Project Gallery

Interlinking research: the *Big Exchange* project

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The *Big Exchange* project investigates large-scale exchange systems in Eurasia and Africa (8000–1 BC). We concentrate on raw materials of known origin ('sourced finds'). Network analysis of tools and artificial intelligence methods are used to analyse the combined data sets. We invite broad collaboration on bimodal exchange networks.

Aim of the project

Large-scale raw material exchange systems connect production from source to demand in a distant location, regardless of whether this demand is for the supply of abundant goods, such as small tools, or for a few highly valued diplomatic gifts. What happens between the source and the find spots is a matter of interpretation: a wide variety of motivations, forms of exchange and differently interlocked regional economic networks of limited reach are to be assumed, whose interactions result in highly complex systems (Brughmans 2022).
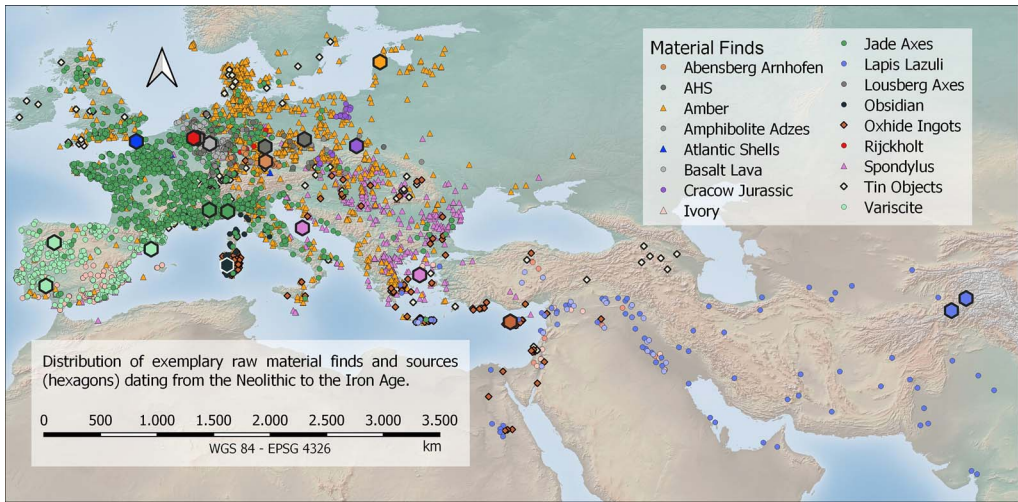
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Figure 1. *Sites with selected sourced raw materials (>6000 sites) (map by S. Strohm).*

This project explicitly does not reconstruct complete economic or social networks, but rather seeks and measures key parameters, some of which are also known from the field of social network analysis. Those parameters can then be followed through time and space where they indicate changes and represent economic and social trajectories. Here, we introduce the project via a case study and invite broad collaboration on providing a platform for joint work.

In the project, however, the analysis is based simply on sources and the find spots related to them. For strictly analytical purposes, this connection is assumed. The aim is not to map entire exchange systems nor to follow individual production stages or exchange steps—the thin, often heterogeneous data structure makes this impossible in most cases.

Within network science, those relations that connect source to find spot by a directed relationship are conceptualised as bimodal (Wasserman & Faust 2019). In combining these spatial and chronological distributions of different raw materials' interdependencies, interchangeability and economic side effects become visible. Within the project, some of the most important examples of outstanding, large-scale exchange networks in prehistory are assembled (Figures 1 & 2). Data collection is currently being expanded to Africa and Asia. The project focuses on how the simultaneous distributions of different commodities were related to the actors' more or less limited access to resources; in doing so, fundamental questions of social inequality and power relations are addressed.

A first example: Central Europe's first farmers' exchange

We present new results for one of the best researched Central European areas and most studied find groups: the north-western Linearbandkeramik Culture (LBK; for extensive references, see Armkreutz 2010; Otten *et al.* 2016). Combining the raw materials in circulation between 5500 BC and 4900 BC provides important insights into the potential of our approach. The first Central European farmers of LBK settled predominantly on isolated patches of loess-derived soils. The spatial expansion of the Neolithic lifeway followed
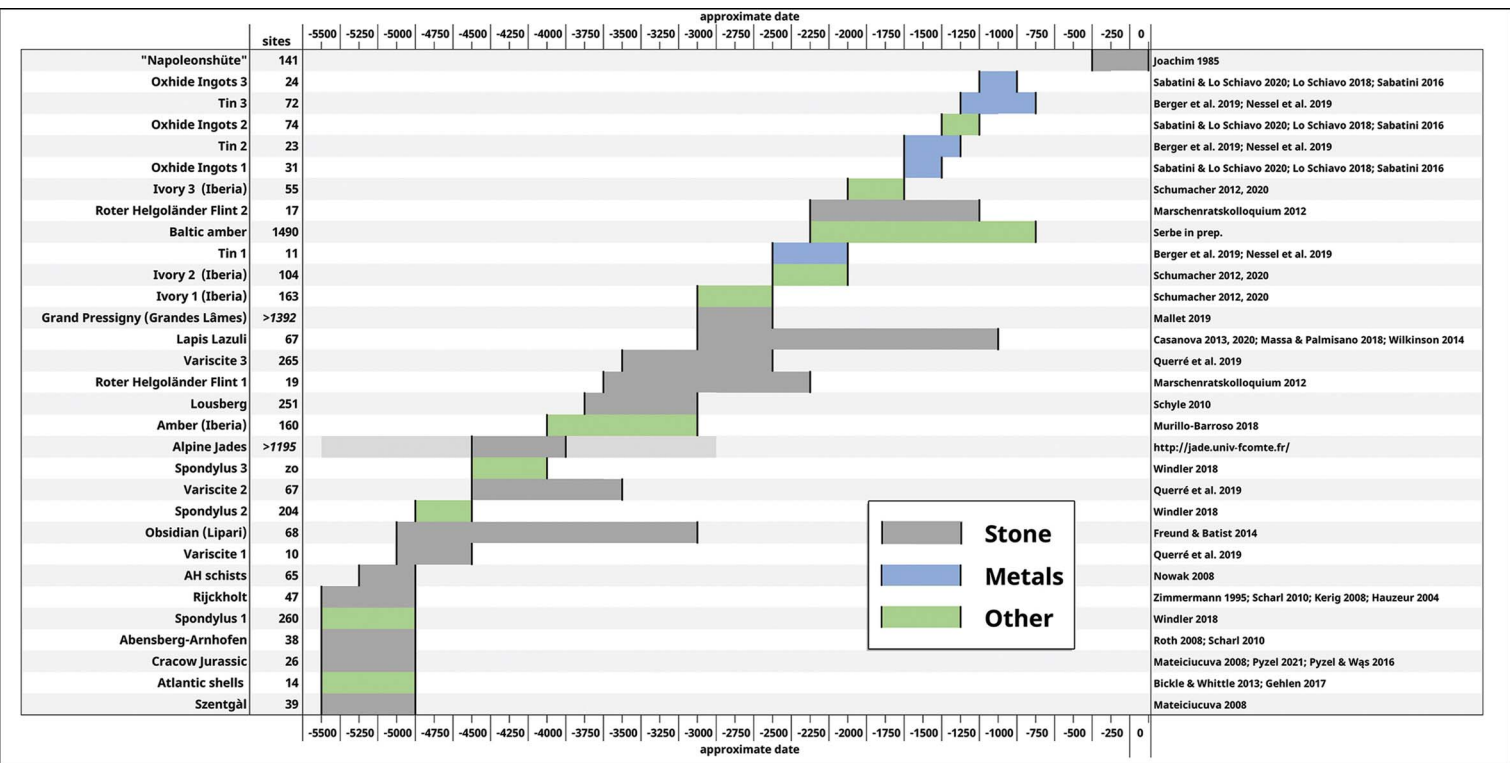
Figure 2. Raw material distributions in the continuously updated "Big Exchange" database in chronological order (for corresponding references, see the online supplementary material (OSM)) (figure by J. Hilpert).

a. Spatial distribution of six specific LBK raw material finds.

b. Find spots of LBK Spondylus and the according Kernel Density Estimation (KDE).

c. KDE and an overlaying 50 x 50 km grid.

d. Grid points and the transferred KDE values for Spondylus finds.

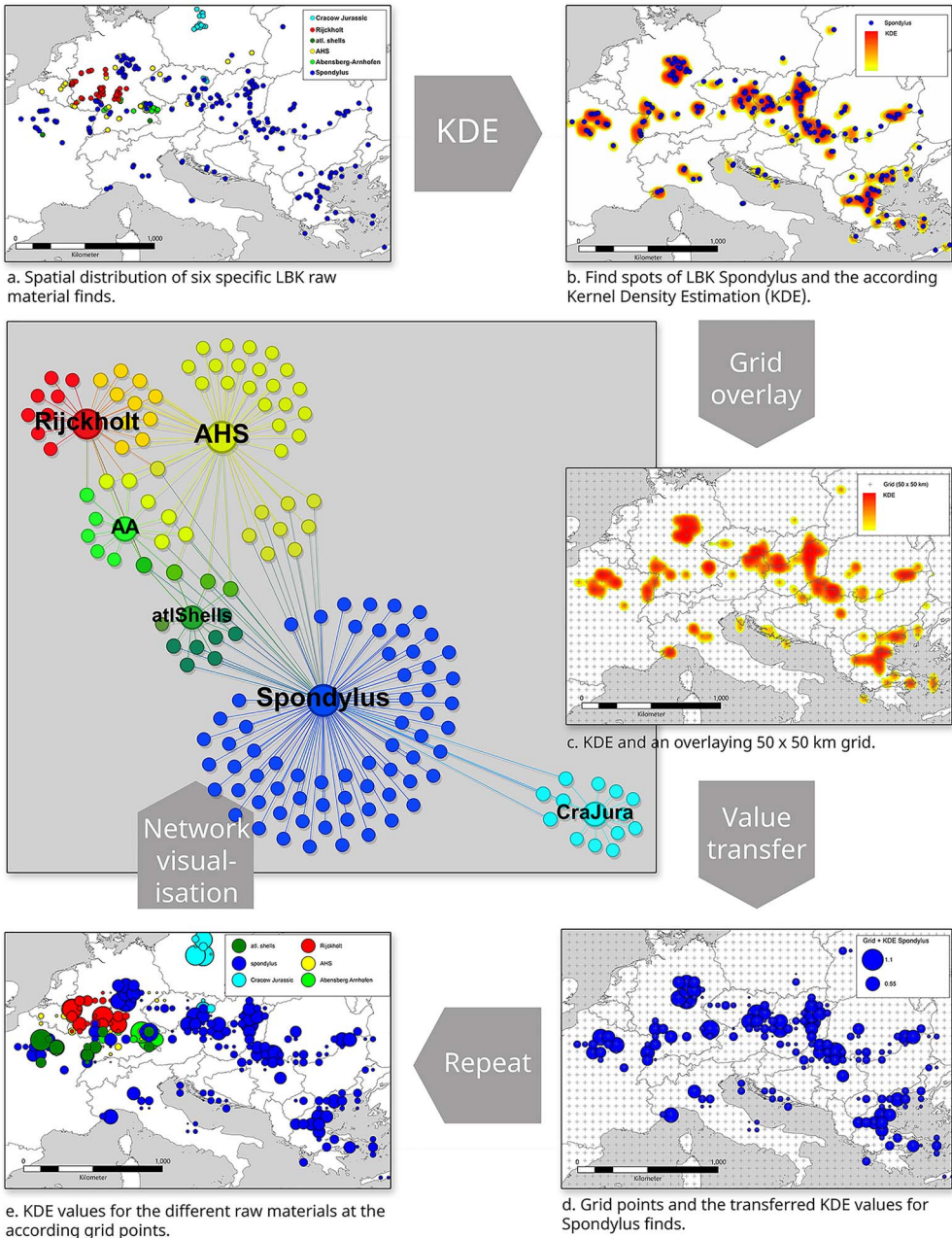e. KDE values for the different raw materials at the according grid points.

Figure 3. Schematic overview of workflow (figure by J. Hilpert).

a leapfrog model from patch to patch (e.g. Fernandez-Dominguez & Reynolds 2017), often keeping the flow of raw material constant in the direction of the line of assumed descent—the social lineage (Kerig 2008).
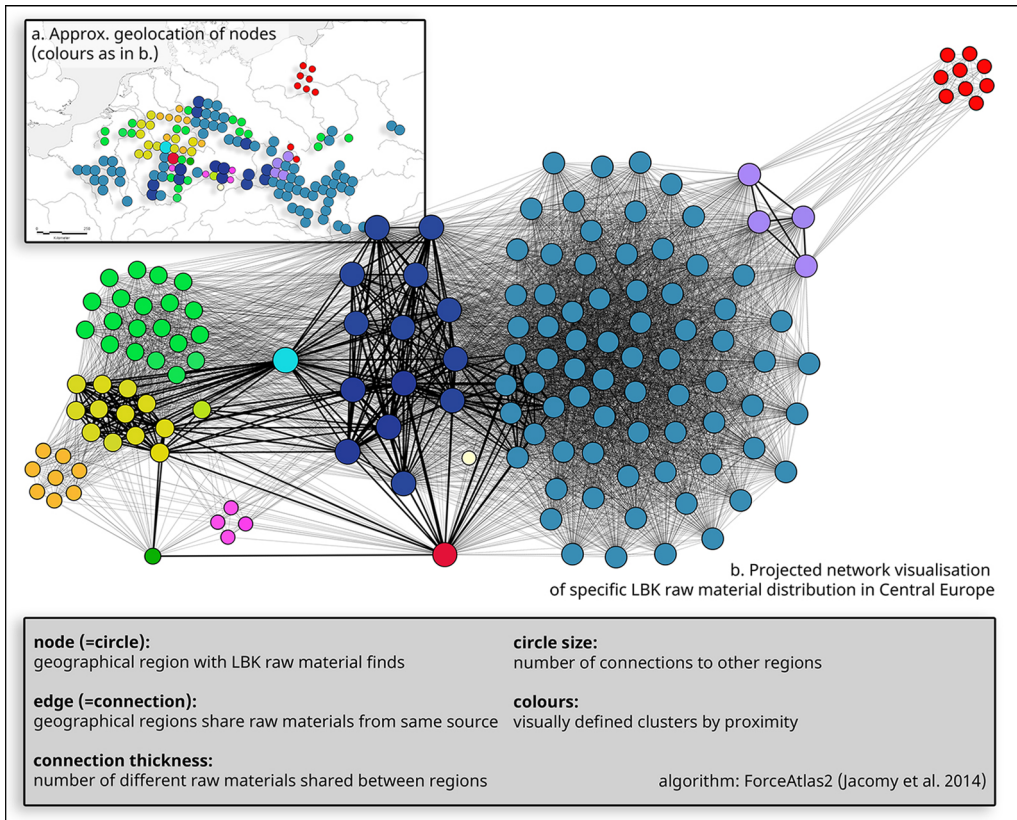
Figure 4. Case study: Early Neolithic Central Europe (LBK) (figure by J. Hilpert).

In contrast to research into the Metal Ages, studies of the Stone Age have often centred on flint, in most cases not a luxury item. However, flint, in the broadest sense, along with ground stone raw materials, might have played an important role in signifying or even channelling social relationships (for locations and references, see: https://www.ucl.ac.uk/neomine; Figure 1).

The combination of datasets with different raw materials enables the reconstruction of more complex relations, such as economic choices, where certain raw materials are substituted for others (cf. Knappet 2021). Here, the data science part of the project comes in: the data integration process focuses on potential for automation as well as domain and research data management requirements. The integrated relational data are mapped to a Heterogeneous Information Network (HIN) to enable the exploration of relationship patterns with a variety of graphical and data mining techniques (Shi 2017).

Regional LBK groups can be distinguished by ceramics. The north-western LBK (NW group) is characterised by a good supply of flint of Rijckholt origin (Zimmermann 1995), but the absence of materials that are otherwise widespread in Central Europe is now becoming apparent; the lack of *Spondylus*, for example (method: Figure 3), in the north-west was suspected to result from local poor preservation conditions (cf. Eckmeier *et al.* 2014). The region
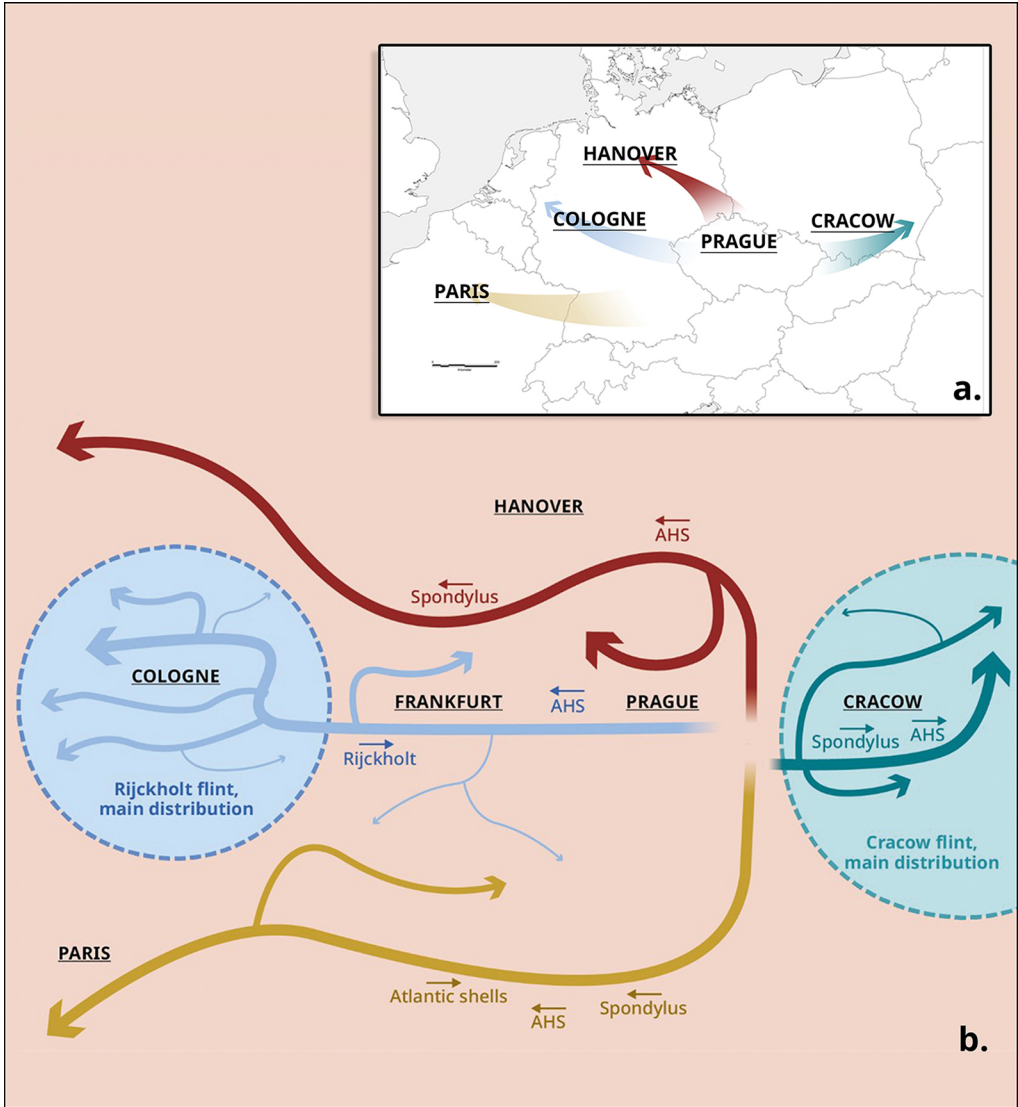
Figure 5. a) Broad trajectory of LBK expansion; b) interpretative model of the LBK expansion into the north-western province. Arrows represent main directions of movement; small arrows indicate the later exchange of raw materials (AHS, Atlantic shells, Spondylus, *flints) along lineages of descent (figure by T. Pape).*

from which these shells are missing, however, is considerably larger than the area with poor preservation. Recent excavations of cemeteries in the NW group (Peters 2018) additionally suggest that this absence reflects the past *Spondylus* distribution (Windler 2018). Thus, analysis of multiple raw material distribution within a network perspective reveals that the NW group is framed by exchange sub-systems in which the NW group played little or no part (Figure 4). These sub-systems reflect the expansion of the LBK, assuming that exchange mostly followed established contacts in accordance with the social lineage of the initial spread.

We reconstruct a pattern called 'directed percolation', similar to a braided stream (Hinrichsen 2000), whereby the exchange probability between individuals decreases with spatial distance and increasing bifurcations. Such an expansion allows easy reconnection in the direction of the origin, following the least social distance but hinders exchange with neighbouring groups (Figure 5). The NW group—for a long time a model region of LBK research (Hilpert 2017)—is such a case within the LBK: a 'clique', in network terms.

Perspectives: an invitation

Researchers working on sourced finds are invited to join the 'Big Exchange' initiative: an international network of researchers from archaeology, material and data sciences, which guarantees professional and sustainable data management, assuring the authors full control over their data at all times.

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Supplementary material

To view supplementary material for this article, please visit https://doi.org/10.15184/aqy.2023.78.

References

AMKREUTZ, L.W.S.W. 2010. "All quiet on the northwestern front?" An overview and preliminary analysis of the past decade of LBK-research in the Netherlands, in D. Gronenborn & J. Petrasch (ed.) *Die Neolithisierung Mitteleuropas: the spread of the Neolithic to Central Europe, international symposium*: 535–50. Mainz: Römisch-Germanisches Zentralmuseum.

BRUGHMANS, T. 2022. Why simulate Roman economies?, in T. Brughmans & A. Wilson (ed.) *Simulating Roman economies: theories, methods, and computational models*: 3–36. Oxford: Oxford University Press. https://doi.org/10.1093/oso/9780192857828.003.0001

ECKMEIER, E., T. ALTEMEIER & R. GERLACH. 2014. Auswirkungen geochemischer Eigenschaften von Böden auf die Knochenerhaltung in Arnoldsweiler, in E. Cziesla & Th. Ibeling (ed.) *Autobahn 4, Fundplatz der Extraklasse: Archäologie unter der neuen Bundesautobahn bei Arnoldsweiler*: 151–54. Langenweissbach: Beier & Beran.

FERNANDEZ-DOMINGUEZ, E. & L. REYNOLDS. 2017. The Mesolithic–Neolithic transition in Europe: a perspective from ancient human DNA, in G. Puchol (ed.) *Times of Neolithic transition along the Western Mediterranean*: 311–38. Cham: Springer. https://doi.org/10.1007/978-3-319-52939-4_12

HILPERT, J. 2017. *Viehzucht und Landnutzung: das Neolithikum im Vergleich zu den preußischen Rheinlanden (1800 AD)*. Cologne: University of Cologne.

HINRICHSEN, H. 2000. Nonequilibrium critical phenomena and phase transitions into absorbing states. *Advances in Physics* 49: 815–958. https://doi.org/10.1080/00018730050198152

JACOMY, M., T. VENTURINI, S. HEYMANN & M. BASTIAN. 2014. ForceAtlas2: a continuous graph layout algorithm for handy network visualization designed for the Gephi software. *PLoS ONE* 9: e98679. https://doi.org/10.1371/journal.pone.0098679

KERIG, T. 2008. *Hanau-Mittelbuchen. Siedlung und Erdwerk der bandkeramischen Kultur: Materialvorlage – Chronologie – Versuch einer handlungstheoretischen Interpretation.* (Universitätsforschungen zur prähistorischen Archäologie 156). Bonn: Habelt.

KNAPPET, C. 2021. Networks in archaeology, in R. Light & J. Moody (ed.) *The Oxford handbook of social networks*: 443–66. Oxford: Oxford University Press. https://doi.org/10.1093/oxfordhb/9780190251765.013.26

OTTEN, T., J. KUNOW, M.M. RIND & M. TRIER (ed.). 2016. *Revolution Jungsteinzeit: Archäologische Landesausstellung Nordrhein-Westfalen*, in Schriften zur Bodendenkmalpflege 11: 103–109. Darmstadt: Theiss.

PETERS, R. 2018. Das Gräberfeld, die Grabenanlage und die Steinartefakte des linearbandkeramischen Fundplatzes Arnoldsweiler-Ellebach. Unpublished PhD dissertation, University of Cologne UoC.

SHI, C. *et al.* 2017. A survey of heterogeneous information network analysis. *IEEE Transactions on Knowledge and Data Engineering* 29: 17–37. https://doi.org/10.1109/TKDE.2016.2598561

WASSERMAN, S. & K. FAUST. 2019. *Social network analysis: methods and application*. Cambridge: Cambridge University Press. https://doi.org/10.1109/TKDE.2016.2598561

WINDLER, A. 2018. *Der Austausch von* Spondylus gaederopus *in Europa zwischen 5.500 und 5.000 v.Chr.: eine ökonomische Analyse*. Rahden: Leidorf. https://doi.org/10.46586/DBM.180

ZIMMERMANN, A. 1995. *Austauschsysteme von Silexartefakten in der Bandkeramik Mitteleuropas: von Andreas Zimmermann* (Universitätsforschungen Zur Prähistorischen Archäologie Bd. 26). Bonn: Habelt.