The querns from the Roman military camp at Hermeskeil (Rhineland-Palatinate): Bridging the gap to Caesar's *De Bello Gallico*

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Abstract:

The late-Republican military camp at Hermeskeil (Rhineland-Palatinate) is one of the few known archaeological sites from the Gallic Wars and can be linked directly to the historical record given in Caesar's *De Bello Gallico*. Among the numerous finds are fragments of several badly preserved querns whose provenances can provide valuable information regarding the dating of the camp. The Hermeskeil querns are made from an unusual variety of rock types compared to material from contemporary settlements in the region. In order to determine the provenances, modal mineralogy, whole rock geochemical compositions as well as mineral chemical compositions were analysed on all fragments found until 2017. Besides vesicular lavas, the querns were made of sedimentary rocks, pebble-rich carbonates and arkoses, as well as acidic lava and plutonic rock. One volcanic rock fragment of a legionary quern is produced from lavas from Cap d'Agde in southern France. Several other querns of the Late La Tène type have their origin in Mayen in the Eifel. The plutonic rock is vaugnerite, a rare rock of granodioritic composition, which can be traced via the oppidum of Bibracte to quarries in the northern Morvan. The rhyolite comes from La Salle in eastern France. Except from the querns made of vesicular lava from the Eifel, none of these materials are known from any contemporary archaeological site in the Hunsrück area. What is more, all of them were discovered far away from their regular areas of distribution. Therefore, these querns directly reflect military supply structures as well as troop movements, because during Caesar's campaigns damaged pieces had to be replaced by locally available products. In a time when the Roman military could not yet rely on a well-functioning supply-infrastructure this category of finds bears the potential to provide important information in connecting the Hermeskeil site with written sources. It becomes possible to prove a use of the camp during Caesar's campaign in 51 BCE, because it was not before 52 BCE that the Roman army had moved within the distribution area of all the querns represented in Hermeskeil. Provenance studies are therefore a valuable supplement for our fragmentary picture of the Gallic War, which to date is almost completely based on historical sources.

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1. Introduction

In contrast to the detailed record of the Gallic Wars given by Julius Caesar himself in *De Bello Gallico,* archaeological evidence connected to the events described there is still sparse. Until 2010 not a single site from his campaigns in the territory of the *Treveri* - a tribe who lived west of the Rhine, in the Hunsrück and Eifel regions and as far as Luxemburg in the west (Caes. Gal. 3.11.1, 4.10.3, 5.3.4) - was actually known. Recently, landscape-archaeological research in the vicinity of Hermeskeil (Lkr. Trier-Saarburg, D), a town 35 km southeast of Trier in the Hochwald mountains, has revealed a late-Republican military camp (Hornung 2012; 2016: 129-164; 2017). With an overall size of more than 30 hectares, it consists of an almost square main camp (19.5 hectares) with an adjacent annex of slightly irregular shape (11.2 hectares), both protected by a ditch and bank system (Figure 1). The site is situated strategically, in direct sight of a Late La Tène *oppidum*, the so-called *Hunnenring* near Nonnweiler-Otzenhausen (Saar district). What is more, the Hermeskeil fortress controls access to two axes of communication, one of which is leading directly towards the "Hunnenring" in the south and the Trier basin in the north (Hornung 2016: 129), and the other connecting the Rhine and Moselle in an East-West direction.

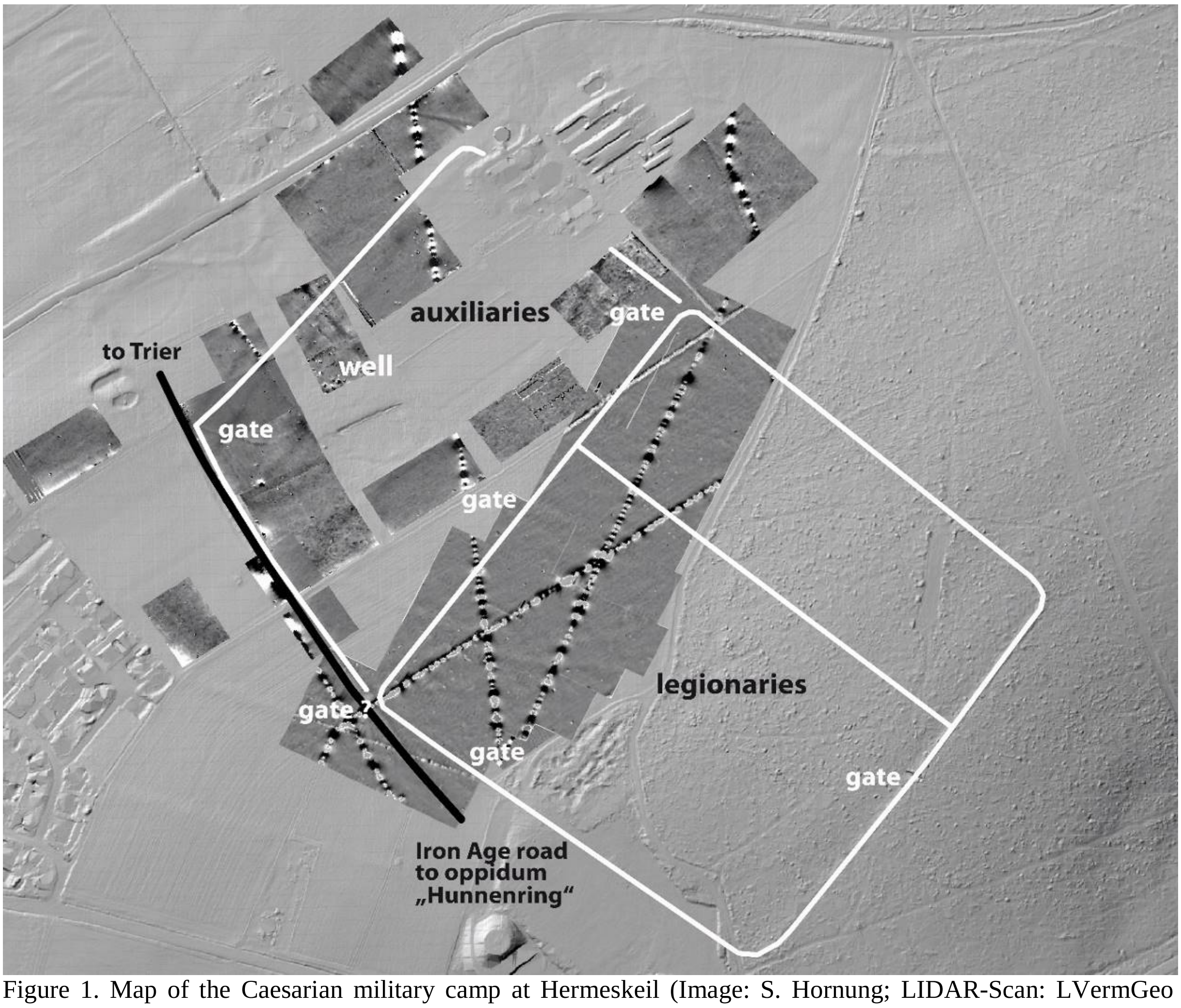

Figure 1. Map of the Caesarian military camp at Hermeskeil (Image: S. Hornung; LIDAR-Scan: LVermGeo Rhineland-Palatinate).

1.1. Historical background

Archaeological evidence for a dating of the Hermeskeil fortress to the time of Caesar's conquest of Gaul is quite strong, judging by pottery, coins and the hobnails found during excavations between 2010-2017. There is also proof that the camp must have been in use over several weeks or months, therefore it has to be regarded as a winter camp or rather a camp from an active campaign to conquer the *Treveri*. The latter is most probable because the Hochwald area has very poor soils and the Roman army would not have risked a shortage of food supplies by spending the winter in a remote highland region (Erdkamp 1998: 25, 152, 247). On the contrary, Roman winter camps were usually established close to rivers that would facilitate supply transport by ship. Therefore, the Hermeskeil camp was most likely built during a summer campaign, a suggestion potentially supported by its proximity to the *Hunnenring oppidum*, which could easily have been controlled from Hermeskeil. These considerations leave the Roman campaigns against the *Treveri* in 53 BCE (three Roman legions) and 51 BCE (two legions) as the most likely historical contexts, both of which were commanded by Caesar's general Titus Labienus (Caes. Gal. 5.2-4, 6.7-8, 8.45).

1.2. A new approach to dating a Roman military camp

It is difficult to narrow down the archaeological dating by looking at the camp's size because there is hardly any information on the exact number of soldiers in a Caesarian legion. Only the finds can potentially help to bridge the gap between archaeological and historical record. Unfortunately, archaeological dating is not sufficiently precise to distinguish between events as little as two years apart. Therefore, the only way to approach the problem is to reconstruct where the Hermeskeil garrison had moved before being stationed there by examining the provenances of the archaeological finds made during excavations and thus allowing a comparison with the account of troop movements given in Caesar's *De Bello Gallico*.

In this regard, the querns are of particular interest because a regular Roman supply-infrastructure does not seem to have existed during the time of the conquest. Caesar's army was originally provisioned with small and light legionary querns from quarries in Italy or southern France working for the Romans before the start of the Gallic Wars. During subsequent years of campaigning broken querns had to be replaced by ones from the areas where the troops were at the time. These querns would necessarily have been the taller and heavier ones common in Late Iron Age Gaul. Such an indigenous supply during the war is indeed reflected in the material from Hermeskeil (Hornung *et al.* 2015), where Late La Tène type querns dominate, as would be expected after several years of campaigning when most of the original equipment was already worn out or broken. So far, only one of the small and light querns regularly used by the Roman army has been found. It is made of vesicular lava, has a diameter of only 33 cm (in contrast to the Late La Tène type querns which are mostly 38-40 cm in diameter) and may indeed be a survivor of the equipment the troops were originally provided with before they entered the Gallic Wars from 58 BCE onwards. This suggests that most querns were broken after only a relatively short period of use and extensive travel. At any rate, the provenance of these querns provides valuable information as to where they were acquired and helps us to reconstruct, in which parts of Gaul the troops were before they arrived in the Hochwald region.

2. Methods

2.1. The basic volcanic rock millstones: Sampling, preparation and measurements

The geochemical analyses of 21 volcanic rock quern fragments followed the procedure suggested by Gluhak & Hofmeister (2011), and used the database provided by Gluhak & Hofmeister (2009). Depending on the size of the fragments, the querns were sampled either by cutting off a piece using a diamond saw or by drilling a core. The weathered crust was removed from the samples and a piece was cut off and reserved for thin section preparation, if necessary. The samples were then rinsed in an ultrasonic bath in distilled water, dried, crushed, and ground to powder in an agate mill.

For whole rock major element determination, 0.4 g of the dried sample powder was used to produce fused glass beads with 5.2 g of lithium tetraborate. The loss on ignition was determined on *ca.* 1 g of dried sample powder. Powder pellets for the whole rock trace element determinations were produced from 6 g of sample powder.

Major and trace elements were determined by wavelength-dispersive X-ray fluorescence in a 2002 model Philips MagXPRO spectrometer with a Rh-X-ray tube, with a maximum excitation of 3.2 kW for major and 3.6 kW for trace elements.

2.2. The rhyolite, vaugnerite and sedimentary rock millstones: Sampling, preparation and measurements

Small samples of 10 quern fragments were used to produce polished thin sections following standard preparation procedures. The slides were polished to a final grade of 1 µm diamond. Only from the vaugnerite quern fragments a rock powder was produced. Due to the small sample size, other sample aliquots were not representative for a bulk rock analysis. A PANalytical, AXIOS Advanced wavelength-dispersive X-ray fluorescence spectrometer at the Geowissenschaftliches Zentrum of the University of Göttingen was used for bulk rock analysis of major and trace elements, following standard preparation and calibration procedures.

Micro X-ray fluorescence analysis of the rhyolite and the sedimentary rocks was conducted on a Bruker M4Tornado energy dispersive X-ray fluorescence spectrometer. A quantitative area scan on two polished rock sections was used to generate a bulk rock analysis.

For electron probe microanalysis (EPMA) of mineral phases and scanning electron microscopy, a JEOL JXA8900 instrument, equipped with five wavelength dispersive spectrometers was used. Excitation conditions were set to 15 kV accelerating voltage and a beam current of 15 nA. The beam diameter was varied, depending on the beam sensitivity of the respective phases. Natural and synthetic standards were used for primary calibration. Matrix corrections were applied by using the phi-rho-z algorithm of the CITZAF program of Armstrong (1995). Optical cathodoluminescence imaging, mainly on quartz and feldspar crystals of the rhyolite and sedimentary rocks, was conducted using a hot-cathode HC3-LM microscope (Simon-Neuser company) equipped with a peltier cooled camera, DX 40C (Kappa company).

3. Data results

3.1. The provenance of the volcanic rock querns

3.1.1. Basic volcanic rock types

The results of the geochemical analyses of the volcanic rock querns are presented in Table 1. The fine-grained volcanic rock querns are classified using the total-alkali-silica-

(TAS-) diagram (Le Bas *et al*. 1986) (Figure 2a). The great majority of the samples are alkali-rich and can be classified as phonotephrites, with one sample plotting in the tephriphonolite field, and a group of samples plotting at the transition from phonotephrites to basaltic trachyandesites which can be further defined as shoshonites according to their Na_2O and K_2O-content. In comparison, quern HK106 has a clearly lower alkali-content and is classified as a potassic trachybasalt.

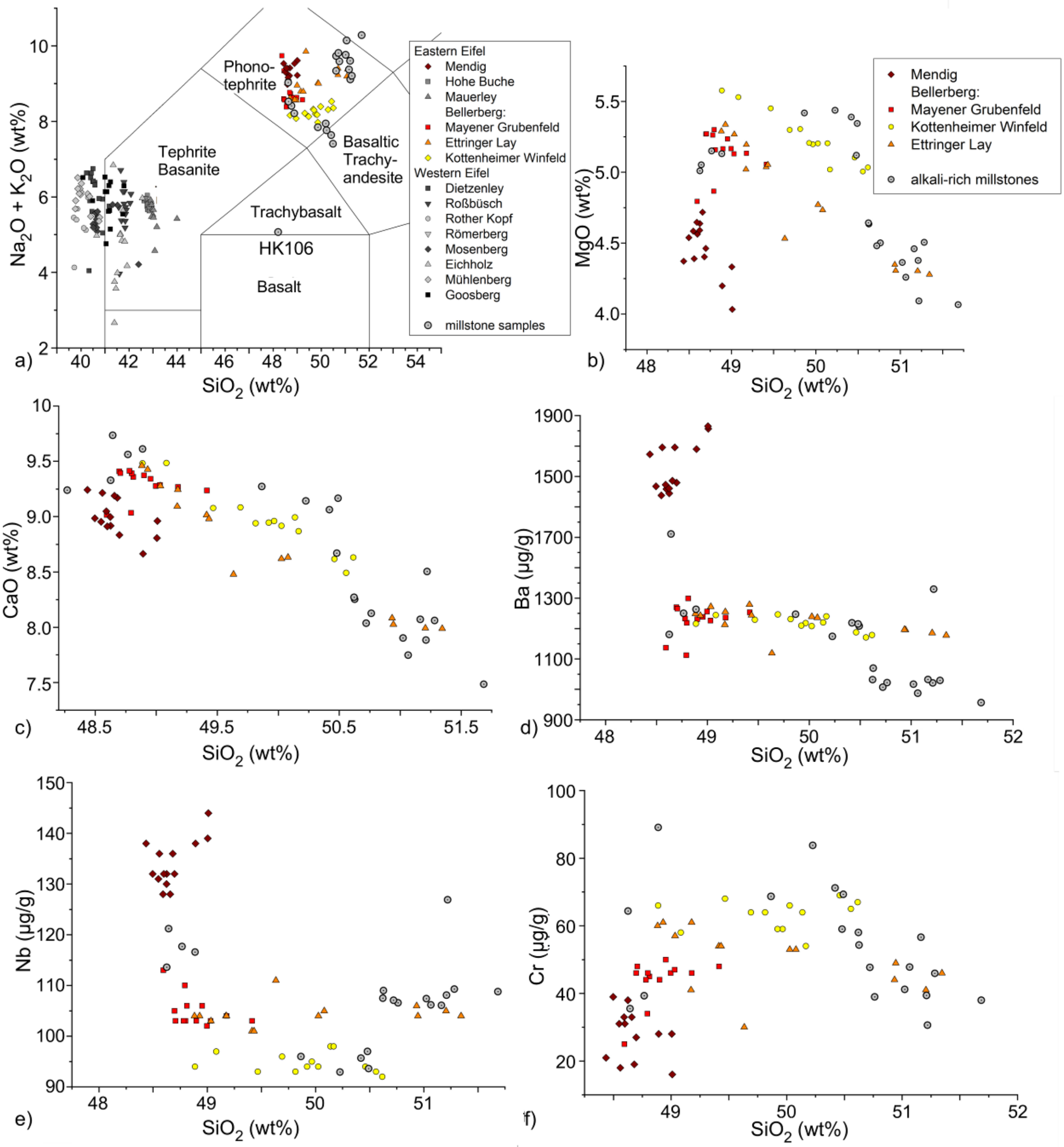

Figure 2. The geochemical composition of the high-alkali querns in comparison to rock samples collected in the Eastern Eifel quarries of the Bellerberg volcano (Gluhak & Hofmeister 2009) and the Mendig lava ("Niedermending lava"; Gluhak 2010).

Table 1. Geochemical composition of the samples. Major element oxides in wt%, trace elements in µg/g.

	HK03/10	HK19	HK38	HK41	HK63	HK95	HK97	HK106	HK113	HK120	HK217	HK271	HK277	HK296	HK333	HK337	HK339	HK346	HK392	HKNSO1	HKNSO2
SiO_2	50.50	50.63	51.22	51.02	50.76	51.21	51.28	48.30	48.77	48.89	51.07	48.63	50.42	50.62	50.23	49.87	50.49	48.64	51.16	51.69	50.72
TiO_2	2.11	1.96	1.95	1.87	1.92	1.86	1.92	2.36	2.23	2.25	1.82	2.20	2.16	1.97	2.15	2.21	2.15	2.27	1.90	1.74	1.90
Al_2O_3	16.36	17.67	18.29	17.72	17.61	17.73	18.18	14.03	17.65	17.79	17.58	17.29	16.50	17.44	16.33	16.52	16.71	17.30	17.66	17.78	17.41
Fe_2O_3(t)	8.65	7.99	8.04	7.70	7.81	7.65	7.85	12.09	9.08	9.15	7.47	8.96	8.88	7.97	8.81	8.84	8.93	9.14	7.80	7.24	7.73
MnO	0.18	0.19	0.20	0.18	0.18	0.18	0.18	0.17	0.19	0.19	0.18	0.20	0.19	0.19	0.18	0.18	0.19	0.20	0.19	0.18	0.18
MgO	5.12	4.63	4.09	4.36	4.50	4.38	4.51	8.07	5.15	5.13	4.26	5.01	5.39	4.64	5.44	5.42	5.34	5.05	4.46	4.07	4.48
CaO	8.67	8.25	8.50	7.90	8.13	7.88	8.06	9.24	9.56	9.61	7.75	9.33	9.06	8.27	9.14	9.27	9.17	9.74	8.07	7.48	8.04
Na_2O	4.09	4.80	4.93	5.16	5.03	5.08	4.83	3.46	4.30	4.18	5.42	4.71	3.84	5.14	3.99	4.01	3.77	4.13	4.91	5.51	5.19
K_2O	3.90	4.54	4.18	4.60	4.56	4.53	4.38	1.61	4.11	4.03	4.71	4.32	3.80	4.59	3.78	3.83	3.64	4.40	4.47	4.77	4.63
P_2O_5	0.41	0.44	0.49	0.41	0.42	0.40	0.42	0.66	0.56	0.57	0.39	0.55	0.46	0.43	0.43	0.47	0.45	0.58	0.42	0.38	0.41
LOI	0.57	1.06	1.80	0.91	0.89	0.88	1.55	0.12	1.55	1.73	0.64	1.15	0.67	1.22	0.46	0.61	0.81	1.39	1.00	0.81	0.66
Sc	17	11	11	12	14	13	14	21	15	14	13	12	15	14	17	16	17	13	13	12	14
V	230	180	178	170	188	185	192	179	225	232	189	224	212	199	225	224	226	198	167	178	198
Cr	59	54	31	41	39	39	46	229	39	89	48	64	71	58	84	69	69	36	57	38	48
Co	49	24	20	21	23	24	22	45	27	27	22	25	27	23	31	28	27	26	25	24	25
Ni	52	41	30	35	38	37	39	178	37	51	36	40	52	39	56	50	52	37	39	36	40
Cu	48	27	22	25	29	29	26	50	28	28	26	29	34	29	35	43	40	27	28	27	27
Zn	89	89	91	88	88	89	90	117	90	91	88	87	83	88	85	83	86	92	89	92	89
Ga	21	23	22	23	23	22	23	21	23	22	22	22	22	22	21	22	22	22	23	23	22
Rb	117	156	149	157	154	161	157	41	140	139	157	136	126	154	120	118	121	128	158	166	153
Sr	983	899	1324	867	879	860	864	808	1134	1138	835	1076	997	885	976	1011	989	1362	861	844	869
Y	28	26	28	25	25	25	24	28	28	29	23	26	28	25	29	28	28	30	25	24	25
Zr	328	408	416	418	407	417	430	219	397	396	412	391	322	403	322	334	348	365	406	429	412
Nb	97	109	127	107	107	108	109	80	118	117	106	114	96	108	93	96	94	121	106	109	107
Ba	1215	1070	1330	1017	1022	1021	1029	573	1250	1263	987	1181	1219	1032	1175	1247	1209	1511	1033	956	1007
Pb	13	16	14	16	15	14	14	6	11	13	13	14	11	15	12	12	12	10	13	14	13
Th	13	15	15	15	14	16	17	7	13	14	15	13	12	14	10	11	12	14	14	17	15
U	4	5	4	4	4	4	3	1	4	4	6	5	2	4	5	3	2	3	4	3	5

Apart from sample HK106, the TAS-diagram, together with other major- and trace element comparisons (Figure 2b-f, with SiO_2-MgO, SiO_2-CaO, SiO_2-Ba, SiO_2-Nb, and SiO_2-Cr as examples), demonstrates that the geochemical compositions of the alkali-rich querns match those of the reference samples from the Bellerberg volcano in eastern Eifel (Gluhak & Hofmeister 2009) and Mendig lava ("Niedermendig lava"; Gluhak 2010).

To verify the eastern Eifel provenance on a multivariate level, cluster analyses are applied. Following the cluster procedure suggested by Gluhak & Hofmeister (2009) every quern sample which plots in the field of the eastern Eifel phonotephrites is clustered with the geochemical data of the Bellerberg and the Mendig lava. These cluster results confirm the provenance of the 18 high-alkali querns from the quarries of the Bellerberg volcano. Interestingly, one quern (HK346) is assigned to the Mendig lava, which is confirmed by using alternative cluster algorithms and different distance measures.

The Mendig lava is not known to be quarried before medieval times, and although earlier quern manufacture from Mendig lava has been assumed it has never been reliably based on evidence from quarries (either extraction marks or finds) or products (Hörter 1994: 71). Thus, quern HK346 can be interpreted as the first indication that the Mendig lava was indeed extracted to produce querns in the Iron Age. However, further provenance studies of Iron Age querns are clearly necessary to evaluate whether Mendig lava was systematically quarried in pre-Roman times and if so, to what extent, or if HK346 is merely an individual example.

The potassic trachybasalt quern HK106 (thin section photo in Figure 3) is not made of Eifel lava. Comparisons with geochemical compositions of our own field data of volcanic rocks collected by T. Gluhak and L. Jaccottey in the French Massif Central and southern France (unpublished data) show that the major- and trace element composition of HK106 is not only comparable to the geological samples from southern France, but has a high correspondence with a sample collected from the volcanic rocks at Cap d'Agde (Figure 4a-d, with TAS, MgO-TiO_2, MgO-Sr and Zr-Nb as example). Although the thin section of the geological sample from Cap d'Agde was not finished at the time of writing, the overall similarity of the major and trace element compositions of both samples strongly suggests a provenance for quern HK106 as Cap d'Agde.

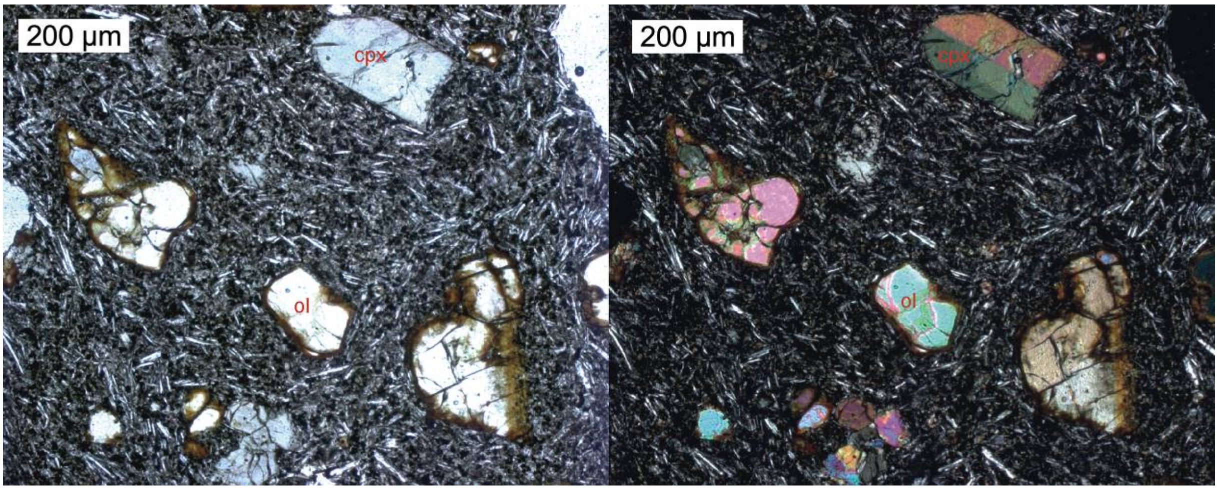

Figure 3. Thin section photography of millstone HK106. Left: plane polarized light. Right: crossed polarizers (Image: T. Gluhak).

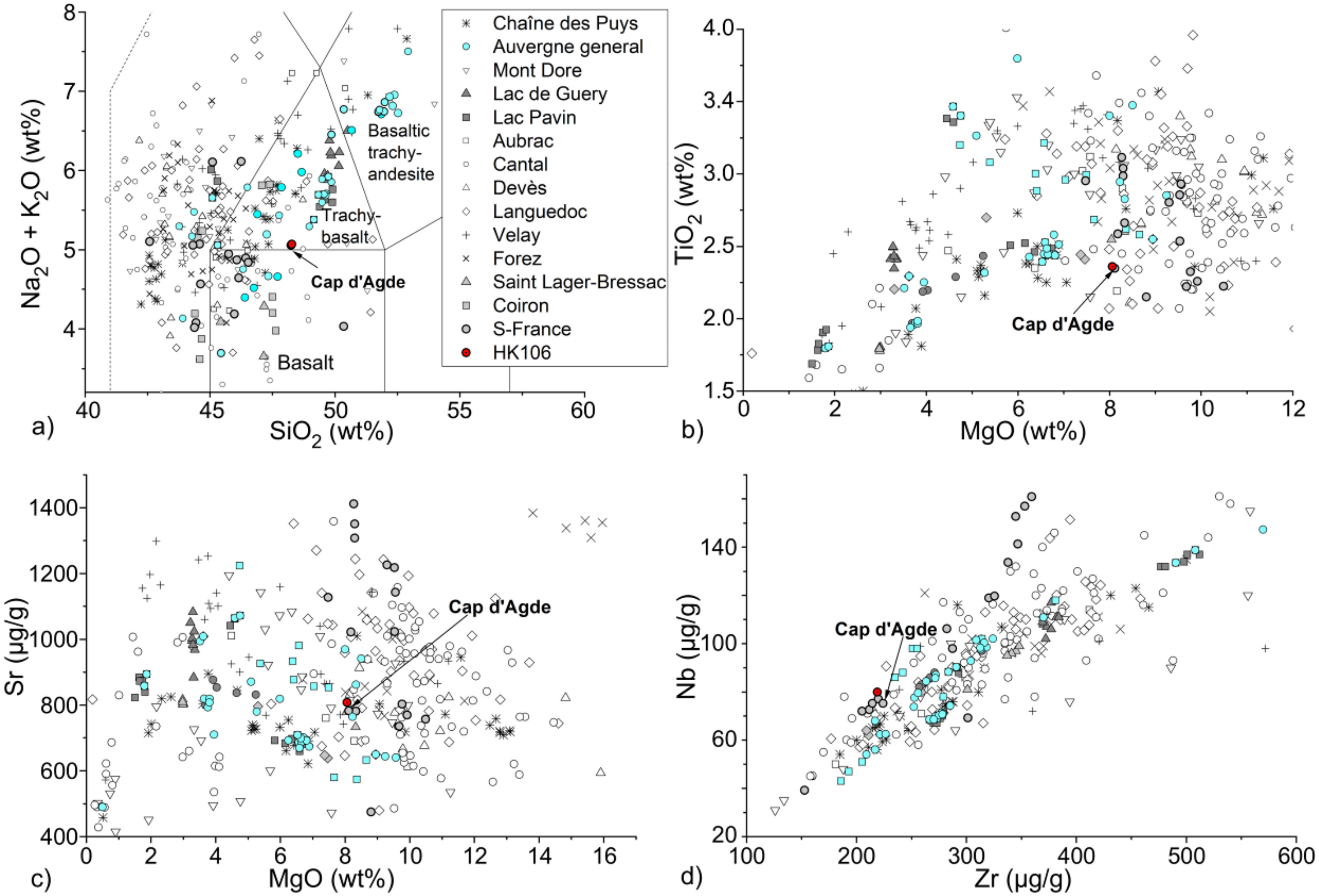

Figure 4. The geochemical composition of quern HK106 in relation to volcanic rocks from France. Chaîne des Puys: Hamelin *et al*. 2009; Laj *et al*. 2017; Liotard *et al.* 1988; *et al*. 1983; Lustrino & Wilson 2007; Martel *et al*. 2013; Maury *et al*. 1980; Oeser *et al*. 2015; own data (unpublished). Auvergne general: own data (unpublished). Aubrac: Baubron & Demange 1982; Chauvel & Jahn 1984. Cantal: Boudon *et al*. 1978; Carmichael 1965; Caroff *et al*. 1997; Chauvel & Jahn 1984; Chesworth *et al*. 1981; Downes 1984; Pilet *et al.* 2002; 2005; Wilson & Downes 1991; Wilson *et al*. 1995. Devès: Liotard *et al*. 1983; *et al*. 1988; Paquette & Mergoil 2009. Mont Dore: Briot *et al*. 1991; Chauvel & Jahn 1984; Legendre *et al*. 2001; Sørensen *et al*. 1999. Lac de Guery and Lac Pavin: own data. Languedoc: Dautria *et al*. 2010; Liotard *et al*. 1999. Velay: Berger *et al.* 1976; Dautria *et al*. 2004; Liotard *et al*. 1988; Villemant & Treuil 1983. Forez: Hernandez 1973; Lenoir *et al*. 2000; Wilson & Downes 1991; Wilson & Patterson 2001. Saint Lager-Bressac, Coirons, S-France: own data (unpublished).

3.1.2. Acidic volcanic rock type: Rhyolite

A single fragment of an upper stone (*catillus*), with a diameter of *ca*. 35 cm and 10.6 cm height was excavated in 2016. Its weathered surface shows a beige-brown colour (Figure 5), whereas the interior, exposed after preparation, shows a fresh bright greyish-violet tint. The porphyritic rock is composed of approximately 40% of phenocrysts in a light grey dense matrix (Figure 6B and D). White, dull and often prismatic euhedral to subhedral potassium-feldspars in the size of 0.5 to 5 mm are dominant (about 20%), with two grain-types: about one third (type 1) are only slightly altered, in contrast to the other two thirds (type 2), which are almost completely altered. Their alteration product is a crumbly, yellow mass which easily disintegrates causing pitting on the surface (Figure 5). The second dominating phase (about 10%) is colourless, rather isometric, anhedral quartz with a grain size of 0.5 to 2 mm. The third dominating phase (about 10%) is euhedral black mica. The grains are at a maximum of 1 mm in size with a partly platy to tabular habit.

Figure 5. Grinding surface of the rhyolite upper stone (*catillus*) Hermeskeil HKL16_10. The pitted structure does not result from gas vesicles, rather it is caused by the facilitated erosion of altered feldspars (Image: J. Gätjen).

All measured feldspars of type 1 are consistently sanidines (Or_{68}). Some of them show twinning and growth zoning. The feldspars of type 2 are completely sericitized and kaolinitized. In grains of both types, authigenic growth of sodium-free potassium feldspars (Or_{99}) is common. The quartz grains are corroded and cathodoluminescence observation displays intensive growth zoning and bays formed by previous inclusions. The mica occurs as mainly to completely opaque sheets of phlogopitic biotite which is only slightly altered to chlorite. From 10 microprobe analyses, the biotite formula can be calculated as:

$(K_{1.79}Na_{0.06}Ca_{0.01})(Fe^{2+}_{1.9}Mg_{3.04}Al_{0.15}Ti_{0.56}Mn^{2+}_{0.02})[(Si_{5.53}Al_{2.47})O_{20}](OH)_4$

Their distinctive opacity is caused by iron- and titanium oxides which cover and pervade the mica-grains and also occur in large amounts in the matrix. Other accessory minerals are zircon and apatite. The matrix is completely devitrified and consists mainly of micro-grained feldspar and quartz. Several of the phenocrysts appear to be fragmented. A directional structure was not recognized in the sample, either macroscopically or microscopically (Gätjen 2017).

Based on its fabric and the whole rock composition (Table 2), the rock can be classified as a potassium feldspar rhyolite (Le Maitre *et al.* 2002; Streckeisen 1974).

Table 2. Bulk rock composition of the rhyolite quern (Sample HKL16_10) from Hermeskeil. Fe is given as Fe_2O_3(total).

Oxide	**wt%**	**Element**	**µg/g**	**Element**	**µg/g**
SiO_2	73.0	S	161	Zn	66
TiO_2	0.26	Cl	1252	Ga	41
Al_2O_3	13.7	V	51	As	34
Fe_2O_3(t)	1.72	Cr	38	Rb	383
MnO	0.017	Co	28	Sr	76
MgO	0.34	Ni	13	Zr	121
CaO	0.18	Cu	15	Ba	179
Na_2O	0.7				
K_2O	10.1				
P_2O_5	0.026				

In comparison to basic lavas, rhyolite was less frequently used for the production of querns. No rhyolite was found amongst the querns from the *oppidum* of Bibracte (Boyer *et al.* 2006; Jaccottey 2014c). Boyer & Fronteau (2011) describe the quarry "Fossottes" at La Salle (Vosges; also described as Nompatelize rhyolite in the geological literature; Rocci & Chrétien 1963) as a quasi-unique deposit for rhyolitic querns. This site has been the subject of numerous research projects (Boyer 2007; Farget & Fronteau 2011; Gravier 1825; Hamon *et al.* 2011; Lagadec 2008) and is considered to be the only known site in France where this type of rock was mined for the production of Roman querns. Farget & Fronteau (2011) describe a porphyritic volcanic rock with numerous mm-sized phenocrysts in a pink to violet matrix. The phenocrysts are corroded quartz, white feldspar, which is strongly altered, and dark mica associated with iron oxides (Figure 6). The mica grains are slightly aligned, forming a flow-texture. The rock is a suitable material for querns because of a pronounced diversity in the hardness of its mineralogical components. The necessary roughness results from the resistant quartz grains, and the cavities result from the abrasion of the altered and decomposed feldspars. According to Farget & Fronteau (2011), these particular properties distinguish the rhyolite of La Salle from other rhyolites in the Vosges (like Blacherupt and Nideck-Wisches). Hence, so far it can be assumed that only the rhyolite of La Salle-Nompatelize supplied a material which was suitable for the production of querns (Farget & Fronteau 2011). However, as other Devonian-Permian rhyolite deposits occur in a wider range around Hermeskeil, other sources come into focus. It is important to note that rhyolites occur in a huge number and variety in the Saar-Nahe-basin (Bad Kreuznach, Nohfelden) and the nearest outcrop of the

Nohfelden rhyolite is situated just 13 km from Hermeskeil (Arikas 1986; von Seckendorff *et al*. 2004).

However, most of these rhyolites can be excluded as a source of querns for one or several of the following reasons:

(a) Many rhyolites exhibit an extreme cleavage, hence no pieces big enough to produce a quern could be mined.

(b) A large number of rhyolites are free or poor of phenocrysts and thus unusable for querns as the necessary hardness-differences within the raw material are not present. Nohfelden-rhyolite mentioned above is an example of a generally phenocryst-poor rhyolite and is therefore not included in the following analyses.

(c) Apart from extreme hard phases like quartz, the occurrence of very soft phases like altered feldspars (clay minerals, chlorite, sericite) might also enhance the quality of a rhyolite quern: The soft inclusions erode and cause pits that would lead to an ideal abrasive surface, as is the case with vesicular lavas.

No querns made of Permian rhyolites from the Saar-Nahe region (Bad Kreuznach, Nohfelden) have yet been identified. However, the extraction of rhyolite for quern production in the La Tène period is described for the Dossenheim rhyolite, on the eastern side of the Rhine valley (6 km north of Heidelberg), some 125 km away from Hermeskeil (Hüneke & Wieland 2015; 2016). Querns from Dossenheim have been found in *oppida* in southern Germany.

Both, macro- and microscopically, the rhyolite of La Salle-Nompatelize and the rhyolite fragment from Hermeskeil show great similarities in their petrographic characteristics, as *e.g.*, amount, type, size and shape of phenocrysts (Figure 6). The total amount of phenocrysts is an especially important parameter for ruling out many other potential rhyolite sources. With more than 20 vol% phenocrysts, the La Salle-Nompatelize rhyolite and the Hermeskeil quern fall in the same phenocryst-rich group. The presence of two types of potassium feldspars as phenocrysts is typical for the La Salle-Nompatelize rhyolite (Rocci & Chrétien 1963) and can be also observed in the Hermeskeil quern. The pronounced alteration of one of the two feldspars is also notable in both rocks. In addition, both contain corroded quartz and early-magmatic opacified biotite. The matrix is completely devitrified.

However, it cannot be excluded that other rhyolite-deposits have similar petrographic characteristics as the La Salle rhyolite (*e.g.*, Arikas 1986; Schneider 1993). Hence, there is still a great need for more data from rhyolite deposits with properties comparable to the Hermeskeil sample, like the above mentioned Dossenheim rhyolite or the Bad Kreuznach rhyolite (*ca*. 60 km from Hermeskeil). Optical cathodoluminescence imaging of the internal growth structures of the quartz phenocrysts appears to be a powerful tool in future investigations at least to exclude other possible sources (Gätjen 2017). Growth zones, resorption structures (Müller & Thomas 2009; Schneider 1993) as well as the Ti-in-quartz thermometry in quartz phenocrysts (Huang & Audetat 2012; Thomas *et al*. 2010; Wark & Watson 2006) can be used to decipher the complex individual cooling history of a rhyolite.

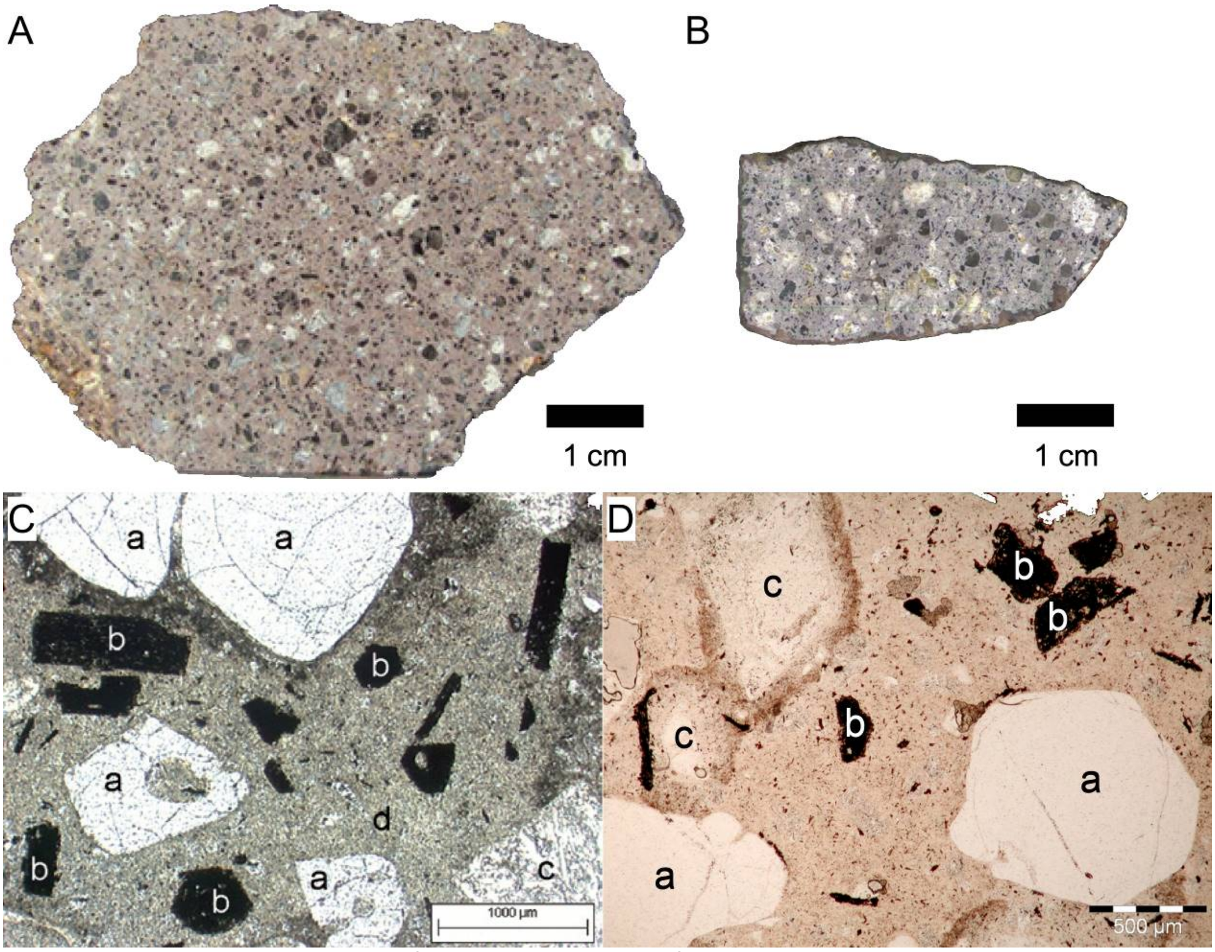

Figure 6. Macro- and micrographs of rhyolite: A: Rhyolite from La Salle - Nompatelize -, “Les Fossottes”, Vosges (Farget & Fronteau 2011). B: Rhyolite from Hermeskeil, sample HKL16_10 (Image: J. Gätjen). C: Rhyolite La Salle, thin section, plane-polarized light (Farget & Fronteau 2011). D: Rhyolite Hermeskeil thin section, plane-polarized light (Image: J. Gätjen). C, D: a=quartz, b=biotite, c=feldspar.

Geochemical data for the rhyolite of La Salle-Nompatelize are scarce. Arikas (1986) has studied the Permian rhyolite deposits in southwest Germany and the Vosges, including the rhyolite of La Salle. His investigation identified a number of characteristics for the Permian volcanic rocks of this region. Permian rhyolites show a large variation in their potassium content, ranging from about 2.5 wt% to 13 wt% K_2O. The rhyolite of La Salle and the Hermeskeil quern can be attributed to the high alkali group (Table 2; Figure 7). Taking the uncertainties of the small database (only one analysis of the La Salle-Nompatelize rhyolite and one rhyolite millstone from Hermeskeil respectively) and the non-representative sample aliquot for the quantitative analysis of the quern sample into account, the rhyolites of the Hermeskeil quern and La Salle-Nompatelize are similar. However, it needs to be stressed that samples from Bad Kreuznach and Dossenheim have a comparable geochemical composition. Although the Hermeskeil rhyolite quern cannot be assigned to a single deposit by geochemical data, the petrographic properties are most similar to the rhyolite of La Salle-Nompatelize. Moreover, this result is strongly supported by the large number of querns made of rhyolite from La Salle (Boyer & Fronteau 2011; Boyer *et al*. 2006), whereas for other rhyolite deposits, as Bad Kreuznach, a production has not yet been proven or, like Dossenheim, the total quantity so far appears to be small. Thus, it can be concluded that a provenance from La Salle in the Vosges is the most likely source of the Hermeskeil rhyolite.

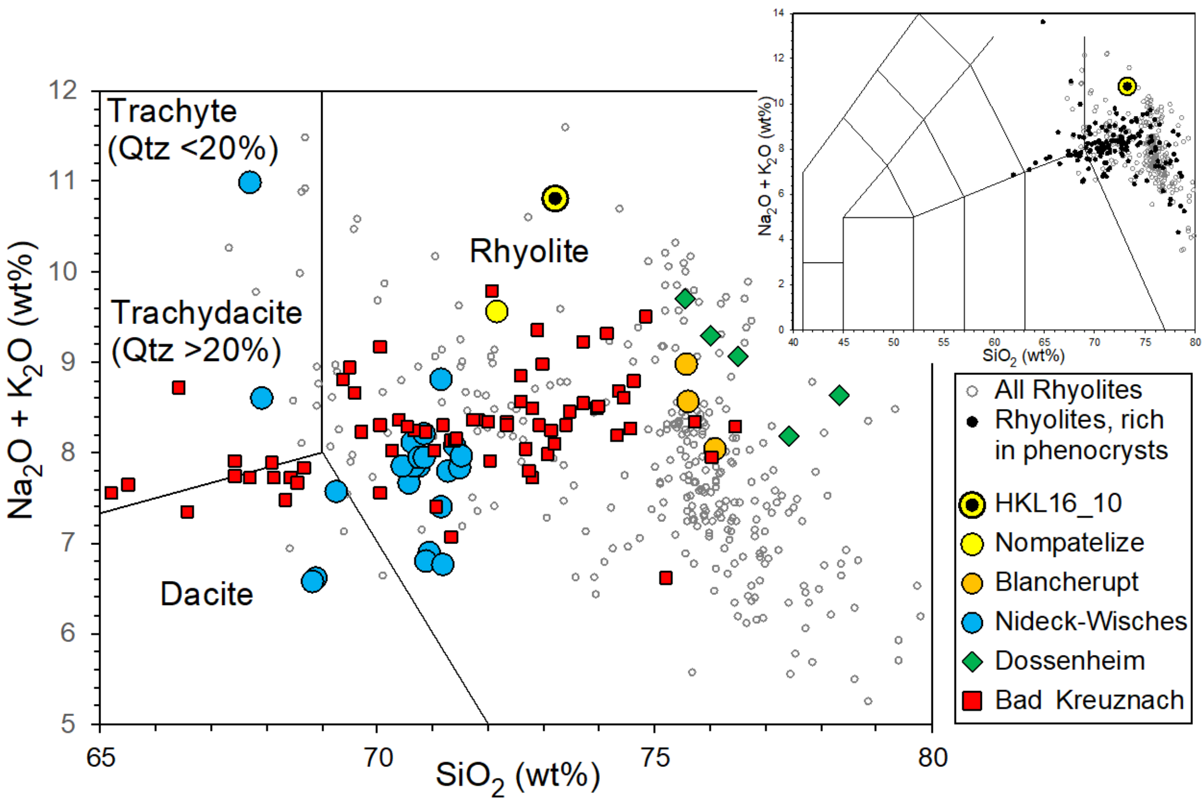

Figure 7. Chemical composition of the rhyolites in the TAS diagram (SiO_2 vs. $Na_2O + K_2O$). Quern from Hermeskeil (HKL16_10) and associated Permo-carboniferous rhyolite in the rhenohercynain and saxothuringian massifs of southwest Germany and eastern France (grey dots); Highlighted in colour: Saar-Nahe region (Bad Kreuznach), Rhine region (Dossenheim) and Vosges (La Salle = Nompatelize, Blancherupt, Nideck-Wisches) (Database: Arikas 1986). Inset: All rhyolite data discriminated by phenocryst-rich and phenocryst-poor varieties.

3.2. The provenance of the plutonic rock: Vaugnerite

One quern was made of a plutonic rock identified as vaugnerite. The material was extremely brittle due to post-depositional alteration and broke into small fragments during excavation (Figure 8).

The holocrystalline mesocratic rock mainly consists of subhedral to euhedral black mica and amphiboles, greyish-white feldspars and colourless anhedral quartz. It is even-grained with grains about 2-4 mm diameter. To a lesser extent, secondary-phase chlorites and accessory apatite and zircon are present. Mica is present as stacks of phlogopitic biotite (Figure 9), rich in apatite and zircon inclusions, and makes up 30-35 vol% of the rock.

The average formula of the biotite can be calculated as:

$$(K_{1.79}Na_{0.03}Ca_{0.01}Ba_{0.02})(Fe^{2+}_{1.7}Mg_{3.42}Al_{0.29}Ti_{0.31}Mn_{0.02}Cr_{0.02})[(Si_{5.67}Al_{2.33})O_{20}](OH,F)_{3.98}Cl_{0.02}.$$

Alteration of biotite to chlorite due to depositional conditions results in K loss and formation of pseudomorphic chlorites. Feldspars consist mainly of plagioclase (An_{25} to An_{68}) with intensive twinning and growth zoning. They make up 25-35 vol% of the rock and exhibit sericitized centers. Very few feldspar grains are alkali feldspars (Or_{84} to Or_{94}), *ca.* 5 vol%). Quartz grains are nearly pure SiO_2 and account for 15-20 vol% of the rock and show wavy extinction patterns under polarized light. Amphiboles are actinolites *sensu lato.*

$(Na_{0.10}K_{0.04})(Ca_{1.82}Fe^{2+}_{0.10}Na_{0.03}Mn_{0.05})(Mg_{3.68}Fe^{2+}_{1.07}Al_{0.21}Ti_{0.03}Cr_{0.01})(Si_{7.65}Al_{0.35})O_{22}(Cl_{0.01}OH_{1.99})$ and make up 10 vol% of the rock (Breedveld 2015).

Figure 8. Vaugnerite quern in situ. Note the dark colour of the plutonic rock, caused by the high amounts of dark mica in the rock (Image: D. Rieth).

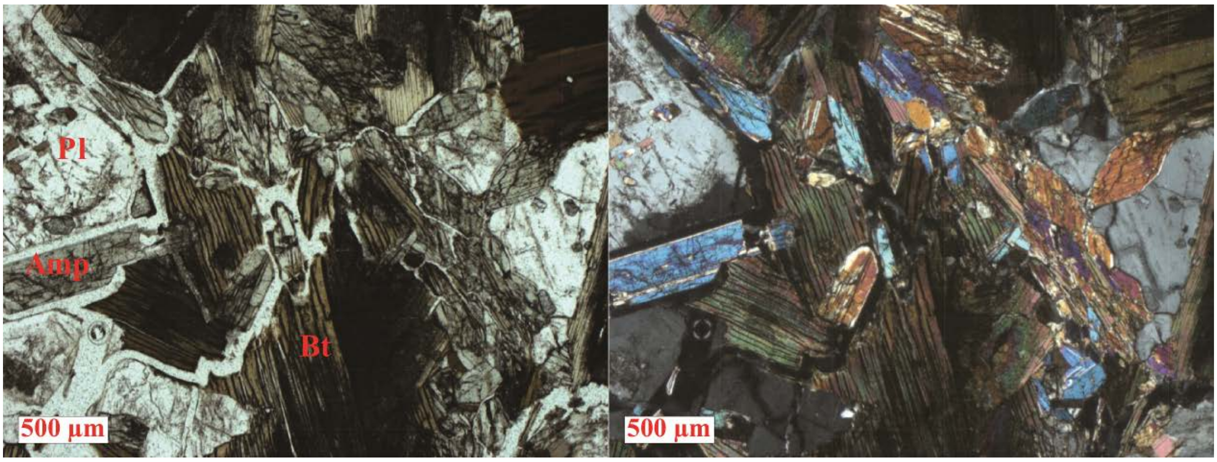

Figure 9. Photomicrographs of the vaugnerite in polarized light plane polarised light (left) and crossed polarisers (right) showing amphiboles (Amp), biotite (Bt) and plagioclase (Pl) (Image: G. Breedveld).

Based on the whole rock composition (Table 3), the rock is classified as (grano-) dioritic in the widest sense (Streckeisen 1974), although the high contents of K and Mg and the resulting high biotite and amphibole fraction in combination with SiO_2 oversaturated conditions are unusual. Such combinations of a magnesio-potassic plutonite are found only in very specific rock types such as selagites, minettes, kersanites and vaugnerites (Le Maitre *et* *al*. 2002; Wimmenauer 1985). Vaugnerites are described as mesocratic plutonic rocks with intermediate SiO_2 contents (55-70 wt%) and a MgO/CaO ratio >1, which is usually found in lamproites and calcalcalic lamprophyric rocks only. They are rich in incompatible trace elements, though very little data on rare earth element contents and isotopic ratios exist. Vaugnerites form a group with redwitzites and durbachites that have a similar chemistry, but different textures and provenances. These vaugnerites *sensu lato* are associated with the European Variscan Basement and are found in the Massif Central, the Black Forest, the Western Alps, Galicia, Corsica and the Bohemian Massif (von Raumer *et al*. 2014). While vaugnerites *sensu stricto* are associated with locations in western Europe, durbachites are found in the central European low mountain ranges and redwitzites within the Bohemian Massif (Sabatier 1991). According to Sabatier (1991), every single vaugnerite body has its own architecture and subsequently its own texture, which yields an additional proxy for provenance studies.

Table 3. Whole rock composition of the vaugnerite. Fe is given as Fe_2O_3(total). LOI: Loss on ignition. Sample HKL12_03.

Oxide	wt%	Element	µg/g	Element	µg/g
SiO_2	54.0	Sc	15	Nb	19
TiO_2	1.033	V	136	Mo	1.7
Al_2O_3	13.47	Cr	528	Ba	1630
Fe_2O_3(t)	6.90	Co	27	La	17
MnO	0.105	Ni	158	Ce	37
MgO	7.42	Cu	10	Nd	28
CaO	3.64	Zn	90	Sm	6.5
Na_2O	1.89	Ga	20	Yb	1.4
K_2O	3.81	Rb	190	Hf	4.8
P_2O_5	0.481	Sr	424	Pb	23
LOI	6.59	Y	21	Th	15.6
Total	99.34	Zr	207	U	3.9

According to the suggestions by Williams-Thorpe (1988) and Boyer & Fronteau (2011), the main element distribution and petrographic identification allows the vaugnerite sample to be assigned to central France. An assessment of large-scale textures was not possible because the samples are very small. Trace element data for vaugnerites is, as mentioned, very rare and therefore unfeasible for provenance determination. Boyer *et al*. (2006) have made a first effort to catalogue querns from France and list the vaugnerite quarries from Saint-Andeux (northern Morvan, Burgundy) as the only known mining and processing location. Jaccottey (2013a, 2013b; 2014a) has identified 12 quarries of variable sizes in this area, some even containing quern roughouts in various processing stages. Several querns excavated at the Bibracte *oppidum* could be provenanced to these quarries (Jaccottey 2014b; 2014c). In addition, whole rock and mineral chemical data for vaugnerites from northern Morvan was published by Carrat (1969). Both the main element composition as well as the Fe/(Fe+Mg) ratios from biotites agree with the data for the Hermeskeil quern. Biotite Fe/(Fe+Mg) ratios can be used to fingerprint single plutonic bodies since they are alteration-resistant and depend on the oxygen fugacity within the magma at the time of pluton emplacement (Speer 1984) (Figure 10, supplementary data, S1). Surprisingly, biotites from rocks of one of the ancient quarries of St. Andeux (Bois de Joux) kindly provided by Luc Jaccottey (Jaccottey 2013a) are not in convergence with the vaugnerite-typical phlogopitic biotites of the Hermeskeil quern but are instead identical to biotites from the basic gneiss units of the northern Morvan (Delfour *et al*.

1988). The rocks in these quarries appear to be more variable so the Hermeskeil quern cannot be directly linked to the specified sampled outcrop. Nevertheless, a connection between the Hermeskeil quern to the northern Morvan vaugnerites and the finds from Bibracte is likely.

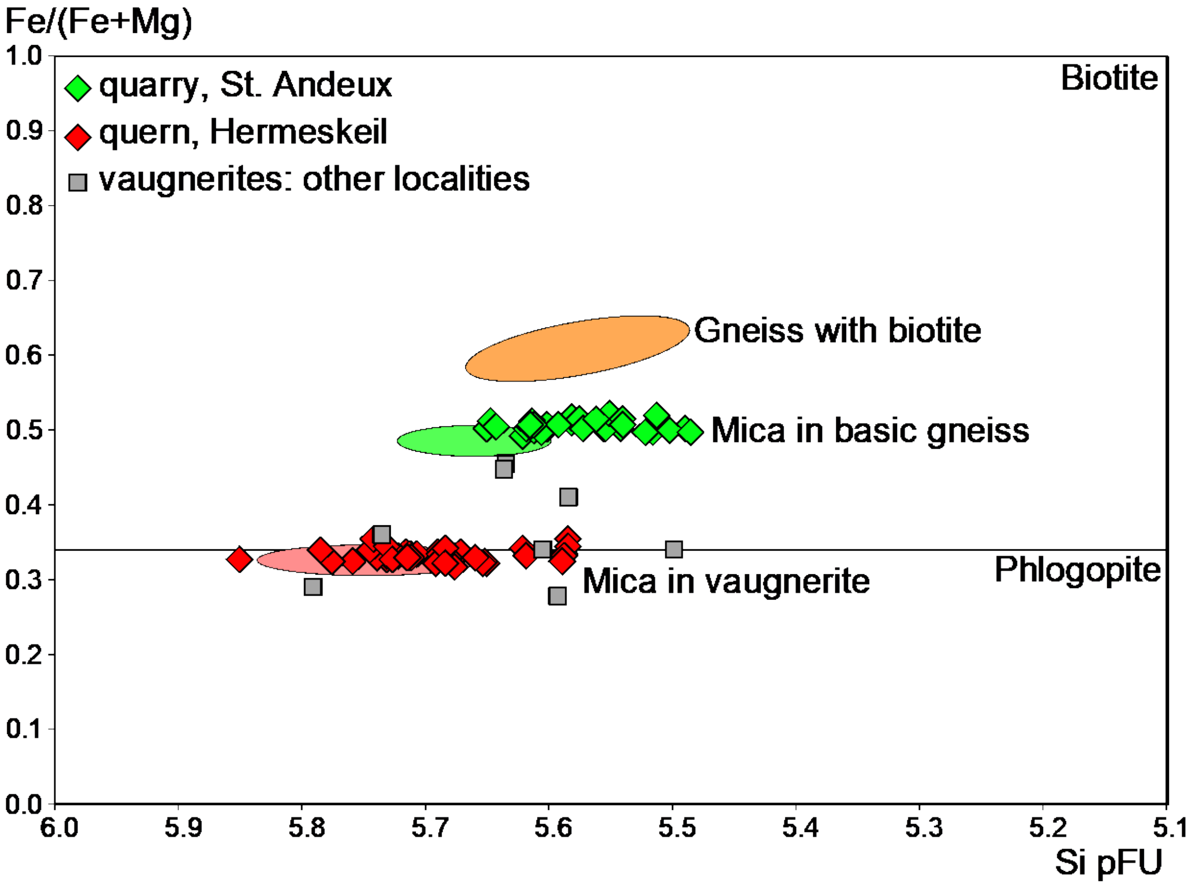

Figure 10. Composition of micas (phlogopite and biotite), Si per formula unit (pFU) *vs.* Fe/(Fe+Mg) (atoms): The biotite composition of the Hermeskeil vaugnerite is in concordance with micas of Morvan vaugnerites (Delfour *et al.* 1988), whereas the investigated micas from the quarry of St. Andeux exhibits a more gneiss related composition. Mica from other vaugnerite deposits exhibit a larger variation (Data: Puziewicz 1988; Sabatier 1980; 1991).

3.3. Querns made of sedimentary rocks

3.3.1. Arkoses

Three fragments of two querns are related to coarse grained arkoses containing high amounts of white to greyish fresh feldspars. A lower stone (*meta*) of a quern has a diameter of approximately 40 cm (Figure 11).

The provenances of the arkoses are not yet clear. Although ancient quarries of Permo-carboniferous conglomerates and arkoses exist in the vicinity of Hermeskeil, the petrographic composition of these rocks does not correspond with the querns (Kronz & Hornung 2010).

A possible source of these rocks might again lie in the Vosges, in the region of the Permian basin of Ville, or, even more likely, in the Triassic sediments in the Bourgogne, around Autun, close to Bibracte (Jaccottey 2013a). In the current state of research, a clear provenance is not possible, however, it should be noted that the great majority (74%) of the querns from Bibracte are sandstones and arkoses (Boyer *et al.* 2006). Thus, although no comparative analyses have been conducted yet, together with the vaugnerite find, the possible source for the arkoses in the region of the Bibracte *oppidum* so far seems likely.

Figure 11. Lower stone (*meta*) of a quern made of a lithic arkose (Image: J. Gätjen).

3.3.2. Pebble-rich carbonate rock

Several fragments of an impure (pebble-rich) carbonate rock were excavated at Hermeskeil. Due to differences in texture and petrographical details, it can be said that they are from at least two different querns. Because of the extremely aggressive depositional environment created by acidic soils on a Devonian substrate (quartzite, sandstone, schist), no original surface was preserved. It appears that the fragments have lost a surface layer of several mm.

The carbonate fraction of the rock is composed of a sparry calcite cement containing bivalve shells, cortoids and echinoderms, the latter indicating a marine environment. The preservation of cortoids imply diagenesis conditions related to a Tertiary or Cretaceous age. The terrigenous fraction consists of different lithoclasts, quartz and feldspar grains with an average size of several mm. These large detrital grains indicate a high energy coastal sedimentation environment. Such deposition conditions of carbonates can be found in a huge number of Tertiary formations, as in the Alpidic forelands, the Paris Basin, and numerous graben structures in central and southern France. Deposits of impure carbonates were quarried for querns in several regions (Anderson 2006; Boyer & Fronteau 2011; Longepierre 2006). In the current state of research, a clear preference for one of the sites cannot be proposed, and further investigation is necessary.

4. The evidence from the querns

The provenance analysis of the Hermeskeil querns illustrates clearly that some of them were discovered far from their production sites and areas of distribution as far as these are currently known. Only Mayen rotary querns of Late La Tenè type are found frequently in Late Iron Age settlements in the region and it cannot be ruled out that these querns were brought to the camp from a nearby settlement. Therefore, the Mayen querns are of no help in resolving the date of the Hermeskeil camp. In addition, Roman forces campaigned within the distribution area of Mayen querns on several occasions from 55 BCE onwards so there were plenty of opportunities to acquire these querns from merchants, by exchange or through plunder after that date.

The quarries at Cap d'Agde were located in the territory of the Roman province of *Gallia Transalpina* (Figure 12) which functioned as the main base of operations during the Battle for Gaul. Some of the legionaries who served in the war were even recruited from the province (Caes. Gal. 1.7.2). Therefore, it comes to no surprise that the quarries at Cap d'Agde provided the army with small and light querns that were used on campaign. Although it cannot be ruled out that the Hermeskeil quern from Cap d'Agde was acquired at some later stage of the conquest - there were troop movements that make this possible but it could also have been brought by auxiliaries or new recruits that were added to the legions each year to return them to strength - it may well be a relic of the equipment that a part of Caesar's army was equipped with at the start of the war.

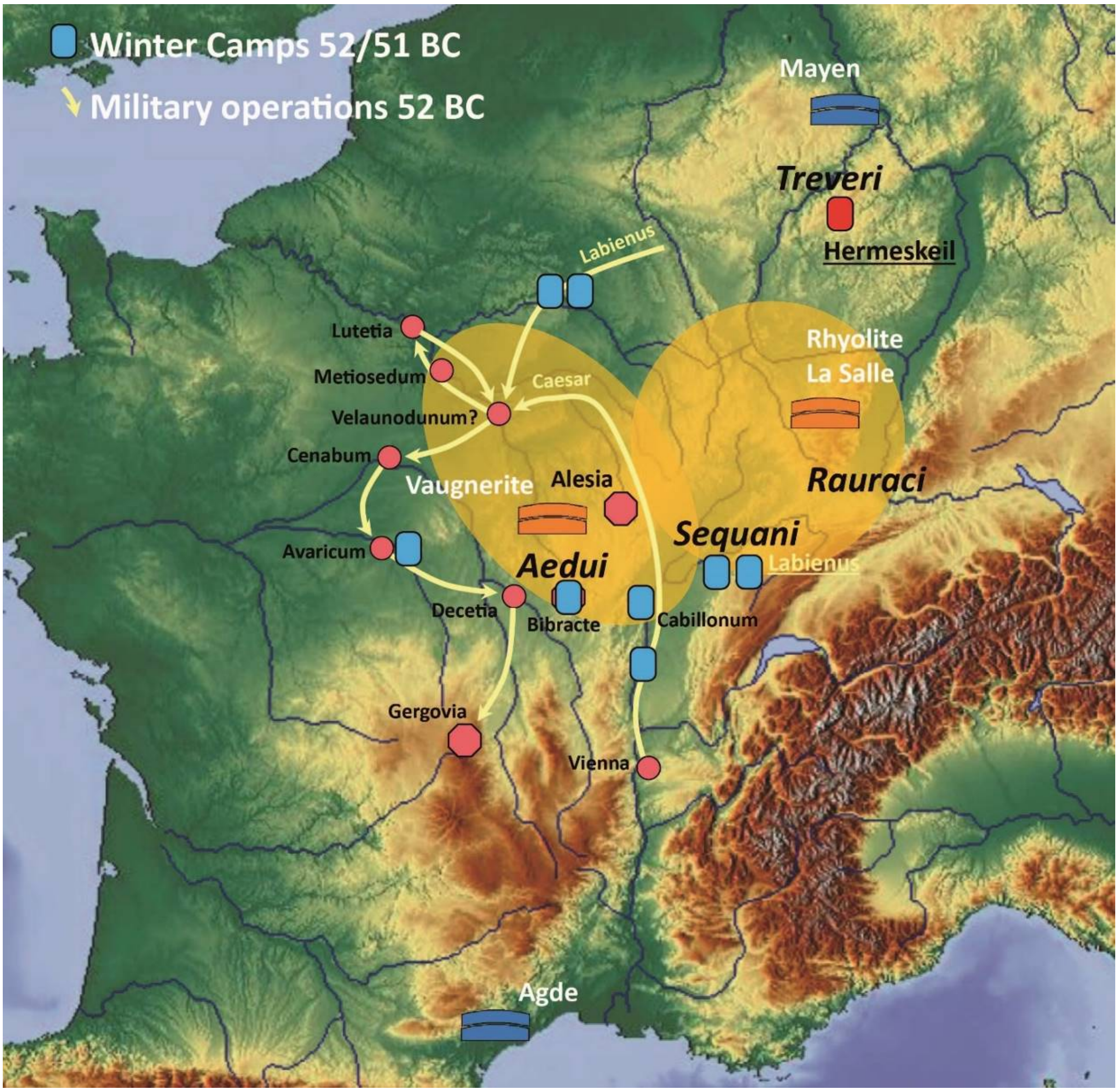

Figure 12. Map of the Roman military campaigns in 52 BCE, location of winter camps 52 to 51 BCE (blue squares) and sites from the Roman campaign in 52 BCE (red dots, large red dots mark the sites with an extended Roman occupation) in relation to the provenance of the querns discovered in Hermeskeil. Yellow ovals: distribution areas of vaugnerite querns from the Northern Morvan and La Salle rhyolite querns (Image: A. Kronz, S. Hornung, base map: OpenStreetMap contributors 2017).

The Late La Tène type quern made from vaugnerite from northern Morvan gives a more important clue to the date of Hermeskeil. Being made of an inferior raw material, at least compared to vesicular lava, these vaugnerite querns came from a quarry distributing querns on a regional scale (Boyer & Fronteau 2011; Boyer *et al.* 2006: 10-12) over an area *ca.* 200-300 km across between eastern Burgundy (Châlons-sur-Saône) and the southern Ile-de-France (Châteaubleau). This area also encompasses northern Burgundy (Alésia, Sens, Vertault) and the southern Champagne (Troyes). At Bibracte, capital of the *Aedui*, about 15% of the querns found at the *oppidum* consist of vaugnerite. Thus, only Roman troop movements in central eastern Gaul (either of legionaries and, or auxiliaries) before Hermeskeil was built can account for the presence of the vaugnerite quern at this site. The same is true of the rhyolite quern from La Salle, another quarry whose products were potentially distributed on a regional scale. The distribution of Late La Tène type querns made of La Salle rhyolite extends between the south-eastern territory of the *Mediomatrici*, the upper Saône valley and the north-western part of the territory of the *Leuci*, with a noticeable concentration in Lorraine (Boyer *et al*. 2006: 8-10), indicating that the Hermeskeil quern must have been acquired somewhere in this distribution area.

5. Synthesis

In order to establish precise dating evidence for the Hermeskeil camp, we need to consider exactly when the Roman army moved within the distribution areas of these querns. Only the quern from Cap d'Agde may have been part of their original equipment; all others must have been acquired during campaigning, like for example, the Mayen querns from 55 BCE onwards. Alternatively, they were brought to Hermeskeil by auxiliaries recruited from Gaulish tribes to support the legions during the conquest. It can hardly be considered a coincidence that the distribution areas of vaugnerite and La Salle rhyolite are both in eastern Gaul and that they partly overlap there. After the first year of the Battle for Gaul (58 BCE) this region only became a focus of campaigning again in 52 BCE (Hornung 2016: 478-482). Only then would there have been another possibility to acquire querns from northern Morvan or La Salle for any soldier in the Roman legions. Of particular importance in this regard is the location of the winter camps. The legate Titus Labienus and two legions spent the winter of 52 to 51 BCE amongst the *Sequani* in the Saône-Doubs region (Caes. Gal. 7.90.4). Labienus then conquered the *Treveri* the following summer, in 51 BCE, and at least some of these troops will have been with him in that campaign. There is a strong possibility that those soldiers would have been equipped with at least some querns from central and eastern Gaul. But there are other winter camps too that were located in the distribution area of vaugnerite querns. On the other hand, the querns from vaugnerite and rhyolite could also have been brought to Hermeskeil by auxiliaries recruited from tribes in central and eastern Gaul. The latter would certainly have to be expected as a measure to pacify Gaul after the revolt of Vercingetorix in which, among many others, *Aedui* and *Sequani* both took part (De Bello Gallico: 7.63.5-8). There is a strong chance that auxiliaries from those tribes would have been equipped with some vaugnerite or La Salle querns. At any rate, in order to account for the provenances of all the different querns, the camp should, in all probability, have served as Roman military base during the final year of the conquest. It is more than likely that Hermeskeil can thus be considered the very military base from which Caesar's general Titus Labienus conquered the *Treveri* in 51 BCE.

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Data accessibility statement

The authors confirm that the data supporting the findings of this study are available within the article and its supplementary files. A complete database is available in Kronz *et al*. 2023: https://doi.org/10.5880/fidgeo.2023.042.

List of supplementary files

Supplementary file 1
“Hornung et al. - Supplementary file 1 - Sample data.xlsx”
Chemical composition of phlogopite/biotite in vaugnerite and related rocks (St. Andeux).

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Die Handmühlen aus dem römischen Militärlager in Hermeskeil (Rheinland-Pfalz): Ein Brückenschlag zu Caesars *De Bello Gallico*

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Abstrakt:

Das spätrepublikanische Militärlager von Hermeskeil (Rheinland-Pfalz) ist eine der wenigen bekannten archäologischen Stätten aus dem Gallischen Krieg und kann direkt mit den historischen Aufzeichnungen in Caesars *De Bello Gallico* in Verbindung gebracht werden. Unter den zahlreichen Funden befinden sich Fragmente mehrerer schlecht erhaltener Mühlsteine, deren Provenienzen wertvolle Hinweise auf die Datierung des Lagers liefern. Im Gegensatz zum Material aus zeitgleichen Siedlungen in der Region bestehen die Mühlsteine von Hermeskeil aus einer ungewöhnlichen Vielfalt verschiedener Gesteinsarten. Um die Provenienzen zu bestimmen, wurden an den bis 2017 gefundenen Fragmenten der mineralogische Modalbestand, die geochemische Zusammensetzung des Gesamtgesteins sowie die mineralchemische Zusammensetzung analysiert.

Für solche Gesteine, bei denen eine pauschalchemische Analyse sinnvoll erschien, wurde diese mit der Methode der wellenlängendispersiven Röntgenfluoreszenzanalyse durchgeführt.

Die damit erhaltenen Haupt- und Spurenelementkonzentrationen liefern besonders für die basischen Vulkanite eine gesicherte Provenienzzuordnung, auch weil für diese Gesteinsgruppe eine umfassende Datenbasis der verschiedenen Vorkommen existiert.

Von den Gesteinsfragmenten wurde polierte Dünnschliffe für polarisationsoptische, Elektronen- und Röntgenstrahl Untersuchungsmethoden hergestellt. Neben der lichtoptischen Mineral- und Gefügebestimmung ist besonders die Mikrobereichsanalyse der verschiedenen Mineralphasen mittels Elektronen Mikrosonde wertvoll zur chemischen Diskriminierung spezifischer Minerale.

Neben vesikulären basischen Laven, einem Rhyolith bestanden die Fragmente aus Sedimentgestein, sowie und plutonischem Gestein. Die Sedimentite liegen rein detritisch (Arkosen) oder als kiesige Karbonate vor. Ein vulkanisches Gesteinsfragment einer Legionärsmühle wurde aus Laven (Basalt bis Trachybasalt) vom Cap d'Agde in Südfrankreich hergestellt. Mehrere andere Drehmühlen des Spätlatène-Typs haben ihren Ursprung in Mayen in der Eifel (Phonotephrite). Bei dem plutonischen Gestein handelt es sich um Vaugnerit, ein seltenes Gestein mit granodioritischer Zusammensetzung, das über das Oppidum von Bibracte bis zu den Vorkommen im nördlichen Morvan (Burgund, Frankreich) zurückverfolgt werden kann. Der Rhyolith stammt aus La Salle in Ostfrankreich (Vogesen). Damit können alle Vulkanite aus dem römischen Militärlager von Hermeskeil den antiken Abbaustellen eindeutig zugeordnet werden. Für den Vaugnerit ist eine direkte Herkunft aus den antiken Steinbrüchen von Bois des Joux bei Saint Andeux (Morvan) aufgrund einer deutlich abweichenden Glimmerzusammensetzung auszuschließen, dennoch kommt die nähere

Umgebung des Morvan aufgrund verschiedener übereinstimmender geochemischer Merkmale als Liefergebiet in Frage. Für die Sedimentite bleibt eine Provenienzzuordnung weiter spekulativ. Die permischen Sedimente der Mittelgebirge im Burgund (Frankreich), wie das Massif de La Serre, St Èmiland - Bois de La Grange und die Vorkommen karbonatischer Ablagerungen des Tertiär am Rand des Massif Central widersprechen zumindest nicht einer möglichen Herkunft der Mühlen aus Sedimentiten aus diesen Regionen.

Mit Ausnahme der Mühlsteine aus vesikulärer Lava aus der Eifel ist keines der im Lager gefundenen Materialien von einer zeitgenössischen archäologischen Fundstelle rund um Hermeskeil im Hunsrück bekannt. Die Funde in Hermeskeil wurden vielmehr weit entfernt von ihren regulären Verbreitungsgebieten entdeckt. Sie spiegeln daher unmittelbar die militärischen Versorgungsstrukturen sowie die Truppenbewegungen wider, denn während der Feldzüge Caesars mussten beschädigte Stücke durch lokal verfügbare Produkte ersetzt werden. In einer Zeit, in der das römische Militär noch nicht auf eine gut funktionierende Versorgungsinfrastruktur zurückgreifen konnte, birgt diese Fundkategorie das Potential, wichtige Informationen zu liefern, um den Standort Hermeskeil mit schriftlichen Quellen in Verbindung zu bringen. Es wird damit möglich, eine Nutzung des Lagers während Caesars Feldzug im Jahr 51 v. Chr. zweifelsfrei nachzuweisen, da sich das römische Heer erst im Jahr 52 v. Chr. im Verbreitungsgebiet aller in Hermeskeil vertretenen Mahlsteine bewegt hatte. Die Trevererfeldzüge der Jahre 53 und ganz besonders 51 v. Chr. sind von historischer Seite nur sehr lückenhaft überliefert. Unsere Provenienzstudien zu den Mühsteinen aus Hermeskeil erlauben nun erstmals eine nähere Lokalisierung dieser Ereignisse und eröffnen zudem auch ganz allgemein neue Potentiale für ein besseres Verständnis der caesarischen Truppenbewegungen.

Schlüsselwörter: Handmühlen; Vaugnerit; Rhyolith; Vulkanite; Provenienz; Römische Armee; Gallische Kriege