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From flint provenance to mobility studies: New raw material determinations from Late Neolithic wetland sites at Lake Biel and Lake Constance

Jehanne Affolter[a,c], Lea Emmenegger[a], Albert Hafner[a,b], Caroline Heitz[a,b], Martin Hinz[a,b], Regine Stapfer[a,e], Helena Wehren[a,d,*]

[a] Institute of Archaeological Sciences, University of Bern, Switzerland
[b] Oeschger Centre for Climate Change Research (OCCR), University of Bern, Switzerland
[c] Ar-Geo-Lab, Neuchâtel, Switzerland
[d] ArchGeo, Biel/Bienne, Switzerland
[e] Archaeological Service of Canton Bern, Switzerland

A R T I C L E I N F O

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A B S T R A C T

The aim of this paper is twofold: first, we strive to find routes of flint supply that may have been used systematically on the northern Alpine Foreland during the fourth millennium BCE, based on the origin of the siliceous raw materials; second, these routes will be interpreted as a part of cultural entanglements. Using the sedimentary microfacies method for sourcing the raw materials of artefacts recovered in prehistoric sites makes it possible to study the provenances of large series' pieces in a non-destructive manner. Besides insights into the economy of flint raw material supply practices of single precisely-dated sites, this cross-regional comparison allows us to gain a deeper understanding of the economic relations and thus the mobility pattern of the respective settlement communities in different time periods. The method used for raw material sourcing is described in Affolter et al., 2021 (this issue) in detail. In this paper, we present as a first research step new raw material determinations from four Late Neolithic wetland sites on the northern Alpine Foreland that encompass several dendrochronologically-dated settlements: Twann Bahnhof (3838–3532 BCE) and Sutz-Lattrigen Hauptstation innen/Hafen (3827–3566 BCE) at Lake Biel and Hornstaad Hörnle IA (3919–3902 BCE) as well as Sipplingen Osthafen A and B (3919–3904 and 3857–3817 BCE) at Lake Constance. Thanks to the precise dating of the settlements and the finds deriving from the respective stratigraphic layers, not only regional differences but also transformations over time in raw material supplies can be approached with an extraordinarily high temporal resolution. Hence, this article demonstrates the interpretative potential of flint provenance determination to study the spatial mobility of prehistoric settlement communities. In addition to the presentation of previously unpublished materials, the aim here is to show an initial approach to the study of spatial mobility and entanglements using flint data, which is to be expanded in the future.

1. Introduction

This study is part of the project "Mobilities, Entanglements and Transformations in Neolithic Societies of the Swiss Plateau (3900–3500 BC)", in short: MET-project, supported by the Swiss National Science Foundation (Project No 1000011_156205). Within the MET-project, different patterns of spatial mobility and the cultural entanglements of Neolithic settlement communities are studied (Hafner et al., 2016). Due to the lack of burials in the period under review, it is not possible to approach spatial mobility directly by the study of human remains. However, since well-preserved and precisely-dated finds from these settlement communities are abundant at wetland sites, mobility patterns and entanglements can be examined on the basis of material culture, e.g. pottery and flint tools. The studies of the pottery deriving from the settlements presented here have shown that the majority of the ceramics were produced on site using locally available raw material. Nevertheless, we regularly find small numbers of vessels that were brought to the settlements from another place or that show stylistic or technical

* Corresponding author. Institute of Archaeological Sciences, University of Bern, Switzerland.
E-mail address: wehren@gmx.ch (H. Wehren).

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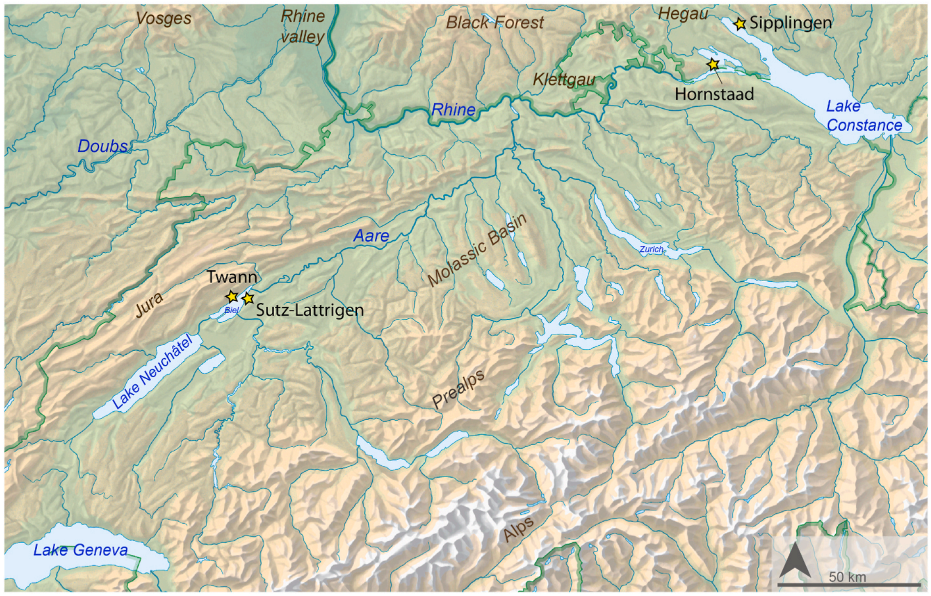

Fig. 1. Localisation of the four key sites at Lake Biel (north-western Switzerland) and Lake Constance (southern Germany). (maps basis © 2015 Bundesamt für Landestopografie).

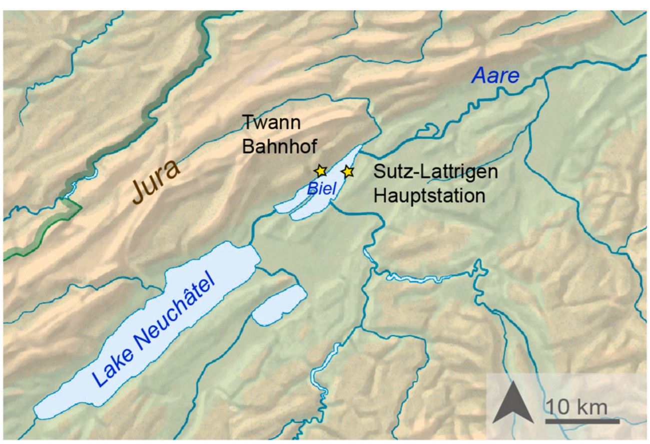

Fig. 2. The sites at Lake Biel Twann Bahnhof and Sutz-Lattrigen Hauptstation (map basis ©2015 Bundesamt für Landestopografie).

features that are characteristic for pottery styles known from other regions. These vessels are indirect proof of human mobility (Heitz/Stapfer, 2017; Heitz, 2018; Stapfer, 2019b). On the other hand, previous studies of flint artefacts show that numerous raw materials from nearby and far away were used in the settlements (Hafner and Suter, 2000; Honegger, 2001; Thevenot, 2005). For this reason, pottery and flint are promising materials for the study of the spatial mobility of Neolithic settlement communities. The discernible material entanglements and, thus, the patterns of relationships based on these two find categories allow us to compare different contexts of mobility with each other.

In this paper, we present raw material determinations of flint artefacts deriving from precisely-dated settlements at four sites located at Lake Biel in western Switzerland and Lake Constance in southern Germany (Fig. 1). The finds from the two regions derive from settlements that were used during the same years as well as from settlements that followed one another in time. This allows us to examine not only regional differences but also transformations (Appendix tab. A).

Lake Biel is located in north-western Switzerland on the southern slopes of the Jura Mountains and reaches into the Swiss Molasse Basin. Its outflow links it to the rivers Aare and Rhine and thus to northern Europe. Studying the finds of simultaneously-existing settlements from the two neighbouring sites of Twann and Sutz-Lattrigen makes it possible to detect variations in the supply of raw materials in the same spatial unit, while avoiding the bias of geographical differences. The site of Twann Bahnhof is located on the narrow northern shore of Lake Biel, directly on the steep slopes of the Jura Mountains, while Sutz-Lattrigen Hauptstation is situated on the opposite southern lake shore, which is flat and has a hinterland of molassic hills with attenuated relief (Fig. 2). The two archaeological sites are within sight of each other and are in easy reach of each other by water. Several settlements were excavated at both sites, all of which have been precisely dated by dendrochronology and which were inhabited almost simultaneously (see Table 1 and Appendix tab. A). We can therefore assume that the inhabitants of these

Table 1
The total number of artefacts corresponds to the finds recovered from the excavated area. For additional detailed information and literature see Appendix tab. A.

Dating BCE	Settlement and layer		Number of silicites		
			total	macroscopically determined	microscopically determined
3596–3532	TW OS	Twann OS	1285	1285	614
3702–3607	TW MS	Twann MS	767	767	294
3838–3768	TW US	Twann US	470	470	98
3607/3582 - 3566	SH I	Sutz-Lattrigen Hauptstation innen	480	480	404
3638–3631	SH OS	Sutz-Lattrigen Haupatstation Hafen OS	222	222	222
3827–3817	SH US	Sutz-Lattrigen Hauptstaton Hafen US	72	72	72
3857-3817	Si B	Sipplingen Schicht B (ex 3)	?	?	85
3919-3904	Si A	Sipplingen Schicht A (ex 1, 2)	?	?	88
3919–3902	HH AI	Hornstaad-Hörnle IA	>120538	2000	543

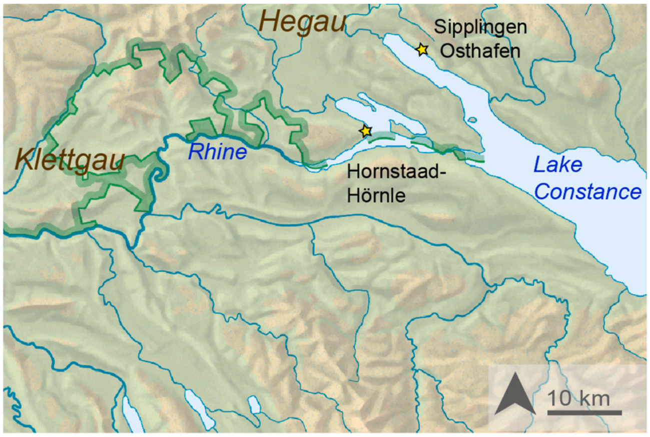

Fig. 3. The sites at Lake Constance Sipplingen Osthafen and Hornstaad Hörnle (map ©2015 Bundesamt für Landestopografie).

sites were somehow related with each other, for which similar supply of raw materials would be indicative.

Lake Constance forms a natural barrier that cuts the molassic area into two parts: the Molasse Basin to the south and the Swabian Bavarian Foreland of the Alps to the north. The settlements of the two discussed sites are located on the lake shore and have the attenuated reliefs of the Hegau and the Klettgau to the rear. Hornstaad Hörnle is situated at the peak of the gently elevated Höri Peninsula reaching into the Untersee (the westernmost part of Lake Constance) while Sipplingen is located on the main body of Lake Constance on the shore with a steeply rising hinterland (Fig. 3). The distance between both sites is 10 km as the crow flies and about three times as far over water or on foot. The precise dendrochronological dating showed that settlements existed on both sites during the same years, which allows us to examine possible relations of the coexisting settlement communities based on similarities in the raw materials (see Table 1 and Appendix tab. A).

Based on these archaeological preconditions, the aim of this paper is twofold: First, the results of the geological provenance determination of flint raw materials used at the settlement sites of Twann Bahnhof and Sutz-Lattrigen Hauptstation at Lake Biel and Hornstaad Hörnle and Sipplingen Osthafen at Lake Constance will be published here for the first time. The few already-published determinations of these four sites are included. Second, the interpretative potential of the results regarding the Neolithic actors' economic relations and related mobilities will be discussed by addressing the following questions: Are there regional and chronological differences in the raw material sources that were used? What can be inferred from the raw materials used for flint tool production regarding the economic entanglements and mobility patterns of the respective settlement communities?

The method of raw material determination used here is outlined in detail in a second publication in the same special issue (Affolter et al., 2021, this issue). The present article concerns the stratigraphical and chronological contexts of the chosen sites, the data base and the specific workflow of this study.

2. Stratigraphical and chronological contexts of the investigated settlements

All four sites studied within the MET-Project consist of dendrochronologically precisely-dated settlements or settlement phases containing numerous well-preserved finds (Appendix tab. A). The key sites are briefly presented in the following:

The Hornstaad Hörnle site is one of the best preserved, oldest and most extensively researched pile-dwelling settlements on Lake Constance. Known since 1857, it was excavated in modern times by the Landesdamt für Denkmalpflege Baden-Württemberg between 1973 and 1980 and again, intensively, between 1983 and 1993. In the shallow water area around the tip of the "Höri" Peninsula, several settlements were built over the time period between 3919 and 2690 BCE, which have been named Hornstaad Hörnle I to VI (Dieckmann et al., 2006; Matuschik, 2011). For this study, only settlement IA (dating to between 3919 and 3902 BCE) is taken into consideration (Dieckmann et al., 2006, 25; Matuschik and Müller, 2011, 16ff; Billamboz, 2006, 312, 318). The series of cultural layers at settlement IA encompasses three archaeological horizons (AH 1–3). AH 1 and AH 3 represent two settlement phases, which are separated by AH 2 - the remains of a settlement fire. The houses were aligned in narrow rows with the long side to the water, reconstructed as pile-shoe-and-post construction with an elevated floor 2–3 m in height. Due to the uncertain attribution of some of the artefacts to AH1 or AH3 and the short duration of the settlement, in this report all artefacts are treated as belonging to one phase (Billamboz, 2006; Dieckmann et al., 2016, 80).

Sipplingen Osthafen, the second site at Lake Constance, is dated to between 3919 and 933 BCE. The settlement area of around 40′000 m^2 lies in the shallow water zone of Lake Überlingen, the north-western part of Lake Constance. It is one of the largest and most frequently settled areas on Lake Constance. A succession of 17 settlements resulted in a stratigraphy that is up to 2 m high, and in which up to eight layers overlap. The Sipplingen lakeshore settlements were excavated between 1978 and 2012 by the Landesamt für Denkmalpflege Baden-Württemberg (Matuschik and Müller, 2016). The oldest settlement, Si A, dates from 3919 to 3904 BCE and the second oldest, Si B, from 3857 to 3817 BCE (Billamboz et al., 2010, 258–259; Matuschik and Müller, 2011, 23; Dieckmann et al., 2016, Fig. 9). Within the MET-project only the settlements Si A and Si B were studied; they contain pottery made in the typical local pottery production practice which was labelled by former research as Hornstaad and Pfyn pottery, respectively (Heitz, 2018). The oldest settlement of Si A was found in two different areas from the same age, and is therefore divided into SiAa and SiAb. Based on the records in the area of SiAb, it is assumed that the eight houses were constructed on a pile-shoe-and-post construction, standing in two rows of buildings separated from each other. In Si B, 16 house locations could be identified, with four more to the back and another along the lakeshore (Heitz, 2018; Billamboz et al., 2010, 259; Matuschik and Müller, 2016, 94).

The remains of the prehistoric settlement of Twann, on the northern shore of Lake Biel, have been known since 1874. Prior to the construction of a new motorway, part of the site was the focus of a large-scale excavation between 1974 and 1976 by the Archaeological Service of Canton Bern (Stöckli, 2018 with further literature). In the 2300 m^2 excavation area, the site revealed a huge stratigraphy of overlapping settlement structures, which are assigned to 21 settlements dating to between 3838 and 2976 BCE (Stöckli, 2018, 68–70). The finds were assigned to three to 13 ensembles (find assemblages), depending on how well the different layers were stratigraphically separable. The finds presented in this study belong to three-layer packages (ensembles), dated to between 3838 and 3768 BCE (TW US), 3709-3607 BCE (TW MS) and 3596-3532 BCE (TW OS). The excavation area is 160 m long and only 14,5 m wide, so only a section of the settlement area was investigated. Nevertheless, the clay lenses, which are interpreted as hearths and floors, indicate that during the first half of the fourth millennium BCE the houses were lined up close together with the narrow side facing the lake (Stöckli, 2018, 70–72).

The shoreline in the bay of Sutz-Lattrigen, which is around 2 km long, was frequently settled in the Neolithic period up to the Early Bronze age. Underwater archaeological investigations have revealed the remains of more than 20 settlements or settlement phases. The Archaeological Service of Canton Bern has carried out large-scale rescue excavations at various sites since 1988 and an area of 10′000 m^2 of the "Hauptstation" site was excavated between 1988 and 2003 (Hafner, 2005). In the first half of the fourth millennium BCE, the site of Sutz-Lattrigen Hauptstation innen/Hafen was inhabited four times. As one settlement (dated to just before 3600 BCE) was only peripherally

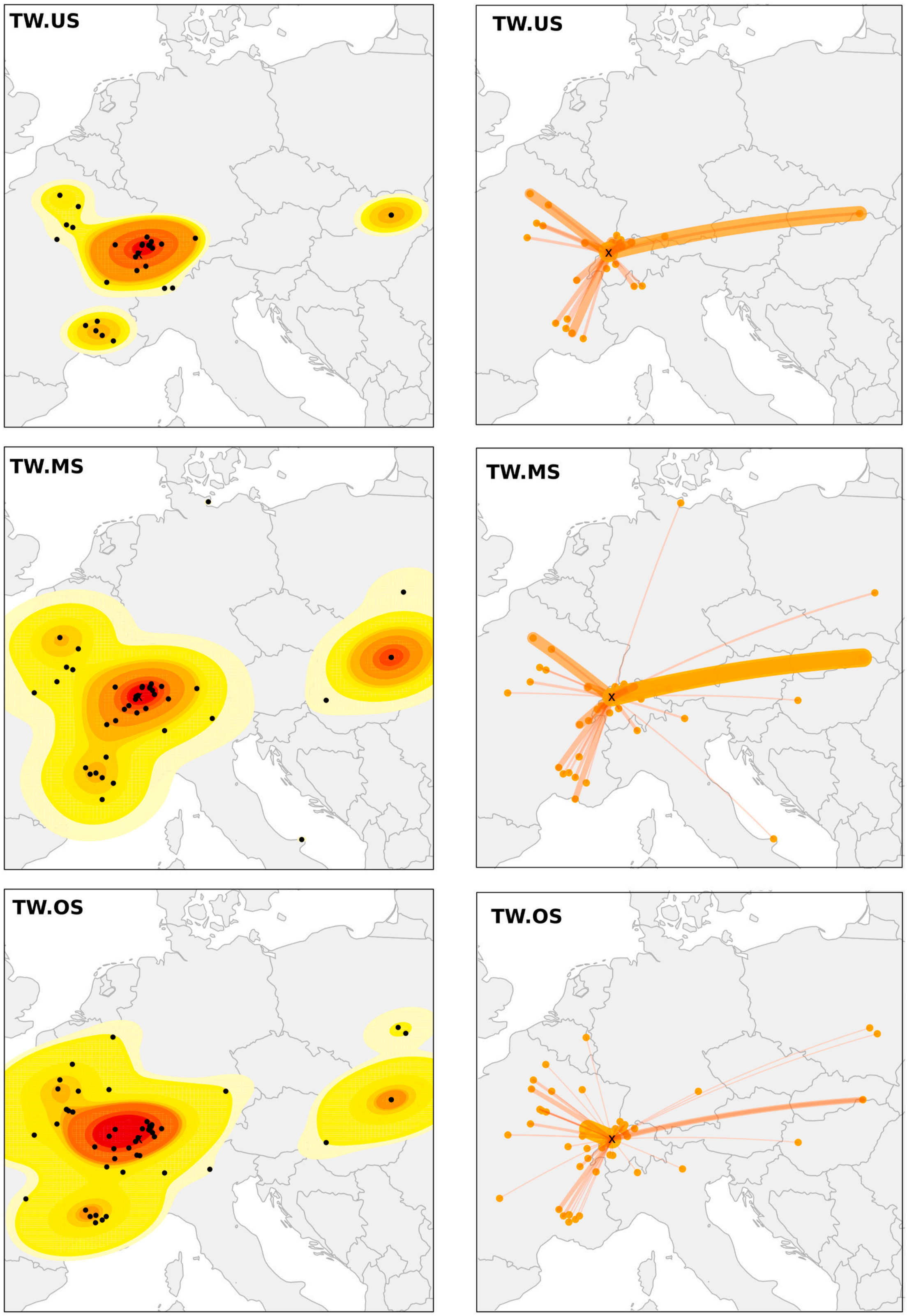

Fig. 4. Geographical origin of the examined raw materials in Twann Bahnhof. Transformation of the networks over time. Left: weighted KDE (heat map): the shading of the areas shows the importance of the region for raw material provision. Right: visualisation of the supply networks: the thicker the line, the more objects that were associated with the region and hence the stronger the connection to Twann Bahnhof, which is marked by x.

excavated, no finds were attributable to this settlement. The oldest finds belonging to the settlement date to between 3827 and 3817 BCE (SH US), the younger finds date to between 3638 and 3631 BCE (SH OS) and 3607/3582-3566 BCE (SH I). Within the MET-project, the three Late Neolithic complexes of this site were studied (Stapfer, 2019a; Stapfer, 2017; Emmenegger, 2016).

3. Data base and workflow of the study

The specific workflow of raw material identification was chosen according to the size and the patination of the series studied, resulting in different implementation for each key site (Table 1). The approach chosen for each site is presented below: In some cases (see below), it was necessary to first sort the pieces macroscopically. For this purpose, we divided the silicites into the following categories: "Malm" comprises all silicites, of Upper Jurassic age and appear in the Jura Mountains (shallow marine to deep neritic sedimentary facies); "Radiolarites" are remains from the oceanic floor (deep sea), dated from the Dogger to the Malm Periods, which outcrop primarily in the Alps; "*Oelquarzite*" are coarse grained materials from the Dogger to the Upper Cretaceous Periods with a Flysch-Facies that is encountered in the Prealps; "Other silicites" is a group that describes all other materials, i.e. all exotic and all specific materials. These four categories allow an initial evaluation of the amount of different categories of raw materials.

Twann Bahnhof: Due to the fact that the lithic material from Twann Bahnhof contains over 2500 pieces, a macroscopic sorting was applied and, because only few silicites show patina, a large part can be approximately assigned to an area of origin by macroscopical sorting. In addition, 1006 exotic/exogenous and atypical samples were examined in more detail using the sedimentological microfacies method for a precise sourcing to an outcrop (see Table 1).

Sutz-Lattrigen Hauptstation: This is a smaller series of 774 silicites in total. The whole lithic inventory (698 pieces except the strongly patinated samples) of the three settlements of Sutz-Lattrigen Hauptstation innen/Hafen was studied in detail using the microfacies method.

Hornstaad Hörnle IA: From the very abundant material, which contains over 120000 pieces, only a fraction of the lithic material was accessible. An initial macroscopic sorting of 2000 pieces made it possible to differentiate local/regional and non-regional/exogenous raw materials. Secondly, the macroscopically sorted samples of potentially exogenous raw material, as well as a part of the local/regional raw materials (not or only slightly patinated or burned samples), were studied in detail by the sedimentological microfacies method (in total 543 pieces) to specify the varieties of exogeneous and local/regional raw materials that were used.

Sipplingen Osthafen: Large parts of the silicites of this site are affected by strong patina. Consequently, only the typologically characterised artefacts were considered for scientific raw material determination, in total 173 pieces. For Sipplingen, the total number of silicites is not known, as further studies (Kaiser in preparation) are not jet accessible.

The raw material determination using the sedimentological microfacies method (Affolter et al., 2021, this issue) was applied to reconstruct the extent of the supply area for each site. In order to get an initial impression of the displacement of the raw material, the distances between the outcrops and the sites were categorised into four levels and classified according to the following classes (analogous to Hafner and Suter, 2000, 77–78): "L" Local <10 km, "R" Regional 10–60 km, "I Z1" Import Zone 1 60–150 km, "dI Z2" Import Zone 2 > 150 km. These distances are valid for travel on flat ground. Where necessary, we made a small modification to take into account the relief (this concerns). This is why the types 109, 114, 135, 142, 1217, 286, 421, 504 and 515 from distances between 40 and 60 km are classified as Import Zone 1 (Appendix Tab B-E). For example, the silicite from Pleigne (Type 142) is less than 60 km away from Lake Biel, but it lies on the other side of the Jura Mountains, so it is not possible to go there and back in one day.

In a second step, the raw materials were grouped by region of origin. This allows us to go beyond the occurrence of each raw material, with the aim to assess directions of economic relations, which are understood to have been part of the overall entanglement of cultures. By taking into account the chronology, the durability and changeability of these relationships can be highlighted.

The analysis and visualisation of the supply network of the sites was implemented from two perspectives. On the one hand, a weighted Kernel Density Estimation (weighted KDE) illustrates the importance of the different areas of origin of the raw material for the supply of the settlement in the form of a heatmap. Here, a more intensive shading means that more outcrops are present in spatial density in the region. The value of the individual source locations was weighted with the corresponding number of pieces found on site, in order to emphasise more frequently observed areas of origin (perspective source). In addition, we have chosen a network representation on the same data basis to put a stronger focus on the integration into supra-regional exchange networks (perspective target).

Finally, to gain an initial insight into the regional and temporal differences in the raw material supply patterns, the sites are compared using a semi-quantitative approach while further quantitative analyses will be the subject of future work by the MET-project team.

4. The raw material supplies of the four wetland sites

4.1. The raw material supply of Twann Bahnhof

The macroscopic sorting of the whole series was possible because of existing extensive prior knowledge of, and familiarity with, the main silicite varieties of Switzerland. One can easily recognize the four major categories: the Malm silicites, the radiolarites, "Ölquarzite", and the others, which do not belong in any of the other categories. This allows us to count the well-known varieties from the Jura Mountains (Malm), the radiolarites and the "Ölquarzite" and to separate the pieces that are too burnt from those with further potential for a stereomicroscopic determination. The percentage of fire-altered pieces is higher (9%) in the lowest level, while it oscillates at around 5% in the upper levels and among pieces outside the stratigraphy. Conversely, the amount of completely indeterminable pieces is less abundant in the lower level (1,7%) and increases slightly in the upper levels (3%). Pieces marked as "unstratified" cannot be specifically attributed to any of the three levels, but date to the period between 3838 and 3532. These pieces show an 8% a higher incidence of patina. In total, the series from Twann contains 72 different raw materials, originating from various regions (Appendix tab B, Fig. 4). Even though most Neolithic settlements on the northern Alpine Foreland show a number of different raw materials, Twann Bahnhof shows a rarely reached high level of variety. This is surprising, since the Olten outcrops were able to provide enough material for the inhabitants of Twann. The high variety of types is reduced if one considers each level of occupation separately. Thus, the lower level (US) contains 31 different materials and the middle (MS) and upper levels (OS) each contain 43 different materials. Twenty-five types are common to all three assemblages (US, MS and OS). However, the same relationship directions are always observable, only their quantities vary somewhat. The classification into distance categories is not a very efficient way to approach the variability or continuity of the raw material production: it seems that different raw materials were used over time and that there is no continuity in the raw material supply. A statistical approach is desirable for future studies.

Both visual perspectives on the source area for the raw materials (Fig. 4) show that, besides a rather strong regional component (Olten), there are, in all three phases, a pronounced number of pieces from Import Zone 2. These came mainly from the West, South-West (French Rhone Valley) and West to North-West (Paris Basin). In addition, we can observe a steady but temporally fluctuating influx of flint material from the East. While in US and MS we can see a dominance of two-three sources, the supply seems to diversify in OS. At the same time, the

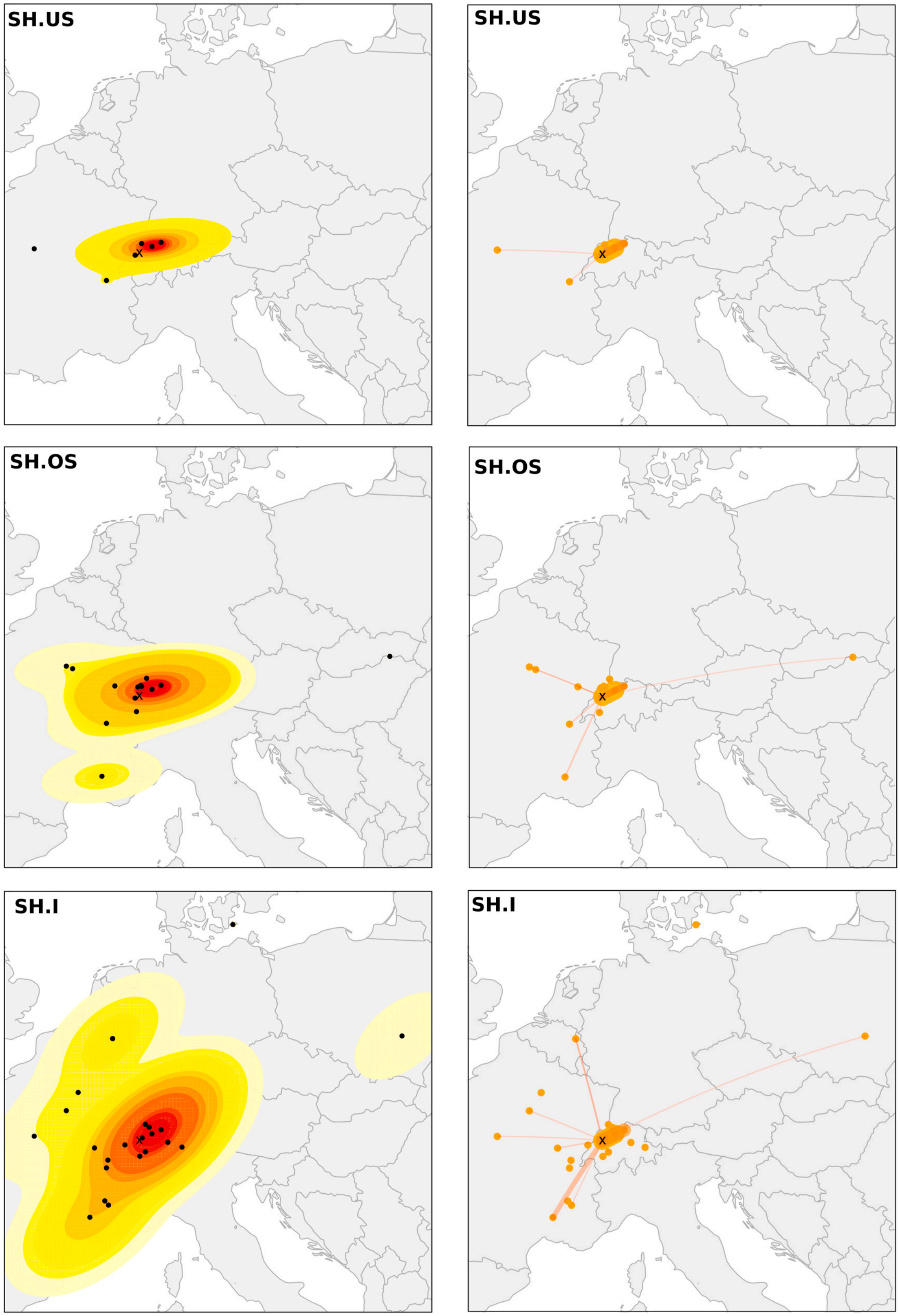

Fig. 5. Geographical origin of the investigated raw materials in Sutz-Lattrigen Hauptstation Hafen/innen. Transformation of the networks over time. Left: weighted KDE (heat map): the shading of the areas shows the importance of the region for raw material provision. Right: visualisation of the supply networks: the thicker the line, the more objects that were associated with the region and hence the stronger the connection to Sutz-Lattrigen Hauptstation, which is marked by x.

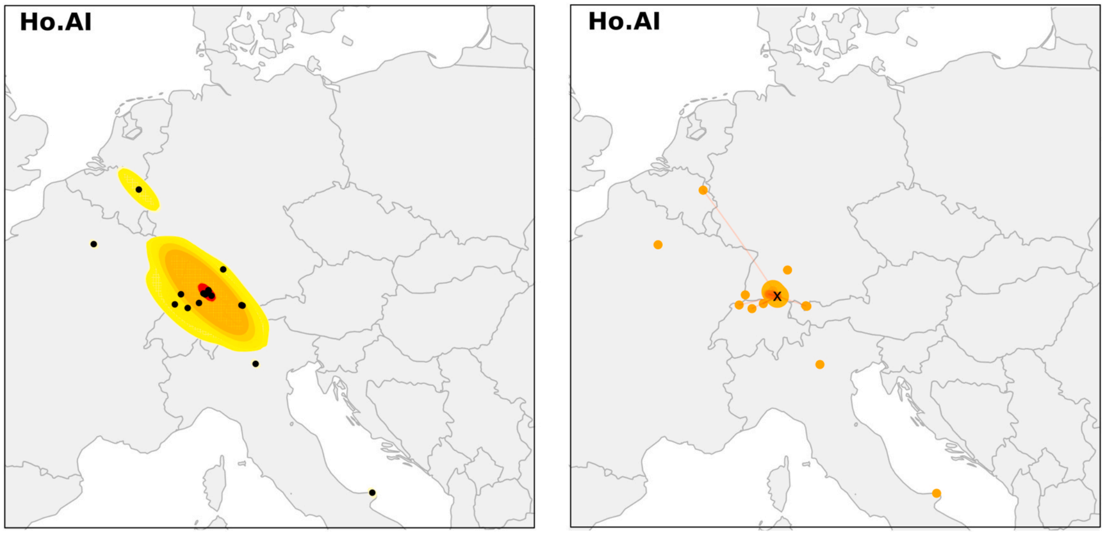

Fig. 6. Geographical origin of the investigated raw materials in Hornstaad-Hörnle IA. Left: weighted KDE (heat map): the shading of the areas shows the importance of the region for the raw material provision. Right: visualisation of the supply networks: the thicker the line, the more objects that were associated with the region and hence the stronger the connection to Hornstaad-Hörnle IA, which is marked by x.

supply regions closer to the site seem to have gained greater importance in this last time slice.

Overall, we can observe a west-east orientation of the network, whose basic configuration changes only quantitatively over the entire observation period.

4.2. The raw material supply in Sutz-Lattrigen Hauptstation innen/Hafen

The silicite series of Sutz-Lattrigen Hauptstation Hafen consists of 297 artefacts. Some pieces could not be certainly attributed to a specific level ("unstratified"), but they are dated by dendrochronology to between 3827 and 3631 BCE. The Sutz-Lattrigen Hauptstation Hafen series was the subject of a Bachelor thesis (Emmenegger, 2016) and the flints of Sutz-Lattrigen Hauptstation innen (SH I) were analysed by J. Affolter in 2010. Five per cent of all silicites deriving from Sutz-Lattrigen Hauptstation Hafen (SH US and SH OS) could not be determined due to strong patina or heat exposure. The remaining artefacts of assemblages SH US and SH OS can be subdivided into 15 different raw materials. The majority of the raw material has a regional origin: namely, the exploitation area around Olten (types 101, 102 and 311). Almost one third of the artefacts consist of raw material from the Import Zones 1 and 2. Most of them originate from the area Lägern/Otelfingen-Weiherboden (type 146). Raw materials of local origin (type 401) are of minor importance (Appendix tab. C).

The whole inventory of Sutz-Lattrigen Hauptstation innen (SH I) contains 499 artefacts. The artefacts can be subdivided into 26 different raw materials. Although raw material from the Olten region dominates, the Lägern becomes more important. In comparison with Sutz-Lattrigen Hauptstation Hafen, distant raw materials originate more often from the South, in the French Rhone Valley. The materials from a north-westerly direction partly come from further away, as Belgian-Dutch flint is found in this settlement layer. There is also one piece from Cmielow in Poland and another is made of Danish flint (Appendix tab. C, Fig. 5).

The representation of the areas of origin and the integration into the supply networks (Fig. 5) clearly reflect the different numbers of artefacts in the individual layers. Also, similar observations can be made to those mentioned above concerning Twann. The entire network shows a stable, more or less clearly western, orientation over time. In the first phase of Twann (TW US), only a small range of the network can be observed, but this is certainly also due to the smaller number of artefacts. For Sutz-Lattrigen as well, a stronger component of influx from import zone 1, and a less dominant one from import zone 2 can be observed. This is due to the constant influx of material from the Olten source region. Apart from this, great structural similarities to the configuration of the Twann network can be observed. However, the western component seems to be more important here.

4.3. The raw materials at Hornstaad-Hörnle

As an important archaeological settlement and a milestone of wetland archaeology at Lake Constance in the 1980s, Hornstaad-Hörnle IA has seen many investigatory projects. The silicites have been the subject of J. Hoffstadt's PhD thesis (Hoffstadt, 2005), and the origin of siliceous raw materials was investigated by J. Affolter, M. Kaiser and H. Wehren. In table D of the Appendix and in Fig. 6, all these determinations are combined. Raw material determinations were attempted by H. Wehren for a Bachelor thesis but the raw material types with the acronym HW could not yet be equated with the types of J. Affolter. The characteristics point to an origin in the Randen area but identical samples are missing in the sites, which were studied by Affolter up to now (Wehren, 2017). Some of the raw material origins have been published by Altorfer and Affolter (2011), 87ff and Dieckmann et al., (2016), 85–87. Unpublished contributions were kindly provided by J. Affolter and J. Hoffstadt (Appendix tab. D).

The macroscopic sorting of the (approximately) 2000 pieces showed that the largest part is assumed to be of regional origin. Of the over 120′538 artefacts found at Hornstaad-Hörnle IA, 634 pieces were analysed by the sedimentary microfacies method. Only a few artefacts from the chosen sample were too patinated, burnt or too uncharacteristic for precise identification. Two per cent could not be determined and 12% were identified as 001, which means an origin in the Jura Mountains that cannot be determined more precisely (Malm). It must be kept in mind that the macroscopic selection process eliminated the largest fraction of the extremely burnt and patinated samples. The series contained mainly raw materials of regional origin (Appendix D, Fig. 6). Due to the selection of artefacts with an unfamiliar aspect, these might be slightly overrepresented. However, it can be inferred that the raw materials from regional areas were clearly preferred.

The mapping of the supply network and the weighted density of the supply regions show a different picture for Hornstaad than we have seen so far at the Lake Biel sites. The regional component is clearly stronger here and the long-distance networks tend to be located north-south, while regions in the East or West play no role here. Overall, no dominant direction can be identified for the long-distance routes: More

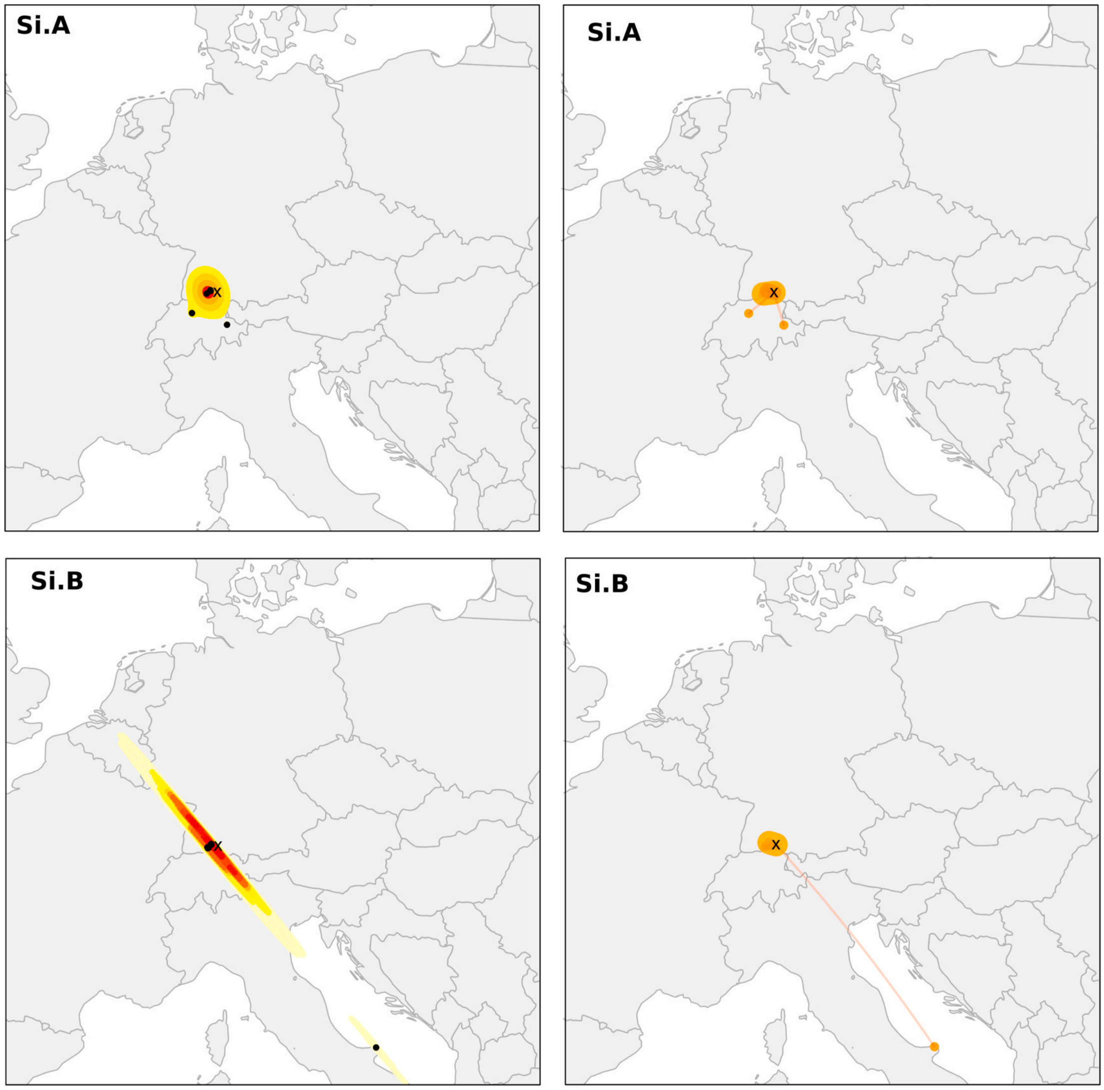

Fig. 7. Geographical origin of the investigated raw materials in Sipplingen Osthafen. Transformation of the networks over time. Left: weighted KDE (heat map): the shading of the areas shows the importance of the region for the raw material provision. Right: visualisation of the supply networks: the thicker the line, the more objects that were associated with the region and hence the stronger the connection to Sipplingen Osthafen, which is marked by x.

distant sources of raw material do not seem to be used systematically. It seems more likely that this is a coincidental influx that might be interpreted as a consequence of other contexts and reasons for spatial mobility that went beyond the mere raw material supply.

4.4. The raw materials in Sipplingen Osthafen

The knapped tools of Sipplingen are made mostly of regional raw materials. Very few artefacts consist of exotic/exogenous raw materials and, of those, most do not have any precise stratigraphic context within the Neolithic layers (unstratified). Only two pieces of exotic raw material were found in the upper layer, Si B, which is dated to between 3857 and 3817 BCE (Appendix E, Fig. 7). The pieces of the entire series are strongly patinated. Depending on the layer, up to 50–90% of the artefacts show a strong patination but, despite this patination, a total of 186 pieces could be determined (Appendix tab. E). The distance classes show a preference for regional materials; exotic silicites are very rare.

This is reflected in the representations of the regions of origin and the supply network as represented using this approach (Fig. 7). The predominant regional networks are directly evident from the examination of the data. This applies to both time slices. In the second time slice, the only Italian raw material source has a negative influence: it causes a computing artefact resulting in an ellipsoid density zone extending also into the north, which is not backed by the actual data.

5. Comparison of the four sites

It seems that the first occupants of the key sites on the northern Alpine Foreland essentially used local to regional raw materials (Fig. 8). Only over the course of time were more diverse and more distant raw materials brought to the sites, which indicates that the economic relations leading to more entangled networks of raw material supply were established gradually over time.

The study of the finds deriving from the settlements on the shore of Lake Constance shows that the inhabitants of the pile-dwelling settlements acquired their flint mainly from the outcrops in the vicinity of Schaffhausen and Singen. The high proportion of silicite raw material from these outcrops shows that the settlement communities were independent of other regions for the procurement of the raw material: The raw material of Sipplingen Osthafen initially shows more references to the South-West (on a regional scale) and no relations to the North-West. Over time, raw material from the South-East was more frequently used. On the other hand, the raw material used in Hornstaad-Hörnle IA derives mainly from the Schaffhausen area in the North-West and rarely from

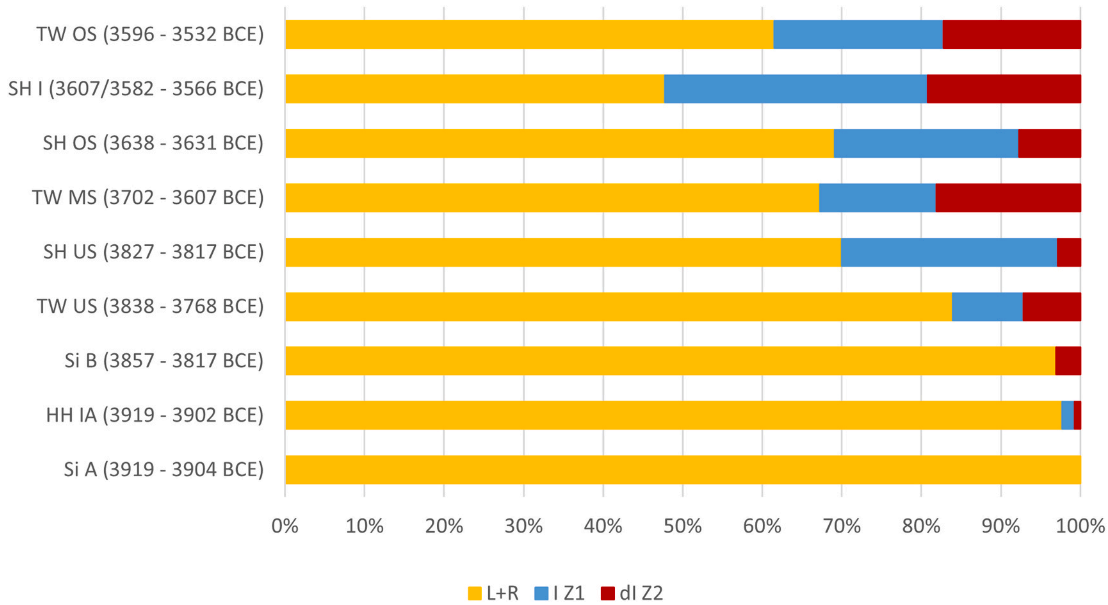

Fig. 8. Transformation of the proportions of local-regional and import/exogenous raw materials throughout the studied period. The locally and regionally occurring raw materials (L + R) are in yellow, the materials imported from nearby are in blue (I Z1) and the materials imported from remote regions are in red (dl Z2). (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

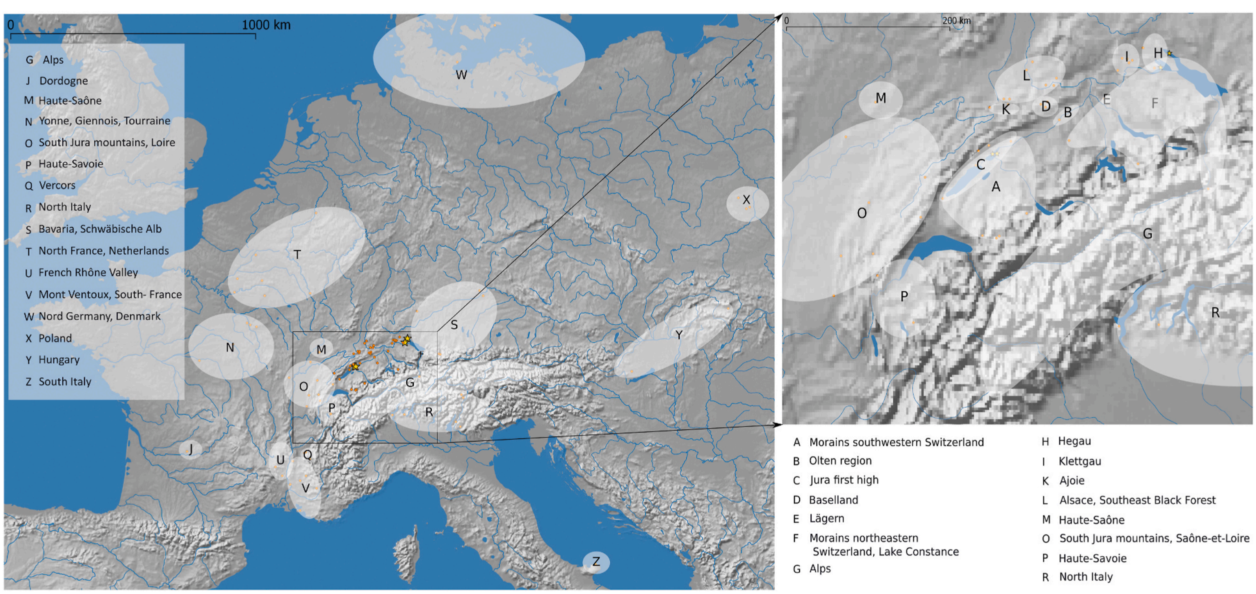

Fig. 9. Visualisation of the geographical origin of the raw materials (see Table 2).

south-western regions. They all had regional resources but, in a more detailed view, they did not use the same outcrops in the same quantities. They either shared the outcrops, so they all used the same raw material outcrops, or they exchanged raw materials. But the latter is unlikely, because if they had traded, one would expect the same exotic raw materials.

At Lake Biel, a different pattern of raw material supply becomes evident: local raw materials were rarely used; instead, regional flint from Olten strongly dominates. The availability of flint deposits of good quality in the area of Olten, which is within the Lake Biel region, seems to have strongly influenced the procurement of siliceous raw material. Furthermore, the supply of the settlements at Lake Biel was probably carried out in a more organized and uniform way. Consequently, in each of the six find-assemblages studied (TW US, TW MS, TW OS, SH US, SH OS and SH I), raw material from the Olten region is the most important. With 31 and 43 different raw materials, Twann Bahnhof shows an exceptionally high variability. Most of the other Neolithic settlements on the northern Alpine Foreland show around ten to twenty varieties of silicite raw materials. Moreover, right from the start of the settlement occupations, relationships in all directions are present. The same can be observed at Sutz-Lattrigen, although there are fewer different raw materials present, and there is a greater diversity of raw material at the youngest settlement of Hauptstation innen than at the older settlements. A comparison of the raw material used in the settlements of Twann and Sutz-Lattrigen could therefore indicate a similar procurement strategy by the settlements at Lake Biel. Although different raw materials varied in quantity over time, procurement networks with the South-West (French Rhone Valley) and the West to North-West (Paris basin) seem more constant than relations with the East.

Looking at the supply of the largest share of the raw materials, a

Table 2
Comparison table with all resource types used in the four settlements. Colour code: dominant types more than 30% █, abundant raw materials 10–30% ▓, rarely occurring types 1–10% ▒, and singular pieces ░ with a presence of less than 1%.

			Raw materials																									
			Morains southwestern Switzerland	Olten region	Jura first high	Baselland	Lägern	Morains northeastern Switzerland	Alps	Hegau	Klettgau	Dordogne	Ajoie	Alsace, Southeast Black Forest	Haute-Saône	Yonne, Giennois, Touraine	South Jura mountains, Saône-et-Loire	Haute-Savoie	Vercors	North Italy	Bavaria, Schwäbische Alb	North France, Netherlands	French Rhône Valley	Mont Ventoux, South- France	Nord Germany, Denmark	Poland	Hungary	South Italy
			108, 205, 305, 357, 616	101, 102, 311	401, 404, 415, 421, 427	109, 504	146/002	359, 633, 632	rock crystal, 655, 9	346, 436, 1218	177, 271, 291, 366, 812, 3403, HW	520	114, 142, 314	135, 159, 286, 313, 341, 349, 419, 652	207	112, 113, 139, 232, 802, 1212, 1213	119, 123, 330, 261, 422, 371	201, 420	167, 334, 337	4, 141, 157, 169, 250, 259, 646, 1215	153, 184, 375, 654, 620	1235	212, 252	129, 156, 262, 388, 413	174, 180	130, 187, 1214, 2328	1216, 2317, 3413	282
Region	Time	Site/ Layer	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z
Biel	3596 - 3532	TW Os	░	█	▒	░	▒	░	░			░	░	▒	▒	▒	▒	░		░	░	▒	▒	░		░	▒	
	3595 - 3566	SH I	░	█	▒		▓	░	▒					░		▒	▒		░			▒	▒		░	░		
	3638 - 3631	SH OS	░	█	░		▓						▒	░	░	▒	▒							▒			░	
	3709 - 3607	TW MS	░	█	▒	░	▒	░	░				░	░	▒	▒	▒	░	░	░	░		▒	▒	░	░	▒	
	3827 - 3820	SH US		█	▒		▓						▒			▒	▒											
	3838 - 3768	TW US	░	█	▒	░	▒		░		░			▒	░	░	░			░			░	▒		░	▒	
Constance	3857 - 3817	Si B								█	█																	▒
	3918 - 3880	HH IA		░			▒	░	░	█	█		░	░						░	░	░						░
	3919 - 3904	Si A						▒	▒	▓	█																	

similar trend can be observed in the two regions: one or a few outcrops in the same area were chosen for exploitation on a regular basis throughout the duration of the settlements. The settlement communities of Hornstaad-Hörnle IA, as well as those at Lake Biel, used quite a large portion of flints deriving from the outcrops of the Lägern (Table 2). However, since the settlement of Hornstaad Hörnle IA is older than those at Lake Biel (Twann Bahnhof and Sutz-Lattrigen Hauptstation Hafen/innen), no direct relationship between the settlement communities can be assumed. Besides the main supply of silicite raw material from one specific outcrop or group of nearby outcrops (e.g. region Olten), a high degree of freedom of choice to obtain raw materials from different regions can be assumed. The settlements at Lake Biel showed surprisingly stable relations with the East, with material from Poland and Hungary that is missing in the settlements at Lake Constance. Chronological differences might be the explanation here. In general, the raw material production at Lake Biel seems to be more east-west oriented than the one at Lake Constance, where an orientation to the south and north dominates.

From another point of view, the notion of a *'Siedlungskammer'*, which implies that the same social groups occupy nearby sites, grouped together in a coherent and well-defined geomorphological ensemble, seems to be contradicted by the great variability of the related supplies of raw materials. This would rather suggest different - or very independent – social groups, at least from an economic point of view. The most important fact highlighted by the determination of siliceous materials is that the majority of the tool production was provided for by a supply from deposits that remained fairly constant over time for each site. Accordingly, raw materials deriving from geographically distant regions seem to have had different meanings beyond the daily needs for tool production. Furthermore, as the presence of raw materials imported from afar does not reflect a lack of suitable material in the region, it might correspond to other contexts and reasons for spatial mobility. The raw materials imported from afar show a high variability at the four studied sites. Therefore, a well organized long-distance exchange seems unlikely for the studied period. The different exogeneous raw materials might reflect cultural entanglements of individuals or groups beyond pure reasons of raw material supply. Whether the inhabitants of the lake shore settlements travelled to these far regions, or if individuals from there came to the lakes on the northern Alpine Foreland for some reason, cannot be decided based on raw material determination studies alone.

6. Conclusion: flint raw material determination and its potential for mobility studies

The provenance of the raw materials shows, in both studied areas, a preference for a group of outcrops in the region that provided the bulk of the industry and which covered the daily needs of the settlement communities. Additionally, each settlement community had relationships that reached distant regions, which can be inferred from the presence of small quantities of exogenous materials. Since similar entanglements of routes for raw material supply prevail in the settlements of a region, it can be assumed that actors from the settlements within the different regions were related to each other or were part of similarly entangled routes of raw material supplies. The fact that these patterns were quite stable over time is reflected in the find assemblages of the chronologically differing settlements of the same site (partly with long settlement interruptions). This indicates that at least some of the settlement communities did not move beyond the respective settlement region but changed residence within their settlement areas (e.g. respective bays or lake shore sections) and passed on their knowledge and raw material supply relationships to future generations (in later settlements).

The smaller amounts of exogenous raw materials that were used in the settlements, especially those from distant areas, could be explained in different ways. Some individuals or smaller social groups from the settlement communities might have been mobile over larger distances for diverse reasons, and they may have brought back exogeneous raw materials as a by-product of their mobility. Or they could indicate some kind of bartering, trade or gifts that changed hands several times before reaching the settlements on the northern Alpine Foreland. Or they could also represent important objects that were highly sought after for unknown reasons, and so the movement was demand driven. It is safe to assume that these mobilities had reasons beyond mere daily raw material supply, as the communities had enough regional raw materials at hand to supply their daily demands. We propose that such rare pieces of far distant flints rather reflect other contexts of spatial mobility that were also a part of the overall cultural entanglements.

The study of lithic raw material alone cannot reflect the whole spectrum of relationships between the settlement communities. Technological studies in combination with raw material studies could provide an indication of whether the unprocessed raw material, reworked tools or the finished tools were mobile. For the present project, typological work could not be addressed. These questions could be approached in more detail in future research, by comparing the direction of raw material supply with the pottery production practices of the same settlements (see Heitz and Stapfer, 2017). The large mass of silicite from Olten at Lake Biel could reflect organized mining/exchange on a regional scale for the vast majority of the tool production. It is very intriguing to see that this phenomenon is missing in the ceramic material. Whereas the strong eastwards tendency seen in the lithic raw materials is also seen in the ceramic styles, these directions seem to overlap with the ceramic proveniences (Affolter et al. in press). A combination of both studies seems promising for reconstructing entanglements between settlement communities and for studying the social organisation of settlement communities and their mobility patterns.

Author contributions

Jehanne Affolter: Data Curation, Investigation, Resources, Writing, Methodology; Lea Emmenegger: Investigation; Albert Hafner: Funding acquisition, Supervision, Project administration; Caroline Heitz: Project administration, Writing, Supervision, Validation; Martin Hinz: Formal analysis; Regine Stapfer: Project administration, Writing, Supervision, Validation; Helena Wehren: Investigation, Resources, Writing, Methodology, Validation.

Data availability

Datasets related to this article can be found at https://zenodo.org/record/4746434, an open-source online data repository hosted at zenodo.org.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.quaint.2021.05.027.

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