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Preliminary geochemical analysis of asbestos minerals from geological and archaeological contexts in Finnmark, north Norway

Evaluating the potential for sourcing tempers in asbestos ceramics

Bryan C. Hood, Erling Krogh Ravna, Trine Merete Dahl & Marianne Skandfer

Abstract

This is a preliminary study of the potential for sourcing asbestos minerals used as temper in ceramics from Early Metal Age sites in Finnmark, northern Norway. Energy dispersive spectroscopy (EDS/EDX) is used to analyze samples from geological sources and archaeological sites. Although tempers were highly portable, the results of the analysis mostly indicate local procurement, however non-local sources are possible in some cases.

Keywords: asbestos ceramics, Finnmark, Norway, sourcing.

4.1 Introduction

Asbestos-tempered pottery is one of the distinctive material culture attributes of Stone Age and Early Metal Age cultures in northern Fennoscandia and northwestern Russia. Mika Lavento has made significant contributions to the analysis of potential geological sources and the distribution patterns of asbestos tempers in Finland (Lavento & Hornytzkyj 1996), which served as an inspiration for this small study of asbestos materials from northern Norway. It was once thought that the asbestos used in north Norwegian ceramics was imported from southern Finland, but we now know there are sources in Finnish Lapland (Lavento & Hornytzkyj 1996: 52), northern Sweden (Hulthén 1991: 14), and in northern Norway as well (Simonsen 1985). This shifts the problem away from long-distance exchange to an understanding of how multiple sources were incorporated into regional and local procurement systems and social networks.

A persistent tendency in north Norwegian archaeology has been that whenever macro-regional variation in ceramic types has been observed, it is interpreted as reflecting the presence of different social identity groups (e.g. Olsen 1994: 129). However, the recognition of greater stylistic variability and a focus on different ceramic practices rather than types can direct our attention towards other sources of variability than regional identity groups (cf. Damm 2012). In particular, the defining attribute of this ceramic ware – the asbestos temper – has been little investigated in northern Norway. If the sources for these tempers can be identified there is potential for tracking raw material distributions, which could inform us about social networks on more localized scales than macro-regions.

We begin with a brief introduction to the archaeological problem, then review the geological properties of asbestos minerals, and outline where these minerals are known to occur or might be present in Finnmark, northern Norway. After an account of our asbestos samples from archaeological and geological sources, we present the results of an energy dispersive spectroscopy (EDS/EDX) analysis. We then discuss these results and provide an assessment of the possibilities for further research.

4.2 Asbestos-tempered ceramics

In northern Norway, asbestos-tempered ceramics appear ca. 2000 calBC and continue until ca. 300 calAD (Jørgensen & Olsen 1988; Skandfer 2011). In Finland the dates for the first asbestos-tempered ceramics are much earlier, ca. 4700 calBC (Pesonen 2021: 85–86). It would seem most likely that asbestos-tempered ceramics were introduced to northern Norway from Finland.

In north Norwegian ceramics, asbestos minerals occur as finely-crushed fibers disseminated throughout the ceramic paste – sometimes with a high proportion of asbestos to clay – as more sparsely disseminated fibers or fragments, or as thick "bars". The latter were sometimes placed around the outer rim of a pot, just below its lip, with clay being folded over them to create a thicker rim circumference (e.g. Hood & Olsen 1988: 113). Macroscopically, it is evident that a variety of asbestos minerals have been used, as the tempers vary in mineralogical structure and color. The functional purpose of adding asbestos to ceramics is uncertain. Asbestos may provide advantages in thermal resistance, and one interpretation has suggested that ceramics with high asbestos content may have been associated with metallurgy (Hulthén 1991: 16, 34–5).

Pieces of raw asbestos occasionally are found together with pottery on archaeological sites in Finnmark. In some cases, such as at Virdnejávri on the Alta-Kautokeino River (see below), the raw material was procured nearby the habitation sites. However, partially processed temper raw materials could easily be transported over considerable distances. Given that ceramic production seems to have been restricted to locations where there was access to appropriate clays, adequate wood for firing, and suitable summer weather conditions for drying the pots, temper raw materials were the most portable component of ceramic technology.

4.3 Mineralogy of asbestos

"Asbestos" is a generic category for a suite of different minerals, which broadly speaking can be divided into two classes. On the one hand is the hydrous phyllosilicates, which contain the serpentine group, represented by the fine fibrous asbestos chrysotile, and the clay mineral group, represented by talc, both hydrous magnesium silicates. Chrysotile occurs as fine, hair-like fibers, while talc has a foliated structure (thin, wafer-like layers), which can grade into the more compact and massive variant known as soapstone. The other main class of asbestos minerals is the amphibole group, hydrous inosilicates which form a solid solution series marked by substitutions between magnesium (Mg), iron (Fe) and calcium (Ca), the different proportions of which result in different minerals. Tremolite is enriched in

Ca and Mg and makes a series with actinolite by exchanging Mg with Fe^{2+}, anthophyllite is enriched in Mg, and actinolite has Ca, but varies in its amount of Mg and Fe (iron-rich variants are ferroactinolite). Hornblende is a more complex mineral with substantial amounts of aluminium (Al), related to tremolite and actinolite. Amphibole asbestos often has the macroscopic form of small rectangular bars or larger "staves", but it can also occur in the form of "rosettes".

4.4 Sources of asbestos minerals in Finnmark

No systematic field investigations for asbestos minerals in Finnmark have been undertaken by archaeologists, and it seems likely that many small occurrences of asbestos minerals have not been reported in the literature by geologists. Our current knowledge of asbestos sources is based on lucky archaeological find circumstances, the bi-catch of surveys directed towards cherts and quartzites, and combing the published geological literature. The following is a summary of what we know; the best-known geological sources are marked in Figure 4.1.

The largest bedrock sources of asbestos in Finnmark are found adjacent to the inland Lake Virdnejávri on the Alta-Kautokeino River, where they are found in metacarbonate rocks on the western side of the lake (Simonsen 1985: 6) and on the western side of the Virdneguoika rapids at the southern end of the lake (Johansen et al. 1984: 24; Simonsen 1985: 9). This asbestos presents as long fibers, hard "bars", and large rosettes, ranging in color from near white to dark green. Geological investigations

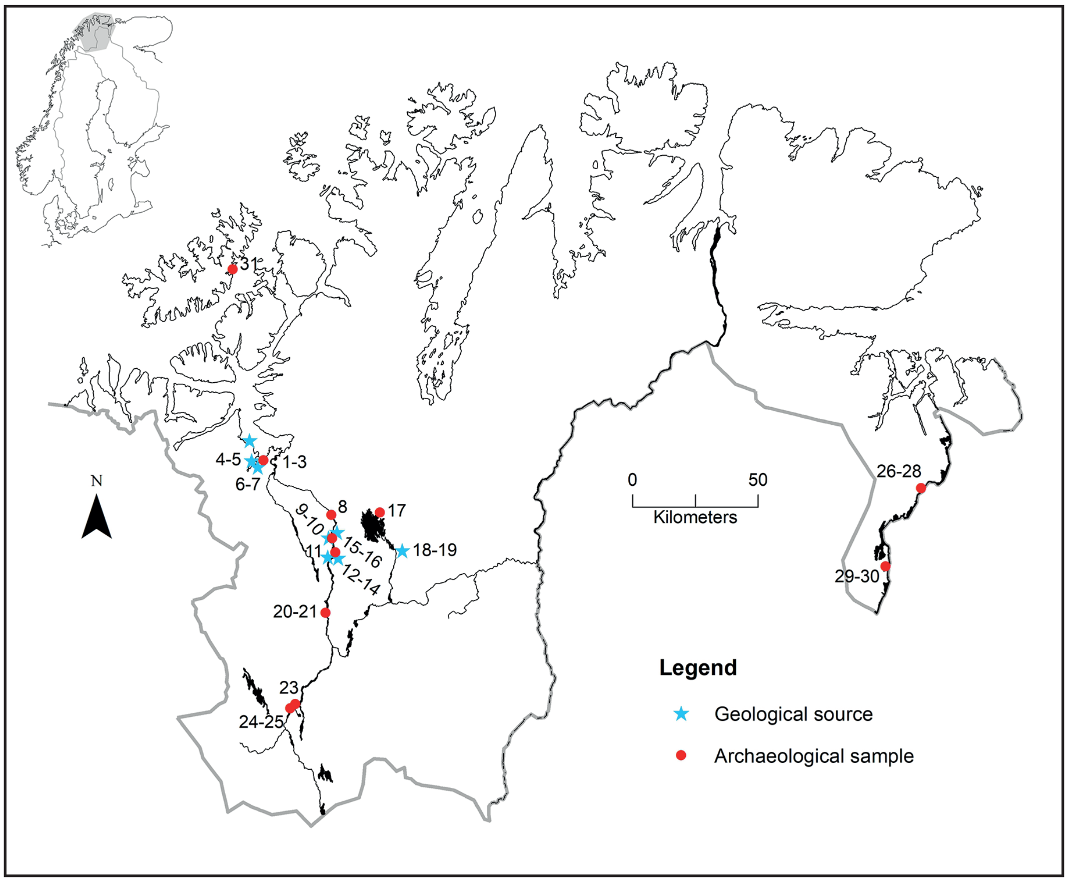

Figure 4.1. Map of Finnmark, with sample sites numbered as in Table 1. Map B. C. Hood, UiT.

also identified tremolite/actinolite in metacarbonates at the southeastern corner of the lake (Johansen et al. 1984: 24), as well as at the northeastern end of Virdnejávri, where it was associated with massive feldspathic rock. The large quantities of raw asbestos found on archaeological sites at Virdnejávri (e.g. Hood & Olsen 1988: 110) indicate that these sources were exploited prehistorically, and the many sherds of asbestos-tempered ceramics found on two sites at the lake suggest the pottery was produced locally, near the sources of the temper.

No other archaeologically investigated asbestos sources are known from inner Finnmark, but the geological literature suggests we can expect to find additional source localities. The asbestos deposits at Virdnejávri occur in the Suoluvuobmi Formation (Siedlecka et al. 1985), so similar occurrences might be found elsewhere in the formation, which extends from Iešjávri in the north to the Finnish border south of Kautokeino. Asbestos may also occur elsewhere in the Kautokeino Greenstone Belt, in metagabbro-sedimentary contact zones similar to those where asbestos has been identified in the Kvenvik Greenstone Formation on the coast at Altafjord. Siedlecka (1985: 109) reports tremolite rosettes in marble at Vuorji, northeast of Iešjávri. In the Karasjok Greenstone Belt, actinolite and tremolite are associated with amphibole-chlorite rocks inland from Lakselv, and more substantial occurrences there are found in metacarbonates (Davidsen 1994: 38–47, 84–8, 255). Asbestos of the serpentine and talc family may occur in the Karasjok Greenstone Belt in association with ultramafic rocks and serpentines, specifically komatiites (Henriksen 1983: 27; Karlsen & Nilsson 2000: 18–20). In the Kautokeino Greenstone Belt, soapstone and talcified ultramafic rocks occur east of Virdnejávri, and talcified rocks have been noted in the Alta River canyon and near Raisjávri, northwest of Kautokeino (Karlsen and Nilsson 2000: 20–21). At Sálteluoppal, near Lake Iešjávri in central Finnmark, asbestos fragments were found in a moraine deposit, suggesting there may be a bedrock source in the vicinity (Skandfer and Hood 2013: 8).

Asbestos minerals are also known from coastal Finnmark. Three locations with actinolite asbestos were discovered on the western side of Altafjord (Hood 1992: 394, 399). Near Kvenvikbukta, asbestos fibers occurred in small patches over a distance of 150 m in a metabasalt/carbonate contact zone, while smaller sources were observed in metabasalts or metagabbros at Møllenes and in a metagabbro/carbonate contact zone at Kråkneset. These localities occur in the Kvenvik Greenstone Formation, so there is potential for similar small occurrences of asbestos minerals at other places throughout the Alta-Kvænangen region, as well as in related formations in the Vargsund-Kvalsund area, where "aggregates" of tremolite were observed in dolomite (Øvereng 1996: 25–26, 28). On the island of Sørøya, tremolite and actinolite occur in metacarbonates (Roberts 1968: 18–20). Regarding the serpentine-talc family, Karlsen and Nilsson's (2000) review of talc mineral sources in Finnmark does not refer directly to asbestos minerals, but well-known deposits of soapstone are present in the Precambrian rocks of the coastal Sør-Varanger region in East Finnmark. Slightly inland, on the Russian side of the Pasvik River, chrysotile associated with serpentines were documented near the Kolosjohka River in the Nikel region (Hausen 1926: 70, map supplement; Hood 1992: 374, 381–82). In coastal West Finnmark, talc-rich schists have been identified in several locations (Karlsen & Nilsson 2000: 21–22), and serpentinization processes have been observed on the island of Seiland (Sturt et al. 1980: 23).

4.5 Samples and analytical techniques

A total of 25 samples were submitted for geochemical analysis; of these, six were from geological sources, the rest from archaeological sites. Four of the archaeological samples were of asbestos embedded in ceramics, the remaining were prepared asbestos fibers. The archaeological samples were selected based

	Map No.	SiO_2	Al_2O_3	TiO_2	Cr_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	H_2O	species
Apana-1	1	54	0.94	0	0	16.26	0.36	13.77	12.03	0.5	0.09	2.05	Act
Apana-2-dark	2	54.3	0.95	0.11	0	15.75	0.33	14.1	11.84	0.5	0.06	2.06	Act
Apana-2-light	3	53.79	1.13	0	0	18.09	0.37	12.46	11.56	0.52	0.04	2.04	Act
Møllnes-dark	4	54.32	0.41	0	0.02	16.07	0.29	13.69	13.11	0.03	0.01	2.06	Act
Møllnes-light	5	51.82	1.32	0	0.01	22.49	0.52	9.12	12.43	0.07	0.23	1.99	Act
Kvenvik-dark	6	51.37	2.81	0.13	0.12	20.47	0.28	9.97	12.5	0.24	0.11	2.01	Act
Kvenvik-light	7	50.93	1.2	0	0	25.68	0.72	6.82	12.37	0.13	0.19	1.95	Act
Cavco-ic	8	57.53	1.38	0	0	1.86	0.17	23.04	13.53	0.28	0.02	2.19	Tr
Virdnejavri-S-1 dark	9	55.78	2.59	0.03	0.08	4.22	0.1	21.21	13.3	0.49	0.03	2.17	Act
Virdnejavri-S-2 light	10	49.97	8.24	0.12	0.06	6.54	0.08	18.27	12.95	1.49	0.15	2.12	Hbl
Virdnejavri-SV	11	58.56	0.6	0.04	0.02	0.8	0	23.96	13.65	0.04	0.12	2.21	Tr
Virdnejavri-112-avb	12	58.2	0.91	0	0	1.3	0.13	23.55	13.42	0.19	0.1	2.2	Tr
Virdnejavri-112-bfz	13	58.54	0.51	0.03	0	1.04	0.07	23.92	13.4	0.2	0.08	2.21	Tr
Virdnejavri-bxh	14	54.12	2.26	0.13	0	11.32	0.08	17.07	12.51	0.33	0.09	2.1	Act
Barjesuolo-li-2	15	58.31	0.16	0.09	0	11.58	0.39	26.86	0.31	0.07	0.05	2.18	Anth
Barjesuolo-li-1	16	57.02	1.93	0.1	0	1.84	0.21	22.99	13.45	0.21	0.05	2.19	Tr
Gasadaknjarga	17	43.32	1.49	0	0	7.45	0.05	34.69	0.2	0.16	0	12.65	Serp
Salteluoppal-1	18	57.22	1.43	0	0.28	6.06	0.12	20.74	11.71	0.27	0	2.17	Act
Salteluoppal-2	19	61.86	0.51	0	0.11	5.68	0	26.81	0.22	0.17	0	4.63	Talc
Habatguoika-1	20	42.75	1.07	0	0.6	3.48	0.12	39.12	0.05	0	0	12.81	Serp
Habatguoika-2a	21	59.77	0.17	0	0	8.17	0.57	28.95	0.15	0	0	2.22	Anth
Habatguoika-2b	22	62.96	0	0	0	1.56	0	30.6	0	0.17	0	4.72	Talc
Njallajavri	23	58.54	0.16	0	0	10.13	0.38	28.23	0.27	0.09	0	2.2	Anth
Guosmarjavri af	24	58.21	0.08	0	0	11.25	0.37	27.53	0.32	0.05	0	2.19	Anth
Guosmarjavri-æ	25	59.37	0.16	0.1	0	7.42	0.35	29.96	0.32	0.1	0	2.23	Anth
Melkefoss-dark	26	55.87	0.52	0	0	9.63	0.27	18.2	13.3	0.07	0.02	2.12	Act
Melkefoss-intermed	27	55.36	0.82	0.06	0	12.41	0.22	15.94	12.9	0.14	0.05	2.09	Act
Melkefoss-c-light	28	54.2	0.88	0.07	0	15.15	0.43	14.2	12.76	0.18	0.07	2.06	Act
Noatun-Neset-u-1	29	58.85	0.23	0.05	0	7.98	0.26	29.83	0.45	0.1	0.03	2.22	Anth
Noatun-Neset-u-2	30	62.76	0	0	0	2.75	0	29.63	0	0.17	0	4.69	Talc
Slettnes-hus-81	31	43.46	1.87	0.1	0.21	5.2	0	36.32	0.05	0	0	12.78	Serp

Table 4.1. Results of the energy dispersive spectrographic analysis (EDS). Species abbreviations: Act – actinolite, Tr – tremolite, Hbl – hornblende, Anth – anthophyllite, Serp – serpentine.

on a visual inspection of variation in color and structure for all known asbestos from prehistoric sites in interior Finnmark. The majority of the samples were from western Finnmark – the Alta-Kautokeino watershed, Altafjord, and Sørøya – with a few "control samples" from the Pasvik River Valley and adjacent fjord basin in eastern Finnmark. Samples were primarily chosen from radiocarbon dated sites. In some samples individual grains of amphibole displayed chemical zoning, seen as lighter and darker areas in the electron microscope, so duplicate and even triplicate analyses were performed on these. The lighter areas were more iron-rich than the darker areas.

The geological and archaeological samples were prepared by embedding them in epoxy (Körapox 439, Kömmerling). The embedded samples were then ground by hand on a glass plate using 600 grit silica carbide powder in water, after which they were polished with 6, 3 and 1 µm diamond paste (Buehler MetaDi Ultra) on a Buehler Phoenix Beta polishing machine. The samples were cleaned ultrasonically and rinsed with alcohol between each step and after the final 1 µm polishing. The polished samples were then coated with carbon to provide a conductive sample surface for scanning electron microscopy (SEM).

Compositional data were collected through maps and spectra obtained by using a Zeiss Merlin Compact VP SEM equipped with an energy dispersive x-ray spectroscopy (EDS) x-mas 80 system by Oxford Instruments, combined with the analytical software Aztec, at UiT – The Arctic University of Norway (Tromsø). Two samples, one of pottery from Mestersanden, Kjelmøy, in East Finnmark and a geological specimen from Kråknes, Alta, West Finnmark, were omitted from the analysis because the initial identification revealed they did not contain asbestos, but quartz (SiO_2) and/or calcite ($CaCO_3$).

4.6 Results

Table 4.1 shows the results of the spectrographic analysis. The sample numbers are keyed to the map locations in Figure 4.1. The designation "species" is a classification of the results relative to the ideal structural formulas of the various asbestos minerals.

Within each mineral group the main difference in composition is seen as variations in the Fe/Mg ratio. Thus, a simple bivariate plot (Fig. 4.2) of these two elements gives us a good visual indication of the various mineral groups, and also shows overlaps of compositions between the archaeological and bedrock samples. The plot shows a clear separation of the samples into the amphibole, talc, anthophyllite and serpentine groups, with tremolite and actinolite as end-members in the amphibole group. All the geological samples from coastal sources in Altafjord are at the actinolite end of the amphibole group and these are the most Fe-rich samples. In contrast, the geological samples from the inland at Virdnejávri are Mg-rich and plot with the tremolite end of the amphibolite group. Most, although not all, of the archaeological samples are Mg-rich. The three archaeological samples from Apana gård in Altafjord are relatively high in Fe and are positioned close to one of the actinolite samples from western Altafjord (Møllnes), suggesting use of a local source. Four of the five samples from archaeological sites at Virdnejávri (Virdnejavri 112 and Virdnejávri 109 Barjesuolo) plot at the tremolite end of the amphibole spectrum, while one is midway on the tremolite-actinolite continuum. Most of the Virdnejávri archaeological samples lie close to the Mg-rich geological sample from the Virdnejávri Southwest bedrock source, as does the single archaeological sample from Čavčo, 10–15 km downriver from Virdnejávri. Again, use of the local sources is implied.

The three archaeological samples from Melkefoss, on the Pasvik River in East Finnmark, plot directly in the middle of the amphibole series. This suggests they were not procured from the serpentine

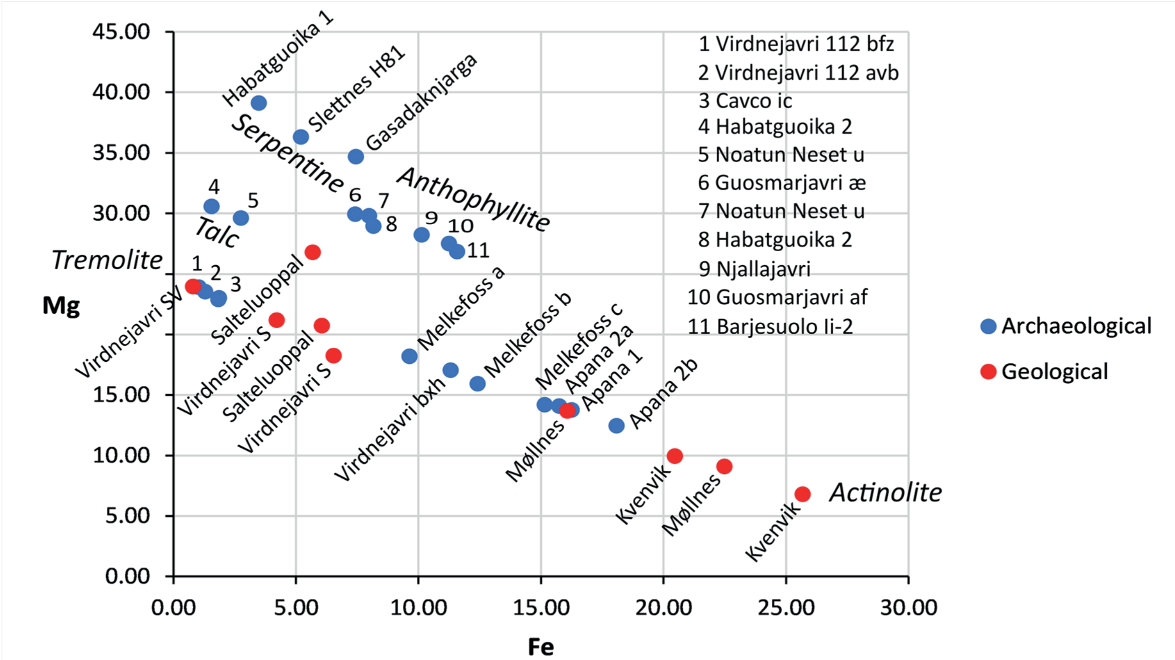

Figure 4.2. Graph showing the range of variation in Fe:Mg composition between the samples, with geological and archaeological samples distinguished. Graph E. K. Ravna & B. C. Hood.

chrysotile source in Russia near Nikel, or from possible sources associated with the coastal serpentine rocks.

The other mineralogical groups are more difficult to evaluate as we do not have any bedrock samples corresponding to these mineralogical species. The talc and anthophyllite groups include four archaeological samples from two sites along the upper Kautokeino River (Njallajávri, Guosmarjávri), two of three samples from a site on the middle reaches of the same river (Habatguoika), one of two samples from Virdnejávri 109 Barjesuolo, and one of two samples from the same moraine-deposited rock from Sálteluobbal on the Iešjohka River in central Finnmark. All could have local talc and anthophyllite sources in the Kautokeino and Karasjok Greenbelts. The sample from the Noatun Neset (House 1) site on the Pasvik River in East Finnmark was analyzed in two portions, one indicating talc, the other anthophyllite. The nearest documented talc/soapstone deposits to Noatun are located 80-100 km downriver in the coastal area near Kirkenes (Karlsen & Nilsson 2000: 16–7). The three samples belonging to the serpentine group are from archaeological sites at Slettnes (House 81) on the West Finnmark coastal island of Sørøya, Gasadaknjarga on Iešjávri in central inner Finnmark, and Habatguoika on the mid-reaches of the Kautokeino River. The nearest source of serpentines for the Slettnes sample may be the neighbouring island of Seiland, while neither of the inner Finnmark samples lie close to serpentine rocks documented in the geological maps.

4.7 Discussion

The analysis shows large variation in asbestos temper minerals, but with a systematic preference for Mg-rich variants. Mg makes the asbestos more heat resistant, whereas Fe-rich material expands more when heated. Heat resistance would have been a crucial quality to avoid cracking in the initial firing of the pots.

Asbestos was accessible in bedrock and in moraines probably close to local outcrops. Although temper raw materials were the most portable components of ceramic technology, the main impression from West Finnmark is that of local procurement. At Virdnejávri a relatively large-scale pottery production relied on local temper material. This could also be the case for the sites with asbestos pottery within the Kautokeino and Karasjok Greenstone Belts, and at Apana gård in Altafjord. Given the western Finnmark results and the plot positions of the Pasvik samples, we might expect local outcrops of actinolite and/or anthophyllite in the Pasvik area. On the other hand, variation in asbestos temper within sites suggests that some temper material was of non-local provenance, such as the talc-anthophyllite at Noatun in upper Pasvik, East Finnmark, and the presence of serpentine asbestos at sites spread from the inland to the outer coast in West Finnmark.

More analyses of pottery temper would provide an indication of which types of asbestos groups to look for as potential raw material sources. Targeted investigation of geological contexts similar to those mentioned here for identifying additional small local occurrences of asbestos minerals would bring us closer to an understanding of the use of local vs. non-local asbestos as ceramic tempering material. A more intensive study of the asbestos material from the large source area at Virdnejávri would provide more information on the range of variation within a geological formation. Finally, the potential of pXRF analysis should be evaluated, as it is a non-destructive method capable of analyzing large sample sizes.

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