

Neolithic pottery from Switzerland: raw materials and manufacturing processes

M. Maggetti¹

Abstract

The Neolithic pottery found at the twelve Swiss sites investigated so far was predominantly manufactured from silicate, fatty clay. This forms a contrast to the clayey objects which were produced from very local, mainly carbonate clays. The former contains approximately 10–30 vol% temper. The clayey objects, on the other hand, were either non-tempered or tempered with organic substances. Two vertical sections show the local origin of the artificially added, a-plastic elements. The oldest ceramic (appr. 5250 BC) found at Bellinzona-Castelgrande TI, for instance, was tempered with gneiss, whereas ceramic from the intermediate time slot (3750–1800 BC) contains mainly amphibolite. Gneiss is again predominant in the objects from the youngest layers. Ceramic from eleven sites of the Swiss Midland show that, over time, granitoid rock became the temper material of choice. This may be due to its characteristic to crumble into a granulous heap when heated in fire and quenched in water. Many potential temper rocks occur in local moraines, dating from the Riss and Würm glaciations, but the Neolithic potter selected specifically mainly granitoids. Generally, pots were manufactured with coils of clay, which were either spiraled upwards or piled up. Swiss Neolithic pottery was open-fired, either in surface bonfires or in pits. The ceramic body recorded temperatures in the range of approximately 500–700°C. Twenty fragments of eleven crucibles from the Pfyn culture from five Swiss provenances were analyzed in order to understand if they were used as smelting or only as casting crucibles. They were made of local, high CaO- as well as low CaO-clays, and most of them were tempered with threshing waste, i.e. chaff. The uppermost parts of the crucibles are molten, which may be explained by the use of blow-pipes acting upon the crucibles from above. The inner parts of these objects show a significantly higher concentration of copper than do the parts which face away from the blow-pipes. In the scorified areas, mostly chalcopyrite and less frequently copper, cuprite, bornite, and chalcantite can be found. While the use of casting crucibles seems most plausible, it may be possible that some crucibles were utilized for smelting sulphide ores.

Introduction

The earliest Neolithic settlement in Switzerland is located on the top of mount Bellinzona-Castelgrande (approximately 5250 BC, Stöckli 1995). However, Neolithic settlements in the Swiss Midland were preferably established around lake shores and especially on the lake beaches. On the one hand, no clearing of the area was necessary before a village could be built, on the other, the lakes offered a suitable means of transport. SPM II (1995) provides

an excellent representation of current archaeological knowledge of the different Neolithic cultures in Switzerland.

Very few papers summarizing and providing an overview of archaeometric investigations on Neolithic ceramics in Europe have been published so far (e.g. Gibson and Woods 1990; Hardmeyer et al. 1995; Muntoni 2002). While the studies of Hardmeyer et al. (1995) focused on the archeological interpretation of scientific results, the following discussion will be

Table 1: Number of Neolithic pottery samples from Switzerland studied by optical microscopy, X-ray fluorescence (XRF) and X-ray diffraction (XRD). Date according to Cueni et al. (1995) and Stöckli (1995).

Location	Cultural group	Date (BC)	microscopy	n analyses		
				XRF	XRD	Literature
Arbon-Bleiche 3 (AB)	Pfyn / Horgen	3384–3370	163	163	163	Bonzon (2003)
Auvernier-La Saunerie (AS)	Auvernier cordé	ca. 2700	16	16	16	Benghezel (1993, 1994)
Bellinzona-Castelgrande (BC)	Castaneda	2600–2500	15	15	15	Schubert (1986), Zanco et al. (2003)
	Lagozza	3750–3500	16	16	16	"
	Vasi a bocca quadrata	4500–4000	31	31	31	"
	Neolitico inferiore	5300–4500	15	15	15	"
Burgäschli See-Süd, SW and Nord (BS)	Cortailod classique	3760–3748	60	60		Nungässer and Maggetti (1978, 1981)
Delley-Portalban (DP)	Auvernier cordé	2634–2440	43	43	43	Benghezel (1994b)
	Auvernier cordé	2700–2650	50	50	50	Di Pierro (2002, 2003)
	Auvernier cordé	2634–2440	6			Sturny and Ramseyer (1987)
Egolzwil 3 (E3)	Egolzwil	4282–4275	15	15	15	Schubert (1986, 1987)
Kleiner Hafner, ZH (KH)	spätes Horgen	2802–2781	5	5	5	"
	östliches Horgen	3222–3201	7	7	7	"
	Pfyn		8	8	8	"
	klassisches Cortailod	3968–3831	27	27	27	"
	frühes Cortailod	4231–4032	23	23	23	"
	Egolzwil	4384–4280	15	15	15	"
Muntelier-Platzbünden (MP)	Horgen occidental	3179–3118	40	40		Rodot et al. (2003)
St. Blaise-Bains des Dames (SB)	Auvernier cordé	2640–2450	9	9	9	Benghezel (1993, 1994)
	Lüscherz	2794–2673	8	8	8	"
	Horgen occidental	3166–3121	6	6	6	"
	Auvernier cordé	2640–2450	63	63	63	Di Pierro (2002, 2003)
Sutz-Lattrigen Rütte (SL)	Auvernier cordé	2754–2652	30	30	30	Benghezel (1993, 1994)
Twann-Bahnhof (TB)	Horgen	3405–3072	20		20	Nungässer et al. (1985)
	Cortailod classique	3838–3768	80		80	"
Vinelz-Alte Station (VA)	Auvernier cordé	2793–2715	30	30	30	Benghezel (1993, 1994)

based on material-technical aspects, mainly the selection and preparation of raw materials and the firing processes. Table 1 provides a general overview of the 12 sites that were investigated, Figure 1 indicates their location and Table 2 the chronology of the Swiss Neolithic period.

Terminology

It is generally known that in clay-based ceramic objects, non-plastic parts are distinguished from

previously plastic parts, i.e. the clay minerals. Non-plastic elements are, according to Maggetti (1979), all grains of an average diameter of ≥ 0.015 mm. In Swiss archaeometrical studies, the differentiation between naturally present and artificially added (temper) a-plastic inclusions is based on the criteria derived by Maggetti (1994), i.e. (1) bimodal (hiatal) distribution of the non-plastic grains; (2) angular outlines of the temper grains; (3) organic material; (4) grog, complemented by the comparison with local raw clays,

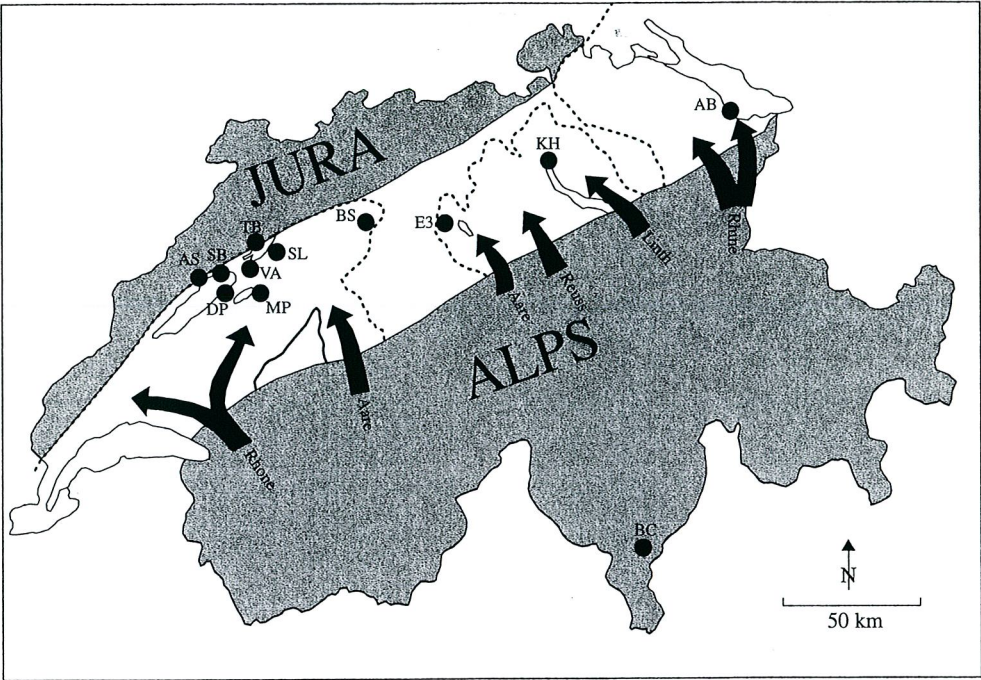


Figure 1: Location of the studied settlements. Dashed line = boundaries of the glacier dating from the Würm period. Arrows = direction of movement of the Würm glaciers. Abbreviations see Table 1.

BC	Svizzera meridionale	Wallis/Valais	Suisse occidentale	Zentralschweiz	Ostschweiz	BC
2000	Bronzo antico	Bronze ancien	Bronze ancien	Frühbronzezeit	Frühbronzezeit	2000
		Campaniforme	Campaniforme	Glockenbecher	Glockenbecher	
2500	Castaneda	Néolithique final valaisan	Auvernier cordé Lüscherz	Schnurkeramik	Schnurkeramik	2500
				spätes Horgen	spätes Horgen	
3000	Carasso-Tamins		Horgen occidental Port-Conty	östliches Horgen	östliches Horgen	3000
3500	Lagozza	Cortailod-Saint-Léonard Cortailod-Petit-Chasseur	Cortailod tardif Cortailod classique	spätes zentral-schweiz. Cortailod klass. Zentral-schweiz.	spätes Pfyn Pfyn	3500
4000		Cortailod ancien valaisan	Cortailod ancien	Frühes zentral-schweizerisches Cortailod Egolzwil	Lutzengüttele spätes Rössen	4000
4500	Vasi a bocca quadrata				Rössen	4500
		Néolithique ancien valaisan	Précortailod		Grossgartach	
5000	Neolithico inferiore padano-alpino		Néolithique ancien (La Hoguette)	Frühneolithikum	Bandkeramik	5000
5500						5500

Table 2: Time line of the Swiss Neolithic Cultures (Stöckli 1995). Empty spaces represent gaps in the scientific knowledge, not interruptions of the occupation.

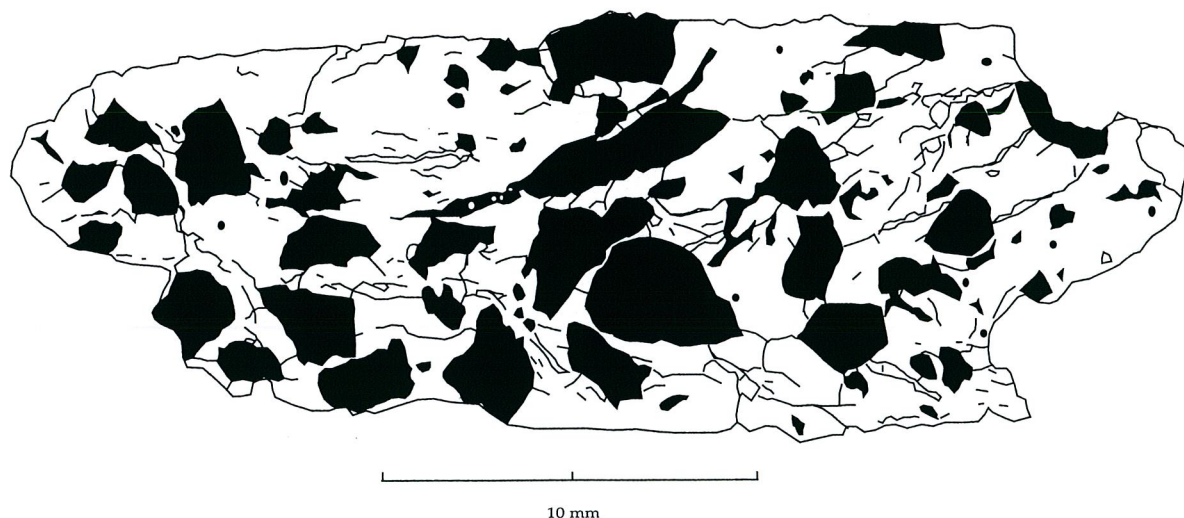


Figure 2: Coarsely tempered Neolithic ceramic, with temper in black.

whereby grains of a diameter ≥ 0.5 mm (Benghezal 1994; Bonzon 2003) or ≥ 1 mm (Di Pierro 2002) indicate artificially added temper. Figure 2 is a typical example of a coarsely tempered Neolithic ceramic, showing hialal distribution of the added, angular granitic fragments. The matrix is defined as the clay used for the pottery production and contains therefore previously plastic components, as well as non-plastic elements ≤ 0.5 mm and ≤ 1 mm respectively. A fatty matrix is inclusion-poor (0–5 vol%), a meager matrix inclusion-rich (> 5 vol%). A silicate matrix contains predominantly silicate minerals, a carbonatic matrix mainly carbonate minerals and a silicatic-carbonatic matrix consists of silicates and carbonates in equal proportions.

Geology

The investigated sites are located in the Swiss Midland, situated between the Jura Mountain belt

and in the Alps (Bellinzona-Castelgrande) (Fig. 1). The Tertiary basement (Oligocene to Miocene) comprises predominantly sandstones and marls and is covered by Quaternary moraine deposits, composed mainly of Pleistocene sediments from the Riss and Würm glaciations. They consist of ground moraine clays, sands, coarse pebbles and big erratic boulders. During the Holocene, clayey, silty, and sandy sediments were deposited in lakes and ponds, which formed as a result of glacial retraction.

Clays for the pottery production

Unfortunately, a detailed description of the matrix is not available for all samples discussed here. However, the 601 sherds (Table 3) can provide an indication as to the selection of clay. Even though the number of different matrix-types varies between the sites, the overall conclusion can be reached that Neolithic

Table 3: Number of pottery samples belonging to the different matrix types.

Settlement	Meager			Fatty			Hetero- geneous	Total
	Silicate	Sil. Carb.	Carb.	Silicate	Sil. Carb.	Carb.		
Arbon-Bleiche 3	5	-	6	152	-	-	-	163
Auvernier-La Saunerie	3	3	1	3	4	-	-	14
Burgäschli See-Süd, SW and Nord	-	-	-	58	-	1	1	60
Delley-Portalban	34	3	-	30	23	2	4	96
St.Blaise-Bains des Dames	14	4	6	26	56	3	-	109
Sutz-Lattrigen Rütte	15	1	1	6	4	3	-	30
Twann-Bahnhof (Cortailod)	37	-	-	26	-	17	-	80
Twann-Bahnhof (Horgen)	8	-	-	12	-	-	-	20
Vinelz-Alte Station	10	1	5	7	6	-	-	29

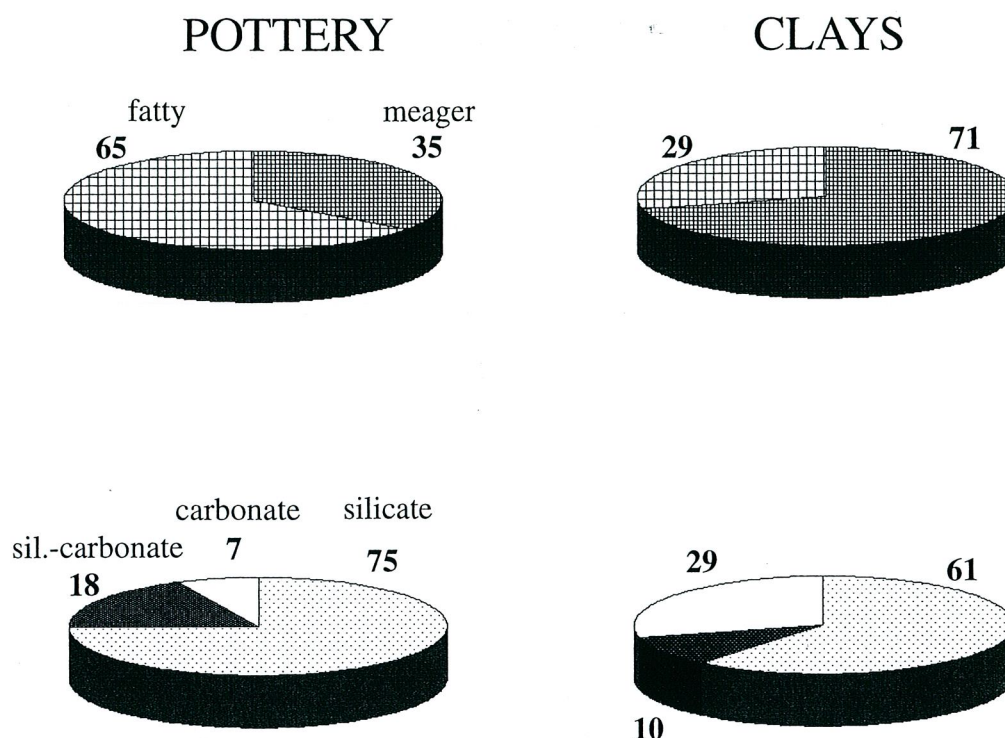


Figure 3: Percent distribution of the different matrix-types in Swiss Neolithic pottery ($n=601$) and of clays ($n=41$) from Western Switzerland (Benghezal 1994).

potters preferred fatty, silicate clay (Fig. 3). So, what types of clay were available to the artisans in those days? When studying 41 superficially outcropping raw materials taken from the vicinity of the investigation sites in Western Switzerland, Benghezal (1994) observed predominantly meager silicate clay (Fig. 3).

The studies of Sigg et al. (1986) have shown that the CaO-content in the Holocene lake sediments are subject to large fluctuations, vertically as well as horizontally. According to detailed studies by Gasser and Nabholz (1969), Jenny and de Quervain (1960, 1961), Mumenthaler (1979) and Peters (1961), the Pleistocene, fine grained sediments found in the Swiss Midland are characterized by a high carbonate content of 25–50 wt%. In fact, it is a common propriety of a carbonate-rich, clayey sediment to be carbonate-poor to carbonate-free in the top layers. This is due to the original carbonate minerals having dissolved in acidic ground water and then precipitated again at deeper layers. This could explain why the ceramics have less carbonate matrices (25% of 601 matrices) in comparison to the clay matrices (39% of 41 matrices). However, the discrepancy between the dominantly fatty matrices in the Neolithic pottery and the meager matrices in local raw materials suggests clearly that

Neolithic potters consciously selected fatty, silicate clay. On the one hand, this type of clay can be moulded easily because of its high plasticity, on the other hand, it can be fired without difficulty due to the absence of carbonate. This applies to open firing in particular, as here temperature cannot be controlled and firing temperatures fall within the critical range for post-firing spalling, i.e. 600–800°C. Another possible explanation could be that Neolithic potters refined meager clays by soaking. However, this is contradicted by the experiments of Di Pierro (2002), who proved that local, soaked clay is not chemically compatible with the separated matrices (see below). But, do these clays occur locally? None of the previous studies has provided convincing evidence of the use of local clays, i.e. raw material found within 1–2 km (Arnold 2001), in Neolithic ceramic production. As a result, Di Pierro (2002, 2003), continuing preliminary experiments of Benghezal (1994b) and Marro (1978), developed a method which allows the matrix to be separated from the temper in low fired sherds. This process was tested on samples from the sites of Delley-Portalban ($n=17$) and St. Blaise-Bains des Dames ($n=17$). Both productions could be distinguished clearly (Fig. 4), with the exception of some samples

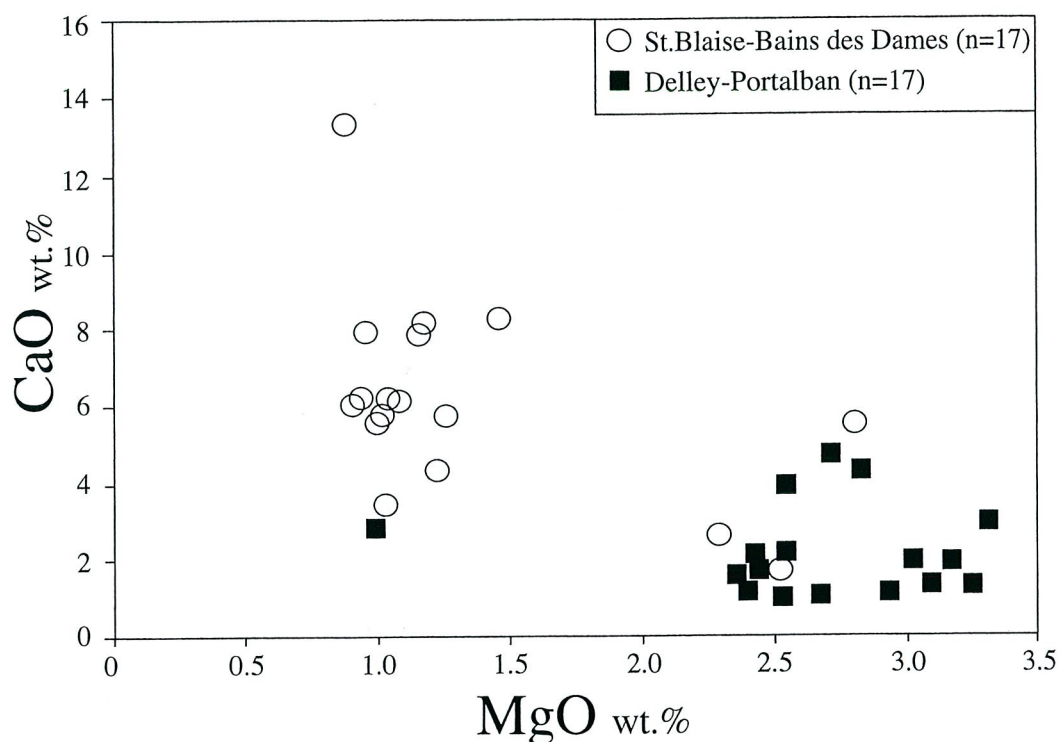


Figure 4: CaO-MgO plot of the matrices of Delley-Portalban and St. Blaise-Bains des Dames pottery (Di Pierro 2002).

which have been discussed in detail by Di Pierro (2002). The matrices from St. Blaise have generally a lower MgO- and a higher CaO-content and the considerable fluctuation in CaO can be attributed to the proximity of the Jura Mountain belt, rich in limestones and marls. This indicates the use of two different clays and, as a result, local production is more likely than production in one centre. Despite this new method, no adequate raw material could be identified in the close neighbourhood of the studied sites, which can be explained (1) by the fact that the prospecting was insufficient, i.e. that the Neolithic clay pits were not detected; (2) by the fact that the clays have been completely used by the Neolithic potters; and (3) that the clay areas have been completely built over. However, this new separation technique represents a promising tool for the future.

Temper for the pottery production

The authors of the publications discussed here postulate either a local or regional production for most of the examined objects. Only a few pieces have been identified as imports. These would have been introduced from an area of no more than 20 km away (Schubert 1987). The following discussion examines, based on the tempered pieces, whether the petro-

graphic nature of the temper changed over time and within certain cultures. Two vertical examples – Castelgrande, Bellinzona (appr. 4'000 years of settlement) and Kleiner Hafner, Zurich (appr. 1'800 years of settlement) as well as four horizontal time slots have been selected for this purpose.

Vertical sections

Bellinzona-Castelgrande (Ticino): The pottery found during the Bellinzona-Castelgrande excavations by P. Donati (1980 – 1984) provides a unique insight into European Prehistory (Carazzetti 1986, 1993; Carazzetti and Donati 1990). Typological classification by R. Carazzetti shows that the ware represents a complete sequence from the early Neolithic (± 5300 BC) to the Late Bronze Age (± 1200 BC), suggesting a permanent settlement of the area around Bellinzona for about 4'000 years (Fig. 5). In addition, some objects belonging to the Early Iron Age (700–600 BC) were found, giving the opportunity to study the time-related development of pottery technology and changes in the used raw materials. 111 samples of different typologies and ages (77 Neolithic ceramics, Table 1) were analyzed, including samples from the Bronze (n=18) and Iron Ages (n=16).

On the basis of the petrographic nature of the non-plastic inclusions, Zanco et al. (2003) identified two

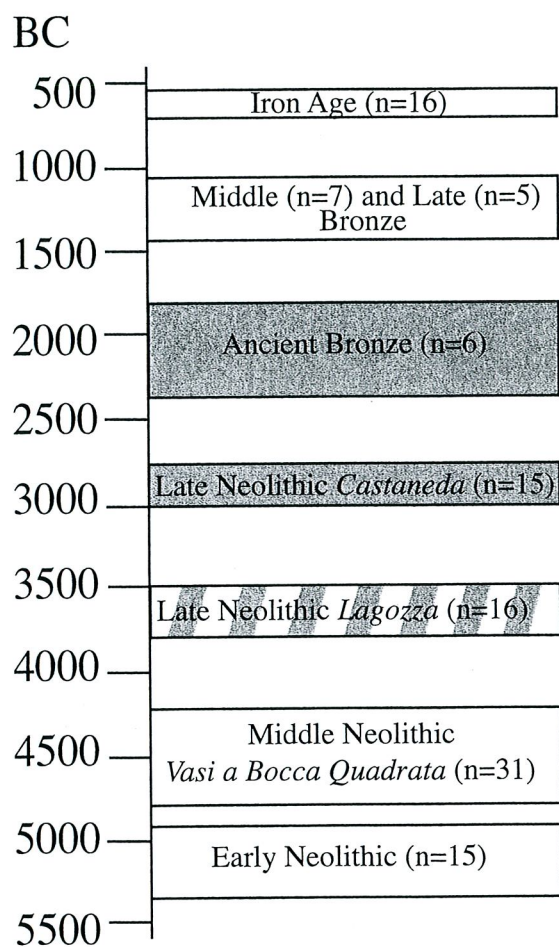


Figure 5: Vertical section of the human occupation at Castelgrande, Bellinzona. Shaded = prevailing amphibolitic temper. White = prevailing gneissic temper.

main petrographic groups: (1) in the first (gneissic type) many gneissic and granitic fragments were recognized, with minor amounts of micaschists and quartzites. Quartz, feldspars, muscovite and sometimes biotite represent single crystals distributed in the groundmass; (2) the second group (amphibolitic type) comprises ceramics characterized by amphibolitic fragments in addition to quartz, muscovite and feldspars monocrystals.

In the course of the 4'000 production years, a remarkable change in the specific choice of the temper material took place (Fig. 5): (1) approximately 5500–3500 BC: the ware of the Neolitico inferiore padano-alpino (Early Neolithic), Vasi a Bocca Quadrata (Middle Neolithic) and some fine Lagozza (Late Neolithic) belongs to the gneissic petrographic type; (2) 3750–1800 BC: from coarse Lagozza to Bronzo antico (Ancient Bronze) the ceramic products are characterized by amphibolitic inclusions; (3)

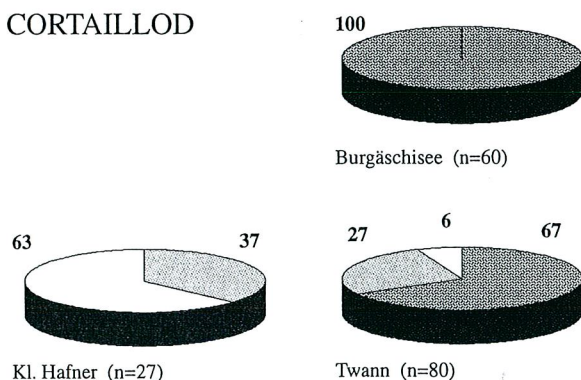
Table 4: Amount of Verrucano temper (vol. %) in the Neolithic station of Kleiner Hafner, ZH (Schubert 1986, 1987)

Culture	n	Verrucano	Rest
Spätes Horgen	5	100	-
Östliches Horgen	7	43	57
Pfyn	8	87	13
Klass. Cortaillod	27	96	4
Frühes Cortaillod	13	46	54
Egolzwil	15	60	40

1400–1100 BC: from the Middle Bronze to the Late Bronze, the potters go back to produce pottery with a gneissic type of temper. The same kind of temper belongs to the Iron Age pottery.

Kleiner Hafner, Zürich: The ceramics date from 4500 to 2700 BC, i.e. come from a period of 1'800 years. The temper typically used by nearly all cultural groups consists of coarse grained and fine grained verrucano-fragments, i.e. a deformed and metamorphosed quartz porphyry (Table 4). The ceramics belonging to the oldest Egolzwil cultural group (4384–4280 BC) are of heterogeneous composition in regards to their a-plastic inclusions. According to Schubert (1987), verrucano, sandstone, radiolarite, quartzite, mica schist and granite are present. Half of the 15 analyzed samples show a hiatal distribution of the non-plastic elements, which suggests tempering. In the following group, that of the older Cortaillod, i.e. "frühes zentralschweizerisches Cortaillod" of Table 2, (4231–4032 BC), the pottery does not differ significantly from the previous group and the non-plastic constituents present are markedly heterogeneous. Coarse a-plastic inclusions are interpreted by Schubert as temper. However, some pots belonging to this culture were tempered with fossil fragments (19–29 vol%) as well as granite. Furthermore, these pots stand out due to a high total temper-content (26–37 vol%). Palaeontological investigation reveals Mesozoic (Oxfordian/Dogger) fauna of the Jura Mountains, which are located at a distance of 20 km from the Kleiner Hafner area. This type of ware may therefore have been imported. In the younger Cortaillod group, i.e. "klassisches zentralschweizerisches Cortaillod" of Table 2 (3968–3831 BC), verrucano is the dominant temper material, an indication of a systematic selection of this material. The Pfyn-ceramic resembles the previous pottery in terms of a-plastic constituents. Granitic fragments are the main constituents of the temper of the older Horgen, i.e. "östliches Horgen" of Table 2 (3222–3201 BC) ceramic. The temper of the

CORTAILLOD



EGOLZWIL

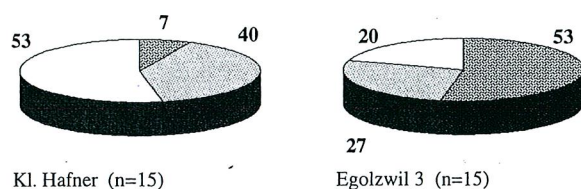


Figure 6: Percental distribution of the three temper types in pottery of the Egolzwil and Cortaillod cultures (dark shaded area: granite only, light shaded area: granite with other rocks, white area: no granite).

younger Horgen, i.e. "spätes Horgen" of Table 2 (2802–2781 BC), on the other hand, is more varied (sandstone, quartzite, verrucano).

Horizontal (culture) time slots

Egolzwil (4500–4000 BC): A noticeable feature of nearly all sherds collected at the site of Egolzwil 3 is a coarse, most often granitic temper, which was added to a very fatty, silicate clay. An unusual characteristic is the presence of angular grog fragments, with a considerable part of the total sherd volume of up to 9 vol%. This forms a contrast to the ceramic of the Kleiner Hafner, which is of the same age and where such a temper is absent. The latter is of a very heterogeneous composition and characterized by verrucano fragments, which are missing from the Egolzwil 3 ceramic. Both products can therefore be well differentiated. Another petrographic criterion can be used too, as the Egolzwil 3 pottery contains much more granitic temper than the Kleiner Hafner products (Fig. 6).

Cortaillod (4000–3750 BC): While granitic temper is most common at the sites of Western Switzerland (Fig. 6), its (quantitative) occurrence decreases in the region of lake Zurich, where verrucano is dominant (Table 4).

Classic Horgen (3500–3000 BC): The ceramic of the transitional period between Pfyn/Horgen found at Arbon-Bleiche 3 contains generally, but not exclusively, a granitic temper (Fig. 7). Its amount increases in the pottery of the Swiss Neolithic stations going from East to West.

Auvernier cordé (2700–2500 BC): The ceramic of all sites was mainly tempered with granite (Fig. 7). Fossil-rich pottery is interpreted as an import from the Jurassic realm.

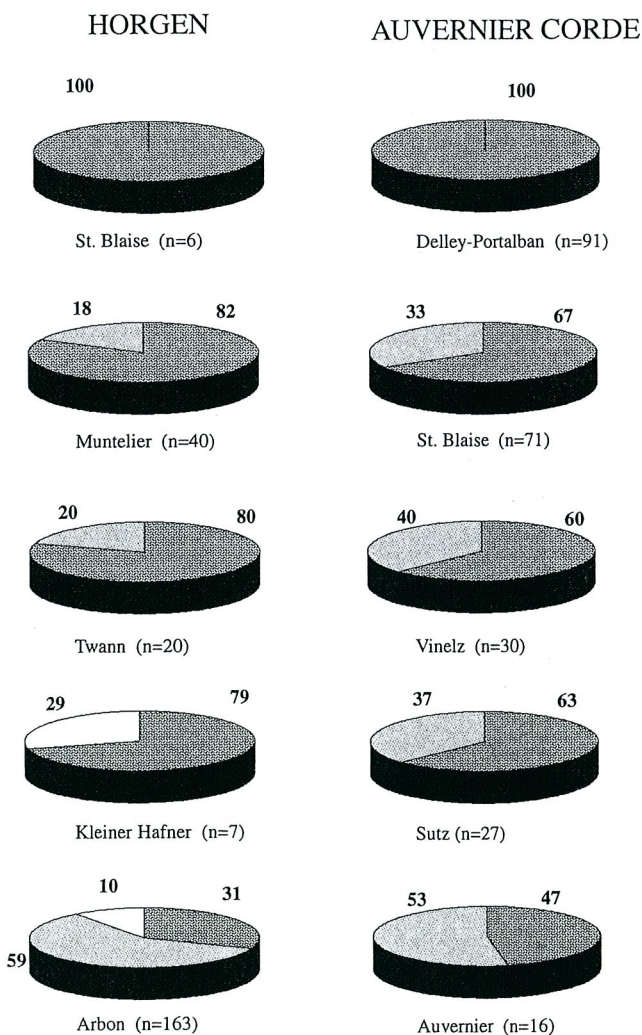


Figure 7: Percental distribution of the three temper types in pottery of the Auvernier cordé and Horgen cultures (dark shaded area: granite only, light shaded area: granite with other rocks, white area: no granite).

Interpretation

Bellinzona-Castelgrande: This settlement was located on a mount consisting of interbedded strata of gneiss and amphibolite. The temper material was therefore right on the potters' doorstep, so to speak. The involvement of temper, as in the case of Bellinzona-Castelgrande, is puzzling and difficult to explain. Technical reasons seem not plausible enough, so socio-cultural aspects are probably the motivation. Only comparisons with other, not yet studied Neolithic settlements in Northern Italy will perhaps give an answer.

Midland settlements: The results presented here show that (1) each site of the Swiss Midland is characterized in regards to the petrographic nature of the temper-elements (e.g. verrucano at the Kleiner Hafner) and (2) an evolution to the preferential use of a specific temper, i.e. granitic fragments can be clearly observed, at least in Western Switzerland. However, it needs to be pointed out that, on the one hand, the number of samples is not always statistically sufficient, even when representative samples were taken. On the other, the Central and Eastern parts of Switzerland have been insufficiently investigated.

Potters collected temper material from local moraines. These show a very heterogeneous composition of the sand (Gasser and Nabholz 1969; Jenny and de Quervain 1960, 1961) and boulder fractions. The occurrence of pure granitic sands at all sites would therefore be hard to explain by geological processes only, in view of the fact that the glacial debris represents a collection of a lot of rock types, outcropping in the Alps and the Midland (Fig. 1). Besides, the angular outlines of the granitic temper further contradict the use of a pure natural granitic sand, as latter would show rounded forms. The assumption of a selective enrichment of granitic sand grains by the potter can be discarded as unrealistic, especially in light of the preparation time involved. It can therefore only be assumed that potters added crushed granite to the ceramic mass. However, as shown by Di Pierro (2002) for Delley-Portalban, granitoids make up only 10% of the bolder spectrum of the local moraines. From this, he concluded correctly, that Neolithic potters selected these rocks consciously and specifically. This view has been supported by Di Pierro and Martineau (2002) and Rodot et al. (2003).

For what reason did Neolithic potters prefer granitic rocks? Probably because this type of rock could be treated in order to meet the desired temper fraction by investing a reasonable amount of time and energy. The potters had fire and water at their

disposal. Hard rocks when heated in fire and quenched with water, will be softened and afterwards crushed easily by mechanical means. Nungässer et al. (1992) have experimentally demonstrated the efficiency of a high temperature/water-shock treatment for metamorphic granites, i.e. gneisses. This method is essentially based on the following processes: (1) heating (in a bonfire during the experiments) causes a volume increase in the rock. This will be reversed through contraction of those surface areas which have been exposed to the cooling water, eventually causing the creation of very fine cracks; (2) the shift from liquid to the gaseous state for the water which infiltrated these cracks can support further formation of cracks/fissures due to the developing gas pressure; (3) areas of mechanical weakness, such as pre-firing cracks or planar layers of micas in parallel-textured rocks (e.g. gneisses), can also be infiltrated by water and become weakened in their local cohesion. This thermal shock method, a basic as well as efficient process, may therefore have guided Neolithic potters in the selection of suitable boulders.

Production of the pottery

As indicated previously, Neolithic potters preferred fatty silicate clay to which they added up to 40 vol% of temper (average of all analyses: 10–30 vol%). According to Hardmeyer et al. (1995), pots were generally manufactured with coils, which were either spiraled upwards or piled up. Big pots were manufactured in several stages. The pots were then open fired, either in a pit or on surface bonfires. According to Rye (1981), the ceramic body becomes cohesive at lower firing temperatures through dry sintering. This occurs between 400–850°C, depending on the composition of the clay mixture. The minimum temperature required for producing a lasting, water resistant sherd during a short firing period, as is the case in such an open firing, is approximately 550°C (Cardew 1970; Rice 1987; Rye 1981; Tobert 1984). Diffractometric analyses indicate that these temperatures have been reached, hence the ceramic body of the analyzed Neolithic pottery documents temperatures of 500–700°C. These values support ethnological studies of similar fired ware (e.g. Shepard 1954; Wotzka 1991) and experimental findings (e.g. Gosselain 1992; Gosselain and Livingstone Smith 1995). Firing of this kind occurred rapidly, within a period of 30 to 60 minutes (Gibson and Woods 1990). During the extended burial period of the broken pots, the partially destroyed clay minerals can be regenerated (Maggetti 1982). Under such uncontrolled firing

conditions, a fluctuation of the reduction factor is to be expected, i.e. the ratio $\text{FeO}/\text{FeO}_{\text{tot}}$ (Maggetti et al. 1988) will vary considerably (in the studied samples approximately in the range of 0.5–0.7). Most of the reduction factors lie above 0.2, thus documenting a reducing firing atmosphere (Maggetti et al. 1988).

Clayey materials

No relics pertaining to the production of Neolithic pottery, such as firing waste, have been preserved to

serve as local reference material. To overcome this problem, scientists will analyze unfired clayey material for which a local origin is highly likely. This applies to wall plaster (i.e. cobs), plaster coat and loom weights. Cobs are clays used as building material (i.e. clay wall fillings). Plaster coats are crude clay or loam packages for the hearth fire or for clay floors. All these types can be ceramized only involuntarily, e.g. during a destructive fire of a Neolithic village. Loom weights are compacted clay pieces used to pull down animal furs during air

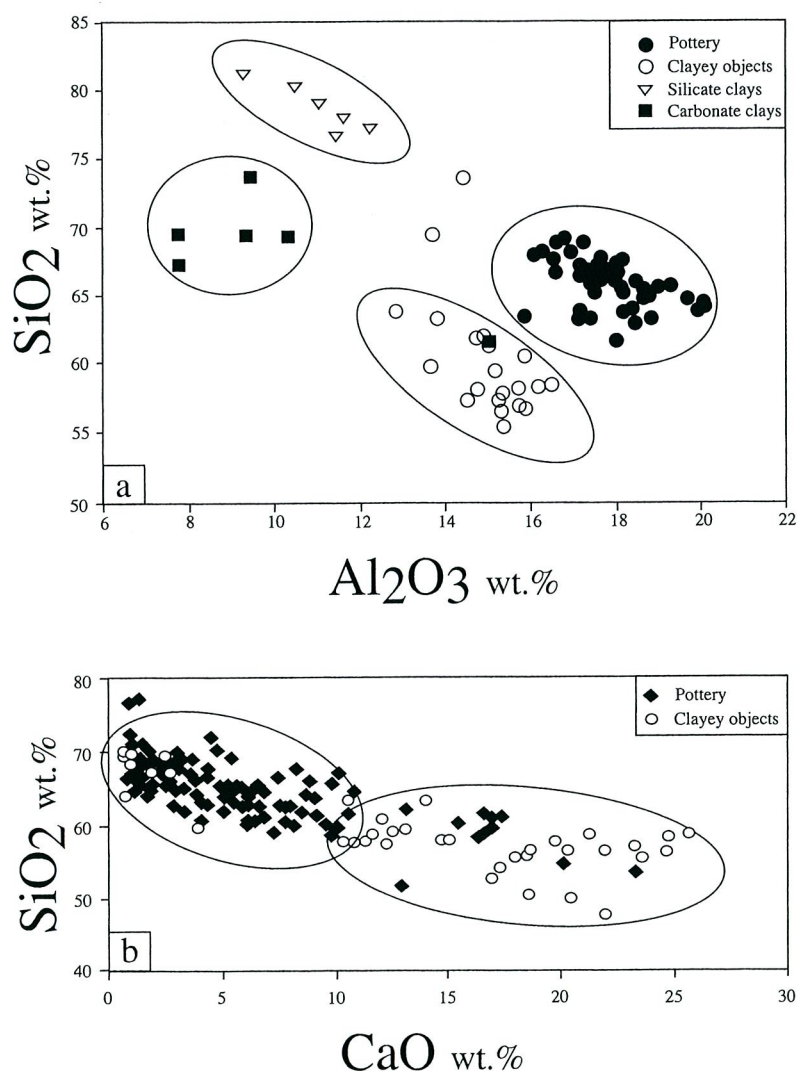


Figure 8 a) SiO_2 - Al_2O_3 plot of potteries ($n=50$), clayey objects ($n=21$) and local clays ($n=12$) from Delley-Portalban (Di Pierro 2002). The carbonate clay in the field of the clayey objects is compatible in its overall chemical composition with the clayey objects. It was collected just outside the ancient Neolithic village, proving that these clayey objects are truly local. b) SiO_2 -CaO plot (Di Pierro 2002) of 147 potteries and 39 clayey objects from the five settlements studied by Benghezal (1994).

drying. Most of the archaeological literature agrees that they were fired before use. Under the microscope, these clayey objects are very heterogeneous in their structure, the petrographical nature of the a-plastics as well as the granulometry. There is no evidence of tempering, except for the loom weights, where up to 10–15 vol% (Di Pierro 2003) of organic matter was added (Benghezal 1994).

As shown by the settlement of Portalban, all these clayey objects, which were manufactured from local clay, differ significantly from the pottery (Di Pierro 2002) (Fig. 8a). This is supported by a regional perspective (Fig. 8b), which highlights the fact that most clayey objects are considerably CaO-richer than the majority of the pottery. In Western Switzerland, fatty, siliceous clay was used in the production of pots during the Neolithic period, whereas unfired or lightly fired clayey objects were manufactured from siliceous-calcareous to calcareous clay.

Crucibles

Ceramic crucibles are characteristic of the Neolithic Pfyn culture of Eastern Switzerland (Fasnacht 1995) and were studied by Maggetti et al. (1991). A similar object of the Cortaillod culture in Western Switzerland has been characterized with non-destructive methods only (Maggetti and Gloor 1978).

Raw Materials

The eleven analyzed Pfyn objects from five different places are made from a fine-grained, mostly silicate clay. The grain diameter of the largest a-plastic grain never exceeds 0.4 mm. The non-plastic elements consist of fragments of dominating quartz as well as little feldspar and chlorite. Only two possess a carbonate-silicate matrix and thus document the making from a marly clay. The non-plastic amount lies in the range of 15–20 vol%. Rough temper (with a grain diameter of granitic rock fragments up to 3mm) can be observed in five specimens. Longish, spiky pores are found in the objects with fine-grained a-plastics, which are attributable to the presence of now burnt-out, purposely added organic material. Marks of such vegetable fragments are also found on the outside and inside of the crucibles. The spectrum of form and shape corresponds entirely to the description by Schlichtherle and Rottländer (1982), according to which they are fragments of straw, spelts and spindles from ears of corn as well as cereal grains. The proportion of added chaff varies considerably from specimen to specimen. It would appear that temperature resistance of these crucibles was increased by varying the artificially added type of

non-plastic elements: (1) organic temper would cause high porosity upon firing; (2) a temper made up of rough fragments of granitoids and gneisses traditionally used in domestic ceramic production would improve the drying and firing properties. Petrographic analysis has shown that at least two clays (silicate, carbonate) were used and that temper was added in order to increase stability. The Neolithic artisans thus did not make a conscious choice of the raw clays, which is also documented by the chemical inhomogeneity of the samples.

Casting or melting crucibles?

Most of the crucibles analyzed show the effects of HT-processes in the form of swollen, melted and pumice-like areas. In most cases, these are only present at the highest parts of the crucibles. However, in a few cases, many can be found on the bottom of the inside or on the handle. As only the uppermost parts of nearly all the crucibles have been affected by the melting phenomenon, heat must have acted upon the objects from above and produced temperatures of over 1100°C, in order to melt the ceramics. X-ray diffraction analyses are consistent with such a punctual high firing, which was caused by blow-pipes acting upon the crucibles from above.

All objects show a polyphase temperature history. The first occurred during the ceramic firing in the T-interval as for the household pottery (500 – 600°C), overlaid by a second HT-phase during metallurgical activities. The inner areas of the crucibles show a significantly higher copper concentration (up to almost 1 wt%) than do the parts which face away from the blow-pipes. In the scorified areas mostly chalcopryite (Cu_5FeS_2), copper (Cu), cuprite (Cu_2O), bornite (CuFeS_4) and chalcantite ($\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$) were found. Much has been published concerning the form and function of metallurgical objects (melting versus casting crucibles, e.g. Tylecote 1976). The frequently occurring handles and the low capacity would speak for such use of the Pfyn crucibles. Mineralogical and chemical analyses of the studied eleven samples would fit well into this pattern: raw copper, mixed with charcoal which had been stacked on top of it, was melted in the crucible, whereby temperatures above 1100°C were reached by using one or more blow-pipes, which acted on the smelting charge from above and caused the raw copper as well as the ceramics to melt.

On the other hand, Zwicker et al. (1985) have shown in experiments that crucibles of similar size with a capacity of approximately 1 kg may also have been used for the roasting or smelting of copper from sulphide ores. The remains of chalcopryite would

indicate such use, however, the possibility cannot be ruled out that this formed from copper through retrograde, bacterial processes during the time they were buried in the soil.

The existence of copper mining in Switzerland has been demonstrated for the Early Bronze Age; however, there is no evidence of such an activity during the Neolithic period (Fasnacht 1995). It may therefore be assumed that the copper melted in Pfyn crucibles was very pure (Fasnacht 1991), and it may have come from the Balkan or the Eastern Alps, where copper had already been mined actively since the 5th millennium BC.

Conclusion

This overview of archaeometric papers on Swiss Neolithic ceramic published so far highlights the following points:

- 1) Neolithic potters consciously selected two different types of clay, depending on the intended use: a fatty, silicate clay for pottery and a meager, carbonate clay for clayey objects. The latter remained before use non-fired or weakly fired. Potters were very aware that calcareous clays needed to be avoided in uncontrollable open firing (where carbonate-critical temperatures of 700–800°C are reached), due to the decomposition of carbonate and the post-firing rehydration of CaO, causing spalling. However, these types of clay were suitable for use as floor lining, wall plaster or loom weights.
- 2) At present, local provenance has been determined for carbonate, but not for silicate clays.
- 3) Neolithic potters specifically selected granitic moraine material to use as temper, possibly because such material could be softened and crushed quickly thanks to a fire/water-shock treatment.
- 4) In Western Switzerland, the use of granitic temper increases progressively from the oldest to the youngest cultural groups. This observation is further corroborated by regional comparisons. This does not apply for the settlement belonging to the Alpine realm, where probably socio-cultural motivations caused a change in temper selection.
- 5) The firing temperatures of appr. 500–700°C, documented by radiographic means as well as the reduction factors, correspond to the conditions of open firing, either in pits or surface bonfires.
- 6) Clay was used randomly in the production of the Pfyn crucibles. However, chaff was added purposely, because it causes the formation of longish pores during ceramic firing, which block the propagation of cracks, induced by subsequent metallurgical

processes.

The standard of pottery during the Neolithic period was advanced. Potters knew very well how to adapt the local clay and temper spectrum to different applications. Further regional comparisons, particularly in Central, Eastern and Southern Switzerland, will complement and refine the results discussed here.

Note

- 1 Department of Geosciences, Mineralogy and Petrography, University of Fribourg, Ch. du Musée 6, CH-1700 Fribourg, Switzerland.

References

- Arnold, D., 2001, Linking Society with the compositional analysis of pottery: a model from comparative ethnography. *XIVe Congrès de l'Union Internationale des Sciences Préhistoriques et Protohistoriques*. Liège 2–8 sept. 2001, Abstract vol., 45.
- Benghezal, A., 1993, Provenance de la céramique fine tardi-néolithique des lacs de Bienne et Neuchâtel: analyses minéralogiques, pétrographiques et chimiques, *Schweizerische Mineralogische und Petrographische Mitteilungen Bulletin* 73, 107–11.
- Benghezal, A., 1994, *Provenance et techniques de la céramique du Néolithique final de stations des trois lacs jurassiens (Suisse)*, (Unpublished PhD Thesis), Institute of Mineralogy and Petrography, University of Fribourg, Fribourg.
- Bonzon, J., 2003, Petrographical and Mineralogical Study of Neolithic Ceramic from Arbon-Bleiche 3 (Canton of Thurgau, Switzerland), in *Ceramic in the Society, Proceedings of the 6th European Meeting on Ancient Ceramics, Fribourg, Switzerland, 3–6 October 2001*, (eds. S. Di Pierro, V. Serneels and M. Maggetti), 25–50, Department of Geosciences, University of Fribourg, Fribourg.
- Carazzetti, R., 1986, La ceramica neolitica di Bellinzona, Castel Grande. Prime osservazione, *Archäologie der Schweiz* 9(3), 110–5.
- Carazzetti, R., 1993, Un ritratto dei primi abitanti di Canton Ticino, *Archäologie der Schweiz* 17(2), 48–51.
- Carazzetti, R., and Donati, P. A., 1990, La stazione neolitica di Castel Grande, in *Die ersten Bauern, 1: Schweiz*, 361–8, Schweizerisches Landesmuseum, Zürich.
- Cardew, M., 1970, Introduction: Pottery techniques in Nigeria, in *Nigerian Pottery, A catalogue compiled by Leith-Ross S.*, (ed. S. Leith-Ross), 9–13, University Press, Ibadan.
- Cueni, A., Hasenfratz, A., Brombacher, C., Gross-Klee, E., Nielsen, E. H., Langenegger, E., Schifferdecker, F., Richoz, I., Schibler, J., Sedlmeier, J., Honegger, M., Corboud, P., Moinat, P., Carazzetti, R., Leuzinger, U., and Stöckli, W. E., 1995, 10. Regesten – Registre – Registro, in *Die Schweiz vom Paläolithikum bis zum frühen Mittelalter, SPM II (Neolithikum)*, (eds. W. E. Stöckli, U. Niffeler and E. Gross-Klee), 301–38, Verlag Schweizerische Gesellschaft für Ur- und Frühgeschichte, Basel.
- Di Pierro, S., 2002, *Domestic production versus pottery exchange during the Final Neolithic: characterization of the Auvernier-cordé ceramics from the Portalban and St. Blaise settlements, Western Switzerland*, (Unpublished PhD Thesis), Institute of Mineralogy and Petrography, University of Fribourg, Fribourg.
- Di Pierro, S., 2003, Matrix – temper separation of Neolithic ceramics: an experimental approach to characterize the original raw materials and determine their provenance, in *Ceramic in the Society, Pro-*

- ceedings of the 6th European Meeting on Ancient Ceramics, Fribourg, Switzerland, 3–6 October 2001, (eds. S. Di Piero, V. Serneels and M. Maggetti), 109–31, Department of Geosciences, University of Fribourg, Fribourg.
- Di Piero, S., and Martineau, R., 2002, Pottery Tempering with Mont Blanc Granite Across the Jura Belt During Swiss and French Final Neolithic, 33rd International Symposium on Archaeometry, Amsterdam, 22–26.04.2002, Abstract, 75–76.
- Fasnacht, W., 1991, Analyses d'objets en cuivre du Néolithique récent du bassin zurichois, in *Découverte du Métal. Actes du Colloque international, St-Germain-en Laye*, (ed. J.P. Mohen), 157–66, Collections Millénaires, Paris.
- Fasnacht, W., 1995, Metallurgie, 4.10, in *Die Schweiz vom Paläolithikum bis zum frühen Mittelalter, SPM II (Neolithikum)*, (eds. W.E. Stöckli, U. Niffeler and E. Gross-Klee), 183–7, Verlag Schweizerische Gesellschaft für Ur- und Frühgeschichte, Basel.
- Gasser, U., and Nabholz, W., 1969, Zur Sedimentologie der Sandfraktion im Pleistozän des schweizerischen Mittellandes, *Eclogae geologicae Helvetiae*, 62(2), 467–516.
- Gibson, A., and Woods, A., 1990, *Prehistoric pottery for the archaeologist*, Leicester University Press, London.
- Gosselain, O.P., 1992, Bonfire of the Enquiries. Pottery Firing Temperatures in Archaeology: What for? *Journal of Archaeological Science* 19, 243–259.
- Gosselain, O.P., and Livingstone Smith, A., 1995, The Ceramics and Society Project, An Ethnographic and Experimental Approach to Technological Choices, in *The Aim of Laboratory Analysis of Ceramics in Archaeology*, (eds. A. Lindahl and O. Stilborg), 147–160, Kungl. Vitterhets Historie och Antikvitets Akademien Konferenser 34, Stockholm.
- Hardmeyer, B., Maggetti, M., and Weiss, J., 1995, 4.9. Keramik, in *Die Schweiz vom Paläolithikum bis zum frühen Mittelalter, SPM II (Neolithikum)*, (eds. W.E. Stöckli, U. Niffeler and E. Gross-Klee), 174–83, 349–51, Verlag Schweizerische Gesellschaft für Ur- und Frühgeschichte, Basel.
- Jenny, V., and Quervain De, F., 1960, Untersuchungen von Kalk- und Dolomitgehalt an Sanden quartärer Ablagerungen der Nordostschweiz 1. Teil, Beiträge zur Geologie der Schweiz, *Geotechnische Serie – Kleinere Mitteilungen* 21, 55–67.
- Jenny, V. and Quervain De, F., 1961, Untersuchungen von Kalk- und Dolomitgehalt an Sanden quartärer Ablagerungen der Nordostschweiz 2. Teil, Beiträge zur Geologie der Schweiz, *Geotechnische Serie – Kleinere Mitteilungen* 21, 471–80.
- Maggetti, M., 1979, Mineralogisch-petrographische Untersuchung des Scherbenmaterials der urnenfelderzeitlichen Siedlung Elchinger Kreuz, Ldkr. Neu-Ulm/Donau, in *Eltschinger Kreuz, Ldkr. Neu-Ulm, Siedlungsgrabung mit urnenfelderzeitlichem Töpferofen*, E. Pressmar, Prähistorische Staatssammlung München 19, 141–68.
- Maggetti, M., 1982, Phase analysis and Its Significance for Technology and Origin, in *Archaeological Ceramics* (eds. J.S. Olin and A.D. Franklin), 121–33, Smithsonian Institution Press, Washington D.C.
- Maggetti, M., 1994, Mineralogical and petrographical methods for the study of ancient pottery, in *1st European Workshop on archaeological ceramics, 10–12.10.1991*, (eds. F. Burragato, O. Grubessi and L. Lazzarini), Dipartimento Scienze della Terra, Università degli studi di Roma "La Sapienza", Roma, 23–35.
- Maggetti, M., and Gloor, F., 1978, Mineralogische und chemische Untersuchungen am Kupferschmelztiegel vom Burgäschisee, *Bull. Soc. Frib. Sc. Nat.* 67(2), 174–80.
- Maggetti, M., Galetti, G., and Schneuwly, R., 1988, Die Feinkeramik von Sissach-Brühl: eine spätlatènezeitliche Referenzgruppe, *Archäologie und Museum, Heft 013*, Amt für Museen und Archäologie, Liestal.
- Maggetti, M., Baumgartner, D., and Galetti, G., 1991, Mineralogical and chemical studies on Swiss Neolithic crucibles, in *Archaeometry '90*, (eds. E. Pernicka and G.A. Wagner), 95–104, Birkhauser, Basel.
- Marro, Ch., 1978, *Recherches en Archéocéramique: A) Recherches minéralogiques sur la céramique Melaun ancienne, B) Essais de séparation d'argile et de dégraissant de céramique cuite*, (Unpublished Diploma Thesis), Institute of Mineralogy-Petrography, University of Fribourg, Fribourg.
- Mumenthaler, T., 1979, *Zusammensetzung und Verwertbarkeit von schweizerischen Kiesschlamm im hydrothermalen Härungsprozess*, Beiträge zur Geologie der Schweiz, Geotechnische Serie, Lieferung 58, 82.
- Muntoni, I.M., 2002, Le analisi archeometriche di ceramiche neolitiche in Italia: storia degli studi, strategie di campionamento, tecniche analitiche e obiettivi delle ricerche, *Origini XXIV*, 165–73.
- Nungässer, W., and Maggetti, M., 1978, Mineralogisch-petrographische Untersuchung der neolithischen Töpferware vom Burgäschisee, *Bull. Soc. Frib. Sc. Nat.* 67(2), 152–73.
- Nungässer, W., and Maggetti, M., 1981, Etude Minéralogique et Péetrographique de la Poterie Néolithique du Burgäschisee (Suisse), *Revue d'Archéométrie*, Supplément no. 5, 225–6.
- Nungässer, W., Maggetti, M., and Stöckli, W.E., 1985, Neolithische Keramik von Twann – Mineralogische und Petrographische Untersuchungen, *Jahrbuch der Schweizerischen Gesellschaft für Ur- und Frühgeschichte* 68, 7–39.
- Nungässer, W., Maggetti, M., and Galetti, G., 1992, Analyse der Scherbensubstanz mit Mikroskop und Röntgenlicht, in *Liechtensteinische Keramikfunde der Eisenzeit. Jahrbuch des Historischen Vereins für das Fürstentum Liechtenstein, Band 91* (eds. J. Bill, W. Nungässer, M. Maggetti and G. Galetti), 119–65.
- Peters, T., 1961, Tonmineralogische Untersuchungen an Glazialmergeln von Zollikofen und an aquitanen Tonen und Mergeln von Pieterlen, Schweiz, *Min. Petr. Mitteilungen* 41, 1, 71–84 und Beiträge zur Geologie der Schweiz, *Geotechnische Serie, Kleinere Mitteilungen* 23, 71–84.
- Rice, P.M., 1987, *Pottery Analysis. A sourcebook*, University of Chicago Press, Chicago, London.
- Rodot, M.-A., Martineaux, R., and Bouvalot, J., 2003, Nature and provenance of Montilier-Platzbünden Horgen pottery (3179–3118 av. J. C. Western Switzerland). Petrographic and chemical (XRF) analysis, 7th European Meeting on Ancient Ceramics, Lissabon 27–31.10.2003, Abstract volume, 64.
- Rye, O.S., 1981, *Pottery Technology. Principles and Reconstruction (Manuals on Archaeology 4)*, Taraxacum, Washington D.C.
- Schlichtherle, H., and Rottländer, R., 1982, Gusstiegel der Pfynrer Kultur in Südwestdeutschland, *Fundberichte aus Baden-Württemberg* 7, 59–71.
- Schubert, P., 1986, Petrographic Modal Analysis – A Necessary Complement to Chemical Analysis of Ceramic Coarse Ware, *Archaeometry* 28, 163–78.
- Schubert, P., 1987, Die mineralogisch-petrographische und chemische Analyse der Keramik, aus: Peter J. Suter, Zürich "Kleiner Hafner", *Tauchgrabungen 1981–1984*, Berichte der Zürcher Denkmalpflege, Monographien, 3, 114–25.
- Shepard, A. O., 1954, *Ceramics for the archaeologist*. Publication 609, Carnegie Institution of Washington, Washington D.C.
- Sigg, J., Maggetti, M., and Galetti, G., 1986, Contribution à l'étude des terres argileuses de la région de Payerne, *Bull. Soc. Vaud. Sc. Nat.* 78(2), 159–93.
- SPM II, 1995, *Die Schweiz vom Paläolithikum bis zum frühen Mittelalter*, (eds. W.E. Stöckli, U. Niffeler and E. Gross-Klee), Verlag Schweizerische Gesellschaft für Ur- und Frühgeschichte, Basel.
- Stöckli, W.E., 1995, 1. Geschichte des Neolithikums in der Schweiz, in *Die Schweiz vom Paläolithikum bis zum frühen Mittelalter, SPM II (Neolithikum)*, (eds. W.E. Stöckli, U. Niffeler and E. Gross-Klee), 19–

- 52, Verlag Schweizerische Gesellschaft für Ur- und Frühgeschichte, Basel.
- Sturny, C., and Ramseyer, D., 1987, Petrographische Analyse neolithischer Keramik aus Delley/Portalban II (Kt. Fribourg/Schweiz) und Charavines (Dept. Isère/Frankreich), *Archéologie Fribourgeoise – Freiburger Archäologie, Chronique archéologique – Archäologischer Fundbericht* 1984, 92–5, Editions Universitaires Fribourg, Fribourg.
- Tobert, N., 1984, Ethno-Archaeology of Pottery Firing in Darfur, Sudan: Implications for Ceramic Technology Studies, *Oxford Journal of Archaeology* 3(2), 141–56.
- Tylecote, R.F., 1976, *A History of Metallurgy*, Metals Society, London.
- Wotzka, M.P., 1991, Keramikbrand im offenen Feuer: Vergleichende Analyse pyrometrischer Daten aus dem Töpferdorf Ikenge (Äquatorregion, Zaire), in *Töpferei- und Keramik-Forschung, Bd 2*, (eds. H. Lüdtke and R. Vossen), Habelt, Bonn, 289–318.
- Zanco, A., Mais, A., Maggetti, M., and Carazzetti, R., 2003, Technological studies on Neolithic to Bronze Age (\pm 5'300–1'400 BC) and Early Iron Age (700–600 BC) pottery from Castel Grande (Bellinzona, Ticino, Switzerland), *7th European Meeting on Ancient Ceramics, October 27–21, Lisbon, Portugal*, Abstract volume, 85.
- Zwicker, U., Greiner, H., Hofmann, K.-H., and Reithinger, M., 1985, Smelting, Refining and Alloying of Copper and Copper Alloys in Crucible-Furnaces during Prehistoric up to Roman Times, in *Furnaces and Smelting Technology in Antiquity*, (eds. P.T. Craddock and M.J. Hughes), 103–15, British Museum Occasional Paper 48, London.

From Mine to Microscope

Advances in the Study of Ancient Technology

edited by
Andrew J. Shortland, Ian C. Freestone
and Thilo Rehren

Oxbow Books

Published by
Oxbow Books, Oxford, UK

© The individual authors, 2009

ISBN 978 1 84217 259 9

A CIP record for this book is available from the British Library

This book is available direct from

Oxbow Books, Oxford, UK
(Phone: 01865-241249; Fax: 01865-794449)

and

The David Brown Book Company
PO Box 511, Oakville, CT 06779, USA
(Phone: 860-945-9329; Fax: 860-945-9468)

or from our website

www.oxbowbooks.com

Printed Great Britain by
Short Run Press, Exeter