lüdtke, 1997, pp.34-37, 46-48; Brandt, 2012, pp.16-18, 70-72, 87). But more research is necessary to distinguish these relations and developments from the earlier vivid and close interactions with the Carolingian world in the 8th and 9th centuries.

Only scientific analysis can prove when and how these contacts developed and which role the mineral resources from the German *Mittelgebirge* or from Central Asian ore deposits played. Basic research and analyses on this topic have been developed during several years by lead isotope and trace element analysis on silver metal finds at the Bochum Graduate School "Raw Materials, Innovation, Technology of Ancient Cultures (RITaK)" (Merkel, Hauptmann and Hilberg, 2012; Merkel, 2013; Merkel et al., 2013; Merkel et al., 2014; Merkel, 2016a), in particular, mass spectrometry with laser ablation is used (based on the method Lehmann, 2011). For the first time scientifically proven, it is now possible to show how silver from different Central European ore deposits like the German *Mittelgebirge* has been circulating in Hedeby since the middle of the 10th century. These metal analyses are supplemented by the investigation of objects made of non-ferrous metal and brass alloys, from the 10th and 11th century, carried out within the framework of the research project funded by the Volkswagen Foundation in Hannover[4]. Basically, the preference for certain alloys – lead-containing brass – is proven, which had been produced by using zinc or calamine deposits around Aachen and Iserlohn. Through these archaeometric investigations, the archaeological-numismatical connections already attested between Hedeby and the Harz region and the Rhineland dominated by its metropolis Cologne, can be verified in the Ottonian-Salian period and placed on a considerably expanded material basis. Further scientific studies of this kind will fundamentally further develop the understanding of the use of mineral raw materials and their importance for South Scandinavia with its lack of raw material resources during the Viking Age and the subsequent Middle Ages.

Notes

1 The preparation of this article had been made possible through the research project "Zwischen Wikingern und Hanse. Kontinuität und Wandel des zentralen Umschlagplatzes Haithabu/Schleswig im 11. Jahrhundert", which was funded between 2012 and 2014 by the Volkswagen foundation in Hannover.

2 These are deniers of the so-called Schmalbalkentyp Typus I (Kilger KN 1 resp. Mehl Gruppe A) with a fence-like arrangement of crosses below the church on the back, cf. Mehl 2011, p.30. However, this type also occurs in the treasure of Leetze, Kr. Salzwedel, deposited after 982 AD; cf. Puhle, 2001, pp.335-337, cat.no. V.7 (B. Kluge) with fig.

4 These archaeometric investigations were also carried out at the German Mining Museum in Bochum by Stephen W. Merkel under the supervision of Andreas Hauptmann. I would like to thank both of them for their constructive cooperation and the stimulating discussions. The results will be published in a monograph on late Viking period Hedeby which is in preparation.

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