Institut de Minéralogie et de Pétrographie
Université de Fribourg (Suisse)

Domestic production versus pottery exchange during the Final Neolithic: characterization of the Auvernier-cordé ceramics from the Portalban and St. Blaise settlements, Western Switzerland.

THESE

presentée à la Faculté des Sciences de l'Université de Fribourg (Suisse) pour l'obtention du grade
de *Doctor Rerum Naturalium*

Simonpietro DI PIERRO
(Italie)

Thèse n° 1391
Imprimerie: Iridea di F.Bugnone & C. Torino.

Acceptée par la Faculté des Sciences de l'Université de Fribourg (Suisse) sur la proposition de :

Prof. Marino Maggetti, Université de Fribourg (Suisse), rapporteur
Prof. Bruno Messiga, Università di Pavia (Italia), co-rapporteur
Dott. Vincent Serneels, Université de Fribourg (Suisse), co-rapporteur
Prof. Dietrich Meyer, Université de Fribourg (Suisse), Président du Jury

Fribourg, le 11 octobre 2002

Le Directeur de thèse

Prof. Marino Maggetti

D. Baeriswyl

Le Doyen

Prof. Dionys Baeriswyl

Ringraziamenti

Voglio dedicare questa ricerca ai miei figli, Samuele e Carola, bambini che non sempre hanno potuto beneficiare della presenza del papà come avrebbero certamente voluto. Questo lavoro non avrebbe mai potuto essere scritto senza l'inestimabile pazienza di mia moglie, Alessandra, la quale provvedendo alla costante cura ed educazione di Samuele e Carola durante le miei settimanali assenze, mi ha permesso di realizzare i miei desideri professionali.

Un ringraziamento affettuoso va ai miei genitori, a mio padre ed in particolare a mia madre, alla sua incondizionata fiducia nell'incentivarmi a studiare ed al suo supporto morale ed economico.

All'Istituto di Mineralogia e Petrografia dell'Università di Friburgo, ho incontrato e lavorato con uno staff di ineguagliabile professionalità per tutti i quattro anni del mio soggiorno svizzero, persone con cui ho condiviso esperienze lavorative, gioie e delusioni.

Ci tengo a ringraziare il Prof. Marino Maggetti, il quale conducendomi attraverso l'avventura dell'Archeometria mi ha insegnato l'importanza del rigore e della serietà nel presentare e sostenere i dati scientifici.

Ringrazio il Prof. Bruno Messiga per gli attenti suggerimenti e commenti riguardanti questo manoscritto.

Desidero ringraziare il Prof. Jürgen von Raumer, il Prof. Bernard H. Grobéty, il Prof. Giulio Galetti and il Dr. Vincent Serneels, per il loro costante aiuto e per la loro disponibilità a fruttuose discussioni e commenti.

Un merito speciale va al Dr. Rémi Martineau, con il quale ho condiviso gran parte del mio tempo lavorativo di ricercatore. Grazie alle sue profonde conoscenze in campo culturale e scientifico, ho potuto beneficiare dell'importanza e della bellezza delle Scienze Umanistiche.

Il Dr. Dénis Ramseyer, il Dr. Robert Michel ed il Dr. François Giligny hanno profondamente contribuito alla chiarezza dei molti aspetti archeologici di questo lavoro.

Ringrazio infinitamente la Sig.ra Odette Marbacher, la Sig.ra Nicole Bisang, il Sig. Paulo Bourqui, il Sig. Patrick Dietsche ed il Sig. Daniel Cuennet per la loro inestimabile disponibilità ed assistenza pratica in laboratorio ed in amministrazione.

Cristiano Ferraris, Boris Cuanoud, Annamaria Lanfranco, Sophie Wolf, Anna Lepora, Jeanne Bonzon, Jessica Chiaverini, Patrick Fracheboud, Folco Giacomini, Lenny Winkel, Gisela Thierrin, Pierre Vonlanthen, Cédric Metraux, Peter Berner, Giacomo Eramo, Simon Fischer, Sebastian Perret, Kuno Matzinger and Cristophe Neururer, sono gli amici con i quali ho condiviso numerosi bei momenti di convivialità, esperienze professionali e di amicizia.

Last but not least, sono in debito con Antonio Pedalino, l'amico con il quale ho condiviso il lungo viaggio attraverso l'avventura svizzera, senza il cui aiuto e supporto morale, questo lavoro di ricerca non avrebbe mai visto la luce. Lo ringrazio inoltre infinitamente per la messa in pagina e la finalizzazione del presente manoscritto.

Table of contents

CERAMIC PRODUCTION TECHNOLOGY AND PROVENANCE DURING THE FINAL NEOLITHIC: THE PORTALBAN SETTLEMENT, NEUCHÂTEL LAKE, SWITZERLAND

THE PORTALBAN POTTERY: MATERIALS VERSUS CERAMIC TYPES AND SPATIAL DISTRIBUTION. CRAFTSMANSHIP OR DOMESTIC PRODUCTION?

MATRIX – TEMPER SEPARATION OF NEOLITHIC CERAMICS: AN EXPERIMENTAL APPROACH TO CHARACTERIZE THE ORIGINAL RAW MATERIALS AND DETERMINE THEIR PROVENANCE.

MATERIAUX ET TYPES CERAMIQUES A SAINT BLAISE, STATION NEOLITHIQUE SUISSE : POTERIE EXOGENE ET PRODUCTION LOCALE.

POTTERY VERSUS COBS AND LOOM WEIGHTS. DIFFERENT RAW MATERIALS FOR DIFFERENT UTILIZATIONS AT THE WESTERN SWISS PLATEAU SCALE

POTTERY TEMPERING WITH MONT BLANC GRANITE ACROSS THE JURA BELT DURING FRENCH AND SWISS FINAL NEOLITHIC

ANNEX I: *Portalban pottery*

ANNEX II: *St. Blaise pottery*

ANNEX III: *Mineralogical and petrographic composition of samples*

ANNEX IV: *Curriculum Vitae*

ABSTRACT

The present research focuses on the ceramic products of the two Final Neolithic dwelling settlements of Portalban and St.Blaise, Western Switzerland, relative to the Old and Medium Auvernier-cordé (2700 – 2400 BC) cultural groups. These two important sites are inserted in the sequence of the Three Lakes Region (Neuchâtel, Bienne and Morat), which includes a complete stratigraphy ranging from Old, Middle and Recent Neolithic. The most important event of the Final Neolithic for the Western Swiss Plateau is the arrival of the "Corded ceramic" civilization from Eastern Switzerland, which spread over the local communities of the region. The allochthonous populations strongly influenced the local know-how concerning the pottery manufacturing, importing their styles and morphologies. The studied pottery has been therefore selected taking into consideration the typological group to which they belonged: (i) "Transition" or "Lüscherz tradition", (ii) "Auvernier" s.s, (iii) "Corded" ceramic and the two sub-groups (iii-a) "Corded true" and (iii-b) "Corded imitation". The spatial distribution of the pottery inside the settlement of origin, with particular interest to the building structure of provenance, has been considered in order to test the hypothesis of a domestic production rather than a craftsmanship activity, always related to the ceramic manufacturing. 107 pottery samples, 14 cobs and 7 loom weights have been characterized with a classical archaeometric approach. Clays and moraine rocks have been sampled for the identification of the potential raw materials. The characterization of the ceramic materials has been carried out by means of the mineralogical compositions (X-ray diffraction), the petrographic analyses (thin sections) and the bulk chemical analyses (X-ray fluorescence). In order to better determine the provenance of the raw materials a new technique has been implemented on a representative portion of the studied pottery. It concerned the separation of the main fractions of the potsherds, matrix and temper, through a properly buffered H_2O_2 attack, in order to chemically characterized them separately.

Several different results have been achieved.

The first one concerned the sharp difference in production technology and materials provenance with reference to the pottery on one side and the cobs & loom weights on the other. This interesting issue has been first determined at the Portalban settlement, from where the calcareous clay used for the cobs and the loom weights preparation has been identified as local. Secondly, exploiting data from literature concerning other settlements, this regular difference has been observed and extended at the scale of the Western Swiss Plateau. Further, the Portalban pottery resulted being composed of very homogeneous materials, in terms of clay and temper both, on petrographic as well as chemical base. A silicate matrix, particularly rich in alumina, and rock fragments with the precise petrographic fingerprint of the *stilpnomelane bearing Mont Blanc granite*, have been identified as the basic components of the pottery. They have been mixed in slightly different proportion, but without remarkable correlations with any morphological group of affiliation or house of provenance. This result would indicate a large and deep technological know-how in relation to the used materials, shared at the scale of the whole village. The presumed local clay source has not been found during the prospecting of the area, either because the intense urbanization shall not allow its exposure anymore or because it has been fully exploited. The Mont Blanc granite has been instead identify in the moraine deposits surrounding the settlement, but as a scarcely available lithotype.

A different important result has been instead obtained at the St.Blaise settlement, and concerned the heterogeneity of pottery composition. Three main petro-chemical groups have been in fact identify, all having their precise fingerprint. The main group of ceramics (46 pot-sherds) is composed of a calco-silicate matrix, MgO-poor, a second group of seven pottery is composed of a silicate matrix, MgO-rich, while the third group (eight pot-sherds) is composed of a calco-silicate matrix, distinguishable on the basis of an high content of Sr + Ba. Only one pottery has a high calcareous composition, and it has been considered as exogenous. The above mentioned compositional differences concerning the matrix may be ascribed to the utilization of different raw materials, which in turn would indicate the utilization of more clays sources. The entire pottery suite, no matter which the petro-chemical group was, has been tempered with the *stilpnomelane bearing Mont Blanc granite*. The correlation with the morphological group of affiliation has permitted to establish a good correspondence between the silicate, MgO-rich ceramics and the "Corded true" typological group. Moreover, the using of other data from the literature has strengthened this result. The difference in material composition as well as the morphological obtained correlation raised the hypothesis of an exogenous provenance of the "Corded true" pottery of St.Blaise. The hypothesis has been tested with the statistical analysis (cluster and discriminant analyses both) and found plausible. The spatial distribution of the ceramic products highlighted the precise correlation existing between the Sr + Ba rich pottery and the house of provenance. A possible contamination problem has been inferred and ruled out. Rather, this result has confirmed the model of a domestic ceramic production, house-linked, for the St.Blaise settlement at least.

RÉSUMÉ

Cette recherche concerne la production céramique des deux sites lacustres de Portalban et St. Blaise, appartenant au Néolithique final de Suisse occidentale, relativement aux groupes culturels « Auvernier-cordé » moyen et ancien (2700 – 2400 av. J.C.). Les deux sites néolithiques font partie de la séquence de la Région des Trois Lacs (Neuchâtel, Bienne et Morat), du Néolithique ancien au Néolithique récent. L'arrivé de la « Civilisation de la Céramique Cordée » est surement l'événement qui caractérise le Néolithique Final en Suisse occidentale. Ces populations se sont installées près des communautés locales, et ils ont fortement influencé la production céramique locale, avec l'importation de leurs styles et savoir-faire. La poterie étudiée dans cette étude a donc été choisie en tenant compte des groupes typologiques : (i) la céramique de « Transition » ou de « Tradition Lüscherz », (ii) la céramique « Auvernier » propre, (iii) la céramique « Cordée » et ses deux sous-groupes (iii-a) de la céramique « Cordé vrai » et (iii-b) de la céramique « Cordé imité ». La répartition spatiale de la poterie à l'intérieur de chaque site a été prise en compte, avec un intérêt particulier aux structures d'habitation, pour tester l'hypothèse d'une production domestique plutôt qu'une production artisanale. 107 poteries, 14 torchis et 7 poids de tisserands ont été caractérisés avec une approche archéométrique classique. En outre, des échantillons d'argiles naturelles et de roches ont été prélevés des dépôts morainiques locaux pour l'identification de matières premières qui auraient pu être utilisées pour la production des poteries. La caractérisation a été effectuée par analyse minéralogique en diffraction des rayons X, étude pétrographique en lame mince et analyse chimique en fluorescence des rayons X. Dans le but d'obtenir une meilleure identification des matières premières, une nouvelle technique de séparation a été appliquée à une série représentative des poteries étudiées. La technique consiste dans l'attaque avec une solution tamponnée de H_2O_2 du tesson céramique pour obtenir la composition des deux composants principaux : la matrice et le dégraissant.

Les résultats obtenus ont été les suivants :

Le premier concerne la nette différence existant en terme de technologie de production et matériaux utilisés, entre la poterie d'un côté et les torchis et le poids de tisserands de l'autre. Ce résultat a été d'abord obtenu sur le site de Portalban, d'où l'argile calcaire utilisée pour la fabrication des torchis et des pesons a été précisément identifiée comme locale. Ensuite, en utilisant les données présentes dans la littérature sur d'autres sites, cette nette différence a été étendue à l'échelle du Plateau suisse occidental. La composition pétrographique et chimique de la poterie de Portalban est très homogène, soit pour la matrice soit pour le dégraissant. On a identifié : une matrice silicatée, riche en Al_2O_3, dégraissée à l'aide de fragments de roche avec une empreinte pétrographique du *granite du Mont Blanc à stilpnomelane*. Ces deux composants ont été utilisés en proportions légèrement différentes, mais aucune corrélation claire n'a été établie avec les groupes typologiques, ou bien avec la localisation des structures d'habitation. Ce résultat indiquerait une connaissance des matériaux et un savoir-faire partagé à l'échelle du village. L'argile utilisée pour la poterie n'a pas été identifiée par la prospection de la zone, soit car l'urbanisation peut en avoir oblitérée la présence, soit parce qu'elle peut être épuisée. Par contre, le granite du Mont Blanc a été trouvé dans la moraine locale, mais sa disponibilité est assez faible.

Un autre résultat important a été obtenu pour la poterie de St.Blaise, et concerne l'hétérogénéité de sa composition. Au moins trois groupes pétrographiques et chimiques ont été déterminés : le groupe principal est constitué par 46 céramiques avec matrice calco-silicatée et pauvres en MgO, un deuxième groupe de sept poteries est par contre composé par une matrice silicatée riche en MgO, un troisième groupe de huit céramiques à matrice calco-silicatée se distingue par une teneur élevée en Sr + Ba. Une seule poterie est composée par une matrice fortement calcaire, et elle a été considérée comme héxogène. Les différences pétro-chimiques déterminées sur les matrices peuvent être attribuées à l'utilisation de matières premières différentes, c'est-à-dire à l'exploitation d'affleurements d'argiles différentes. Tout le corpus céramique, indépendamment de sa composition pétro-chimique, a été dégraissé avec du *granite du Mont Blanc à stilpnomelane*. Une bonne corrélation a été trouvée entre la poterie à matrice silicatée et riche en MgO et le groupe typologique de la céramique « Cordé vrai ». Ce résultat a été renforcé par l'utilisation des données bibliographiques existant déjà sur le site. Les différences entre les matériaux et la bonne corrélation avec la typologie ont permis de penser à une provenance héxogène de la poterie « Cordé vrai » de St. Blaise. Cette hypothèse a été testée avec l'analyse statistique multivariée des données chimiques (classification ascendante hiérarchique «cluster analysis» et l'analyse discriminante) et a été trouvée plausible. La répartition spatiale de la céramique à l'intérieur du site a permis de mettre en évidence une corrélation précise entre le groupe de poteries riches en Sr + Ba et une maisonnée particulière. La contamination chimique de ces poteries a pu être exclue. Au contraire, ce dernier résultat confirme plutôt l'hypothèse d'une production domestique de la céramique, liée aux structures d'habitation du site de St. Blaise.

RIASSUNTO

La presente ricerca concerne lo studio dei prodotti ceramici provenienti dai due siti lacustri, del Neolitico finale, di Portalban e St. Blaise, in Svizzera occidentale, relativamente al gruppo culturale "Auvernier-cordé" (2700 – 2400 a.C.). Questi due importanti siti fanno parte della sequenza della Regione dei Tre Laghi (Neuchâtel, Bienne e Morat), la quale include la completa stratigrafia dal tardo al Neolitico recente. Il più importante evento caratterizzante il Neolitico finale per l'altopiano svizzero occidentale, è sicuramente l'arrivo della Civilizzazione della Ceramica cordata dalla Svizzera orientale, installatasi presso le comunità locali. Le popolazioni alloctone hanno fortemente influenzato la produzione ceramica locale, importando i propri stili e morfologie esogene. La ceramica studiata in questo lavoro è stata quindi selezionata tenendo conto del gruppo morfologico d'appartenenza: (i) la ceramica di "Transizione" o di "Tradizione Lüscherz", (ii) la ceramica "Auvernier" *s.s.*, (iii) la ceramica "Cordata" ed i due sottogruppi della (iii-a) ceramica "Cordata vera" e della (iii-b) ceramica "Cordata d'imitazione". Inoltre, per testare l'ipotesi di una produzione domestica piuttosto che artigianale, è stata inoltre considerata la distribuzione spaziale della ceramica all'interno dei due siti d'origine, con particolare riguardo alle strutture abitative di provenienza. 107 campioni di vasi, 14 argille cotte per rivestimento dei muri interni e pavimentazione delle abitazioni nonché 7 argille cotte utilizzate per la tessitura e la concia delle pelli, sono state caratterizzate con il classico approccio archeometrico. Sono stati campionati inoltre argille naturali e campioni di roccia provenienti dalle morene locali per la potenziale identificazione delle materie prime usate per la produzione ceramica. La caratterizzazione è stata effettuata tramite l'individuazione della composizione mineralogica (diffrazione raggi X) dei manufatti, la loro composizione petrografica tramite analisi in sezione sottile e la composizione chimica totale (fluorescenza raggi X). Una nuova tecnica di studio è stata implementata su una serie rappresentativa dei precedenti campioni, con lo scopo di meglio identificare le materie prime utilizzate. La tecnica consiste in un attacco con una soluzione tamponata di H_2O_2 sul frammento di ceramica, ed ha come obiettivo la separazione delle parti principali della ceramica, la matrice e lo smagrante.

Nello studio sono stati raggiunti i seguenti risultati.

Il primo concerne la netta differenza in tecnologia di produzione ed utilizzazione dei materiali esistente tra la ceramica *s.s.*, cioè il vasellame, e gli altri oggetti in argilla cotta usati per le abitazioni e la concia delle pelli. Questo risultato è stato ottenuto dapprima sul materiale proveniente da Portalban, da dove l'argilla calcarea utilizzata per la preparazione delle argille cotte è stata identificata con precisione e come locale. Secondariamente, utilizzando i dati presenti in letteratura concernenti altri siti, questa netta e regolare differenza è stata estesa alla scala dell'altopiano svizzero occidentale. Per quanto riguarda la ceramica *s.s.*, essa è risultata composta da materiali molto omogenei, sia per quanto riguarda la matrice (l'argilla) che per quanto riguarda lo smagrante, sia su base petrografica che chimica. I componenti di base identificati sono: una matrice silicatica, particolarmente ricca d'allumina, e frammenti di roccia con una chiara impronta petrografica del *granito del Monte Bianco a stilpnomelano*. I due componenti sono stati utilizzati in proporzioni leggermente differenti da vaso a vaso, ma non è stato possibile stabilire alcuna correlazione con i gruppi morfologici d'appartenenza o struttura abitativa di provenienza. Questo risultato indicherebbe una profonda conoscenza dei materiali e del know-how tecnologico, condiviso alla scala dell'intero villaggio. L'affioramento dell'argilla utilizzata, presunta locale, non è stato trovato durante la prospezione dell'area, sia a causa dell'intensa urbanizzazione che non ne consente l'esposizione, sia perché potrebbe essere stata completamente utilizzata. Invece, il granito del Monte Bianco è stato effettivamente individuato nei depositi morenici locali, ma la sua disponibilità è risultata scarsa.

Un risultato differente, altrettanto importante, è stato invece ottenuto sulla ceramica proveniente da St. Blaise. Esso riguardo l'eterogeneità della composizione di quest'ultima. Sono stati infatti identificati almeno tre gruppi, ognuno con le proprie caratteristiche chimiche e petrografiche. Il gruppo principale è costituito da 46 ceramiche ed è composto da una matrice calco-silicatica, povera di MgO; un secondo gruppo di sette ceramiche è invece composto da una matrice silicatica, ricca di MgO; il terzo gruppo si distingue per un tenore elevato degli elementi traccia Sr e Ba. Una sola ceramica è costituita da una matrice fortemente calcarea, ceramica in seguito considerata esogena. Le differenze composizionali determinate sulle matrici sono riconducibili all'utilizzo di materie prime diverse tra loro, a loro volta ascrivibili ad affioramenti di argille differenti. Tutte le ceramiche, indipendentemente dal gruppo chimico-petrografico d'appartenenza, sono state smagrate tramite l'aggiunta di frammenti di *granito del Monte Bianco a stilpnomelano*. E' stata trovata una buona correlazione tra il gruppo di ceramiche a composizione silicatica e ricche di MgO ed il gruppo morfologico della ceramica "Cordata vera". Inoltre, questo risultato è stato rafforzato dall'utilizzo di dati bibliografici già esistenti riguardanti lo stesso sito. Le differenze nei materiali utilizzati, cosi come le correlazioni con la morfologia, hanno permesso di pensare ad una provenienza esogena della ceramica "Cordata vera" di St. Blaise. Questa ipotesi è stata testata tramite l'analisi statistica dei dati chimici ("cluster" e discriminante), ed è risultata plausibile. La distribuzione spaziale all'interno dell'insediamento dei prodotti ceramici ha evidenziato una precisa correlazione tra il gruppo di ceramiche ricche in Sr + Ba e la struttura abitativa dalle quali provengono. E stato considerato un possibile problema di contaminazione dei prodotti ceramici in questione, in seguito escluso. Invece, questo risultato conferma il modello di una produzione domestica del vasellame, legato alle case d'abitazione, almeno per il sito di St. Blaise.

PREFACE

The craftsmanship has always been considered as an important engine of the trading activities in the human history. One central issue of the archaeology relates to when the craftsmanship activity had started, since the concept itself of craftsman has been and still is the subject of a long lasting debate inside the scientific archaeological community. For the European Neolithic the character himself of the craftsman is ruled out by the majority of the archaeologists. For instance, the ceramic production is thought to be a domestic activity concerning mainly the women of the village, while men are mainly concerned with the weapons preparation, arrows and knives made of flint, destined to the hunting activities. Moreover, the pottery manufacturing has to be related to every single house or hut, considered as the elementary social and economic cell of the village[1].

Alternatively to the above interpretation, can we assume for the Neolithic the existence of a sort of specialization related to the pottery manufacturing? In other word, could potters be considered as craftsmen (or craftswomen)?

The present Ph.D research consists in estimating the degree of specialization of the ceramic production for the Swiss Final Neolithic. Two well-known dwelling settlements have been selected for this purpose: Portalban and St. Blaise, both in the Three Lakes Region of the Western Swiss Plateau.

The Delley/Portalban II station was the subject of several different detailed publications[2,3,4], as well as the site of Saint Blaise/Bains de Dames[5]. For both sites the pottery manufacturing is considered an outstanding feature, which permitted the archaeologists to set up the whole sequence of Civilizations and Cultural Groups, which ranged from the Cortaillod Port-Conty phase until the Bronze Age.

The archaeometric characterization of the ceramic production, ranging Horgen, Lüscherz and Auvernier-cordé cultural groups (3200 – 2400 BC), of these two and other Neolithic settlements of Western Switzerland and France has been already published[6]. The main objective of that study was the provenance of the Swiss ceramic, with particular interest to the potential importation from the Northwestern France of fine potteries. The local production of the Swiss ceramic products was determined, at the regional scale of the Western Swiss Plateau at least, while the question of the importation of the fine pottery could be definitely excluded.

The present study is focused on the Auvernier-Cordé cultural groups of the Portalban and St. Blaise settlements, 2700 – 2400 BC. The question of the specialization of the pottery manufacturing has been faced with a multiple approach, which concerns:

- constrained and well studied ceramic typologies,
- the spatial distribution of pottery inside each settlement,
- a new petrographic and chemical characterization of expressively chosen ceramic samples.

The ceramic production is characterized at both sites by several different styles and morphologies, which are all contemporary. The “Lüscherz Tradition”, the “Auvernier” s.s. and the “Corded” ceramics are among the main ones. The latter in particular is very important because its appearance in Westerns Switzerland reflects the arrival of populations from Eastern Switzerland, from which it constitutes the local ceramic fingerprint. The detailed studies of ceramic types have permitted to distinguish, in the Western Swiss Plateau, the “Corded” ceramic in two main sub-groups: the “Corded Imitation” ceramic, which shows the local know-how, and the “Corded True” ceramic, which still owns the exogenous decorations of Eastern Switzerland. The importance of setting up morphological groups of ceramics resides in the link existing between ceramic types, people and their “savoir-faire”.

The Portalban and St.Blaise lakeshore sites have been both interpreted as pile-dwelling villages. The repartition of logs and the dendrochronology data sets have permitted to identify the building structures used by the inhabitants. As for all the other archaeological artifacts, the ceramic findings are linked to the single houses or huts. The pottery spatial distribution has been therefore used to determine each domestic provenance.

The pottery characterization has been pursued beyond the classical archaeometric approach, since the raw materials sources and distances from the settlements assume a particular importance in relation to the potential specialization of ceramic production.

Starting from the above state of the art, the following questions have been raised.

1) Is the ceramic at the Portalban and St. Blaise settlements a local or a non-local[7] production? In

---

[1] PÉTREQUIN, P., PÉTREQUIN, A.M., GILIGNY, F. & RUBY, P., 1994, Produire pour soi, la céramique de Chalain 2 C au Néolithique final. *Bulletin de la Société Préhistorique française*, t. 91, n° 6, p. 407-417.

[2] SCHWAB, H., 1982, *Portalban/Muntelier: zwei reine Horgener Siedlungen der Westschweiz.* Archäologisches Korrespondenzblatt, 12, Mainz, pp. 15-32

[3] RAMSEYER, D., 1987, Delley-Portalban. Contribution à l'étude du Néolithique en Suisse occidentale. Archéologie friburgoise 3, Fribourg.

[4] GILIGNY, F., 1993, La variabilité des récipients céramiques au Chalcolithique moyen-récent jurassien (3400-2400 av. J.C.). Analyse archéologique d'un système d'objets. Thèse de Doctorat, Université de Paris I – Panthéon/Sorbonne UFR 03 – Histoire de l'Art et Archéologie.

[5] MICHEL, R., 2002, Saint-Blaise/Bains des Dames, 3. Typologie et chronologie de la céramique néolithique: céramostratigraphie d'un habitat lacustre. Neuchâtel, Service et Musée cantonal d'archéologie *Archéologie neuchâteloise*, 27; 2 vol.

[6] BENGHEZAL, A., 1994, *Provenance et techniques de la céramique du Néolithique final de stations des trois lacs jurassiens Suisse.* Thèse de doctorat, Université de Fribourg, 174 pp.

[7] In the sense defined by Arnold (1985 ; 2001)

ARNOLD, D., 1985, *Ceramic theory and cultural process. New studies in Archaeology* . Cambridge University Press.

ARNOLD, D., 2001, *Linking society with the compositional analyses of pottery : a model from comparative ethnography.* XIVe the case it were non-local, do exist one or more "Centers" for the pottery production?

2) In the case it were local, can the materials used for the pottery manufacturing be correlated either to the ceramic types (morphologies) and/or to the ceramic repartition (buildings)? Was the ceramic production a domestic or a specialized activity?

The potential answers to this second question would range between the following two extremes:

a) no links with morphologies but links with buildings, to which it might correspond a domestic production;
b) links with morphologies but no links with buildings, to which it might correspond a specialization.

Of course, several other answers and possibilities exist, since rules and interpretation are not fixed or unique and do not correspond necessary to any standard. Each settlement is a single case study and relevant results should be interpreted in the local context, at the scale of the settlement, but at the same time in the framework of the regional scale (potential exchanges of ceramics between settlements, migration of populations and so on).

Structure of the Ph.D research

This work has been structured into six main parts.

The first chapter focuses on the characterization of the ceramic products from the Portalban settlements, and the potential raw materials prospected in the same area. The main objective is to determine whether the pottery production was performed with local or non-local materials.

The second chapter relates to the craftsmanship or domestic production of the Portalban pottery. Petrographic and chemical results are compared on one hand to the ceramic morphologic groups, and to their repartition inside the settlement on the other.

In the third chapter the implementation of a new methodology, concerning the separation of the matrix and the temper of a pottery sherd, is presented. The main aim is to establish a technique, which may allow characterizing the two basic fractions of a ceramic separately. The objective is to obtain better and focused information about the provenance of raw materials used in pottery manufacturing. The new method has been carried out on a suite of Portalban ceramic sherds.

The fourth chapter deals with the characterization of the ceramic products from the St. Blaise settlement. Even in this case, the local or non-local provenance of the raw materials, temper and clay, is presented. The data concerning the separation method carried out to the St. Blaise pottery suite are shown as well. Contextually, the comparative study concerning the ceramic morphologic groups on one side, and the spatial distribution of the pottery at the site is investigated too.

The fifth chapter concerns a reinterpretation of the archaeometric data sets presented by Benghezal[6], at the light of the obtained results of the Portalban settlement. In particular, the sharp difference in production technology and materials provenance between pottery and cobs & loom weights is stressed. The regularity of these discrepancies at the scale of the Western Swiss Plateau is presented.

The last chapter focuses on the regular utilization of the Mont Blanc granite as temper material at Portalban as well as at St. Blaise. The utilization of the same lithotype has been encountered during the characterization of a particular pottery suite coming from Chalain, France. The data sets of the separation technique concerning the three settlements are presented in a comparative study.

Congrès de l'Union International des Sciences Préhistoriques et Protohistoriques, Liège, 2 - 8 septembre 2001. Abstract, p. 45.

CHAPTER I

CERAMIC PRODUCTION TECHNOLOGY AND PROVENANCE DURING THE FINAL NEOLITHIC: THE PORTALBAN SETTLEMENT, NEUCHÂTEL LAKE, SWITZERLAND[1]

by Simonpietro DI PIERRO

Abstract

This paper deals with the difference in production technology and provenance, between pottery and other fired clay objects such as cobs and loom weights, during the Old Auvernier-Cordé occupation (2.700 – 2.650 BC) from the Portalban settlement, Neuchâtel Lake, Western Switzerland. Petrographic and chemical investigations have permitted to clearly distinguish between two completely different groups. The pottery has been produced with a silicate, Al-rich, inclusion-poor clay, to which a 20-25% in volume of granite temper grains with a clear Mont Blanc granite fingerprint have been added. The cobs were made with a carbonate clay; no temper has been added. Loom weights have been produced with the same carbonate clay, but they have been tempered with organic matter. Local prospecting of available raw materials allowed to identify the raw clay used for the cobs and the loom weights. The clay used for the pottery preparation has not been identified. Mont Blanc granite is available in the moraine deposits, which surround Portalban, but is quantitatively negligible. While the production of the cobs and the loom weights is doubtless local, the source of the pottery raw materials should be further investigated.

Keywords: Final Neolithic, ceramic, pottery, cobs, loom weights, production technology.

Résumé

Ce travail traite les différences de technologie de production et de provenance, entre la poterie et les autres objets fabriqués en argile cuite comme les torchis et les poids de tisserand, pendant l'occupation du groupe Auvernier-Cordé ancien (2.700-2.650 av. J.C.) au site de Portalban, Lac de Neuchâtel, Suisse occidentale. Les études pétrographiques et géochimiques ont permis de distinguer deux groups très bien différenciés. La poterie a été produite à partir d'une argile à composition silicate, riche en aluminium et pauvre en inclusions naturelles, dans laquelle un 20-25% en volume de dégraissant granitique, avec une claire empreinte du granit Mont Blanc, a été ajouté. Par contre, les torchis ont été produits à partir d'une argile à composition carbonatée, et ils n'ont pas été dégraissés du tout. Les poids de tisserands ont été fabriqués à partir de la même argile carbonatée, mais ils ont été dégraissés avec de la matière organique. La prospection des matières premières disponibles sur place a permis d'identifier l'argile crue utilisée pour les torchis et les poids de tisserands. Au contraire, l'argile utilisée pour la production de la poterie n'a pas été identifiée. Le granit du Mont Blanc est disponible dans la moraine locale, mais il est quantitativement négligeable. Si la production des torchis et des poids de tisserand est sans doute locale, l'approvisionnement des matières premières pour la fabrication de la poterie doit être ultérieurement investiguée.

Mots-clés : néolithique final, céramique, poterie, torchis, poids des tisserand, technologie de production.

---

[1] *Proceedings of the "4ème colloque d'Archéometrie", GMPCA, La Rochelle 24 – 28 avril 2001. Revue d'Archéometrie. In press.*

1. INTRODUCTION

The modern village of Portalban lies in the territory of the Canton of Fribourg, on the South-eastern bank of the Neuchâtel Lake. It shares with the Delley municipality one of the most important Neolithic sites of the Swiss Plateau and the Jurassic lakes (figure 1).

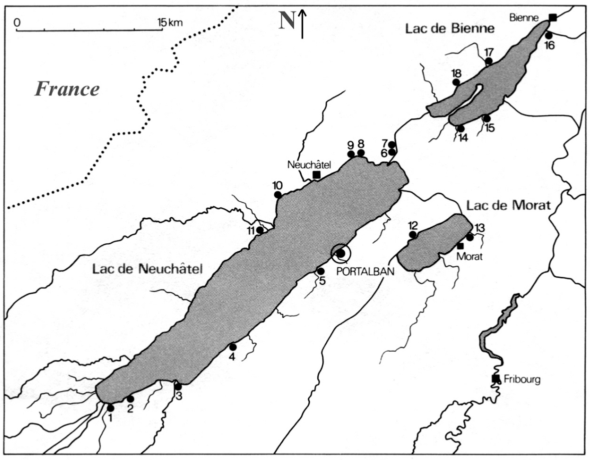


Figure 1. Localisation of Portalban. The Neolithic site lies on the South-eastern bank of the Neuchâtel Lake and is among one of the most important Final Neolithic settlements of Western Switzerland (extract from Ramseyer, 1987).
1. Yverdon (avenue de Sports), 2. Chéseaux (Châble-Perron), 3. Yvonand, 4. Font, 5. Gletterens, 6. Thielle-Wavre (Thielle-Mottaz), 7. Thielle-Wavre (Pont-de-Thielle), 8. Saint Blaise, 9. Hauterive (Champréveyres), 10. Auvernier, 11. Cortaillod, 12. Guévaux, 13. Montilier/Muntelier, 14. Vinelz, 15. Lüscherz, 16. Port, 17. Twann, 18. La Neuveville (Schafis).

Thanks to the second "Jura waters correction" (1962-1973), which lowered the Neuchâtel Lake level of 2.73 m and moved the actual shoreline some 300 m westwards, the prehistoric Portalban village came again into light. Delley/Portalban II is one of the five main distinct sites, where the ceramics concerning this work come from. It is likely to be the richest area and cover a long period of times, ranging from Old, Final Neolithic to the Bronze Age (Schwab, 1982).

Several works concerning the Delley/Portalban II settlement that deal with archaeological and archaeometric different issues have already been published (Schwab, 1982; Sturny & Ramseyer, 1984; Ramseyer, 1987; Danerol *et al.*, 1990; Giligny, 1993; Giligny & Michel, 1995; Benghezal, 1993, 1994; Picouet, 1997; Médard, 2000).

This paper concerns the ceramic production technology during the Old Auvernier-Cordé occupation of the site (2.700- 2.650 BC, calendar year, Giligny, 1993). 50 pottery sherds, coming from 47 different reconstructed vases, 14 cobs (foyer"torchis") and 7 loom weights (poids de tisserand) have been characterized with optical microscopy, X-ray diffraction (XRD) and X-ray fluorescence (XRF). 12 clays and 100 moraine rock specimens from the surroundings of the Neolithic village have been sampled and characterized (table 1).

The study concerns primary the provenance of the Portalban ceramic in terms of *local* production as it has been recently defined by Arnold (2001); this author defined, on the basis of statistic and ethnographic approaches, a distance to clay and temper resources within a radii of 1-2 km, in order to state the *local* origin of ceramic products. Benghezal (1994) stated the local production of Western Swiss final Neolithic ceramics, but at the regional scale of the lakes of Bienne and Neuchâtel. Differentiating between the pottery and the other fired clay objects (cobs and loom weights), we will test this hypothesis.

Secondly, this paper concerns some technological aspects of Portalban ceramic production. There is a wide general assumption in the archaeological and archaeometric communities that pottery, cobs and loom weights, coming from the same settlement, can be considered as a whole from the technological point of view. At least for the Portalban final Neolithic site, this paper will demonstrate that such a general statement should be discontinued.

1.1 Archaeological context

The Neolithic station of Delley/Portalban II is inserted in the sequence of the Three Lakes Region (Neuchâtel, Bienne, Morat), which has been described by Vouga (1929). This author first distinguished, on the basis of the Auvernier settlement stratigraphy, an Old Neolithic, a Middle Neolithic and a Recent Neolithic for the Swiss Western Plateau. These phases were all considered as a unique civilization (Giligny, 1993, and references therein). A timetable concerning the Swiss Neolithic is presented in figure 2.

The first findings at Delley/Portalban II date back to 1858. The first documented borings have been performed between 1952 and 1957 and published by Schwab (1971), (Giligny, 1993, and reference therein). The main excavation campaign lasted from 1962 to 1979 under Hanni Schwab, Fribourg Cantonal Archaeologist, leading first, and of Denis Ramseyer afterwards.

Schwab (1982) published the first comprehensive report on the artefacts found at Portalban, as well as at Muntelier on the Morat Lake. At the Portalban station II, several different settlements ranging from Cortaillod, Horgen, Lüscherz, Auvernier to Corded ceramic (with Eastern Swiss influences) cultures, have been identified.

Ceramics are not the only important artefacts found at the site. Almost twenty years of excavations have brought to light hundreds of different objects and tools, which allowed to design and interpret several centuries of human history.

Among the other findings were „green rock" serpentinitic axes, which are typical of final Neolithic Corded ceramic culture (Schnurkeramik), bones industry, metal industry (copper), wooden artefacts, vegetal fibres artefacts and jewels (Schwab, 1982; Ramseyer, 1987). Of particular interest were the flint (silex) objects, which evidenced an importation from Grand-Pressigny, France (Ramseyer, 1987). The intercalation of different layers of grey sands and clays excavated up to 2.5 to 3 m of depth, and the necessary comparisons with the artefacts found, have

PORTALBAN - Old Auvernier-Cordée cultural group

Analysis n.	Inventory n.	Sample kind	Morphological kind
DP 1	PA 78/XXVIII/i 43/Fs 6/905	Pottery sherd	Lüscherz tradition
DP 2	"	"	"
DP 3	"	"	"
DP 4	"	"	"
DP 5	PA 78/XXVIII/i43/Fs 6 uk/537	"	"
DP 6	PA 78/XXVIII/i48/Fs 6/834	"	"
DP 7	PA 78/té.a 49/Fs 3 uk/998	"	Corded Imitation
DP 8	PA 78/SE XXVIII/k 41/Fs 7/947	"	"
DP 9	PA 77/XXVIII/g 43/Fs 4/949	"	"
DP 10	PA 78/SE XXVIII/d 48/Fs 5/945	"	Corded True
DP 11	PA 78/SE XXIX/m 48/Fs 7/940	"	"
DP 12	PA 78/té.a 44/Fs 2 uk/953	"	"
DP 13	PA 77/té.z 52/Fs 4 uk/982	"	"
DP 14	PA 78/XXVI/i 45/Fs 5/532	"	Corded Imitation
DP 15	PA 78/XXVIII/k 46/Fs 6/832	"	"
DP 16	PA 78/XXVIII/g 48/Fs 6 uk/837	"	Corded True
DP 17	PA 78/té.a 45/Fs 3/810	"	"
DP 19	PA 76/XXVI/g 30/Fs 3 uk/338	"	"
DP 20	PA 76/XXII/c 32/Fs 4/352	"	"
DP 21	PA 76/XXII/g 30/Fs 3 uk/340	"	"
DP 22	PA 76/XXII/b 30/Fs 4 uk/355	"	"
DP 23	PA 77/XXII/k 30/SF 5 uk/369	"	"
DP 24	PA 77/té.e 29/Fs 5 uk/404	"	Corded Imitation
DP 25	PA 76/XXII/b 31/Fs 3 uk/976	"	"
DP 26	PA 76/XXII/b 31/Fs 3 uk/400	"	"
DP 27	PA 76/XXI/m 28/Fs 6/486	"	"
DP 28	PA 76/XXIII/m 30/Fs 3 wk/485	"	"
DP 29	PA 76/XXII/e 32/Fs 4/407	"	"
DP 30	PA 76/té.m 29/Fs 5 uk/408	"	"
DP 31	PA 76/XXII/k 31/Fs 4 uk/349	"	"
DP 32	PA 76/XXII/g 31/3 uk/336	"	"
DP 33	PA 76/XXIV/f 39/Fs 3/334	"	"
DP 34	PA 76/h 33/Fs 5/335	"	"
DP 35	PA 76/XXI/n 28/Fs 5 uk/468	"	"
DP 36	PA 76/XXII/f 31/Fs 4/402	"	"
DP 37	PA 78/té.d 34/Fs 4/401	"	Corded True
DP 38	PA /XXII/450	"	"
DP 39	PA 77/n 29/Fs 5/467	"	"
DP 40	PA 78/té.34/z 34/Fs 2/542	"	"
DP 41	PA 76/XXII/g 31/Fs 4/350	"	"
DP 42	PA 77/té.l 31/Fs 5/360	"	"
DP 43	PA 62/Haus 2/g 45/Fs 1 Ok/115	"	Lüscherz tradition
DP 44	PA II 62/50 E/Ks 1/116	"	"
DP 45	PA 62/49 D/Ks 1/117	"	"
DP 46	PA 62/Haus 2/Fs 1/118	"	"
DP 47	PA 62/49 F/Ks 10 k/136	"	Corded Imitation
DP 48	PA 62/49 D/Ks 1/139	"	"
DP 49	PA 62/49 c/1089	"	"
DP 50	PA 62/Haus 2/50 E Fs 1/109	"	"
DP 51	PA 62/41 e/101	"	"

Table 1a samples list : pottery

permitted the archaeologist to re-build an almost exact evolution of the site during the Neolithic.

In particular 13 different horizons have been characterized. The deepest one (level 13) has been assigned to a „pré-Cortaillod“ phase, dated with the C^{14} back between 4.900 and 2.390 BC (Ramseyer, 1987). Levels 12 to 10 have been assigned to the Cortaillod Port-Conty phase (late medium Neolithic). Levels 9 and 8 have been assigned to the Horgen civilization (recent Neolithic), while levels 7 to 1 belong to the Saône-Rhône civilization (final Neolithic).

In particular, levels 7 and 6 have been assigned to the Lüscherz group while the horizons 5 to 1 belong to the „Auvernier cordé“ group (Ramseyer, 1987).

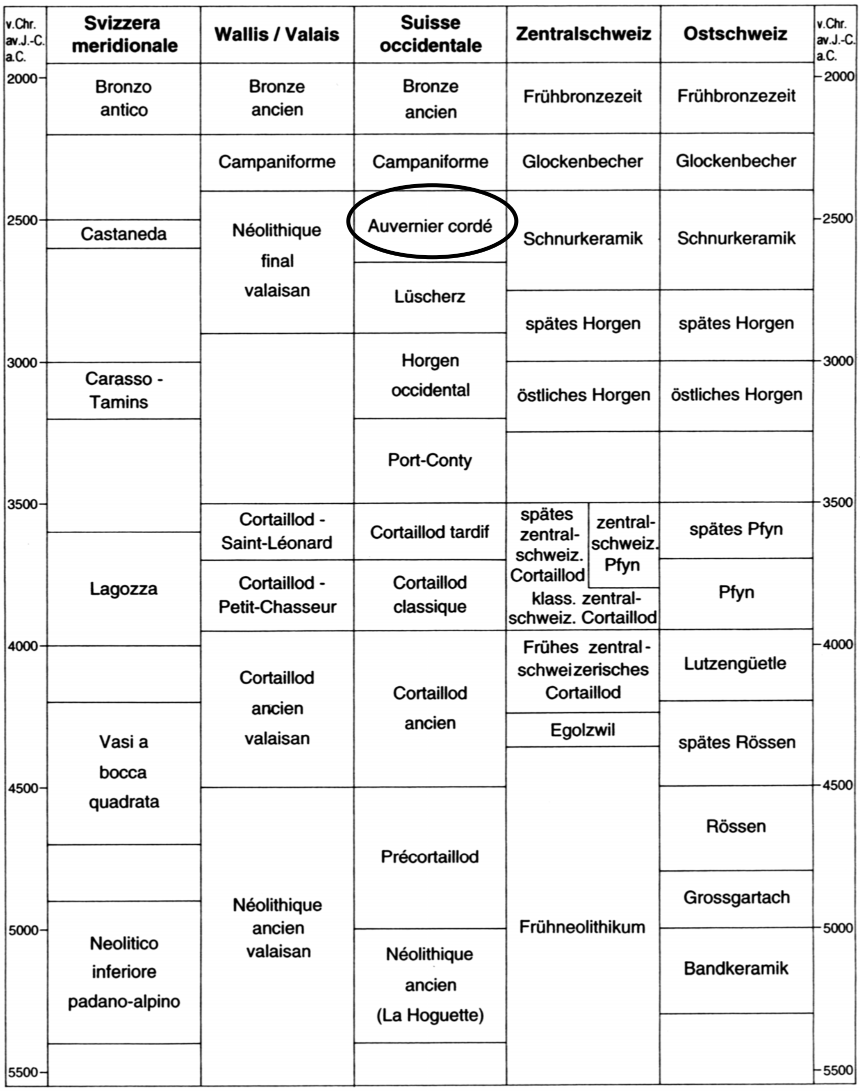
Other fired clay tools

Analysis n.	**Inventory n.**	**Sample kind**
DP 52	FS 3, e / 44, sector 28	Cob
DP 53	FS 3, g / 48, sector 28	"
DP 54	FS 3, a / 47, sector 28	"
DP 55	FS 4, c / 49, sector 28	"
DP 56	FS 6, c / 49, sector 28	"
DP 57	FS 6, c / 43, sector 28	"
DP 58	FS 6 UK, b / 46, sector 28	"
DP 59	FS 4 UK, Z / 51, sector 31	"
DP 60	FS 3, k / 32, sector 22	"
DP 61	FS 3, Z / 33, sector 22	"
DP 62	FS 4, g / 31, sector 22	"
DP 63	FS 4, c / 29, sector 22	"
DP 64	FS 5, c / 29, sector 22	"
DP 65	FS 4, F / 49, sector 16	"
DP 66	PA 62/ Haus 2, A/48-49, FS 1 OK, 908	Loom weight
DP 67	PA 76/ SE 22, a/33, FS 3, 6099	"
DP 68	PA 76/ SE 28, e/47, FS 2, 6131	"
DP 69	PA 78/ TEM a/47, FS 3, 8435	"
DP 70	PA 78/ TEM a/46, FS 3, 8436	"
DP 71	PA 78/ TEM y/34, FS 5 UK, 8440	"
DP 72	PA 78/ d/32, FS 7 UK, 8434	"

Raw materials

Analysis n.	**Geographical coordinates**	**Sample kind**
DP 73	563.025/196.525	carbonate clay
DP 74	563.350/196.175	"
DP 75	563.425/196.150	silicate clay
DP 76	563.200/195.975	carbonate clay
DP 77	562.300/192.700	silicate clay
DP 78	563.150/195.975	gabbro
DP 79	563.175/196.025	"
DP 80	563.800/196.700	metabasite
DP 81	563.825/196.725	"
DP 82	563.550/196.650	limestone
DP 83	563.350/196.375	sandstone
DP 84	562.300/192.700	marl
DP 85	562.800/196.600	syenite
DP 86	563.850/196.750	"
DP 87	563.550/196.725	granite
DP 88	562.800/196.700	carbonate clay
DP 89	563.550/196.500	"
DP 90	563.825/196.575	silicate clay
DP 91	564.150/196.600	carbonate clay
DP 92	564.200/196.725	silicate clay
DP 93	564.400/196.800	"
DP 94	564.850/196.025	"

Table 1b - samples list: cobs, loom weights and raw materials.



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

Figure 2. Chronological timetable concerning the Swiss Neolithic. Empty spaces correspond to lacunes in scientific knowledge and do not represent interruption of the occupation (extracted from Stöckli, 1995). The ceramic products concerning this paper belong to the Auvernier-cordé cultural group (highlighted), which is characteristic of Final Neolithic of Western Switzerland.

Sector A, Saône-Rhône civilisation, gave rise to a more articulated situation. The Rentsch parcel provided three different occupation periods (2.917 – 2.912, 2.759 – 2.724, 2.640 – 2.549 BC) with clear evidences of long interruption between two subsequent logging phases (fourteen in total). In the Camping parcel ninety well distinguished logging phases have been dated between 2.787 and 2.462 BC, but eight different interruption periods, higher than ten years between two subsequent logging phases, allow to doubt whether there was a continuous occupation of the settlement for more than three centuries. Anyway, dendrochronology data are in good agreement with those concerning the dendrochronology of the other settlements of the area. In addition to the dating analyses, the authors, coupling the position data of clay earths (châpes d'argile in French literature) and dated oak logs, proposed an architectural reconstruction of the Neolithic village, characterizing at least two different terrestrial huts, presumably for human and animal dwelling respectively (Danerol *et al.*, 1990).

As far as the the pottery is concerned, thousands of ceramic sherds have been found. Some of them were entire samples. They range from fine to coarse ceramics (figure 3a) from flat to decorated ones, corded mainly, showing a large degree of technology and production know-how.

In his doctoral thesis, Giligny (1993) performed a huge morphological and chrono-typological study on 1165 individual reconstructed pottery samples (around 40% of the total mass available) belonging to the Lüscherz and Auvernier-cordé occupations of the site, excavated from the Rentsch, Kull, Wyler and Camping parcels. He performed a comparative study concerning the lake dwelling Neolithic settlements of Clairvaux and Châlain in France. Among the main results of his

Figure 3a. Auvernier-cordé ceramic vases: typical shapes and decorations (photo with the kind permission of the Archaeological Cantonal Service of Fribourg). Right-low corner vase has been analysed in this work (DP 12).

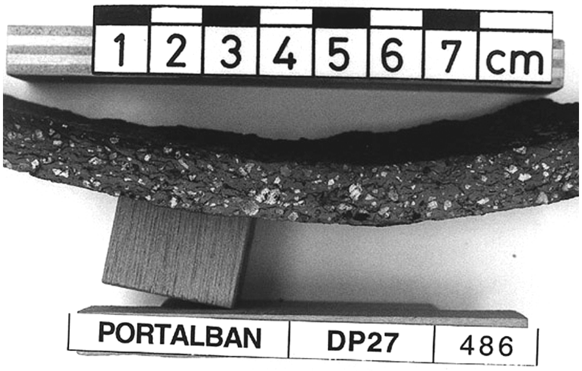


Figure 3b. Cross-section of typical Portalban pottery sherd, DP27. Angular shaped whitish rock grains, mm sized, included in brownish matrix

study, Giligny first described the Z-shaped torsion of corded pottery characteristic of the Eastern Swiss Neolithic settlements in opposition to the S-shaped torsion of corded vases typical of the Western Swiss Neolithic sites. On the basis of this typological features, Giligny & Michel (1995) determined a new chrono-typological sequence of reference across the Delley/Portalban II and Bains des Dames-St.Blaise stations. Giligny (1993) highlighted as well a strict correlation between kind of shape and kind of paste for Portalban ceramic. Correlating the different kinds of decorations and forms the author determined three main morphological groups of the pottery: the "Corded True" with actual influence of the Eastern Swiss tradition, the "Corded Imitation" and the "Lüscherz tradition". All types are present during the Auvernier-cordé occupation of the settlement. In the Corded True the decorations are *directly modelled* on the crude ceramic paste with torsion *Z*-shaped, in the Corded Imitation the decorations are *added* to the ceramic paste and have a torsion *S*-shaped (Giligny, 1993). Other morphological distinguishing features confirm the either Eastern Swiss or local Lüscherz tradition influences.

The term *Saône-Rhône civilisation* has been extensively used in archaeological and archaeometrical literature. However, it has been more recently the subject of a long debate within the scientific community. The term was proposed by Thévenot *et al.* (1976) (Pétrequin *et al.*, 1987 – 88, and references therein) on the basis of some morphologic and decorative similarities between ceramics of the Saône valley and Savoie, France, and the Lüscherz group in Western Switzerland (Giligny & Michel, 1995). Pétrequin *et al.* (1987 – 88) as well as Giligny & Michel (1995) argued that the term Saône-Rhône civilisation, with the meaning of grouping the Lüscherz and Auvernier-cordé cultural groups of Western Switzerland together, should in fact be discontinued. The most important event of the Final Neolithic in Western Switzerland is the arrival of the Corded culture (Schnurkeramik) from Eastern Switzerland around 2.700 BC (Giligny & Michel, 1995). This event strongly influenced the local ceramic production. The Auvernier group, first characterized at Auvernier/La Saunerie, Neuchâtel Lake, became in fact Auvernier-cordé group to highlight the correlation and correspondence with the homologous Corded group from Eastern Switzerland (Ramseyer, 1987; 1988; Giligny, 1993). In this report we will refer to the Old Auvernier-cordé cultural group.

The first mineralogical and petrographical data concerning Delley/Portalban II have been published by Sturny & Ramseyer (1984). Coarse ceramics and fine ceramics have been immediately distinguished at Portalban, since the first archaeological reports concerning the site (Schwab, 1982; Ramseyer, 1987). In particular, a group of vases, dimensionally and proportionally of reduced size, drawn the attention of archaeologists, for their strong similarity with the fine pottery locally produced in Eastern France. As already mentioned, evidences of importation from France were determined, and concerned the flint made "blades" for which a provenance from Grand-Pressigny (Indre and Loire Department, France) was stated (Ramseyer, 1987). Therefore archaeologists envisaged an importation for these fine ceramics vases too.

The paper of Sturny & Ramseyer (1984) was a first attempt to demonstrate such hypothesis. The authors took into consideration 8 samples of fine ceramics coming from Charavine (Eastern France) and compared them to 6 sherds of fine ceramics found at Portalban. The petrographical study allowed to distinguish different groups in each site, on the basis of the either silicate or carbonate matrix composition, the either granitic or calcareous nature of the inclusions, and the presence of grog (chamotte) fragments. The limited number of analysed samples and the lack of chemical data did not permit the authors to resolve the main questions about the importation (Sturny & Ramseyer, 1984).

In her doctoral work, Benghezal (1994) tried to answer the above question, on the basis of a wider and more complete approach. Fine ceramics were found not only at Portalban, but at all the other Neolithic stations surrounding the Neuchâtel and Bienne Lakes banks.

She therefore considered 239 samples of fine and coarse ceramics both coming from six Swiss localities (Vinelz, Sutz, Auvernier, Portalban, St. Blaise and Nidau), and compared them to 105 fine and coarse ceramics sherds coming from three Eastern French localities (Charavines, Chalain and Clairvaux) from where fine ceramics were known to be locally produced; she took into consideration 8 samples of fine ceramics coming from Barrou-Les Marais, a ten km South off Le Grand Pressigny (Indre and Loire Department, France) as well. She could not establish any correlation and correspondence between French and Swiss fine ceramics, mainly because coarse and fine Swiss ceramics taken together were already non differentiable on a petrographic as well as chemical basis. Multivariate analysis confirmed the dissimilarity between French and Swiss Final Neolithic ceramics, no matter whether they were coarse or fine samples (Benghezal, 1994).

The question of the potential importation from France of the Swiss fine pottery was only one of the main objectives of the huge work of Benghezal. In addition to the archaeological artefacts, she sampled and investigated 41 specimens of clays outcropping in the surroundings of the Neolithic settlements as an attempt to identify the original raw materials used for the pottery preparation, and to establish a geological correlation between environment and pottery.

In the framework of the general provenance of Swiss samples, she characterized two main reference groups: on the basis of the CaO wt% content she fixed a limit at 5% to distinguish between calcium poor (reference group “CH 36”) and calcium rich (reference group “CH 37”) ceramics respectively. Statistically analysing ceramics and sampled clay geochemical data, she found a good correspondence between kind of ceramics and kind of clays, stating that the local raw clays were used for ceramics manufacturing, at the regional scale at least.

Médard (2000) has recently published a report concerning the craftsmanship textile production at Delley/Portalban II. Her paper includes a deep morphological study of the Neolithic loom weights coming from Portalban.

In the framework of the above composite archaeological and archaeometric context, a main question remains still open. All the Neolithic cited sites have always been mentioned as settlements, and never as workshops. This is because any traces and evidences of the pottery production such as kilns, for instance, have never been found in the region. Where and how the ceramics artefacts were produced? In terms of provenance of raw materials at least, this paper will try to partially answer the above questions.

1.2 Geological context

Several papers (Portmann, 1955; 1966; Frei *et al.*, 1974; Meia & Becker, 1976) concerning the regional Geology of the area have been published.

Tectonically, Portalban lies on the Molasse Plateau, which is situated between the Jura Mountain Belt towards Northwest, and the Pre-Alps and Helvetic nappes towards Southeast. The Molasse Plateau is a Tertiary unit composed in the Southeastern portion of Neuchâtel Lake of two main facies; the “Lower Fresh Water Molasse”, the Oligocene (Aquitanian) Molasse, which is overlain by the “Upper marine Molasse”, the Miocene (Burdigallian) Molasse (Meia & Becker, 1976). The Aquitanian is composed of coarse grained sandstones with a calcareous matrix, interlayered with marls and marly-limestones; fossils are rare. The Burdigallian, which is limited to a few outcrops, is composed of sandstones and secondary marls; no fossils have been found in it (Meia & Becker, 1976). In the Portalban territory, the Aquitanian basement outcrops along the main and secondary creeks. Otherwise it is covered by thin moraine Quaternary deposits (Frei *et al.*, 1974). The Pleistocene is composed of the Riss and Würm phases; the second one outcrops in the Portalban area, and it is composed of rounded coarse pebbles immerged into a fine sandy matrix; some rare erratic boulders are present mainly along the lake’s banks (Meia & Becker, 1976). The composition of pebbles and boulders has been described by Portmann (1955; 1966): conglomerates, quartzites, granites, limestones, sandstones and orthogneiss are the principal lithologies. The crystalline rocks have been mainly brought up to the Swiss Plateau by the Rhône glacier. They represent the basements of the Helvetic and Pennidic internal units of the Alps (Portmann, 1966). Holocene deposits are composed, among the most important, of silt and dwelling deposits, recent floods, swamp and peat deposits (Meia & Becker, 1976).

1.3 Sampling

The pottery samples have been chosen by F. Giligny. He considered that the Old Auvernier-cordé occupation of Portalban (2.700 – 2.650 BC, calendar year), is a cultural transition phase. Three types of ceramic production are coexistent: (i) the Corded True, (ii) the Lüscherz tradition, and (iii) the Corded imitation (table 1a).

The cobs and the loom weights have been chosen by D. Ramseyer. They correspond to the same pottery age.

With the objective of identifying the source(s), clays have been sampled along the creeks flowing down to the Neuchâtel Lake and passing beside the Neolithic site; on the terraces immediately on the backward of the village, upon the molasses cliff; and from the clays’ quarry of Vallon, 15 km South off the village (table 1b).

For the moraine rocks potentially used as source for temper material, a group of one hundred pebbles and stones have been randomly taken into consideration. They were mainly mixed in the soil or lying directly upon the Molasse basement along the creeks. Among the most representative lithologies, ten rock pebbles have been petrographically characterized. A particular attention has been paid to four coarse plutonic rocks, which have been petrographically and chemically characterized. They have been chosen because of their identical general outlook. They are massive and isotrope, not easy to be broken, they have the same density (weight) in average, the bulk colour is always white – dark spotted, they produce the same kind of external weathering.

1.4 Investigation methodologies

Standard thin sections (30 µm thick) have been prepared from the ceramic sherds, the cobs, the loom weights and the moraine rock samples, for the mineralogical identification and petrographic characterization (polarised light microscope - Leitz Laborlux 11 Pol). The clays, previously homogenized, have been used for the preparation of bricks (75 x 40 x 10 mm), which have been dried for 24 hours at room temperature and further fired under oxidising conditions at 700° C for around 3 hrs, with a Nabertherm Program Controller C19 electrical furnace. From the bricks, standard thin sections have been prepared as well. Under thin section, the content in volume% of a-plastic inclusions has been visually estimated with the comparion charts proposed by Matthew *et al.* (1991).

All the ceramic samples, previously powdered in a tungsten carbide grinder, have been analysed with the X-ray diffractometer Philips PW 1800 (Cu K_α radiation) in the range of 2-65° 2θ, mainly to determine the argilleous composition of the groundmass (X-Pert Organiser software).

XRF analyses concerning nine major elements plus the Fe_{tot} (as Fe_2O_3), expressed in weight percent, as well as eleven trace elements, expressed in ppm, have been performed with the X-ray spectrometer Philips PW 2400; the FeO wt% has been measured using the dipyridil protocol and a Visible Spectrophotometer (Philips Pye Unicam PU 8650); the Fe_2O_3 wt% has been obtained for stoichiometric difference from FeO wt%. The Loss On Ignition (LOI) has been obtained from samples weight differences at 110° C and 1000° C, respectively. CO_2 and H_2O wt% have been obtained with a Multiphase Carbon Determinator (Leco RC 412).

An estimate of the bulk density, weight/volume ratio, of 10 pottery sherds has been determined. Samples weights were between 50 and 70 gr. Sherds previously tightly embedded with cling film have been immerged into deionised water to obtain the ΔV in ml.

1.5 Terminology

Terms regarding the different kinds of matrix and a-plastic inclusions observable under the mineralogy microscope have been proposed by different authors in their ancient ceramics studies (Nungässer & Maggetti, 1978; Maggetti, 1982; Nungässer *et al.*, 1985; Whitbread 1986; Burmester *et al.*, 1989). They are widely accepted by the scientific community.

1.5.1 Pottery

On the basis of macroscopic parameters such as wall thickness and the size of the vases, archaeologists distinguish between fine and coarse ceramics. In contrast, archaeometrists mainly classify fine and coarse pottery sherds as a function of quantity and size of rock fragment inclusions added to the argilleous raw paste. This second classification will be used further on.

In thin section, two main domains are normally sharply distinguishable: the (i) *temper* grains as the rock-fragments intentionally added to the argilleous paste, and the (ii) *matrix* which correspond to the fired raw clay.

Maggetti (1994) established the following criteria to determine the intentionally added a-plastic inclusions (*temper*) in thin section. They are listed in table 2.

Hiatal texture, i.e. bimodal distribution of a.p.i. grains
Angular shaped outline of a.p.i.
Organic material
Grog or "chamotte" (crushed ceramic sherd)

Table 2 - a.p.i.= a-plastic inclusions (Maggetti, 1994).

Matrix kind	a.p.i. volume	a.p.i. diameter
Inclusion-poor	0 – 5 %	0.01 mm
Sandy	5 – 10 %	0.01 mm
Inclusion-rich	10 – 15 %	0.15 mm

Table 3 - a.p.i.= a-plastic inclusions (Nungässer *et al.*, 1985; Benghezal, 1994).

Different kinds of matrix, depending on quantity of the natural a-plastic inclusions, have been proposed by Nungässer *et al.* (1985), for the study of the Neolithic ceramics from Twann, Switzerland.

Whitbread (1986), on the basis of different criteria such as boundaries, roundness, shape, optical density, internal and external features, kind of constituents and pottery colors, introduced the parameters to distinguish different elements from each other, such as ARF (argilleous rock-fragments), grog (chamotte), clay pellets (natural clay inclusions), clay temper (artificial clay inclusions).

On the basis of microscopical observations carried out on Portalban clays samples, in this report a diameter of at least *1 mm* has been fixed in order to discriminate between temper and natural a-plastic inclusions. In fact, in these specimens, quartz grains up to the above size have been regurarly observed.

1.5.2 Cobs

The English meaning of cob corresponds to any mixture of clay and straw used as a building material. In French literature several different terms exist to indicate the different use of cobs: "torchis" for wall fillings, "crépi" for wall coverings, "châpe d'argile" for the floor. Cobs are by definition prepared as crude unfired clays or clay mixtures. They can be rescued from archaeological excavations, if and when they have undergone a firing event such as the destructive burning of the building, for example.

1.5.3 Loom weights

Also called “pesons” or “poids de tisserands” in French literature, loom weights were prepared with a mixture of clay or loam. Their main function was to pull down animal furs during air drying (figure 4).
Most of archaeologists agree about the fact that they were fired before use (i.e. Médard, 2000).

Figure 4. Loom weights: typical aspects and shape of Portalban “poids de tisserands” (photo with the kind permission of the Archaeological Cantonal Service of Fribourg).

2. CHARACTERIZATION

2.1 Petrography

2.1.1 Pottery

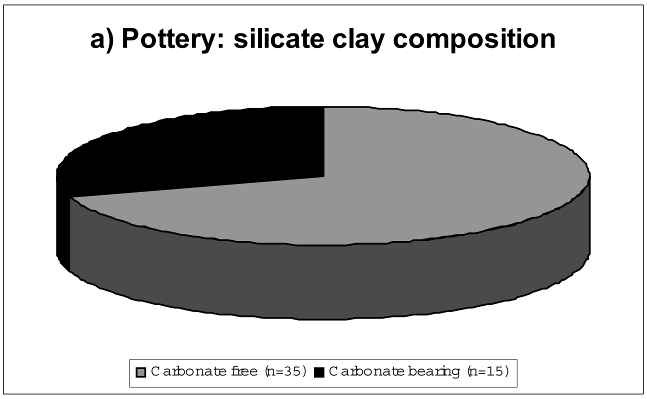
Macroscopically the Portalban pottery is quite homogeneous, externally grey, brown or black coloured; it is mostly coarse grained, neither coated nor painted, most of vases are corded (figure 3a). The a-plastic inclusions are angular to sub-rounded shaped. They are rather abundant and well distributed in a brown to reddish matrix (figure 3b). The thickness of the sherds ranges between 5 to 15 mm, the average being 9,95 mm; but unfortunately the statistical distribution of these data does not show a clear trend. It is therefore not possible to obtain any technological information.

Most of the sherd cross sections show a color gradient ranging from an outer reddish matrix to a grey inner portion. This latter is covered in many cases by a thin and reflective light layer of dark black organic matter residues.

Optical microscopy

Matrix

On the basis of the composition, two main kinds of groundmass are distinguishable under the microscope: a carbonate-free and a carbonate bearing silicate clay respectively. The natural a-plastic inclusions (a.p.i.), are mainly composed of silicate phases such as quartz, feldspars, muscovite and some rare epidote, in the carbonate-free type; the same average composition plus very fine grained crystals of calcite, is instead present in the carbonate-bearing one. But it is noteworthy that calcite crystals, and carbonate material more in general, constitute only a small fraction (< 5% in volume) of the matrix considered as a whole. On the basis of the quantity of natural a.p.i., one can distinguish between an inclusion-poor, a sandy and an inclusion-rich matrix. Figure 5 shows how the silicate (carbonate-free) and inclusions poor clay predominates.


a) Pottery: silicate clay composition

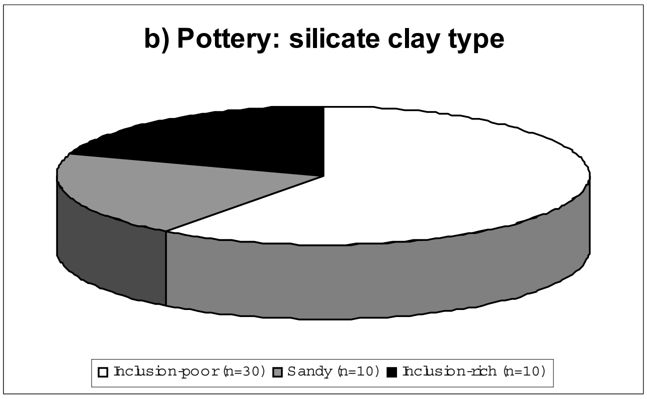

b) Pottery: silicate clay type

Figure 5. Portalban pottery (n=50) has been produced mainly with a silicate, carbonate free, inclusion-poor clay.

Temper

The temper grains constitute in average 20-25% in volume of the sherds. They are angular to sub-angular and range 1 up to 7.5 mm in size. The grains are preserved, less frequently they are broken and invaded by the matrix material.

With the exception of only two cases (hornblende & tourmaline bearing granite, analysis DP 13, mesh matrix texture of albite+Mg-chlorite+muscovite bearing granite, analysis DP 5), the examined pottery has the same rock-fragments composition. The main lithotype used to temper the pottery is a *epidote ± stilpnomelane bearing metagranite* (figure 6a-c) with the following mineral association: quartz, K-feldspar, plagioclase as main minerals and biotite, muscovite, clinozoisite and epidote s.s. as subordinate phases. Accessory minerals are titanite, zircon, apatite, zoisite, chlorite and stilpnomelane. Quartz, K-feldspar, plagioclase and biotite witness the primary magmatic paragenesis; clinozoisite and epidote constituting “fresh” blasts, chloritization of biotite, indicate for this lithotype a metamorphic assemblage of greenschists facies conditions. More petrographical details are given in table 4.

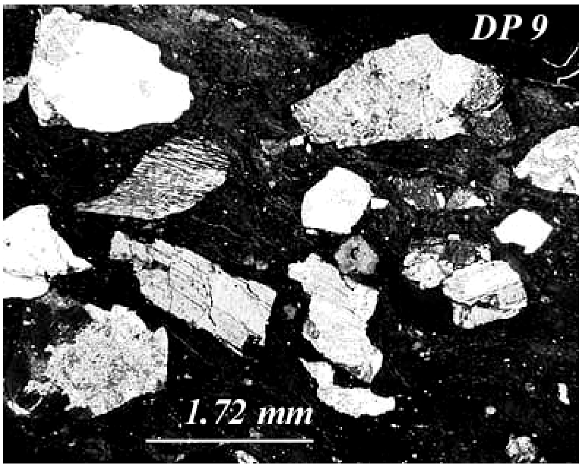


Figure 6a. Pottery sherd thin section, DP 9. Granite temper grains added to a silicate, inclusion-poor clay.

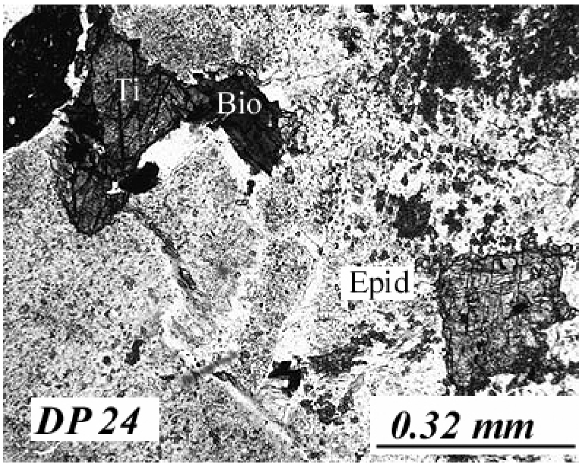


Figure 6b. Titanite (Ti), biotite (Bio) and epidote (Epid) inclusions in feldspars of granite temper grains, DP 24.

The mineral association and textural features described in table 4 are strongly similar to those of the *stilpnomelane bearing Mont Blanc granite*, reported in literature by several authors such as Von Raumer (1967; 1969; 1984), Marro (1986) and Bussy (1990).

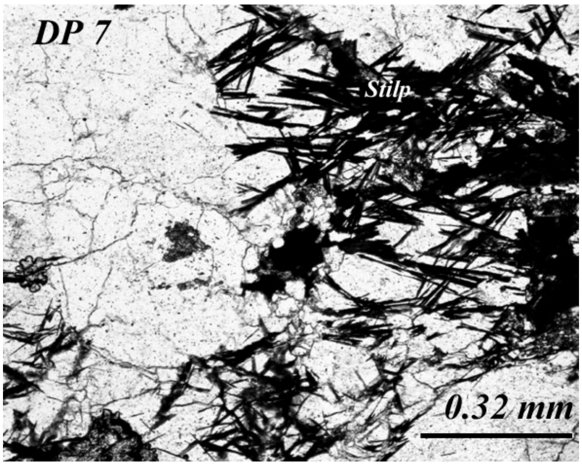


Figure 6c. Thin section photo, DP 7, showing stilpnomelane (Stilp) inclusions in K-feldspar.

The optical observations concerning temper grains have underlined the presence of quantitatively secondary amount of carbonate material (diameter > 1 mm). It ranges in composition from pure calcite crystals to marl clasts, but some rounded limestone grains are present as well. The carbonate material is present in less than the 30% of ceramic sherds.

X-ray diffraction

Figure 7a shows a qualitative XRD spectra of the bulk sample of typical Portalban pottery. Beside the presence of quartz, K-feldspars and plagioclase peaks, mainly coming from the temper and as very fine grained minerals from the matrix too, illite and chlorite have been detected as main clay minerals. As previously mentioned, calcite is part of the carbonate bearing sherds matrix as well but it is semi-quantitatively speaking a deeply secondary mineral (figure 7a). Illite and chlorite are not always present both at the same time. Two main kinds of matrix have been therefore distinguished. Their statistical distribution is shown in figure 8a.

Main minerals	Description
Quartz	Equivalent in quantity to the K-feldspar, is often associated with the latter, the plagioclase and the micas, less frequently isolated into the matrix. Some domains are made of quartz organized in a sort of granoblastic texture. Some muscovite crystals are located on the rims of the quartz or form rare inclusions in it.
K-feldspars	It is a perthitic orthoclase mainly, with albite intergrowth, secondly microcline is present too. In some cases it is transforming into muscovite along the rims or it is strictly associated with the latter, secondly with the biotite.
Plagioclase	An_{10-30} composition essentially, is strongly weathered and is being replaced by sericite (muscovite ± Mg-chlorite) and saussirite (zoisite mainly) inclusions.
Biotite	Large individuals with pleochroism ranging green to reddish brown, are weathered and associated mainly with the epidote. Brown hornblende is sometimes pseudomorph after biotite.
Clinozoisite and epidote	Form aggregates of fine to medium grained crystals, idio- to hypidiomorphic shaped; their presence characterized the lithotype.
Titanite	Forms brownish idio- to hypidiomorphic medium grained crystals associated to epidote and zircon, included mainly into feldspars.
Stilpnomelane	Forms aggregates of acicular shaped crystals (figure 6c) brown to black, weathered along the rims, strongly oxidized and no more pleochroic. It's included in K-feldspars.

Table 4. Epidote and stilpnomelane bearing metagranite temper grains: main phases description.

2.1.2 **Cobs** ("torchis")

Cob fragments have a stone-like general outlook, color is brown otherweise beige. Some reddish portions constitute the thin external layer of samples. One specimen (DP 53) shows a color gradient with a double layering brown to black. Inclusions of round quartz grains up to 1 mm are observable already at the macroscopic scale. Some ARFs are clearly observable as well. Sample DP 63 presents undulate rims typical of "torchis" utilisation.

Optical microscopy

At Portalban, except analysis DP 53, all the specimens have two main characteristics in common: they are *without temper* and have a deep *heterogeneity* in the clays mixture (figure 9). In fact, different matrix domains are recognisable under the microscope; they range from (i) red, inclusion-rich, argilleous mineral-rich only to (ii) brown, inclusion-less, carbonate-rich.

In addition, several calcite-filled veins are present. The natural a-plastic inclusions ranges up to 1 mm in size and are composed mainly of plagioclase, quartz and alkali-feldspar; some residual spots of marl and limestone are present as well.

X-ray diffraction

Figure 7b shows a qualitative XRD spectra of the bulk sample of a typical Portalban cob. Beside the presence of quartz, plagioclase and K-feldspar already observed in thin section, calcite has been detected as the main matrix phase. Illite has been determined as main clay mineral in most of the samples. Chlorite is less present.

2.1.3 **Loom weights** ("poids de tisserands")

Most specimens present a color gradient ranging from a brownish outer portion to a black pervasive inner part. Other loom weights are grey (DP 69) or completely black (DP 68). As for the cobs, the loom weight fragments have a clear pebble-like outlook, black mm-sized inclusions are widespread throughout the specimens. Clearly observable at the macroscopic scale are rarer whitish rounded inclusions of quartz.

Optical microscopy

At Portalban, like the cobs, the loom weights contain no rock-fragments. They have a lot of organic matter as added inclusion up to 10-15% in volume (figure 10). The brown to dark-brown carbonate clay is full of vegetal residuals, which in some cases are well preserved. Vegetal fibres (some are straight or deformed, 3-4 mm of length, partially broken, rectangular with perfectly preserved corners) and charcoal are the main inclusions recognised. In many cases the outlines of burnt vegetal inclusions are still well distinguishable. In addition to this, some fossil shells of uncertain determination have been observed too.

Besides the content of organic matter, the matrix is natural a.p.i. very rich. These are angular quartz, feldspars and some rare epidote. Calcite and clasts of marl are pervasively distributed into the groundmass.

X-ray diffraction

With the exception of analysis DP 71, calcite is the main matrix phase in the loom weights as for the cobs. Illite is the main clay mineral. Chlorite is present in two samples (DP 68 & 71). Quartz, K-feldspar and plagioclase are present too. Figure 8b shows the statistical distribution of the cobs and the loom weights compositions.

2.1.4 Clays

Optical microscopy and X-ray diffraction

All the twelve clays are dishomogeneous mixtures of inclusion-rich argilleous materials.

The *carbonate clays* are composed of a calcite mesh-texture groundmass mixed to illite ± chlorite (figure 11a & 12a). Fine-grained angular quartz crystals and different very fine-grained single crystals of silicates such as plagioclase, K-feldspar and muscovite form the inclusions.

The *silicate clays* have instead a sandy aspect. They have a large amount of angular shaped single crystals of quartz and other minor silicates all immerged into an illite ± chlorite clay matrix (figure 11b & 12b).

The sampled clay composition reflects the geomorphology of the Portalban area. In particular, the six clays sampled along the creeks, directly on the Aquitanian basement, are the carbonate-rich sediments, while the five clays sampled on the terraces, where the moraine deposits cover is more important, and the Vallon quarry one, are the silicate sandy sediments (figure 13).

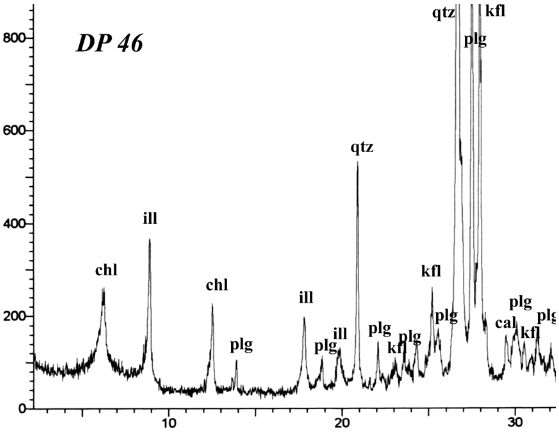


Figure 7a. XRD spectra (bulk sample) of pottery DP 46 (chl=chlorite, ill=illite, plg=plagioclase, qtz=quartz, kfl=K-feldspar, cal=calcite; y axis=count/s, x axis= 2θangle). Illite and chlorite predominate as clay minerals.

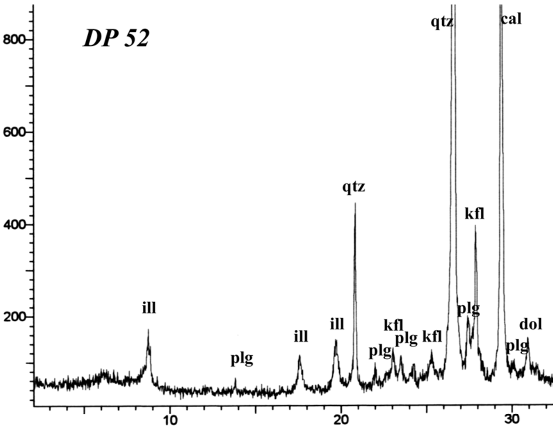


Figure 7b. XRD spectra (bulk sample) of cob DP 52 (ill=illite, plg=plagioclase, qtz=quartz, kfl=K-feldspar, cal=calcite, dol=dolomite; y axis=count/s, x axis= 2θangle). Calcite predominates as matrix mineral (see optical data).

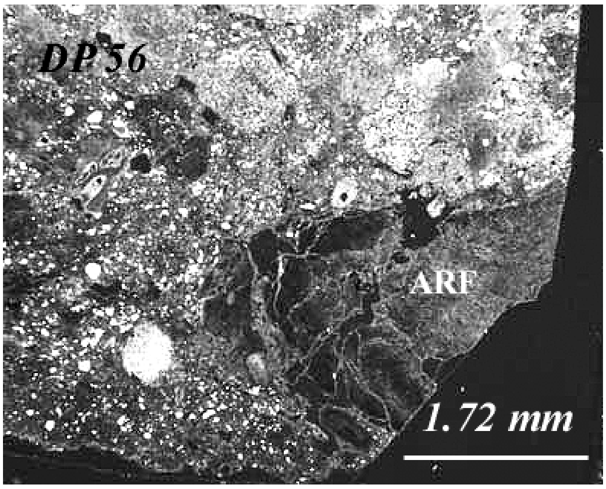


Figure 9. Thin section of typical cob, DP 56. Lack of any temper, fine grained quartz natural inclusions, heterogeneity of the clay mixture, ARF right-low corner (Whitbread, 1986).

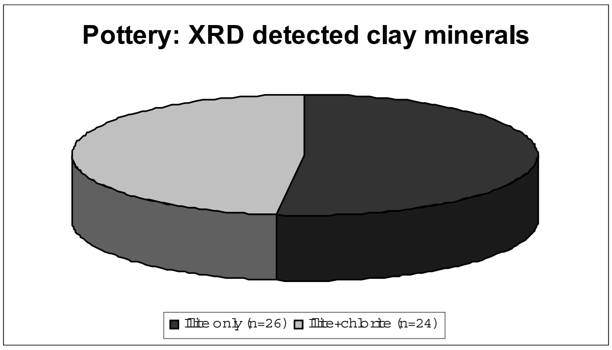


Figure 8a. XRD qualitative bulk analyses of Portalban pottery (n=50). Illite ± chlorite are the main clay minerals composing pottery matrix.

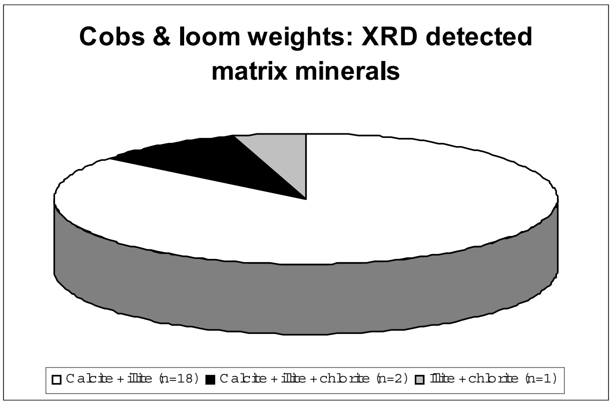


Figure 8b. XRD qualitative bulk analyses of other clay tools (n=21). Calcite and secondary illite are instead characteristic of cobs and loom weights matrix.

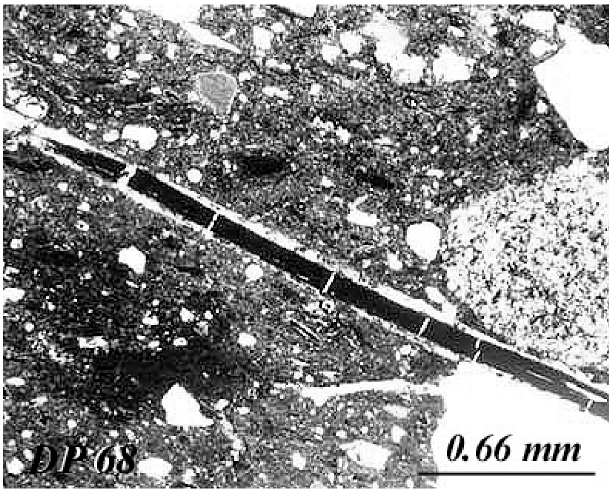


Figure 10. Thin section of a typical loom weight, DP 68. Heterogeneous clay mixture, vegetal fibres as organic matter inclusion, fine grained quartz natural inclusions.

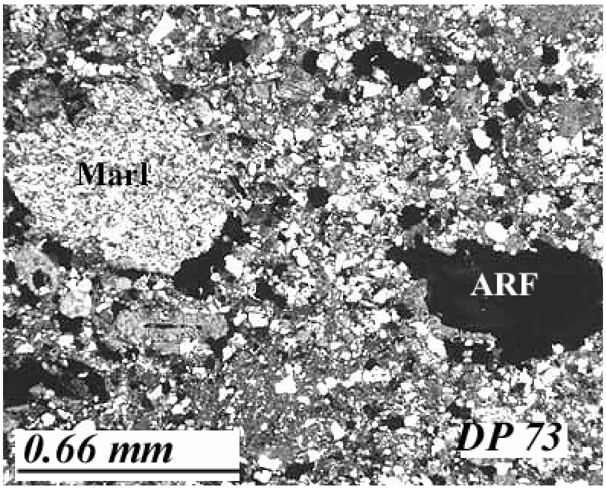


Figure 11a. Thin section photo of carbonate clay DP 73. Marl and ARF (Whitbread, 1986) pellets are regularly mixed in an dishomogeneous argilleous and calcareous material. Very fine grained natural inclusions of quartz crystals are present too.

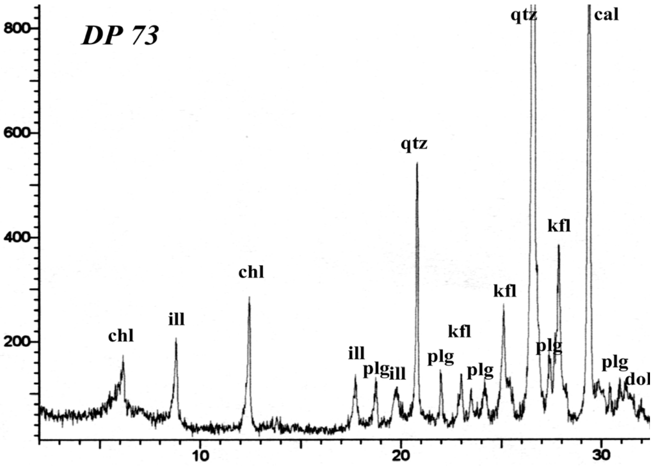


Figure 12a. XRD spectra (bulk sample) of carbonate clay DP 73 (chl=chlorite, ill=illite, plg=plagioclase, qtz=quartz, kfl=K-feldspar, cal=calcite, dol=dolomite; y axis=count/s, x axis= 2θangle). Large amount of calcite highlights the calcareous nature of the sample

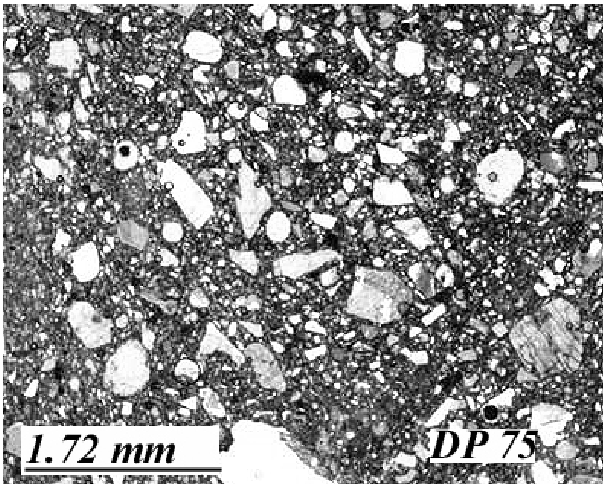


Figure 11b. Thin section photo of silicate clay DP 75. Fine grained crystals of quartz as main mineral of this inclusion rich sandy loam.

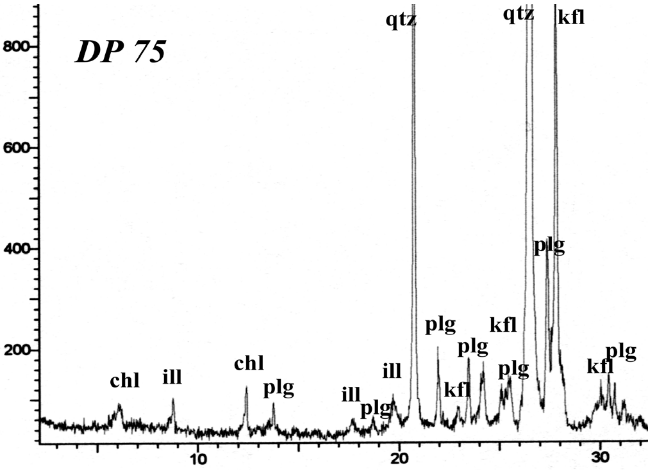


Figure 12b. XRD spectra (bulk sample) of silicate clay DP 75 (chl=chlorite, ill=illite, plg=plagioclase, qtz=quartz, kfl=K-feldspar, y axis=count/s, x axis= 2θangle). Calcite is absent.

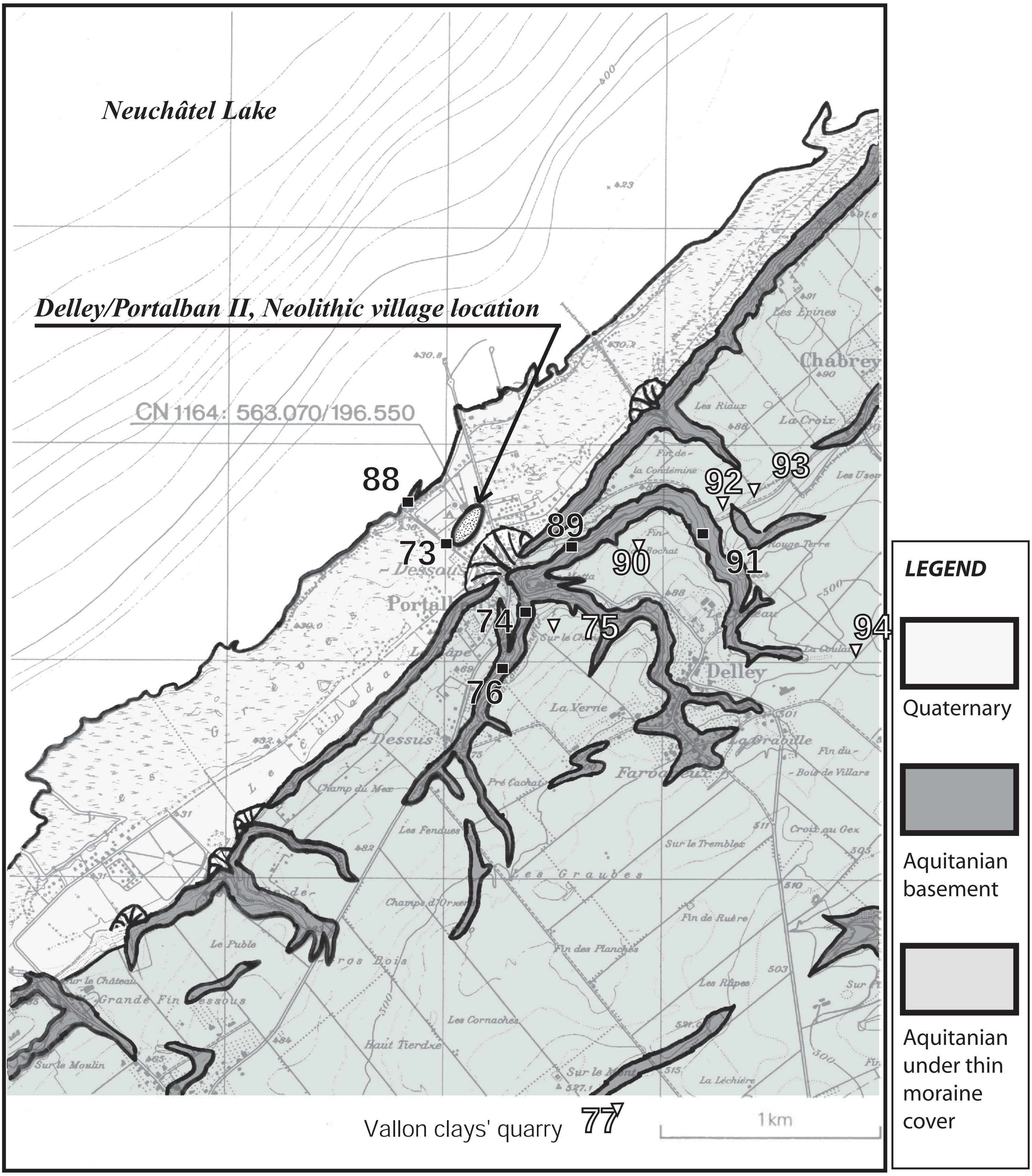


Figure 13. Simplified geological sketch (after Frei *et al*, 1974) and location of sampled clays around Portalban. Carbonate clays (black squares) outcrop along the two creeks which flow down to the Neuchâtel Lake, and lie directly on the Molasse Aquitanian basement; the silicate clay (white triangles) outcrop on the terraces and cliffs which characterize the landscape around Portalban, and lie on the Aquitanian under weak moraine cover. Numbers correspond to analyses. Geographic coordinates of the settlement refer to Swiss "Carte Nationale" 1164.

2.1.5 Moraine rocks

Macroscopical characterization

Figure 14 shows the list of macroscopically characterized rocks with their relative abundance.

The main lithotype are evidently Molasse sandstones and marls, that compose the local basement. With the exception of limestones, dolomites and conglomerates, which presumably come from the Jura or the Prealps, the remaining 30% of rocks available in the region (magmatic and metamorphic) have a clear Alpine origin. They originate from the Helvetic and Pennidic Internal Units mainly, Portmann (1955; 1966).

Optical microscopy

Among the sampled rocks, particular attention has been paid to those lithotypes that have plutonic texture still preserved (see sampling strategy). The petrographic descriptions are given in table 5. They belong by far not to the same lithotype. Textures and mineral associations are in fact very different. According to the IUGS classification (1973), one gabbro, two quartz-syenites and one granite have been determined. Attention is drawn to sample DP 87. The fine-grained, white granite has a mineral association very similar to that of the Mont Blanc granite.

DP 78	**Metadiorite** (or **metagabbro**). It is composed of a groundmass of sericite in which diopside is transforming into hornblende. Weathered biotite altering into Fe-chlorite are immerged. Coarse grained apatite, magnetite and ilmenite are secondary minerals. The plagioclases are no more recognisable having been deeply replaced by a very fine-grained sericite + calcite + clay minerals mesh-texture.
DP 85	**Quartz-syenite** with the main paragenesis still fresh and preserved. Quartz, perthitic orthoclase, plagioclase (An$_{30-35}$) still draw a magmatic texture, being hypidio- to idiomorphous as well as coarse grained. Plagioclase are only slightly altered to sericite; they also have undergone a weak deformation event. Among the accessory minerals there are biotite transforming into Fe-chlorite, and muscovite, all mainly allotriomorphic.
DP 86	**Quartz-syenite** with a paragenesis composed of large crystals of quartz, mainly inclusion-less, coarse grained plagioclase (An$_{15-30}$) and alkali-feldspar, both being deeply replaced by sericite (muscovite ± Mg-chlorite ± calcite) and saussirite (zoisite mainly) inclusions. Secondary minerals are coarse grained hypidiomorphic brown hornblende, brown biotite being partially replaced by clinochlore, strictly associated with medium grained individuals of epidote ± clinozoisite and titanite; this latter is yellowish-brown in perfectly idiomorphic crystals and colourless in allotriomorphic individuals. Accessory minerals are still apatite, opaque and zircon. This rock has clearly undergone a greenschist facies metamorphism event.
DP 87	Fine-grained white **granite** composed mostly of felsic minerals. Fine-grained quartz, mainly ipidiomorphic and organised in a sort of granoblastic texture, are associated with fine-grained crystals of plagioclase (An$_{25-30}$) and alkali-feldspar. Very fine grained epidote and titanite constitute interstitial domains associated with Fe-chlorite. The paragenesis and texture of this lithotype are mostly consistent with *Mont Blanc granite*, leucogranite central facies, described in detail by Bussy (1990). Its bulk chemical composition is consistent with the published one as well (table 6).

Table 5. Petrographic description of sampled crystalline rocks with preserved plutonic texture. Nomenclature according to IUGS (1973). XRF chemical analyses are given in table 6.

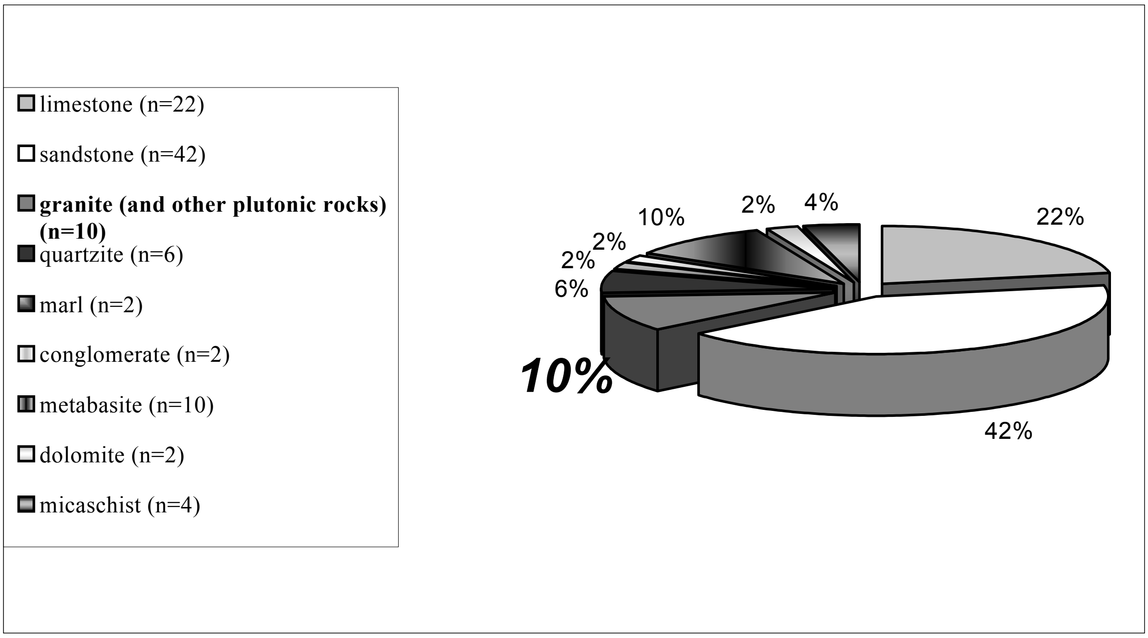


Figure 14. Statistic distribution of moraine rock deposits at Portalban (n=100). Granites (and other plutonic rocks) constitutes around 10% of available lithologies. Mont Blanc granite is found at Portalban, but it is just one of several granitoides (and plutonic texture rocks), which were potentially exploitable from moraine deposits.

2.2 Chemical analyses of pottery, cobs, loom weights and clays (table 6)

Figure 15a-c clearly show the difference in composition between the pottery on one hand and the cobs and loom weights on the other. With the exception of two loom weights, which are in outlier positions, the cobs and loom weights can be assimilated as a unique chemical group. Their average SiO_2-content is below 60 wt%, and the Al_2O_3 is around 15 wt%. The pottery has higher SiO_2-content, with an average value around 65 wt%, and higher value of Al_2O_3 around 18 wt%.

Considering the CaO-content, the pottery ranges between 1 to 4 wt%, while the cobs and loom weights range between 8 and 16 wt%. The pottery shows in this case the presence of two slightly different chemical groups; most of the pottery sherds have a narrow CaO-content around 1,5 wt%, while nine samples approach an average of 3,5 wt%. In addition, two pots can be considered as outliers.

As far as the Rb-content is concerned, the cobs and loom weights range between 100 to 150 ppm, while the pottery ranges 150 to 300 ppm, with almost the double average value.

Two main groups of clays can be clearly distinguished in the three graphs (figure 15a-c). The petrographically defined carbonate clays have a CaO-content ranging between 9 and 18 wt%, while the petrographically defined silicate clays range around 1 wt%. Regarding the CaO-content, the two clay compositions reflect the same variation between the pottery versus the cobs and loom weights. This is not true for the SiO_2-concentration. In fact, the Ca-rich clays have SiO_2 around 70 wt%, the Ca-poor clays approach 80 wt% (figure 15b).

Only one clay (DP 73), which correponds to the clay sample closest to the Neolithic village (figure 13), is chemically different within the carbonate clay group. It fits much better the cobs and loom weights with respect to SiO_2, CaO, Al_2O_3 and Rb-contents.

Figure 15d shows the ternary composition of all samples regarding Fe_{tot}, K_2O and CaO wt%. The graph confirms the above observations. The pottery is clearly distinct in composition when compared to the cobs and most of the loom weights; the carbonate and silicate clays strongly differ in Fe_{tot}- and K_2O-content. The carbonate clay DP 73 again fits the field of the cobs and loom weights. In this case, the silicate clays correspond to the pottery.

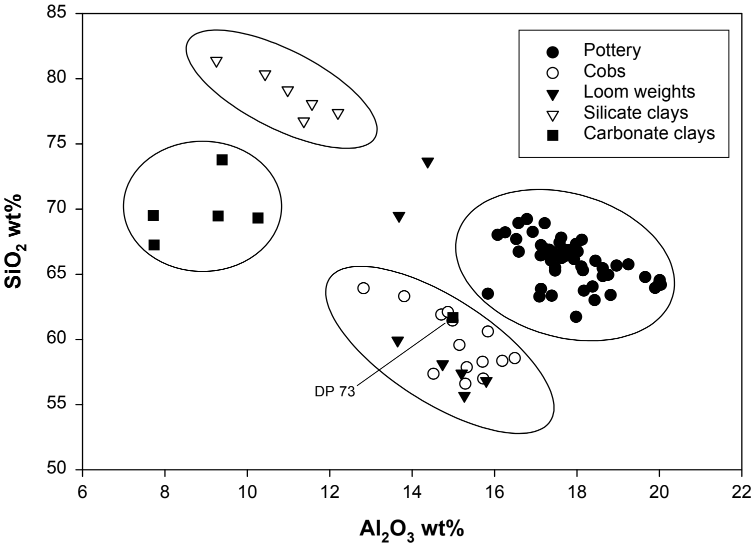


Figure 15a. Al_2O_3 - SiO_2 correlation diagram (XRF results) of fired clay objects and sampled clays. Pottery is an almost homogeneous group. Cobs and loom weights, with the exception of two outliers (DP 71 & 72) can be assimilated as a unique group. Both geochemical groups are clearly distinct from each other. Pottery is in average higher in Al and Si. Silicate and carbonate (see optical data) clays are clearly two distinct geochemical groups too, and are poorer in Al and richer in Si when compared to pottery, cobs and loom weights. Carbonate clay DP 73 fits in composition the cobs group and most of the loom weights.

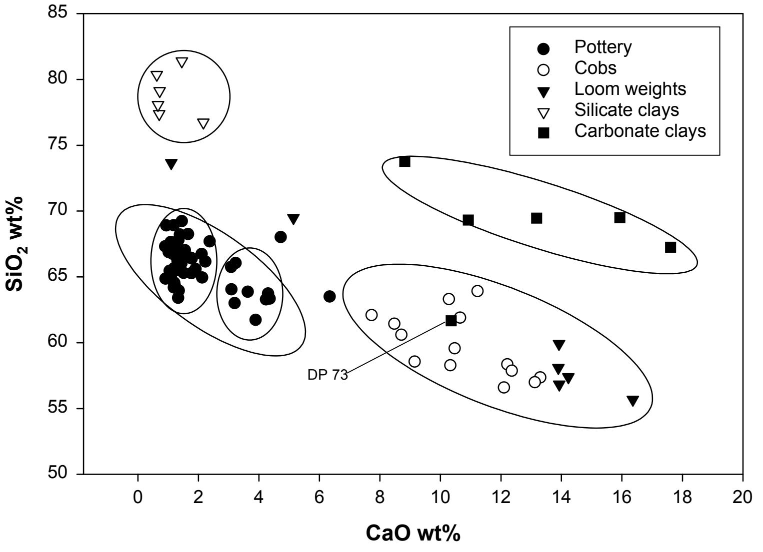


Figure 15b. CaO - SiO_2 correlation diagram (XRF results) of fired clay objects and sampled clays. Two groups of pottery are slightly different in CaO content. Two analyses, DP 10 & 47, are outlying the main group. Cobs and loom weights (except the two outliers, DP 71 & 72) have a relatively large but continuous range of values. Again, pottery versus cobs and loom weights are two clearly distinct chemical groups. Pottery is in average four times poorer in CaO. Carbonate and silicate clay groups are again very different. The carbonate clay group mirror the same range of values of cobs and loom weights. The clay DP 73 matches the average composition of the cobs group.

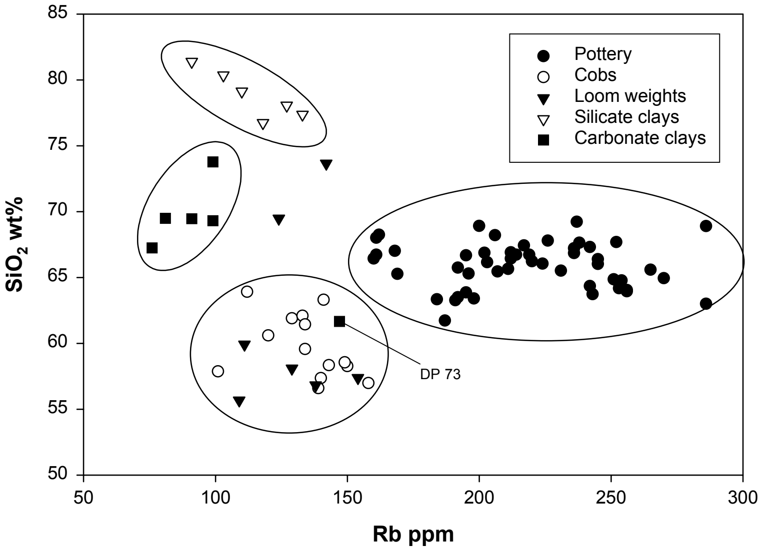


Figure 15c. Rb - SiO_2 correlation diagram (XRF results) of fired clay objects and sampled clays. Pottery has a rather wide Rb-content range of values. Cobs and loom weights, except outliers DP 71 & 72, can be easily assimilated as a unique group. They are again well distinguishable when compared to pottery, showing half of the average Rb-content. Less evident is in this case the difference between carbonate and silicate clays, exception made for clay DP 73, which again fits better in composition the cobs (and most of loom weights) group.

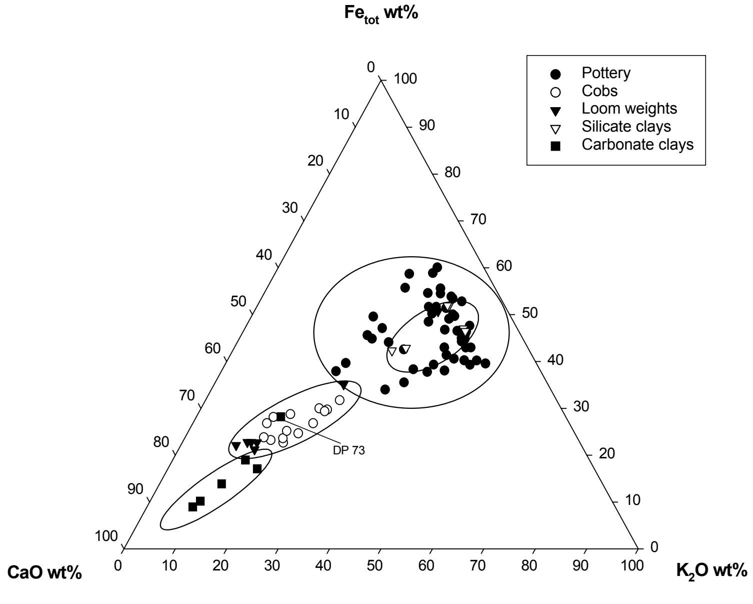


Figure 15d. Ternary correlation diagram (XRF results) of fired clay objects and sampled clays – Fetot, K_2O, CaO. The geochemical difference between pottery versus cobs and loom weights is confirmed. Carbonate and silicate clay groups are again deeply different in composition, but in this case the silicate ones corresponds to the pottery group. Carbonate clay DP 73 fits again cobs and loom weights group.

Pottery

Oxide/Element		DP 1	DP 2	DP 3	DP 4	DP 5	DP 6	DP 7	DP 8	DP 9	DP 10	DP 11	DP 12	DP 13	DP 14	DP 15	DP 16	DP 17	DP 19	DP 20	DP 21	DP 22	DP 23
SiO_2	wt%	59.94	60.60	60.74	57.91	59.34	64.15	58.93	66.23	60.09	57.49	64.03	61.17	62.10	59.81	60.03	60.59	63.44	59.67	62.59	58.74	64.55	62.55
TiO_2	wt%	0.56	0.57	0.59	0.54	0.64	0.56	0.59	0.48	0.38	0.55	0.74	0.61	0.69	0.66	0.50	0.64	0.66	0.64	0.53	0.65	0.56	0.53
Al_2O_3	wt%	18.58	18.92	18.88	18.02	16.29	15.67	17.24	16.55	16.59	14.34	16.59	16.31	16.00	17.75	15.79	16.21	15.77	16.00	16.70	15.86	15.39	15.94
Fe_2O_3	wt%	2.21	1.11	1.67	1.35	3.44	1.18	2.29	1.41	1.37	2.91	4.18	4.00	3.28	3.99	0.23	2.74	2.46	3.57	0.90	3.21	2.67	2.88
FeO	wt%	2.22	2.92	2.59	2.78	2.51	2.38	2.65	1.97	2.68	2.29	2.06	2.52	2.75	2.29	3.17	2.65	3.54	2.27	3.19	2.51	2.14	2.23
MnO	wt%	0.04	0.05	0.04	0.04	0.07	0.05	0.07	0.03	0.04	0.05	0.06	0.05	0.04	0.05	0.03	0.05	0.08	0.07	0.07	0.06	0.09	0.04
MgO	wt%	1.95	1.99	2.04	2.09	2.24	1.82	1.96	1.45	1.51	2.28	2.29	1.90	2.42	2.01	1.90	2.19	2.35	2.21	1.82	2.20	1.97	1.96
CaO	wt%	1.11	1.12	1.15	1.22	4.08	2.25	2.99	0.90	1.75	5.74	0.98	1.21	1.64	1.25	2.94	1.64	2.01	3.39	1.68	3.93	1.32	0.94
Na_2O	wt%	1.61	1.65	1.55	1.54	1.13	2.01	1.90	2.31	2.32	1.06	1.02	1.37	1.04	1.72	1.76	1.51	0.65	1.59	2.09	1.61	1.99	1.87
K_2O	wt%	4.46	4.65	4.46	4.36	3.35	4.07	4.08	4.59	4.42	3.21	3.33	3.54	2.82	3.97	3.88	3.68	3.08	3.46	4.22	3.45	3.42	3.66
P_2O_5	wt%	0.22	0.31	0.33	0.27	0.25	0.29	0.31	0.14	0.11	0.37	0.11	0.21	0.11	0.28	0.08	0.30	0.21	0.23	0.17	0.21	0.17	0.09
L O I	wt%	7.42	5.90	5.90	9.76	6.61	5.49	6.76	4.10	8.69	9.73	4.47	6.91	6.83	5.93	9.46	7.47	5.31	6.83	6.09	7.45	5.61	7.20
Ba	ppm	785	947	923	701	718	767	730	554	613	675	607	612	536	831	532	1126	725	590	561	585	564	437
Cr	ppm	94	100	105	94	100	77	88	71	66	103	136	113	124	102	85	102	142	87	80	83	151	80
Cu	ppm	82	59	54	57	236	44	28	23	22	16	18	148	32	29	36	16	21	32	21	29	48	33
Nb	ppm	13	14	13	13	13	17	26	14	14	14	17	16	15	17	15	13	15	13	15	14	14	14
Ni	ppm	53	53	55	53	67	49	57	45	39	55	59	61	62	64	44	58	67	57	53	57	138	54
Pb	ppm	29	30	28	25	32	27	32	26	20	24	31	31	31	34	25	37	31	30	35	31	27	30
Rb	ppm	235	239	228	232	172	239	267	275	243	174	193	216	150	187	204	157	153	182	231	177	195	220
Sr	ppm	96	113	107	88	117	143	117	70	100	215	112	91	106	99	80	324	120	138	90	145	98	59
V	ppm	103	102	110	99	98	79	96	78	73	93	121	112	125	101	89	106	135	100	86	99	82	91
Y	ppm	23	26	27	22	31	35	47	33	24	28	28	24	25	31	25	32	26	25	40	26	34	33
Zn	ppm	102	81	80	85	128	88	101	74	76	101	113	117	95	107	113	123	144	118	99	116	97	80
Zr	ppm	131	136	145	129	120	142	135	140	104	131	168	143	156	137	123	174	129	149	146	146	159	124
SUM %	wt%	100.32	99.80	99.94	99.88	99.96	99.92	99.78	100.17	99.96	100.04	99.86	99.80	99.72	99.71	99.76	99.68	99.54	99.93	100.04	99.89	99.86	99.89
CO_2	wt%	12.46	10.85	10.56	17.09	7.70	8.76	12.39	6.38	16.76	14.48	5.13	10.59	10.56	8.43	15.29	12.21	6.34	7.62	8.61	7.88	7.04	10.70
H_2O	wt%	5.90	4.92	5.46	8.43	5.13	4.39	4.97	4.12	7.26	6.06	5.36	7.11	7.29	5.84	6.79	6.28	5.03	5.88	5.50	5.54	5.30	6.81
Fe_{tot} as Fe_2O_3	wt%	5.04	4.61	4.82	4.90	6.65	4.04	5.60	3.74	4.75	6.03	6.76	7.28	6.78	6.93	4.13	6.13	6.73	6.52	4.71	6.46	5.34	5.76

Table 6 – Chemical analyses

Pottery

Oxide/Element		DP 24	DP 25	DP 26	DP 27	DP 28	DP 29	DP 30	DP 31	DP 32	DP 33	DP 34	DP 35	DP 36	DP 37	DP 38	DP 39	DP 40	DP 41	DP 42	DP 43	DP 44	DP 45
SiO_2	wt%	65.36	62.25	65.43	65.40	59.13	60.36	58.24	62.60	63.75	60.88	63.98	61.63	62.84	63.39	63.95	63.51	64.54	63.74	64.54	62.02	60.81	61.05
TiO_2	wt%	0.47	0.39	0.46	0.58	0.43	0.50	0.46	0.54	0.63	0.62	0.55	0.51	0.55	0.52	0.59	0.56	0.55	0.60	0.49	0.60	0.58	0.62
Al_2O_3	wt%	15.72	16.18	17.53	17.05	16.86	17.43	16.72	16.35	17.21	17.49	17.88	18.70	16.61	16.26	16.88	16.48	17.24	16.98	16.01	17.91	17.31	16.97
Fe_2O_3	wt%	2.21	0.79	1.28	1.04	1.71	1.46	1.53	2.83	2.19	2.29	2.72	2.69	2.14	2.22	2.96	2.89	2.77	1.63	2.33	3.32	3.39	1.72
FeO	wt%	1.83	2.62	2.22	2.86	2.24	2.30	2.57	2.72	2.55	3.09	1.23	1.91	2.26	2.42	1.72	2.00	1.63	2.45	2.04	1.64	1.98	3.55
MnO	wt%	0.05	0.05	0.05	0.05	0.03	0.05	0.04	0.06	0.06	0.08	0.04	0.03	0.05	0.08	0.06	0.05	0.04	0.04	0.06	0.08	0.07	0.07
MgO	wt%	1.58	1.49	1.59	1.70	1.63	1.87	1.96	1.89	1.96	2.03	2.08	1.86	1.85	1.99	1.69	1.61	1.77	1.85	1.80	1.82	1.83	1.86
CaO	wt%	1.12	1.23	1.05	1.18	3.99	1.97	2.81	1.20	1.10	0.85	1.40	1.07	1.19	1.47	1.48	1.28	0.86	1.08	1.57	1.13	0.98	1.41
Na_2O	wt%	1.97	2.23	2.05	2.36	2.03	1.75	1.83	1.92	1.73	1.65	1.69	1.81	1.84	1.98	2.25	2.19	1.82	1.87	2.24	1.79	1.73	2.30
K_2O	wt%	4.07	4.49	4.52	4.42	4.18	4.57	4.25	3.69	3.99	4.26	4.68	4.51	4.15	3.41	4.06	4.03	4.18	4.20	3.32	4.01	3.90	3.30
P_2O_5	wt%	0.18	0.17	0.26	0.13	0.10	0.24	0.09	0.12	0.16	0.12	0.16	0.10	0.15	0.26	0.16	0.10	0.13	0.21	0.23	0.08	0.05	0.22
L O I	wt%	5.37	8.52	3.52	3.34	7.48	7.32	9.33	6.46	4.77	6.48	3.24	5.07	6.33	5.66	3.92	5.06	4.31	4.89	5.69	5.72	7.33	6.91
Ba	ppm	652	618	754	646	600	728	543	645	656	636	848	656	624	699	658	635	574	670	767	533	498	585
Cr	ppm	76	71	81	76	74	88	79	79	93	91	95	93	79	102	84	81	89	85	93	100	95	81
Cu	ppm	33	39	27	32	214	27	61	32	37	35	25	23	23	34	28	27	404	52	25	49	48	28
Nb	ppm	15	18	17	18	14	14	13	17	19	16	16	14	14	11	20	21	17	16	9	18	16	16
Ni	ppm	43	45	44	46	45	46	43	62	62	59	52	49	50	54	51	50	58	57	50	55	58	56
Pb	ppm	24	26	27	27	25	18	25	35	31	28	29	25	24	41	32	29	32	30	40	28	29	33
Rb	ppm	190	207	230	210	225	251	233	183	209	236	237	242	199	159	204	204	232	225	153	199	192	183
Sr	ppm	92	91	82	110	91	97	87	87	76	65	86	87	99	228	114	103	54	87	250	56	51	115
V	ppm	81	75	90	80	85	101	93	98	100	108	109	113	95	99	90	88	96	99	92	109	106	97
Y	ppm	29	32	30	33	28	32	29	31	39	26	28	23	25	24	40	36	36	35	21	26	28	21
Zn	ppm	74	87	74	82	141	70	70	106	116	99	88	83	102	105	84	79	91	96	95	85	88	93
Zr	ppm	132	130	121	190	104	141	110	130	169	127	125	110	144	125	168	182	117	163	118	128	124	139
SUM %	wt%	99.93	100.40	99.95	100.10	99.81	99.82	99.82	100.40	100.10	99.85	99.64	99.89	99.96	99.64	99.72	99.74	99.85	99.53	100.31	100.11	99.95	99.97
CO_2	wt%	8.25	15.00	4.32	5.20	9.24	12.24	13.56	8.94	5.94	9.82	2.91	6.74	9.64	10.15	5.13	7.77	5.50	7.66	9.49	6.45	11.33	10.04
H_2O	wt%	4.31	6.22	3.43	2.99	5.05	4.97	7.51	6.19	4.77	5.58	3.40	4.88	5.80	4.66	3.43	4.33	3.83	4.64	4.48	5.72	7.67	6.89
Fe_{tot} as Fe_2O_3	wt%	4.47	4.03	3.87	4.35	4.53	4.32	4.82	6.24	5.26	6.10	4.22	5.06	4.95	5.19	5.06	5.37	4.78	4.56	4.86	5.44	6.02	6.06

Table 6 – Chemical analyses

		Pottery					**Cobs (torchis)**														**l.m.**	
Oxide/Element		DP 47	DP 48	DP 49	DP 50	DP 51	DP 52	DP 53	DP 54	DP 55	DP 56	DP 57	DP 58	DP 59	DP 60	DP 61	DP 62	DP 63	DP 64	DP 65	DP 66	DP 67
SiO_2	wt%	60.24	61.25	67.04	56.22	61.71	51.23	55.34	56.59	53.31	56.06	50.09	54.03	50.88	56.78	52.55	56.26	50.08	52.72	48.62	44.87	49.73
TiO_2	wt%	0.53	0.44	0.49	0.67	0.70	0.61	0.58	0.61	0.60	0.61	0.53	0.64	0.60	0.46	0.59	0.52	0.58	0.64	0.55	0.52	0.57
Al_2O_3	wt%	14.24	16.60	16.26	16.37	18.07	14.22	13.15	13.55	13.56	13.67	12.68	14.12	13.48	11.39	14.17	12.27	13.53	14.85	13.42	12.31	13.83
Fe_2O_3	wt%	0.73	1.38	1.88	4.80	3.15	2.08	2.24	3.05	2.37	4.71	3.08	3.23	2.76	2.07	4.60	1.94	3.49	3.92	1.56	1.37	2.91
FeO	wt%	3.37	2.39	1.60	1.59	1.50	2.52	2.22	2.02	2.42	0.29	1.33	1.55	1.54	1.62	0.36	1.96	1.27	1.17	2.53	2.68	1.35
MnO	wt%	0.05	0.05	0.07	0.07	0.06	0.07	0.08	0.08	0.08	0.07	0.09	0.08	0.07	0.12	0.12	0.07	0.11	0.11	0.09	0.17	0.11
MgO	wt%	0.80	1.44	1.58	2.45	0.87	2.29	2.17	2.19	2.60	2.42	2.44	2.11	2.23	2.09	2.60	2.21	2.73	2.48	3.06	1.91	2.56
CaO	wt%	4.18	2.06	1.40	3.54	2.89	10.72	9.52	7.05	9.37	7.74	11.61	7.77	10.87	9.98	9.32	9.13	10.71	8.24	11.19	13.19	12.19
Na_2O	wt%	1.16	2.22	2.35	1.25	1.33	0.79	1.03	0.98	1.16	0.95	1.01	0.78	0.69	1.02	0.90	1.11	0.90	0.77	0.86	0.73	0.93
K_2O	wt%	2.63	4.17	3.96	3.14	3.21	2.63	2.51	4.36	3.17	4.19	3.96	3.80	3.63	2.82	4.37	3.13	4.29	4.34	2.82	2.11	2.82
P_2O_5	wt%	0.27	0.19	0.13	0.13	0.25	0.19	0.28	0.24	0.29	0.31	0.26	0.43	0.46	0.25	0.31	0.17	0.32	0.33	0.19	0.19	0.26
L O I	wt%	11.83	7.67	3.34	9.06	6.33	12.46	10.85	9.07	10.75	8.79	12.83	10.98	12.22	11.36	9.86	11.39	11.64	10.09	14.97	19.68	12.65
Ba	ppm	452	683	553	572	867	715	636	958	699	1167	597	1222	2112	577	1013	460	675	1135	398	725	615
Cr	ppm	75	73	79	107	84	102	96	91	93	90	81	99	93	76	88	80	87	100	94	82	92
Cu	ppm	9	19	22	42	11	36	30	40	37	44	35	39	47	32	32	39	38	51	31	75	35
Nb	ppm	17	17	14	14	21	13	13	13	12	14	12	14	14	9	12	10	12	13	12	13	11
Ni	ppm	43	41	53	66	55	66	58	62	57	62	57	68	66	52	60	53	61	67	61	56	56
Pb	ppm	26	21	25	36	29	25	24	28	21	26	27	28	20	23	28	19	23	26	20	24	21
Rb	ppm	143	188	230	170	180	126	115	121	120	122	122	107	89	99	135	125	123	134	135	88	121
Sr	ppm	100	115	76	200	130	208	227	198	220	236	282	241	361	190	287	170	230	204	215	262	262
V	ppm	104	80	73	122	120	102	87	88	84	86	87	84	73	68	89	80	76	97	96	85	95
Y	ppm	30	29	35	22	35	25	26	27	29	26	25	26	26	22	28	25	26	26	24	23	25
Zn	ppm	77	60	86	114	73	93	97	88	83	81	96	86	90	64	90	92	102	89	125	117	82
Zr	ppm	142	128	121	141	179	142	165	167	166	168	151	161	152	140	145	149	157	150	136	128	132
SUM %	wt%	100.02	99.86	100.11	99.29	100.07	99.81	99.99	99.78	99.67	99.81	99.91	99.52	99.43	99.95	99.74	100.17	99.65	99.64	99.84	99.72	99.90
CO_2	wt%	15.22	13.31	4.40	8.03	4.95	13.20	11.22	8.28	11.29	6.85	13.20	10.04	10.26	12.35	7.29	11.84	11.47	8.65	16.79	27.57	13.05
H_2O	wt%	9.34	5.54	2.83	7.22	6.86	5.56	4.55	5.82	5.85	5.14	4.56	8.38	9.59	5.27	5.47	4.96	5.61	6.96	6.27	10.10	5.22
Fe_{tot} as Fe_2O_3	wt%	5.05	4.36	3.78	7.21	5.13	5.56	5.27	5.81	5.65	5.52	5.22	5.55	5.09	4.36	5.55	4.64	5.54	5.80	5.12	5.39	5.04

Table 6 – Chemical analyses

		loom weights (poids de tisserand)					**clays**												**plutonic rocks**			
Oxide/Element		DP 68	DP 69	DP 70	DP 71	DP 72	DP 73	DP 74	DP 75	DP 76	DP 77	DP 88	DP 89	DP 90	DP 91	DP 92	DP 93	DP 94	DP 78	DP 85	DP 86	DP 87
SiO_2	wt%	47.93	52.68	49.40	70.24	64.17	54.63	61.65	78.02	60.14	78.53	57.46	59.62	74.72	67.65	74.39	78.07	76.74	48.82	59.68	61.93	77.31
TiO_2	wt%	0.51	0.52	0.54	0.59	0.54	0.57	0.30	0.50	0.22	0.39	0.22	0.35	0.44	0.28	0.41	0.44	0.48	2.15	0.44	0.62	0.06
Al_2O_3	wt%	12.69	12.00	12.54	13.71	12.63	13.28	8.24	10.13	6.68	8.93	6.61	8.83	10.37	8.61	11.73	11.57	11.37	17.93	20.51	17.21	12.53
Fe_2O_3	wt%	0.41	2.31	0.96	1.26	1.49	2.33	0.87	1.80	0.41	1.28	0.57	0.47	1.24	1.15	1.84	2.95	3.42	3.84	0.79	2.60	0.44
FeO	wt%	3.18	1.80	2.93	2.39	2.43	2.10	1.19	0.96	1.21	1.12	0.96	1.98	1.74	0.86	1.06	0.88	1.57	4.80	2.47	2.60	0.36
MnO	wt%	0.10	0.08	0.10	0.07	0.08	0.10	0.06	0.09	0.06	0.09	0.05	0.09	0.10	0.07	0.09	0.09	0.10	0.13	0.06	0.10	0.02
MgO	wt%	2.51	2.29	2.42	1.90	1.75	2.44	1.48	1.03	1.00	1.08	1.15	1.36	1.11	1.12	1.13	1.06	1.24	4.07	0.99	1.81	0.07
CaO	wt%	11.88	12.24	11.82	1.05	4.75	9.18	11.70	0.60	13.79	1.40	15.05	9.39	0.68	8.09	0.67	0.66	2.16	10.17	0.84	4.78	0.36
Na_2O	wt%	0.82	1.13	1.07	1.41	1.22	1.20	1.44	1.84	1.31	1.55	1.37	1.48	1.77	1.81	2.14	2.20	1.97	3.06	5.11	3.95	4.28
K_2O	wt%	2.75	2.39	2.47	2.77	3.01	2.72	1.91	2.06	1.68	1.97	1.63	1.99	2.26	2.15	2.73	2.74	2.50	0.80	6.92	2.25	4.35
P_2O_5	wt%	0.20	0.24	0.28	0.09	0.19	0.12	0.08	0.07	0.10	0.12	0.20	0.15	0.13	0.08	0.08	0.07	0.19	0.54	0.53	0.16	0.01
L O I	wt%	16.83	12.29	15.27	4.92	7.95	11.70	11.44	3.02	13.64	3.64	14.67	14.20	5.78	8.44	3.98	2.63	5.62	2.96	1.54	1.85	0.26
Ba	ppm	376	450	448	476	554	357	258	333	254	284	232	253	314	297	351	341	363	196	414	558	27
Cr	ppm	86	77	82	100	84	90	47	69	35	51	32	52	71	50	45	70	71	46	13	14	5
Cu	ppm	33	29	34	31	30	29	15	13	12	15	8	28	19	7	11	7	24	4	2	2	2
Nb	ppm	10	12	10	10	12	12	8	7	6	7	4	8	8	9	10	10	10	10	26	9	38
Ni	ppm	56	47	51	61	57	53	27	31	19	25	19	30	41	27	29	28	38	10	3	8	3
Pb	ppm	20	18	22	23	22	23	13	23	17	21	14	31	23	13	18	18	28	8	28	7	9
Rb	ppm	129	98	110	135	115	130	81	100	70	88	65	85	104	91	128	127	118	25	388	81	343
Sr	ppm	243	259	231	77	118	181	211	74	231	87	203	184	69	170	78	81	104	645	111	259	3
V	ppm	96	75	82	94	78	89	42	53	32	53	32	42	53	35	53	50	72	296	28	91	5
Y	ppm	24	23	25	26	24	27	20	30	15	23	16	24	26	19	26	23	30	33	19	23	114
Zn	ppm	89	111	112	79	84	81	34	44	49	38	100	114	139	134	125	41	59	169	117	143	86
Zr	ppm	127	141	141	166	170	151	135	270	126	181	137	159	215	148	187	206	211	487	241	169	70
SUM %	wt%	99.81	99.97	99.81	100.39	100.23	100.37	100.36	100.11	100.23	100.09	99.94	99.90	100.34	100.31	100.26	99.86	100.18	99.26	99.89	99.86	100.05
CO_2	wt%	21.60	13.01	18.77	5.64	10.26	11.51	11.91	2.90	15.51	3.92	14.89	17.71	7.40	8.03	4.14	1.99	6.30	1.09	0.16	0.16	0.20
H_2O	wt%	7.17	4.35	6.13	5.55	4.88	5.48	2.75	3.37	2.92	3.17	2.52	5.59	5.41	2.60	4.31	2.71	3.58	2.96	1.86	2.34	0.29
Fe_{tot} as Fe_2O_3	wt%	4.72	4.90	4.96	4.11	4.54	5.27	2.47	2.95	2.03	2.62	1.92	3.10	3.36	2.30	3.14	2.95	3.42	9.40	3.58	5.58	0.84

Table 6 – Chemical analyses

3. DISCUSSION

3.1 Technology

3.1.1 Introduction

The pottery has been manufactured with a *silicate*, inclusion-poor clay that is Al-rich and Ca-poor (figures 5 & 15a-b). 20-25% in volume of granite *temper* grains have been added to this clay (figure 6a). Concerning the color gradient observable in the cross sections of the sherds, the proportions between red and grey layers (around 1:1) allows to estimate a firing phase similar to the type III with a peak firing temperature between 750 and 800° C envisaging a longer time of oxidising conditions (Martineau & Petrequin, 2000; Martineau, pers. inform).

The cobs and the loom weights have been produced by using a *carbonate*, inclusion-rich clay, that is Al-poorer and Ca-rich, (figures 8b & 15a-b). Whereas the cobs have not been tempered at all, most of the loom weights have been tempered with organic matter, mainly wood and vegetal residues mainly (figure 9 & 10). The stone or pebble-like outlook of the cob fragments leave little doubt that the specimens have undergone a firing event. The reddish thin outer portion of the fragments indicates a clear oxidising environment such as in a fire, for instance. In agreement with Médard (2000), the loom weights have been doubtlessly intentionally fired. The color layering brown (rim) to black (core) is consistent with a firing phase of the type I to II, which allows to estimate a peak firing temperature between 400 and 600° C (Martineau and Petrequin, 2000).

3.1.2 Pottery

Matrix (fired clay)

As far as the silicate clay used for the pottery is concerned, we can calculate its rough chemical composition. The two basic components to produce the vases are the clay (matrix) and the temper. We know their respective *volume%* and *density*. If we have the *chemical element content* of at least one of the basic components and the bulk ceramic one, we can compute the missing data on the basis of the following formula:

$$\mathbf{c} \times \mathbf{d} \times \mathbf{v}\%_{\text{(ceramic)}} = \mathbf{c} \times \mathbf{d} \times \mathbf{v}\%_{\text{(temper)}} + \mathbf{c} \times \mathbf{d} \times \mathbf{v}\%_{\text{(matrix)}} \quad (1)$$

where **c**= content of chemical element, **d**=density and **v**=volume.

For Portalban ceramics we have the following data: the *temper* is a granite, which has a clear fingerprint of the Mont Blanc granite. Its density is $\mathbf{d}_1$=2.7, its average volume% is $\mathbf{v}_1$=23%, its SiO_2-content is $\mathbf{c}_1$=77 wt% (Bussy, 1990; DP 87, table 5 & 6). A *pottery sherd* has a volume% corresponding to $\mathbf{v}_3$=100%, a density calculated and averaged on 10 specimens of $\mathbf{d}_3$=1.8, and a SiO_2 wt% averaged value of $\mathbf{c}_3$=65 wt% (figure 15a). If the *matrix* has an average volume% of $\mathbf{v}_2$=77%, we can extrapolate a mean density value of $\mathbf{d}_2$=1.5, whilst the SiO_2 wt% is unknown $\mathbf{c}_2$=x.

The results can be considered as estimates only. However, the calculations can give some idea about raw materials composition.

Applying (1), the SiO_2 wt% content of the ceramic matrix is around $\mathbf{c}_2$=**60** wt%.

If we now compute the relevant data concerning the Al_2O_3 wt% ($\mathbf{c}_1$=12.5 wt%, DP 87 table 6, $\mathbf{c}_3$=18 wt%, figure 15a) we obtain a value for the matrix of $\mathbf{c}_2$=**20** wt%.

The above data are in excellent agreement with the data recently obtained on the separated temper and matrix of Portalban ceramics (Di Pierro, 2002).

A matrix with an Al_2O_3 wt% around 20% can derive from a clay very rich in kaolinite, for instance. Figure 15d shows a good geochemical correspondence between the silicate clays and the pottery groups, regarding Fe_{tot}, K_2O and CaO wt%. But if we consider the previous calculations and couple them with the data from figure 15a, we can easily see that the more important SiO_2 and Al_2O_3 wt% contents of the silicate clays (80% and 11.5 %) do not fit at all the calculated ones and the data recently obtained with the separation technique (60% and 20%: Di Pierro, 2002). Therefore the silicate clays sampled at Portalban do not correspond to the used ones for pottery manufacturing. In fact, figure 16 shows the Portalban situation, concerning the sampled silicate clays, Mont Blanc granite XRF analyses and pottery data. Even though the three geochemical groups are in linear correlation, it is evident that if the silicate clays were those used for the pottery manufacturing, their chemical analyses should lie on the right-side of the pottery field, as it is shown in the ideal situation concerning the sought Al-rich clay. The pottery being the result of the mixing of temper and clay must lie somewhere in the middle of the correlation line between the two raw materials, but never on its extreme ends.

In addition to this, from the mineralogical and textural points of view, the silicate clays have a too high quartz-content. They have been in fact defined as an inclusion-rich, sandy loam (figure 11b). The matrix observable in thin section concerning the pottery is instead an inclusion-very poor argilleous material (figure 6a).

Temper

As far as the granitic inclusions are concerned, the petrographical observations have underlined the constant use of a specific lithotype, which mineralogically and texturally matches the Mont Blanc granite. If we assume the utilisation of local available lithologies from the moraine deposits, and if reconsider the statistical study concerning the prospection of such materials in the surroundings of the Neolithic village (figure 14), we can state the following.

Even being available, and of good quality for tempering pottery as underlined by some authors (i.e. Nungässer *et al.*, 1992) neither metabasites nor quartzites have been used by the Portalban potters. As already demonstrated by many authors (Benghezal, 1994, Maggetti, 1994, Nungässer and Maggetti, 1978, Nungässer *et al.*, 1985, 1992; Martineau *et al.*, 2000), the seeking and intentional use of a granitic lithotype for pottery tempering is more than a simple speculation.

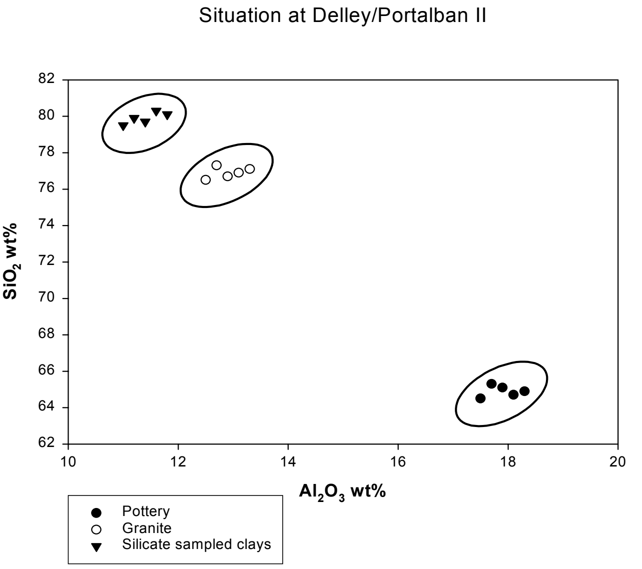
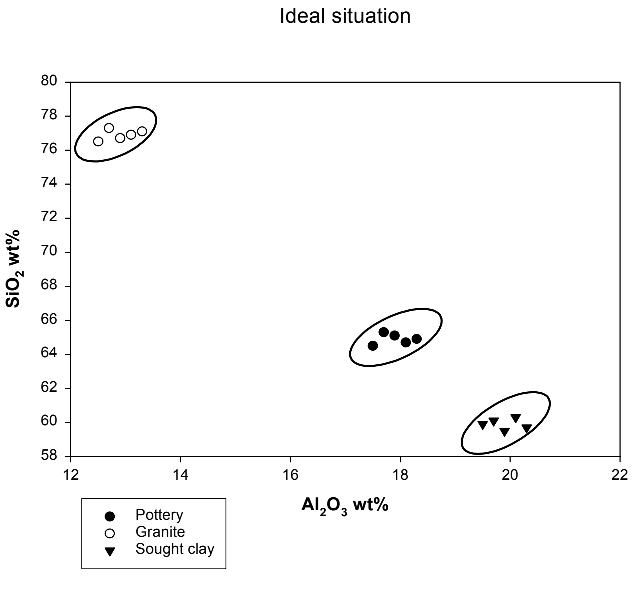


Figure 16. Chemical relationship between SiO_2 and Al_2O_3 wt% concerning some more significant Portalban pottery, some Mont Blanc granite analyses available from the literature (Bussy, 1990) and some silicate sampled clay (above). The three groups are in linear correlation but if silicate sampled clays were those used for pottery manufacturing, their plots should lie on the right side of the pottery field, as it is shown in the below calculated ideal situation (see discussion).



The above mentioned prospection has mainly highlighted three different aspects: (i) granitoide rocks do not constitute more than 10% of available lithotypes, while they are the unique used rock for ceramic tempering; (ii) among the available granitoide, several different petrographic lithologies are present, while the Mont Blanc granite is the virtually unique used lithotype during Old Auvernier-Cordé group occupation at Portalban; (iii) Mont Blanc granite has been in fact petrographically and chemically identified among the available granitoide rocks.

The utilisation of Mont Blanc granite has been recently geochemically demonstrated with the matrix – temper separation technique (Di Pierro, 2002).

Hence, how did Neolithic potters recognise the Mont Blanc granite? Why did they use this material in such a systematic way?

It is our opinion that such a regularity cannot be explained with the random collection of material. We think that Neolithic potters were able to exploit a sort of specific and well known source, such as an erratic boulder, for instance.

Nungässer *et al.* (1992) stated that granite was the easiest lithology self-crushing after having been fired and rapidly cooled down with water. Therefore, it is envisageable that Mont Blanc granite was an "easier" material to be crushed to mm-sized grains compared to other granitoide rocks.

3.1.3 Cobs and loom weights

If it is not too astonishing that the cobs were not tempered at all, because it was not necessary to fire them before use, it is very interesting to note the regularity in tempering the loom weights with organic matter.

Several cases of ceramic tempering with vegetal fibres are now known from the Paris Basin Neolithic pottery, from archaeological sites in Egypt, and from some ethnographic cases in Africa (Sestier, 2001). Tempering with chaff and charcoal has been reported for Swiss crucibles of the Pfyn culture (Maggetti *et al.,* 1990). The adding of this kind of organic temper to the raw clay is interpreted as necessary to avoid fissuring during the firing. In fact, the organic temper should increase the bulk plasticity of the clay artefact, its workability, and the average porosity, allowing a proper firing (Claude Sestier, personal communication).

The utilisation of a carbonate clay for Portalban loom weights could have caused in fact problems during the firing due to the instability of calcite around 700-750 °C. We think that Neolithic villagers could have experienced a technological solution by adding simple vegetal material to their crude clay mixture before firing it.

3.2 Provenance

Some aspect concerning this issue have already been briefly introduced in previous sections. The definition of "local" has been the main subject of a long-lasting debate within the archaeological and archaeometrical communities. Arnold (2001) recently proposed to define as *local*, only ceramic products manufactured with starting raw materials found at a distance of 1 – 2 km. If we apply this approach, we can state that the cobs and loom weights have been locally produced at Portalban during the Old Auvernier-cordé occupation of the settlement, while the pottery was not.

3.2.1 Pottery

The clays available around Portalban have been accurately prospected. We have stated based on chemical and mineralogical argumentations, that the silicate clays are not those used for pottery preparation. The clay compositions are strictly related to the rock-basement and the geomorphology of the area (figure 13). The Aquitanian Molasse, along with its facies "under weak moraine cover", is widespread over a larger area of several tens of Km^2 of the Swiss Plateau around Portalban (see geological map n.1164, Neuchâtel, Frei *et al.*, 1974). Therefore the silicate, Al-rich and inclusion-poor clay used for the pottery preparation is likely to be sought far away from the Neolithic village settlement.

The calculation of the potential chemical composition of the clay used to produced the pottery, as well as the quantitative XRF analyses obtained with the separation technique (Di Pierro, 2002) should be helpful to further investigate the provenance of the pottery raw clay.

3.2.2 Cobs and loom weights

The carbonate clay used for the preparation of these objects has been found and determined with sample clay DP 73 (figure 15a-d). It outcrops just beside the Neolithic village settlement and it is definitely the closest one (figure 13).

The wide prospection of samples underlined the deep variation in composition within the carbonate clays group (figure 15b). Clays just a few tens of meters far from the settlement differ quite deeply in composition when compared to analysis DP 73 (figure 13 & 15b, table 6).

It is therefore not a mere speculation to affirm the use of that clay in particular, DP 73, for the preparation of the cobs and most of the loom weights.

According to the ethnoarchaeological approach of Arnold (2001) cobs and loom weights have been locally produced.

4. CONCLUSIONS

In this paper, 50 pottery sherds belonging to the same archaeological horizon have been characterized with a classical archaeometrical approach. In addition, 14 cobs and 7 loom weights have been analysed and compared to pottery. An attempt to identify the original raw materials used for ceramic production has been carried out by prospecting and sampling of available clays and moraine rocks, locally found in the woods and neighbourhood of the Portalban Neolithic village.

This work has permitted to identify a sharp and deep difference in the production techniques, in terms of raw materials provenance of the pottery on one hand and the other fired clay tools (the cobs and the loom weights) on the other.

The pottery has a constant and homogeneous chemical composition. Petrographic observations have confirmed their homogeneity. They have been produced with a silicate, Al-rich, inclusion-poor clay, to which a 20-25% in volume of granite temper with a clear Mont Blanc fingerprint has been added. The raw clay just mentioned does not outcrop in Portalban terrains. Mont Blanc granite pebbles can be found in moraine deposits around Portalban, but they are quantitatively negligible to be thought as an easy source for temper preparation. Its systematic exploitation should be envisaged elsewhere.

In contrast, the cobs and the loom weights constitute another homogeneous chemical group. Petrographical characterization revealed that the cobs are all temper-less fired clay objects. The loom weights are rock fragments-less too, but they have been tempered with organic matter, wood and vegetal residues mainly, to allow the firing. Cobs and loom weights are both the result of a "bad" mixture of carbonate and inclusion-rich clay. This clay has been identified as the closest clay available at the Neolithic village. It is the weathering product of the Aquitanian Molasse basement.

The pottery has therefore a stronger and finer background technology degree, if compared with the cobs and the loom weights. The raw clay used for its preparation is very unlikely local, because it does not match any silicate clay found within an area of at least ten to fifteen km of ray. This clay is Al-rich (Di Pierro, 2002); the high alumina content can be explained with a kaolinite-rich sediment, the localisation of which should be further investigated. The systematic exploitation of a precise and unique granite source for tempering is quite astonishing; the presence of a well-known source such as an erratic boulder might be envisaged.

The cobs and the loom weights are in contrast relatively "easy" objects to be produced. The nearest sediment was in fact systematically exploited for this purpose. A quick mixing with organic matter for loom weights, absent in cobs, was the only working step performed by Neolithic villagers before firing.

REFERENCES

ARNOLD, D., 2001, *Linking society with the compositional analyses of pottery : a model from comparative ethnography*. XIVe Congrés de l'Union International des Sciences Prehistoriques et Protohistoriques, Liège, 2 - 8 septembre 2001. Abstract.

BENGHEZAL, A., (1993), *Provenance de la céramique fine tardi-néoloithique des lacs de Bienne et Neuchâtel : analyses minéralogiques, pétrographiques et chimiques*. Schweiz. Mineral. Petrogr. Mitt. 73, 107-111.

BENGHEZAL, A., (1994), *Provenance et techniques de la céramique du Néolithique final de stations des trois lacs jurassiens (Suisse)*. Thèse de doctorat, Université de Fribourg, 174 pp.

BURMESTER, A., GOEDICKE, C., HENNICKE, H.W., KLEINMANN, B., KNOLL, H., MAGGETTI, M., ROTTLÄNDER, R. & SCHNEIDER, G., (1989), *Naturwissenschaftliche Kriterien und Verfahren zur Beschreibung von Keramik*. Diskussionsergebnisse der Projektgruppe Keramik im Arbeitskreis Archäometrie in der Fachgruppe Analytische Chemie der Gesellschaft Deutscher Chemiker. Acta praehistorica et archaeologica 21, 7-39.

BUSSY, F., (1990), *Pétrogenèse des enclaves microgrenues associées aux granitoides calco-alcalins: exemple des massifs varisque du Mont Blanc (Alpes occidentales) et miocène du Monte Capanne (Ile d'Elbe, Italie)*. Thèse de Doctorat, Université de Lausanne. Mémoire de Géologie n.7, 309 pp.

DANEROL, A., ORCEL, A., ORCEL, C. & RAMSEYER, D., (1990), *Delley/Portalban II, vol.2, les villages néolithiques révélés par la dendrochronologie*. Archéologie Friburgeoise, Editions Universitaires, Fribourg, 1990, 168 p., 5 annexes.

DI PIERRO, S., (2002), *Matrix-temper separation of Neolithic ceramics; an experimental approach to characterize the original raw materials.* Proceedings of the 6th European Meeting on Ancient Ceramics (EMAC '01), Ceramic in the Society, Fribourg, Switzerland, 3-6 October 2001. In press.

FREI, E., MEIA, J., BECKER, F., BÜCHI, O., BUXTORF, R., RYNIKER, K. & SUTER, H., (1974), *Atlas géologique de la Suisse 1:25.000, feuille 1164, Neuchâtel.* Commission géologique Suisse.

GILIGNY, F., (1993), *La variabilité des récipients céramiques au Chalcolithique moyen-récent jurassien (3400-2400 av. J.C.). Analyse archéologique d'un système d'objets.* Thèse de Doctorat, Université de Paris I – Panthéon/Sorbonne UFR 03 – Histoire de l'Art et Archéologie, Vol.1, 273 pp.

GILIGNY, F. & MICHEL, R., (1995), *L'évolution des céramiques de 2920 à 2440 av.J.-C. dans la région des trois lacs (Suisse Occidentale).* Chronologies néolithiques. De 6000 à 2000 avant notre ère dans le Bassin rhodanien. Actes du Colloque d'Ambérieu-en-Bugey, 19-20 septembre 1992. Documents du Département d'Anthropologie de l'Université de Genève, n°20. Ambérieu-en-Bugey, éd. Société Préhistorique Rhodanienne, 1995, p. 347-361.

IUGS, Subcommission on the systematic of the igneous rocks (1973), *Classification and nomenclature of plutonic rocks*, Neus Jahrb. Mineral, Mh., 149 - 164.

MAGGETTI, M., (1982), *Phase analysis and its significance for Technology and Origin.* Archaeological Ceramics, ed. J.S.Olin and A.D.Franklin Smithsonian Institution Press, 121-133.

MAGGETTI, M., BAUMGARTNER, D. & GALETTI, G., (1990), *Mineralogical and chemical studies on Swiss neolithic crucibles*. Archaeometry, 95-104.

MAGGETTI, M., (1994), *Mineralogical and Petrographical methods for the study of ancient pottery.* In: 1st Eropean Workshop on archaeological ceramics, Burragato F., Grubessi O., Lazzarini L., (eds), Università degli Studi di Roma "La Sapienza" 1994.

MARTINEAU, R., CONVERTINI, F. & BOULLIER, A., (2000), *Provenances et exploitations des terres à poterie des sites de Chalain (Jura), aux 31e et 30e siècles avant J.-C.* Bull. de la Soc. Préhist. Franç., 97, n.1, p. 57-71.

MARTINEAU, R. & PETREQUIN, P., (2000), *La cuisson des poteries néolithiques de Chalain (Jura), approche expérimentale et analyse archéologique.* Arts du feu et productions artisanales. XX° Rencontres Internationales d'Archéologie et d'Histoire d'Antibes. Editions APDCA, Antibes, 2000.

MARRO, C., (1986), *Les granitoides du Mont Blanc en Suisse.* Thèse de Doctorat, Université de Fribourg, 145 pp.

MATTHEW, A.J., WOODS, A.J. & OLIVER, C., (1991), *Spots before the eyes: new comparision charts for visual percentage estimation in archaeological material.* British Museum, occasional paper, number 81, 211- 263.

MEDARD, F., (2000), *L'artisanat textile au Néolithique. L'exemple de Delley-Portalban II (Suisse) 3272-2462 avant J.-C.* Préhistoires 4. Editions Monique Mergoil. Montagnac, France. 251 pp.

MEIA, J. & BECKER, F. (1976), *Notice explicative de la feuille 1164, Neuchâtel, de l'Atlas géologique de la Suisse 1:25.000*, Commission géologique Suisse.

NUNGÄSSER, W. & MAGGETTI, M., (1978), *Mineralogisch-petrographische Untersuchung der neolitischen Töpferware vom Burgäschisee.* Bull. Soc. Frib. Sc. Nat. 67/2, 152 – 173.

NUNGÄSSER, W., MAGGETTI, M. & STÖCKLI, W.E., (1985), *Neolitische Keramik von Twann – Mineralogische und Petrographische Untersuchungen.* Jahrbuch der Schweiz. Ges. für Ur- und Frügeschichte, 68, 7-39.

NUNGÄSSER, W., MAGGETTI, M. & GALETTI, G. (1992): *Analyse der Scherbensubstanz mit Mikroskop und Röntgenlicht.* In: J.Bill, W. Nungässer, G. Galetti: Liechtensteinische Keramikfunde der Eisenzeit. Jahrbuch des Historischen Vereins für das Fürstentum Liechtenstein, Band 91, p. 119-165.

PETREQUIN, P., CHASTEL, J., GILIGNY, F., PETREQUIN, J.M. & SAINTOT, S., (1987 – 1988), *Réinterpretation de la civilisation Saône-Rhône ; une approche des tendances culturelles du Néolithique final.* Gallia Préhistoire, tome 30, p. 1-89.

PICOUET, P., (1997), *Application de la cathodolouminescence à l'étude des céramiques archéologiques et modernes.* Thèse de doctorat, Université de Fribourg, 175 pp.

PORTMANN, J.P. (1955), *Pétrographie des moraines du glacier würmien du Rhône dans la région des lacs subjurassiens (Suisse).* Bull. Soc. neuchât. Géogr. 51/5 (1954-1955).

PORTMANN, J.P. (1966), *Pétrographie des formation glaciaiers à l'est du lac de Bienne.* Eclogae geol. Helv. 59/2.

RAMSEYER, D., (1987), *Delley-Portalban. Contribution à l'étude du Néolithique en Suisse occidentale.* Archéologie friburgoise 3, Fribourg.

RAMSEYER, D. (1988), *La céramique néolithique d 'Auvernier/La Saunerie (fouilles 1964 – 1965). Auvernier 7.* Cahiers d'Archéologie Romande 45, Lausanne.

SESTIER, C., (2001), *Technologie céramique et utilisation de dégraissants végétaux: résultats d'essais en contexte « néolithique ».* XIVe Congrés de l'Union International des Sciences Prehistoriques et Protohistoriques, Liège, 2 - 8 septembre 2001. Abstract.

SCHWAB, H., (1971), *Junsteinzeitliche Fundstellen im Kanton Freiburg*, Schriften zur Ur- und Frügeschichte der Schweiz 16, Schweizerische Gesellschaft für Ur- und Frühgeschichte, Basel, 1971, 136 p., 85 fig.

SCHWAB, H., (1982), *Portalban/Muntelier: zwei reine Horgener Siedlungen der Westschweiz.* Archäologisches Korrespondenzblatt, 12, Mainz, pp. 15-32

STÖCKLI, W.E. (1995), *L'evolution du Néolithique Suisse*. In « La Suisse du Paléolithique à l'aube du Moyen Age. De l'homme de Néanderthal à Charlemagne ». SPM II, Néolithique. Veralg Scweizerische Gesellschaft für Ur- und Frügeschichte, Basel. 358 pp.

STURNY, C. & RAMSEYER, D., (1984), *Petrographische Analyse neolithischer Keramik aus Delley/Portalban II (Kt. Freiburg) und Charavines (Dpt.Isère, Frankreich).* Freiburger Archäologie, Fundbericht 1984, 92-95, Fribourg.

THEVENOT, J.P., STRAHM, C., *et al*., (1976), *La Civilisation Saône-Rhône*, Revue Archéologique de l'Est, XXVII, 3-4, 331-420.

VOUGA, P., (1929), *Classification du Néolithic lacustre Suisse*. Indicateur des antiquités suisse, 31, pp. 81-91; 161-180.

VON RAUMER, J., (1967), *Kristallisation und Gefügebildung im Mont-Blanc-Granit.* Habilitationsschrift zur Erlangung der Venia legendi an der mathematisch-naturwissenschaftlichen Fakultät der Universität Freiburg i. Ü. (Schweiz), 499-579.

VON RAUMER, J., (1969), *Stilpnomelan als alpinmetamorphes Produkt im Mont-Blanc-Granit.* Contr. Mineral. Petrol. 21, 257-271.

VON RAUMER, J. (1984), *The external massifs, relics of Variscan Basement in the Alps.* Geologische Rundschau, 73, 1, 1-31.

WHITBREAD, I. K. (1986), *The characterisation of argillaceous inclusions in ceramic thin sections.* Archaeometry 28, 1, 79-88.

CHAPTER II

THE PORTALBAN POTTERY: MATERIALS VERSUS CERAMIC TYPES AND SPATIAL DISTRIBUTION. CRAFTSMANSHIP OR DOMESTIC PRODUCTION?

1. INTRODUCTION

The main framework of the present Ph.D research concerns the issue of the potential craftsmanship production of ceramics during the Final Neolithic on the Western Swiss Plateau. The Portalban/Delley II and the Saint Blaise/Bain des Dames settlements have been selected for this purpose. The pottery related to the Late and Medium Auvernier-cordé cultural groups has been chosen to investigate the matter.

The chemical and petrographic characterization of ceramic products is the base of the study. In opposition to previous archaeometric works (i.e. Sturny & Ramseyer, 1984; Benghezal, 1994), the sampling strategy of this research has been focused on the different ceramic types, separately characterized by the archaeologists (i.e. Giligny, 1993, Michel , 2002), and taking into account the spatial distribution of the pottery inside the settlement, as per the model suggested by Petrequin *et al.*, (1994) for the Neolithic ceramics of Chalain, France.

The archaeological, geographical and geological contexts of Portalban have been already given in Di Pierro (2002a-b). The main results concerning the petrography and the chemistry of Portalban ceramics are here briefly reminded.

The sharp difference existing in the raw materials, in terms of composition, provenance and utilization for the pottery preparation on one side and the cobs and the loom weights on the other hand has been extensively discussed in Di Pierro (2002a). In particular, while the pottery has been produced with a silicate clay to which granite temper grains have been added, the cobs and the loom weights have been produced with a calcareous clay and have not been tempered. Some loom weights present the adding of organic matter (charcoal for most). In addition to these differences, the prospecting of the potential raw materials in the surroundings of the settlement has permitted to identify the calcareous clay used for the cobs and the loom weights preparation as local, while the silicate clay used for the pottery has not been found. The granite used as temper, characterized as the Mont Blanc granite, has been found, but as a scarce material, in the moraine deposits around Portalban.

The main aim of this chapter is to correlate the chemical results obtained on Portalban ceramics (Di Pierro, 2002a) to the existing pottery types and to its repartition in the settlement.

2. THE SAMPLING OF PORTALBAN POTTERY

The Auvernier-cordé period, which dates between 2700 – 2400 BC (i.e. Stöckli, 1995), is characteristic of the Western Swiss Plateau. The peculiarity of the Auvernier-cordé cultural group is the influence of the Corded Ceramic Civilization from Eastern Switzerland, Bodensee and Zürich See mainly (Schwab, 1982; Ramseyer, 1987; 1988; Giligny, 1993; Michel 2002). The arrival of groups of people from there is witnessed with the adoption by the Western Swiss populations of some of the Eastern exogenous productions: for instance the serpentine axes (Schwab, 1982) and the corded decorations of ceramics (Ramseyer, 1987), both uniformly widespread on the Western settlements.

Giligny & Michel (1995) studied and highlighted the existing links between the Eastern and Western ceramics, in terms of morphologies and decorations. In fact, studying the shape and the torsion direction of the decorations made with the cord, they were able to distinguish between two sharp fingerprints. They observed the Z-shaped torsion of the corded decorations in almost all the pottery of Eastern Switzerland, while the S-shaped and Z-shaped torsion were both present in the Western pottery (Giligny, 1993; Michel 2002). On the basis of this main, but also other differences (Di Pierro *et al.*, 2002), they characterized the corded ceramics with the S-shaped torsion as a local fingerprint of the Western Swiss Plateau ceramic production; they instead confirmed as an exogenous fingerprint, original of the Eastern settlements, the corded ceramics with the Z-shaped torsion. These two main types of pottery was contemporary of the other local ceramics, morphologically still different, as for instance the “Lüscherz Tradition” pottery, with a clear heritage of the previous cultural group of Lüscherz.

At Portalban, as well as in many other Western Swiss settlements, the three morphologies are simultaneously present during the Late Auvernier-cordé occupation. The (i) “Lüscherz Tradition”, the (ii) “Corded imitation” S-shaped, and the (iii) “Corded true” Z-shaped pottery. Some examples of the three morphologies have been summarized in fig.1.

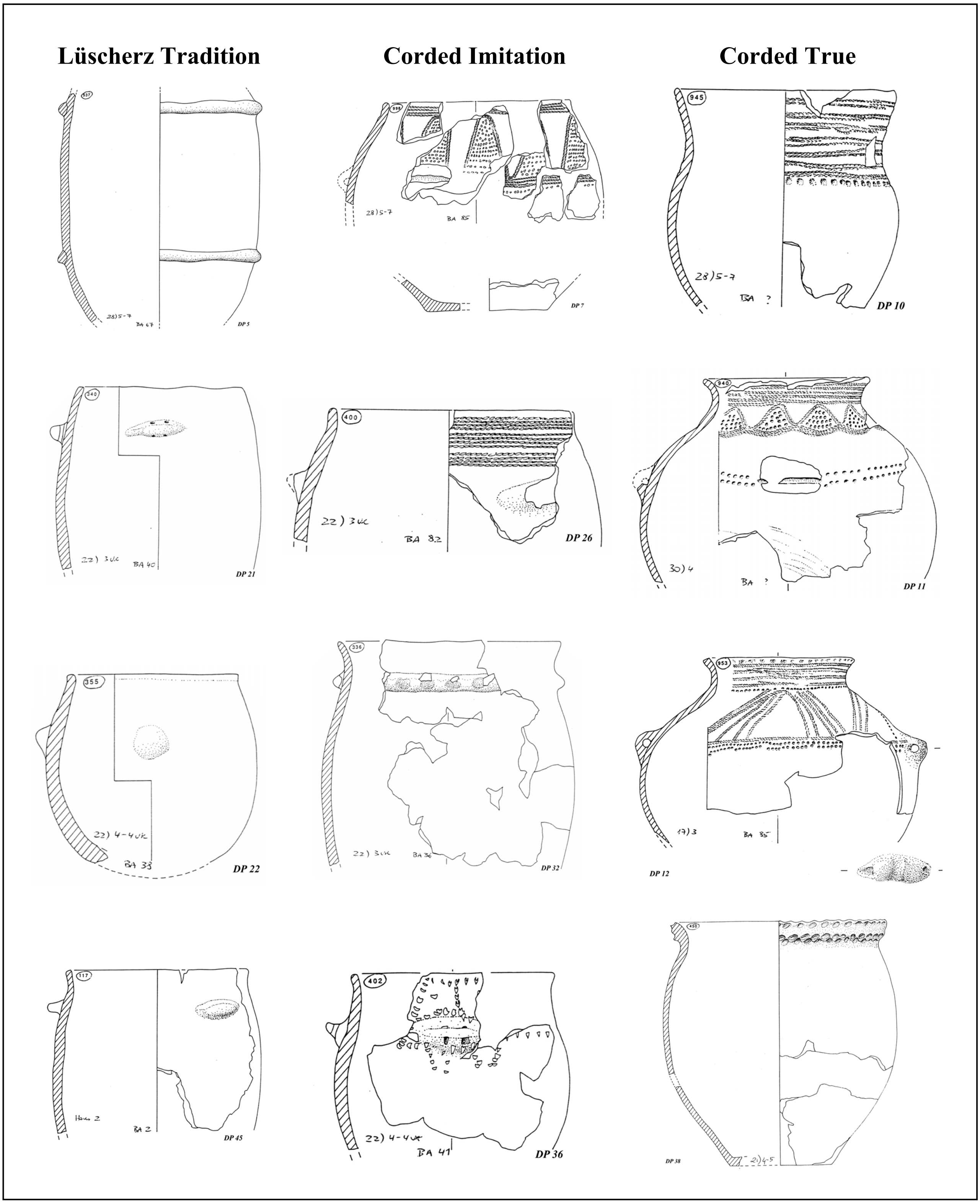


Figure 1. Ceramic types at Portalban (drawns by F. Giligny, 1993). Scale 1:9.

Analysis n.	Inventory n.	Ceramic type	Localisation
DP 1	905	Lüscherz tradition	Zone A
DP 2	"	Lüscherz tradition	Zone A
DP 3	"	Lüscherz tradition	Zone A
DP 4	"	Lüscherz tradition	Zone A
DP 5	537	Lüscherz tradition	Zone A
DP 6	834	Lüscherz tradition	Zone A
DP 7	998	Corded imitation	Zone A
DP 8	947	Corded imitation	Zone A
DP 9	949	Corded imitation	Zone A
DP 10	945	Corded true	Zone A
DP 11	940	Corded true	Zone A
DP 12	953	Corded true	Zone A
DP 13	982	Corded true	Zone A
DP 14	532	Corded imitation	Zone A
DP 15	832	Corded imitation	Zone A
DP 16	837	Corded true	Zone A
DP 17	810	Corded true	Zone A
DP 19	338	Lüscherz tradition	Zone G
DP 20	352	Lüscherz tradition	Zone G
DP 21	340	Lüscherz tradition	Zone G
DP 22	355	Lüscherz tradition	Zone G
DP 23	369	Lüscherz tradition	Zone G
DP 24	404	Corded imitation	Zone G
DP 25	976	Corded imitation	Zone G
DP 26	400	Corded imitation	Zone G
DP 27	486	Corded imitation	Zone G
DP 28	485	Corded imitation	Zone G
DP 29	407	Corded imitation	Zone G
DP 30	408	Corded imitation	Zone G
DP 31	349	Corded imitation	Zone G
DP 32	336	Corded imitation	Zone G
DP 33	334	Corded imitation	Zone G
DP 34	335	Corded imitation	Zone G
DP 35	468	Corded imitation	Zone G
DP 36	402	Corded imitation	Zone G
DP 37	401	Corded true	Zone G
DP 38	450	Corded true	Zone G
DP 39	467	Corded true	Zone G
DP 40	542	Corded true	Zone G
DP 41	350	Corded true	Zone G
DP 42	360	Corded true	Zone G
DP 43	115	Lüscherz tradition	Haus 2
DP 44	116	Lüscherz tradition	Haus 2
DP 45	117	Lüscherz tradition	Haus 2
DP 46	118	Lüscherz tradition	Haus 2
DP 47	136	Corded imitation	Haus 2
DP 48	139	Corded imitation	Haus 2
DP 49	1089	Corded imitation	Haus 2
DP 50	109	Corded imitation	Haus 2
DP 51	101	Corded imitation	Haus 2
AB 122	138	Corded imitation	Haus 2
AB 124	942	Corded imitation	Zone A
AB 126	957	Corded true	Zone A
AB 129	943	Corded imitation	Zone A
AB 131	809	Lüscherz tradition	Zone A
AB 133	820	Corded true	Zone A

Table 1. Samples list, ceramic type and localization of pottery, fig.1. DP = Di Pierro, AB = Benghezal.

Therefore, one of the main objective of this paper is to investigate the potential connection between different pottery morphologies and different ceramic pastes. In other words, the chemical and petrographic characterization aims to identify any potential correlation between ceramic shape and paste composition. This should serve to lead the archaeological interpretation to a sort of craftsmanship production of pottery at Neolithic times, in contrast to the domestic production of ceramics carried out by every householder of the village, as per the model proposed by Pétrequin *et al.* (1994).

In order to even better face the matter, the spatial distribution of the pottery has been included in the sampling strategy. Tab.1 lists the samples chosen for the study. It includes for each sherd the typology and the location from where they have been found. Fig.2 shows a partial schematic plan of the Portalban village as it has been interpreted during the excavations works of the settlement (Ramseyer, 1987). The exact location of every single reconstructed vase has been indicated. As it can be seen, three main areas have been selected for the purpose of this study. Zone A and “Haus 2” have been interpreted by the archaeologists (Dr. Denis Ramseyer and Dr. François Giligny pers. commun.) as single living building structures, while Zone G has been classified as a waster. In this case too, the main objective is to find any potential correlation between the pottery composition and the single area of provenance.

The idea in the background is to test whether the utilization of clay and temper sources can be correlated to a sort of specialization in the pottery production. This assumption has been recently tested by Arnold *et al.* (2000). These authors studied six contemporary workshops, which still produce nowadays ceramics, with a mean distance of 6 to 15 km from each others. They characterized with the Neutron Activation Analysis (NAA) the pottery and the clay and temper sources. They statistically worked out their results and eventually they were unable to identify for each ceramic production the relevant workshop.

Despite those results, we tried to test the above assumption relatively to a single Neolithic settlement. Our approach is based on the morphology and the spatial distribution of the found ceramics inside the settlement. Our characterization is based on the X-rays fluorences (XRF).

Tab.1 summarizes the ceramic sherds chosen by Dr. François Giligny to test the above-mentioned hypothesis.

Tab.2 below shows the samples linked to their ceramic type and location respectively.

	Zone A	Haus 2	Zone G	Total
Lüscherz tradition	7	4	5	16
Corded imitation	7	6	13	26
Corded true	8		6	14
Total	22	10	24	56

Tab.2 – Repartition of samples per ceramic type, fig. 1, and per the spatial distribution, fig.2.

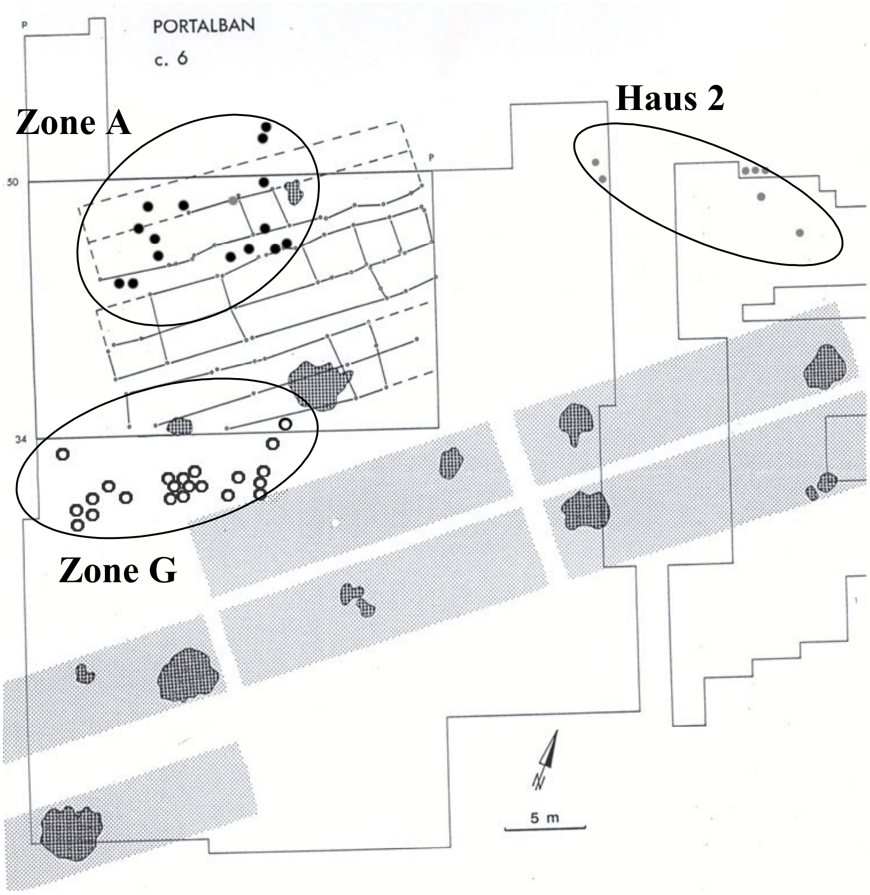


Figure 2. Partial schematic plan of the Portalban Neolithic village and main inhabitants building structures as per archaeologists interpretations. Circles (black, gray and white) correspond to the location of pottery relative to their findings. The above unpublished map is a field working table used by D. Ramseyer, main archaeologist, at the excavation site. Zone A and "Haus 2" correspond to two specific living structures. Instead Zone G has been interpreted as a waster.

3. MAIN CORRELATIONS AND RESULTS

The chemical (XRF) analyses of Portalban pottery have been presented in Di Pierro (2002a). In the same paper, the relatively homogeneous composition of the pottery has been extensively discussed. No main chemical neither petrographic groups have been highlighted.

3.1 Correlation with the ceramic types

Fig.3 is a diagram correlation showing the chemical composition of Portalban pottery with reference to the two main oxides SiO_2 and CaO expressed in weight per cent (wt%).

Some potteries have some distinguishing features when compared to the bulk group. But as the figure intends to underline, the chemical analyses are scattered throughout the graph when grouped per ceramic type or morphology. There are no particular differences between the "Lüscherz tradition", the "Corded imitation" and the "Corded true" ceramics in terms of silica and CaO composition. The three kinds of pottery are in overlapping position, even considering the sub-groups that delineate from right to left of the graph.

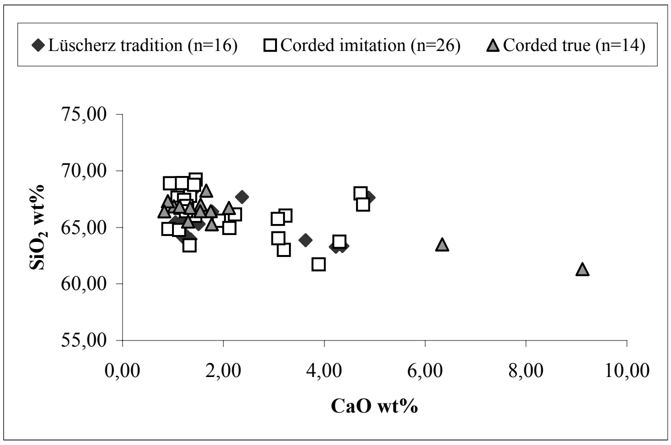


Figure 3. Correlation diagram SiO_2 – CaO per ceramic type.

Fig.4 concerns the MgO – CaO relationship. The MgO content of St. Blaise ceramics (Di Pierro *et al*., 2002) served to discriminate between different pottery types. The MgO content at 1wt% seems to be a feature of St. Blaise ceramics, some pottery always of St. Blaise with the MgO content above 2wt% have been interpreted as coming from Portalban (Di Pierro *et al*., 2002).

When Portalban analyses are plotted as per ceramic type we can observe the MgO content between 1,5 and 2,5 wt% characteristic of Portalban pottery, but we cannot distinguish any ceramic group with reference to morphologies. Three potteries have the MgO content at 1wt%. They have been interpreted as coming from St. Blaise (Di Pierro *et al*., 2002), but they belong to “Corded imitation” and “Lüscherz tradition”.

Fig.5 shows a positive correlation between the Cr and MgO content of ceramics. This is interpreted as due to the presence of magnesium bearing silicates, as the chlorite detected with the XRD analyses, which is a common phase widespread in the ceramic matrix. Its source could be from the weathering of rocks with mafic or ultramafic composition, green-schists and or serpentinites, present in the Portalban moraine deposits (Di Pierro, 2002a).
However, ceramic compositions are again scattered throughout the graph when they are considered per type, without fitting the morphology groups.

Fig.6 shows the relationship between Al and Fe oxides, which could reflect the variation in composition of the matrix (clay). The ranges of data for both oxides do not show any particular trend. The “Corded imitation” group seems to be slightly poorer in iron in average, in contrast to a slight enrichment of the same element in the “Corded true” group. But no clear repartition between the two is actually visible.

A sort of positive correlation seems to link CaO and Sr, fig.7, correlation perhaps due to the composition of the few carbonate minerals composing the matrix (Di Pierro, 2002a). However, neither in this case, any correlation exist with the ceramic types. Most of the “Corded true” are low in CaO and Sr, but the richest pottery in these two elements are again “Corded true”. In any case, the overlapping position with the other two groups rules out any correspondence with the composition.

Fig.8 has been plotted in order to observe any potential correlation due to the granite composition. Again, the “Corded true” have the highest and the lowest values of Sr, the “Corded imitation” range right to left of the diagram.

A particular graph is that shown in fig.9, concerning the relationship between CaO and CO_2 wt%. The bisect indicates the stoichiometric balance of the calcite ($CaCO_3$ atomic weight ratio $CaO/CO_2 = 0{,}784$). If we assume as negligible the CaO content due to the minerals of the granite, any excess of CO_2 represents the organic matter contribution. According to several authors, pottery at Neolithic times was used above all for the cooking (i.e. Pétrequin *et al*., 1994, Giligny, 1993).

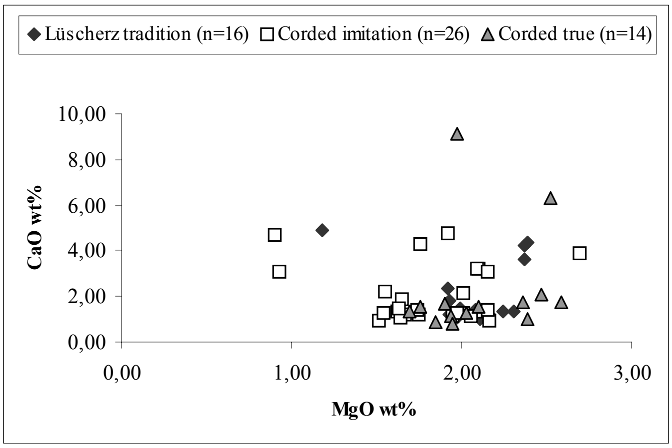


Figure 4. Correlation diagram CaO - MgO per ceramic type.

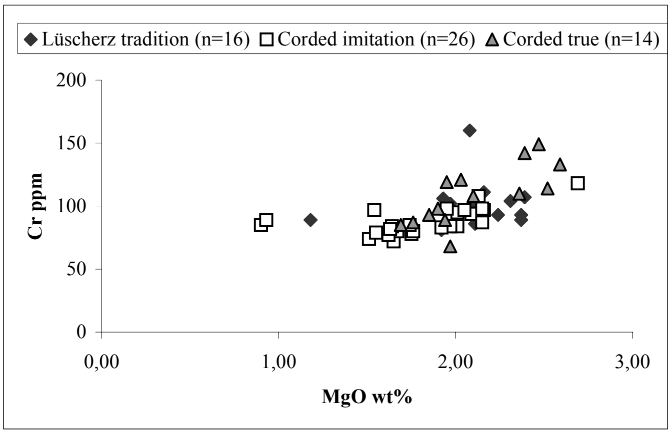


Figure 5. Correlation diagram Cr – MgO per ceramic type.

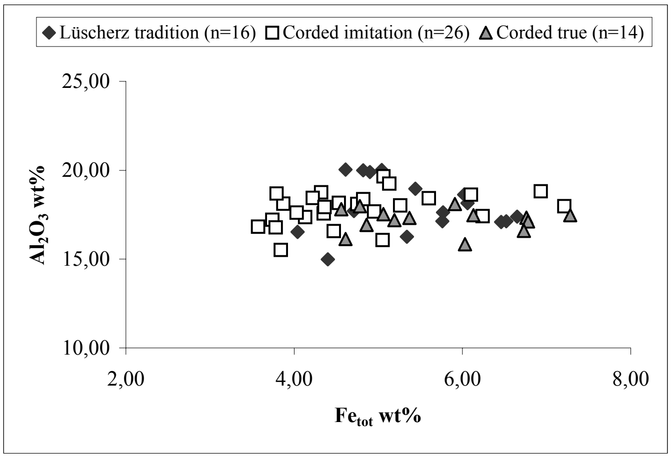


Figure 6. Correlation diagram Al_2O_3 – Fe_{tot} per ceramic type.

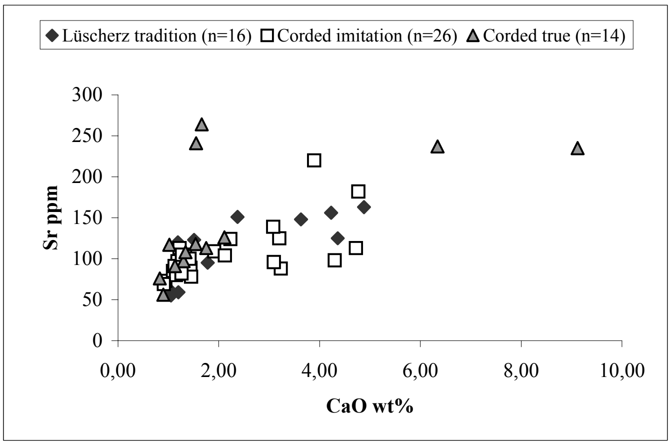


Figure 7. Correlation diagram CaO – Sr per ceramic type.

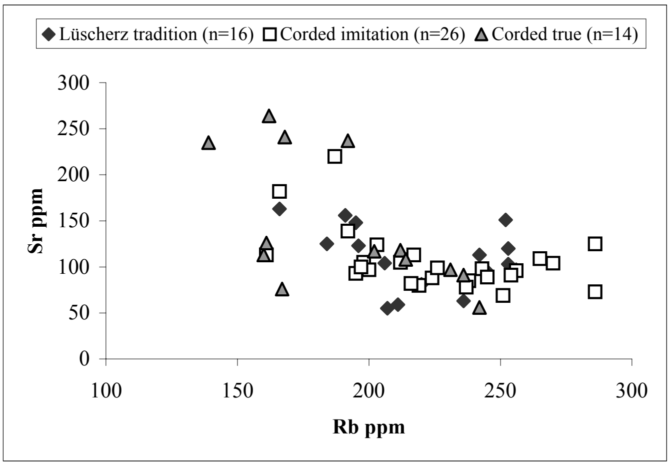


Figure 8. Correlation diagram Sr – Rb per ceramic type.

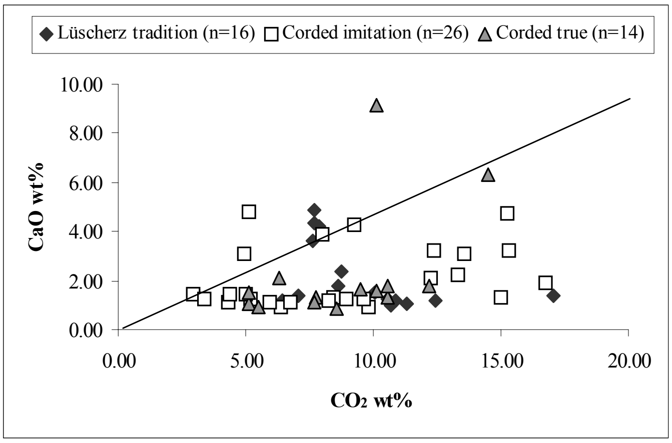


Figure 9. Diagram correlation between CaO and CO_2 per ceramic type.

This graphs confirms therefore the utilization of Portalban pottery for the food preparation. However, no remarkable difference exists between the three main typologies. Just a few pottery lie on or above the bisect, indicating perhaps uses and destinations other than cooking. But they belong again to the three type groups.

3.2 Correlations with the spatial distribution

We will now see if any correspondence between composition and localization of the pottery exists. The same graphs as above will be briefly discussed.

Figure 10 above correlates the two major oxides SiO_2 and CaO with reference to the spatial distribution of the pottery, as per fig.2. The three chosen areas of sampling are scattered throughout the graph and in evident overlapping position.

Figure 11, concerning iron oxide and alumina, does not show any relevant trend and variation in composition concerning the matrix used in the pottery preparation, relative to its localization.

Figure 12 confirms that the use of pottery for the cooking was a widespread activity throughout the village. The two building structures used for living by the inhabitants as well as the waster are composed of cooking pottery.

The scattering of the analyses and the lacking of any clear correlation between pottery composition and localization is a common feature of any other diagram concerning any other couple of analyzed elements.

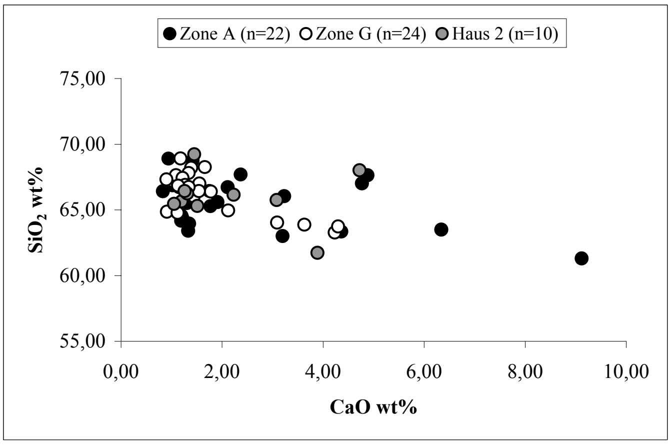


Figure 10. Diagram correlation between SiO_2 and CaO per ceramic localization.

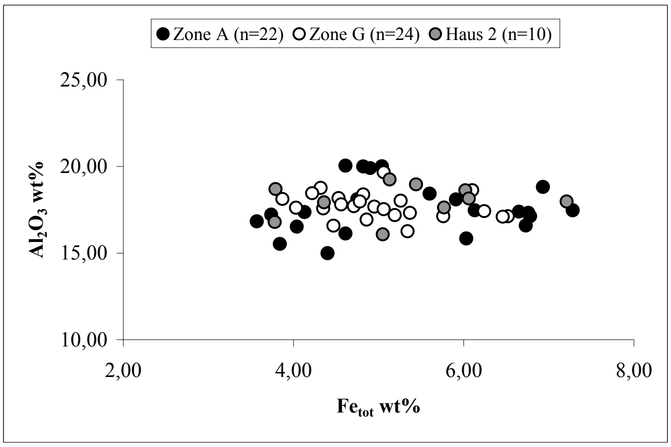


Figure 11. Diagram correlation between Fe and Al oxides per ceramic localization.

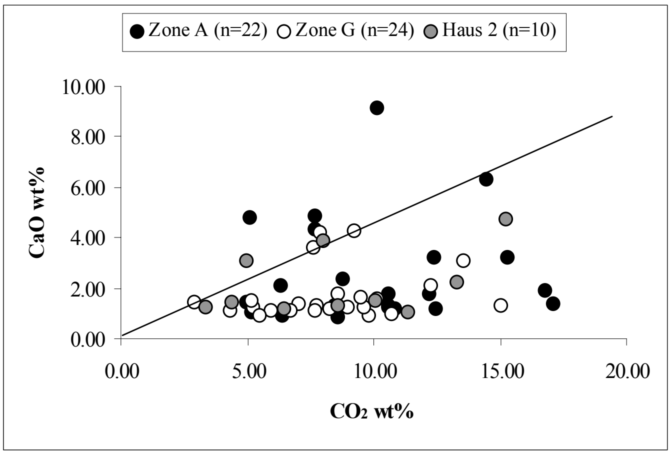


Figure 12. Diagram correlation between CaO and CO_2 per ceramic localization.

4. INTERPRETATION

The deep homogeneity of Portalban pottery composition has been here confirmed in terms of ceramic types and localization both. The utilization of unique sources, for the clay and the temper both, envisaged in Di Pierro (2002a-b) should be supported again.

The homogeneous scattering of the analyses plots implies a certain degree of variation in composition of the ceramic paste anyway. If the clay and temper sources are unique, the proportion between the two can vary of some units. For instance, the adding of the Mont Blanc granite ranges 10 to 30% in volume (Di Pierro, 2002a). Consequently the matrix contribution varies 90 to 70%. Even a source with a constant composition could affect the final composition of the pottery when the mixing proportions vary of such order of magnitude. However, we cannot rule out that a compositional range exists in the raw materials, even though these are coming from a unique outcrop, for clay and temper.

However, the fact that no correlation or clear correspondence exists between the pottery composition towards the different existing morphologies and its spatial distribution could have more than one interpretation.

1) Everyone in the village had access to the same sources, knew the same recipe for pottery preparation and produced for his/her own the ceramic.
2) One or more specialized potter had access to a specific (clay and temper) source and produced the ceramic for everyone in the village as a sort of regular activity.

The first hypothesis is more consistent with the model of a domestic production of ceramics proposed by Pétrequin *et al.* (1994) for the station II of Chalain, France. The same model is more consistent with the results concerning the study of the pottery from the St. Blaise settlement (Di Pierro *et al.*, 2002).

It is hard to evaluate the second hypothesis. The specialization in the pottery production has never been demonstrated for the Neolithic. Whether this could correspond to the presence of craftsmen and a consequent sort of trading inside the settlement does not correspond to any known ethnographic case study concerning nowadays-archaic societies.

It is our opinion that the chemical and petrographic characterization of pottery, even if coupled with morphologic and localization parameters is not exhaustive to clearly answer the question of the specialized production. For the Portalban settlement, the presence of specific sources for providing the necessary materials and the precise know-how in producing ceramics should be envisaged. This interpretation is in good agreement with the model proposed by Constantin & Courtois (1985) of the "material choice" corresponding to a "cultural behavior" and not to the case. But this could not be automatically interpreted and called a craftsmen specialization. A better understanding of this phenomenon could come for instance from the study of the different techniques used to produce ceramics (i.e. Martineau, 2000). The combined and multiple approach consisting in the characterization of the material, the detailed study of the morphologies and the different production techniques, as well as the exact localization of pottery, properly inserted in its own environment of production, use and dismissing, could perhaps be useful to answer the main question of the specialization.

REFERENCES

ARNOLD, D. E., NEFF, H. & GLASCOCK, M. D., 2000, *Testing assumptions of neutron activation analysis : communities, workshops and paste preparation in Yucatan, Mexico.* Archaeometry 42, 301 – 316.

BENGHEZAL, A., 1994, *Provenance et techniques de la céramique du Néolithique final de stations des trois lacs jurassiens Suisse.* Thèse de doctorat, Université de Fribourg, 174 pp.

COSTANTIN, C. & COURTOIS, L. C., 1985, *Le materiau céramique comme caractéristique culturelle. L'example du dégraissant pendant le Néolithique dans le bassin parisien.* IGAL. Etudes des céramiques en archéologie. Documents et travaux

DI PIERRO, S., 2002a, Ceramic production technology and provenance during Final Neolithic : the Portalban settlement, Neuchâtel Lake, Switzerland. Proceedings of the "4e Colloque d'Archéometrie", La Rochelle, France, 24 - 28 April 2001, *Revue d'Archéometrie*. In press.

DI PIERRO, S., 2002b, Matrix-temper separation of Neolithic ceramics ; an experimental approach to characterise the original raw materials. In: Proceedings of the 6th European Meeting on Ancient Ceramics EMAC '01, Ceramic in the Society, Fribourg, Switzerland, 3-6 October 2001. In press.

DI PIERRO, S., MICHEL, R. & MARTINEAU, R., 2002, *Matériau et types céramique à St. Blaise (Néolithique Suisse) Poterie exogène et production locale.* Proceedings of the XIVth Congress of the U.I.S.P.P.,Liège, Belgium, 2 – 8 September 2001. British Archaeological Report. In press.

GILIGNY, F., 1993, *La variabilité des récipients céramiques au Chalcolithique moyen-récent jurassien 3400-2400 av. J.C.. Analyse archéologique d'un système d'objets.* Thèse de Doctorat, Université de Paris I – Panthéon/Sorbonne UFR 03 – Histoire de l'Art et Archéologie, Vol.1, 273 pp.

GILIGNY, F. & MICHEL R., 1995, *L'évolution des céramiques de 2920 à 2440 av.J.-C. dans la région des trois lacs Suisse Occidentale.* Chronologies néolithiques. De 6000 à 2000 avant notre ère dans le Bassin rhodanien. Dans: Actes du Colloque d'Ambérieu-en-Bugey, 19-20 septembre 1992. Documents du Département d'Anthropologie de l'Université de Genève, n° 20. Ambérieu-en-Bugey, éd. Société Préhistorique Rhodanienne, 1995, p. 347-361.

MARTINEAU, R., 2000, *Poterie, techniques et sociétés. Etudes analytiques et expérimentales à Chalain et à Clairvaux (Jura), entre 3200 et 2900 av. J.-C.* Thèse de doctorat, Archéologie-préhistoire, Besançon, Université de Franche-Comté, UFR des Sciences de l'Homme, du Langage et de la Société, multigraphiée.

MICHEL, R., 2002, Saint-Blaise/Bains des Dames, 3. Typologie et chronologie de la céramique néolithique : céramostratigraphie d'un habitat lacustre. Neuchâtel, Service et Musée cantonal d'archéologie *Archéologieneuchâteloise*, 27; 2 vol.

PÉTREQUIN, P., PÉTREQUIN, A.M., GILIGNY, F. & RUBY, P., 1994, Produire pour soi, la céramique de Chalain 2 C au Néolithique final. *Bulletin de la Société Préhistorique française*, t. 91, n° 6, p. 407-417.

RAMSEYER, D., 1987, Delley-Portalban. Contribution à l'étude du Néolithique en Suisse occidentale. *Archéologie fribourgeoise* 3, Fribourg.

RAMSEYER, D., 1988, La céramique néolithique d'Auvernier/La Saunerie fouilles 1964 – 1965. Auvernier 7. *Cahiers d'Archéologie Romande* 45, Lausanne.

SCHWAB, H., 1982, *Portalban/Muntelier: zwei reine Horgener Siedlungen der Westschweiz.* Archäologisches Korrespondenzblatt, 12, Mainz, pp. 15-32

STÖCKLI, W.E., 1995, L'evolution du Néolithique Suisse. In « La Suisse du Paléolithique à l'aube du Moyen Age. De l'homme de Néanderthal à Charlemagne ». In *SPM II, Néolithique*. Veralg Scweizerische Gesellschaft für Ur- und Frügeschichte, Basel. 358 pp.

STURNY, C. & RAMSEYER, D., 1984, *Petrographische Analyse neolithischer Keramik aus Delley/Portalban II (Kt. Freiburg) und Charavines (Dpt.Isère, Frankreich).* Freiburger Archäologie, Fundbericht 1984, 92-95, Fribourg.

CHAPTER III

Matrix – temper separation of Neolithic ceramics: an experimental approach to characterize the original raw materials and determine their provenance[1]

Abstract

A separation technique has been implemented on a suite of 17 Neolithic ceramics, coming from Portalban, Switzerland. The separation carried out through an H_2O_2 attack concerned the basic components of pottery: the temper and the matrix. These latter have been characterized by XRF. The separation has been effective. The temper and the matrix chemical groups are homogeneous and sharply distinct; they reflect the composition of the original raw materials. The temper composition is consistent with the Mont Blanc granite. The systematic utilisation of this lithotype is in contrast with the negligible availability in the moraine deposits surrounding the Neolithic site; this allows the possibility of a targeted exploitation of a precise source, such as for instance some erratic boulders. The matrix composition is consistent with an Al_2O_3-rich and CaO less clay. This composition does not match the local available prospected clays, in a ray of 5 km. A material with the sought composition outcrops closed to the Cornaux village, 15 km north off Portalban. It is very likely that a similar material exist(s)ed at Portalban as well. It is either no more accessible or fully exploited. In terms of the raw material used, Portalban potter(s) owned a deep technological know-how. The choice of the materials can hide a cultural behavior.

Keywords – Pottery, Neolithic, Portalban, Temper, Matrix, Mont Blanc, Al_2O_3-rich clay, Materials know-how.

---

[1] *Proceedings of the 6th European Meeting on Ancient Ceramics (EMAC '01), Ceramic in the Society, Fribourg, Switzerland, 3-6 October 2001. In press.*

1. INTRODUCTION

Ancient ceramics studies are crucial to understand the evolution of Civilizations and cultural groups in the past. For instance, the characterization of pottery is a powerful tool to determine its provenance (e.g. Arnold *et al.*, 2000), while typological studies of ceramics allow establishing the technological transfer between populations (e.g. Giligny, 1994). Moreover, the spatial distribution of pottery inside a settlement permit to distinguish between different domestic productions (e.g. Pétrequin *et al.*, 1994), while the utilization of specific raw materials to manufacture ceramics is interpreted as a cultural behavior (e.g. Constantin & Courtois, 1985).

The final Neolithic in Switzerland has been and still is an excellent example where applied studies on archaeological materials permitted to establish precise chronological sequences (e.g. Vouga, 1929; Schwab, 1971). Moreover, such investigations allowed authors to either determine relationships between populations across time and space (e.g. Ramseyer, 1987; Giligny, 1993; Giligny & Michel, 1995), or to rule them out (e.g. Benghezal, 1994).

In the framework of a research project concerning two final Neolithic settlements of Portalban and St. Blaise, Western Switzerland, we have tested the potential relationships between materials and spatial distribution of the pottery, and we have explored for those sites the possibility that the pottery production were a craftsmanship activity (Di Pierro, 2002a). At St. Blaise we found a precise correlation between a group of pottery, with its clear chemical fingerprint, and a house of the settlement (Di Pierro *et al.*, 2002). This result strengthened the assumption of Pétrequin *et al.* (1994) that the pottery manufacturing was rather a domestic production at Neolithic times, in Switzerland as well as in France.

However, at Portalban the homogeneity of the studied pottery has been helpless to identify more than one petrographic or chemical group, and consequently any relationship with the spatial distribution (Di Pierro, 2002b). The petrographic and chemical constant composition of Portalban pottery can be due to: an homogeneity of the raw materials used or, different raw materials used in different proportions, resulting in an homogeneous mixture.

In the first case, the knowledge concerning the pottery production could be thought as shared at the scale of the settlement. One or more potters (craftsmen?) produced the pottery for the whole village. Alternatively, every potters of the village knew the same procedure and used the same sources for temper and matrix preparation.

In the second case, different potters of the settlement produced their own ceramic, using different raw materials and/or different techniques, as stated by Pétrequin *et al.*, (1994) or as partially found at St. Blaise (Di Pierro *et al.*, 2002). Alternatively, different raw materials could reflect different provenance of the pottery.

As an attempt to test the above hypothesis, in this paper we have raised the following questions:

1) is it possible to separate the matrix and the temper from a ceramic sherd without affecting their original compositions, in order to chemically characterize them separately?
2) when dealing with a homogeneous group of pottery, are the matrix and temper, once separated, useful to answer the question of the pottery provenance, and therefore determine its local production or its importation?

We have therefore implemented a separation technique through an H_2O_2 attack on a suite of 17 ceramic sherds of Portalban, with known bulk chemical compositions (Di Pierro, 2002b).

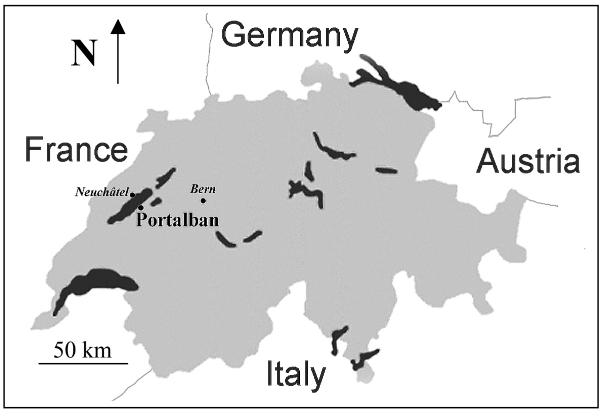


Figure 1. Map of Switzerland with the location of Portalban

2. ARCHAEOLOGICAL CONTEXT AND MAIN ISSUES

The Neolithic station of Delley/Portalban II lies on the Neuchâtel Lake banks, and is one of the most important settlements of the Western Swiss plateau, fig.1. The ceramic production at Portalban is known since the Cortaillod civilisation, 3500 BC. It has been characteristic throughout the whole Neolithic, and lasted until the Bronze Age, 2.000 BC (Ramseyer, 1987). The settlement has been the subject of several different archaeological (Schwab, 1982; Danerol *et al.*, 1990; Giligny, 1993; Giligny & Michel, 1995) and archaeometric (Sturny & Ramseyer, 1984; Benghezal, 1994; Picouet, 1997) publications. Some of the main archaeological and archaeometric topics concerning Portalban have been extensively discussed recently (Di Pierro, 2002b and references therein).

This latter study concerned the petrographic and chemical characterization of a suite of 47 pottery, 14 cobs and 7 loom weights, belonging to the Old Auvernier-Cordé occupation of the site (2700 - 2650 BC, calendar year, Giligny, 1993). The sampling has been carried out starting from three different building structures. These have been interpreted and identified as houses or huts (Ramseyer, 1987). Three different typological morphologies of the pottery are simultaneously present at the settlement and have been found within each of the three houses. They are the "Lüscherz tradition", the "Corded True" and the "Corded Imitation" ceramics (Giligny, 1993). Further details concerning the morphological differences and the archaeological origins and interpretations of those ceramics types can be found in Giligny (1993), Giligny & Michel (1995), Michel (2002), Di Pierro (2002a) and Di Pierro *et al*. (2002).

The aim of Di Pierro (2002a) was to identify any particular existing relationship between materials against (i) the spatial distribution of the pottery and (ii) the morphologies. Hence, we explored the hypothesis of a potential craftsmen activity for the ceramic production. In other words, we tried to sort out any chemical and/or petrographic group and we compared them to the houses of provenance or to the pottery morphology group they belonged. In the case of existing relationships between materials against houses and/or morphologies, the result could have been interpreted as a specialization in pottery production.

The study gave as main results: (i) on the petrographic basis, added a-plastic inclusions of metagranite rock fragments, temper, having always the same mineralogical composition and textural characteristics corresponding to those of the Mont Blanc granite, fig.2a; (ii) matrix of silicate composition and in average natural a-plastic inclusions (n.a.p.i.) very poor, fig.2a; (iii) a deep homogeneity of the chemical features of the pottery, consisting of a unique group.

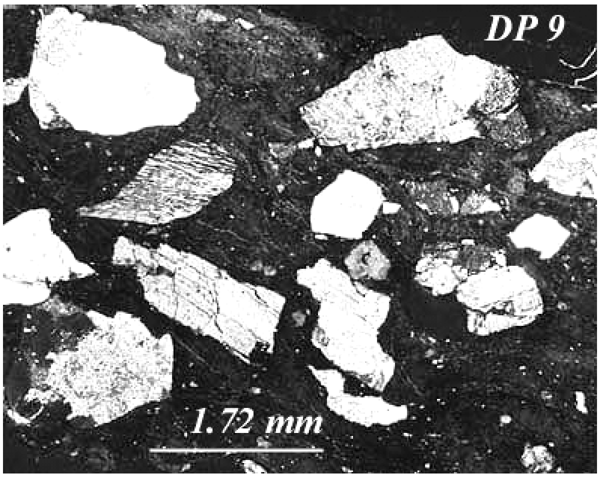


Figure 2a. Thin section photo of pottery sherd (DP 9). Coarse temper grains in a matrix with few n.a.p.i.

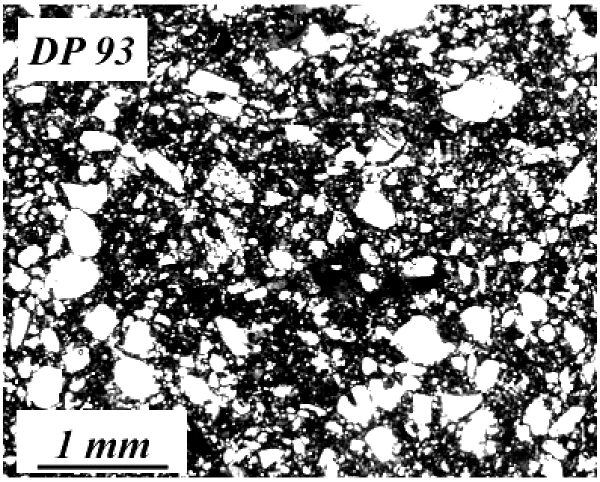


Figure 2b. Thin section photo of a local clay (DP 93). The texture shows n.a.p.i. rich silicate material

It has been therefore impossible to correlate any pottery to any house or any morphology. Moreover, the constant composition of rock and mineral fragments arose the hypothesis that Portalban potters used a unique source to temper their ceramics: an erratic boulder for example. In this case the "material choice" would correspond to a "cultural behaviour" as foreseen by Costantin & Courtois (1985). With regard to the matrix, the prospecting of clays in an area of 5 km^2 around the Neolithic settlement did not permit to find a material chemically and texturally similar to the pottery used one (Di Pierro, 2002b). The sampled silicate clays were in fact chemically and petrographically different, fig. 2b. Furthermore, given the strict correlation between local geology and sampled clay compositions, it was supposed that silicate clays in a ray of at least 5 km should have had the same composition (e.g. Frei *et al*., 1974). In contrast, the raw material used for the cobs and the loom weights preparation was identified as the calcareous clay outcropping at the settlement (Di Pierro, 2002b).

Consequently, the above results opened new questions. 1) Is the clay used for the Portalban pottery exogenous to the settlement? 2) Is the pottery production non-local? As an attempt to answer these questions we decided to chemically characterize the two single fractions of the pottery: the matrix and the temper.

Therefore, a matrix – temper separation technique has been implemented. Obtained results have been compared to data concerning potential raw materials, not only outcropping in proximity of the village but at the scale of the Western Swiss Plateau.

3. METHODS

3.1 The separation procedure

3.1.1 Previous attempts

Marro (1978) described and proposed several techniques to separate the main components of a ceramic. Firstly, he produced its own ceramics using industrial clay and quartz. He fired the obtained "bricks" at different temperatures in order to observe different behaviors. Secondly, he tried six different methods; 1) direct immersion into water, 2) gentle crushing, 3) vibration by ultrasonic, 4) immersion into desogene (methyl-phenyl-dodecyl-trimethyl-ammonium) 5) cooling down to ice formation and 6) heating with H_2O_2. Methods 3 and 6 were the most successful. The recovered material after the separation achieved percentages around 98-99 wt%. The author already stated that good results were a function of the bulk porosity, the coarseness and the firing temperature undergone by the sample. Nevertheless, the author concluded stating that the above methods were useless for a quantitative analysis concerning the temper, while they were useful for qualitative and quantitative analyses concerning the matrix.

Benghezal (1994) used the vibration by ultrasonic method proposed by Marro (1978), in order to separate the matrix from the coarse grained temper of four Portalban sherds. She analyzed chemically (XRF) only the obtained matrix and compared them to the corresponding bulk chemical data of the whole ceramics. She observed an enrichment of those elements expected to come from the matrix, such as Al, Ca, Ti, Fe, Mg, Mn, V, Ni and Zr, and a depletion of those elements expected to come from the granite temper grains, such as Si, K, Na and Rb.

Because of its effectiveness, the method proposed by Marro (1978) of using H_2O_2 has been selected. A diameter of 1 mm has been fixed in order to properly discriminate between added a-plastic inclusions, the temper, and the matrix portion of the sherd. In fact, in clay samples of Portalban the n.a.p.i. have a max length of 1 mm (Di Pierro, 2002b).

3.1.2 The samples

The separation technique described further on has been an attempt to implement a quite new technique. Therefore, the choosing of specimens presented some constraints. As already Marro (1978) had stated, the good result of the method is function of the porosity and of the coarseness of the sample to deal with. Therefore, pot-sherds with a visible porosity should be preferred. In order to try to standardize the procedure, specimens with an equivalent weight should be considered, fig.3A.

A suite of 17 ceramic sherds has been selected among the most representative from the Portalban pottery.

3.1.3 Step by step methodology

Fig.3 schematically summarize the different steps performed throughout the separation.

1) For each sample, a standard solution of H_2O_2 37% in volume (50 ml) + deionized H_2O (200 ml) has been prepared, tab.1. The pH of the solution has been verified with the quick test of the color-fixed indicator sticks (by Macherey-Nagel AG). The liquid solution had a pH value of 5 (± 0.5). Even weak acid washing could affect the composition of the treated samples. Carbonate species and mobile elements, such as Na, K and Al, are the most likely candidates (i.e. Mathez *et al.*, 1984). Therefore the solution has been buffered to neutral pH (7 ± 0.5) with the adding of 3 drops of NH_3 25% in volume. Some sample did not react completely. Hence, additional solution had to be prepared.

2) Every single sherd has been gently crushed in smaller pieces to increase the specific surface available for the H_2O_2 attack, fig.3B.

3) The crushed sherd has been immerged into the liquid solution.

4) To start up the reaction the liquid has been heated up to boiling T (around 120-130° C). Depending on the sample the heating could last 5 to 30 minutes. The heating produced a violent reaction, which had to be controlled and properly stopped, fig.3C. Normally, the adding of small quantities of deionized water has been necessary.

5) The result of the reaction was a mixed disaggregate made of coarse a-plastic plus fine-grained material, still immerged into the liquid.

6) The mixed disaggregate has been sieved (1 mm), fig. 3D1.

7) The finest fraction (Ø < 1mm) fully passed into the recovered liquid.

8) This latter has been filtered with a Schleicher & Schuell AG paper filter Nr.602, in order to separate the solid from the liquid medium, fig. 3D2. The obtained concentrate, the matrix of the sherd corresponding to the former clay, has been dried at 60-70° C for approximately 3 hours[2]. For the solute, cfr. para. 3.1.4

9) The coarser fraction (Ø > 1 mm) of point 6), has been washed with deionized water and dried at ambient T.

10) Two main types of coarse particles (Ø > 1 mm) have been recovered: (i) the whitish angular rock and mineral grains and (ii) what has been called the middling, a mixed composite made of fired clay minerals and very fine grained rock or quartz grains, which did not disaggregate enough during the H_2O_2 attack.

11) Further handpicking under the binocular microscope has been necessary to separate (i) from (ii) of 10), fig.3E1.

12) Each sherd has been recovered as far as its three main components are concerned; (i) the rock and mineral coarse fragments, (ii) the matrix powder and (iii) the middling.

3.1.4 Reliability of the separation technique.

Despite a neutral pH, dealing with the previous described violent reaction, mainly due to the presence of free oxygen in the solution, could affect the composition of the final fractions of the separation anyway. This can occur, for instance, in terms of loss of very fine-grained minerals, which could easily disaggregate along main cracks of rock-fragments rims.

It has been therefore decided to verify the reliability of the H_2O_2 attack procedure, by way of four different independent controls.

1) K ions concentration has been checked for every solute with a Potassium quick-test (colored-fixed indicator sticks - Merk AG). The test detects ions concentrations from 0 up to 1.000 mg/l (4 ranges of 250 mg/l each). K concentrations have been detected at the minimum range, 0 – 250 mg/l, throughout the whole samples suite. Therefore, any important K leaching did not occurred.

2) The solute of analysis DP 14, which has not been diluted with deionized water to stop the H_2O_2 attack, has been selected for a complete bulk chemical analysis, concerning anions and cations. The Chemistry Cantonal Laboratory of Fribourg has performed the analysis. Contents have been determined with a ionic High Pressure Liquid Chromatography probe.

This test too has not given rise to any important loss of ion species, as can be seen in the results given in tab.2.

3) A powder sample (50 g) of metagranitoide DP 86 sampled at Portalban has been analyzed by XRF after having been attacked with 250 ml of the solution described at. 3.1.3 (1).

---

[2] Empirically, as per the acquired experience.

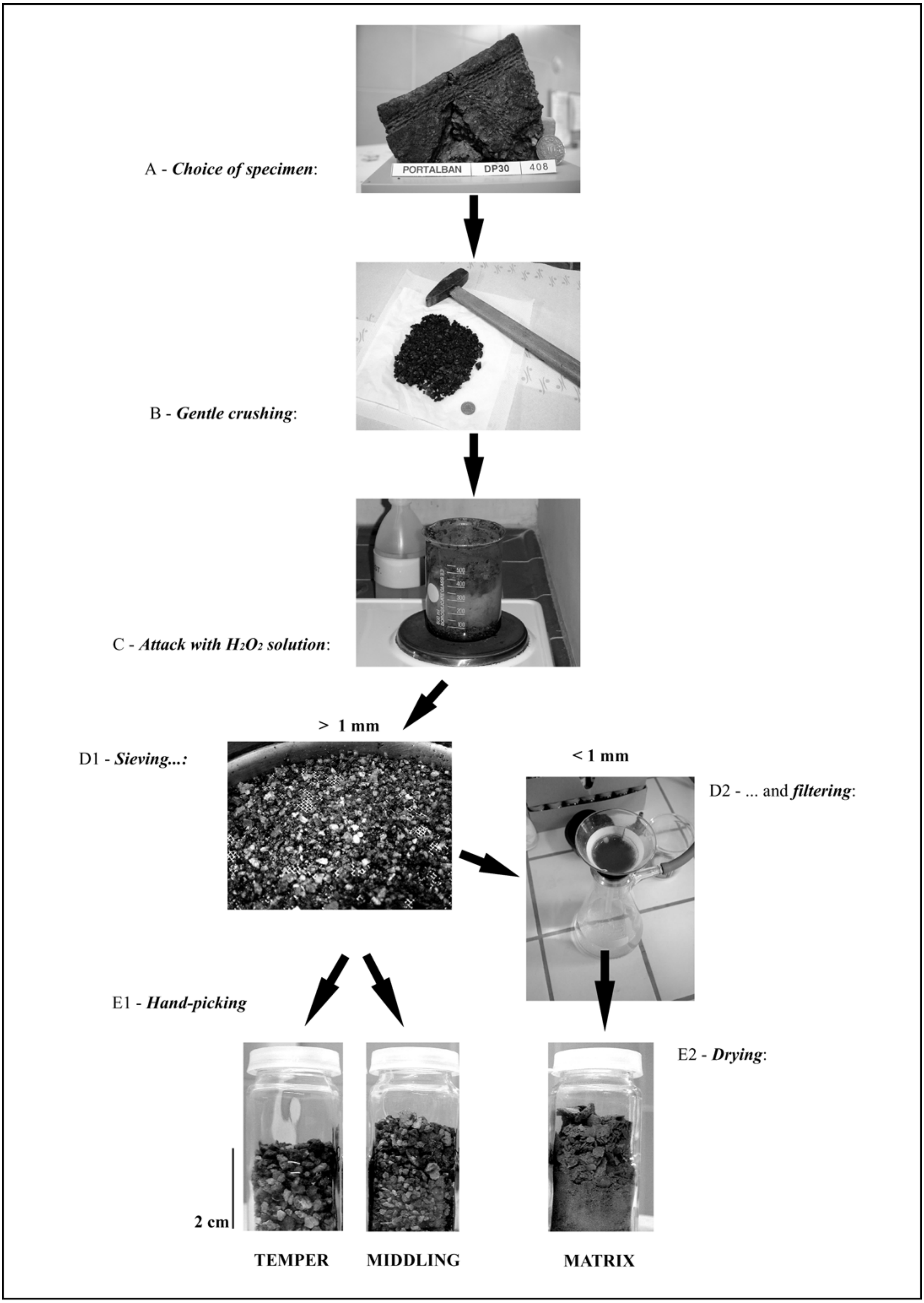


Figure 3. Schematic flow chart showing the step by step separation procedure. From A to E, it takes six to eight hours of work.

Sample n°.	**initial wt.**	**H_2O_2 37 vol%**	**H_2O** deion.°	**heating**	**temper**		**matrix**		**middling**		**final wt.**	
	gr	**ml**	**ml**	**min**	**gr**	***wt%***	**gr**	***wt%***	**gr**	***wt%***	**gr**	***lost wt%***
DP 7	48.92	50	200	15	6.64	*14.35*	3.93	*8.49*	35.70	*77.16*	46.27	*5.42*
DP 8	14.02	50	200	5	5.55	*42.20*	5.20	*39.50*	2.41	*18.30*	13.15	*6.20*
DP 9	22.54	50	200	5	9.11	*43.83*	7.74	*37.25*	3.93	*18.92*	20.79	*7.76*
DP 14	17.41	50	200	6	3.78	*22.07*	1.99	*11.63*	11.34	*66.30*	17.11	*1.74*
DP 15	9.17	40	150	4	2.85	*33.63*	4.37	*51.62*	1.25	*14.75*	8.46	*7.75*
DP 20	23.01	50	200	5	4.58	*20.45*	1.04	*4.64*	16.77	*74.92*	22.39	*2.71*
DP 24	28.98	50	200	5	9.39	*34.02*	8.41	*30.46*	9.80	*35.52*	27.60	*4.76*
DP 27	26.64	125	300	33	5.68	*21.85*	2.96	*11.38*	17.35	*66.77*	25.99	*2.44*
DP 28	36.75	50	200	15	7.99	*22.06*	1.59	*4.39*	26.64	*73.55*	36.22	*1.44*
DP 29	55.90	50	200	25	13.95	*25.40*	3.28	*5.97*	37.70	*68.63*	54.93	*1.74*
DP 30	89.85	50	200	10	21.05	*23.84*	13.89	*15.73*	53.37	*60.43*	88.31	*1.71*
DP 31	36.77	50	200	20	7.73	*21.98*	11.27	*32.04*	16.17	*45.98*	35.17	*4.35*
DP 32	43.48	50	200	20	6.75	*15.95*	12.46	*29.44*	23.11	*54.61*	42.32	*2.67*
DP 33	20.25	95	300	18	5.44	*28.88*	7.25	*38.52*	6.14	*32.60*	18.83	*7.00*
DP 43	70.79	50	200	20	8.29	*12.29*	14.54	*21.56*	44.60	*66.14*	67.43	*4.75*
DP 49	48.70	50	200	30	8.25	*17.34*	4.50	*9.46*	34.82	*73.20*	47.57	*2.32*
DP 51	17.14	50	200	25	1.90	*11.54*	0.53	*3.22*	14.03	*85.24*	16.46	*3.97*
Mean	35.90				7.58	*24.22*	6.17	*20.90*	20.89	*54.88*	34.65	*4.04*

° To all liquid solutions, **3 drops of NH_3 25%** in volume have been added in order to obtain a **pH 7 (± 0.5)**

Table 1 - List of treated samples, composition and timing of hot solution, weight and percentage of recovered material, per fraction.

Chloride	13	mg Cl^- / l
Nitrite	< 0.05	mg NO^{2-} / l
Nitrate	26	mg NO^{3-} / l
Sulphate	*	mg $SO_4{}^{2-}$ / l
Sodium	12	mg Na^+ / l
Ammonium	10	mg $NH_4{}^+$ / l
Magnesium	4	mg Mg^{2+} / l
Calcium	45	mg Ca^{2+} / l
Potassium	< 10	mg K^+ / l
Conductivity	373	µS / cm (20°

Tab. 2 – Chemical results of solute DP 14.

Tab.3 compares the results of the sample before and after treatment. Major oxides such as TiO_2, MnO, MgO, Na_2O and P_2O_5 as well as trace elements such as Ba, Cr, Nb, Ni, Rb, Sr, V and Y do not present significant variations between the untreated and the treated sample. However, other major oxides (concentrations above 2 wt% at least) but even some trace elements present more significant variations. For instance the Al_2O_3 content decreased of 0.31 wt% (-1.77% of the initial value); the Fe_{tot} loss is of 0.11 wt% (-1.97%) while the CaO decreased of 0,11 wt% (-2.26%)[3]. The Zn depletion is of 68 ppm (-46.90%) while the Zr loss is of 21 ppm (-13.91%). Instead, the SiO_2 content increased of 1.52 wt% (2.42% of the initial value). Cu and Pb increased proportionally of even higher values.

Despite some important elements (i.e. Na, Ba, Rb and Sr) have not been affected by the attack, others (i.e. Si, Al, and Zn) seem to have been influenced by the separation technique. It is not easy to evaluate how these variations could be due by other factors such as the sampling error and the reproducibility limit of the XRF analyses between the two runs of the treatment (without and after the attack). Therefore, if we assume that the loss of material listed on column (c) of tab.3 is entirely due to the separation technique, we can conclude that those data are the maximum expected errors, per each single oxide/element.

Oxides (wt%) Elements (ppm)	**DP 86** before (a)	after (b)	**difference** absolute (c) = (a)-(b)	% (d) = (c)/(a)
SiO_2	62.91	64.43	1.52	2.42
TiO_2	0.63	0.61	-0.02	-3.17
Al_2O_3	17.48	17.17	-0.31	-1.77
Fe_{tot}*	5.58	5.47	-0.11	-1.97
MnO	0.10	0.10	0.00	0.00
MgO	1.84	1.80	-0.04	-2.17
CaO	4.86	4.75	-0.11	-2.26
Na_2O	4.01	3.99	-0.02	-0.50
K_2O	2.29	2.18	-0.11	-4.80
P_2O_5	0.16	0.15	-0.01	-6.25
Ba	567	538	-29	-5.11
Cr	14	15	1	7.14
Cu	2	11	9	450.00
Nb	9	9	0	0.00
Ni	8	7	-1	-12.50
Pb	7	36	29	414.29
Rb	82	78	-4	-4.88
Sr	263	265	2	0.76
V	92	87	-5	-5.43
Y	23	22	-1	-4.35
Zn	145	77	-68	-46.90
Zr	172	151	-21	-12.21
SUM wt%	99.99	100.66		

Table 3 - Major and trace elements variations before (Di Pierro, 2002b) and after the H2O2 37vol% attack (this study) on the metagranitoide DP 86. *as Fe2O3.

(4) Separated grains of temper (two analyses: DP 29te & DP 30te) and of middling (two analyses: DP 29mi & DP49mi) have been embedded into glue (9/10 Araldite D as the glue – 1/10 Haerter HY951 as the hardener). Four standard thin sections (30 µm thick) have been prepared for mineralogical and petrographic observations of separated components (polarized light microscope - Leitz Laborlux 11 Pol). Petrographic analyses aimed to the observation of any potential changes in the mineralogical composition of separates. In particular, minerals such as epidote, clinozoisite, titanite, chlorite and stilpnomelane were determined during the bulk characterization (Di Pierro, 2002b). It has been checked if they were still present after the H_2O_2 attack. Optical observations have confirmed that the whole paragenesis has been preserved.

3.2 Processing of clay

The non-correspondence between the locally available silicate clays and the matrix of the pottery (cfr. para. 2) opened different hypothesis. (i) An exogenous provenance of the clay or (ii) the washing of the local clays either by the potters or trough a natural process.

In order to test the second hypothesis, clay sample DP 93 of fig.2b, composed of silicate matrix, illite and chlorite, and quartz as n.a.p.i. (Di Pierro, 2002b), has been processed. The main objective was to reduce the quantity of n.a.p.i. The clay has been immerged into water and shaken for 30 min. A further decantation step lasted 24 hrs. The uppermost layer only, supposed to be the most influenced fraction of the treatment, 1 cm thick, has been finally recovered.

3.3 Chemical analyses

X-ray fluorescence (XRF) analyses, concerning nine major elements plus the Fe_{tot}, as Fe_2O_3, expressed in weight percent, as well as eleven trace elements, expressed in weight ppm, have been performed with the X-ray spectrometer (Philips PW 2400). The preparation procedure of pill samples is given in Zanco (1998).

---

[3] The K_2O loss is of 0,11 wt% (-4,80%). To correctly compare this result with previous controls we have to deal with the following data: 0,11 wt% of 50 g of starting material corresponds to 550 mg of K_2O. The weight conversion factor between K_2O and K is 0,8302. This gives a corresponding amount of 456 mg of K. The solution used was 250 ml. These data give a final concentration of 114 mg/l of K, in the range of the K quick-test of control 1).

4. RESULTS

4.1 Overall view

Tab.1 summarizes the data concerning the 17 samples selected for the experimental treatment. Initial and final weights of the components (in grams and percentage), the exact quantities of H_2O_2 used and the timing of reactions are shown. The mean value of recovered material approaches the 96 wt%. This is a quite good result taking into account the loss of material during the sieving, the handpicking and the filtering of the finest fraction. The ranges of values in grams of the temper, the matrix and the middling are quite different and therefore unpredictable. The middling (fired clay minerals for most) is function likely of the firing conditions of ceramics (the temperature and duration); its either high or low quantity, reflects therefore those parameters. The timing and volume of solution used are a direct function of the bulk visible porosity of the sherd. In same cases, i.e. DP 14 and DP 51, the quantity of recovered material, for the temper and the matrix, is very low. This could affect the representativeness of the chemical analyses, table 4a-b.

Of course, the quantity of 5 kg per sample, considered the minimum for a representative chemical analysis for a granite, could not be respected.

4.2 Chemistry

Fig.4 shows the chemical relationships concerning major elements oxides, Fe_{tot} versus Na_2O and SiO_2 versus Al_2O_3 respectively, with regard to the temper and the matrix analyses. Bulk analyses of the pottery have been included too. Within the potential marginal error discussed at 3.1.4 (3), listed in tab.3, the separation technique has been effective. In fact, the temper and the matrix clearly constitute sharp different homogeneous chemical groups. Fe_{tot} content ranges 5.31 to 9.44 wt% for the matrix, and 0.77 to 1.85 wt% for the temper. Na_2O ranges 0.60 to 1.47 wt% for the matrix, and 3.28 to 4.63 wt% for the temper. SiO_2 varies 71.42 to 77.28 wt% in the temper group, while varies 56.60 to 66.38 wt% in the matrix one; Al_2O_3 ranges 12.45 to 16.05 wt% for the temper, while is 18.30 to 22.51 wt% for the matrix. In addition, temper and matrix are the two distinct poles of the pottery bulk group, being in linear correlation with this latter, for both graphs. Moreover. there is a certain degree of overlapping between the pottery and the matrix group. This was expected because temper grains do not constitute more than 20-25% in volume of the whole ceramic samples (Di Pierro, 2002b). Consequently, being matrix around 75-80% in volume of pottery, chemical consistency reflects the above percentages.

As far as the middling analyses are concerned, fig.5 shows the chemical relationships of major elements oxides, compared again to the pottery bulk data. SiO_2 versus CaO as well as Al_2O_3 against Fe_{tot} wt% graphs, clearly show a large degree of overlapping between the middling and the pottery areas.

4.2.1 The temper

The temper grains are composed of a alkali-granite, see tab.5 and fig.6. The lithotype is high in SiO_2 and in $Na_2O + K_2O$ ($\sum$=8.77 wt%) too, Fe_{tot} + MgO ($\sum$=1.32 wt%) are low to very low, CaO content is low too, TiO_2 is fairly negligible. Standard deviations *s* of the tempers are in general non significant when one considers the low quantity of available material, see tab.1. Notwithstanding, *s* of major oxides such as SiO_2, Al_2O_3, Na_2O and K_2O are below 10% and in the same range of the corresponding values of pottery, tab.5. These data are the most significant because their XRF average analyses are > 4 wt%; in particular for SiO_2 with x=74.71 wt% and *s*=2.20% only.

4.2.2 The matrix

Composition data, which had been predicted with calculations based on bulk XRF pottery analyses (Di Pierro, 2002b), have been here confirmed by the separation method, tab.5. In fact, the matrix is composed of 20.12 wt% Al_2O_3 and of 61.27 wt% SiO_2; strong enrichment in Fe_{tot} and MgO; Al_2O_3 and CaO are enriched too, K_2O remained fairly constant, SiO_2 is depleted while Na_2O resulted strongly depleted. Although Rb and Sr remained almost constant, in general trace elements are enriched to strongly enriched in the matrix, in particular as far as Cr and V are concerned. Standard deviations of the matrix are relatively higher if compared to the temper ones. But they are in the same range of the *s*% of the pottery.

	SiO_2	TiO_2	Al_2O_3	Fe_{tot}	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	Ba	Cr	Cu	Nb	Ni	Pb	Rb	Sr	V	Y	Zn	Zr	SUM
DP 7te	75.03	0.07	14.24	1.20	0.04	0.24	0.58	3.89	5.03	0.04	208	20	94	17	14	16	419	43	11	44	24	98	100.47
DP 8te	76.95	0.05	13.13	0.70	0.02	0.17	0.41	3.80	4.87	0.02	225	7	<2	<5	4	7	320	50	8	26	8	51	100.12
DP 9te	74.22	0.04	14.87	0.79	0.02	0.22	0.74	4.30	5.09	0.02	425	6	<2	<5	<3	9	278	120	10	18	3	45	100.31
DP 14te	72.05	0.21	14.98	1.80	0.05	0.55	1.27	3.83	4.40	0.10	557	13	<2	8	7	25	176	133	22	31	29	115	99.24
DP 15te	74.34	0.04	14.40	0.64	0.02	0.10	0.79	4.28	5.09	0.02	358	8	<2	10	5	10	261	73	5	19	<2	57	99.72
DP 20te	77.28	0.09	12.45	1.01	0.02	0.24	0.51	3.28	5.01	0.04	398	11	<2	9	5	15	262	53	11	33	8	83	99.93
DP 24te	76.51	0.04	13.18	0.67	0.04	0.15	0.93	3.87	4.27	0.03	513	5	<2	<5	<3	10	161	109	8	14	<2	53	99.68
DP 27te	72.61	0.11	15.20	1.12	0.02	0.24	1.18	4.43	4.76	0.05	628	8	<2	8	3	12	205	147	13	17	10	91	99.73
DP 28te	74.01	0.07	14.85	1.21	0.02	0.28	0.86	4.09	4.68	0.04	410	21	<2	8	12	10	261	103	12	29	10	72	100.21
DP 29te	73.40	0.18	14.63	1.85	0.03	0.53	0.68	3.52	4.97	0.08	439	28	<2	13	16	10	320	96	16	43	19	144	99.98
DP 30te	75.15	0.04	14.27	0.86	0.02	0.22	1.02	4.07	4.34	0.02	408	20	<2	<5	12	<7	246	111	14	20	14	55	100.09
DP 31te	74.83	0.06	14.13	0.76	0.02	0.20	0.57	3.99	4.94	0.03	675	5	<2	5	3	13	175	109	8	16	8	63	99.53
DP 32te	76.04	0.07	13.73	1.02	0.03	0.16	0.78	4.07	4.33	0.04	368	19	<2	6	10	10	251	83	8	24	12	86	100.36
DP 33te	75.72	0.06	13.35	0.76	0.02	0.22	0.21	3.31	6.05	0.02	349	<5	<2	<5	4	11	319	47	5	17	4	50	99.73
DP 43te	76.39	0.06	13.48	0.92	0.02	0.24	0.43	3.54	4.97	0.02	170	25	<2	7	16	9	203	15	18	21	8	72	100.12
DP 49te	74.13	0.07	14.58	1.33	0.03	0.23	0.38	4.20	4.87	0.04	227	18	<2	13	13	16	340	37	11	42	9	118	99.94
DP 51te	71.42	0.10	16.05	1.57	0.03	0.23	1.30	4.63	4.26	0.05	424	19	<2	7	14	11	277	140	12	31	8	142	99.75
DP 7mi	61.03	0.71	19.30	6.43	0.09	2.44	3.75	1.32	4.08	0.32	889	124	28	19	78	32	249	137	112	45	120	141	99.66
DP 8mi	64.31	0.81	19.73	5.72	0.03	2.52	0.75	1.33	4.31	0.37	873	125	18	16	78	27	226	81	122	62	116	167	99.88
DP 9 mi	60.84	0.58	20.28	5.95	0.04	2.38	3.17	1.73	4.65	0.15	738	109	26	14	63	19	252	98	111	29	82	118	99.77
DP 14mi	61.38	0.86	20.12	7.59	0.08	2.73	1.16	1.30	4.21	0.49	922	137	26	17	84	36	197	106	140	40	140	162	99.92
DP 15mi	62.68	0.66	18.33	5.22	0.03	2.54	5.34	1.34	4.03	0.13	588	106	39	14	59	20	204	92	119	27	102	138	100.31
DP 20mi	63.69	0.68	18.70	5.76	0.09	2.29	2.24	1.92	4.22	0.30	753	102	27	20	65	34	227	103	108	47	114	143	99.89
DP 24mi	66.34	0.59	17.92	5.04	0.05	2.10	1.14	1.88	4.46	0.32	730	94	22	14	57	24	204	92	94	26	98	138	99.85
DP 27mi	65.66	0.69	18.70	4.71	0.04	2.11	1.19	2.12	4.40	0.19	693	94	23	20	60	24	211	113	101	37	109	183	99.81
DP 28mi	60.32	0.51	19.25	5.52	0.03	2.19	5.98	1.36	4.37	0.13	730	114	33	17	66	24	237	102	117	28	135	110	99.82
DP 29mi	62.47	0.63	20.65	4.99	0.05	2.44	2.15	1.22	4.96	0.29	950	128	20	14	67	19	257	104	132	32	138	135	100.04
DP 30mi	61.63	0.51	19.66	5.62	0.03	2.30	3.53	1.59	4.49	0.11	669	111	34	9	62	21	242	95	118	24	175	102	99.64
DP 31mi	63.98	0.62	18.71	6.52	0.06	2.05	1.28	2.40	3.91	0.18	714	93	18	17	67	31	202	106	101	33	111	133	99.70
DP 32mi	65.58	0.70	18.73	5.94	0.05	2.35	0.84	1.33	4.00	0.19	697	124	45	16	84	24	208	73	126	27	118	163	99.87
DP 33mi	62.41	0.82	19.95	7.39	0.10	2.63	0.79	1.37	4.12	0.17	786	119	33	20	76	33	223	73	133	29	130	144	99.75
DP 43mi	65.93	0.60	18.98	5.45	0.09	1.92	0.97	1.78	4.07	0.07	590	121	50	14	66	25	201	53	113	28	96	131	100.03
DP 49mi	65.05	0.75	18.40	5.56	0.10	2.50	1.88	1.46	3.74	0.18	755	123	25	15	78	24	199	96	115	31	109	154	99.63
DP 51mi	63.60	0.85	20.69	5.73	0.06	1.07	3.53	0.72	3.11	0.27	1029	125	16	22	75	28	171	137	149	33	97	202	99.84

Table 4a - XRF analyses of separated fractions (te=temper, mi=middling). Oxides in wt%, trace elements in ppm. Fe_{tot} as Fe_2O_3

	SiO_2	TiO_2	Al_2O_3	Fe_{tot}	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	Ba	Cr	Cu	Nb	Ni	Pb	Rb	Sr	V	Y	Zn	Zr	SUM
DP 7ma	57.05	0.90	20.89	7.80	0.09	2.71	4.77	0.87	4.16	0.61	954	149	520	25	103	92	236	144	135	49	459	177	100.15
DP 8ma	63.92	0.87	19.40	6.47	0.05	2.53	1.06	1.21	4.18	0.26	776	118	40	31	85	33	259	69	117	59	532	245	99.96
DP 9ma	58.73	0.85	22.00	7.47	0.06	3.17	2.02	0.85	4.71	0.24	874	133	40	25	94	27	261	79	153	41	150	279	100.10
DP 14ma	61.42	0.87	18.82	7.62	0.07	2.54	2.16	1.33	4.16	0.92	918	121	37	20	86	38	196	113	118	49	194	185	99.91
DP 15ma	62.17	0.86	20.28	6.16	0.04	3.02	2.02	1.02	4.29	0.19	764	125	55	19	78	23	218	75	134	33	195	165	100.04
DP 20ma	64.00	0.77	18.81	6.27	0.08	2.44	1.76	1.47	4.09	0.39	733	110	49	19	91	43	232	84	111	39	240	159	100.07
DP 24ma	65.01	0.77	18.30	6.23	0.06	2.42	1.40	1.36	4.30	0.31	719	106	31	25	76	30	228	87	118	54	128	227	100.17
DP 27ma	65.12	0.89	17.83	6.92	0.07	2.39	1.62	1.11	3.76	0.34	660	122	181	26	78	55	208	88	115	45	304	352	100.26
DP 28ma	57.96	0.81	20.43	7.94	0.07	2.82	4.34	0.98	3.91	0.21	819	126	122	39	78	36	220	101	146	71	177	286	99.69
DP 29ma	58.89	0.75	20.95	6.08	0.05	2.54	3.96	0.76	4.79	0.52	974	137	60	20	72	47	258	108	142	39	154	147	99.52
DP 30ma	56.60	0.90	21.82	8.34	0.07	3.31	3.02	0.60	4.51	0.26	787	142	95	30	85	42	280	86	155	58	144	222	99.65
DP 31ma	58.61	0.93	21.37	9.44	0.08	3.25	1.37	0.79	3.62	0.19	802	154	47	22	110	51	221	74	153	41	191	179	99.86
DP 32ma	63.25	0.84	19.49	7.30	0.06	2.67	1.11	0.87	3.79	0.20	718	138	38	20	93	37	213	69	130	36	183	211	99.76
DP 33ma	58.69	0.95	21.50	9.06	0.11	3.09	1.40	0.89	3.95	0.25	840	146	58	20	100	34	214	76	153	31	180	156	99.90
DP 43ma	59.62	0.92	22.51	7.82	0.09	2.93	1.20	0.61	3.73	0.08	735	158	98	22	95	32	224	64	167	31	140	178	99.70
DP 49ma	64.11	0.77	18.77	6.68	0.11	2.29	2.65	1.03	3.26	0.30	782	126	121	23	119	31	191	96	113	39	391	160	100.18
DP 51ma	66.38	0.79	18.94	5.31	0.06	0.99	2.82	0.98	3.12	0.27	876	110	58	26	67	31	176	125	122	39	164	230	99.86
DP 7	63.01	0.63	18.43	5.60	0.08	2.10	3.20	2.03	4.36	0.33	781	94	30	28	61	34	286	125	103	50	108	144	99.94
DP 8	68.90	0.50	17.22	3.74	0.03	1.51	0.94	2.40	4.78	0.15	576	74	24	15	47	27	286	73	81	34	77	146	100.32
DP 9	65.59	0.42	18.11	4.75	0.04	1.65	1.91	2.53	4.83	0.12	669	72	24	15	43	22	265	109	80	26	83	113	100.10
DP 14	63.41	0.70	18.82	6.93	0.05	2.13	1.33	1.82	4.21	0.30	881	108	31	18	68	36	198	105	107	33	113	145	99.88
DP 15	66.05	0.55	17.37	4.13	0.03	2.09	3.23	1.94	4.27	0.09	585	94	40	17	48	28	224	88	98	28	124	135	99.91
DP 20	66.39	0.56	17.71	4.71	0.07	1.93	1.78	2.22	4.48	0.18	595	85	22	16	56	37	245	95	91	42	105	155	100.19
DP 24	68.92	0.50	16.58	4.47	0.05	1.67	1.18	2.08	4.29	0.19	687	80	35	16	45	25	200	97	85	31	78	139	100.07
DP 27	67.43	0.60	17.58	4.35	0.05	1.75	1.22	2.43	4.56	0.13	666	78	33	19	47	28	217	113	82	34	85	196	100.27
DP 28	63.74	0.46	18.17	4.53	0.03	1.76	4.30	2.19	4.51	0.11	647	80	231	15	48	27	243	98	92	30	152	112	99.97
DP 29	64.95	0.54	18.76	4.32	0.05	2.01	2.12	1.88	4.92	0.26	783	95	29	15	49	19	270	104	109	34	75	152	99.98
DP 30	64.04	0.51	18.38	4.82	0.04	2.15	3.09	2.01	4.67	0.10	597	87	67	14	47	28	256	96	102	32	77	121	99.96
DP 31	66.69	0.58	17.42	6.24	0.06	2.01	1.28	2.05	3.93	0.13	687	84	34	18	66	37	195	93	104	33	113	138	100.56
DP 32	66.74	0.66	18.02	5.26	0.06	2.05	1.15	1.81	4.18	0.17	687	97	39	20	65	32	219	80	105	41	121	177	100.27
DP 33	64.86	0.66	18.63	6.10	0.09	2.16	0.91	1.76	4.54	0.13	678	97	37	17	63	30	251	69	115	28	106	135	99.99
DP 43	65.65	0.63	18.96	5.44	0.08	1.93	1.20	1.89	4.24	0.08	564	106	52	19	58	30	211	59	115	28	90	135	100.24
DP 49	69.23	0.51	16.79	3.78	0.07	1.63	1.45	2.43	4.09	0.13	571	82	23	14	55	26	237	78	75	36	89	125	100.23
DP 51	65.75	0.75	19.25	5.13	0.06	0.93	3.08	1.42	3.42	0.27	924	89	12	22	59	31	192	139	128	37	78	191	100.26

Table 4b - XRF analyses of separated fractions (ma=matrix) and of pottery bulk compositions (Di Pierro, 2002b). Oxides in wt%, trace elements in ppm. Fe_{tot} as Fe_2O_3

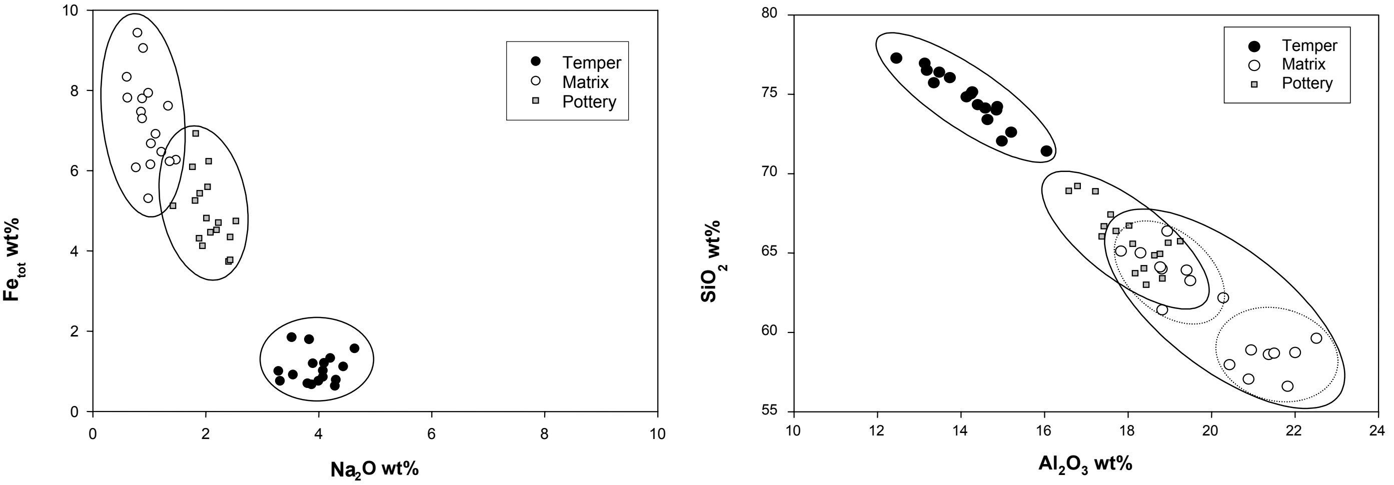


Figure 4. Binary graphs related to major elements, XRF results (Fe$_{tot}$ as Fe_2O_3). Chemical data of separated temper and matrix are clearly distinguishable as separate groups. Pottery bulk data are presented too.

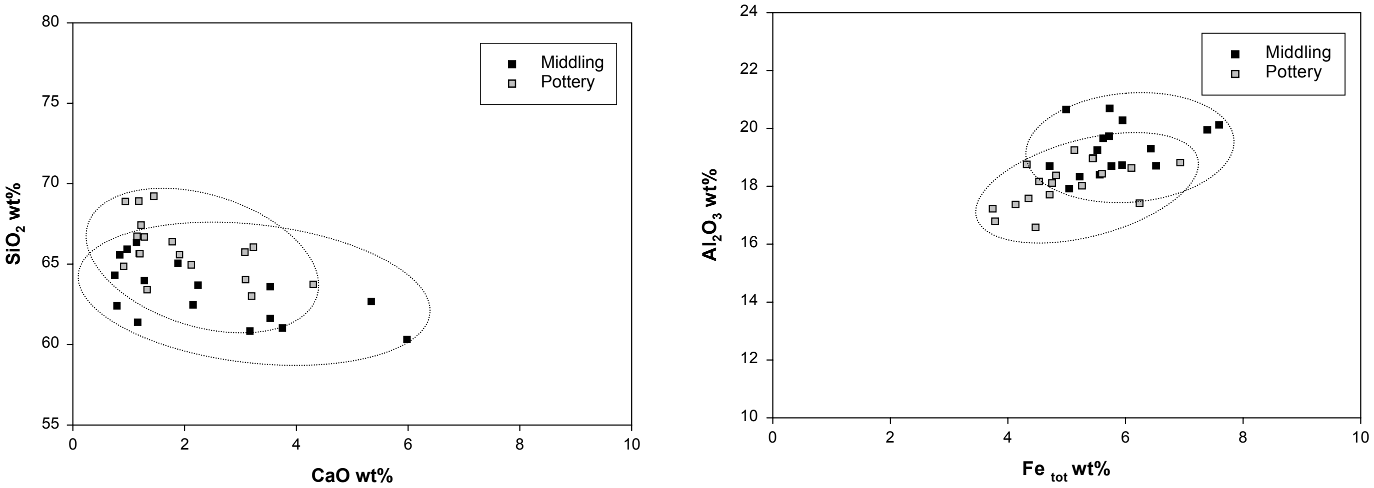


Figure 5. Middling versus pottery chemical analyses. Black and grey squares constitute a fairly continuous group, the overlapping areas are quite large. Their respective compositions are therefore rather consistent with each other.

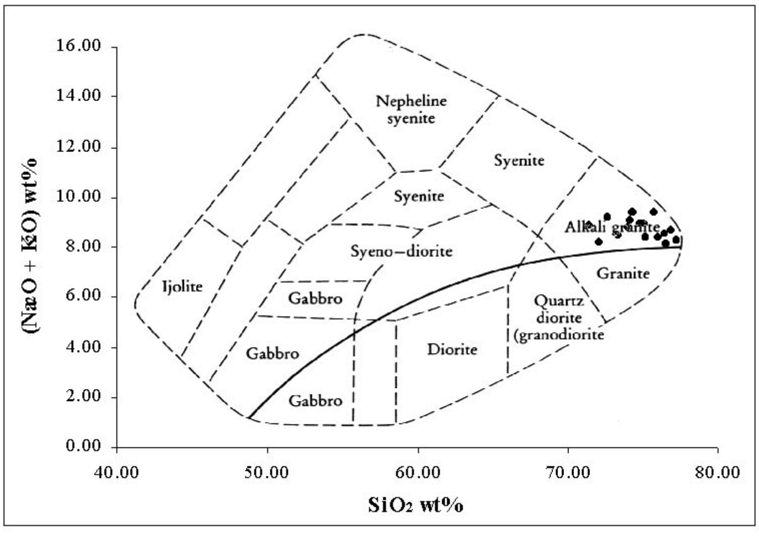


Figure 6 – Correlation diagram total alkali versus silica (TAS) of Cox et al. (1979) adapted by Wilson (1989) for plutonic rocks. The curved solid line subdivides the alkalic from subalkalic rocks. Temper XRF analyses from the separation lye on the “Alkali granite” field.

Oxides (wt%) Elements (ppm)	**Temper** (n=17)			**Middling** (n=17)			**Matrix** (n=17)			**Pottery** (n=17)		
	x	*s*	*s%*	x	*s*	*s%*	x	*s*	*s%*	x	*s*	*s%*
SiO_2	74.71	*1.65*	*2.20*	63.35	*1.88*	*2.97*	61.27	*3.08*	*5.03*	65.96	*1.85*	*2.80*
TiO_2	0.08	*0.05*	*58.47*	0.68	*0.11*	*15.65*	0.85	*0.06*	*7.18*	0.57	*0.09*	*15.02*
Al_2O_3	14.21	*0.87*	*6.15*	19.30	*0.81*	*4.22*	20.12	*1.40*	*6.93*	18.01	*0.75*	*4.17*
Fe_{tot}	1.07	*0.37*	*34.51*	5.83	*0.76*	*12.98*	7.23	*1.08*	*14.97*	4.96	*0.86*	*17.28*
MnO	0.03	*0.01*	*34.14*	0.06	*0.03*	*42.40*	0.07	*0.02*	*26.71*	0.06	*0.02*	*32.30*
MgO	0.25	*0.11*	*46.10*	2.27	*0.37*	*16.14*	2.65	*0.52*	*19.59*	1.85	*0.31*	*16.52*
CaO	0.74	*0.31*	*41.87*	2.33	*1.58*	*67.61*	2.28	*1.12*	*49.42*	1.96	*1.00*	*50.75*
Na_2O	3.95	*0.37*	*9.31*	1.54	*0.38*	*24.96*	0.98	*0.24*	*24.59*	2.05	*0.28*	*13.74*
K_2O	4.82	*0.43*	*8.85*	4.18	*0.39*	*9.35*	4.02	*0.44*	*10.96*	4.37	*0.35*	*8.12*
P_2O_5	0.04	*0.02*	*55.79*	0.23	*0.11*	*46.75*	0.33	*0.19*	*58.99*	0.17	*0.07*	*43.90*
Ba	399	*138*	*34.58*	771	*119*	*15.49*	808	*85*	*10.58*	681	*103*	*15.17*
Cr	14	*7*	*53.36*	115	*13*	*11.19*	131	*15*	*11.68*	88	*10*	*11.48*
Cu	6	*0*	*0.00*	28	*9*	*32.66*	97	*113*	*116.16*	45	*48*	*107.10*
Nb	7	*3*	*50.84*	16	*3*	*18.99*	24	*5*	*21.06*	18	*3*	*19.38*
Ni	8	*5*	*58.68*	70	*8*	*12.16*	89	*13*	*15.16*	54	*8*	*14.65*
Pb	11	*4*	*36.38*	26	*5*	*19.84*	40	*15*	*38.28*	29	*5*	*16.61*
Rb	263	*66*	*24.97*	218	*23*	*10.45*	226	*26*	*11.67*	235	*30*	*12.85*
Sr	86	*39*	*44.77*	98	*20*	*20.95*	90	*21*	*23.32*	95	*20*	*20.62*
V	11	*4*	*38.27*	118	*14*	*11.81*	134	*17*	*12.92*	98	*14*	*14.50*
Y	26	*10*	*36.60*	34	*9*	*27.79*	44	*11*	*24.08*	34	*6*	*17.28*
Zn	10	*7*	*67.95*	117	*21*	*18.14*	231	*116*	*50.27*	98	*21*	*21.37*
Zr	82	*31*	*37.73*	145	*25*	*16.93*	209	*54*	*26.03*	145	*23*	*16.23*

Table 5 - Average (x) and standard deviation (s; s%=s/x) values concerning, temper, middling and matrix, compared to pottery bulk values, tab.4a-b.
Fe_{tot} as Fe_2O_3

4.2.3 The middling

Tab.5 shows average values of the middling largely comparable to those of the pottery, confirming the large degree of overlapping shown in fig.5. This was expected because, being the middling a composite mix of “too” fired clay minerals and fine grained a-plastic inclusions, its composition is consistent with the pottery from which it has been extracted. For the standard deviations, the same considerations made for the temper and the matrix are valid.

4.2.4 The processed clay

Tab.6 shows the chemical data concerning silicate clay DP 93 before (Di Pierro, 2002b) and after having been processed as previously described.

The SiO_2 content reflects a loss of 9.07 wt% (-11.62% of the initial value). This variation is of course due to the effect of washing out the coarsest sandy fraction of the clay composed mainly of quartz. Except for Na_2O and K_2O, all the other oxides/elements strongly increased their proportions. Major oxides such as Fe_{tot} and MgO doubled their already important content, Al_2O_3 and CaO increased their value of more than 40%. The main objective of reducing the quartz content has been therefore achieved.

Oxides (wt%)	**DP 93**		**difference**	
Elements (ppm)	before (a)	washed (b)	absolute (c) = (a)-(b)	% (d) = (c)/(a)
SiO_2	78.07	69.00	-9.07	-11.62
TiO_2	0.44	0.80	0.36	81.82
Al_2O_3	11.57	16.43	4.86	42.01
Fe_{tot}*	2.95	5.90	2.95	100.00
MnO	0.09	0.15	0.06	66.67
MgO	1.06	2.09	1.03	97.17
CaO	0.66	0.98	0.32	48.48
Na_2O	2.20	2.17	-0.03	-1.36
K_2O	2.74	2.72	-0.02	-0.73
P_2O_5	0.07	0.11	0.04	57.14
Ba	341	422	81	23.75
Cr	70	104	34	48.57
Cu	7	37	30	428.57
Nb	10	16	6	60.00
Ni	28	66	38	135.71
Pb	18	32	14	77.78
Rb	127	162	35	27.56
Sr	81	96	15	18.52
V	50	102	52	104.00
Y	23	42	19	82.61
Zn	41	157	116	282.93
Zr	206	235	29	14.08
SUM wt%	99.86	100.36		

Table 6 - Major and trace elements variations of clay DP 93 before (Di Pierro, 2002b) and after having been processed (this study). *as Fe_2O_3

5. DISCUSSION AND ARCHAEOLOGICAL IMPLICATIONS

5.1 The temper

The average chemical composition of temper group fits that of the Mont Blanc granite XRF analyses, published in the literature (i.e. Marro, 1986; Bussy, 1990). Moreover, it is in good agreement with analysis DP 87 (Di Pierro, 2002b) concerning a white, fine grained granite, sampled in the moraine deposits surrounding the Neolithic settlement. The consistency between temper grains of Portalban pottery and the Mont Blanc granite, were largely predicted already with the petrographical characterization performed on ceramics thin sections (Di Pierro, 2002b). The mineral paragenesis and textural features, besides the characteristic presence of stilpnomelane among the accessory minerals (Von Raumer, 1969), were already clear tracks concerning the petrographical provenance of the raw material used to temper ceramic vases. The separation technique has permitted to quantitatively confirmed the above statements.

The fact that Mont Blanc granite is not whatever granite, can even be deeper argued.

(a) It has already been discussed and accepted that Neolithic potters provided rock-materials for ceramic preparation, mainly exploiting available lithotypes widely outcropping in moraine deposits, and largely distributed upon the Western Swiss Plateau (i.e. Nungässer & Maggetti, 1978; Nungässer *et al.,* 1985; Benghezal, 1994). The prospecting of potential rock source from moraine deposits of Portalban has given as impressive result that granitoide rocks, or more in general rocks bearing preserved plutonic texture, do not constitute more than 10% of available lithotypes, randomly considered in an area of about 5 km^2 (Di Pierro, 2002b). Inside this group, rock lithotypes with a petrographical composition corresponding to the Mont Blanc granite, were only a few samples. The separation technique strengthens the hypothesis of the exploitation of a well-known ore-source.

(b) The crystalline elements of moraine deposits presently outcropping along the Swiss Plateau have a clear origin from the basement of Helvetic domains, and from the Internal Pennidic Units of the Alps (i.e. Portmann, 1966). They have been brought up to the Neuchâtel Lake region, mainly by the Rhône glacier (i.e. Portmann, 1955; Meia & Becker, 1976). The Mont Blanc Massif is not the only crystalline complex which could have potentially provided the Würm glacier with granitoide elements. The Aar Massif, in the Swiss Valais, could and have provided huge quantities of crystalline material too (i.e. Portmann, 1966), fig. 7. If the choice of granitoides had been randomly made at Neolithic times, Portalban potters could have had the same chance to collect Mont Blanc granite and Aar granitoides, being both widely present on the Swiss Plateau. But the two groups of lithotypes have different geochemical fingerprints.

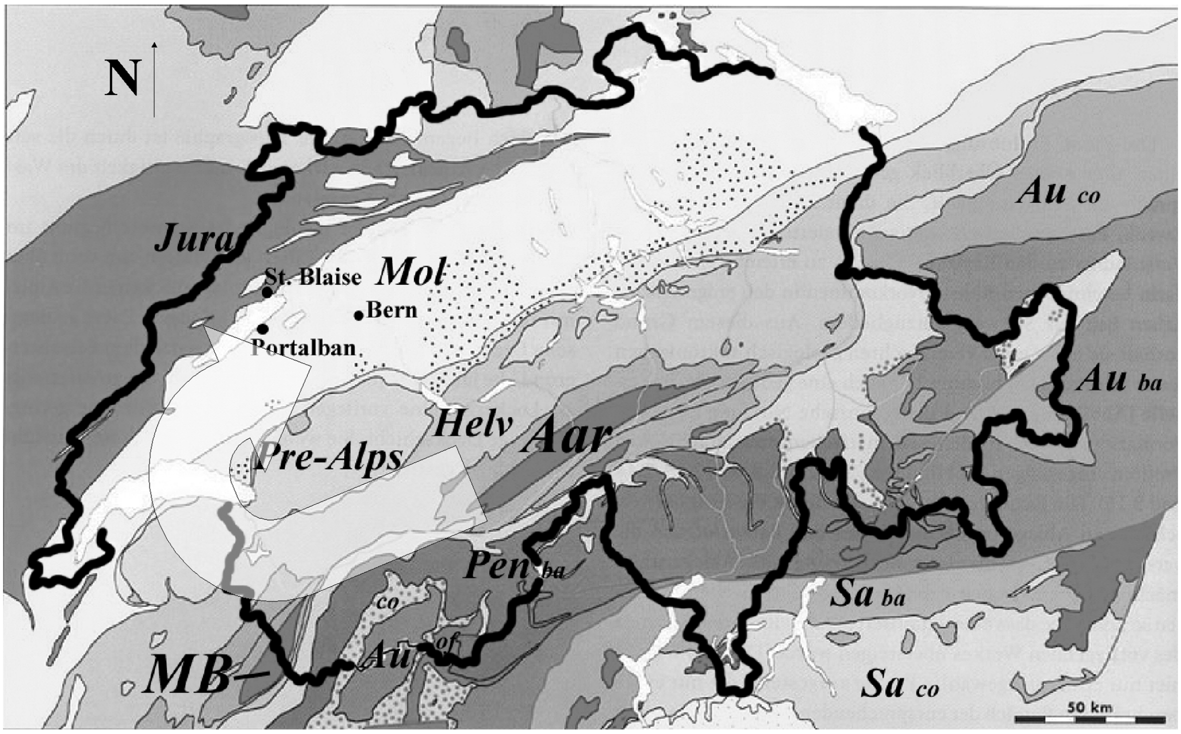


Figure 7. Simplified tectonic sketch (modified after Von Raumer *et al*., 1999) showing the motion of the Rhône glacier towards the Western Swiss Plateau (i.e. Portmann, 1955). The Mont Blanc (MB) and the Aar massifs are both composed of granitoide rocks (i.e. Bussy, 1990; Schaltegger & Krähenbühl, 1990). Both have provided to the Würm Glacier with granitoide elements. These latter can be both found among the crystalline lithotypes in the moraine deposits covering the Western Swiss Plateau (Au = Australpine; Hel = Helvetic; Mol = Molasse; Pen = Pennidic; Sa = South-alpine; ba = crystalline basement; co = sedimentary cover; of = ophiolits)

Fig.8 shows a ternary diagram with the chemical analyses of separated temper grains and of the plutonic rocks collected from the moraine deposits. The composition fields of the Mont Blanc (data from Marro, 1986 and Bussy, 1990) and of the Aar Massifs (data from Schaltegger & Krähenbühl, 1990) have been included as well. The ternary graph concerns K_2O, Na_2O and Fe_{tot}. Portalban temper grains represent again a quite homogeneous chemical group. Their composition is clearly consistent with the Mont Blanc granite composition field. Besides a degree of overlapping with the felsic mineral-rich granitoides from the Aar, the range of this latter is evidently not consistent with that of Portalban temper grains. It is noteworthy that the Mont Blanc granite outcrops in moraine deposit at Portalban, analysis DP 87.

Fig.9 shows the ternary diagram concerning trace elements, Ba, Zr and Sr. Bearing in mind the representativeness of trace elements data, previously discussed, the good correspondence between the Mont Blanc composition field and the temper one is rather clear. Again the Aar Massif composition field is largely widespread throughout the graph, and again is less consistent with temper ones.

The exploitation of the Mont Blanc granite in particular to temper ceramics, is not a new hypothesis. Already Nungässer & Maggetti (1978) raised it. They published a comprehensive report concerning the Neolithic ceramics of the Burgäschisee, across the

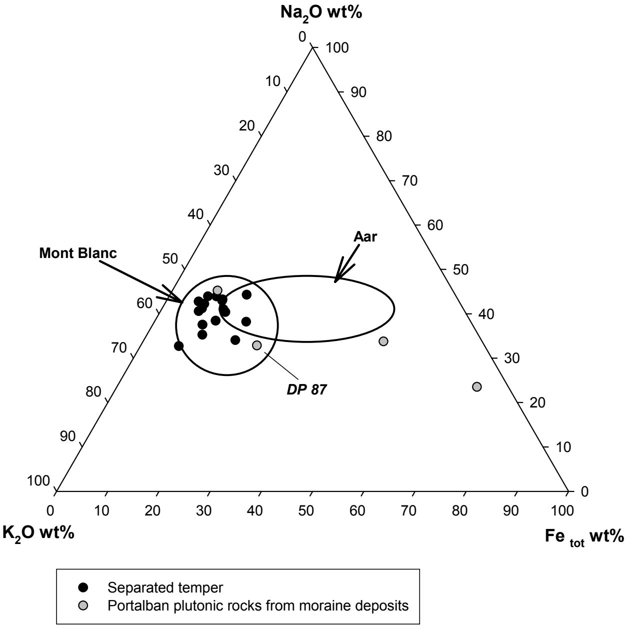


Figure 8. Major elements ternary graph (Fe_{tot} as Fe_2O_3) concerning separated temper granite grains and moraine rocks with plutonic texture from Portalban. Mont Blanc, n=30, (Marro, 1986; Bussy, 1990) and Aar massif, n=15, (Schaltegger & Krähenbühl, 1990) granitoide composition fields have been included. Temper chemical values are more consistent with the Mont Blanc granite values range. This latter lithotype is available in the Quaternary deposits surrounding the Neolithic settlements (analysis DP 87).

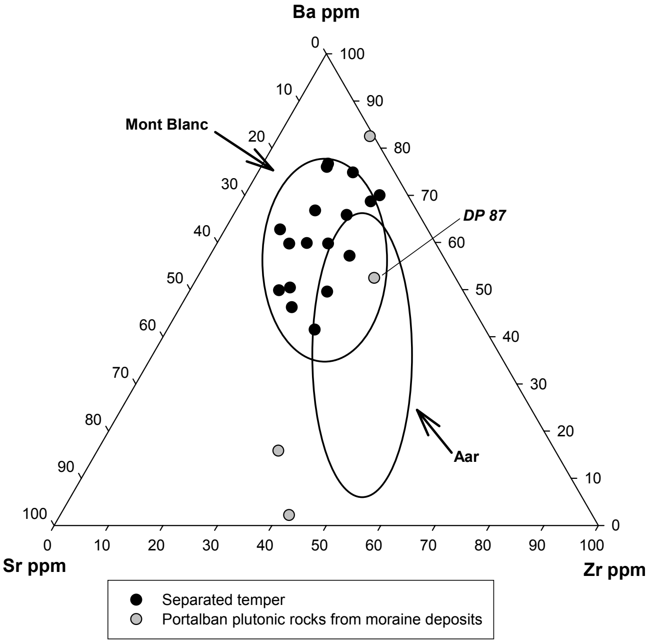


Figure 9. Trace elements ternary graphs. Even having a wider values range, chemical data of temper group are more consistent with the Mont Blanc composition field than the Aar Massif one.

Solothurn and Bern Cantons. These potteries belong mainly to the Cortaillod phase of the settlement (around 3.500 BC, Stöckli, 1995). The petrographic study gave rise to; (i) the identification of temper grains of granite nature, deeply used in different quantities to produce the coarse and fine pottery; (ii) mineralogical associations and textural features identical or almost to those described in the literature for the Mont Blanc granite (i.e. Von Raumer, 1967; 1984; Bussy, 1990). The stilpnomelane, the accessory fingerprint mineral, was found in at least 7 samples. Nungässer & Maggetti (1978, p.165) therefore determined the precise nature of the lithotype as the Mont Blanc granite. They identified in the moraine deposits surroundings the settlements, the main source exploited by potters to provide their temper materials.

At the Neolithic settlement of Saint-Blaise, Neuchâtel Lake, the Mont Blanc granite has been extensively used to temper a suite of 63 ceramics (Di Pierro *et al*., 2002). The pottery belong to the Old and Middle Auvernier-cordé cultural groups. In particular, beside the typical mineralogical paragenesis and textural features, stilpnomelane is a common accessory mineral of temper grains. It has been clearly determined in 19 different ceramics. The chemical composition of the granite has been recently determined with the separation technique (Di Pierro, 2002a).

At Chalain, in the French side of the Jura Belt, a suite of Neolithic coarse ceramics has been tempered with granite grains (Martineau *et al*., 2000). Stilpnomelane and epidote have been regularly observed (Martineau, pers. comm.). The other mineralogical and textural features of the Mont Blanc granite have been recently confirmed (Di Pierro & Martineau, 2002). Rare erratic boulders of the Mont Blanc granite have been described in the French Jura Mountains by Campy (1982). They have been brought up to there by some secondary Rhône glacier tongs, which passed over the Western side of the belt.

Granite, as a general rock lithotype, has very often been observed as a preferential raw material for pottery tempering (besides the above authors, i.e. Nungässer et al., 1985; Schubert, 1987). It has been even demonstrated that granites are easily crashed after firing and quick water cooling (Nungässer *et al*. 1992). It is therefore widely accepted their preferential utilisation given the large abundance as moraine deposit rock too.

However, this paper, Nungässer & Maggetti (1978), Di Pierro (2002a), Martineau *et al.* (2000), have demonstrated that the Mont Blanc granite is not whatever granite. Its systematic exploitation could have possibly occurred across time and space in Switzerland. This preferential choice cannot be the result of a randomly made choice. On the contrary, it should correspond to a "cultural behaviour" as already reported by Costantin & Courtois (1985) for the Paris Basin and the French Neolithic. These authors state that choosing the temper with a particular material is not the result of whatever choice. It hides instead a social attitude.

The regularity in time and space concerning the utilisation of the Mont Blanc granite would strengthen the above authors' hypothesis for the Western Swiss Plateau as well as for France.

5.2 The matrix

Fig.10 shows the chemical data concerning the three major oxides, SiO_2, Al_2O_3 and CaO, with reference to the separated matrix and the two chemically different sorts of clay prospected in the Portalban area. Here is briefly reminded that the local (Arnold, 2001) available raw carbonate clay corresponding to analyses DP 73, fits the chemical composition of the cobs and most of the loom weights, coming from the Portalban settlement (Di Pierro, 2002b).

Fig.10 shows the presence of what can be considered very likely two sub-groups of Al_2O_3-rich matrix. If the CaO content is almost constant, the two sub-groups have silica content above/below 60 wt% and alumina below/above 20%, respectively. Whether this chemical difference could have any correlation with different sources of raw clays should be further investigated.

Always fig.10 clearly shows how the separated matrix group does not correspond to the available local clays, prospected in an area of around 5 km^2. The silicate clay group does not fit in composition the clay used by Neolithic potters for ceramic preparation. The Portalban silicate clays are; (i) from a petrographic point of view n.a.p.i. very-rich, even sandy sediments, fig.2b; (ii) from a chemical point of view SiO_2 rich (78.07 wt%) and Al_2O_3-poor (11.57 wt%), tab.6. The separated matrix is instead (i) n.a.p.i. poor, see fig.2a,

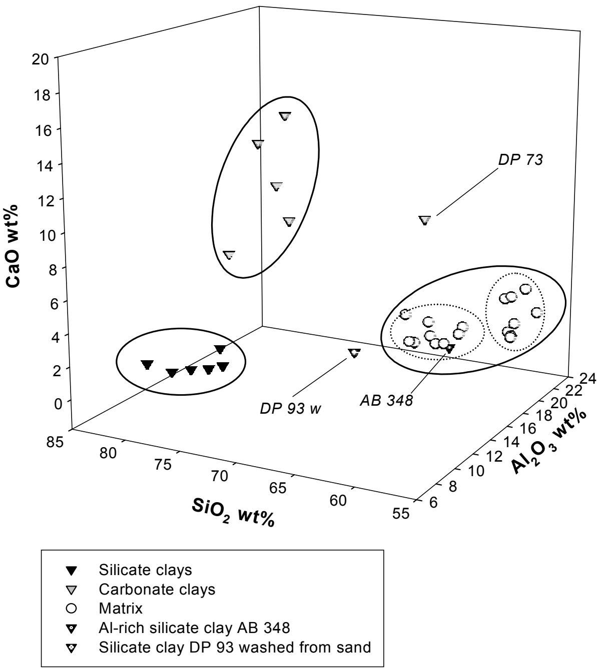


Figure 10. Chemical data concerning available clays at Portalban (black & grey triangles) compared to separated matrix from pottery. The separation technique has permitted to highlight the presence of two groups of clays used for pottery preparation; they are slightly different in Al_2O_3 composition, as well as in SiO_2, below and above 60wt% respectively. The obtained matrix data do not fit local available clays. This is in strong contrast with the utilisation of a local raw material, analysis DP 73, used for the cobs and the loom weights preparation (Di Pierro, 2002b). Analysis DP 93 w correspond to clay DP 93, but processed in order to wash out of it the sandy fraction, tab.6. Analysis AB348 (Benghezal, 1994), concerns a silicate clay sampled by the author. It is one among 41 specimens of different carbonate and silicate clays sampled in the Jura Three Lakes Area, fig.12. It outcrops closed to the Cornaux village, between the Neuchâtel and the Biel Lakes, 15 km North from Portalban, fig.11. This clay only, has a particular chemical composition, being high in alumina and low in Ca, which fits the chemical group of separated matrix concerning Portalban vases.

and (ii) SiO_2 poorer (61.27 wt%) and Al_2O_3 richer (20.12 wt%), tab.5.

The non correspondence between the obtained matrix and the silicate clay group open the discussion to different hypothesis.

1) The clay used by the Portalban Neolithic potters could have not been found during the prospecting because either it is not accessible or it has been fully exploited.

2) Neolithic potters used the silicate clays outcropping around the settlement, but they use to process them washing out the sandy fraction of the material. In alternative, the silicate clays could have undergone a decantation process naturally occurring in a shore or a swamp area close to the settlement.

3) A third hypothesis could concern a non local provenance of the raw clay used for pottery manufacturing. In this case the exogenous provenance of the pottery could be envisaged.

To test the first hypothesis a deeper and more systematic prospecting of the area should be implemented. Unfortunately the current urbanization of the area does not give access to most of the terrains potentially hosting the sought material.

To explore the second hypothesis a test on a sample of silicate clay has been carried out. This was an attempt to replicate the potential processing of the local available raw clays. Tab.6 and fig.10 show that despite the decreasing of 11.62% of SiO_2, silicate sample DP 93 does still not fit in composition the obtained matrix. Moreover, tab. 6 shows that the K_2O content of the processed clay at 2.72 wt% is far to be the K_2O value of the separated matrix, which accounts for 4.02 wt%, tab.5.

An attempt to test the third hypothesis has been carried out seeking throughout the data available in the literature (i.e. Letsch *et al.*, 1907; Sigg *et al.*, 1986; Maggetti & Galetti, 2000) a clay with the sought petrographic and chemical compositions. Given the relatively high Al_2O_3 content, attention has been paid to kaolinite bearing clay in particular. Even having been mentioned from different parts of Switzerland, such composition resulted being rather rare.

Peters *et al.* (1982), published a comprehensive study concerning chemical and mineralogical analyses of clays throughout all Switzerland. They reported kaolinite clays mostly in the Northern and North-eastern part of the country. Some rarer outcrops of kaolinite bearing clays have been mentioned in the Geneva region and in the South-western part of the Swiss Jura Belt. Kaolinite clays have not been instead reported in the Portalban area and more in general across the Northern part of the Neuchâtel Lake.

Benghezal (1994), in her study concerning the provenance and technology of Swiss and French Neolithic ceramics, also sampled 41 clays in the Jura Three Lakes region, in the areas around the Neolithic settlements she investigated, fig.11. She chemically and petrographically characterized them, and she defined three main kinds of clays; CaO rich, CaO poor and clay with an intermediate composition to which roughly correspond the carbonate, the silicate and the carbonate–silicate clay groups plotted in fig.12. Among the 41 specimens, only one analysis has an high alumina content, AB 348. It has the following major elements composition: SiO_2 63.51 wt%, Al_2O_3 19.80 wt%, Fe_{tot} 6.97 wt%, MgO 3.61 wt% and CaO 0.75 wt%. It has been sampled within the isthmus connecting the Neuchâtel and the Bien/Bielle lakes, a few hundred meters south off the Cornaux village, on the Aquitanian basement (Schär *et al.*, 1971), but at 15 km North from Portalban. She petrographically characterized it as silicate, n.a.p.i. poor silicate clay.

This clay fits most of the chemical and petrographic features of the sought clay(s) used for pottery preparation at Portalban. It is Al-rich and Ca-poor, it is carbonate free and the n.a.p.i. are of silicate nature. Unfortunately it does not outcrop in the Portalban area, fig.11.

The Cornaux village is instead very close to the St. Blaise Neolithic settlement. As already mentioned, a suite of 63 pottery, contemporary to the Portalban ceramics of this investigation, has been recently characterized with regard to the bulk pottery composition as well as to the separated components (Di Pierro *et al.*, 2002). St. Blaise ceramics resulted composed of at least two different chemical groups. 89% of the ceramics have been produced with a calco-silicate clay. This latter has a MgO content of 1 wt% in average. This last parameter discriminates the remaining 11% of the pottery. These latter ceramics have been manufactured with a silicate clay with a MgO content between 2 and 2.5 wt%. This second group of pottery owns a good correlation with the typological group of the "Corded True" ceramic. This typological group has been found and characterized at Portalban too (Giligny, 1993). The Portalban pottery has always a silicate clay composition with a MgO content in average of 2.65 wt%, tab.5. Therefore the petrographic and chemical features of Portalban pottery and the MgO-rich pottery of St. Blaise are impressively consistent with each other. This rather good correspondence allowed to raised the hypothesis of an exogenous provenance of the MgO-rich ceramics of St. Blaise, for instance from Portalban (Di Pierro *et al.*, 2002).

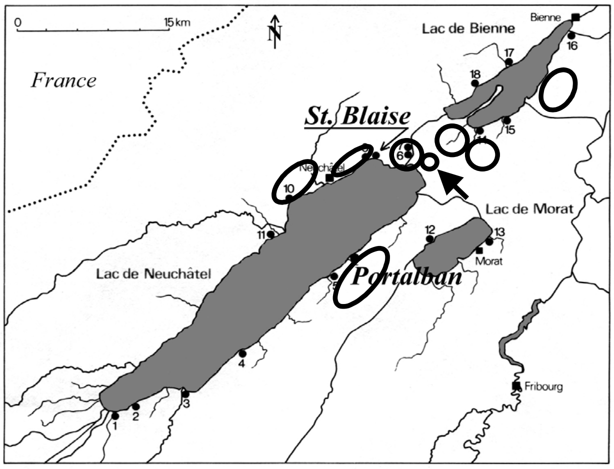


Figure 11. Geographical settings of main Neolithic settlements in the Three Jura Area Lakes (modified after Ramseyer, 1987). Circled areas roughly represent Benghezal (1994) prospected areas in view to characterize potential clays exploited for ceramic manufacturing. Sampled clay AB 348 comes from the area, indicated by the black arrow, close to the Cornaux village (see text). This clay outcrops definitely closer to St. Blaise (5-6 km) than to Portalban (15 km at least). This clay has a chemical and petrographic outlook comparable to Portalban separated matrix. This result increases the possibility that clays with similar compositions exist(s)ed around Portalban too.

1. Yverdon (avenue de Sports), 2. Chéseaux (Châble-Perron), 3. Yvonand, 4. Font, 5. Gletterens, 6. Thielle-Wavre (Thielle-Mottaz), 7. Thielle-Wavre (Pont-de-Thielle), 9. Hauterive (Champréveyres), 10. Auvernier, 11. Cortaillod, 12. Guévaux, 13. Montilier/Muntelier, 14. Vinelz, 15. Lüscherz, 16. Port, 17. Twann, 18. La Neuveville (Schafis).

The chemical fingerprint of a MgO content at around 2.5 wt% and the silicate nature of the clay are features consistent with the Portalban ceramics production. Instead the MgO content at 1 wt% and the calcareous nature of the clay is the fingerprint of the St.Blaise ceramics production. But if the Portalban potters would have exploited the Cornaux clay, 15 km off their village, why the St. Blaise potters did not use the same source, 5 km only far from their settlement?
The rarity of MgO rich ceramic at St. Blaise and the massive presence of pottery with a calco-silicate and MgO poor composition rules out a systematic exploitation of silicate and MgO rich clay. The good relationship between pottery compositions and geological environments allows to envisage local ceramic productions for both the Neolithic site (Di Pierro, 2002a).

It is very unlikely that Portalban potters exploited the Cornaux clay. But this does not exclude that a clay with petrographic and chemical corresponding compositions outcrop(s)ped near the Portalban settlement. In fact, the Cornaux clay lies over some sporadic Aquitanian basement outcrops (Schär *et al.*, 1971). This geological environment is definitively proper to the Portalban area (Frei *et al.*, 1974).

Given the above investigations and considerations, the first raised hypothesis seems to be the most likely one. It is very probable that such a clay exist(s)ed at the settlement. Portalban potters exploited it for the ceramics production. Nowadays the clay outcrop could have been either covered by the urbanization or already fully exploited.

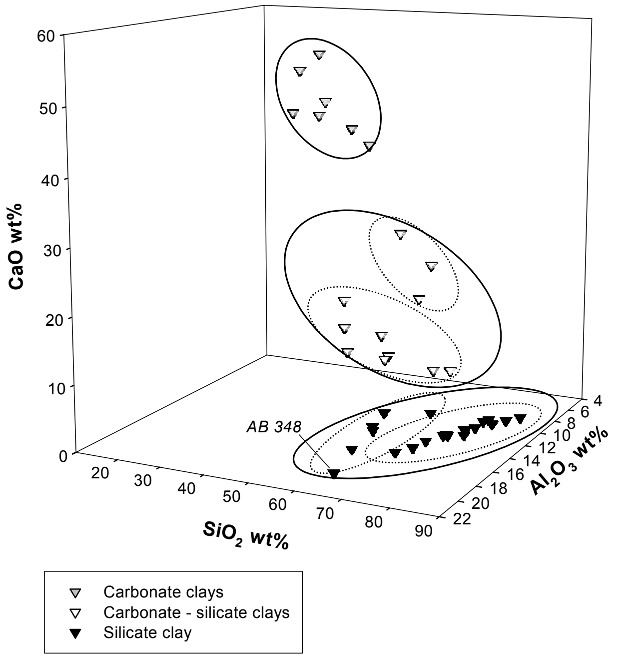


Figure 12. Chemical data concerning Benghezal (1994) Swiss sampled clays. Three chemical different groups exist. Depending on the CaO, SiO_2 and Al_2O_3 wt% content, she classified a carbonate-rich, a carbonate – silicate and a silicate-rich groups respectively. On the basis of this classification, she established the local provenance, at the regional scale of the Western Swiss Plateau at least, of her Neolithic ceramic products. These clay groups fit mostly the ceramic groups she obtained and determined as group of references. The sampled clays covers several km^2, see fig.11. Only analysis labelled AB 348, fits the composition of separated matrix concerning Portalban pottery of this report, fig.10.

6. CONCLUSIONS

In this study we have explored the two following issues:

1) The matrix and the temper, the two basic components of a ceramic sherd, can be separated one from the other without affecting their original composition, in order to characterize them separately?

2) In a compositionally homogeneous group of pottery, are the matrix and the temper, once properly separated and characterized, useful to answer the question of the pottery provenance?

In order to answer the first question we have implemented a separation procedure, which is based upon an H_2O_2 attack with a properly buffered liquid solution. The ceramic sherd reacts allowing to split three main components: (i) a-plastic coarse inclusions composed of rock and mineral fragments to which it corresponds the temper; (ii) very fine grained plastic material in form of powder to which it corresponds the matrix; (iii) a mixed composite of the previous two fractions, which it has been called the middling. The separation technique is an almost cost-less procedure but it is time consuming. The reliability of the procedure has been checked. Within a determined marginal error, see tab.3, the technique is effective. The chemical results on distinct fractions allows distinguishing sharply separated groups of temper and matrix.

To answer the second question we have applied the separation technique to a suite of 17 ceramic sherds. They have been chosen among a wider pottery suite of 47 ceramics of known bulk composition. These latter come from the Neolithic settlement of Portalban, Western Switzerland, and concerns the Old Auvernier-Cordé occupation of the site (2700 – 2650 BC). The previous characterization of those materials gave as an important result the deep homogeneity on a petrographic and a chemical basis. We have explored the possibility to analyze separately the main components of the pottery.

The Portalban pottery is homogeneous because the raw materials used are homogeneous. The temper is a granite. Its chemical composition is rather consistent with the Mont Blanc granite, as expected from petrography. This lithotype has been found as a rare rock in the moraine deposits surrounding the site. The matrix is of silicate nature and Al_2O_3 rich. In addition its MgO content is of 2.65 wt%. However, its chemical composition is not consistent with previously prospected raw clays at the settlement. Despite the processing of these latter materials, further analyses have confirmed the non correspondence on a chemical basis between the obtained matrix and the available clay. Instead, a clay material with the needed petrographic and chemical features has been mentioned by Benghezal (1994). It outcrops at Cornaux, 15 km far from the Portalban settlement, but at 5 km only far from another dwelling settlement, St. Blaise.

The characterization of a contemporary pottery suite of 63 ceramics from St. Blaise revealed that the 89% of those pottery have been manufactured with a calco-silicate clay with an MgO fingerprint of 1 wt%. Even having it at disposal in the proximity of the village, the potters of St. Blaise did not use the Cornaux clay. Therefore, it is highly unlikely that the potters of Portalban exploited such a far clay. This would be in strong contrast with any known ethnographic example (e.g. Arnold, 2001). However, the existence of the Cornaux clay permits to envisage that clays with a corresponding composition could and/or have outcropped at Portalban or in its proximity. This would be consistent with the correspondence between the geological settings of the Cornaux area, definitely more similar to the Portalban one.

The separation technique is therefore an helpful tool to investigate ceramics. It permits to characterize their basic components, to determine their provenance and that of the pottery.

The ceramics of Portalban hides an excellent technological background. The potter(s) of the settlement must have known exactly where and how to provide the necessary raw materials, for the temper and the matrix both. These results confirm and strengthen the hypothesis that the "material choice" is a social attitude and can hide a "cultural behavior" (Constantin & Courtois, 1985).

REFERENCES

ARNOLD, D. E., NEFF, H. & GLASCOCK, M. D., 2000, *Testing assumptions of neutron activation analysis : communities, workshops and paste preparation in Yucatan, Mexico.* Archaeometry 42, 301 – 316.

ARNOLD, D. E., 2001, *Linking society with the compositional analyses of pottery : a model from comparative ethnography.* XIVe Congrès de l'Union International des Sciences Préhistoriques et Protohistoriques, Liège, 2 - 8 septembre 2001. Abstract.

BENGHEZAL, A., 1994, *Provenance et techniques de la céramique du Néolithique final de stations des trois lacs jurassiens (Suisse).* Thèse de doctorat, Université de Fribourg, 174 pp.

BUSSY, F., 1990, *Pétrogenèse des enclaves microgrenues associées aux granitoides calco-alcalins: exemple des massifs varisque du Mont Blanc (Alpes occidentales) et miocène du Monte Capanne (Ile d'Elbe, Italie).* Thèse de Doctorat, Université de Lausanne. Mémoire de Géologie n.7, 309 pp.

CAMPY, M., 1982, *Le Quaternaire franc-comtois. Essai chronologique et paléoclimatique*, unpubl. Ph. D. dissertation, Faculté des Sciences et Techniques de l'Université de Franche-Comté.

COSTANTIN, C. & COURTOIS, L. C., 1985, *Le materiau céramique comme caractéristique culturelle. L'example du dégraissant pendant le Néolithique dans le bassin parisien.* IGAL. Etudes des céramiques en archéologie. Documents et travaux

COX, K.G., BELL, J.D. & PANKHURST, R.J., 1979, The interpretation of igneous rocks. George, Allen and Unwin, London.

DANÉROL, A., ORCEL, A., ORCEL, C. & RAMSEYER, D., 1990, *Delley/Portalban II, vol.2, les villages néolithiques révélés par la dendrochronologie*. Archéologie Friburgeoise, Editions Universitaires, Fribourg, 1990, 168 p., 5 annexes.

DI PIERRO, S., 2002a, *Domestic production versus pottery exchanges during the Final Neolithic: characterization of the Auvernier-cordé ceramics of the Portalban and Saint Blaise settlements, Western Switzerland.* Ph.D dissertation. University of Fribourg, Switzerland, pp.184.

DI PIERRO, S., 2002b, *Ceramic production technology and provenance during the Final Neolithic: the Portalban settlement, Neuchâtel Lake, Switzerland.* Proceedings of the "4ème colloque d'Archéometrie", GMPCA, La Rochelle 24 – 28 avril 2001. Revue d'Archéometrie. In press.

DI PIERRO, S. & MARTINEAU M., 2002, *Pottery Tempering With Mont Blanc Granite Across The Jura Belt During French And Swiss Final Neolithic*. 33rd International Symposium on Archaeometry ISA, 22 - 26 April 2002, Amsterdam. Abstract

DI PIERRO, S., MICHEL, R. & MARTINEAU, R., 2002, *Matériau et types céramique à St. Blaise (Néolithique Suisse) Poterie exogène et production locale*. Proceedings of the XIVth Congress of the U.I.S.P.P.,Liège, Belgium, 2 – 8 September 2001. British Archaeological Report. Submitted.

FREI, E., MEIA, J., BECKER, F., BÜCHI, O., BUXTORF, R., RYNIKER, K. & SUTER, H., 1974, *Atlas géologique de la Suisse 1:25.000, feuille 1164, Neuchâtel*. Commission géologique Suisse.

GILIGNY, F., 1993, *La variabilité des récipients céramiques au Chalcolithique moyen-récent jurassien (3400-2400 av. J.C.). Analyse archéologique d'un système d'objets.* Thèse de Doctorat, Université de Paris I – Panthéon/Sorbonne UFR 03 – Histoire de l'Art et Archéologie, Vol.1, 273 pp.

GILIGNY, F., 1994, *Variabilité et transferts techniques dans le Jura à la fin du IV^{e} et au III^{e} millénaires av. J.-C.* Terre cuite et société : la céramique. Document technique, économique, culturel. XIV^{e} Rencontres Internationales d'Archéologie et d'Histoire d'Antibes. Editions APDCA, Juan-les-Pins, p. 1 – 18.

GILIGNY, F. & MICHEL R., 1995, *L'évolution des céramiques de 2920 à 2440 av.J.-C. dans la région des trois lacs (Suisse Occidentale).* Chronologies néolithiques. De 6000 à 2000 avant notre ère dans le Bassin rhodanien. Actes du Colloque d'Ambérieu-en-Bugey, 19-20 septembre 1992. Documents du Département d'Anthropologie de l'Université de Genève, n°20. Ambérieu-en-Bugey, éd. Société Préhistorique Rhodanienne, 1995, p. 347-361.

LETSCH, E.; ZSCHOKKE, B.; ZSCHOKKE, B., ROLLIER, L. & MOSER, R. 1907, *Die Schweizerischen Tonlager*. Beiträge zur Geologie der Schweiz, Geotechnische Serie, IV. Lieferung. Bern.

MAGGETTI, M. & GALETTI, G. 2000, Naturwissenschaftliche Analyse der Fayence von Matzendorf. In: 200 Jahre keramische Industrie in Matzendorf und Aedermannsdorf, 1798 - 1998, Vogt A., Egli M., Maggetti M., Galetti G. Albrecht Druck AG, Obergerlafingen. 190 pp.

MARRO, C., 1978, *Recherches en Archeocéramique ; (a) recherches minéralogiques sur la céramique Malaun ancienne, (b) essais de séparation d'argile et de dégraissant de céramique cuite.* Travail de diplôme, Université de Fribourg, 139 pp.

MARRO, C., 1986, *Les granitoides du Mont Blanc en Suisse.* Thèse de Doctorat, Université de Fribourg, 145 pp.

MARTINEAU, R., CONVERTINI, F. & BOULLIER, A., 2000, *Provenances et exploitations des terres à poterie des sites de Chalain (Jura), aux 31^{e} et 30^{e} siècles avant J.-C.* Bull. de la Soc. Préhist. Franç., 97, n.1, p. 57-71.

MATHEZ, E.A., DIETRICH, V.J. & IRVING, A.J., 1984, The geochemistry of carbon in mantle peridotites. Geochim. Cosmochim. Acta 48, p. 1849 – 1859.

MEIA, J. & BECKER, F. 1976, *Notice explicative de la feuille 1164, Neuchâtel, de l'Atlas géologique de la Suisse 1:25.000*, Commission géologique Suisse.

MICHEL, R., 2002, Saint-Blaise/Bains des Dames, 3. Typologie et chronologie de la céramique néolithique: céramostratigraphie d'un habitat lacustre. Neuchâtel, Service et Musée cantonal d'archéologie *Archéologie neuchâteloise*, 27; 2 vol.

NUNGÄSSER, W. & MAGGETTI, M., 1978, *Mineralogisch-petrographische Untersuchung der neolitischen Töpferware vom Burgäschisee.* Bull. Soc. Frib. Sc. Nat. 67/2, 152 – 173.

NUNGÄSSER, W., MAGGETTI, M. & STÖCKLI, W.E., 1985, *Neolitische Keramik von Twann – Mineralogische und Petrographische Untersuchungen.* Jahrbuch der Schweiz. Ges. für Ur- und Frügeschichte, 68, 7-39.

NUNGÄSSER, W., MAGGETTI, M. & GALETTI, G. 1992: Analyse der Scherbensubstanz mit Mikroskop und Röntgenlicht. In: J.Bill, W. Nungässer, G. Galetti: Liechtensteinische Keramikfunde der Eisenzeit. Jahrbuch des Historischen Vereins für das Fürstentum Liechtenstein, Band 91, p. 119-165.

PETERS, T., IBERG, R. & MUMENTHALER, T. 1982, *Kiesschlamm als potentieller Rohstoff?* Schweizer Ingenieur und Architekt, Sonderdruck aus Heft 19. K. Bösch AG, Zürich.

PETREQUIN, P., PETREQUIN, A.M., GILIGNY, F. & RUBY, P., 1994, Produire pour soi, la céramique de Chalain 2 C au Néolithique final. *Bulletin de la Société Préhistorique française*, t. 91, n° 6, p. 407-417.

PICOUET, P., 1997, *Application de la cathodolouminescence à l'étude des céramiques archéologiques et modernes.* Thèse de doctorat, Université de Fribourg, 175 pp.

PORTMANN, J.P. 1955, *Pétrographie des moraines du glacier würmien du Rhône dans la région des lacs subjurassiens (Suisse).* Bull. Soc. Neuchât. Géogr. 51/5 1954-1955.

PORTMANN, J.P. 1966, *Pétrographie des formations glaciaires à l'Est du lac de Bienne.* Eclogae Geol. Helv. 59/2.

RAMSEYER, D., 1987, *Delley-Portalban. Contribution à l'étude du Néolithique en Suisse occidentale.* Archéologie friburgoise 3, Fribourg.

SCHALTEGGER, U. & KRÄHENBÜHL, U., 1990, Heavy rare-earth element enrichment in granites of the Aar Massif (Central Alps, Switzerland). Chemical Geology , 89, 49-63.

SCHÄR, U., RYNIKER, K., SCHMID, K., HÄFELI, CH. & RUTSCH, R.F. 1971, *Atlas géologique de la Suisse 1:25.000, feuille 1145, Bieler See.* Commission géologique Suisse.

SCHWAB, H., 1971, *Junsteinzeitliche Fundstellen im Kanton Freiburg*, Schriften zur Ur- und Frügeschichte der Schweiz 16, Schweizerische Gesellschaft für Ur- und Frühgeschichte, Basel, 1971, 136 p., 85 fig.

SCHWAB, H., 1982, *Portalban/Muntelier: zwei reine Horgener Siedlungen der Westschweiz.* Archäologisches Korrespondenzblatt, 12, Mainz, pp. 15-32

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, 114-125

SIGG, J., MAGGETTI, M. & GALETTI, G. 1986, *Contribution à l'étude des terres argileuse de la région de Payerne.* Bull. Soc. Vaud. Sc. Nat. 78.2, 159-193.

STÖCKLI W.E., 1995, L'évolution du Néolithique Suisse. In « La Suisse du Paléolithique à l'aube du Moyen Age. De l'homme de Neandertal à Charlemagne ». In *SNP II, Néolithique*. Veralg Scweizerische Gesellschaft für Ur- und Frügeschichte, Basel. 358 pp.

STURNY, C. & RAMSEYER, D., 1984, *Petrographische Analyse neolithischer Keramik aus Delley/Portalban II (Kt. Freiburg) und Charavines (Dpt.Isère, Frankreich).* Freiburger Archäologie, Fundbericht 1984, 92-95, Fribourg.

VON RAUMER, J., 1967, *Kristallisation und Gefügebildung im Mont-Blanc-Granit.* Habilitationsschrift zur Erlangung der Venia legendi an der mathematisch-naturwissenschaftlichen Fakultät der Universität Freiburg i. Ü. (Schweiz), 499-579.

VON RAUMER, J., 1969, *Stilpnomelan als alpinmetamorphes Produkt im Mont-Blanc-Granit.* Contr. Mineral. And Petrol. 21, 257-271.

VON RAUMER, J., 1984, *The external massifs, relics of Variscan Basement in the Alps.* Geolog. Runds., 73, 1, 1-31.

VON RAUMER, J., ABRECHT, J., BUSSY, F., LOMBARDO, V., MENOT, R.P. & SCHALTEGGER, U., 1999, *The Paleozoic metamorphic evolution of the Alpine External Massifs*. Schweiz. Mineral. Petrogr. Mitt., 79, 5-22.

VOUGA, P., 1929, *Classification du Néolithique lacustre Suisse*. Indicateur des antiquités suisse, 31, pp. 81-91; 161-180.

WILSON, M., 1989, Igneous petrogenesis. Unwin Hyman, London.

ZANCO, A., 1998, *Provenance and technology of Galloroman Terra Sigillata imitations from Western Switzerland.* Ph.D Dissertation. University of Fribourg. Switzerland.

CHAPTER IV

MATERIAUX ET TYPES CÉRAMIQUES À SAINT BLAISE, STATION NÉOLITHIQUE SUISSE: POTERIE EXOGÈNE ET PRODUCTION LOCALE[1].

par Simonpietro DI PIERRO*, Robert MICHEL** & Rémi MARTINEAU*

*Département de Géosciences, Minéralogie et Pétrographie, Université de Fribourg, chemin du Musée 6, Fribourg, 1700 Suisse.
**Service Archéologique Cantonal de Neuchâtel, avenue du Mai 59, Neuchâtel, 2000 Suisse.

Résumé

63 céramiques néolithiques (2770 - 2626 av. J.-C.) provenant du village néolithique de Saint Blaise, Lac de Neuchâtel (Suisse occidentale), ont été pétrographiquement et chimiquement caractérisées. 29 autres céramiques contemporaines provenant du même site et déjà caractérisées lors d'une précédente étude (Benghezal, 1994) ont été inclues. L'étude a permis de différencier trois groupes de poteries. Des corrélations ont été recherchées avec les groupes typologiques existant, en fonction de la répartition spatiale de la poterie à l'intérieur du site.

Un groupe de 10 poteries, caractérisées par leur teneur en Sr et Ba, correspond à une maison du village. L'exploitation d'un gisement d'argile particulier par les habitants de cette maison pourrait être à l'origine de la composition chimique différente des poteries.

Une bonne corrélation a été trouvée entre un groupe de 15 poteries, pétrographiquement et chimiquement distinctes (riches en MgO) et le groupe typologique de la poterie « Cordé vrai ». L'étude morphologique des poteries de ce groupe a montré une forte similitude avec la poterie typique de la Civilisation de la « Céramique Cordée », originaire de Suisse orientale. Les caractéristiques pétrographiques et chimiques sont très proches de celles de la poterie contemporaine de Portalban, un autre site lacustre situé à 15 km. L'analyse multivariée a confirmé l'hypothèse que la poterie riche en MgO et appartenant au groupe de la céramique « Cordé vrai » puisse avoir une provenance hexogène au site de St.Blaise.

Abstract

63 Neolithic (2.770 – 2.626 BC) ceramics from Saint Blaise, Neuchâtel Lake – Western Switzerland, have been studied through petrographic and chemical characterizations. 29 contemporary ceramics coming from the same settlement and already characterized (Benghezal, 1994) have been included. The investigation permitted to clearly distinguish between three pottery groups. Correlations with typological groups and the spatial distribution of pottery have been implemented.

A group of 10 pottery, characteristic for its Sr and Ba chemical content, corresponds to a specific house of the site. This feature would be consistent with the exploitation of a specific clay source by the inhabitants of this house.

Moreover, a good correlation exists between a particular petrographic and chemical group of 15 pottery (MgO rich) with the typological "Cordé vrai" group. This group of pottery was already identified on the morphological basis, for its strong similarities with the pottery of the "Corded Ceramic" Civilization, with origin in Eastern Switzerland. However, the particular petrographic and chemical features are largely similar to the contemporary pottery of Portalban, another dwelling settlement 15 km off Saint Blaise. The statistical analyses have confirmed the hypothesis of an exogenous provenance of the MgO rich, Corded true ceramics of St. Blaise.

---

[1] *Proceedings of the XIVth Congress of the U.I.S.P.P.,Liège, Belgium, 2 – 8 September 2001. British Archaeological Report. In press.*

1. INTRODUCTION

En archéologie, notamment au Néolithique, la céramique est considérée depuis longtemps comme un excellent marqueur chronologique, et l'étude de la poterie est essentielle pour l'identification des différents groupes culturels (i.e. Giligny, 1993). La caractérisation des matériaux céramiques est généralement utilisée pour répondre aux questions relatives à la provenance de la poterie (i.e. Nungässer & Maggetti, 1978 ; Benghezal, 1994 ; Martineau *et al*., 2000), mais l'étude des matériaux permet également de répondre à d'autres problématiques concernant la mise en évidence de successions temporelles (Martineau *et al.* 2000, Martineau, 2000), ou bien la répartition spatiale de groupes de matériaux à l'intérieur d'un site (i.e. Pétrequin *et al*., 1994).

Sur la base des données typologiques et morphométriques des poteries, les archéologues du Néolithique ont parfois envisagé l'hypothèse que des formes ou des épaisseurs différentes entre des poteries pourraient exprimer ou refléter des provenances différentes. Par exemple, les différences morphologiques entre la céramique « grossière » et « fine » du néolithique final de Suisse occidentale avaient permis d'envisager une provenance exogène de la poterie « fine », sur la base des ressemblances avec la poterie « fine » de la France nord orientale (Ramseyer, 1987). Pourtant, l'étude pétrographique et chimique des matériaux avait permis de montrer que les matériaux des poteries « fines » étaient les mêmes que ceux des poteries « grossières » et avaient une même origine locale (Benghezal, 1994).

Dans le cadre d'un projet de recherche concernant la céramique néolithique suisse du site de St. Blaise, fig.1, (Di Pierro, 2002a), nous avons testé les hypothèses suivantes :

1) dans un corpus céramique constitué par différents types morphologiques, est-ce qu'il y a eu l'utilisation de différents types de matériaux (plusieurs argiles et/ou dégraissant)? Dans le cas d'une réponse positive, quelles sont les corrélations qui peuvent être établies entre ces types de poteries et les différents matériaux trouvés ?
2) Existe-t-il une répartition spatiale particulière des poteries, sur la base des données pétrographiques et/ou chimiques ? Autrement dit, peut-on mettre en évidence des exploitations et utilisations de matériaux particulières à l'intérieur du site ? Y a-t-il des différences entre les unités d'habitation ?

La recherche de corrélations entre types morphologiques de la céramique et groupes pétrographiques ou chimiques a été replacée dans le cadre de l'étude des répartitions spatiales à l'intérieur du site. L'objectif était de savoir si le contexte de production des poteries était de type domestique, autrement dit si chaque unité d'habitation fabriquait des poteries, ou si des potiers produisaient pour les autres maisons du village. L'existence d'une production domestique de la poterie devrait (ou pourrait) alors se manifester sous la forme de groupes de poteries dont les matériaux devraient posséder des caractéristiques différentes les uns des autres.

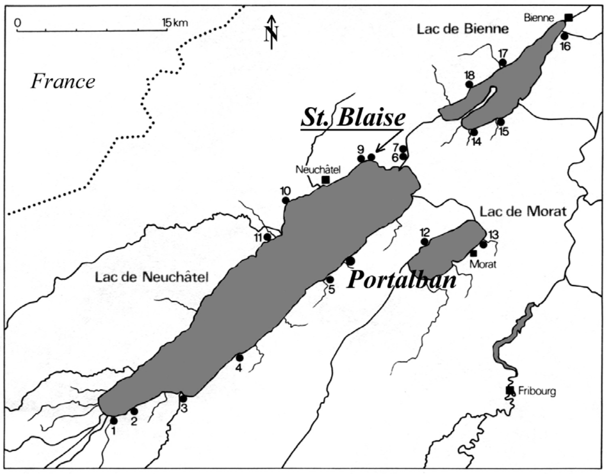


Figure 1. Sites du Néolithique final de la Région des Trois Lacs (Suisse). Le site lacustre de Saint-Blaise/Bain des Dames se trouve sur le côté nord-ouest du Lac de Neuchâtel en Suisse, (d'après Ramseyer, 1987).
1. Yverdon (avenue de Sports). 2. Chéseaux (Châble-Perron). 3. Yvonand. 4. Font. 5. Gletterens. 6. Thielle-Wavre (Thielle-Mottaz). 7. Thielle-Wavre (Pont-de-Thielle). 9. Hauterive (Champréveyres). 10. Auvernier. 11. Cortaillod. 12. Guévaux. 13. Montillier/Muntelier. 14. Vinelz. 15. Lüscherz. 16. Port. 17. Twann. 18. La Neuveville (Schafis).

L'idée d'une production domestique de la poterie au Néolithique final a été avancée à partir de l'étude de la station 2 de Chalain (Pétrequin *et. al*., 1994). Cette idée repose sur l'hypothèse que chaque structure d'habitation exploite des matières premières différentes des autres maisonnées et produit ses propres poteries. Dans le cadre de l'étude du site de St. Blaise, le but est de caractériser les productions par l'étude de la matrice et du dégraissant. L'objectif est de voir si l'analyse des matériaux utilisés pour fabriquer les poteries, permettait de mettre en évidence des productions particulières et différentes d'une maison à une autre.

Dans le cas de corrélations positives ont peut envisager différentes interprétations archéologiques. Ces corrélations peuvent être attribuées soit à :

a) des productions différentes entre les potières pour marquer leur identité culturelle ;
b) des productions différentes entre les maison(s) et les groupes familiaux ;
c) une provenance exogène depuis un autre site.

L'approche multiple concernant la typologie de la poterie, sa répartition spatiale relative aux maisons et la caractérisation chimique et pétrographique des matériaux est fondamentale pour pouvoir tester ces hypothèses.

1.1 Contexte archéologique

Le Néolithique final sur le plateau suisse occidental est compris entre 3300 et 2400 av. J.-C. Cette période comprend trois groupes culturels différents : Horgen, Lüscherz et Auvernier-cordé (i.e. Stöckli, 1995), principalement distingués sur la base des différences typologiques de la poterie.

Le site de Saint-Blaise/Bains des Dames (Canton de Neuchâtel), fouillé de 1986 à 1988 sur le tracé de l'autoroute A5, a livré les vestiges de plusieurs villages qui se sont succédé sur le même emplacement au cours du Néolithique final. Des milliers de recollages entre tessons ont permis de reconstituer des centaines de poteries caractéristiques des complexes culturels Horgen (3250 à 2950 av. J.-C.), Lüscherz (2950 à 2700 av. J.-C.) et Auvernier-cordé (2700 à 2400 av. J.-C.) (Michel, 2002). La fin de la période Lüscherz est marquée dans la Région des Trois Lacs par l'influence de la Civilisation de la « Céramique Cordée », dont l'aire de diffusion va de la Scandinavie au Nord des Alpes, et du lac de Neuchâtel aux plaines de l'Ukraine (Giligny & Michel, 1995).

L'influence typologique de la Civilisation « Céramique Cordée » (« Schnurkeramik » dans la littérature allemande) se manifeste dans le groupe culturel Auvernier/La Saunerie (Ramseyer, 1988). Ces influences de la « Céramique Cordée » ont amené les auteurs à définir le nouveau groupe culturel Auvernier-cordé (Ramseyer, 1987 ; Giligny, 1993).

A St. Blaise la céramique du groupe culturel Auvernier-cordé comprend quatre principaux types morphologiques, tab.1.

Ces quatre types céramiques, fig.2, sont contemporains et ils caractérisent plusieurs sites lacustres du Lac de Neuchâtel, parmi lesquels St. Blaise (Michel, 2002) et Portalban (Giligny, 1993), fig.1.

1.2 Echantillonnage

Pour évaluer ces hypothèses, nous avons échantillonné le corpus céramique et réalisé la répartition spatiale des poteries, à partir d'une approche céramo-stratigraphique (Michel, 2002). Cette approche est basée sur le regroupement des poteries en assemblages. Les remontages des tessons d'une poterie constituent ce qu'on appelle un ensemble. Quand on compare un ensemble à un autre, si sa position stratigraphique est inférieure, alors son dépôt est antérieur ; si sa position est supérieure, alors son dépôt est postérieur, si les 2 ensembles sont au même niveau, alors leurs dépôts sont contemporains.

Tous les ensembles qui se situent dans le même horizon stratigraphique proviennent très probablement de dépôts contemporains (ou très proches dans le temps) et forment alors un assemblage. Un assemblage (dépôt) est cohérent du point de vue spatial et temporel. Chaque assemblage (dépôt) correspond très probablement au dépotoir d'une maisonnée, pour laquelle on peut supposer une identité domestique commune. 63 échantillons appartenant à autant poteries provenant de six assemblages ont été sélectionnées pour cette étude, tab.2a. Quatre assemblages forment chacun un dépotoir en relation avec une maison dont la construction a été datée par la dendrochronologie (Michel, 2002) : assemblage A et maison construite en 2630[2] av. J.-C. , assemblage B et maison datée de 2626 av. J.-C., assemblage C et maison datée de 2626 av. J.-C., assemblage D et maison datée de 2630 av. J.-C., soit des assemblages et des maisons témoignant de la phase Auvernier-cordé moyen. D'autre part, deux assemblages (E et F) constituent deux étapes d'un même dépotoir mis en relation topographique avec une maison construite en 2702 av. J.-C. et habitée au moins jusqu'en 2672 av. J.-C. (dernière phase de réfection), que l'on peut attribuer à la phase Auvernier-cordé ancien. D'un point de vue spatial, le dépotoir de l'assemblage D est superposé au dépotoir lié aux assemblages E et F.

Types morphologiques			Description
1	Cordé vrai	1a) Cordé Z	Céramique à impression de cordelette dont le sens de torsion des empreintes est en Z, ce qui correspond à la définition des céramiques dites « Cordé vrai » (Giligny, 1993).
		1b) Cordon modelé cordé	Céramique dont le décor est constitué par un cordon modelé de type classique pour la Civilisation de la « Céramique Cordée », c'est-à-dire festonné (« Wellenleiste »).
2	Cordé imité	2a) Cordé S	Céramique à impression de cordelette dont le sens de torsion des empreintes est en S, ce qui correspond à la définition des céramiques dites « Cordé imité » (Giligny, 1993).
		2b) Cordon modelé imité	Céramique dont le décor est constitué par un cordon modelé de type atypique pour la Civilisation de la « Céramique Cordée » et que l'on suppose être d'imitation locale.
		2c) Cordon appliqué	Céramique imitant très grossièrement un cordon modelé, interprété comme une imitation locale, réalisée lors de la phase de transition appelée Auvernier-cordé ancien.
3	Auvernier		Céramique typique de la phase Auvernier-cordé moyen (entre 2640 et 2560 av. J.-C.) : la morphologie de type cordé (fond plat et profil sinueux) a été adoptée, mais le décor est différent de celui du type Cordé et constitué de rangées d'impressions digitales ou d'impressions à la baguette (« Einstichverzierte ») sur le col ou sur la lèvre.
4	Transition		Céramique typique de la phase Auvernier-cordé ancien (entre 2700 et 2640 av. J.-C.) : on perçoit à côté des céramiques de tradition Lüscherz à fond arrondi, profil droit et décor de languettes, une transformation, sous l'influence de la Civilisation de la Céramique Cordée, qui se marque par l'apparition de céramiques à fond plat et profil sinueux mais qui conservent encore des languettes.

Tab.1 – Principaux types morphologiques du groupe culturel Auvernier-cordé identifiés à St. Blaise, (Michel, 2002).

---

[2] Les dates dendrochronologiques se réfèrent à la date de la construction des maisons. On sous-entend que chaque maison a été habitée pendant une génération, c'est-à-dire 20 à 30 ans.

Les résultats obtenus sur cette série d'échantillons ont été complétés par 29 échantillons, tab.2b, d'une précédente étude déjà réalisée sur le site de St. Blaise (Benghezal, 1994)[3]. 15 des 29 poteries appartiennent aux six dépotoirs considérés. Au total, le corpus de notre étude est constitué de 92 échantillons (tab.3 & 4).

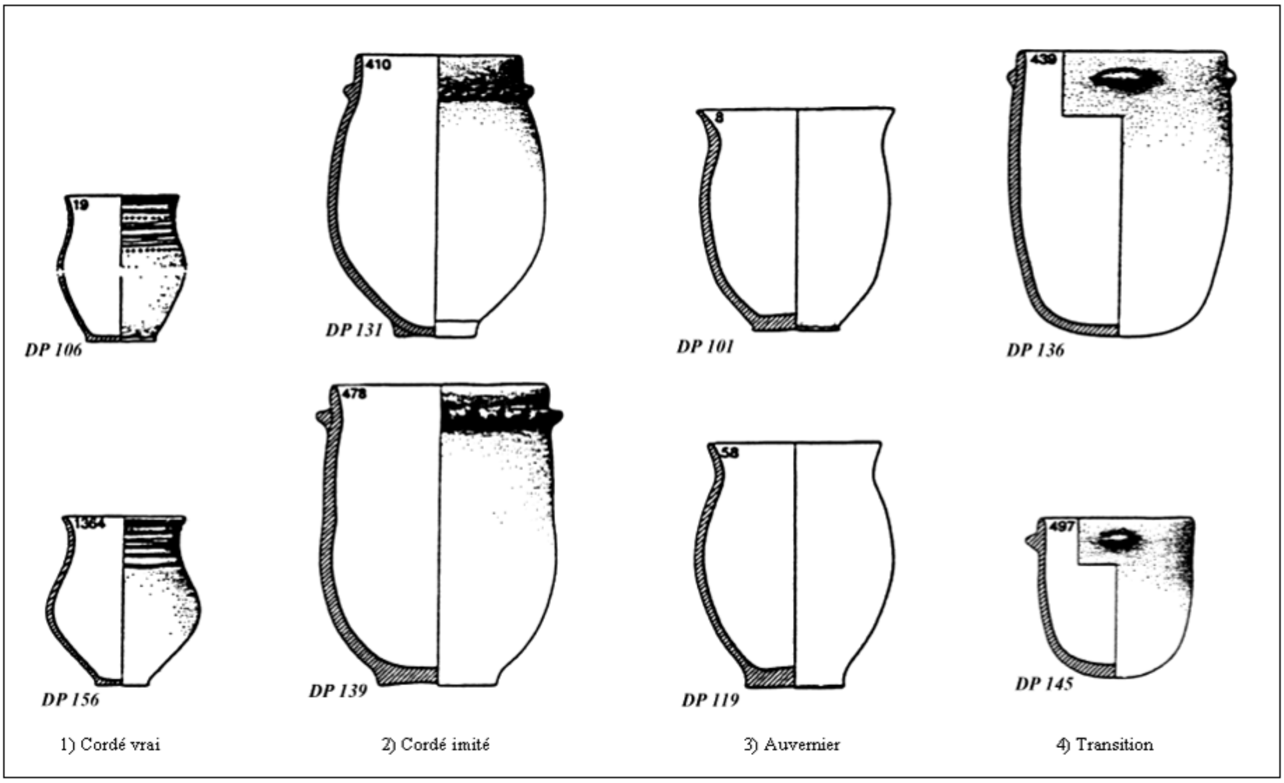


Figure 2 – Types morphologiques de la céramiques des phases Auvernier-cordé ancien et moyen à St. Blaise. Echelle 1:8.

---

[3] Les résultats présentés dans la caractérisation pétrographique et chimique de cet article ne se réfèrent qu'aux 63 échantillons expressément choisis à partir des assemblages/dépotoirs A à F (tab.2a). Les résultats concernant le précédent travail sont publiés dans la thèse de doctorat de Benghezal (1994). 29 poteries seules concernant les périodes Auvernier-cordé ancien et moyen de St. Blaise, faisant partie de ce travail, ont été prises en considération, tab.2b. Les données chimiques relatives sont présentées dans le tab.6b. Les objectifs de la thèse de Benghezal (1994) étaient différents des nôtres, et donc son échantillonnage avait été établi différemment. Cependant, de ces 29 céramiques, 15 appartiennent aux mêmes dépotoirs A à F, et ont, pour cette raison, été intégrées pour permettre une meilleure approche statistique. Les 14 autres poteries appartiennent à 10 autres dépotoirs ou bien à aucun en particulier. Nous n'en tiendrons pas compte pour les corrélations entre chimie et répartition spatiale de la poterie. Cependant, les 29 poteries sont prises en compte pour les corrélations entre chimie et types céramiques.

Numéro d'analyse	**Numérotation archéologique**	Secteur	Carré	Couche	**Assemblage**	**Phase Auvernier-cordé**	**Type morphologique**	**groupe pétrographique**
DP 100	2	758	AB 12	3	A	moyen	Auvernier	Vc
DP 101	8	758	EF 78	3	B	moyen	Auvernier	VIc
DP 102	10	758	CO 34	3	B	moyen	Auvernier	VIc
DP 103	11	758	EF 56	3	B	moyen	Auvernier	IIa
DP 104	15	758	EF 56	3	B	moyen	Cordé S	Vc
DP 105	17	758	LM 12	3	B	moyen	Cordé Z	VIc
DP 106	19	760	G 7	2	B	moyen	Cordé Z	Ia
DP 107	23	758	IK 78	3	B	moyen	Cordon modelé imité	IIb
DP 108	24	758	LM 56	3	B	moyen	Auvernier	Vc
DP 109	25	758	CD 56	3	B	moyen	Cordon modelé imité	VIc
DP 110	26	758	CD 78	3	B	moyen	Auvernier	Vc
DP 111	28	758	EF 12	3	B	moyen	Auvernier	VIc
DP 112	29	758	IK 34	3	B	moyen	Auvernier	VIc
DP 113	30	758	IK 78	3	B	moyen	Auvernier	Vc
DP 114	31	758	LM 12	3	B	moyen	Cordé Z	Vc
DP 115	34	758	AB 34	3	A	moyen	Auvernier	Vc
DP 116	42	658	NO 12/AB 12	3	A	moyen	Auvernier	VIc
DP 117	45	658	NO 34	3	A	moyen	Auvernier	Vc
DP 118	54	658	LM 78	3	A	moyen	Auvernier	Vc
DP 119	58	657	LM 8	3	A	moyen	Auvernier	VIc
DP 120	64	658	IK 78	3	A	moyen	Auvernier	Vc
DP 121	67	658	PQ 12	3	A	moyen	Cordon modelé cordé	Vd
DP 122	72	658	IK 34	3	A	moyen	Auvernier	Vc
DP 124	333	158	A 5	3	E	ancien	Transition	IIa
DP 125	334	257	P 8	3o2	F	ancien	Cordon appliqué	Vc
DP 126	340	258	M 3	3q	F	ancien	Transition	Vc
DP 127	346	758	LM 12	3	B	moyen	Auvernier	Vc
DP 128	377	458	A 3	3p	F	ancien	Transition	VIc
DP 129	402	658	LM 34	3	A	moyen	Auvernier	VIc
DP 131	410	2359	E 7	3F2	E	ancien	Cordon appliqué	VIc
DP 132	411	158	P 3	3c	E	ancien	Cordon appliqué	VIc
DP 133	413	2358	C 8	3F4	E	ancien	Cordon appliqué	Vc
DP 134	416	2357	E 4	3p	F	ancien	Transition	Vc
DP 135	417	157	P 7	3Fb/3Fe	F	ancien	Transition	VIc
DP 136	439	257	E 1/D 1	3r/3n	E	ancien	Transition	IIa
DP 137	469	456	K 5	3h	D	moyen	Cordé Z	Vd
DP 138	475	257	C 5	3k2	F	ancien	Transition	Vc
DP 139	478	257	L 1	3v	F	ancien	Cordon appliqué	VId
DP 140	489	257	H 6	3p	F	ancien	Cordon appliqué	Vc
DP 141	480	257	L 4	3n2	F	ancien	Transition	IIa
DP 142	493	568	NO 12/LM 12	3	C	moyen	Auvernier	VIc
DP 143	494	257	H 5	3p	F	ancien	Cordon modelé cordé	Vc
DP 144	496	159	K 5	3hc	E	ancien	Transition	VIc
DP 145	497	159	L 2	3gd	E	ancien	Transition	IIa
DP 146	501	256	M 5	3f	F	ancien	Transition	IIa
DP 147	506	256	E 8	3L	F	ancien	Cordon modelé imité	Vc
DP 148	521	256	E 7	3L	F	ancien	Transition	Vc
DP 149	536	256	G 8	3L	F	ancien	Transition	Vc
DP 150	550	256	K 8	3m	F	ancien	Transition	Vd
DP 151	555	256	M 7	3k2	F	ancien	*Transition*	IXc
DP 152	812	258	K 5	3L	E	ancien	Cordon modelé imité	IIa
DP 153	940	258	Coupe Nord		F	ancien	Transition	VIc
DP 154	1000	256	K 6	3m	F	ancien	Cordé Z	IIa
DP 155	1005	257	G 5	3k2	F	ancien	Transition	Vc
DP 156	1364	568	K 3	3	C	moyen	Cordé Z	Ib
DP 157	1365	568	K 2	3	C	moyen	Auvernier	Vc
DP 158	1369	568	O 4	3	C	moyen	Auvernier	VIc
DP 159	1370	568	P 2	3	C	moyen	Cordon modelé imité	Vc
DP 160	1371	568	P 3	3	C	moyen	Auvernier	VIc
DP 161	1372	568	O 5	3	C	moyen	Auvernier	Vc
DP 162	1382	759	IK 78	3	B	moyen	Auvernier	Vc
DP 163	1383	567	L 8	3a	C	moyen	Auvernier	IIa
DP 164	1386	568	Q 4	3	C	moyen	Auvernier	IIb

Tab.2a - Liste d'échantillons (DP = analyses Di Pierro)

Numéro d'analyse	Numérotation archéologique	Assemblage	Phase Auvernier-cordé	Type morphologique
AB 156	328	F	ancien	Cordon appliqué
AB 157	500	F	ancien	Transition
AB 158	406	E	ancien	Cordon modelé cordé
AB 159	349	E	ancien	Cordé Z
AB 160	466	F	ancien	Cordé Z
AB 161	441	D	moyen	Auvernier
AB 163	344	4T28	ancien	Transition
AB 164	503	2A47	moyen	Auvernier
AB 165	578	D	moyen	Auvernier
AB 166	582	4A45	moyen	Auvernier
AB 167	581	D	moyen	Cordé S
AB 172	476	2A39	moyen	Auvernier
AB 174	335	1T31	ancien	Cordon appliqué
AB 179	429	E	ancien	Cordé Z
AB 180	27	B	moyen	Auvernier (fine)
AB 181	397	aucun	moyen	Auvernier (fine)
AB 182	393	aucun	moyen	Auvernier (fine)
AB 183	534	E	ancien	Transition
AB 184	418	1T33	ancien	Cordon appliqué
AB 185	419	E	ancien	Transition
AB 186	474	2A68	moyen	Auvernier
AB 187	428	1T30	ancien	Cordé Z
AB 188	398	E	ancien	Transition
AB 189	407	D	moyen	Auvernier
AB 190	511	1T25	ancien	Cordon modelé cordé
AB 191	351	2A47	moyen	Cordon modelé cordé
AB 192	432	F	ancien	Transition
AB 193	540	2A39	moyen	Cordon modelé cordé
AB 194	440	2A66	moyen	Cordé S

Tab.2b – Liste d'échantillons de A. Benghezal (1994).

Assemblage	Phases Auvernier-cordé	Date[2]	Benghezal (1994)	Cette étude	Total
A (6A42*)	moyen	2630	-	10	10
B (7A43*)	moyen	2626	1	16	17
C (8A44*)	moyen	2626	-	9	9
D (4A40*)	moyen	2630	4	1	5
E (2T26*)	ancien	2672	6	8	14
F (2T32*)	ancien	2702	4	19	23
			15	**63**	**78**
Autres (tab.2b)	ancien et moyen		14	-	14
Total			29	63	92

Tab.3 - Nombre et répartition des échantillons par étude et par assemblage. Le signe *correspond à la numérotation des fouilles archéologiques des dépotoirs (Michel, 2002).

Types morphologiques		Phases Auvernier-cordé	Benghezal (1994)	Cette étude	Total
1	Cordé vrai	ancien et moyen	8	8	16
2	Cordé imité	ancien et moyen	5	12	17
3	Auvernier	moyen	10	26	36
4	Transition	ancien	6	17	23
	Total		**29**	**63**	**92**

Tab.4 - Nombre et répartition des échantillons par étude et par types morphologiques.

1.3 Contexte géologique

Plusieurs travaux concernant la géologie de la région de St. Blaise ont été publiés (i.e. Portmann, 1955 ; 1966 ; Bourquin *et al.*, 1968 ; Suter & Lüthi, 1969). Géographiquement, St. Blaise se trouve au pied de la chaîne du Jura, sur la côte nord-ouest du Lac de Neuchâtel. Le soubassement affleurant est composé par des formations calcaires d'âge Crétacé inf. (Urgonien inf. et Hauterivien sup. – Pierre jaune de Neuchâtel) ; des lambeaux sporadiques de marne et grès d'âge Tertiaire (Molasse d'eau douce inf.) affleurent aussi. Le site est entouré par des formations quaternaires qui varient entre des dépôts morainiques d'âge würmien et des dépôts alluviaux plus récents (Suter & Lüthi, 1969). Dans les dépôts morainiques, plusieurs éléments de roches cristallines tels que granites, quartzites, gneiss et serpentinites ont été signalés. Leur origine est clairement alpine et leur provenance dérive des unités Helvétiques et Pénniques internes des Alpes ; ces éléments ont été transportés par le Glacier du Rhône sur le Plateau Suisse (Portmann, 1955 ; 1966).

1.4 Méthodes d'étude

Pour la caractérisation pétrographique, des lames minces standard (30 µm d'épaisseur) ont été préparées pour tous les tessons de céramiques et observées au microscope optique en lumière polarisée (Leitz Laborlux 11 Pol). Le volume de dégraissant a été estimé à partir des tables de comparaison proposées par Matthew *et al.* (1991).

Les échantillons broyés dans une meule de carbure de tungstène ont été analysés au Diffractomètre rayons X (XRD) Philips PW 1800 (radiation Cu Kα) dans l'intervalle 2-65° 2θ, pour déterminer la composition de la matrice et du dégraissant (logiciel X-Pert Organiser).

Les analyses chimiques en fluorescence (XRF) concernent neuf éléments majeurs y compris le Fe^{3+}_{tot} exprimés en poids pourcentage (%pd) et onze éléments traces exprimés en ppm, mesurées avec le Spectromètre rayons X Philips PW 2400. L'erreur est du 1% pour les éléments majeurs et du 10% pour les éléments traces. Les pastilles pour la fluorescence ont été préparées selon la procédure décrite par Zanco (1998). Le FeO %pd a été mesuré en utilisant le protocole dipyridil et le Spectrophotomètre Philips Pye Unicam PU 8650 ; CO_2 et H_2O %pd ont été obtenus avec un Déterminateur de Carbone Multiphases (Leco RC 412).

Une série de 18 échantillons a été choisie parmi les plus significatifs, à partir de les 63 poteries de cette étude, pour séparer leurs composants principaux, matrice et dégraissant, selon la technique de séparation par l'attaque avec H_2O_2 décrite dans Di Pierro (2002c). Les composants séparés ont été analysés chimiquement (XRF) selon la procédure sus-mentionnée.

Le traitement statistique des données chimiques globales a été effectué par « cluster analysis » (classification ascendante hiérarchique) (Average-linkage – Squared Euclidean distances) et par l'analyse discriminante (DA). Les deux types d'analyses considèrent les données en $\log_{10}$, et tous les éléments majeurs et traces ont été pris en compte.

1.5 Terminologie

La description et caractérisation pétrographique des lames minces reprend la terminologie courante (i.e. Maggetti, 1982 ; Nungässer *et al.*, 1985 ; Whitbread, 1986).

Pour l'identification du matériel non plastique et distinguer entre les inclusions naturelles et le dégraissant ajouté, nous avons utilisé les paramètres suivants (Maggetti, 1994) ;

1) inclusions naturelles : a) distribution granulométrique unimodale, b) diamètre ou longueur principale inférieur à 1 mm (Di Pierro, 2002a), c) forme arrondie à sub-anguleuse de grains ;
2) dégraissant ajouté : a) distribution granulométrique bimodale, b) diamètre ou longueur principale supérieur à 1 mm (Di Pierro, 2002a), c) forme anguleuse à sub-anguleuse de grains de roche à composition silicatée, forme sub-anguleuse à arrondi pour les grain de roche à composition carbonatée ;

Selon le pourcentage d'inclusions naturelles (%volume), les différents types de matrices ont été réparties en plusieurs catégories : grasses (0 à 5%), sableuses (5 à 10%) et maigres (10 à 15%).

2. CARACTÉRISATION

Du point de vue macroscopique, les tessons étudiés sont relativement homogènes. L'épaisseur de la paroi varie entre 7 et 16 mm, avec une moyenne autour de 10 mm. La couleur externe est normalement beige ou rouge, mais certains tessons se présentent gris ou complètement noirs. Un gradient de couleur est fréquent. Il varie entre une portion externe plus rougeâtre et une interne plus grise. Une couche noire très mince de résidus organiques est fréquente aussi.

2.1 Analyses pétrographiques

2.1.1 Microscopie optique

Matrice

Sur la base de la composition on distingue trois types de matrice : une matrice calcaire, une matrice calco-silicatée et une matrice silicatée, tab.5a.

L'échantillon DP 151 est le seul qui possède une matrice calcaire, c.à.d. de nature marneuse avant la cuisson.

Dans les matrices calco-silicatées les inclusions naturelles non plastiques (de taille inférieur à 1 mm) sont constituées principalement par des grains de quartz et de calcaire. Ces derniers sont présents sous forme de roche carbonatée ou de monocristaux de calcite, et peuvent constituer jusqu'a 15% en volume. Des monocristaux de feldspaths, de muscovite et d'épidote sont également présents, dans une moindre proportion.

En revanche, le matériel calcaire est totalement absent ou très rare dans les matrices silicatées. Dans ce cas, quartz, feldspath, muscovite, épidote, hornblende et titanite composent les inclusions naturelles non plastiques.

Des fragments de roche argileuse (pellets ou ARF, Whitbread, 1986), rouge ou noir, se trouvent inclus dans les matrices silicatées et calco-silicatées. Les échantillons suivants (DP 106, 107, 124, 130, 131, 140, 142, 145, 148, 153, 154, 162 et 164) présentent une matrice partiellement ou totalement optiquement isotrope.

Sur la base de la quantité en volume des inclusions naturelles non plastiques, on distingue trois types de matrices : grasse (10 échantillons soit le 16%), sableuse (13 soit le 21%) et maigre (40 soit le 63%). Les matrices calco-silicatées et maigres prédominent pour la poterie étudiée.

Dégraissant

Deux tessons (DP 106 & 156, fig.3) ne présentent pas d'inclusions non plastiques de taille supérieure à 1 mm. Ils sont constitués uniquement par une matrice maigre où la distribution unimodale des inclusions naturelles non plastiques est très évidente. Pour cinq autres tessons (DP 116, 119, 124, 142 & 145), malgré la présence de quelques grains de roche de diamètre supérieur à 1 mm, on observe l'absence de distribution bimodale du dégraissant.

En revanche, pour toutes les autres céramiques on observe clairement la distribution bimodale du dégraissant. Les grains de roche de taille supérieur à 1 mm constituent en moyenne entre 10 et 20% en volume des tessons, fig.3. La majorité de ces grains a un diamètre ou une longueur principale de 2-3 mm, mais ils dépassent aussi les 7 mm.

Selon la composition pétrographique on observe deux types de dégraissants (grains de roche de taille supérieur à 1 mm), tab.5a.

Le dégraissant plus abondant, présent dans toutes les lames minces sauf les deux sus-mentionnées, est un métagranite à épidote et stilpnomélane (fig.4a-b) Les grains de roche ont une forme principalement anguleuse à sub-anguleuse. Le granite comprend l'association minéralogique suivante : quartz, feldspath alcalin et plagioclase parmi les minéraux principaux ; biotite, hornblende, muscovite, clinozoïsite et épidote parmi les phases secondaires. Titanite, apatite, zircon, calcite, zoïsite, chlorite et stilpnomélane constituent les minéraux accessoires présents en quantité et fréquence très variables. Quartz, feldspaths, biotite et hornblende témoignent de la paragenèse magmatique encore visible au niveau de la texture. La composition plutôt sodique du plagioclase (An_{15-30}), la clinozoïsite, l'épidote, la transformation en chlorite de la biotite et la présence de stilpnomélane indiquent que ce lithotype a clairement subi un événement métamorphique correspondant aux conditions du faciès schistes verts.

Le stilpnomélane à été identifié dans 19 lames minces, fig.5. Dans plusieurs cas il a été observé sur différents grains de la même lame, soit au total sur 29 morceaux de granite différents.

Les paragenèses sus-mentionnées ont été décrites dans la littérature pétrographique et correspondent au granite à stilpnomélane du Mont Blanc (Von Raumer ; 1967 ; 1969 ; 1984 ; Marro, 1986 ; Bussy, 1990).

Le deuxième type de dégraissant (> 1 mm) se présente sous forme de grains de roches carbonatées comme les calcaires, calcaires oolitiques et monocristaux de calcite, fig.4a. Dans la plupart des cas, ils ont une forme plutôt arrondie, rarement sub-anguleuse. Ce type de matériel n'a été observé que dans 19 lames minces. Dans les cas où il est présent, il est quantitativement fortement subordonné au premier type de dégraissant, le granite du Mont Blanc. Le matériel carbonaté ne constitue finalement que 5 à 10% du total du dégraissant (> 1mm).

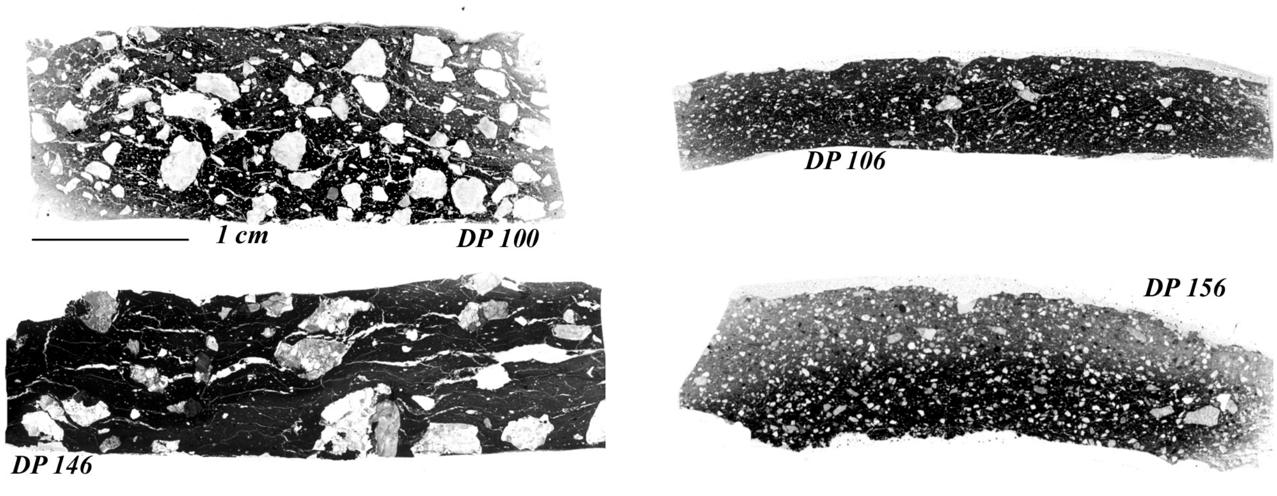


Figure 3. Photos de lames minces de tessons caractéristiques. Dans celles de gauche, la distribution bimodale en termes de taille des inclusions non plastiques et la forme sub-anguleuse des morceaux de roche indiquent la présence de dégraissant ajouté à la céramique. L'échantillon DP 100 présente une matrice sableuse, DP 146 au contraire une matrice plutôt grasse. Par contre dans les photos de droite, tessons DP 106 et DP 156, on observe l'absence systématique de dégraissant ajouté. Les céramiques sont composées dans ce cas par une matrice maigre uniquement.

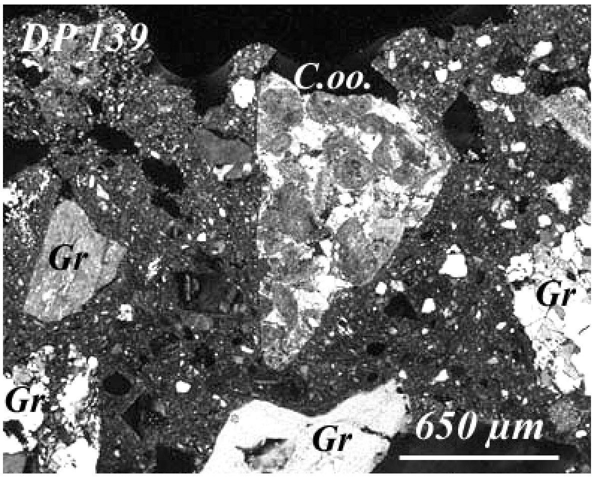


Figure 4a. Photo de lame mince, lumière polarisée, DP 139. Inclusions granitiques (Gr) ajoutées à une matrice sableuse. Des morceaux de roches carbonatées, comme ici un calcaire oolitique (C.oo.), sont souvent présents dans la poterie.

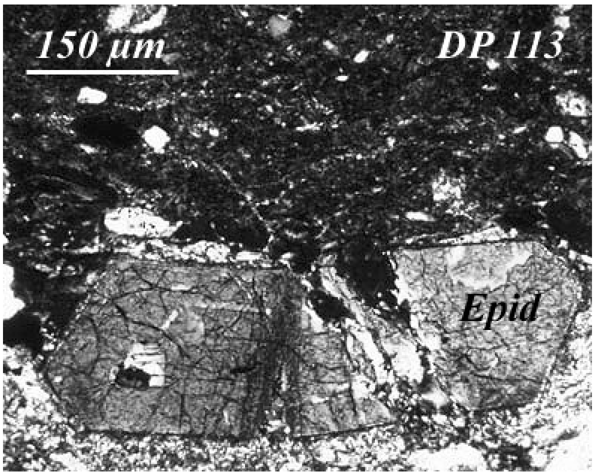


Figure 4b. Photo de lame mince, lumière polarisée, DP 113. L'épidote (Epid) est un minéral accessoire fréquent du granite ajouté à la poterie de St.Blaise.

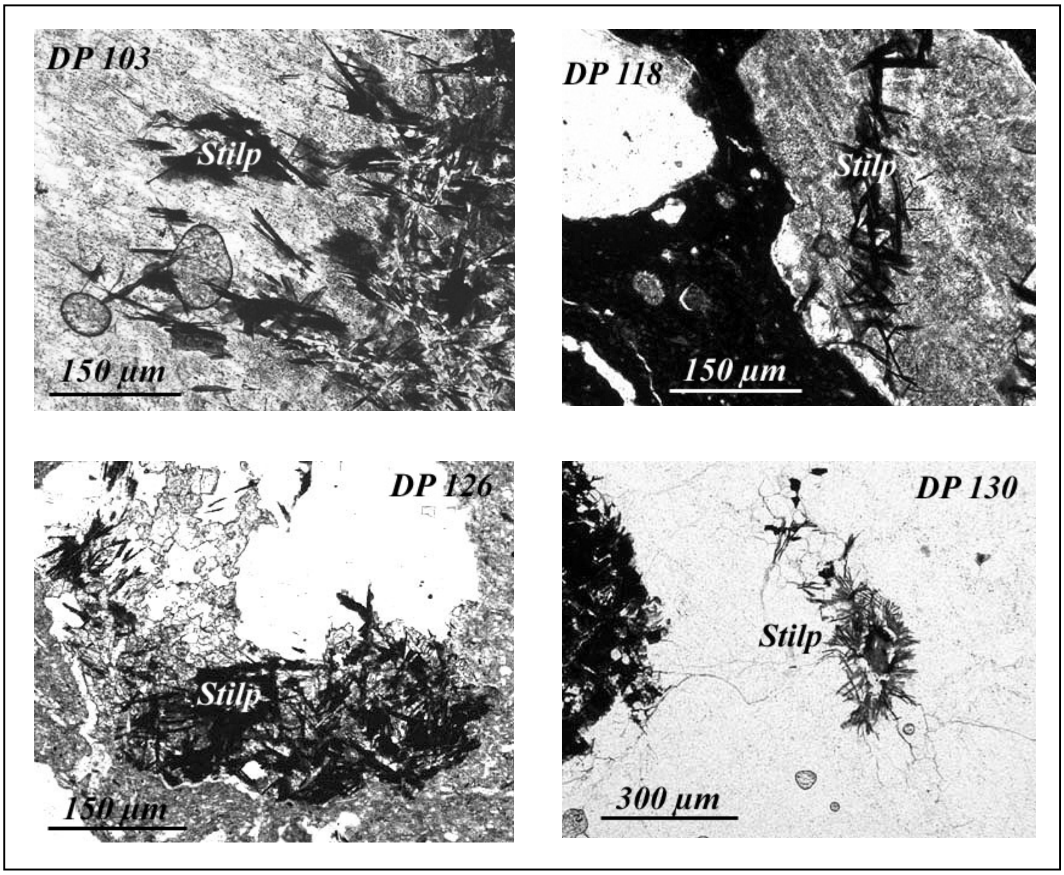


Figure 5. Photos de lames minces, lumière polarisée. Le stilpnomélane (Stilp) est un minéral accessoire fréquent dans les grains de granite de la céramique de St.Blaise. Sa présence est un indicateur pétrographique précis permettant d'identifier ces fragments comme du granite du Mont Blanc (Von Raumer, 1969).

L'analyse du tesson DP 151 a permis de mettre en évidence une forte proportion de matériel calcaire. Morceaux de roches carbonatées, calcaires oolitiques et fossiles de *turritella* distinguent clairement cette céramique du reste du corpus. La même céramique a été dégraissée par l'ajout de granite du Mont Blanc aussi.

Dans quatre tessons (analyses DP 102, 106, 113, 164) on observe aussi de rares morceaux de charbon de bois.

Lorsqu'on peut observer clairement la distribution bimodale en terme de taille des inclusions non plastiques, les morceaux de granite du Mont Blanc de taille supérieure à 1 mm et de forme anguleuse à sub-anguleuse sont interprétés comme du dégraissant intentionnellement ajouté. Pour les mêmes raisons, le matériel calcaire de taille supérieure à 1 mm est considéré comme du dégraissant ajouté aussi.

Le tab.5a résume les principaux groupes pétrographiques identifiés en microscopie optique. 97% de la poterie étudiée a été intentionnellement dégraissée. 65% des tessons montrent l'ajout du granite du Mont Blanc seulement. 32% présentent les deux types de dégraissants ajoutés : le granite et les autres matériels carbonatés, calcaires, calcaires oolitiques et cristaux de calcite. Deux tessons seulement, soit 3% du total, ne présentent que du dégraissant naturel. Les groupes pétrographiques V et VI (matrice calco-silicatée avec ajout de granite et/ou carbonate) représentent 78% du corpus céramique étudié.

2.1.2 Diffractométrie des rayons X

Les fig.6a-b montrent deux spectres d'analyse qualitative XRD typiques de la poterie de St.Blaise. Au-delà de la présence du quartz et des feldspaths qui viennent de la matrice et du dégraissant, comme déjà observé en lame mince, la plupart de la céramique contient de la calcite, par ex. fig.6a. Un groupe de céramique ne contient pas de matériel carbonaté du tout, par ex. fig.6b. Dans la plus part de la céramique, 56 tessons, soit à matrice calco-silicatée que à matrice silicatée, le seul minéral argileux identifié est l'illite. La chlorite a été identifiée dans 7 tessons uniquement, tab.5b.

	Association de phases	n	
a	**illite**	10	16%
b	**illite & chlorite**	3	5%
c	**illite & calcite**	46	73%
d	**illite, calcite & chlorite**	4	6%
	total	63	

Tab.5b – Synthèse des association des phases de la matrice (XRD).

Le tab.5b résume les associations des phases présentes dans les différentes sortes de matrices. Les groupes a et b du tab.5b correspondent aux matrices silicatées du tab.5a. Les groupes c et d aux matrices calcaires et calco-silicatées. La présence de chlorite peut être due à une composition minéralogique différente des argiles, ou bien à des températures de cuisson de la poterie différentes de la même argile. La chlorite en effet devient instable dans l'intervalle de température compris entre 670 et 720°C (Maggetti, 1982).

Matrices	Dégraissant									totaux	
	non ajouté			ajouté							
				granite			**granite + carbonate**				
	n		groupe pétro.	n		groupe pétro.	n		groupe pétro.	n	
silicatée	2	3%	I	11	17.5%	II	-	-	III	13	20.5%
calco-silicatée	-	-	IV	30	47.5%	V	19	30.5%	VI	49	78%
calcaire	-	-	VII	-	-	VIII	1	1.5%	IX	1	1.5%
totaux	2	3%		41	65%		20	32%		63	

Tab.5a – Synthèse des groupes pétrographiques (microscopie optique).

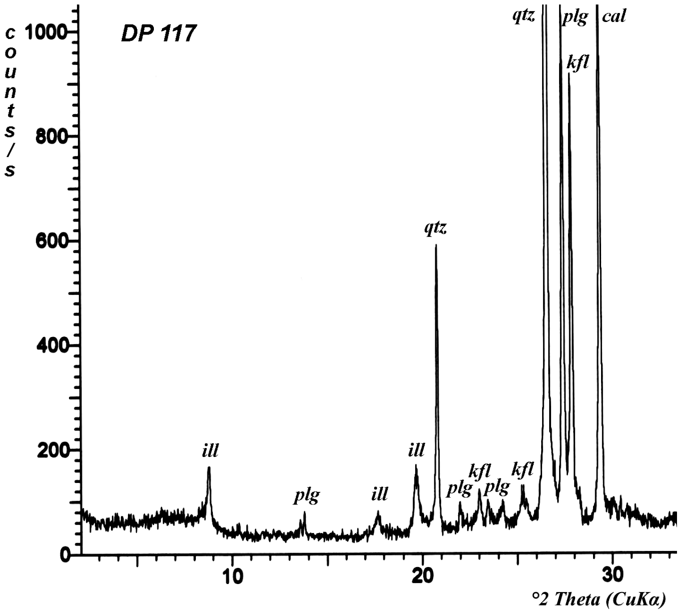


Figure 6a. Spectre de diffraction XRD de la céramique DP 117. Exemple typique d'une poterie de St.Blaise (ill=illite, qtz=quartz, plg=plagioclase, kfl=feldspath potassique, cal=calcite). La calcite est le minéral dominant qui caractérise la matrice calcaire utilisée pour la production de la céramique. Dans ce cas, les feldspaths sont quantitativement importants car ils témoignent de la présence du dégraissant ajouté granitique.

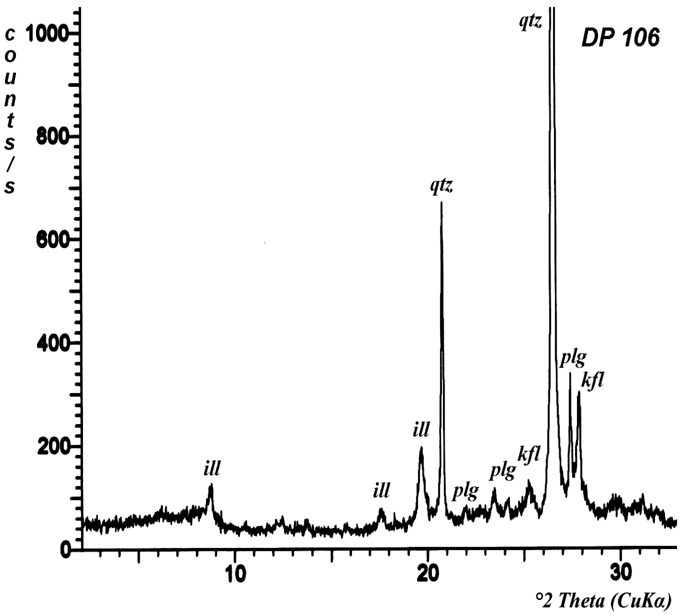


Figure 6b. Spectre de diffraction XRD de la céramique DP 106 (ill=illite, qtz=quartz, plg=plagioclase, kfl=feldspath potassique). Les carbonates sont absents, les minéraux détectés proviennent uniquement de la matrice, le pot n'ayant pas été dégraissé.

2.1.3 Groupes minéralo-pétrographiques

Pour résumer, sur le plan pétrographique nous avons identifié au moins deux grands groupes : (i) la poterie fabriquée à partir d'une argile (matrice) silicatée à illite (et/ou à illite et chlorite) et (ii) la poterie produite à partir d'une argile (matrice) calco-silicatée à illite & calcite (et/ou illite, calcite & chlorite). A l'intérieur de ces deux groupes on peut distinguer la céramique dégraissée par l'ajout du granite du Mont Blanc seul et celle qui contient du granite et du matériel carbonaté. Deux poteries, DP 106 et 156, constituent des exceptions. Leur matrice est silicatée et elles n'ont pas été dégraissés intentionnellement. C'est aussi le cas de la céramique DP 151, composée par une matrice calcaire, de composition marneuse et riche en fossiles. Le tab.5c résume les résultats principaux.

	Description	n		groupes pétrographiques	analyses
1	Matrice calco-silicatée avec MB et/sans carbonates	49	78%	Vc, Vd, VIc, VId	Voir Tab.2a
2	Matrice silicatée avec MB	11	17.5%	IIa, IIb	Voir Tab.2a
3	Matrice silicatée seulement	2	3%	Ia, Ib	DP 106 & DP 156
4	Matrice calcaire avec MB, calcaire et fossiles	1	1.5%	IXc	DP 151
	total	63	100%		

Tab.5c – Groupes minéralo-pétrographiques. MB = granite du Mont Blanc.

2.2 Analyses chimiques

2.2.1 Contamination

Le tab.6a montre les analyses chimiques des 63 poteries de St.Blaise concernant cette étude. La teneur moyenne de P_2O_5 est de 0.35 %pd, sa déviation standard σ_1 est de 0.18. Ces valeurs sont dans l'intervalle de 0.2 à 0.5 %pd indiqué par Collomb & Maggetti (1996) comme teneur maximale de phosphore présent dans les argiles et les sols. Malgré quelques poteries présentant des teneurs en P_2O_5 entre 0.5 et 0.8 %pd, les valeurs nous permettent d'exclure qu'il y ait eu contamination de la céramique pendant l'enfouissement dans le sol (Lemoine & Picon, 1982), et qu'il y ait eu fixation importante d'éléments externes à l'environnement, due à la percolation des eaux (Picon, 1991). Cependant, certaines poteries présentent des valeurs anomales d'enrichissement en Sr et Ba, éléments normalement considérés comme très mobiles (i.e. Picon, 1987). Des considérations plus approfondies sur cette question seront reprises lors de la discussion sur les matériaux, voir para. 3.1.

2.2.2 La poterie

L'étude précédente de Benghezal (1994) avait permis d'établir deux grands groupes de références de la céramique néolithique de la région des Trois Lacs. Sur la base de la teneur en CaO fixée à 5 %pd, elle distinguait la céramique appartenant au groupe CH 36 (< 5 %pd) et au groupe CH 37 (> 5 %pd) à l'échelle du plateau suisse occidental. Cette répartition ne permettait pas la distinction de groupes particuliers au sein du corpus de St. Blaise (Benghezal, 1994).

La fig.7a montre l'histogramme concernant les teneurs de CaO %pd répartis selon les nombres de poteries de cette étude. On observe une distribution de type gaussienne, avec des valeurs comprises entre 0 et 10 %pd et un maximum égal à 5 %pd de CaO. La répartition entre les deux groupes de références CH 36 et CH 37 ne permet donc pas d'établir un réel résultat. Par contre, la fig.7a montre la présence de trois poteries qui se distinguent de l'ensemble du corpus. La céramique DP 151, déjà mise en évidence lors de la caractérisation pétrographique, a une teneur en CaO de 25.91 %pd, c'est-à-dire cinq fois plus importante que la moyenne du reste de la poterie (5.63 %pd). La teneur correspondante de CO_2 est de 27.24 %pd, deux fois et demie plus grande que la moyenne du reste de la céramique (10.71 %pd). Ces valeurs reflètent la présence quantitativement élevée de matériel carbonaté, déjà observée en microscopie optique et confirme l'anomalie de la composition de cette céramique par rapport aux autres, ainsi que sa classification dans un groupe pétrographique distinct (IXc, tab.2a). Les poteries DP 125 et DP 150 présentent elles aussi une différence significative de la teneur en CaO %pd, mais moins importante par rapport à la céramique précédente. Pour ces deux poteries on peut également corréler cette teneur plus élevée en CaO avec une quantité plus significative de matériel carbonaté composant la matrice calco-silicatée (groupe pétrographique Vc et Vd respectivement, tab.2a).

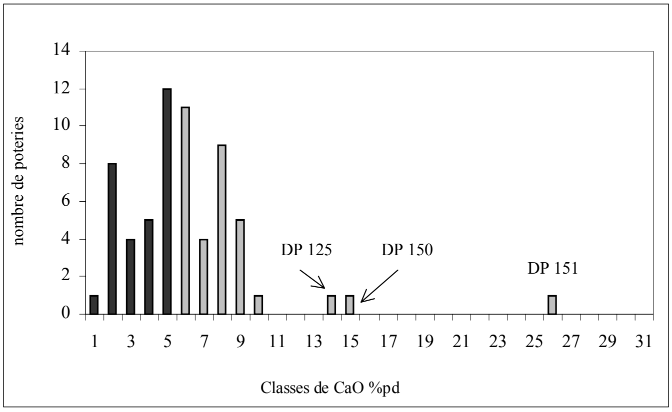


Figure 7a - Histogramme des classes de CaO %pd par nombre de poteries. La limite de 5 %pd de CaO fixée par Benghezal (1994) pour les groupes de références CH 36 (en noir) et CH 37 (en gris) établis pour la céramique néolithique à l'échelle de la région de Trois Lacs, n'est pas significative pour le site de St. Blaise et la poterie de cette étude.

La fig.7b montre un diagramme de corrélation entre Cr et MgO. Deux groupes chimiques sont mis en évidence sur le graphique. Si l'on considère la teneur en MgO, on observe que la plupart de la céramique oscille entre 0.67 et 1.29 %poids et que sept poteries montrent des teneurs deux fois plus élevées, comprises entre 1.92 et 2.48 pd%. Cette différence est à notre avis très importante car ce groupe contient les céramiques DP 106 et DP 156, déjà distinguées pétrographiquement comme des poteries à matrice silicatée et sans dégraissant ajouté (groupes pétrographiques Ia et Ib, tab.2a et tab.5c).

La fig.7b montre aussi que les sept poteries riches en MgO présentent une corrélation positive entre cet oxyde et le Cr. Cette corrélation est due à la présence de minéraux à composition magnésienne, provenant de roches à composition basique ou ultrabasique, et se trouvant dispersés dans les matrices silicatées de ces sept céramiques.

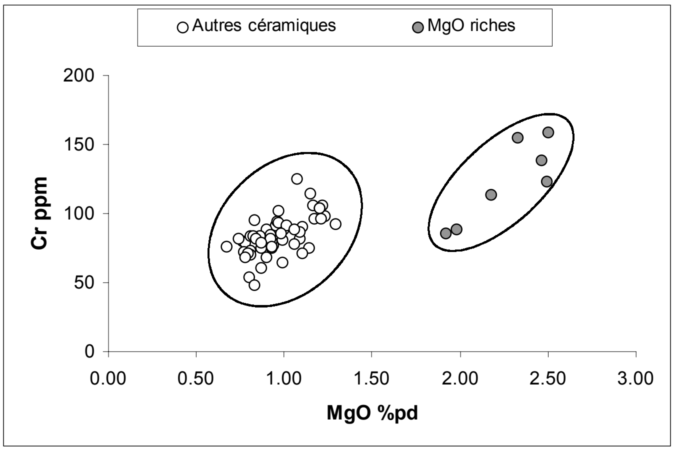


Figure 7b. Diagramme de corrélation Cr - MgO. Il existe une corrélation positive à l'intérieur du groupe de poteries riches en MgO, entre Cr et Mg.

	SiO_2	TiO_2	Al_2O_3	Fe_2O_3t	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	Ba	Cr	Cu	Nb	Ni	Pb	Rb	Sr	V	Y	Zn	Zr	Somme	CO_2	H_2O^+	FeO
DP 100	64.98	0.64	17.82	4.78	0.03	0.94	4.76	1.91	3.70	0.15	617	77	6	32	43	26	205	579	102	50	155	174	99.92	8.72	5.11	1.11
DP 101	61.06	0.73	18.26	6.15	0.03	1.22	7.91	1.01	3.27	0.18	741	106	12	22	55	26	181	423	140	35	170	184	100.03	12.10	6.93	1.21
DP 102	67.92	0.46	14.09	2.73	0.04	0.76	8.40	1.75	2.99	0.37	455	80	24	21	55	17	205	632	82	41	138	155	99.70	13.16	6.13	1.36
DP 103	64.49	0.66	18.42	4.80	0.03	1.00	3.30	1.75	4.57	0.29	921	88	14	27	49	28	237	732	123	43	163	178	99.57	9.38	5.58	1.65
DP 104	63.91	0.69	18.20	5.21	0.03	1.09	4.58	1.75	3.76	0.18	697	82	11	22	41	27	221	470	117	38	157	174	99.59	9.24	5.94	1.75
DP 105	60.49	0.76	18.49	5.90	0.02	1.16	8.36	0.92	3.18	0.18	575	106	7	23	56	29	183	581	147	36	180	195	99.68	16.35	8.06	1.86
DP 106	69.86	0.67	15.34	6.59	0.03	2.50	0.96	0.92	2.96	0.10	474	159	12	15	67	26	144	269	122	20	204	166	100.09	16.83	7.13	2.85
DP 107	66.43	0.61	16.20	6.15	0.05	2.49	2.43	1.52	3.85	0.16	391	123	12	17	57	29	245	259	114	40	181	141	100.06	15.07	7.11	2.47
DP 108	65.18	0.69	18.50	5.44	0.03	0.95	4.25	1.55	3.45	0.20	556	91	15	20	46	30	179	343	123	36	167	200	100.43	7.22	6.22	1.20
DP 109	65.77	0.61	14.86	6.02	0.02	0.96	7.04	0.72	2.80	0.56	642	94	15	13	103	32	120	408	159	32	246	165	99.55	17.60	8.01	2.07
DP 110	64.93	0.64	17.17	4.20	0.03	0.78	6.32	1.58	3.53	0.21	576	79	6	23	40	24	216	386	111	40	145	179	99.58	9.05	5.30	1.16
DP 111	63.14	0.64	16.94	4.96	0.04	0.97	7.86	1.50	3.23	0.22	499	93	8	20	55	27	205	457	117	36	168	158	99.68	8.32	5.50	0.95
DP 112	62.69	0.71	17.84	5.26	0.03	1.23	7.01	1.23	3.25	0.19	618	98	36	18	56	26	174	637	130	31	170	180	99.65	14.00	7.06	1.85
DP 113	66.27	0.58	17.00	4.60	0.03	0.87	4.34	1.86	3.65	0.16	616	75	16	16	42	25	161	413	105	28	156	153	99.53	8.80	5.44	1.42
DP 114	61.28	0.71	17.77	5.52	0.02	1.17	8.26	0.92	3.44	0.27	613	96	5	17	52	27	169	514	142	30	170	173	99.55	11.88	6.53	1.02
DP 115	65.02	0.67	18.03	5.06	0.03	0.99	5.04	1.43	3.46	0.21	728	81	10	14	43	25	149	640	134	27	161	171	100.26	12.76	6.95	1.95
DP 116	62.68	0.70	16.32	5.63	0.03	1.01	8.78	1.02	2.81	0.42	811	91	24	18	69	26	130	772	153	29	189	193	99.64	13.09	6.35	1.72
DP 117	61.89	0.65	16.99	5.48	0.03	1.10	8.52	1.45	2.87	0.17	556	90	6	16	48	25	153	450	122	30	161	183	99.33	10.70	5.89	1.46
DP 118	63.02	0.69	18.66	5.23	0.05	1.09	6.00	1.67	3.37	0.32	763	87	10	19	50	30	157	600	139	30	178	188	100.32	9.75	5.99	1.32
DP 119	67.64	0.60	16.42	4.37	0.02	0.81	4.38	1.59	3.85	0.29	660	73	10	17	45	21	200	676	108	35	158	156	100.19	8.39	4.68	0.78
DP 120	67.27	0.60	17.73	4.74	0.03	0.87	3.19	1.80	3.70	0.26	663	83	33	33	42	27	242	596	111	53	167	169	100.42	7.55	5.64	1.05
DP 121	61.47	0.77	18.88	5.89	0.03	1.21	7.09	1.16	3.06	0.16	614	96	3	21	53	27	161	574	134	34	175	189	99.93	8.69	6.59	1.17
DP 122	66.14	0.65	17.39	5.00	0.03	1.14	3.59	1.77	3.97	0.28	739	75	16	21	44	20	185	615	119	33	160	187	100.18	8.17	5.66	1.20
DP 124	68.98	0.56	15.90	3.85	0.04	0.77	3.39	1.86	3.75	0.72	749	72	15	21	55	23	200	396	112	47	191	166	100.01	7.22	3.93	1.52
DP 125	61.94	0.52	14.12	3.10	0.05	0.87	13.32	1.61	3.36	0.57	927	61	5	18	26	20	182	1441	74	40	121	202	99.77	15.36	4.99	0.98
DP 126	62.82	0.74	18.89	5.03	0.03	0.83	5.80	1.09	3.52	0.72	1064	95	6	25	53	25	165	1392	133	26	158	225	99.80	9.27	7.11	1.39
DP 127	65.91	0.59	16.04	4.90	0.03	0.93	5.80	1.52	3.56	0.35	446	76	4	16	48	29	225	423	118	31	171	169	99.81	16.21	6.49	1.84
DP 128	63.64	0.68	18.13	4.54	0.03	0.81	5.42	1.75	3.52	0.63	1188	84	10	24	47	21	191	1361	118	33	154	213	99.49	6.93	4.02	1.17
DP 129	63.00	0.67	18.28	5.29	0.03	0.93	5.32	1.87	3.73	0.18	758	80	6	18	43	27	203	524	119	33	154	204	99.53	7.44	4.91	1.39
DP 131	66.77	0.57	15.74	3.73	0.03	0.99	5.98	1.75	3.45	0.58	910	64	15	20	40	24	221	589	100	37	152	180	99.83	10.01	3.51	1.56
DP 132	64.02	0.57	16.64	4.05	0.04	0.93	6.79	1.78	3.98	0.59	1015	75	15	21	40	28	244	814	107	48	147	176	99.66	12.65	4.84	1.23
DP 133	62.47	0.71	17.56	4.54	0.04	0.90	7.80	1.34	3.18	0.78	997	88	4	28	45	25	172	504	127	35	144	232	99.58	11.14	6.04	1.67
DP 134	62.65	0.84	20.46	5.44	0.03	1.20	2.80	1.17	3.90	0.79	1444	104	11	23	57	26	228	1362	153	27	197	202	99.66	7.88	6.81	1.47
DP 135	65.00	0.73	17.74	4.68	0.04	0.89	4.97	1.63	3.40	0.50	1036	82	7	23	43	25	211	545	116	47	148	234	99.82	10.85	5.34	0.08
DP 136	65.57	0.80	18.77	5.90	0.03	1.29	1.81	1.74	3.00	0.44	1009	92	8	18	60	25	176	791	132	27	200	213	99.63	4.54	5.28	1.24
DP 137	68.42	0.45	14.56	4.10	0.04	1.98	3.80	1.96	4.16	0.26	341	88	21	15	41	26	271	244	75	40	166	131	99.89	10.48	4.31	1.56
DP 138	63.98	0.65	17.98	4.31	0.02	0.74	5.39	1.29	4.15	0.70	1208	82	8	20	46	27	164	1072	125	26	147	207	99.52	7.00	4.70	1.17
DP 139	67.26	0.41	13.38	2.81	0.04	0.80	9.51	2.43	2.94	0.22	475	54	11	17	28	19	156	320	62	32	126	160	99.94	9.02	3.03	0.61
DP 140	65.21	0.54	15.84	3.98	0.03	0.90	7.22	1.66	3.35	0.55	1001	68	9	15	44	22	177	1367	95	34	154	186	99.59	12.17	4.37	1.46

Tab.6a - Analyses chimiques concernent la poterie. $Fe_2O_3t = Fe_{tot}$ en Fe_2O_3. Oxydes et somme en %poids, éléments traces en ppm.

	SiO_2	TiO_2	Al_2O_3	Fe_2O_3*	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	Ba	Cr	Cu	Nb	Ni	Pb	Rb	Sr	V	Y	Zn	Zr	Somme	CO_2	H_2O^+	FeO
DP 141	64.73	0.54	18.70	4.24	0.05	1.92	1.45	2.38	5.13	0.45	874	86	28	15	45	21	249	427	92	33	153	146	99.83	4.58	2.98	1.23
DP 142	67.80	0.58	14.63	5.43	0.03	0.92	5.92	1.18	2.90	0.32	391	85	6	16	57	27	173	187	139	38	185	178	99.85	11.33	5.43	1.31
DP 143	69.03	0.54	14.91	3.90	0.04	0.81	5.95	1.79	2.91	0.38	726	70	4	27	36	23	172	570	88	39	138	201	100.48	9.57	4.95	1.40
DP 144	65.62	0.63	17.28	4.24	0.04	0.92	4.45	1.68	3.71	0.62	1530	82	8	21	51	24	215	1234	97	38	170	186	99.55	6.34	4.31	0.89
DP 145	70.79	0.49	15.60	3.25	0.04	0.67	1.95	2.27	4.21	0.26	518	76	29	29	48	25	268	364	83	61	141	150	99.70	3.41	1.91	1.59
DP 146	62.78	0.83	20.72	5.98	0.03	1.15	1.84	1.21	4.11	0.58	1053	114	11	21	58	28	231	1111	152	31	166	205	99.53	17.78	8.11	1.54
DP 147	69.35	0.60	15.86	4.43	0.04	0.86	2.51	1.61	3.62	0.48	856	84	10	21	44	23	204	627	99	39	145	213	99.60	6.12	4.68	0.90
DP 148	65.78	0.56	17.44	3.60	0.03	0.79	4.58	2.19	4.04	0.30	707	71	9	19	36	20	234	399	89	31	139	175	99.50	13.20	5.36	1.47
DP 149	65.34	0.64	17.62	4.46	0.03	0.98	4.03	1.57	4.13	0.51	828	86	13	23	50	27	214	632	128	35	197	188	99.55	13.34	6.57	1.45
DP 150	62.35	0.44	13.11	2.49	0.06	0.83	14.64	2.03	3.30	0.34	540	48	14	22	22	15	198	558	57	41	164	191	99.77	13.23	3.29	1.10
DP 151	54.24	0.32	11.40	1.67	0.02	1.16	25.91	1.85	2.95	0.19	291	52	4	12	19	11	171	453	52	26	118	135	99.86	27.24	4.53	1.27
DP 152	71.35	0.63	15.89	4.17	0.02	0.97	1.70	1.30	2.93	0.57	522	102	14	17	84	28	185	305	154	36	244	178	99.73	6.19	5.65	1.14
DP 153	65.68	0.56	16.02	4.08	0.03	0.93	6.61	1.62	3.64	0.38	686	76	4	18	43	25	200	373	103	30	149	177	99.74	9.31	4.14	1.28
DP 154	66.54	0.70	17.87	5.95	0.05	2.46	1.03	1.09	3.74	0.16	767	138	16	16	76	26	210	420	137	34	194	145	99.81	10.81	6.37	2.80
DP 155	64.05	0.67	17.41	4.03	0.03	0.82	7.40	1.56	3.10	0.33	696	84	16	27	41	26	198	559	110	38	147	211	99.62	9.13	5.71	1.49
DP 156	70.97	0.57	13.09	7.44	0.03	2.33	1.48	0.94	2.81	0.19	359	155	11	11	64	26	136	183	108	26	202	148	99.99	11.33	6.49	2.00
DP 157	66.73	0.55	16.60	4.54	0.03	0.78	4.70	1.80	3.71	0.23	477	68	11	20	41	23	236	246	101	40	139	162	99.82	7.84	4.53	1.07
DP 158	64.07	0.65	17.60	4.70	0.03	0.84	5.71	1.62	3.82	0.42	785	82	10	21	45	22	188	331	118	33	149	184	99.65	9.64	5.20	1.41
DP 159	64.87	0.58	17.46	4.81	0.03	0.87	4.72	1.92	4.06	0.29	594	79	7	19	46	24	251	278	107	37	154	170	99.77	15.51	6.30	1.77
DP 160	61.10	0.75	18.78	5.67	0.03	1.20	7.16	1.09	3.41	0.22	579	104	10	18	55	30	198	287	143	34	170	189	99.59	10.04	6.94	1.34
DP 161	62.80	0.69	18.51	5.58	0.03	1.06	5.52	1.49	3.60	0.25	518	88	3	20	46	25	221	254	127	31	172	179	99.70	12.57	7.04	2.02
DP 162	65.11	0.64	17.46	5.13	0.03	1.06	4.52	1.71	3.65	0.21	570	78	23	21	48	21	219	432	120	62	177	168	99.71	15.22	6.78	2.21
DP 163	66.35	0.62	18.46	4.47	0.04	1.10	2.08	2.23	4.06	0.24	556	71	8	20	37	22	234	229	102	39	162	174	99.80	4.54	4.59	1.15
DP 164	67.71	0.62	16.44	5.72	0.03	2.18	1.30	1.43	4.23	0.15	563	113	7	14	53	22	177	147	113	23	173	142	99.96	11.29	5.96	2.39

Tab.6a - Analyses chimiques concernent la poterie. $Fe_2O_3t = Fe_{tot}$ en Fe_2O_3. Oxydes et somme en %poids, éléments traces en ppm.

Si l'on revient au tab.6a, ce dernier montre des variations significatives en ce qui concerne la teneur en Sr. Dans certaines poteries le Sr a des valeurs comprises entre 1072 et 1441 ppm, teneurs deux à trois fois plus importantes que la moyenne du corpus céramique (568 ppm). En plus, les teneurs plus élevées en Sr sont corrélées à des teneurs en Ba comprise entre 927 et 1530 ppm, 40% à 100% en plus que la moyenne de 716 ppm seulement. La fig.7c montre un diagramme de corrélation entre MgO et Sr + Ba. Le graphique montre clairement qu'il existe un groupe de huit poteries qui se distinguent du groupe de céramiques riches en MgO, mais aussi du groupe quantitativement plus important des céramiques pauvres en MgO.

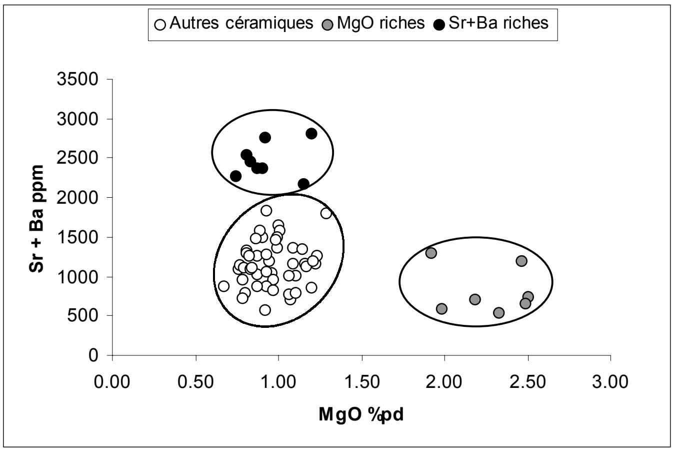


Figure 7c. Diagramme de corrélation Sr - MgO. Si l'on considère les éléments trace Sr+Ba, le groupe principal des céramiques se décompose en deux sous-groupes différents. La majorité des vases, y compris le groupe riche en MgO, ont une teneur en Sr+Ba qui varie entre 578 et 1829 ppm. Un troisième groupe se différencie sur la base d'une teneur en Sr+Ba qui varie entre 2164 et 2806 ppm.

La fig.7d montre un diagramme de corrélation entre CaO et CO_2, en %pd. La ligne sécante représente les valeurs stœchiométriques de la calcite $CaCO_3$ (CaO/CO_2 rapport poids atomiques = 0.784).
Les valeurs de CO_2 rapportées au tab.6a ne sont pas balancées sur le plan stœchiométrique, mais les rapports avec CaO restent comparables. On assume que tout le CaO mesuré dans les tessons provient de la calcite, considérant que l'apport dû à l'épidote, aux plagioclases et à la titanite sont négligeables. Le graphique de la fig.7d montre un enrichissement en carbone dû essentiellement à la présence de matière organique en forme de résidus dans les pores ou sur les parois internes des tessons. Plus l'éloignement des points-analyses par rapport à la sécante est grand, plus la quantité de matière organique est importante. Le tesson DP 151, qui est très riche en matériel carbonaté, ne contient pas de résidus de matière organique.

2.2.3 La poterie étudiée par Benghezal (1994)

Le tab.6b montre les analyses effectuées par Benghezal (1994) sur 29 échantillons de poteries appartenant aux groupes culturels Auvernier-Cordé ancien et moyen de St. Blaise, tab.2a.

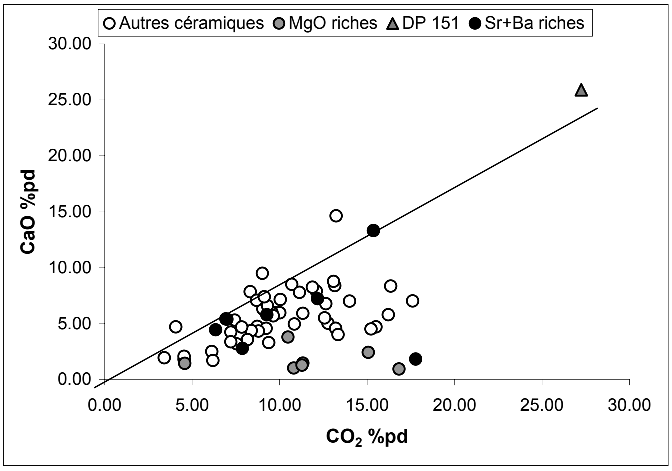


Figure 7d. Diagramme de corrélation CaO - CO_2, résultats XRF et Leco. La ligne sécante indique l'équilibre stœchiométrique de la calcite $CaCO_3$ (voir texte). Les points-analyses à droite de la sécante indiquent un enrichissement en carbone, donc en matière organique. L'analyse DP 151 a des teneurs très élevées en CaO et CO_2 pd%, mais elle ne présente pas un enrichissement en résidu organique. On ne distingue pas les groupes chimiques riches en MgO et Sr+Ba du reste du corpus céramique.

Le fig.7e montre le diagramme de corrélation MgO vers Sr + Ba concernant 92 poteries des deux études. A confirmer les résultats déjà discutés, on trouve encore trois groupes chimiques différents : la poterie riche en MgO, la poterie riche en Sr + Ba et la poterie plus pauvre en ces trois éléments. Les variations à l'intérieur des groupes deviennent plus larges par rapport à celles de la fig.7c, mais les mêmes considérations déjà discutées restent valables.

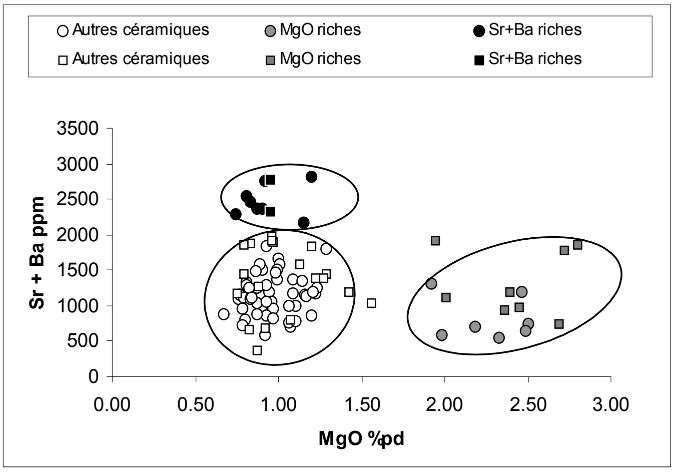


Figure 7e. Diagramme de corrélation MgO - Sr+Ba, concernant les poteries de cette étude (ronds) et de Benghezal (1994), (carrés). Les mêmes groupes chimiques que ceux de la fig.7c sont mis de nouveau en évidence.

2.2.4 Matrices et dégraissant

La méthode de séparation concernant dégraissant et matrice des poteries, élaborée avec succès sur une série de céramiques provenant de Portalban, un autre site néolithique suisse (Di Pierro, 2002c), a été appliquée à une série de 18 poteries de St. Blaise, choisies en tenant compte des trois groupes chimiques déjà identifiés, à partir des 63 céramiques de cette étude, tab.6c.

	SiO_2	TiO_2	Al_2O_3	Fe_2O_3t	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	Ba	Cr	Cu	Ga	Nb	Ni	Pb	Rb	Sr	Th	V	Y	Zn	Zr	Somme	CO_2	H_2O^+	FeO
AB 156	66.26	0.63	17.93	4.35	0.04	1.13	3.82	2.22	3.69	0.29	1007	64	14	16	17	45	3	169	577	37	130	31	66	144	100.37	5.61	3.70	1.57
AB 157	66.55	0.62	17.83	3.85	0.03	0.83	4.32	2.14	3.65	0.30	1213	73	14	16	19	43	1	149	668	27	139	28	56	150	100.12	5.94	3.51	1.43
AB 158	62.60	0.71	16.85	5.51	0.10	2.72	5.87	1.01	3.89	0.64	1065	104	19	17	12	64	1	164	706	14	138	25	105	126	99.90	6.99	3.96	2.68
AB 159	62.57	0.72	16.97	5.54	0.09	2.80	6.62	0.97	3.61	0.43	1143	104	20	15	10	60	1	156	707	18	139	24	104	123	100.33	9.42	4.35	2.68
AB 160	58.26	0.63	14.45	3.69	0.07	1.22	16.37	1.40	3.00	0.73	809	43	13	10	13	38	1	123	589	17	98	25	52	139	99.81	16.88	3.99	1.40
AB 161	62.93	0.78	20.09	5.27	0.03	0.95	4.32	1.53	3.72	0.59	1280	78	17	18	20	50	2	166	1049	29	156	31	75	160	100.19	4.93	4.64	1.02
AB 163	70.23	0.55	14.53	3.86	0.03	0.96	4.78	1.40	2.75	0.87	1243	88	19	14	18	63	2	132	738	32	139	42	94	143	99.97	5.69	3.83	1.61
AB 164	62.80	0.64	17.21	4.77	0.03	0.97	7.57	1.57	3.89	0.47	1244	70	10	15	14	51	1	153	653	23	130	27	70	133	99.94	4.66	3.37	0.56
AB 165	66.97	0.63	17.51	4.43	0.03	0.79	3.61	1.60	3.50	0.46	928	71	13	17	17	41	4	164	516	25	146	23	71	137	99.54	4.54	3.79	0.95
AB 166	63.25	0.75	19.61	5.09	0.03	0.96	4.08	1.61	4.06	0.43	1275	90	15	19	20	50	1	178	637	28	163	28	80	149	99.86	4.05	4.04	0.83
AB 167	61.78	0.61	16.01	5.00	0.06	2.69	8.52	1.40	3.87	0.39	488	96	13	13	12	59	2	153	262	22	115	21	86	99	100.32	16.64	5.36	2.16
AB 172	60.93	0.52	12.99	2.58	0.07	0.88	17.39	1.56	2.84	0.55	607	51	16	9	12	26	1	124	659	32	66	30	37	145	100.29	12.03	2.30	0.60
AB 174	69.21	0.49	14.78	3.43	0.03	0.82	5.40	1.93	3.58	0.37	504	51	13	13	18	44	1	175	157	33	91	28	72	131	100.05	4.32	1.94	1.51
AB 179	67.12	0.61	16.82	5.46	0.04	2.45	1.76	1.69	3.89	0.32	671	95	15	16	9	54	8	135	305	37	147	24	85	113	100.15	6.61	4.05	2.16
AB 180	62.84	0.96	21.19	6.55	0.03	1.42	2.84	0.89	2.92	0.24	776	98	11	19	21	53	7	148	420	25	186	30	95	207	99.88	2.87	5.43	1.64
AB 181	51.60	1.01	21.36	7.08	0.07	2.01	12.90	0.31	2.85	0.76	707	99	21	16	18	68	1	96	409	36	156	29	121	133	99.95	9.88	5.98	1.38
AB 182	64.70	0.68	18.11	4.50	0.02	1.07	6.26	1.37	3.20	0.30	562	83	16	19	27	50	10	186	238	52	144	38	73	134	100.23	4.60	3.97	0.90
AB 183	67.14	0.46	13.18	2.97	0.03	0.75	10.12	1.50	3.03	0.89	837	50	11	11	16	45	3	126	345	35	114	29	70	113	100.07	14.93	3.80	1.42
AB 184	72.45	0.59	16.78	3.48	0.02	0.92	0.94	1.71	3.29	0.19	532	97	15	18	21	64	17	164	155	70	182	29	107	130	100.37	7.48	5.64	1.48
AB 185	68.96	0.57	16.67	3.88	0.03	0.79	3.01	1.84	3.58	0.66	1267	83	14	16	17	54	9	190	590	38	122	33	76	142	100.00	2.68	2.91	1.16
AB 186	68.72	0.55	16.56	3.90	0.02	0.87	3.31	1.82	3.91	0.30	282	68	16	19	21	50	5	216	96	55	124	30	74	126	99.98	1.71	1.17	1.99
AB 187	64.19	0.71	18.67	5.52	0.03	1.29	3.85	1.68	3.50	0.45	1014	80	11	16	14	53	1	144	440	22	160	26	88	134	99.90	6.69	4.60	1.46
AB 188	43.19	0.47	10.85	3.28	0.07	1.27	36.77	0.89	1.97	0.70	732	34	12	1	9	38	1	73	661	14	66	21	55	86	99.45	26.50	3.25	1.24
AB 189	24.13	0.42	9.07	3.06	0.03	1.56	57.19	0.08	1.66	0.28	379	31	15	1	4	40	1	47	657	2	48	10	38	48	97.47	37.04	3.50	1.05
AB 190	69.03	0.54	16.28	4.65	0.08	1.94	1.39	1.48	4.31	0.48	1224	87	17	15	8	47	3	146	688	17	123	19	76	117	100.17	9.26	3.11	2.82
AB 191	69.65	0.63	14.83	6.63	0.04	2.39	1.16	0.92	3.10	0.17	866	128	12	14	12	60	1	134	331	13	159	19	100	129	99.52	5.57	3.36	2.89
AB 192	65.13	0.64	18.19	4.05	0.03	0.95	5.06	2.01	3.46	0.67	1588	63	16	16	13	40	8	139	1184	34	138	23	62	158	100.19	5.51	4.20	0.88
AB 193	70.45	0.62	14.57	6.76	0.05	2.36	1.10	0.96	3.10	0.17	677	133	12	14	7	58	3	128	253	33	152	18	93	122	100.13	4.48	2.34	2.84
AB 194	63.26	0.72	18.40	5.23	0.04	1.20	5.52	1.39	3.79	0.49	1159	78	9	16	15	49	4	146	686	20	182	22	73	137	100.03	8.71	4.45	1.57

Tab.6b - Analyses chimiques de Benghezal (1994). $Fe_2O_3t = Fe_{tot}$ en Fe_2O_3. Oxydes et somme en %poids, éléments traces en ppm.

	SiO_2	TiO_2	Al_2O_3	Fe_2O_3t	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	Ba	Cr	Cu	Nb	Ni	Pb	Rb	Sr	V	Y	Zn	Zr	Somme
DP 103 de	74.27	0.20	14.19	1.49	0.02	0.31	0.65	4.23	4.43	0.10	338	25	4	31	12	13	328	96	12	55	20	125	99.90
DP 111 de	74.06	0.16	14.00	1.50	0.03	0.36	1.07	4.12	4.49	0.04	346	16	2	18	11	18	328	122	15	35	18	101	99.84
DP 113 de	74.61	0.18	13.93	1.55	0.03	0.34	1.39	3.98	4.17	0.05	438	22	2	8	11	13	186	138	16	24	11	99	100.24
DP 115 de	71.88	0.25	15.24	2.14	0.03	0.55	1.82	3.99	4.03	0.07	497	28	2	7	14	14	164	150	22	18	46	119	100.00
DP 118 de	68.61	0.30	17.03	2.67	0.07	0.60	1.82	4.50	4.44	0.12	780	16	2	14	12	23	203	355	23	32	56	186	100.16
DP 119 de	73.80	0.20	14.44	1.36	0.02	0.33	0.78	3.97	5.14	0.07	376	21	2	13	12	11	305	88	13	29	7	121	100.11
DP 125 de	72.48	0.17	15.09	1.44	0.03	0.29	1.37	4.51	4.60	0.07	456	19	2	18	13	15	298	196	14	38	13	121	100.05
DP 126 de	76.08	0.16	12.75	1.23	0.02	0.28	1.41	3.27	4.88	0.09	402	26	2	6	13	16	187	252	19	15	7	89	100.17
DP 128 de	71.93	0.21	15.30	1.76	0.04	0.35	1.76	4.59	4.07	0.08	497	18	2	9	11	18	238	188	14	29	20	135	100.09
DP 131 de	68.37	0.35	16.67	3.09	0.05	0.95	2.76	3.94	4.00	0.12	502	21	4	30	16	7	319	218	46	33	34	147	100.30
DP 137 de	76.83	0.09	12.88	0.79	0.02	0.14	0.46	3.91	5.01	0.02	131	11	2	13	7	18	391	33	7	50	2	80	100.16
DP 140 de	71.29	0.24	15.35	2.06	0.04	0.69	2.05	4.16	4.43	0.15	531	25	2	8	14	12	255	286	30	25	22	124	100.46
DP 141 de	72.39	0.20	15.18	1.41	0.03	0.26	1.19	4.71	4.78	0.09	481	20	2	12	11	23	259	150	11	30	8	127	100.24
DP 143 de	73.70	0.19	14.09	1.56	0.04	0.41	1.28	4.38	4.09	0.06	424	16	2	16	11	16	243	149	14	39	12	142	99.79
DP 144 de	75.86	0.18	12.99	1.40	0.03	0.38	1.31	3.37	4.78	0.07	407	18	2	13	14	14	307	152	13	30	12	98	100.36
DP 148 de	71.32	0.20	16.27	1.65	0.03	0.42	0.74	4.75	4.96	0.07	495	23	2	13	12	9	304	143	16	27	13	100	100.41
DP 160 de	73.90	0.16	13.61	1.27	0.02	0.27	1.92	3.95	4.77	0.05	321	12	2	11	3	15	265	99	9	33	6	109	99.92
DP 164 de	75.92	0.15	13.23	1.35	0.02	0.43	0.63	3.20	5.33	0.03	679	20	2	5	11	16	169	115	10	10	14	89	100.29
DP 103 ma	65.72	0.75	17.66	5.44	0.03	1.03	3.45	1.41	3.83	0.67	988	97	24	21	56	30	214	684	115	44	108	184	100.00
DP 111 ma	64.15	0.75	17.36	5.05	0.04	1.17	8.18	1.01	2.47	0.27	542	114	8	19	65	30	159	467	136	37	105	180	100.45
DP 113 ma	62.92	0.92	19.35	7.28	0.03	1.22	4.34	0.96	3.07	0.27	794	114	16	24	69	41	162	468	147	35	122	216	100.35
DP 115 ma	63.74	0.84	18.29	5.97	0.02	1.07	6.14	0.78	2.69	0.39	739	127	12	18	66	32	135	655	147	31	121	195	99.92
DP 118 ma	62.74	0.87	19.54	5.70	0.03	1.25	5.78	0.88	3.18	0.33	717	107	18	22	73	34	161	480	155	31	123	186	100.30
DP 119 ma	65.01	0.77	16.98	5.55	0.02	1.00	5.61	1.00	3.36	0.52	731	101	10	20	60	26	171	688	129	32	107	170	99.82
DP 125 ma	63.07	0.58	13.40	3.27	0.05	0.87	13.34	1.50	3.01	0.78	1118	58	7	22	25	20	172	1919	60	37	53	210	99.87
DP 126 ma	61.98	0.83	19.06	5.58	0.03	0.91	6.06	0.91	3.06	1.22	1881	104	19	26	58	31	157	3160	145	30	99	238	99.62
DP 128 ma	61.99	0.91	18.90	5.76	0.04	1.04	6.23	1.12	3.15	0.80	1449	99	10	31	53	36	208	1601	130	41	95	271	99.94
DP 131 ma	68.53	0.60	14.83	3.64	0.03	0.93	6.24	1.63	3.29	0.63	858	64	22	21	43	23	216	564	98	37	85	178	100.33
DP 137 ma	65.79	0.63	15.04	5.50	0.05	2.80	5.58	1.34	3.32	0.35	431	106	24	23	53	30	203	269	101	45	138	149	100.39
DP 140 ma	65.90	0.63	15.34	4.26	0.03	0.95	7.95	1.27	2.95	0.84	1308	78	14	19	52	27	159	1877	98	35	105	187	100.12
DP 141 ma	63.25	0.73	18.96	5.26	0.05	2.43	2.14	1.72	4.62	0.87	914	106	64	18	55	25	239	499	108	35	162	163	100.04
DP 143 ma	65.24	0.80	15.42	5.61	0.05	1.16	7.92	1.06	2.46	0.59	834	97	23	31	52	29	181	537	110	50	117	282	100.32
DP 144 ma	65.35	0.65	16.41	4.71	0.04	0.93	6.23	1.69	3.34	0.69	1884	83	11	19	52	27	200	1342	95	36	184	183	100.03
DP 148 ma	64.82	0.77	17.47	4.80	0.04	1.01	5.77	1.47	3.56	0.60	1026	84	21	25	46	30	226	569	107	37	107	220	100.31
DP 160 ma	59.56	0.91	19.12	6.97	0.04	1.46	8.30	0.55	2.74	0.29	611	113	15	27	62	36	183	280	152	37	158	214	99.94
DP 164 ma	66.20	0.74	17.03	6.75	0.03	2.52	1.78	1.19	3.80	0.24	571	134	21	18	64	30	179	161	117	29	153	149	100.28

Tab.6c - Analyses chimiques concernent le dégraissant (de) et les matrices (ma). $Fe_2O_3t = Fe_{tot}$ en Fe_2O_3. Oxydes et somme en %poids, éléments traces en ppm.

La fig.7f montre le diagramme de corrélation entre Sr + Ba et MgO des fractions séparées. Le graphique montre clairement l'existence de quatre groupes chimiques distincts : le groupe chimique concernant le dégraissant et trois groupes chimiques concernant les matrices, en particulier les matrices pauvres en MgO, les matrices riches en MgO et les matrices riches en Sr + Ba.

Ces résultats deviennent encore plus intéressants lorsqu'on intègre dans le diagramme les analyses chimiques des deux poteries (analyses des poteries non séparées) DP 106 et DP 156, caractérisées comme céramiques non dégraissées et riches en MgO. Leur compositions chimiques correspond aux matrices séparées des poteries identifiées comme riches en MgO. Le diagramme confirme donc que la teneur plus élevée en MgO est due à la matrice (voir argile) utilisée pour fabriquer la poterie de ce groupe.

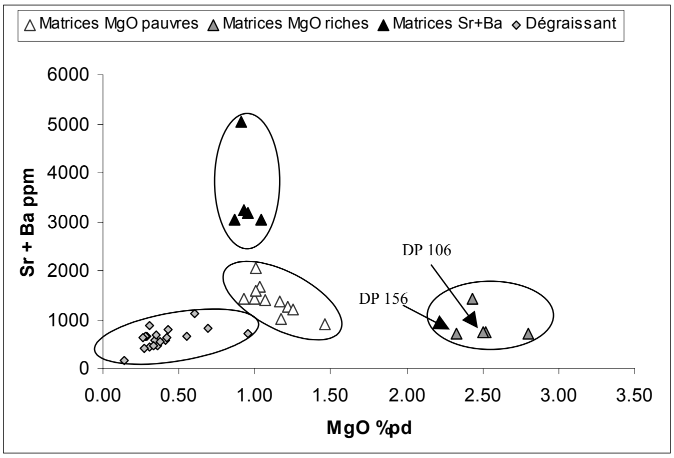


Figure 7f. Diagramme de corrélation MgO - Sr+Ba, relative à la séparation matrice - dégraissant. Les analyses DP 106 et DP 156 marquées dans le graphe se réfèrent aux analyses des poteries. Les données de la séparation ont confirmé que les teneurs plus élevées en MgO, mais aussi en Sr + Ba, sont dues aux matrices et non pas au dégraissant.

Les mêmes considérations sont valables pour le groupe de céramiques riches en Sr + Ba. Les analyses concernant le dégraissant séparé montrent des valeurs en Sr + Ba comprises entre 164 et 1135 ppm, tab.6c et fig.7f. Les analyses des matrices riches en Sr + Ba montrent des teneurs comprises entre 3037 et 5041 ppm, contre des valeurs comprises entre 700 et 2051 ppm et une moyenne inférieure à 1500 ppm des autres matrices.

Donc les données de la séparation matrice – dégraissant confirme la présence de trois grands groupes chimiques, tab.7. La poteries riche en MgO, celle riche en Sr + Ba et les autres céramiques plus pauvres en ces trois éléments, auxquelles on peut ajouter la céramique DP 151.

	Groupes chimiques	Nombre d'analyses	(n=63)
1	Autres céramiques	47	74.5%
2	Céramique riche en MgO	7	11%
3	Céramique riche en Sr+Ba	8	13%
4	Céramique DP 151	1	1.5%

Tab.7 - Synthèse des groupes chimiques identifiés.

3. DISCUSSION

3.1 Les matériaux

Le tab.8 montre les numéros d'analyses correspondant aux céramiques qui ont des caractéristiques pétrographiques et/ou chimiques qui se distinguent de l'ensemble du corpus. Dans la colonne (a) on trouve les tessons qui, dans les observations optiques et les analyses en diffraction des rayons X, ne contiennent pas de matériel carbonaté et qui ont été définies comme céramique à matrice silicatée (13 individus, 20.5% du corpus). La colonne (b) montre les analyses XRD où la chlorite a été identifiée comme minéral présent dans la matrice (7 individus, 11% du corpus). Dans la colonne (c) on trouve les tessons qui n'ont pas été dégraissés (2 individus, 3% du corpus). Les colonnes (d) et (e) montrent les analyses des tessons qui se distinguent chimiquement par leurs teneurs en MgO (7 individus, 11% du corpus) et Sr + Ba (8 individus, 13% du corpus), fig.7c.

On peut facilement remarquer la correspondance entre les six premières poteries à matrice silicatée de la colonne (a) et les mêmes poteries riches en MgO de la colonne (d). Toujours dans ce groupe on trouve les deux poteries DP 106 et DP 156 non dégraissées, fig.3. Nous avions donc déjà l'indication que la teneur plus élevée en MgO était due uniquement à la matrice, c'est-à-dire à l'argile, et sûrement pas au dégraissant granitique qui est absent dans ces poteries. La fig.7f concernant les résultats de la séparation matrice – dégraissant démontre que la teneur double de MgO est due à la matrice et non pas au dégraissant. Nous avons déjà affirmé que cette teneur peut être attribuée à la présence de minéraux magnésiens. Cette interprétation pourrait être confirmée par la présence de chlorite, silicate à composition magnésienne, déterminée dans les analyses aux rayons X sur quatre de ces sept poteries, tab.8 et colonne (b). La chlorite se déstabilise, comme nous l'avons dit, à une température > à 720° C (Maggetti, 1982). On peut donc envisager comme hypothèse, l'utilisation d'une même argile silicatée à chlorite pour tout le groupe de poterie, mais des températures de cuisson supérieures à 720° C pour les céramiques qui ne présentent plus ce minéral.

Les corrélations sus-mentionnées mettent en évidence la présence de deux matériaux argileux différents. L'argile (matrice) calco-silicatée (sous-groupes pétrographiques V et VI) riche en CaO et pauvre en MgO, et l'argile (matrice) silicatée (sous-groupes pétrographiques I et II) avec chlorite et donc plus riche en MgO, en même temps pauvre en CaO.

Pour ce qui concerne le groupe de céramiques riches en Sr + Ba, il n'y a aucune corrélation avec les groupes pétrographiques, tab.8. On peut envisager plusieurs explications à cela. Cette variation pourrait être due à (i) une composition chimique différente des feldspaths alcalins qui composent le granite ajouté, (ii) une contamination de la poterie liée à la mobilité des ces deux éléments (Picon, 1987) ou (iii) une variation de la composition chimique des carbonates qui composent la matrice.

Nous pouvons exclure la première hypothèse concernant le granite ajouté, comme les données de la

Listes d'échantillons avec...				
a *matrice silicatée (optique. & XRD)*	b *chlorite (XRD)*	c *pas de dégr.ajouté (optique.)*	d *MgO riches (XRF)*	*e* *Sr+Ba riches (XRF)*
106	-	**106**	**106**	-
107	**107**	-	**107**	-
-	**137**	-	**137**	-
141	-	-	**141**	-
154	-	-	**154**	-
156	**156**	**156**	**156**	-
164	**164**	-	**164**	-
-	-	-	-	-
103	121	-	-	*125*
124	139	-	-	*126*
136	150	-	-	*128*
145	-	-	-	*134*
146	-	-	-	*138*
152	-	-	-	*140*
163	-	-	-	*144*
-	-	-	-	*146*
-	-	-	-	-

Tab.8. Céramiques qui se distinguent par rapport à l'ensemble du corpus de St.Blaise Les numéros se réfèrent aux numéros d'analyses DP xxx.

séparation nous indiquent clairement un enrichissement en Sr + Ba dû à la matrice et non pas au dégraissant, tab.6c et fig.7f.

En ce qui concerne la deuxième hypothèse, la fixation du Ba et du Sr a été décrit dans la littérature pour une trentaine d'amphores massaliètes provenant des fouilles d'Olbia à Hyères dans le Var, France (Picon, 1985 ; 1987) et dans cinq céramiques, sur un corpus de treize, du type de la campanienne B découvertes à Feurs, Loire, France (Picon, 1991). L'auteur indique des valeurs du Ba de 2000 à 3000 ppm pour les amphores d'Olbia qui sont considérées anormales en comparaison avec les amphores du même type retrouvées à Marseille, Espeyran et Lyon, et qui ont une teneur en Ba comprise entre 500 et 1000 ppm (Picon, 1985). L'auteur indique des valeurs de Ba de 500 à 800 ppm dans les cinq céramiques du type de la campanienne B provenant de Feurs (200 ppm pour les huit autres) auxquelles le Sr serait corrélé (Picon, 1991). Les deux éléments sont corrélés à des teneurs anormales de P_2O_5 de 1 à 3 %pd, ce qui semblerait indiquer la percolation de fluides et une conséquente contamination des deux éléments précédents. Picon (1985 ; 1987 ; 1991) indique précisément la source de la contamination pour les deux cas par la présence de filons de barytine ($BaSO_4$) à proximité des sites. Cependant, l'existence d'une contamination nécessite un fort taux de phosphore dans les céramiques. Comme nous l'avons déjà discuté pour les poteries de St. Blaise, la teneur de phosphore est très basse et nous permet *à priori* d'exclure une éventuelle contamination, pollution, lessivage ou fixation d'éléments. Cependant cette hypothèse sera reprise lors des corrélations entre la composition de la poterie et sa répartition spatiale, voir para. 3.2.2.

Pour ce qui concerne la troisième hypothèse on peut en effet envisager que cette variation dans la composition chimique soit due à une variation chimique des carbonates qui composent la matrice. Parmi les carbonates, la calcite ($CaCO_3$) est le minéral détecté dans les analyses XRD. La dolomite $CaMg(CO_3)_2$ n'a pas été identifiée. Parmi les autres carbonates existant, la strontianite ($SrCO_3$) et la whiterite ($BaCO_3$) sont deux espèces minéralogiques importantes (i.e. Deer *et al.*, 1962). Il existe une solution solide complète ou presque entre strontianite et witherite (Baldasari & Speer, 1979), et aussi une solution solide jusqu'à 55 mol.% de $BaCO_3$ dans la calcite (Deer *et al.*, et références citées). Speer & Hensley-Dunn (1976) reportent les analyses chimiques d'échantillons de strontianite provenant de 12 localités mondiales différentes. Ces auteurs indiquent des teneurs en Ba entre 2500 et 3600 ppm dans les échantillons de strontianite. Il nous semble donc tout à fait plausible sur le plan minéralogique que l'enrichissement en Sr + Ba dans les poteries concernées soit dû à la présence de quelques milliers de ppm de strontianite et whiterite en solution solide dans la calcite qui compose les matrice calco-silicatées.

Les différences chimiques entre matrices calco-silicatées pauvres en Sr+Ba et calco-silicatées riches en Sr+Ba peuvent être reconduites (i) à une variation chimique à l'intérieur d'un même gisement d'argile calco-silicatée ou (ii) peuvent impliquer l'existence d'un troisième type d'argile utilisée pour la poterie de St. Blaise. Les données pétrographiques et chimiques dont nous disposons ne nous permettent pas d'exclure ni la première ni la deuxième hypothèse. Cependant, le Sr et le Ba étant des traceurs importants des environnements géologiques carbonatés (Speer & Hensley-Dunn, 1976 ; Baldasari & Speer, 1979), l'utilisation d'un troisième type d'argile pour fabriquer la poterie riche en Sr + Ba nous semble l'hypothèse la plus probable.

Pour résumer, la caractérisation pétrographique et chimique des 63 poteries étudiées montre, pour la fabrication de la poterie de St. Blaise, l'utilisation de trois types majeurs de matériaux argileux, c.à.d. : (i) une argile calco-silicatée et pauvre en MgO et Sr + Ba, (ii) une argile silicatée et riche en MgO et (iii) une argile calco-silicatée et riche en Sr + Ba. La céramique DP 151 a par contre une composition très différente des autres poteries du corpus céramique, fig.7a. Il est remarquable que l'ensemble de la poterie étudiée, y compris DP 151, ait été dégraissé avec l'ajout du même lithotype granitique, fig.7f, en particulier le granite à stilpnomélane du Mont Blanc, fig.5. Seules quelques poteries ont été dégraissées aussi avec du matériel carbonaté.

En ce qui concerne la provenance des matériaux listés en haut, on peut faire les considérations suivantes :

L'origine du granite du Mont Blanc est presque certainement rapportable aux dépôts morainiques locaux (i.e. Bourquin *et al.*, 1968). Son utilisation massive est discutée dans d'autres travaux (i.e. Di Pierro, 2002a ; Di Pierro & Martineau, 2002).

Par contre, la provenance des trois argiles utilisées pour la fabrication de la poterie de cette étude reste encore inconnue. La prospection des matières premières sur le site néolithique n'a pas été effectuée car il n'est plus accessible ; ses alentours sont aujourd'hui fortement urbanisés et en général les argiles locales ne sont plus accessibles non plus. Benghezal (1994) avait essayer de prospecter certains sédiments fluviatiles se trouvant au pied du Jura, dans un rayon de quelques km autour de St. Blaise ; mais malheuresement aucune des cinq analyses effectuées par l'auteur ne correspond aux matrices (argiles) utilisées pour la production des poteries néolithiques étudiées dans ce travail.

3.2 Corrélations matériaux - types morphologiques de la céramique

Le tab.9 et la fig.8 résument les corrélations entre les types morphologiques et les données chimiques. Les deux tiennent compte de la céramique étudiée dans cette étude et par Benghezal (1994), tab.4. Dans le groupe de la céramique « Cordé vrai » domine une argile riche en MgO (10 vases sur 16, soit 63%). Au contraire, la céramique « Cordé imité » ne correspond à l'argile riche en MgO que dans 12% des cas (2 vases sur 17). Une seule poterie de type « Transition » (4%), et seulement 2 poteries de type « Auvernier » (6 %) ont été fabriquées à partir d'une argile riche en MgO. Aucune céramique de type « Cordé vrai » n'a été fabriquée avec l'argile riche en Sr+Ba. Par contre, les corrélations avec les trois autres types ne sont pas évidentes pour ce groupe chimique.

Les tab.10a-b montrent les corrélations qui existent entre la teneur en MgO et les 33 céramiques Cordés, pour les deux types Cordé vrai (Cordé Z et Cordon modelé cordé) et Cordé imité (Cordé S, Cordon modelé imité et Cordon appliqué), par types de décor.

Types morphologiques	**Groupes chimiques**						**Total**
	Autres céramiques		Riche en MgO		Riche en Sr+Ba		
Cordé vrai	6	37%	10	**63%**	-	-	16
Cordé imité	13	76%	2	**12%**	2	12%	17
Auvernier	33	91%	2	6%	1	3%	36
Transition	15	66%	1	4%	7	30%	23
Total	67		15		10		92

Tab. 9 - Répartition des types morphologiques en fonction de la teneur chimique des argiles utilisées.

Décor	**Groupes chimiques**			**Total**
	Autres céramiques	Riche en MgO	Riche en Sr+Ba	
Cordé Z	4	**6**	-	10
Cordé S	**2**	1	-	3
Total	6	7	-	13

Tab. 10a - Répartition des décors à impression Cordé selon les groupes chimiques, voir tab.1.

Décor	**Groupes chimiques**			**Total**
	Autres céramiques	Riche en MgO	Riche en Sr+Ba	
Cordon modelé cordé	2	**4**	-	6
Cordon modelé imité	**4**	1	-	5
Cordon appliqué	**7**	-	2	9
Total	13	5	2	20

Tab. 10b - Répartition des décors à cordon modelé selon les groupes chimiques, voir tab.1.

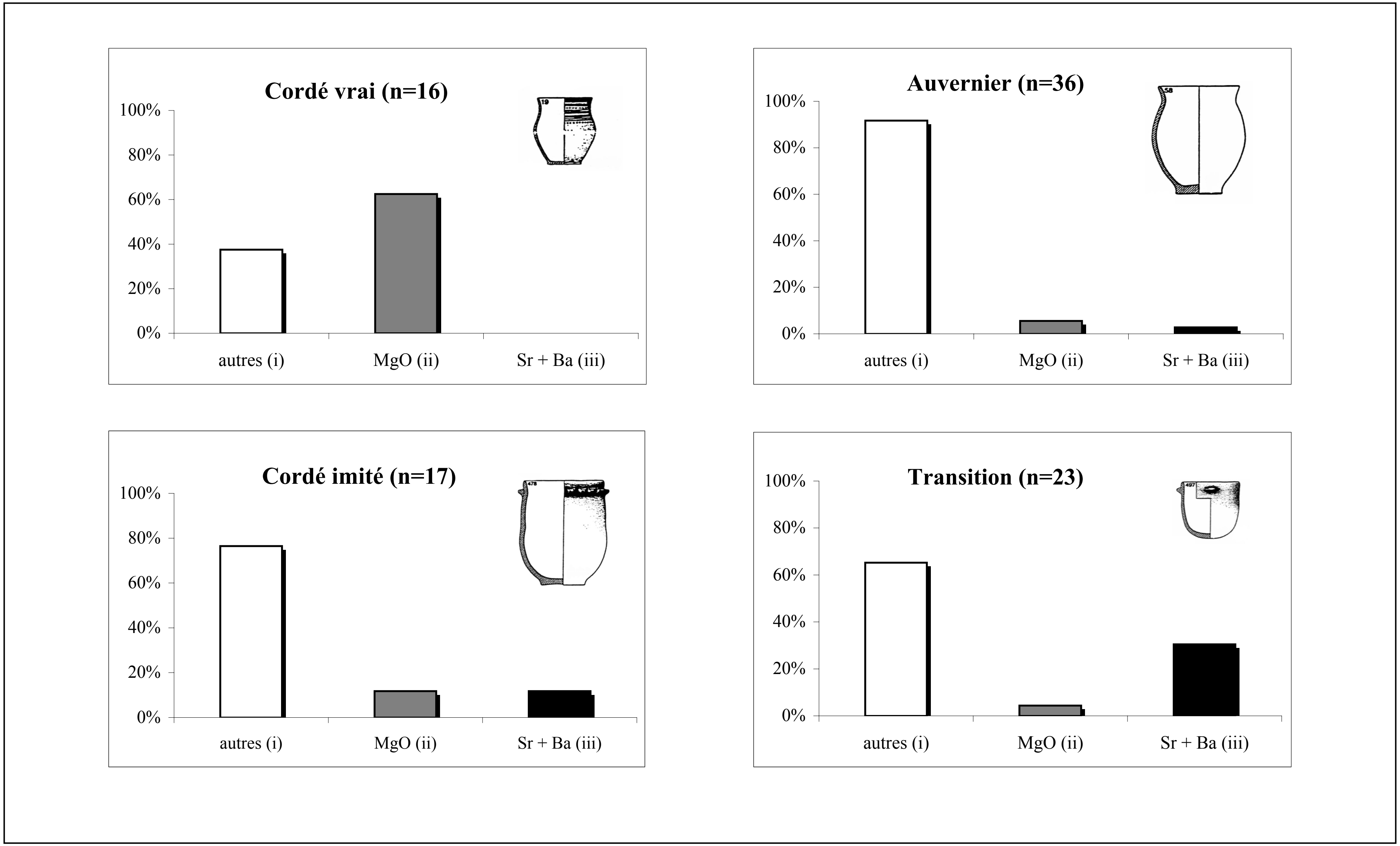


Figure 8 - Corrélation entre les types céramiques des phases Auvernier-cordé ancien et moyen et les groupes chimiques.

Comme on peut le constater, les relations entre les poteries riches en MgO et le type « Cordé vrai » restent importantes lorsqu'on considère les différents types de décors, imprimés ou modelés. 60% des Cordé Z et 66% des Cordon modelé cordé sont des poteries riches en MgO. Par contre, 66% des Cordé S, 80% des Cordon modelé imité et 100% des Cordon appliqué sont des poteries pauvres en MgO.

La production céramique du plateau suisse est caractérisée sur le plan morphologique par le type « Transition » pour la phase ancienne et par le type « Auvernier » pour la phase moyenne. Les types « Cordé » sont issus du savoir-faire local, avec des influences de la Civilisation de la « Céramique Cordé ». En particulier, le type « Cordé vrai » (Cordé Z et Cordon modelé cordé) est celui qui représente le mieux le lien avec les influences culturelles de la Suisse orientale. Le décor à impression de cordelette dont le sens de torsion est en Z et le Cordon modelé cordé, sont des décors d'origine exogène au plateau occidental. Par contre, ces décors sont caractéristiques de la poterie de la Civilisation de la « Céramique Cordé » de Suisse orientale (Giligny, 1993 ; Giligny & Michel, 1995).

Pour conclure, la céramique Auvernier-Cordé de St. Blaise montre clairement l'usage très important de l'argile riche en MgO et au début de l'influence Cordé. En revanche, pour les types « Transition » et « Auvernier », les céramiques riches en MgO représentent une très faible proportion.

3.3 Corrélations matériaux - répartition spatiale

Les fig.9a-b et le tab.11 montrent la localisation des assemblages/dépotoirs comprenant les 63 poteries prises en considération dans cette étude, ainsi que les 15 poteries concernant l'étude de Benghezal (1994), tab.3. On a cherché à voir si il existait des relations entre les groupes chimiques des poteries et les dépotoirs des maisonnées. Comme on peut le noter, neuf des dix poteries riches en Sr + Ba, soit 90%, appartiennent aux assemblages du même dépotoir lié à la même maisonnée, datés en dendrochronologie de la période Auvernier-cordé ancien. En particulier, une poterie appartient à l'assemblage E et les huit autres appartiennent à l'assemblage F, fig. 9a. Une seule poterie appartient au dépotoir D, daté de la période Auvernier-cordé moyen, fig. 9b. Notons que le dépotoir D se trouve au même endroit que les dépotoirs E et F. Les deux maisonnées appartenant aux deux périodes, Auvernier-cordé ancien et moyen, sont localisées dans la même zone, mais stratigraphiquement superposées, fig.9a-b.

Ainsi, la répartition spatiale des données chimiques de la poterie indique que 100% de la céramique riche en Sr + Ba est située dans le même secteur du village. Ce résultat permettrait de penser effectivement à une contamination de la poterie riches en Sr + Ba, dans le sens d'une fixation de ces deux éléments par les eaux de percolation ayant intéressées le site (Picon, 1985 ; 1987 ; 1991). Cependant, si l'on considère les fig.9a-b, on peut facilement constater que les trois dépotoirs D, E et F, ou la céramique riche en Sr + Ba se concentre, sont composés par 42 poteries au total, dont dix seulement enrichies en ces deux éléments. Sept autres appartiennent au groupe chimique riche en MgO (et pauvre en Sr + Ba), 25 autres appartiennent au groupe de céramiques pauvres en MgO et en Sr + Ba. On répète ici que les 42 poteries dont on parle ont été fouillées au même endroit du site et appartiennent aux mêmes assemblages, tels qu'ils ont été définis par un des auteurs.

Il nous semble peu vraisemblable qu'une contamination ne puisse avoir impliqué qu'une faible proportion de toute la céramique du site. Si une fixation en Sr + Ba a pu se produire, contaminant la composition d'une argile calco-silicatée pauvre en MgO, elle doit nécessairement avoir eu lieu avant la fabrication de la poterie. Nous restons persuadés que l'enrichissement en Sr + Ba identifié est primaire et ne concerne pas l'enfouissement de la poterie. La corrélation entre composition chimique et répartition spatiale de la céramique reste valable dans le sens de l'utilisation d'une matière première (contaminée ou pas) précise, chimiquement différente des autres. Il est donc envisageable qu'un gisement d'argile calco-silicatée contenant une teneur particulière de ces deux éléments chimiques affleurait à proximité de ces deux maisonnées construites successivement au même endroit. Les habitants exploitaient ce gisement pour la production de leurs poteries. Ce résultat renforce l'hypothèse selon laquelle pendant le Néolithique final la poterie était une activité domestique, liée à chacune des maisons, considérées comme des cellules socio-économiques élémentaires (Pétrequin *et al.*, 1994).

Assemblage	**Période Auvernier-cordé**	**Groupes chimiques**						**Total**
		Autres céramiques		Riches en MgO		Riches en Sr+Ba		
A	moyen	10	18%	-	-	-	-	10
B	moyen	15	26%	2	18%	-	-	17
C	moyen	7	12%	2	18%	-	-	9
D	moyen	2	4%	2	18%	1	10%	5
E	ancien	10	17%	3	28%	**1**	**10%**	14
F	ancien	13	23%	2	18%	**8**	**80%**	23
Total		57	100%	11	100%	10	100%	78
Autres	ancien et moyen	10		4		-		14
Total		67		15		10		92

Tab. 11 - Répartition des groupes chimiques de la poterie par assemblages.

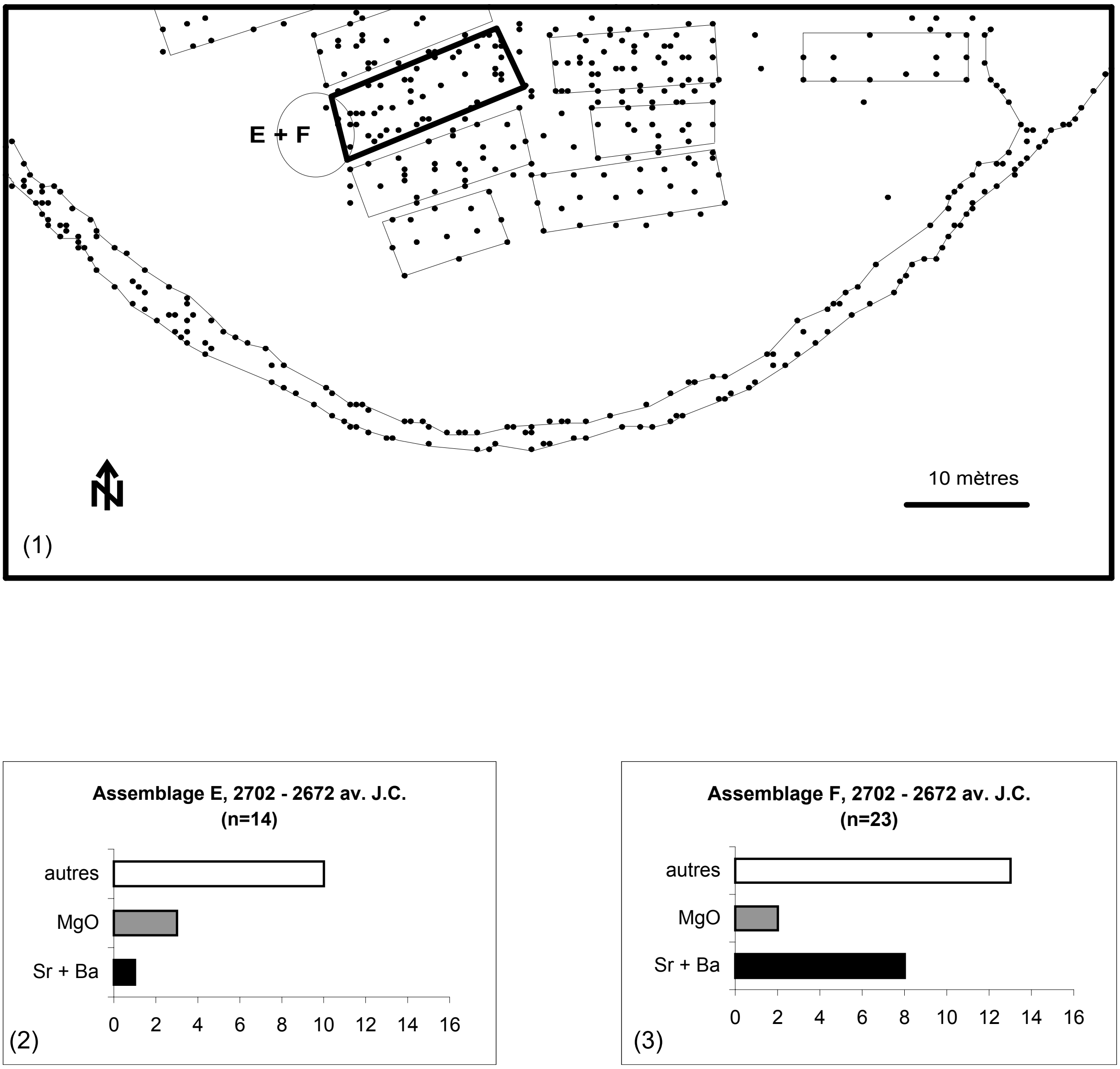


Figure 9a. Schéma du plan des pieux et interprétation des maisonnées (1), pour la phase Auvernier-cordé ancien. (2- 3), répartition de la poterie par assemblage (E et F) et par groupe chimique. 90% de la céramique riche en Sr + Ba se trouve dans ces deux assemblages.

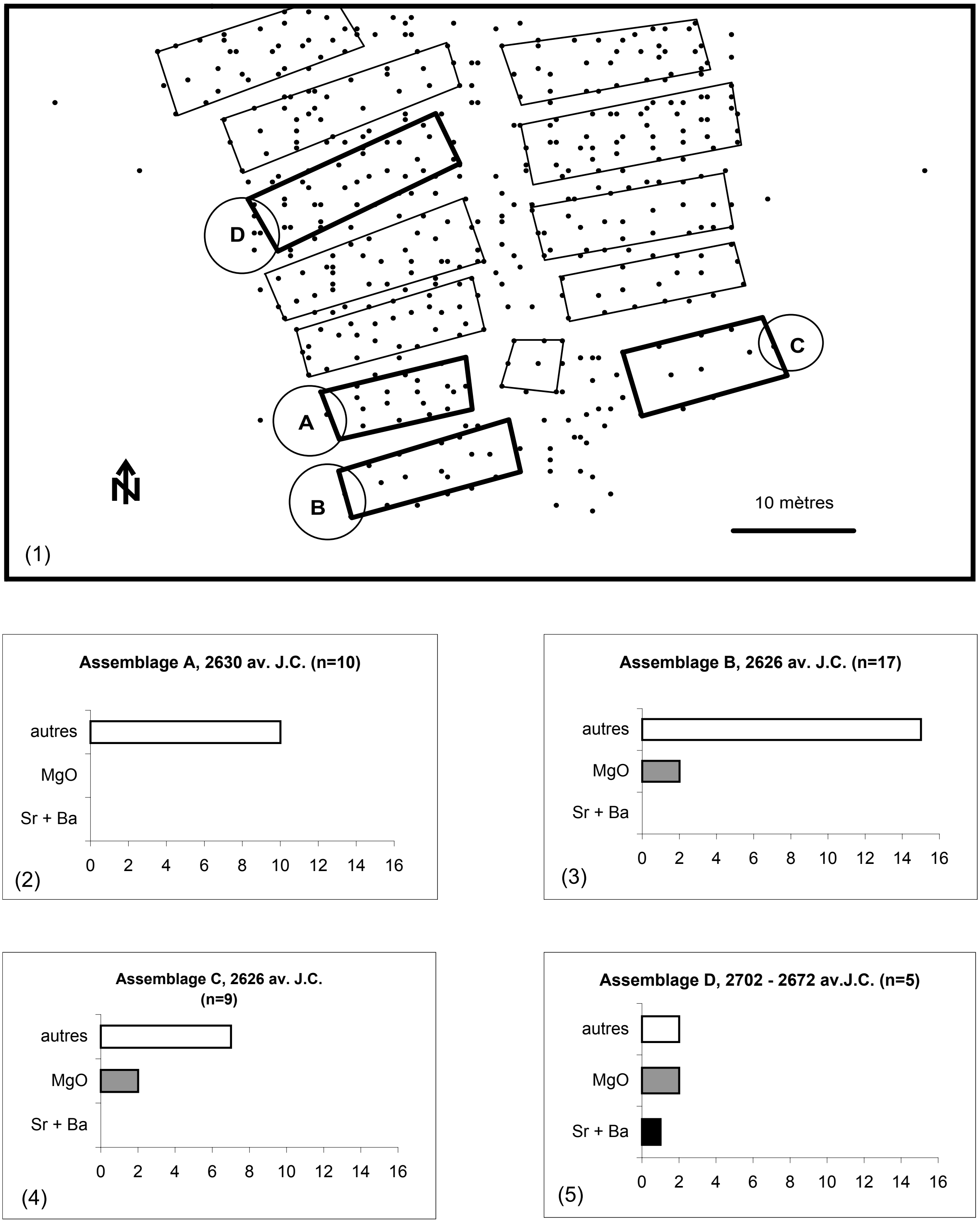


Figure 9b. Schéma du plan des pieux d'une partie du village de St. Blaise à l'Auvernier-Cordé moyen et interprétation des maisonnées (1).
(2 à 5), répartition de la poterie Auvernier-cordé moyen par assemblage (A, B, C et D) et par groupe chimique. Les céramiques riches en Sr + Ba ne sont pas présentes à cette période, sauf une poterie (sur 41) appartenant a l'assemblage D. Ce dernier est localisé dans la même partie du site que les deux assemblages E et F, qui datent de l'Auvernier cordé ancien, et qui comprennent les autres poteries riches en Sr+Ba.

Sans entrer dans le détail de toutes les corrélations entre les types céramiques et les groupes chimiques pour chaque assemblage, les résultats montrent que les poteries Cordé vrai, riches en MgO, sont réparties dans tous les assemblages étudiés. A la différence du groupe Sr + Ba, elles ne correspondent pas à un dépotoir lié à une maison particulière. Le phénomène Cordé-poteries riches en MgO n'a pas concerné que certaines maisons, mais l'ensemble des unités d'habitation du village de St. Blaise. Dans ce cas, l'absence de corrélations est un phénomène qu'il sera intéressant d'essayer d'approfondir.

3.4 Corrélations avec d'autres sites néolithiques

La plupart de la céramique des phases Auvernier-cordé moyen et ancien à St. Blaise a été fabriquée à partir d'une argile calco-silicatée très maigre, argile (i). Par contre un groupe de pots des mêmes phases culturelles a été produit à partir d'une argile silicatée qui se distingue surtout par une teneur en MgO deux fois plus importante (2.27 pd%) que la moyenne (0.96 pd%), argile (ii). Nous avons mis en évidence que 63% des poteries « Cordé vrai » ont été fabriquées avec cette argile. Cependant, les provenances exactes des groupes d'argile identifiés n'étant pas connues, ces résultats permettent d'envisager au moins trois hypothèses, amenant à des interprétations archéologiques tout à fait différentes les unes des autres :

- exploitation de deux gisements différents d'argiles locales (i) & (ii), dans un rayon inférieur à 7 km[4],
- utilisation d'un gisement d'argile (i) locale et d'un gisement d'argile (ii) non locale par les potiers du village,
- une production locale de céramiques avec l'argile (i) et une importation de la céramique produite avec l'argile (ii).

Lorsqu'on considère l'ensemble de la céramique étudiée de St. Blaise et qu'on la compare à la poterie étudiée de Portalban (Di Pierro 2002b), on observe que les deux corpus sont très proches l'un de l'autre.

La céramique de la période Auvernier-cordé ancien à Portalban a été fabriquée à partir d'une argile silicatée, avec une teneur moyenne en MgO de 2,65 pd% (Di Pierro, 2002b-c), donc avec des caractéristiques pétrographiques et chimiques très similaires à l'argile (ii) de St. Blaise.

La fig. 10 montre un diagramme de corrélation MgO vers Sr + Ba pour les deux ensembles céramiques de Portalban (Di Pierro, 2002b) et de St. Blaise, montrant clairement que la teneur en MgO permet de bien discriminer les deux sites. A Portalban les céramiques ont une teneur moyenne en MgO deux fois plus importante qu'à St. Blaise. Mais, on constate que les sept poteries de St. Blaise identifiées comme riches en MgO appartiennent chimiquement au groupe de Portalban. Inversement, deux pots de Portalban appartiennent chimiquement au groupe « autres céramiques » de St. Blaise, car ces deux pots ont une teneur en MgO correspondant à celle de St. Blaise. De plus, ils ont été fabriqués avec une argile calco-silicatée (Di Pierro, 2002b), ce qui constitue un point commun supplémentaire avec la poterie de St. Blaise. Le groupe de céramiques identifiées comme riches en Sr + Ba reste un sous-groupe de la poterie de St. Blaise.

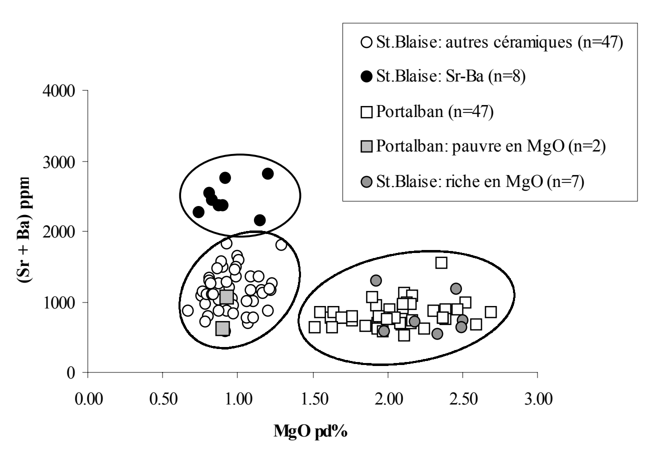


Figure 10. Diagramme de corrélation (Sr + Ba) - MgO, concernant le site de St. Blaise comparé au site de Portalban (Di Pierro, 2002b). La teneur en MgO pd% discrimine clairement les deux sites néolithiques.

Les différences entre les deux sites reflètent deux environnements géologiques différents. St. Blaise se trouve au pied de la chaîne du Jura, composée essentiellement par des roches calcaires (Bourquin *et al.*, 1968). Par contre, Portalban se trouve sur le plateau suisse, composé essentiellement par un soubassement de grès Molassique avec une couverture morainique à élément cristallins (Frei *et al.*, 1974). Les gisements d'argiles locales, dérivant de la décomposition météorique des roches affleurant localement, sont le reflet des compositions de ces dernières. Pour St. Blaise et ses alentours on peut donc s'attendre à une composition des argiles locales principalement calcaire. A Portalban, on trouve au contraire des argiles silicatées (Di Pierro, 2002c).

Les résultats pétrographiques et chimiques et leurs corrélations avec les groupes typologiques permettent de discuter des liens possibles entre les sites de St. Blaise et de Portalban, contemporains et distants de seulement 15 km, de part et d'autre du lac de Neuchâtel, fig. 1.

Nous avons voulu tester l'hypothèse que les poteries riches en MgO de St. Blaise proviennent de Portalban, et que certaines céramiques de Portalban aient fait le parcours inverse, à l'aide de l'analyse statistique multivariée

La classification ascendante hiérarchique (cluster analysis) de fig. 11 montre clairement l'existence de deux grands groupes distincts, plus la céramique « outlier » DP 151, correspondant respectivement à Portalban et à St. Blaise. En plus, elle montre que cinq des sept poteries riches en MgO de St. Blaise appartiennent aux « clusters » de Portalban. Vice versa, les deux poteries pauvres en MgO de Portalban font partie du groupe de St. Blaise. Le groupe de céramiques riches en Sr + Ba constitue un sous-groupe de la poterie de St. Blaise.

---

[4] Dans le sens défini par Arnold (1985 ; 2001).

Légende:

Portalban: lignes et texte en gris

St. Blaise: lignes et texte en noir et italique
groupe Sr + Ba
groupe MgO

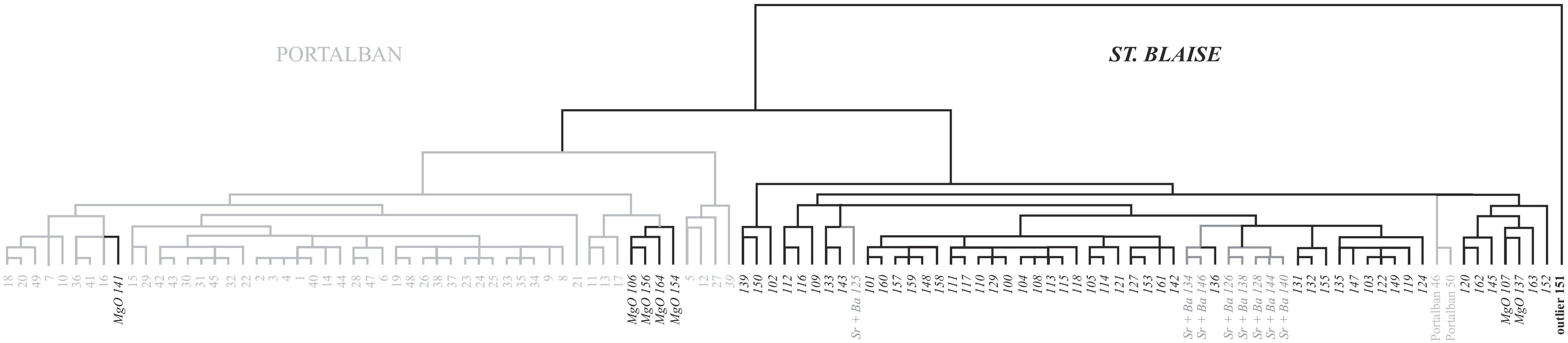


Figure 11 - Analyse multivariée, classification ascendante hiérarchique de la poterie des corpus de Portalban (Di Pierro, 2002b) et St. Blaise.

Ces résultats, qui renforcent notre hypothèse concernant des échanges entre les deux sites, ont été testés avec l'analyse discriminante, fig. 12. Ce graphe montre clairement l'existence des deux groupes principaux de poteries de Portalban et de St. Blaise. Les résultats confirment que la poterie riche en Sr + Ba de St. Blaise est un sous-groupe de ce site. Par contre, les poteries riches en MgO de St. Blaise n'appartiennent pas chimiquement au site d'origine, et les poteries pauvres en MgO de Portalban n'appartiennent pas à ce dernier site.

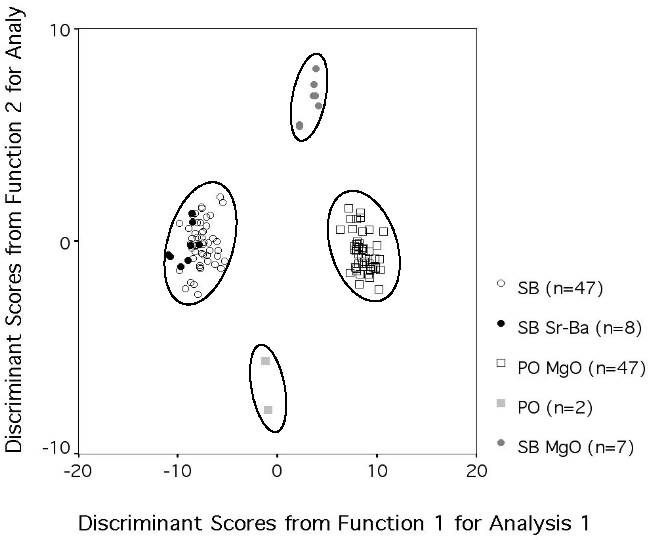


Figure 12 – Analyse multivariée des données chimiques concernant la céramique de la période Auvernier-cordé ancien du site de Portalban (Di Pierro, 2002b) comparée à la céramique des périodes Auvernier-cordé moyen et ancien du site de St. Blaise (analyse discriminante). PO = Portalban, SB= St. Blaise.

Si d'une part l'analyse statistique nous a confirmé la provenance exogène de la poterie riche en MgO de St. Blaise, mais aussi de certaines poteries de Portalban, il est certain qu'une meilleure compréhension de ces résultats en terme archéologique ne pourra être obtenue que par la multiplication d'analyses réalisées sur d'autres sites contemporains, situés dans la région étudiée. Ces nouvelles recherches permettraient de mieux évaluer la variabilité chimique de la poterie du Néolithique final, à l'échelle du plateau suisse occidental. De nouvelles études permettraient d'envisager des échanges avec d'autres sites, mais aussi de préciser les modes et les contextes d'exploitation et de production des poteries à cette période.

4. CONCLUSIONS

Relativement aux questions posées dans cette étude, nous avons obtenu les résultats suivants :

1) dans un corpus céramique composé de différents types morphologiques et/ou décoratifs, nous avons trouvé des correspondances entre typologies et matériaux, fig.8 ;
2) la répartition spatiale de la poterie à l'intérieur du village montre que certains groupes de matériaux sont localisés dans des zones particulières du village, fig.9.

Pour obtenir ces résultats, nous avons caractérisé pétrographiquement et chimiquement 63 poteries Auvernier-cordé ancien et moyen du site de St. Blaise/Bains des Dames (Suisse). Dans le but de réaliser une meilleure approche statistique, 29 résultats chimiques d'une précédente étude (Benghezal, 1994) concernant le même site et les mêmes phases culturelles ont été pris en considération

Du point de vue stylistique, on distingue quatre types de poterie datant de l'Auvernier-cordé. La céramique cordée qui se différencie en deux sous groupes, (i) la poterie « Cordé vrai » et (ii) la poterie « Cordé imité » ; la céramique sans décor cordé, morphologie et d'autres types de décors (iii) « Auvernier » propre et (iv) de « Transition », tab.1. L'échantillonnage a été effectué en tenant compte de leur répartition spatiale à l'intérieur du site, en fonction des six assemblages/dépotoirs principaux, bien identifiés et caractérisés (Michel, 2002).

Du point de vue des matériaux, trois argiles différentes ont été identifiées ; (i) une argile calco-silicatée et pauvre en MgO et en Sr+Ba qui a été utilisée pour produire 67 poteries ; (ii) une argile silicatée et riche en MgO qui a été utilisée pour fabriquer 15 céramiques ; (iii) une argile calco-silicatée et riche en Sr + Ba qui a été utilisée pour produire 10 poteries, fig.7e. En plus, une seule poterie, céramique DP 151, a une composition totalement différente des autres céramiques.

Mis à part deux tessons, toute la céramique a été dégraissée avec du granite du Mont Blanc, provenant de la moraine locale ou régionale.

Nous confirmons la production locale de la poterie correspondant aux types « Transition », « Auvernier » et « Cordé imité » produite à partir de l'argile calco-silicatée (i).

Par contre, nous avons trouvé une bonne corrélation entre le groupe de poterie fabriqué avec l'argile riche en MgO (ii), et la céramique de typologie « Cordé vrai». Ce type céramique reflète une forte influence de la Civilisation « Céramique Cordée », qui provient de Suisse orientale (Giligny, 1993 ; Giligny & Michel, 1995). 63% des poteries de type « Cordé vrai » font partie du groupe chimique riche en MgO. Par contre, seulement 12% de la céramique « Cordé imité » fait partie de ce groupe. Pour tous les autres types de décors et formes, l'appartenance de la poterie au groupe riche en MgO est très faible (3%), fig.8.

Nous avons testé l'hypothèse d'une provenance exogène de la poterie « Cordé vrai » et riche en MgO. La mise en corrélation des corpus céramiques contemporains de St.Blaise et de Portalban (Di Pierro, 2002b) a permis de constater une forte similitude chimique et pétrographique entre la poterie MgO riche de St.Blaise et celle de Portalban. Au contraire, certaines poteries de Portalban qui se distinguaient déjà chimiquement et pétrographiquement du reste du corpus semblent appartenir au groupe principal de St.Blaise, fig.10. La provenance exogène de ces deux sous-groupes de poterie a été confirmée par l'analyse statistique, fig.11 & 12. Cependant, ceux mêmes résultats permettent d'envisager des échanges de poterie entre St. Blaise et aussi d'autres sites néolithiques de la région, dont Portalban reste un candidat potentiel.

Nous avons également trouvé une concentration de poteries produites avec une argile riche en Sr + Ba (iii) localisée dans une zone du village. Cette concentration appartient à trois dépotoirs qui sont rattachés à la même structure d'habitation. Les dépotoirs E et F (9 poteries, 90%) liés à la maisonnée de la phase Auvernier-cordé ancien ; le dépotoir D (une poterie, 10%) lié à la maisonnée de la phase Auvernier-cordé moyen, situé stratigraphiquement au-dessus de la précédente, fig.9a-b. Les poteries de ce groupe chimique ont très probablement été fabriquées à partir d'une argile locale.

Ces données renforcent l'hypothèse qu'au Néolithique final, dans l'est de la France comme en Suisse occidentale, la production céramique était une production domestique liée aux structures d'habitation, dans lesquelles chaque groupe d'habitant fabriquait ses propres poteries (Pétrequin *et al.*, 1994).

BIBLIOGRAPHIE

ARNOLD, D., 1985, *Ceramic theory and cultural process. New studies in Archaeology* . Cambridge University Press.

ARNOLD, D., 2001, *Linking society with the compositional analyses of pottery : a model from comparative ethnography*. XIVe Congrès de l'Union International des Sciences Préhistoriques et Protohistoriques, Liège, 2 - 8 septembre 2001. Abstract, p. 45.

BALDASARI, A. & SPEER J. A., 1979, Witherite composition, physical properties, and genesis. *Amer. Miner.* 64, 742 – 747.

BENGHEZAL, A., 1994, *Provenance et techniques de la céramique du Néolithique final de stations des trois lacs jurassiens Suisse.* Thèse de doctorat, Université de Fribourg, 174 pp.

BOURQUIN, PH., BUXTORF, R., FREI, E., LÜTHI, E., MUHLETHALER, C., RYNIKER, K. & SUTER, H., 1968, *Atlas géologique de la Suisse 1:25.000, feuille 1144, Val de Ruz.* Commission géologique suisse.

BUSSY, F., 1990, *Pétrogenèse des enclaves microgrenues associées aux granitoïdes calco-alcalins: exemple des massifs varisque du Mont Blanc Alpes occidentales et miocène du Monte Capanne Ile d'Elbe, Italie.* Thèse de Doctorat, Université de Lausanne. Mémoire de Géologie n°7, 309 pp.

COLLOMB, P.& MAGGETTI, M., 1996, Dissolution des phosphates présents dans des céramiques contaminées. *Revue d'Archéometrie*, 20, 69 – 75.

DEER, W. A., HOWIE R. A. & ZUSSMAN J., 1962, *Rock-Forming Minerals, Vol. 5, Non-silicates.* Wiley, New York.

DI PIERRO, S., 2002a, *Domestic production versus pottery exchanges during the Final Neolithic: characterization of the Auvernier-cordé ceramics from the Porttalban and St. Blaise settlements, Western Switzerland.* Ph.D dissertation. University of Fribourg, Switzerland, pp.184.

DI PIERRO, S., 2002b, Ceramic production technology and provenance during Final Neolithic : the Portalban settlement, Neuchâtel Lake, Switzerland. Proceedings of the "4e Colloque d'Archéometrie", La Rochelle, France, 24 - 28 April 2001, *Revue d'Archéometrie*. Sous presse.

DI PIERRO, S., 2002c, Matrix-temper separation of Neolithic ceramics ; an experimental approach to characterise the original raw materials. In: Proceedings of the 6th European Meeting on Ancient Ceramics EMAC '01, Ceramic in the Society, Fribourg, Switzerland, 3-6 October 2001. Sous presse.

DI PIERRO, S. & MARTINEAU M., 2002, *Pottery Tempering With Mont Blanc Granite Across The Jura Belt During French And Swiss Final Neolithic.* 33rd International Symposium on Archaeometry ISA, 22 - 26 April 2002, Amsterdam. Abstract

FREI, E., MEIA, J., BECKER, F., BÜCHI, O., BUXTORF, R., RYNIKER, K. & SUTER, H., (1974), *Atlas géologique de la Suisse 1:25.000, feuille 1164, Neuchâtel.* Commission géologique suisse.

GILIGNY, F., 1993, *La variabilité des récipients céramiques au Chalcolithique moyen-récent jurassien 3400-2400 av. J.C.. Analyse archéologique d'un système d'objets.* Thèse de Doctorat, Université de Paris I – Panthéon/Sorbonne UFR 03 – Histoire de l'Art et Archéologie, Vol.1, 273 pp.

GILIGNY, F. & MICHEL R., 1995, *L'évolution des céramiques de 2920 à 2440 av.J.-C. dans la région des trois lacs Suisse Occidentale.* Chronologies néolithiques. De 6000 à 2000 avant notre ère dans le Bassin rhodanien. Dans: Actes du Colloque d'Ambérieu-en-Bugey, 19-20 septembre 1992. Documents du Département d'Anthropologie de l'Université de Genève, n° 20. Ambérieu-en-Bugey, éd. Société Préhistorique Rhodanienne, 1995, p. 347-361.

LEMOINE, C. & PICON, M., 1982, La fixation du phosphore par les céramiques lors de leur enfouissement et ses incidences analytiques. *Revue d'Archéometrie*, 6, 101 – 112.

MAGGETTI, M., 1982, Phase analysis and its significance for Technology and Origin. In *Archaeological Ceramics*, ed. J.S.Olin and A.D.Franklin. Smithsonian Institution Press, p. 121-133.

MAGGETTI, M., 1994, *Mineralogical and Petrographical methods for the study of ancient pottery.* In: 1st European Workshop on archaeological ceramics, Burragato F., Grubessi O., Lazzarini L., eds, Università degli Studi di Roma "La Sapienza" 1994.

MARRO, C., 1986, *Les granitoïdes du Mont Blanc en Suisse.* Thèse de Doctorat, Université de Fribourg, 145 pp.

MARTINEAU, R., 2000, *Poterie, techniques et sociétés. Etudes analytiques et expérimentales à Chalain et à Clairvaux (Jura), entre 3200 et 2900 av. J.-C.* Thèse de doctorat, Archéologie-préhistoire, Besançon, Université de Franche-Comté, UFR des Sciences de l'Homme, du Langage et de la Société, multigraphiée.

MARTINEAU, R., CONVERTINI, F. & BOULLIER, A., 2000, Provenances et exploitations des terres à poterie des sites de Chalain (Jura), aux 31e et 30e siècles avant J.-C., *Bulletin de la Société Préhistorique française*, t. 97, n° 1, p. 57-71.

MATTHEW, A.J., WOODS, A.J. & OLIVER C., 1991, Spots before the eyes : new comparision charts for visual percentage estimation in archaeological material. In: *British Museum, occasional paper*, number 81, p. 211- 263.

MICHEL, R., 2002, Saint-Blaise/Bains des Dames, 3. Typologie et chronologie de la céramique néolithique : céramostratigraphie d'un habitat lacustre. Neuchâtel, Service et Musée cantonal d'archéologie *Archéologieneuchâteloise*, 27; 2 vol.

NUNGÄSSER, W. & MAGGETTI, M., 1978, Mineralogisch-petrographische Untersuchung der neolitischen Töpferware vom Burgäschisee. *Bull. Soc. Frib. Sc. Nat.* 67/2, p. 152 – 173.

NUNGÄSSER, W., MAGGETTI, M. & STÖCKLI, W.E., 1985, Neolitische Keramik von Twann – Mineralogische und Petrographische Untersuchungen. *Jahrbuch der Schweiz. Ges. für Ur- und Frügeschichte*, 68, p. 7-39.

PÉTREQUIN, P., PÉTREQUIN, A.M., GILIGNY, F. & RUBY, P., 1994, Produire pour soi, la céramique de Chalain 2 C au Néolithique final. *Bulletin de la Société Préhistorique française*, t. 91, n° 6, p. 407-417.

PICON, M., 1985, Un example de pollution aux dimensions kilométrique: la fixation du Baryum par les céramiques. *Revue d'Archéometrie*, 9, 27 – 29.

PICON, M., 1987, La fixation du Baryum et du Strontium par les céramiques. *Revue d'Archéometrie*, 11, 41 – 47.

PICON, M., 1991, Quelques obsérvations complémentaires sur les altérations de composition des céramiques au cours du temps: cas des quelques alcalins et alcalino-terreux. *Revue d'Archéometrie*, 15, 117 – 122.

PORTMANN, J.P., 1955, Pétrographie des moraines du glacier würmien du Rhône dans la région des lacs subjurassiens Suisse. *Bull. Soc. neuchât. Géogr.* 51/5, 1954-1955.

PORTMANN, J.P., 1966, Pétrographie des formations glaciaires à l'est du lac de Bienne. *Eclogae geol. Helv.* 59/2, p. 697 - 721.

RAMSEYER, D., 1987, Delley-Portalban. Contribution à l'étude du Néolithique en Suisse occidentale. *Archéologie fribourgeoise* 3, Fribourg.

RAMSEYER, D., 1988, La céramique néolithique d'Auvernier/La Saunerie fouilles 1964 – 1965. Auvernier 7. *Cahiers d'Archéologie Romande* 45, Lausanne.

SPEER, J. A. & HENSLEY-DUNN, M. L., 1976, Strontianite composition and physical properties. *Amer. Miner.* 61, 1001 – 1004.

STÖCKLI, W.E., 1995, L'evolution du Néolithique Suisse. In « La Suisse du Paléolithique à l'aube du Moyen Age. De l'homme de Néanderthal à Charlemagne ». In *SMP II, Néolithique*. Veralg Scweizerische Gesellschaft für Ur- und Frügeschichte, Basel. 358 pp.

SUTER, H. & LÜTHI, E., 1969, *Erläuterungen des Atlasblatt 51, Val de Ruz, des Geologischer Atlas der Schweiz 1:25.000*, Schweizerische Geologische Kommission.

VON RAUMER, J., 1967, *Kristallisation und Gefügebildung im Mont-Blanc-Granit.* Habilitationsschrift zur Erlangung der Venia legendi an der mathematisch-naturwissenschaftlichen Fakultät der Universität Freiburg i. Ü. Schweiz, p. 499-579.

VON RAUMER, J., 1969, Stilpnomelan als alpinmetamorphes Produkt im Mont-Blanc-Granit. *Contr. Mineral. Petrol.* 21, p. 257-271.

VON RAUMER, J., 1984, The external massifs, relics of Variscan Basement in the Alps. *Geologische Rundschau*, 73, 1, p. 1-31.

WHITBREAD, I. K., 1986, The characterisation of argillaceous inclusions in ceramic thin sections. *Archaeometry* 28, 1, p. 79-88.

ZANCO, A., 1998, *Provenance and technology of Galloroman Terra Sigillata imitations from Western Switzerland.* Ph.D Dissertation. University of Fribourg. Switzerland.

CHAPTER V

POTTERY VERSUS COBS AND LOOM WEIGHTS. DIFFERENT RAW MATERIALS FOR DIFFERENT UTILIZATIONS AT THE WESTERN SWISS PLATEAU SCALE

1. INTRODUCTION

The present Ph.D. research represents the continuation of the previous huge work performed by Benghezal (1994). In her doctorate, she was assigned different issues and tasks. The Neolithic ceramics of the Western Swiss Plateau had been classified by the archaeologists between fine and coarse ceramics. One of the main archaeological questions was the provenance of the fine ceramics, given the morphologic similitude with the fine ceramics, found in France (Schwab, 1982; Ramseyer, 1987). The hypothesis of a potential importation from there was launched. Apart from the work of Sturny & Ramseyer (1984), Benghezal (1994) work represents the first important attempt to characterize the Western Swiss Final Neolithic ceramics with a classic archaeometric approach. Hence, her work concerned the study of 239 samples of fine and coarse ceramics coming from six Swiss localities (Vinelz, Sutz, Auvernier, Portalban, St. Blaise and Nidau), and compared them to 105 fine and coarse ceramics sherds coming from three Eastern French localities (Charavines, Chalain and Clairvaux) from where fine ceramics were known to be locally produced. As an attempt to identify the original raw materials used to produce the ceramic products, she investigated 41 specimens of clay samples around the Swiss settlements.

The main outcomes and results of her work have been:

1) The Swiss fine and coarse ceramics were undistinguishable from a chemical and petrographic point of view. The same kind of raw materials should have therefore been used to produce both types.
2) The bulk composition of the Swiss ceramic products was consistent with the raw clays sampled at the settlements. The provenance of the ceramics has been therefore established as local, at the regional scale of the Western Swiss Plateau at least.
3) She established two main groups of references, CH 36 (CaO < 5 wt%) and CH 37 (CaO > 5wt%), for the Swiss samples.
4) The French fine and coarse ceramics were sharply different in composition when compared to the Swiss samples. The importation from those sites was therefore ruled out.
5) She studied other technological issues such as the firing temperature conditions of ceramics, for instance.

The 239 Swiss ceramics products she investigated were heterogeneously composed. Among them there were in fact fine and coarse potteries and other fired clays tools such as cobs[1], earths[2] and loom weights[3]. The definitions and descriptions of the different utilizations of these ceramic objects have been extensively given in Di Pierro (2002). The main objective of this sampling strategy was based on the general believed assumption that tools such as the loom weights for instance should have been locally produced (i.e. Médard, 2000). The potential correlation between their composition with that of pottery can or could have been an evidence of the local production of this latter.

It has been shown in Di Pierro (2002) that the above assumption was wrong, as far as the Portalban ceramic production was concerned.

The main aim of this chapter is the reinterpretation of the chemical data sets published by Benghezal (1994) from five Swiss settlements (at Nidau no cobs and no loom weights have been characterized), at the light of the results presented in Di Pierro (2002).

2. BENGHEZAL DATA SETS PER SETTLEMENTS

The following figures are all correlation diagrams between major oxides SiO_2 and CaO expressed in

---

[1] « torchis »

[2] « chape d'argile »

[3] « poids de tisserands » or « pesons »

weight per cent (wt%), and concern each a single settlement as per the data set published by Benghezal (1994). They are presented taking into account the difference between pottery on one side and the other fired clay objects, mainly cobs and loom weights, on the other.

2.1 The settlements

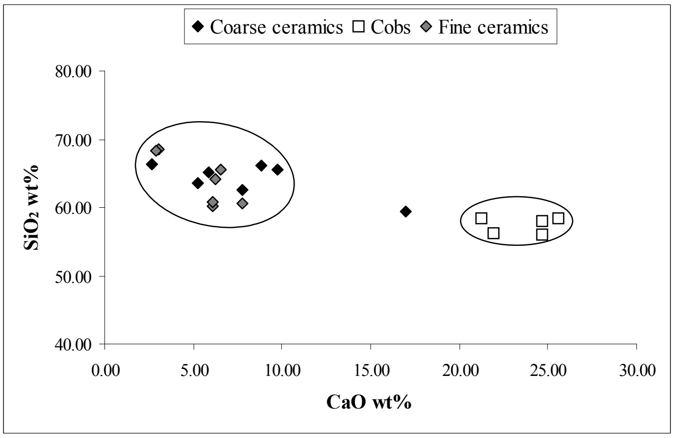


Figure 1 - The Auvernier settlement.

The above graph clearly shows the sharp difference in composition between the pottery, coarse and fine ceramics on the left, and the cobs of the Auvernier settlement. Beside only one exception, the pottery ranges in composition 3 to 10 wt% of CaO (and > 60wt% of SiO_2 content), while the cobs range 20 to 25 wt% of CaO (and < 60wt% of SiO_2). This discrepancy is mainly due to the utilization of a silicate clay for the pottery manufacturing in contrast to the utilization of a calcareous clay for the cobs preparation.

The graph of fig.2 concerns the ceramic products of Portalban. The pottery data are again ranging between 2 to 10 CaO wt%, while most of the cobs and the loom weights are clearly distinguished as a separated group ranging 12 to 18 CaO wt%. A few exceptions exist since one cob and two loom weights lie in the pottery field, while one fine ceramic belong to the cobs and loom weights field. Attention is drawn to the presence of two outlying pottery with CaO content above 20 wt%. The above data are in excellent agreement with those obtained for the same settlement in Di Pierro (2002). In that paper the presence of a calcareous clay at Portalban fitting in composition the cobs and loom weights field has been reported. The local provenance of such tools has been therefore demonstrated.

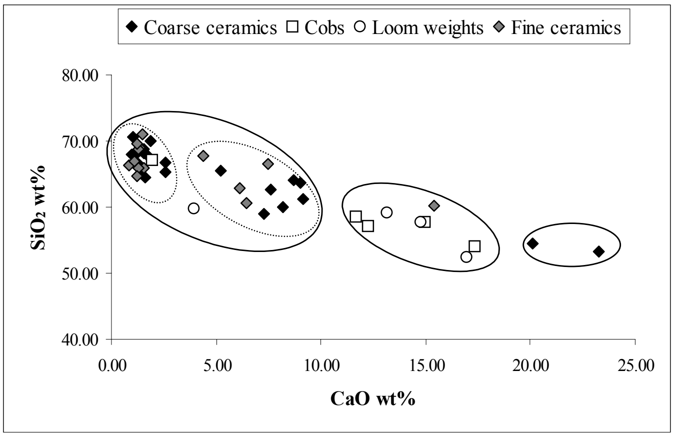


Figure 2 – The Portalban settlement.

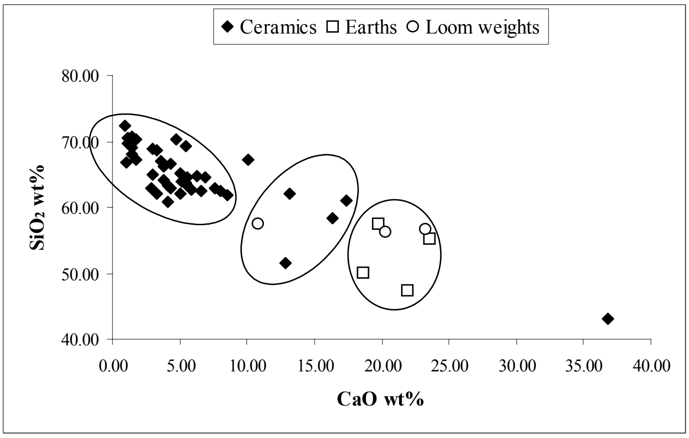


Figure 3 – The St.Blaise settlement.

Fig.3 concerns the St. Blaise settlement. It is clearly evident the existence of two sharply separated groups. The pottery is a relatively homogeneous group ranging 1 to 10 wt% of CaO, while earths and loom weights range 19 to 24 wt%. A limit exists at 60 wt% of SiO_2: above is the pottery, below are the other objects. These rules have of course their exceptions such as the four potteries and one loom weight that lies in the corridor between the two major groups. But attention is again drawn to the one pottery that exhibits an outlying position being CaO-rich, up to 37 wt%.

Fig.4, concerning the Vinelz settlement,is perhaps the less clear example since in this case all the ceramics products range between 1 to 11 wt% of CaO without distinguishing between pottery and the other fired clay objects. Two chemical subgroups seem to exist anyway, the first one between 1 to 4 wt% of CaO,

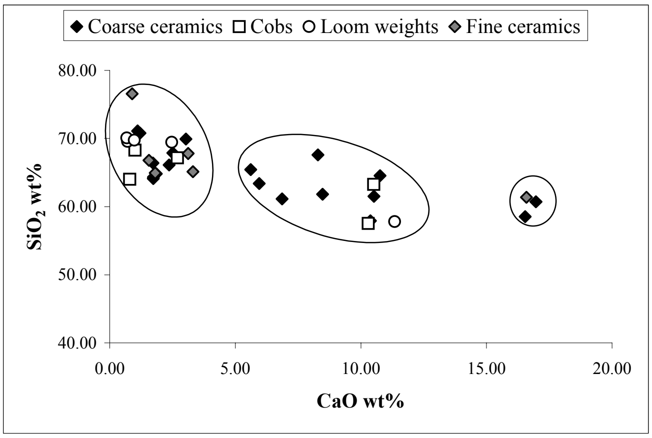


Figure 4 –The Vinelz settlement.

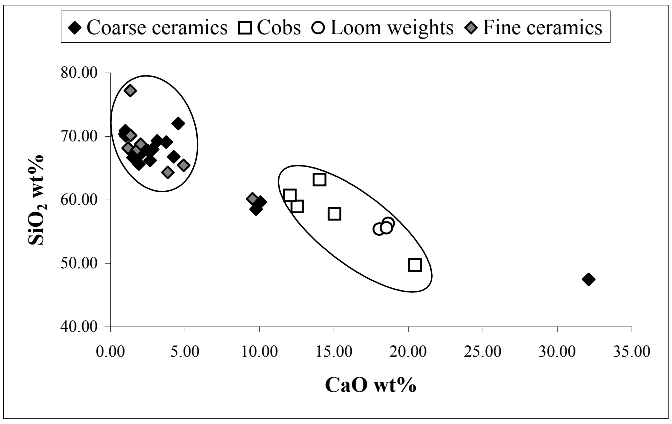


Figure 5 – The Sutz settlement.

the second one between 5 to 12 wt%. It seems to be more interesting in this case the presence of a threesome pottery group again richer in CaO if compared to the average content of this oxide.

In the case of the Sutz settlement, fg.5, the main differences between pottery on one side and cobs and loom weights on the other are again sharply evident. Pottery ranges up to 10 wt% of CaO (and above 63 wt% of SiO_2), while cobs and loom weights range 12 to 21 wt% of CaO (and are below 62 wt% of SiO_2). Again, we have the presence of an isolated pottery richer in CaO up to 32 wt%.

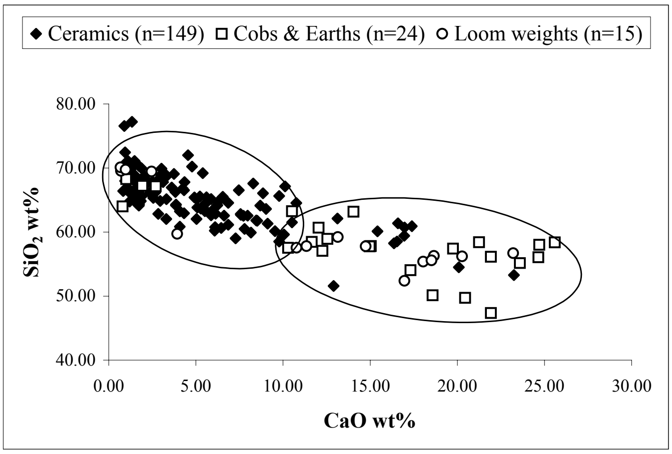


Figure 6 – The situation at the regional scale.

The graph of fig.6 summarizes the situation for the five settlements discussed so far in details. The trend at the regional scale is easily confirmed. Despite few exceptions of some cobs and loom weights lying in the pottery field and vice versa, a clear tendency comes out at the Western Swiss Plateau scale. Ceramic s.s. in the sense of pottery used as vessels are mainly manufactured with silicate clays, which range 0 to 10 wt% in CaO and 60 to 70 wt% in SiO_2. All the other ceramic products such as the cobs (clay wall filling), earths (clay floor) and loom weight (compacted clay used for animal furs drying) are manufactured with calco-silicate to calcareous clays ranging 10 to 25 wt% of CaO and normally below the 60 wt% of SiO_2. This distinction can't be the result of the case, but it seems to be a rule (with its exception) across the five considered settlements.

3. DISCUSSION

The utilization of a silicate clay for most of the pottery and of a calco-silicate when not a calcareous clay for the preparation of the cobs and the loom weights is confirmed by the petrographic analyses performed by Benghezal (1994). She mentioned the adding of organic matter to the loom weights as well. For the Portalban settlement the source of the calcareous clay used for the preparation of cobs and loom weights has been localized as the closest to the village (Di Pierro, 2002) sampled clay, thus confirming the evident local production of such tools, at the scale of the single settlement. The adding of organic matter to the loom weights has been mentioned as a general rule too.

The analysis of the five settlements studied by Benghezal has confirmed the utilization of different raw materials for different ceramic objects. The same interpretation made for Portalban (Di Pierro, 2002) can be extrapolated for the other settlements as well.

The utilization of a calcareous material could depend on the final destination concerning the using of the objects. Cobs and earths were employed as crude unfired clay mixture to fill or to cover the walls and the floors of the building structures. The higher plasticity of a calcareous material (Claude Sistier, pers. commun.) could be at the base of such choice. Most of the archaeologists (i.e. Médard, 2000) agree that loom weights were fired before being used, but at lower temperatures and for less time if compared to pottery. The calcareous nature of the chosen material could confirm this hypothesis. In order to avoid the fissuring of their loom weights, Neolithic people must have fired the loom weights well below 700° C (Di Pierro, 2002), temperature above which the calcite breaks down.

It remains astonishing and interesting from the archaeological point of view to observe such a regularity in the knowledge and know-how that the Neolithic potters shared at the regional scale. In perspective such regularity should and could be sought for other settlements in Switzerland and other European countries hosting Neolithic settlements.

Another point which could deserve our attention is the presence of the CaO-rich sporadic pottery which seems to be present across the six studied settlements, fig.1 to 5. One pottery with such composition has been studied in details at the St. Blaise site by Di Pierro *et al.* (2002). An exogenous provenance of that ceramic has been envisaged. It could be worth to investigate in details the other potteries highlighted in this brief chapter, in order to test their exogenous provenance at the scale of the Swiss Plateau.

REFERENCES

BENGHEZAL, A., 1994, *Provenance et techniques de la céramique du Néolithique final de stations des trois lacs jurassiens Suisse.* Thèse de doctorat, Université de Fribourg, 174 pp.

DI PIERRO, S., 2002, Ceramic production technology and provenance during Final Neolithic : the Portalban settlement, Neuchâtel Lake, Switzerland. Proceedings of the "4e Colloque d'Archéometrie", La Rochelle, France, 24 - 28 April 2001, *Revue d'Archéometrie*. In press.

DI PIERRO, S., MICHEL, R. & MARTINEAU, R., 2002, *Matériau et types céramique à St. Blaise (Néolithique Suisse) Poterie exogène et production locale.* Proceedings of the XIVth Congress of the U.I.S.P.P.,Liège, Belgium, 2 – 8 September 2001. British Archaeological Report. Submitted.

MEDARD F., 2000, *L'artisanat textile au Néolithique. L'exemple de Delley-Portalban II (Suisse) 3272-2462 avant J.-C.* Préhistoires 4. Editions Monique Mergoil. Montagnac, France. 251 pp.

RAMSEYER, D., 1987, Delley-Portalban. Contribution à l'étude du Néolithique en Suisse occidentale*.* *Archéologie fribourgeoise* 3, Fribourg.

SCHWAB, H., 1982, *Portalban/Muntelier: zwei reine Horgener Siedlungen der Westschweiz.* Archäologisches Korrespondenzblatt, 12, Mainz, pp. 15-32

STURNY, C. & RAMSEYER, D., 1984, *Petrographische Analyse neolithischer Keramik aus Delley/Portalban II (Kt. Freiburg) und Charavines (Dpt.Isère, Frankreich).* Freiburger Archäologie, Fundbericht 1984, 92-95, Fribourg.

CHAPTER VI

POTTERY TEMPERING WITH MONT BLANC GRANITE ACROSS THE JURA BELT DURING FRENCH AND SWISS FINAL NEOLITHIC

by Simonpietro DI PIERRO & Rémi MARTINEAU

1. INTRODUCTION

The pottery manufacturing often hides a social attitude and a cultural behavior, since the choice of a given material is not the result of the case (Costantin & Courtois, 1985).

For instance, the Neolithic potters of Portalban have used systematically the same materials to produce their ceramics, in terms of the matrix (clay) as well as the temper, exploiting unique sources. As far as the temper is concerned, they have always chosen moraine pebble of the Mont Blanc granite. This fact has been demonstrated on a petrographic (Di Pierro, 2002a) as well as on a chemical base (Di Pierro, 2002b).

If at one Neolithic settlement the utilization of a specific rock for pottery tempering is a fairly interesting attitude, the utilization of the same material at another contemporary settlement becomes quite astonishing.

The petrographic study of the St. Blaise pottery has in fact given, among the main results, the exploitation of the Mont Blanc granite for ceramic tempering (Di Pierro *et al.*, 2002). A suite of 61 pottery, composed of at least three different bulk chemical groups, have all been tempered with the above mentioned lithotype.

At the Neolithic settlement of Chalain, France, another suite of 46 ceramics has been tempered with the stilpnomelane bearing Mont Blanc granite (Di Pierro & Martineau, 2002).

The aim of the present chapter is to quantitatively estimate the degree of correspondence between the three pottery suites. We have therefore decided to investigate the composition of the separated matrix and temper of the concerned ceramic samples. We have exploited the data set of Di Pierro (2002b) recently obtained on the Portalban pottery. We have applied the same separation technique on the St. Blaise and Chalain pottery suites as well, and compared the relevant chemical results.

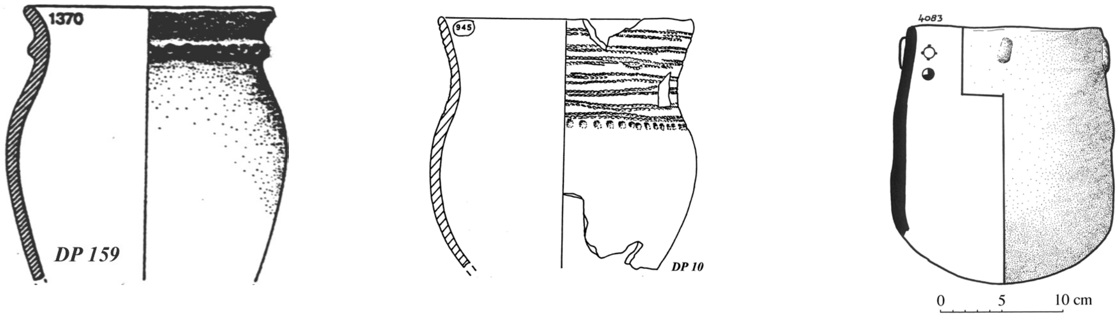
1.1 Geological and archaeological context

Fig.1 shows the geographic settings of the three studied settlements. The geological and archaeological context have been given in Di Pierro *et al.* (2002) for St. Blaise, in Di Pierro (2002a) for Portalban and in Martineau *et al.* (2000) for Chalain. The following are just few reminders for easy reference.

The St. Blaise settlement lies on the Western banks of the Neuchâtel Lake, Neuchâtel Canton, Switzerland. Geologically it is situated at the foot of the Jura Belt, composed of Mesozoic limestones mainly. Sporadic moraine deposits outcrop in the area. 63 ceramics belonging to the Old Auvernier-cordé (2.700 - 2.670 B.C) and to the Middle Auvernier-cordé (2.630 - 2.600 B.C) occupations of the settlements have been already characterized (Di Pierro *et al.*, 2002).

The Portalban site is located on the Eastern banks of the Neuchâtel Lake, Fribourg Canton, Switzerland. Geologically it lies on the Molasse s.s., a sandstones Tertiary unit, which is commonly cover by thin moraine deposits (Würm), rich of allochtonous crystalline rocks of Alpine origin, granites included. 47 ceramics belonging to the Old Auvernier-cordé occupation of the site (2.700 - 2.650 B.C) have been already characterized (Di Pierro, 2002a-b).

Figure 1 - Geographic settings of the studied settlements



St. Blaise **Portalban** **Chalain**

Figure 2 – Three typical examples of the studied pottery.

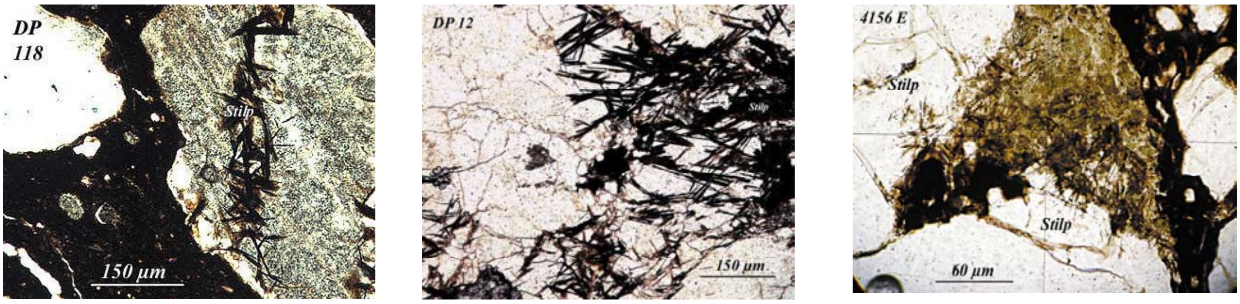
The dwelling settlements of Chalain lies on the Western side of the Chalain Lake, Jura Department, France. Geologically it belongs to the glacier depression of the "La Combe d'Ain", which basement is composed of Jurassic limestone mainly. Very rare moraine deposits with crystalline rocks of Alpine origin have been documented 50 km off the site. 46 ceramics with granite inclusions and non calcareous matrix have been already studied (Martineau *et al*., 2000). They belong to the Clairvaux cultural group (3.050 - 3.000 B.C) initial and late phases.

Fig.2 shows the morphologies of typical pottery from the three settlements.

2. RESULTS

2.1 Petrography

The mineralogical features of the granite used to temper the Portalban and St. Blaise ceramics have been given in Di Pierro (2002a) and Di Pierro *et al*., (2002) respectively[1]. On the basis of the data and description from the literature it has been identified as the Mont Blanc granite (i.e. Von Raumer, 1967; 1984; Bussy, 1990; Marro, 1986). This lithotype has been prospected in the moraine deposits around Portalban (Di Pierro, 2002a-b) or mentioned in the literature concerning the



St. Blaise **Portalban** **Chalain**

Figure 3 – Thin section photos of the stilpnomelane (Stilp) bearing Mont Blanc granite, in ceramic sherds.

---

[1] The main paragenesis and textures of the temper are common to the three mentioned pottery suites. The granite is composed of quartz, alkali-feldspar, plagioclase and biotite among the main minerals; hornblende, epidote, clinozoisite, titanite among the secondary phases; chlorite, zoisite, apatite, zircon and stilpnomelane among the accessories. The rock has clearly undergone a greenschist facies metamorphic event. Alkali-feldspar is a perthitic orthoclase mainly; Na-plagioclase is being replaced by sericite and saussirite; hornblende is often pseudomorph after biotite, this latter is being replaced by Fe-chlorite as well.

On the contrary, matrix are different. They are composed of biotite at Chalain, illite and calcite at St.Blaise, illite and chlorite at Portalban.

Quaternary deposits of the Western Swiss Plateau (i.e. Portmann, 1955; Frei *et al*., 1974; Meia & Becker, 1976). The granite temper grains of the Chalain pottery have been recently characterized as the stilpnomelane bearing Mont Blanc granite (Di Pierro & Martineau, 2002). The lithotype has been mentioned as scarce but present among the rare crystalline elements of Alpine origin in the Quaternary deposits of the French side of the Jura belt (Campy, 1982).

The stilpnomelane is a main mineralogical fingerprint of the Mont Blanc granite (Von Raumer, 1969). It has been clearly observed in most of the ceramics concerning the three settlements, fig.3.

Its presence constitutes a clear mineralogical evidence of the utilization of this lithotype in particular for the ceramic tempering at the three sites.

2.2 Bulk chemistry

The chemical results (X-ray fluorescence) of the bulk ceramics have been presented in Di Pierro *et al.* (2002) for St. Blaise and in Di Pierro (2002a) for Portalban. The Chalain data set of the bulk pottery are original data. For the aim of this chapter, the statistical analysis of the three pottery suites will be presented and briefly discussed here only.

Fig.4 below shows the discriminant analysis concerning the three settlements. It clearly shows as, from a strict chemical point of view, the three pottery suites are sharply distinct. This is mainly due to the utilisation of different clays in every settlement, which reflects three different compositions of the matrix. The CaO and MgO wt% contents of these latter, along with their correlated trace elements, are the main ranging values, which characterized the three different sites (Di Pierro *et al*., 2002).

Hence, the bulk chemistry confirms a distinct provenance of the material composing each pottery suite.

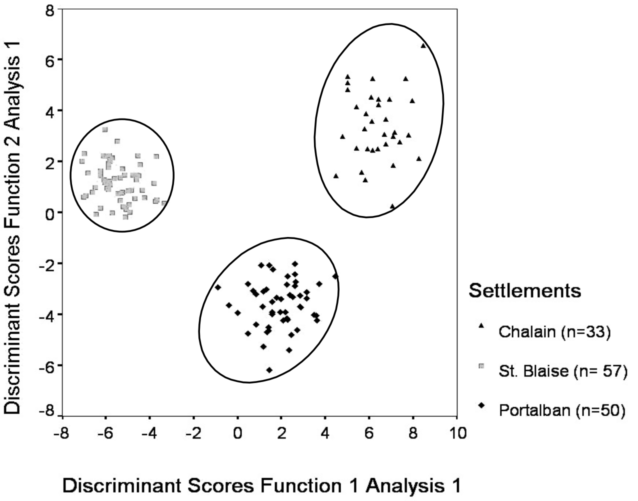


Figure 4 – The three settlements as per the statistical analysis of the XRF data sets.

2.3 Chemical data from the separation technique

The method concerning the matrix-temper separation procedure has been described in details (Di Pierro, 2002b). The method consists mainly of an attack with H_2O_2, properly buffered to neutral pH, carried out on a ceramic sherd. It permits to separate the two main components of the pottery sherd: the fine grained matrix and the a-plastic inclusions, the temper. In that paper it was applied to 17 ceramics from Portalban. Its effectiveness was tested and positively evaluated. Those data will be used here again for the comparison with the other two settlements data sets.

2.3.1 The St. Blaise results

19 ceramic sherds have been chosen, out of the 63 already characterized samples, among the main representative ones. Tab.1 summarizes the data concerning the initial and final weights of the recovered materials, with regard to the temper, the matrix and the middling. It is here briefly reminded that the middling consists of a hard mix of temper and matrix, which did not disaggregate enough during the H_2O_2 attack (Di Pierro, 2002b). The middling composition fairly matches that of the pottery. Tab.1 shows the composition and quantity of the liquid medium used for every reaction, as well as the timing. Compared to the Portalban suite, given the availability of more material, bigger specimens have been employed, almost 62 gr. in average. A mean of 96% of the initial weight has been recovered, which reflects a fairly high performance of the procedure. An average of around 10 gr. for the temper, with a peak up to 19 gr., and 12 gr. for the matrix, with a peak higher than 44 gr., have been obtained respectively. These good results have a positive influence on the representativeness of the chemical data.

Tab.2a-b concerns the XRF results. They have been listed per each component: temper, middling and matrix. The corresponding pottery bulk data have been included for easy reference.

The characterization of the pottery had allowed to distinguish between at least three different chemical groups, as per the following steps. The MgO wt% content discriminated two main groups. Most of the ceramics belonged to the MgO-poor group, 7 pottery constituted the MgO-richer group. This last had a clear correspondence with a petrographic group, the ceramic manufactured with a silicate clay, in opposition to the ceramics produced with a calco-silicate clay. A third chemical group was identified on the basis of an enrichment in Sr + Ba, which was a further distinction of the main MgO-poor group (Di Pierro *et al*., 2002, fig.7f).

The same elements have been used here to show in fig.5 how the three found chemical groups still discriminate well, even after the separation technique has been applied. The graph clearly highlights the presence of four distinct chemical groups: one constitutes the temper group, the three others are the

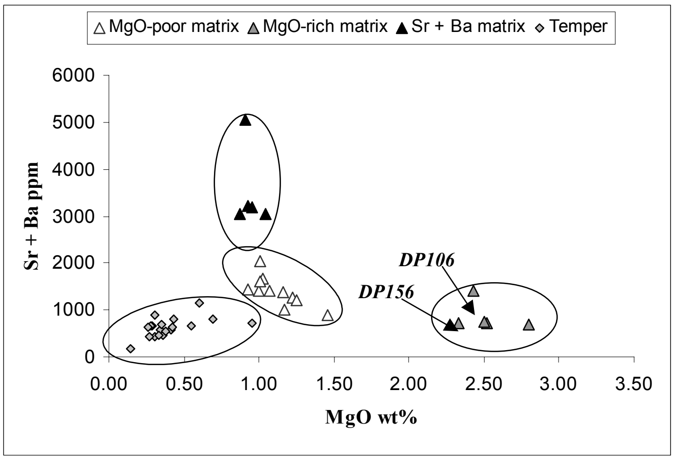


Figure 5 – Correlation diagram between Sr + Ba and MgO data of St. Blaise samples.

matrix groups. The MgO-rich matrix group, the Sr + Ba rich matrix group and the remaining MgO-poor matrix group. Fig.5 confirms the following points:

- the separation technique is effective since permits to separate and recognize the temper from the matrix.
- At St. Blaise the temper is composed of a fairly homogeneous material. It is MgO, Sr and Ba very poor.
- The pottery suite has been manufactured with the same kind of a-plastic inclusions but three different matrix (clays).
- The same ΔMgO wt% exists between the MgO-poor (around 1 wt%) and the MgO-rich (around 2.5 wt%) matrix, as already determined with the bulk pottery characterization (Di Pierro *et al.*, 2002, fig.7f). The MgO content of the temper is very low to fairly negligible. These features confirm that the higher MgO content in the ceramics is due to the matrix (clay) only. Fig.5 includes the bulk composition of the ceramic sherds DP 106 and DP 156. These two have not been processed with the separation run (tab.1 & 2) because they had been characterized as temper-free ceramics (Di Pierro *et al.*, 2002). Their compositions fits the MgO-rich matrix group, confirming once again the existence and utilization of this raw material.
- The Sr + Ba ppm content of the relevant matrix group is around 3000 ppm with a peak at around 5000 ppm, in opposition to an average of around 1500 ppm of the MgO-poor group. Therefore, the Δ(Sr + Ba) even increased if compared to the pottery bulk analyses. Values were around 2500 ppm for the Sr + Ba rich pottery group and of 1200 ppm for the MgO-poor pottery group (Di Pierro *et al.*, 2002, fig.7d). On the contrary, the temper content in Sr + Ba is always below 1000 ppm after the separation. These data confirm that the higher values of Sr + Ba in the pottery are due to the matrix (clay) only.
- In general, the composition of the three matrix group is quite homogeneous.

2.3.2 The Chalain results

15 ceramic sherds have been selected by Dr. Rémi Martineau for the separation technique. They belong to the pottery suites of 46 “crystalline” ceramics already petrographically (Martineau *et al.*, 2000) characterized.

Tab.3 concerns the data sets of the recovered temper, matrix and middling, as well as the principal data of every reaction. The availability of the material was not that large compared to the St. Blaise run. Less than 32 gr of ceramic sherd were used in average. A mean of around 95% of the initial material has been rescued from the separation. The recovered temper weight ranges 1.54 to 13.99 gr being the mean around 5 gr. In same cases, RM 4065 for instance, the representativeness of the relevant XRF analyses might be strongly influenced by the low final weight. On the contrary, the recovered matrix is in average of around 14 gr with a peak above 26 gr. Only two analyses are less than 5 gr of material and therefore less representatives. But in general, the amount of matrix overcomes in weight that of the middling for instance, which is a good result in the limited experience accumulated up to now concerning the method. This fact might hide some technological information about the firing temperature of the pottery for instance. The more the amount of recovered matrix (compared to the middling), the higher the porosity of the sherd, the lower the firing T of the pottery.

Tab.4a-b show the XRF results per component: temper, middling and matrix. The pottery bulk analyses have been included for easy reference. These latter present unfortunately already some constraints. Except analysis RM 3034, they show a P_2O_5 content above 1 wt% with some peak at 2.56 and 3.10 wt%. These data indicate that the pottery composition has been influenced by some contamination troubles. In fact, the maximum accepted P_2O_5 content in the soils and clays is 0.5 wt% (Lemoine & Picon, 1982) or 0.8 wt% (Collomb & Maggetti, 1996). Values above are considered to be due to the fixation in acid environments of Phosphorous coming mainly from the organic matter (Picon, 1985), the main scope of pottery being that of cooking vessels. The pollution due to the Phosphorous is mainly due to the ground water circulation in soils. This phenomenon is often accompanied by the fixation of another mobile element, the Barium (Picon, 1985; 1987; 1991)

Fig.6 shows in fact a correlation diagram between Al_2O_3 wt% and Ba ppm of the separated matrix of Chalain. It clearly shows the presence of two distinct groups. Five matrix have a content of Ba around 500 ppm (and Al_2O_3 below 20 wt%), while other nine show a Ba content around 1500 ppm (and Al_2O_3 above 20 wt%), two-three time higher than the previous group. This anomalous enrichment in Ba might in fact be produced by some contamination and fixation trouble undergone by the ceramics.

Analysis	**initial wt.**	**H_2O_2 37 v%**	**H_2O** deion.°	**t_{tot} heat.**	**temper**		**matrix**		**middling**		**final wt.**	
n°.	**gr**	**ml**	**ml**	**min**	**gr**	**%**	**gr**	**%**	**gr**	**%**	**gr**	**%**
DP 103	29.82	50	200	20	5.38	*18.65*	1.64	*5.68*	21.83	*75.67*	28.85	*96.75*
DP 111	106.52	50	200	25	19.07	*17.97*	44.19	*41.65*	42.85	*40.38*	106.11	*99.62*
DP 113	46.49	50	200	25	13.71	*30.05*	7.47	*16.37*	24.44	*53.57*	45.62	*98.13*
DP 115	27.53	50	200	25	5.74	*21.12*	5.10	*18.76*	16.34	*60.12*	27.18	*98.73*
DP 118	38.23	50	200	20	7.19	*19.49*	9.36	*25.37*	20.35	*55.15*	36.90	*96.52*
DP 119	36.18	50	200	25	7.35	*21.02*	5.89	*16.85*	21.72	*62.13*	34.96	*96.63*
DP 125	38.37	50	200	20	4.69	*12.59*	6.99	*18.77*	25.57	*68.64*	37.25	*97.08*
DP 126	103.38	50	200	20	9.63	*9.52*	14.27	*14.10*	77.27	*76.38*	101.17	*97.86*
DP 128	69.53	50	200	20	15.59	*23.42*	10.35	*15.55*	40.63	*61.03*	66.57	*95.74*
DP 130	119.84	50	200	25	13.77	*11.67*	13.94	*11.82*	90.25	*76.51*	117.96	*98.43*
DP 131	94.45	50	200	20	5.59	*6.05*	23.19	*25.10*	63.60	*68.85*	92.38	*97.81*
DP 137	14.55	100	250	30	4.21	*30.75*	8.20	*59.90*	1.28	*9.35*	13.69	*94.09*
DP 140	54.48	50	200	20	6.64	*12.70*	9.52	*18.21*	36.13	*69.10*	52.29	*95.98*
DP 141	23.29	100	250	30	4.54	*23.56*	2.89	*15.00*	11.84	*61.44*	19.27	*82.74*
DP 143	65.61	50	200	45	17.06	*26.68*	5.54	*8.66*	41.34	*64.65*	63.94	*97.45*
DP 144	55.33	100	400	60	7.29	*13.61*	5.44	*10.15*	40.84	*76.24*	53.57	*96.82*
DP 148	30.78	100	250	30	7.57	*25.42*	3.47	*11.65*	18.74	*62.93*	29.78	*96.75*
DP 160	46.30	100	250	30	5.94	*13.51*	9.44	*21.46*	28.60	*65.03*	43.98	*94.99*
DP 164	49.17	100	250	30	8.53	*18.42*	11.18	*24.15*	26.59	*57.43*	46.30	*94.16*
Mean	61.76				9.97	*18.75*	11.65	*19.96*	38.25	*61.29*	59.87	*96.12*

° To all liquid solutions, **3 drops of NH_3 25%** in volume have been added in order to obtain a **pH 7 (± 0,5)**

Table 1 - list of samples from St. Blaise.

	SiO_2	TiO_2	Al_2O_3	Fe $_{tot}$	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	Ba	Cr	Cu	Nb	Ni	Pb	Rb	Sr	V	Y	Zn	Zr	SUM
DP 103 te	74.27	0.20	14.19	1.49	0.02	0.31	0.65	4.23	4.43	0.10	338	25	4	31	12	13	328	96	12	55	20	125	99.90
DP 111 te	74.06	0.16	14.00	1.50	0.03	0.36	1.07	4.12	4.49	0.04	346	16	2	18	11	18	328	122	15	35	18	101	99.84
DP 113 te	74.61	0.18	13.93	1.55	0.03	0.34	1.39	3.98	4.17	0.05	438	22	2	8	11	13	186	138	16	24	11	99	100.24
DP 115 te	71.88	0.25	15.24	2.14	0.03	0.55	1.82	3.99	4.03	0.07	497	28	2	7	14	14	164	150	22	18	46	119	100.00
DP 118 te	68.61	0.30	17.03	2.67	0.07	0.60	1.82	4.50	4.44	0.12	780	16	2	14	12	23	203	355	23	32	56	186	100.16
DP 119 te	73.80	0.20	14.44	1.36	0.02	0.33	0.78	3.97	5.14	0.07	376	21	2	13	12	11	305	88	13	29	7	121	100.11
DP 125 te	72.48	0.17	15.09	1.44	0.03	0.29	1.37	4.51	4.60	0.07	456	19	2	18	13	15	298	196	14	38	13	121	100.05
DP 126 te	76.08	0.16	12.75	1.23	0.02	0.28	1.41	3.27	4.88	0.09	402	26	2	6	13	16	187	252	19	15	7	89	100.17
DP 128 te	71.93	0.21	15.30	1.76	0.04	0.35	1.76	4.59	4.07	0.08	497	18	2	9	11	18	238	188	14	29	20	135	100.09
DP 130 te	72.45	0.20	15.31	1.34	0.04	0.31	1.06	4.47	4.99	0.09	620	21	2	12	10	12	239	260	8	30	14	126	100.25
DP 131 te	68.37	0.35	16.67	3.09	0.05	0.95	2.76	3.94	4.00	0.12	502	21	4	30	16	7	319	218	46	33	34	147	100.30
DP 137 te	76.83	0.09	12.88	0.79	0.02	0.14	0.46	3.91	5.01	0.02	131	11	2	13	7	18	391	33	7	50	2	80	100.16
DP 140 te	71.29	0.24	15.35	2.06	0.04	0.69	2.05	4.16	4.43	0.15	531	25	2	8	14	12	255	286	30	25	22	124	100.46
DP 141 te	72.39	0.20	15.18	1.41	0.03	0.26	1.19	4.71	4.78	0.09	481	20	2	12	11	23	259	150	11	30	8	127	100.24
DP 143 te	73.70	0.19	14.09	1.56	0.04	0.41	1.28	4.38	4.09	0.06	424	16	2	16	11	16	243	149	14	39	12	142	99.79
DP 144 te	75.86	0.18	12.99	1.40	0.03	0.38	1.31	3.37	4.78	0.07	407	18	2	13	14	14	307	152	13	30	12	98	100.36
DP 148 te	71.32	0.20	16.27	1.65	0.03	0.42	0.74	4.75	4.96	0.07	495	23	2	13	12	9	304	143	16	27	13	100	100.41
DP 160 te	73.90	0.16	13.61	1.27	0.02	0.27	1.92	3.95	4.77	0.05	321	12	2	11	3	15	265	99	9	33	6	109	99.92
DP 164 te	75.92	0.15	13.23	1.35	0.02	0.43	0.63	3.20	5.33	0.03	679	20	2	5	11	16	169	115	10	10	14	89	100.29
DP 103 mi	63.92	0.82	19.10	5.72	0.03	1.13	3.62	1.26	3.89	0.26	914	114	15	25	64	33	212	716	140	37	100	181	99.76
DP 111 mi	61.07	0.79	17.93	5.76	0.04	1.14	8.77	1.42	2.61	0.23	504	129	20	21	79	27	170	396	141	34	98	184	99.77
DP 113 mi	62.63	0.83	19.43	6.57	0.02	1.14	5.16	1.13	3.11	0.19	733	121	11	21	70	32	158	499	148	31	97	184	100.22
DP 115 mi	63.57	0.83	18.75	5.85	0.02	1.09	5.99	0.93	2.95	0.28	742	117	3	19	65	29	138	716	155	29	94	185	100.26
DP 118 mi	62.29	0.80	18.74	5.86	0.03	1.19	6.86	1.01	2.99	0.34	775	116	9	20	71	32	146	628	161	31	102	179	100.12
DP 119 mi	64.34	0.81	18.12	5.94	0.02	1.07	5.57	0.94	3.28	0.31	781	119	9	21	70	29	171	787	144	32	101	181	100.40
DP 125 mi	60.28	0.61	14.15	3.35	0.05	0.97	15.75	1.36	2.88	0.83	1203	79	12	22	39	23	160	2292	79	36	49	217	100.23
DP 126 mi	61.15	0.83	19.41	5.38	0.03	0.91	6.93	0.87	2.96	1.33	1761	123	14	25	66	31	151	3297	147	29	91	233	99.79
DP 128 mi	60.40	0.90	20.04	5.59	0.03	0.97	7.07	0.91	2.96	0.97	1458	128	28	31	69	31	170	2166	151	34	104	227	99.83
DP 130 mi	63.92	0.84	18.63	6.32	0.02	1.19	5.14	0.96	2.96	0.30	478	143	12	22	91	29	179	418	160	29	150	199	100.29
DP 131 mi	66.92	0.64	15.89	4.00	0.03	1.03	6.20	1.78	3.24	0.59	855	65	21	25	44	22	213	586	105	35	83	174	100.32
DP 137 mi	66.55	0.57	15.01	5.05	0.05	2.50	5.00	1.66	3.47	0.22	378	107	137	13	52	30	220	265	95	33	96	121	100.06
DP 140 mi	65.97	0.66	16.34	4.54	0.03	0.94	6.87	1.42	3.08	0.55	950	81	20	16	52	28	170	1177	115	37	277	180	100.39
DP 141 mi	62.34	0.71	20.03	5.39	0.05	2.60	1.52	1.74	4.97	0.67	1001	112	54	14	61	29	239	615	122	34	119	161	100.02
DP 143 mi	65.23	0.75	15.93	5.26	0.04	1.01	8.17	0.99	2.34	0.69	804	108	55	23	52	23	149	613	116	37	75	244	100.41
DP 144 mi	64.55	0.75	17.98	5.10	0.03	1.03	5.14	1.27	3.24	0.71	1651	102	13	23	63	28	193	1353	111	36	113	190	99.81
DP 148 mi	64.49	0.72	17.96	4.54	0.03	0.92	5.48	1.70	3.64	0.46	846	83	7	26	42	24	227	544	106	37	71	211	99.94
DP 160 mi	59.26	0.92	19.53	6.89	0.03	1.42	8.50	0.48	2.77	0.23	640	124	11	25	67	30	166	318	164	34	109	201	100.02
DP 164 mi	67.15	0.74	16.96	6.41	0.03	2.50	1.26	1.25	3.76	0.15	551	128	59	13	59	31	181	157	121	28	115	155	100.21

Table 2a - Chemical analyses of the St. Blaise suite: (te) temper and (mi) middling. Fe$_{tot}$ as Fe_2O_3. Oxides in wt%, trace elements in ppm.

	SiO_2	TiO_2	Al_2O_3	Fe_{tot}	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	Ba	Cr	Cu	Nb	Ni	Pb	Rb	Sr	V	Y	Zn	Zr	SUM
DP 103 ma	65.72	0.75	17.66	5.44	0.03	1.03	3.45	1.41	3.83	0.67	988	97	24	21	56	30	214	684	115	44	108	184	100.00
DP 111 ma	64.15	0.75	17.36	5.05	0.04	1.17	8.18	1.01	2.47	0.27	542	114	8	19	65	30	159	467	136	37	105	180	100.45
DP 113 ma	62.92	0.92	19.35	7.28	0.03	1.22	4.34	0.96	3.07	0.27	794	114	16	24	69	41	162	468	147	35	122	216	100.35
DP 115 ma	63.74	0.84	18.29	5.97	0.02	1.07	6.14	0.78	2.69	0.39	739	127	12	18	66	32	135	655	147	31	121	195	99.92
DP 118 ma	62.74	0.87	19.54	5.70	0.03	1.25	5.78	0.88	3.18	0.33	717	107	18	22	73	34	161	480	155	31	123	186	100.30
DP 119 ma	65.01	0.77	16.98	5.55	0.02	1.00	5.61	1.00	3.36	0.52	731	101	10	20	60	26	171	688	129	32	107	170	99.82
DP 125 ma	63.07	0.58	13.40	3.27	0.05	0.87	13.34	1.50	3.01	0.78	1118	58	7	22	25	20	172	1919	60	37	53	210	99.87
DP 126 ma	61.98	0.83	19.06	5.58	0.03	0.91	6.06	0.91	3.06	1.22	1881	104	19	26	58	31	157	3160	145	30	99	238	99.62
DP 128 ma	61.99	0.91	18.90	5.76	0.04	1.04	6.23	1.12	3.15	0.80	1449	99	10	31	53	36	208	1601	130	41	95	271	99.94
DP 130 ma	66.50	0.68	16.30	5.10	0.03	1.01	5.13	1.73	2.98	0.65	785	96	8	21	60	28	176	1266	113	36	123	230	100.11
DP 131 ma	68.53	0.60	14.83	3.64	0.03	0.93	6.24	1.63	3.29	0.63	858	64	22	21	43	23	216	564	98	37	85	178	100.33
DP 137 ma	65.79	0.63	15.04	5.50	0.05	2.80	5.58	1.34	3.32	0.35	431	106	24	23	53	30	203	269	101	45	138	149	100.39
DP 140 ma	65.90	0.63	15.34	4.26	0.03	0.95	7.95	1.27	2.95	0.84	1308	78	14	19	52	27	159	1877	98	35	105	187	100.12
DP 141 ma	63.25	0.73	18.96	5.26	0.05	2.43	2.14	1.72	4.62	0.87	914	106	64	18	55	25	239	499	108	35	162	163	100.04
DP 143 ma	65.24	0.80	15.42	5.61	0.05	1.16	7.92	1.06	2.46	0.59	834	97	23	31	52	29	181	537	110	50	117	282	100.32
DP 144 ma	65.35	0.65	16.41	4.71	0.04	0.93	6.23	1.69	3.34	0.69	1884	83	11	19	52	27	200	1342	95	36	184	183	100.03
DP 148 ma	64.82	0.77	17.47	4.80	0.04	1.01	5.77	1.47	3.56	0.60	1026	84	21	25	46	30	226	569	107	37	107	220	100.31
DP 160 ma	59.56	0.91	19.12	6.97	0.04	1.46	8.30	0.55	2.74	0.29	611	113	15	27	62	36	183	280	152	37	158	214	99.94
DP 164 ma	66.20	0.74	17.03	6.75	0.03	2.52	1.78	1.19	3.80	0.24	571	134	21	18	64	30	179	161	117	29	153	149	100.28
DP 103	64.49	0.66	18.42	4.80	0.03	1.00	3.30	1.75	4.57	0.29	921	88	14	27	49	28	237	732	123	43	163	178	99.57
DP 111	63.14	0.64	16.94	4.96	0.04	0.97	7.86	1.50	3.23	0.22	499	93	8	20	55	27	205	457	117	36	168	158	99.68
DP 113	66.27	0.58	17.00	4.60	0.03	0.87	4.34	1.86	3.65	0.16	616	75	16	16	42	25	161	413	105	28	156	153	99.53
DP 115	65.02	0.67	18.03	5.06	0.03	0.99	5.04	1.43	3.46	0.21	728	81	10	14	43	25	149	640	134	27	161	171	100.26
DP 118	63.02	0.69	18.66	5.23	0.05	1.09	6.00	1.67	3.37	0.32	763	87	10	19	50	30	157	600	139	30	178	188	100.32
DP 119	67.64	0.60	16.42	4.37	0.02	0.81	4.38	1.59	3.85	0.29	660	73	10	17	45	21	200	676	108	35	158	156	100.19
DP 125	61.94	0.52	14.12	3.10	0.05	0.87	13.32	1.61	3.36	0.57	927	61	5	18	26	20	182	1441	74	40	121	202	99.77
DP 126	62.82	0.74	18.89	5.03	0.03	0.83	5.80	1.09	3.52	0.72	1064	95	6	25	53	25	165	1392	133	26	158	225	99.80
DP 128	63.64	0.68	18.13	4.54	0.03	0.81	5.42	1.75	3.52	0.63	1188	84	10	24	47	21	191	1361	118	33	154	213	99.49
DP 130	64.39	0.74	18.09	5.58	0.03	1.07	4.72	1.25	3.33	0.22	451	125	11	21	73	25	185	250	141	35	210	186	99.61
DP 131	66.77	0.57	15.74	3.73	0.03	0.99	5.98	1.75	3.45	0.58	910	64	15	20	40	24	221	589	100	37	152	180	99.83
DP 137	68.42	0.45	14.56	4.10	0.04	1.98	3.80	1.96	4.16	0.26	341	88	21	15	41	26	271	244	75	40	166	131	99.89
DP 140	65.21	0.54	15.84	3.98	0.03	0.90	7.22	1.66	3.35	0.55	1001	68	9	15	44	22	177	1367	95	34	154	186	99.59
DP 141	64.73	0.54	18.70	4.24	0.05	1.92	1.45	2.38	5.13	0.45	874	86	28	15	45	21	249	427	92	33	153	146	99.83
DP 143	69.03	0.54	14.91	3.90	0.04	0.81	5.95	1.79	2.91	0.38	726	70	4	27	36	23	172	570	88	39	138	201	100.48
DP 144	65.62	0.63	17.28	4.24	0.04	0.92	4.45	1.68	3.71	0.62	1530	82	8	21	51	24	215	1234	97	38	170	186	99.55
DP 148	65.78	0.56	17.44	3.60	0.03	0.79	4.58	2.19	4.04	0.30	707	71	9	19	36	20	234	399	89	31	139	175	99.50
DP 160	61.10	0.75	18.78	5.67	0.03	1.20	7.16	1.09	3.41	0.22	579	104	10	18	55	30	198	287	143	34	170	189	99.59
DP 164	67.71	0.62	16.44	5.72	0.03	2.18	1.30	1.43	4.23	0.15	563	113	7	14	53	22	177	147	113	23	173	142	99.96

Table 2b - Chemical analyses of the St. Blaise suite: (ma) matrix and bulk pottery. Fe_{tot} as Fe_2O_3. Oxides in wt%, trace elements in ppm.

Analysis n°.	**initial wt.**	**H_2O_2 37 v%**	**H_2O deion.°**	**t_{tot} heat.**	**temper**		**matrix**		**middling**		**final wt.**	
	gr	**ml**	**ml**	**min**	**gr**	**%**	**gr**	**%**	**gr**	**%**	**gr**	**%**
RM 3034	27.47	100	250	20	2.51	*9.53*	15.48	*58.79*	8.34	*31.67*	26.33	*95.85*
RM 3036	41.03	200	250	30	1.54	*3.90*	13.13	*33.29*	24.77	*62.80*	39.44	*96.12*
RM 3046	40.70	100	250	20	8.63	*22.79*	15.28	*40.36*	13.95	*36.85*	37.86	*93.02*
RM 3047	23.44	100	250	25	3.32	*14.88*	10.14	*45.45*	8.85	*39.67*	22.31	*95.18*
RM 4012	21.06	150	250	30	2.02	*10.33*	12.91	*66.04*	4.62	*23.63*	19.55	*92.83*
RM 4051	19.64	200	250	30	3.08	*16.74*	12.01	*65.27*	3.31	*17.99*	18.40	*93.69*
RM 4056	20.52	200	250	30	2.87	*14.52*	11.25	*56.90*	5.65	*28.58*	19.77	*96.35*
RM 4065	24.25	200	250	30	1.13	*4.94*	18.20	*79.58*	3.54	*15.48*	22.87	*94.31*
RM 4083	20.08	100	250	20	4.74	*25.01*	11.35	*59.89*	2.86	*15.09*	18.95	*94.37*
RM 4084	49.87	200	250	40	9.31	*19.34*	19.39	*40.28*	19.44	*40.38*	48.14	*96.53*
RM 4101	56.29	150	250	30	13.99	*25.63*	25.31	*46.36*	15.29	*28.01*	54.59	*96.98*
RM 4170	15.94	100	250	20	3.14	*20.93*	4.75	*31.67*	7.11	*47.40*	15.00	*94.10*
RM 4174	18.75	100	250	25	3.61	*20.99*	2.51	*14.59*	11.08	*64.42*	17.20	*91.73*
RM 4176	52.24	200	250	30	8.26	*16.91*	18.79	*38.47*	21.79	*44.62*	48.84	*93.49*
RM 4181	46.90	200	300	60	11.40	*24.54*	26.26	*56.53*	8.79	*18.92*	46.45	*99.04*
Mean	31.88				5.30	*13.21*	14.45	*38.60*	10.63	*27.13*	30.38	*94.91*

° To all liquid solutions, **3 drops of NH_3 25%** in volume have been added in order to obtain a **pH 7 (± 0,5)**

Table 3 - list of samples from Chalain

	SiO_2	TiO_2	Al_2O_3	Fe_{tot}	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	Ba	Cr	Cu	Nb	Ni	Pb	Rb	Sr	V	Y	Zn	Zr	SUM
RM 3034 te	83.70	0.07	9.26	0.28	0.00	0.18	0.31	2.03	4.17	0.06	769	7	2	5	5	36	199	151	6	7	2	58	100.07
RM 3046 te	78.01	0.14	12.07	0.65	0.00	0.19	0.57	1.46	6.77	0.13	2445	22	10	5	14	34	244	421	10	7	7	69	100.00
RM 3047 te	78.47	0.12	11.75	0.52	0.00	0.15	0.30	1.50	6.94	0.13	2493	22	31	5	14	39	278	374	12	4	3	70	99.90
RM 4012 te	98.24	0.13	0.75	0.07	0.00	0.15	0.07	0.33	0.27	0.06	52	8	2	5	6	7	7	3	8	8	2	99	100.08
RM 4051 te	75.38	0.06	13.15	0.52	0.00	0.13	0.55	4.15	4.68	0.04	218	5	2	46	3	16	325	48	5	40	2	48	98.69
RM 4056 te	97.25	0.10	1.37	0.18	0.00	0.17	0.08	0.14	0.37	0.06	47	10	2	5	5	7	16	3	12	7	2	65	99.75
RM 4065 te	68.20	0.11	16.73	0.87	0.02	0.26	4.61	5.61	3.43	0.12	672	8	2	6	3	15	167	276	11	16	17	67	99.97
RM 4083 te	73.95	0.17	13.80	0.78	0.00	0.24	0.73	1.96	7.52	0.18	2346	10	2	5	6	36	345	409	23	8	16	82	99.34
RM 4084 te	78.27	0.13	11.55	0.60	0.00	0.19	0.39	1.28	6.85	0.15	2377	13	2	5	4	38	251	374	16	5	10	71	99.44
RM 4101 te	74.80	0.18	13.38	0.93	0.00	0.27	0.76	2.02	6.86	0.16	2190	10	3	5	5	32	329	423	18	6	25	90	99.37
RM 4170 te	80.90	0.14	10.50	0.52	0.00	0.19	0.26	1.01	6.36	0.23	2133	15	49	5	14	37	217	315	13	6	4	73	100.10
RM 4174 te	85.62	0.08	7.80	0.32	0.00	0.14	0.16	0.65	4.89	0.18	2800	7	2	5	4	25	133	304	5	3	2	35	99.86
RM 4176 te	78.04	0.15	11.80	0.70	0.00	0.24	0.58	1.47	6.62	0.13	2145	13	2	5	4	34	276	381	21	4	10	81	99.74
RM 4181 te	75.17	0.17	13.27	0.88	0.00	0.24	0.75	2.07	6.85	0.15	2182	11	2	5	4	35	287	425	18	6	16	83	99.57
RM 3034 mi	67.41	0.90	18.09	4.25	0.03	1.41	1.31	2.15	4.09	0.34	694	78	17	26	38	47	224	166	77	26	108	251	100.00
RM 3036 mi	51.30	1.80	31.78	6.56	0.02	0.63	2.52	0.50	1.71	2.56	359	199	31	41	77	73	107	126	254	108	191	575	99.38
RM 3046 mi	60.62	1.02	20.39	6.03	0.03	1.92	2.17	1.76	4.39	1.29	1173	78	15	16	41	65	222	324	82	30	143	344	99.61
RM 3047 mi	61.89	1.02	20.22	5.59	0.02	1.67	1.81	1.62	4.41	1.74	1346	84	10	18	42	77	227	290	85	26	155	334	99.99
RM 4012 mi	68.32	0.91	18.77	4.60	0.00	1.46	1.45	0.33	1.91	2.09	539	138	19	22	78	24	88	88	155	45	164	214	99.83
RM 4051 mi	62.71	0.81	20.32	5.08	0.03	2.40	1.69	1.46	3.50	1.48	592	146	37	38	107	33	209	101	117	46	137	133	99.47
RM 4056 mi	69.81	0.90	18.31	4.33	0.00	1.52	1.19	0.30	1.61	1.06	398	135	18	19	72	26	82	74	151	41	168	210	99.03
RM 4065 mi	64.37	1.00	19.60	4.09	0.00	1.70	3.58	0.70	2.79	1.87	597	116	30	18	59	38	118	106	112	39	147	325	99.70
RM 4083 mi	56.57	1.41	24.16	4.69	0.02	1.64	2.10	2.18	4.87	2.16	1367	87	26	23	49	106	259	307	99	44	191	488	99.81
RM 4084 mi	57.59	1.19	23.60	6.03	0.02	1.88	1.75	1.04	4.57	1.80	1608	94	22	21	44	125	234	242	116	30	185	381	99.47
RM 4101 mi	57.76	1.25	22.50	5.85	0.02	1.67	2.05	1.74	4.42	2.09	1433	84	31	21	47	90	257	313	101	45	219	408	99.35
RM 4170 mi	57.56	1.13	21.83	5.77	0.02	1.84	2.11	1.00	4.75	3.71	1784	88	20	22	44	124	238	281	102	31	139	379	99.71
RM 4174 mi	51.91	1.11	26.06	6.57	0.04	2.17	3.00	1.32	3.48	4.00	1343	81	12	22	35	40	198	304	90	33	169	304	99.66
RM 4176 mi	60.17	1.14	21.66	5.00	0.04	1.64	1.87	1.34	4.88	1.16	1711	82	25	17	40	98	249	281	97	39	141	404	98.89
RM 4181 mi	57.94	1.19	22.06	6.29	0.02	1.88	2.09	1.50	4.58	1.74	1519	86	16	22	46	94	228	292	100	33	200	403	99.29

Table 4a - Chemical analyses of the Chalain suite: (te) temper and (mi) middling. Fe_{tot} as Fe_2O_3. Oxides in wt%, trace elements in ppm.

	SiO_2	TiO_2	Al_2O_3	Fe_{tot}	MnO	MgO	CaO	Na_2O	K_2O	P_2O_5	Ba	Cr	Cu	Nb	Ni	Pb	Rb	Sr	V	Y	Zn	Zr	SUM
RM 3034 ma	68.06	0.87	17.43	4.27	0.02	1.33	1.58	1.99	3.78	0.32	654	71	13	23	36	46	223	155	74	23	135	264	99.65
RM 3036 ma	52.32	1.66	29.60	6.30	0.02	0.74	2.85	0.59	2.10	2.46	404	181	40	37	73	63	122	131	236	97	248	516	98.65
RM 3046 ma	58.04	1.13	21.38	6.59	0.03	2.17	2.91	1.81	4.41	1.71	1182	84	23	19	43	69	230	336	90	30	186	385	100.20
RM 3047 ma	58.42	1.18	21.61	6.37	0.02	1.99	2.49	1.65	4.35	1.93	1291	88	18	21	46	78	227	294	99	32	204	407	100.00
RM 4012 ma	70.47	0.83	16.67	4.39	0.00	1.37	2.06	0.32	1.71	1.69	480	117	22	17	75	26	80	84	121	36	223	195	99.52
RM 4051 ma	63.07	0.80	19.76	5.55	0.03	2.46	2.26	1.46	3.43	1.23	545	125	49	19	105	33	194	109	110	41	246	145	100.04
RM 4056 ma	71.81	0.79	16.39	4.06	0.00	1.39	2.43	0.33	1.49	1.11	369	114	24	17	73	27	76	90	126	37	329	197	99.80
RM 4065 ma	66.17	0.73	18.19	3.97	0.02	1.64	3.39	1.42	3.03	0.94	535	97	29	16	64	36	138	118	94	31	214	196	99.52
RM 4083 ma	59.03	1.22	22.47	4.09	0.02	1.45	2.31	2.26	5.09	1.99	1415	72	27	22	45	93	262	317	83	40	197	423	99.92
RM 4084 ma	57.11	1.12	22.62	5.58	0.02	1.78	2.58	1.14	4.88	2.32	1606	87	25	21	43	118	234	271	108	32	263	365	99.15
RM 4101 ma	57.85	1.23	22.23	5.64	0.02	1.67	2.32	1.78	4.46	2.01	1435	81	35	22	46	88	257	322	97	43	270	434	99.21
RM 4170 ma	58.76	1.06	20.92	5.22	0.02	1.82	2.27	1.04	5.11	3.43	1792	75	23	19	40	102	242	303	91	28	174	378	99.65
RM 4174 ma	50.38	1.07	25.67	6.49	0.03	2.26	3.88	1.37	3.83	4.75	1517	71	18	22	37	46	199	350	80	34	267	355	99.72
RM 4176 ma	59.90	1.05	20.86	4.76	0.02	1.61	3.22	1.40	4.95	1.53	1648	72	27	17	35	90	245	308	92	36	222	368	99.29
RM 4181 ma	58.13	1.21	21.63	6.31	0.02	2.01	2.44	1.67	4.34	1.36	1359	84	18	19	42	90	230	288	96	36	218	388	99.12
RM 3034	69.64	0.74	16.90	3.80	0.02	1.27	1.51	1.71	3.98	0.36	662	87	250	22	44	45	219	160	76	23	89	233	100.12
RM 3036	53.25	1.60	30.11	7.12	0.02	0.70	2.60	0.34	1.96	2.19	388	200	30	36	74	61	117	112	237	98	182	509	100.09
RM 3046	63.19	0.81	18.89	5.03	0.03	1.59	2.40	1.44	4.96	1.41	1414	77	32	14	40	50	220	343	71	23	140	303	100.02
RM 3047	62.88	0.86	19.63	4.91	0.02	1.44	1.88	1.48	5.02	1.55	1539	84	10	15	43	62	236	310	77	25	143	326	99.96
RM 4012	72.16	0.61	16.24	3.39	0.02	1.43	2.31	0.77	2.31	0.97	381	137	24	16	91	23	126	87	116	32	123	160	100.34
RM 4051	64.41	0.65	19.25	5.05	0.03	2.21	1.75	1.53	3.92	1.05	536	135	36	23	103	27	223	96	111	39	113	128	100.01
RM 4056	74.30	0.68	15.30	3.66	0.01	1.29	1.58	0.11	1.71	1.45	427	126	23	15	70	19	72	68	125	35	134	178	100.22
RM 4065	69.84	1.10	18.81	4.51	0.01	0.84	2.06	0.01	1.53	1.09	319	151	14	26	84	33	77	47	189	61	125	376	99.95
RM 4083	63.51	0.85	20.08	3.27	0.01	1.20	1.87	1.80	6.28	1.17	1824	70	16	15	40	75	286	342	78	31	123	311	100.36
RM 4084	62.22	0.82	21.01	4.40	0.01	1.31	1.66	0.90	6.05	1.52	2093	89	72	16	42	120	251	319	94	26	159	307	100.26
RM 4101	62.71	0.91	20.67	3.68	0.01	1.14	1.96	1.47	5.15	2.56	1772	86	45	15	42	78	267	353	91	33	141	325	100.58
RM 4181	63.07	0.87	19.66	4.74	0.02	1.39	1.99	1.52	5.22	1.33	1663	77	867	16	41	72	234	337	88	26	143	309	100.20
RM 4170	64.46	0.81	19.71	4.23	0.02	1.52	1.59	0.79	5.65	1.48	1773	80	24	14	38	92	259	273	82	23	529	296	100.61
RM 4174	59.10	0.80	22.46	5.09	0.03	1.69	2.35	0.96	4.65	3.10	2045	72	12	18	36	50	191	344	70	25	130	267	100.56
RM 4176	64.47	0.85	19.58	4.21	0.02	1.40	1.85	1.09	5.40	1.06	1791	76	21	14	40	86	260	306	89	30	111	311	100.24

Table 4b - Chemical analyses of the Chalain suite: (ma) matrix and bulk pottery. Fe_{tot} as Fe_2O_3. Oxides in wt%, trace elements in ppm.

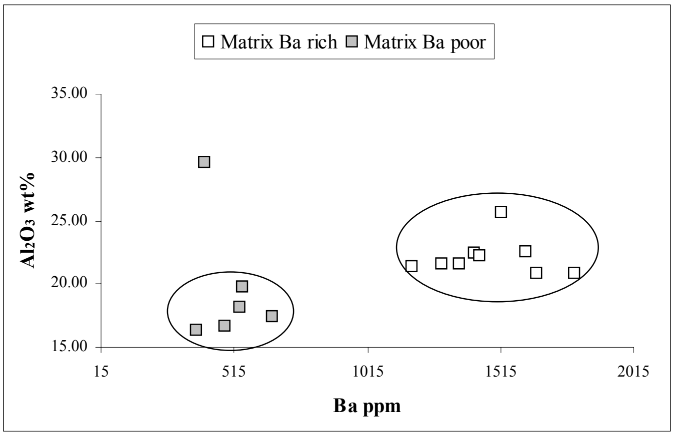


Figure 6 – The two matrix groups of Chalain.

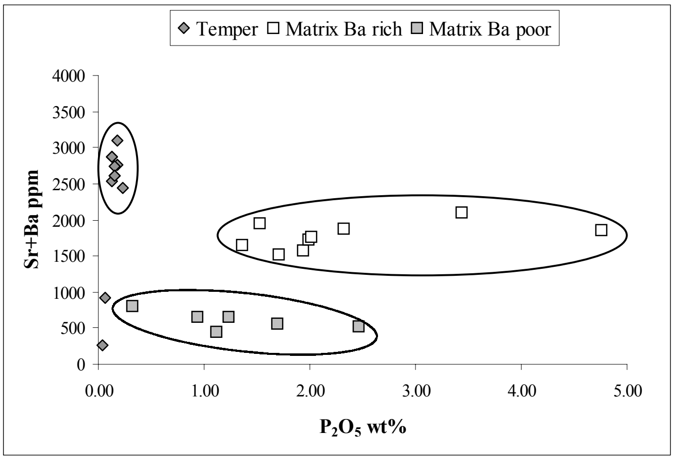


Figure 7 – The separated components of Chalain.

Fig.7 shows a correlation diagram between Sr + Ba and P_2O_5 wt% of all the separated components of Chalain. The same grouping concerning the matrix has been kept between Ba-rich and Ba-poor. Sr has been added to the Ba content since the two elements are correlated, tab.4a.

The P_2O_5 content is strongly increased in the matrix analyses if compared to the bulk pottery. On the contrary, the P_2O_5 content is always very low or negligible in the separated temper. This would mean a clear sign of contamination of the matrix of Chalain pottery. The existence of two groups of matrix, both contaminated but at different magnitudes, seems to be correlated to the size of the pottery. Relatively undersized ceramic vases are those less polluted by Phosphorous and Barium, coarser and bigger sized ceramic vases result those more contaminated (R. Martineau, personal communication). Further investigations should be necessary to confirm this correspondence between size of the pottery and degree of contamination. But this correlation might be plausible at the light of the specific surface “offered” by the pottery to the ground water circulation at the settlement during the burial of the ceramic. If the concentration of circulating dissolved elements would not be homogeneous, and it could be the case, the less the surface exposed to the contamination, the less the contaminants and vice versa.

Always fig.7 shows the presence of the temper main group between around 2500 and 3000 ppm of Sr + Ba, as a quite homogeneous group. Other analyses are outlying the main group. Two of them, RM 4012 te & RM 4056 te of tab.4a, are composed of SiO_2 only. A more careful investigation of the corresponding thin sections revealed the utilization of quart or quartzite grains as temper for those two ceramics. A third analysis, RM 4065 te, shows a CaO content of 4,61 wt% in opposition to a mean of the other temper analyses of around 0.5 wt%. The presence of carbonate material, beside the granite, as temper grains observed in the corresponding thin section should justify such a high content. These three analyses could and will be treated therefore separately. Analysis RM 3036 te has not been performed, see tab.4a, since the hand-picking step of the separation procedure under the binocular clearly revealed the utilization of a micaschist as temper.

As a final remark concerning the Chalain results of the separation, it should be stated once again the effectiveness of the separation procedure capable to discriminate the composition of temper and matrix, and able to keep evident the potential troubles of a contamination for instance, stressing and highlighting on the component concerned. In other words, in the Chalain case the effects of the contamination in the order of few percents of P_2O_5 and a thousand ppm of Ba have been not only not obliterated by the separation method, but on the contrary even more underlined and identified in the concerned component, the matrix.

This final remark will be further discussed in the next paragraph concerning the comparison between the three settlements.

2.3.3 The comparative study across the three settlements

In the following paragraph we will compare the data set of Di Pierro (2002b) concerning Portalban and the data sets of St. Blaise and Chalain from the present study, tab.2 & 4

The matrix

Fig.8 shows the correlation diagram that best expresses similitude and differences between and within each site. It concerns the Sr + Ba and the MgO contents, which served to discriminate the three kind of matrix identified at St. Blaise (Di Pierro *et al.*, 2002), which identify the Portalban matrix MgO-rich (Di Pierro, 2002b), and which discriminate the two differently polluted kinds of matrix of Chalain, Ba enriched, see previous discussion.

The above figure permits to discuss the following points:

- four to five distinct chemical groups of matrix exist across the three settlements.
- At St. Blaise (gray triangles), as previously discussed, we have three groups: Sr + Ba rich, MgO-poor and MgO-rich matrix.

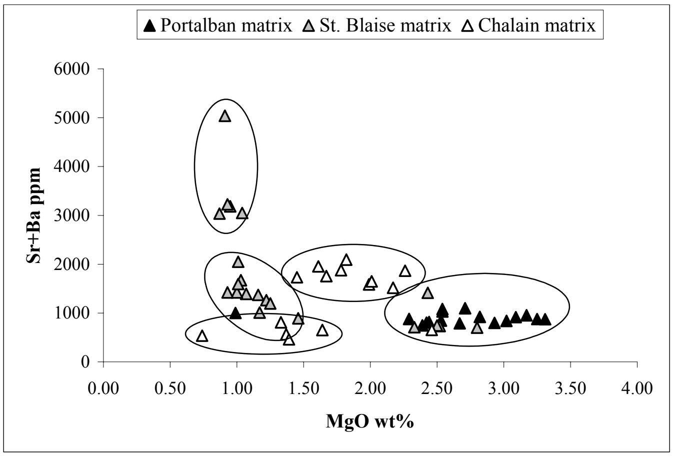


Figure 8 – Comparative study of the three settlements separated matrix: (Sr + Ba) – MgO.

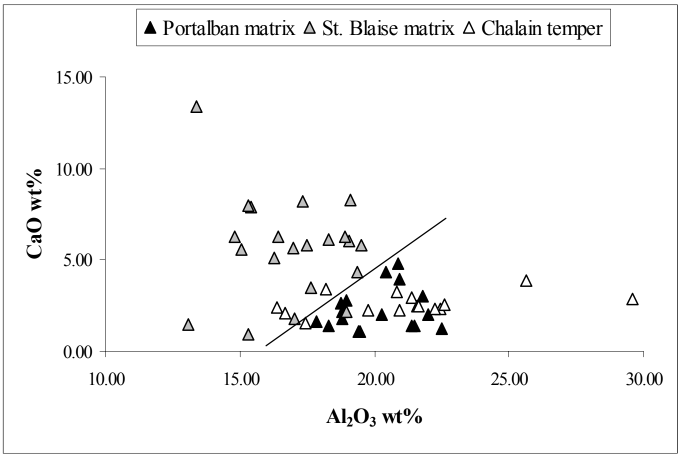


Figure 9 – Correlation diagram concerning the three settlements separated matrix: CaO - Al_2O_3.

- These latter fit in composition the Portalban matrix (black triangles).
- The Portalban matrix are a unique and homogeneous group, except…
- one matrix of Portalban, which lies in the field of the MgO-poor matrix of St. Blaise.
- The Chalain matrix (white triangles) are two distinct groups: Ba-richer and Ba-poor. It has been discussed that the Ba content is correlated to an enrichment in P_2O_5, and that those ceramics have very likely undergone a pollution problem.
- Fig.8 shows that the enrichment of Ba in the Chalain groups caused a shift in the MgO content between the Ba-poor and the Ba-richer group. At St.Blaise, where the Sr + Ba content is not correlated to the P_2O_5, which is always very low to negligible, the same shift in the MgO content is not present. The Sr + Ba-rich group keeps the same MgO-content of the main MgO-poor group. It's our opinion that this different behavior of those two trace elements could be an evidence that if at Chalain the enrichment is secondary and due to a contamination, at St. Blaise the enrichment is primary, more likely due to the raw material composition.

The graph of fig.9 highlights the basic differences existing between the matrix (clay) of Portalban and St. Blaise. The St. Blaise matrix composition reflects that of a calco-silicate clay, while the Portalban matrix that of a silicate only clay. The Chalain matrix are rich in Al_2O_3 as expected for a biotite-rich clay.

Fig.10 shows a positive correlation between the Cr and the Fe_{tot} content across the three settlements. In particular those contents are higher at Portalban than at St. Blaise. This was expected too because of the higher content of femic minerals in the Portalban clays, chlorite-richer, than at St. Blaise (Di Pierro *et al.*, 2002). The Chalain spots are instead scattered throughout the graph. This is probably due to the contamination problems already discussed.

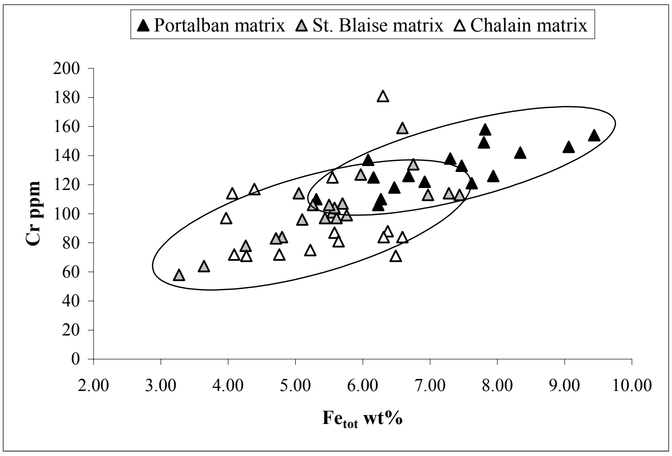


Figure 10 – Correlation diagram concerning the three settlements separated matrix: Cr - Fe_{tot}.

The temper

Aware of the contamination problems occurred to the Chalain ceramics, we decided to implement the separation procedure to those sherds as well, hoping that the pollution had not influenced the composition of the separated temper. The main objective of the study was in fact to chemically compare the granite grains used at the three settlements. Unfortunately, notwithstanding the effectiveness of the separation technique, the contamination troubles of the Chalain ceramics strongly influenced the granite composition too, in terms of elements fixation and lixiviation.

Figure 11 - Correlation diagram concerning the three settlements separated temper: Na_2O – K_2O.

In fact, fig.11 allows to discuss the following:

- The Portalban and St. Blaise temper analyses are undistinguishable and form an homogeneous chemical group. They correspond to a granite composition.
- Except one analysis, the Chalain spots show a depletion of the Na_2O content. The values are not those of a granite. Being the Na strongly mobile, it is instead very likely that the

lixiviation of that element has occurred as a consequence of the contamination problem of the Chalain ceramics. The K_2O content shows a very strange pattern too.

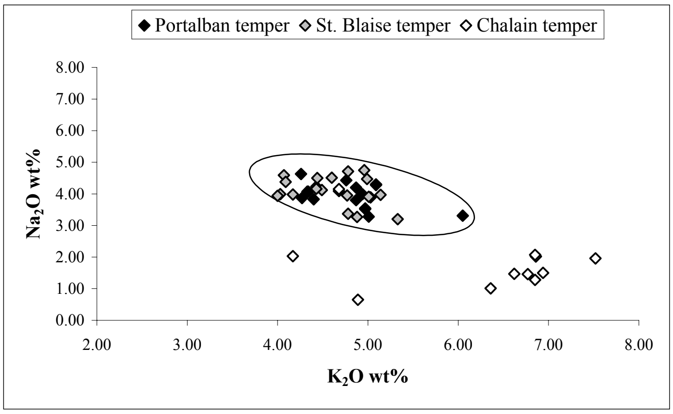


Figure 11 - Correlation diagram concerning the three settlements separated temper: Na_2O – K_2O.

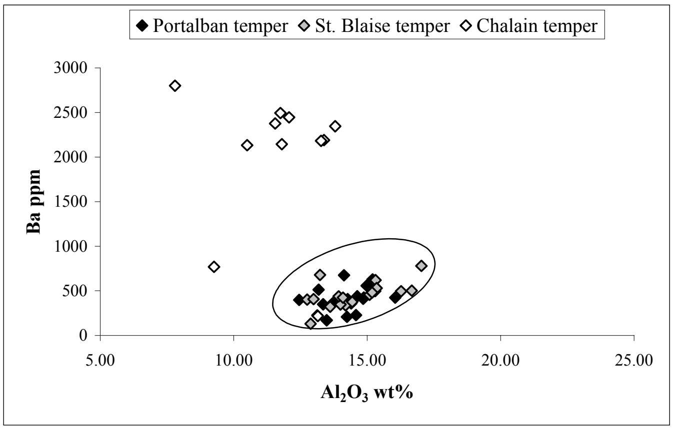


Figure 12 - Correlation diagram concerning the three settlements separated temper: Ba – Al_2O_3.

The graph of fig.12 unfortunately confirms the contamination problems undergone by the Chalain ceramics. In fact, the following remarks are possible:

- The Portalban and St. Blaise temper analyses show the pattern of a chemically strongly homogeneous material. Its composition fits that of a granite.
- Except one analysis, the Chalain temper spots present a strong enrichment in Ba, which parallels that of the matrix already discussed. It is likely that the contamination troubles of the ceramics induced the fixation of Ba in the granite grains.

The above data allows two hypothesis. Either the temper grains of the Chalain pottery are not those of a granite. This hypothesis is in strong contrast with the data from petrography. Furthermore, the obtained chemical compositions would be tricky to be solved and correctly interpreted or the contamination problems envisaged in the previous paragraph actually influenced the current composition of the temper.

3. CONCLUSIONS

1) This separation run confirmed the efficiency of the procedure proposed in Di Pierro (2002b). In fact the separation technique allows obtaining the main components of the ceramics, temper and matrix, for further characterization. The procedure does not affect the composition of the original raw materials and maintain even little chemical differences potentially existing.
2) The Chalain pottery was not suitable for the purpose of the present study. Unfortunately the contamination problems encountered by the ceramics strongly influenced the composition of matrix and temper both. The comparative study of this latter with the Mont Blanc granite used at Portalban and St. Blaise was vane. Despite these constraints, at least one analysis fits the composition field of the granite extracted from the Portalban and St. Blaise sherds. It is probable that without the contamination identified at Chalain, the separation technique would have allowed to chemically characterize the Mont Blanc granite utilization at that settlement as well.
3) The Portalban and St. Blaise temper data are in excellent good agreement. Not only they both belong to a granite, but they deeply overlap each other. Despite the utilization of more kinds of clays (matrix), the utilization of always the same tempering material, inside each pottery suite and across the two settlements too is an important result, which would deserve further investigations, enlarged to other settlements of the Swiss Plateau. The material choice as “cultural behavior” proposed for the French Neolithic by Costantin & Courtois (1985) would be valid for the Swiss contemporary populations too.
4) The Mont Blanc granite have met an extraordinary success as pottery manufacturing material during the Swiss Final Neolithic. Its systematic utilization by the local populations might hide some technological advantages compared to other “crystalline” available rocks. This aspect too would deserve further investigations.

REFERENCES

BUSSY, F., 1990, *Pétrogenèse des enclaves microgrenues associées aux granitoides calco-alcalins: exemple des massifs varisque du Mont Blanc (Alpes occidentales) et miocène du Monte Capanne (Ile d'Elbe, Italie).* Thèse de Doctorat, Université de Lausanne. Mémoire de Géologie n.7, 309 pp.

CAMPY, M., 1982, *Le Quaternaire franc-comtois. Essai chronologique et paléoclimatique*, unpubl. Ph. D. dissertation, Faculté des Sciences et Techniques de l'Université de Franche-Comté.

COLLOMB, P.& MAGGETTI, M., 1996, Dissolution des phosphates présents dans des céramiques contaminées. *Revue d'Archéometrie*, 20, 69 – 75.

COSTANTIN, C. & COURTOIS, L. C., 1985, *Le materiau céramique comme caractéristique culturelle. L'example du dégraissant pendant le Néolithique dans le bassin parisien*. IGAL. Etudes des céramiques en archéologie. Documents et travaux

DI PIERRO, S., 2002a, *Ceramic production technology and provenance during Final Neolithic: the Portalban settlements, Neuchâtel Lake, Switzerland.* Proceedings of the "4ème colloque d'Archéometrie", GMPCA, La Rochelle 24 – 28 avril 2001. Revue d'Archéometrie. In press.

DI PIERRO, S., 2002b, Matrix-temper separation of Neolithic ceramics ; an experimental approach to characterise the original raw materials. In: Proceedings of the 6th European Meeting on Ancient Ceramics EMAC '01, Ceramic in the Society, Fribourg, Switzerland, 3-6 October 2001. In press.

DI PIERRO, S. & MARTINEAU M., 2002, *Pottery Tempering With Mont Blanc Granite Across The Jura Belt During French And Swiss Final Neolithic*. 33rd International Symposium on Archaeometry ISA, 22 - 26 April 2002, Amsterdam. Abstract

DI PIERRO, S., MICHEL, R. & MARTINEAU, R., 2002, *Matériau et types céramique à St. Blaise (Néolithique Suisse) Poterie exogène et production locale.* Proceedings of the XIVth Congress of the U.I.S.P.P.,Liège, Belgium, 2 – 8 September 2001. British Archaeological Report. In press.

FREI, E., MEIA, J., BECKER, F., BÜCHI, O., BUXTORF, R., RYNIKER, K. & SUTER, H., 1974, *Atlas géologique de la Suisse 1:25.000, feuille 1164, Neuchâtel.* Commission géologique Suisse.

LEMOINE, C. & PICON, M., 1982, La fixation du phosphore par les céramiques lors de leur enfouissement et ses incidences analytiques. *Revue d'Archéometrie*, 6, 101 – 112.

MARRO, C., 1986, *Les granitoides du Mont Blanc en Suisse.* Thèse de Doctorat, Université de Fribourg, 145 pp.

MARTINEAU, R., CONVERTINI, F. & BOULLIER, A., 2000, *Provenances et exploitations des terres à poterie des sites de Chalain (Jura), aux 31e et 30e siècles avant J.-C.* Bull. de la Soc. Préhist. Franç., 97, n.1, p. 57-71.

MEIA, J. & BECKER, F. 1976, *Notice explicative de la feuille 1164, Neuchâtel, de l'Atlas géologique de la Suisse 1:25.000*, Commission géologique Suisse.

NUNGÄSSER, W. & MAGGETTI, M., 1978, *Mineralogisch-petrographische Untersuchung der neolitischen Töpferware vom Burgäschisee.* Bull. Soc. Frib. Sc. Nat. 67/2, 152 – 173.

PICON, M., 1985, Un example de pollution aux dimensions kilométrique: la fixation du Baryum par les céramiques. *Revue d'Archéometrie*, 9, 27 – 29.

PICON, M., 1987, La fixation du Baryum et du Strontium par les céramiques. *Revue d'Archéometrie*, 11, 41 – 47.

PICON, M., 1991, Quelques obsérvations complémentaires sur les altérations de composition des céramiques au cours du temps: cas des quelques alcalins et alcalino-terreux. *Revue d'Archéometrie*, 15, 117 – 122.

PORTMANN, J.P. 1955, *Pétrographie des moraines du glacier würmien du Rhône dans la région des lacs subjurassiens (Suisse).* Bull. Soc. Neuchât. Géogr. 51/5 1954-1955.

VON RAUMER, J., 1967, *Kristallisation und Gefügebildung im Mont-Blanc-Granit.* Habilitationsschrift zur Erlangung der Venia legendi an der mathematisch-naturwissenschaftlichen Fakultät der Universität Freiburg i. Ü. (Schweiz), 499-579.

VON RAUMER, J., 1969, *Stilpnomelan als alpinmetamorphes Produkt im Mont-Blanc-Granit.* Contr. Mineral. And Petrol. 21, 257-271.

VON RAUMER, J., 1984, *The external massifs, relics of Variscan Basement in the Alps.* Geolog. Runds., 73, 1, 1-31.

FINAL CONCLUSIONS

Two Western Swiss Neolithic settlements and their relevant ceramic productions belonging to the Auvernier-Cordé occupations, 2700 – 2400 BC, have been studied and characterized on petrographic and chemical bases.

From Portalban, 47 potteries, 14 cobs and 7 loom weights have been selected. The local prospecting of the potential raw materials has concerned 14 clays and 100 randomly chosen rocks from the moraine deposits.

From St. Blaise, 63 potteries have been selected.

In view of estimating the degree of specialization related to the pottery manufacturing, and starting from the characterization of the above samples, a comparative study has been performed and concerned (i) well constrained ceramic types and morphologies ("Lüscherz Tradition", "Auvernier" s.s., "Corded Imitation" and "Corded True") on one side, and (ii) the ceramic spatial distribution inside each settlement on the other.

A new investigation methodology has been implemented and carried out on the above ceramic sherds. It consisted in the set up of a separation technique, which concerned the main fractions of a pottery sherd: the matrix and the temper. The characterization of these latter, once properly separated, better reflect the composition of the original raw materials. The new method has been applied to 17 ceramics of Portalban and 19 ceramics of St. Blaise. The technique has been applied to an additional suite of 15 ceramics from Chalain, France, for which the rock fragments used to temper the pottery was supposed to be of the same petrographic nature of those used at Portalban and St.Blaise. The relevant comparative study has been presented.

Main results

A) **The Portalban settlements**.

1) the bulk characterization of the pottery suite gave as result the large homogeneity of the ceramic composition. The pottery has been manufactured with a silicate clay, which is in turn particularly Al_2O_3-rich, while the MgO content is around 2 wt%. The rock-fragments used to temper the ceramic have been identified throughout all the pottery suite as the *stilpnomelane bearing Mont Blanc granite*.
2) The provenance of the ceramics remained partially unraveled. It is supposed to be local, but the relevant clay source has not been identified with the prospecting of the raw materials in an area of at least 5 km^2. A petrographically and chemically very similar clay exists on the Western Swiss Plateau, but outcrops at Cornaux, 15 km North off Portalban. No evidence exists that Portalban potters used to exploit that clay source in particular. On the contrary, it is highly probable that a similar clay outcrop(s)ped at Portalban, but it is now either not exposed since covered by the modern urbanization, or it has been fully exploited by the Neolithic potters, or it has not been found during the prospecting. The Mont Blanc granite has been instead found in the surroundings of the settlement, but as a scarcely available lithotype.
3) As far as the ceramic correlations with either the ceramic morphologies and/or the ceramic spatial distribution, no evident correspondence has been determined. Petrographic and chemical results indicate the exploitation of unique well-known sources, for the clay and the temper both. This knowledge should have been shared at the village scale. The question of the specialization and of the craftsmanship activity of the ceramic production remained unsolved.
4) It exists a sharp compositional discrepancy between the pottery on one hand and the cobs & loom weights on the other side. In fact, the cobs & loom weights have been manufactured with a calcareous clay. No rock fragments have been added to these objects. The cobs are completely temper less, while most of the loom weights are organic matter rich.
5) The raw calcareous clay used for the cobs and the loom weights manufacturing has been identified. It outcrops at the settlement, just beside the main excavation area. The local provenance of those objects has been therefore established.
6) The previously obtained data concerning the Benghezal[1] study have been reinterpreted at the light of the above results of Portalban. The sharp difference in the composition between pottery and cobs & loom weights is a regular and constant feature of the other Neolithic settlements too, at the scale of the Western Swiss Plateau.

---

[1] BENGHEZAL, A., 1994, *Provenance et techniques de la céramique du Néolithique final de stations des trois lacs jurassiens Suisse.* Thèse de doctorat, Université de Fribourg, 174 pp.

B) **The St. Blaise settlements**

1) The main result concerns the non homogeneity of the pottery composition; in fact, depending on the chemical and petrographic composition, at least three different groups have been found:
    a) the pottery Sr + Ba rich, with a calco-silicate matrix (n=8),
    b) the pottery MgO-rich with a silicate matrix (n=7),
    c) the pottery MgO-poor with a calco-silicate matrix (n=48).

    The composition of the temper is instead uniform throughout the pottery suite. It has been again characterized as the *stilpnomelane bearing Mont Blanc granite*.
2) A sharp correspondence exists between the Sr + Ba rich ceramics and one house of the settlement. In fact, these ceramics come all from a unique deposit of sherds linked to a reconstructed hut. But not all the ceramics coming from that hut are Sr + Ba rich pottery. This should rule out any secondary contamination of the pottery. A contamination problem could have occurred as a primary event and concerned the clay outcrop, at most. This correspondence between ceramic composition and house of provenance might reflect the domestic production of that pottery.
3) A good correspondence has been found between the MgO-rich ceramics and the "Corded True" pottery type.
4) The sharp difference in composition between the MgO-rich pottery and all the other samples, along with the above good correlation with the morphologic group, has raised the hypothesis of an exogenous provenance of that pottery. This hypothesis has been tested and found plausible on the basis of the multivariate statistical approach (clusters and discriminant analyses).

C) **The separation technique**.

1) The set up method is fairly cost less, time consuming but it is effective.
2) It consists roughly of an attack with a H_2O_2 solution properly buffered to neutral pH.
3) It permits to recover 3 main fractions:
    a) the matrix, to which it would correspond the former clay;
    b) the middling, compositionally still consistent with the pottery;
    c) the rock-fragments, to which it would correspond the temper.
4) It has been successfully carried out on 17 ceramics of Portalban. A silicate matrix up to Al_2O_3 20 wt% rich has been obtained for all samples, while the MgO content is as high as 2.65 wt%. The Mont Blanc granite petrographic characterization has been chemically confirmed.
5) It has been successfully implemented on 19 potteries of St.Blaise. Three chemically different matrix have been in fact determined:
    a) the Sr + Ba rich,
    b) the MgO-rich and
    c) the MgO-poor matrix.

    The Mont Blanc granite petrographic characterization has been chemically confirmed.
6) It has been applied to 15 ceramics of Chalain. These ceramics were not suitable because of a contamination problem, which involved the fixation of Phosphorous and Barium in the matrix, the lixiviation of Sodium and the fixation of Barium in the temper. The chemical composition of the used temper is unfortunately no more that of a granite. Therefore, the comparative study was unexpectedly not successful for the Chalain settlement.
7) On the contrary, an excellent agreement and correspondence has been found between the chemical data sets of Portalban and St.Blaise concerning the temper. This is a very important archaeological result, since it demonstrates that:
    a) the material choice in the pottery manufacturing process is not the result of the case but it corresponds to a "cultural behavior" and a "social attitude"[2].
    b) The utilization of the Mont Blanc granite has occurred across the two 15 km distant settlements, which in turn would mean that this technological knowledge was shared at that scale.

We propose that the pottery chemical data of this study concerning:

- Portalban, and its whole pottery suite (47 ceramics), and
- St. Blaise, for the MgO-poor pottery suite (48 ceramics),

be used as "Groups of Reference" for further studies concerning the Final Neolithic ceramics of the Western Swiss Plateau.

The question of the specialization

The fact that at Portalban no correlation or clear correspondence had been found between the pottery composition towards (i) the different existing morphologies and (ii) the spatial distribution could have more than one interpretation.

1) Everyone in the village had access to the same sources, knew the same recipe for pottery preparation and produced his/her own the ceramic.

---

[2] COSTANTIN, C. & COURTOIS, L. C., 1985, *Le materiau céramique comme caractéristique culturelle. L'example du dégraissant pendant le Néolithique dans le bassin parisien*. IGAL. Etudes des céramiques en archéologie. Documents et travaux

2) One or more specialized potter had access to a specific (clay and temper) source and produced the ceramic for everyone in the village as a sort of regular activity.

The first hypothesis is more consistent with the model of a domestic production of ceramics proposed for the station II of Chalain, France[3]. The same model is more consistent with the results concerning the study of the pottery from the settlement of St. Blaise[4].

In this case in fact, the good correlation found between a specific group of pottery and its house of provenance, is definitely more consistent with the local and very likely domestic production model.

It is hard to evaluate the second hypothesis. The specialization in the pottery manufacturing has never been demonstrated for the Neolithic, at our knowledge. Whether this could correspond to the presence of craftsmen and a consequent sort of trading inside the settlement does not match neither any known ethnographic case study concerning nowadays-archaic societies.

It is our opinion that the chemical and petrographic characterization of pottery, even if coupled with the morphologic data and the localization per house of provenance, is not exhaustive to clearly answer the question of the specialized production. For the Portalban settlement, the presence of specific sources for providing the necessary materials and the precise know-how in producing ceramics should be envisaged. This interpretation is in good agreement with the proposed model of the “material choice” corresponding to a “cultural behavior” and not to a “whatever case”. But this could not be automatically interpreted and called a craftsmen specialization. A better understanding of this phenomenon could come for instance from the study of the different techniques used to produce ceramics[5]. The combined and multiple approach consisting in the characterization of the material, the detailed study of the morphologies and the different production techniques, as well as the exact localization of pottery, properly inserted in its own environment of production, use and dismissing, could have more chances for answering this challenging question.

---

[3] PÉTREQUIN, P., PÉTREQUIN, A.M., GILIGNY, F. & RUBY, P., 1994, Produire pour soi, la céramique de Chalain 2 C au Néolithique final. *Bulletin de la Société Préhistorique française*, t. 91, n° 6, p. 407-417.

[4] DI PIERRO, S., MICHEL, R. & MARTINEAU, R., 2002, *Matériau et types céramique à St. Blaise (Néolithique Suisse) Poterie exogène et production locale.* Proceedings of the XIVth Congress of the U.I.S.P.P.,Liège, Belgium, 2 – 8 September 2001. British Archaeological Report. Submitted.

[5] MARTINEAU, R., 2000, *Poterie, techniques et sociétés. Etudes analytiques et expérimentales à Chalain et à Clairvaux (Jura), entre 3200 et 2900 av. J.-C.* Thèse de doctorat, Archéologie-préhistoire, Besançon, Université de Franche-Comté, UFR des Sciences de l'Homme, du Langage et de la Société, multigraphiée.

PERSPECTIVES

A) **The utilization of the Mont Blanc granite for pottery tempering**.

1) The *stilpnomelane bearing Mont Blanc granite* met a wide success during the Neolithic for the ceramic tempering and manufacturing. Its utilization has been determined at different places, distant from each other in time and space. In the present Ph.D research it has been identified and characterized at Portalban and St. Blaise, Switzerland – Auvernier-cordé group, as well as it has been characterized at Chalain[1], France – Clairvaux group. It has been identified at the Burgäschisee[2], Switzerland – Cortaillod phase, but granite has been mentioned as the main lithotype used to temper Final Neolithic ceramics all across other Swiss settlements[3].
2) Why did the Mont Blanc granite obtained such a large success?
    a) does its utilization hide some technological advantage compared to other crystalline rocks?
    b) or was it simply its availability and/or its easiness in recognizing it?
3) Further insight:
    a) other investigations on other settlements should be first implemented analyzing the material on a petrographic base, and once properly separated from the matrix, on a chemical base.
    b) Experiments concerning its easiness in crushing, as those already performed[4], should be again implemented as a comparative study on the Mont Blanc granite and other granitoide rocks, to evaluate their differences and physical properties.
    c) A wider petrographic study should be implemented on the whole lithologic available objects such as (i) the serpentinites axes, (ii) the flint and (iii) the granitoide grindstones ("meules"). This should help to better estimate the degree of correlation, in terms of provenance, between the rock materials, and in particular if the Mont Blanc granite was preferentially used as grindstones as well.

B) **Provenance of ceramics and their raw materials**

1) Calcareous clay numbered DP 73 found beside the settlement of Portalban corresponds to the calcareous clay used for the cobs and loom weights preparation at that site.
2) A silicate clay with the petrographic and chemical features of the clay used for the Portalban pottery outcrops at Cornaux, on the Swiss Plateau, but 15 km far from Portalban.
3) At St. Blaise clays determined as MgO-poor and Sr + Ba rich have been characterized. The primary contamination problems of this latter have been inferred.
4) In order to better answer the question of the provenance of ceramics, even in terms of local production, the set up of a database with the existing data sets from literature should be helpful for that purpose.
5) The database should be integrated with data coming from the systematic prospecting and characterization of the potential raw clays.

C) **The provenance of the "Corded True" ceramics of St. Blaise / Evaluation of pottery exchanges**.

1) The good correspondence between the St. Blaise "Corded true" pottery and the materials used at Portalban for the ceramic is and remains an hypothesis.
2) It should be better tested:
    a) comparing it also to other settlements, for instance Vinelz and Lüscherz, where MgO-rich pottery has been characterized[3] as well.
    b) Comparing in details the morphologies and decorations of other "Corded True" ceramics coming from the potential settlement of provenance.

---

[1] DI PIERRO, S. & MARTINEAU M., 2002, *Pottery Tempering With Mont Blanc Granite Across The Jura Belt During French And Swiss Final Neolithic*. 33rd International Symposium on Archaeometry ISA, 22 - 26 April 2002, Amsterdam. Abstract

[2] NUNGÄSSER, W. & MAGGETTI, M., 1978, Mineralogisch-petrographische Untersuchung der neolitischen Töpferware vom Burgäschisee. Bull. Soc. Frib. Sc. Nat. 67/2, 152 – 173.

[3] BENGHEZAL, A., 1994, Provenance et techniques de la céramique du Néolithique final de stations des trois lacs jurassiens Suisse. Thèse de doctorat, Université de Fribourg, 174 pp.

[4] NUNGÄSSER, W., MAGGETTI, M. & STÖCKLI, W.E., 1985, *Neolitische Keramik von Twann – Mineralogische und Petrographische Untersuchungen*. Jahrbuch der Schweiz. Ges. für Ur- und Frügeschichte, 68, 7-39.

D) **The provenance of the pottery manufactured with calcareous and fossils-rich clays**.

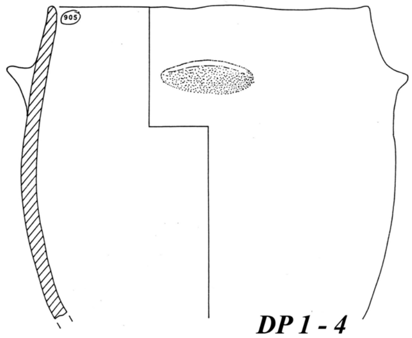
1) This kind of pottery has been found in this study and in the Benghezal one, at all the sites of the Western Swiss Plateau, as exceptions. Its provenance might be disputed between two hypothesis:
    a) it can be exogenous to the Western Swiss Plateau, or
    b) it might represent the “mistakes” of Neolithic potters in using the wrong raw material.
2) Both hypotheses are worth valued to be tested.

E) **The question of the specialization:** If the multiple approach used in this research was not successful, further approach could be evaluated and tested. The detailed study of the different manufacturing techniques, as applied elsewhere[5], could be more fruitful.

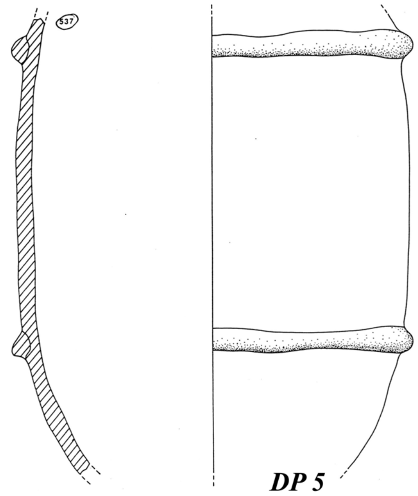
---

[5] MARTINEAU, R., 2000, *Poterie, techniques et sociétés. Etudes analytiques et expérimentales à Chalain et à Clairvaux (Jura), entre 3200 et 2900 av. J.-C.* Thèse de doctorat, Archéologie-préhistoire, Besançon, Université de Franche-Comté, UFR des Sciences de l'Homme, du Langage et de la Société, multigraphiée.

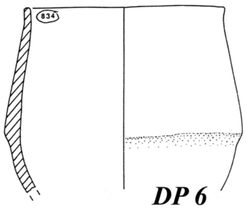
ANNEX



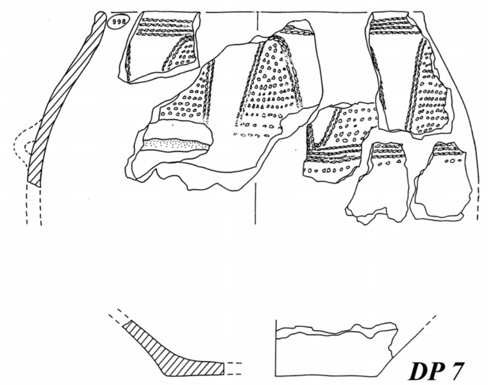
DP 1 - 4



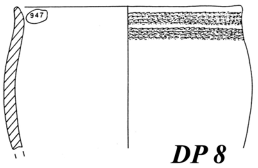
DP 5



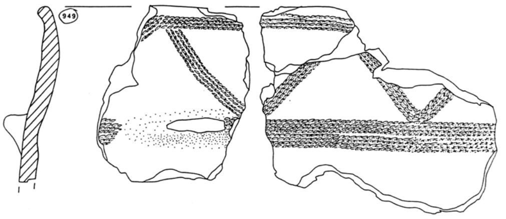
DP 6



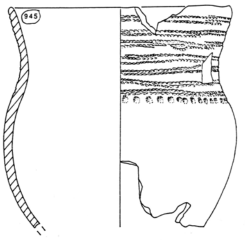
DP 7



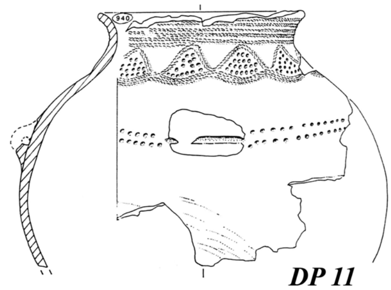
DP 8



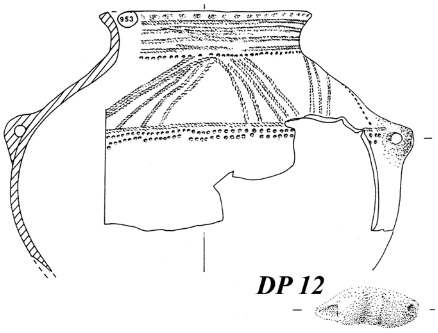
DP 9



DP 10

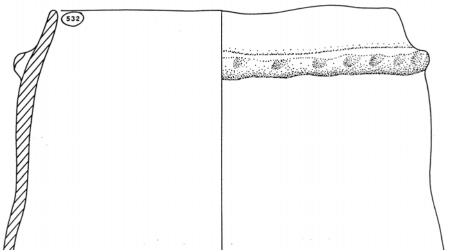


DP 11

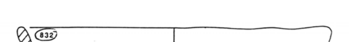


DP 12

DP 13

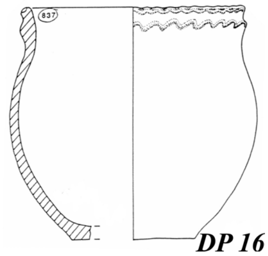


DP 14

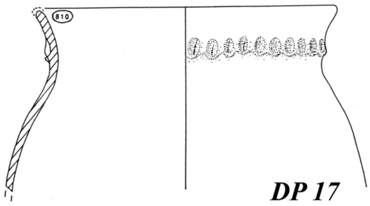


DP 15

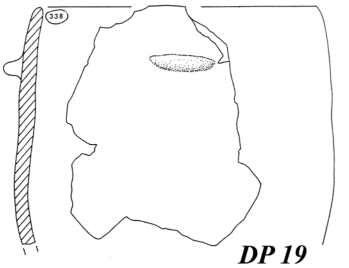
Drawns by F. GILIGNY (1993). Scale 1:6. *DPxx: DI PIERRO samples*



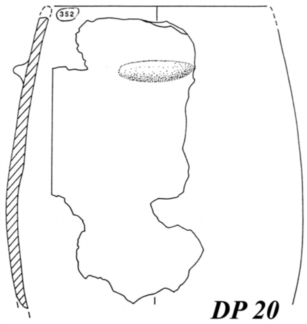
DP 16



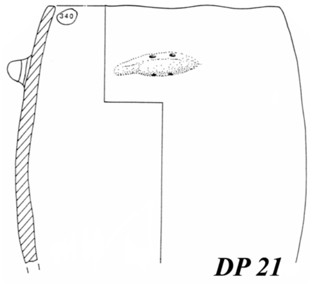
DP 17



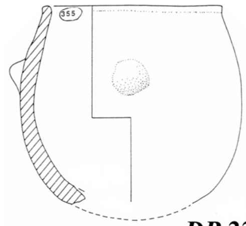
DP 19



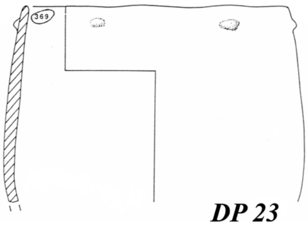
DP 20



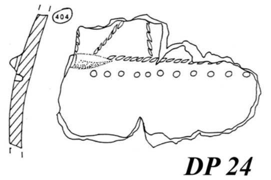
DP 21



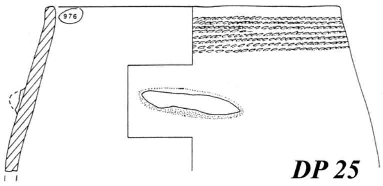
DP 22



DP 23

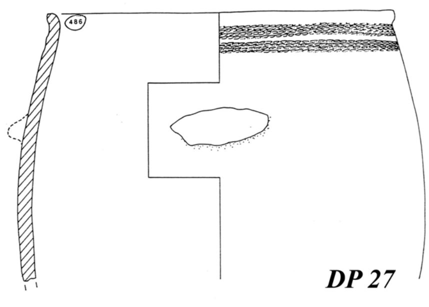


DP 24

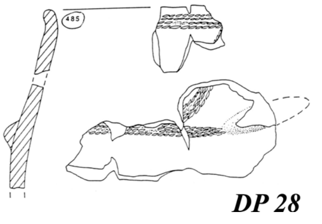


DP 25

DP 26

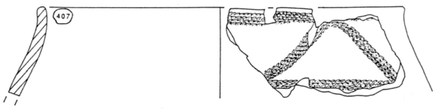


DP 27

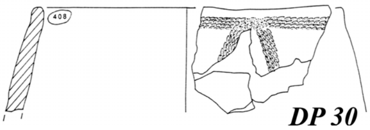


DP 28

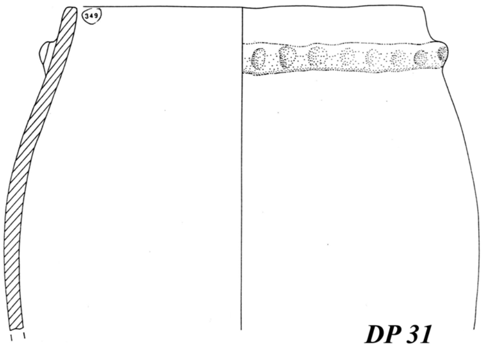
Drawns by F. GILIGNY (1993). Scale 1:6. *DPxx: DI PIERRO samples*



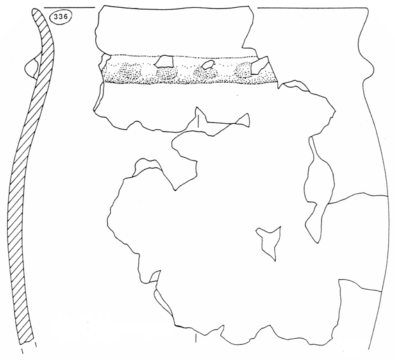
DP 29



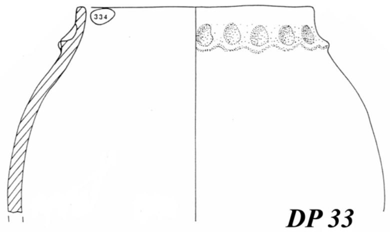
DP 30



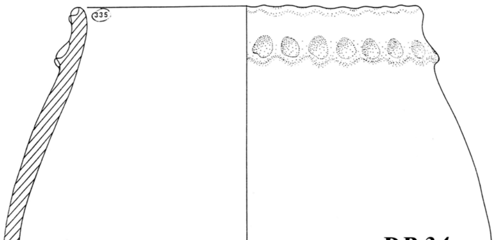
DP 31



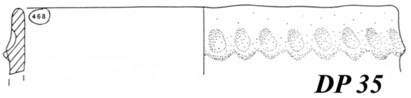
DP 32



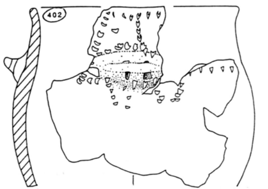
DP 33



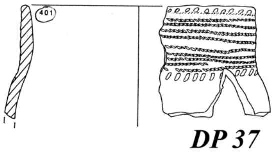
DP 34



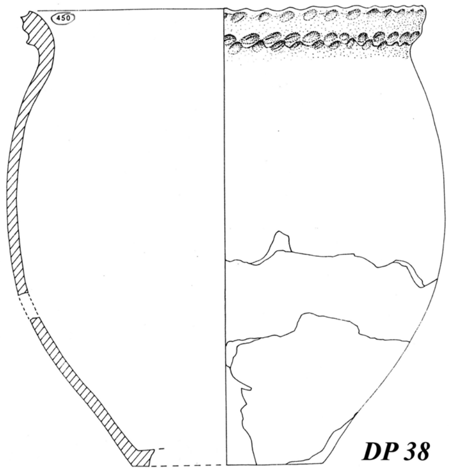
DP 35



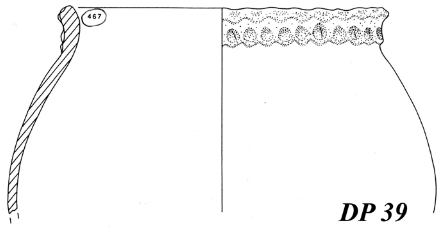
DP 36



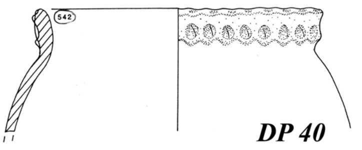
DP 37



DP 38

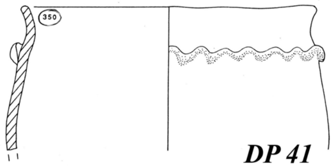


DP 39

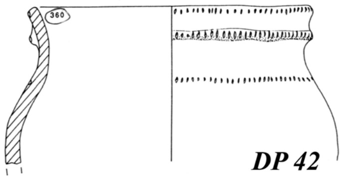


DP 40

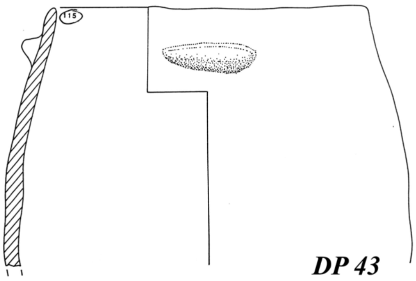
Drawns by F. GILIGNY (1993). Scale 1:6. *DPxx: DI PIERRO samples*



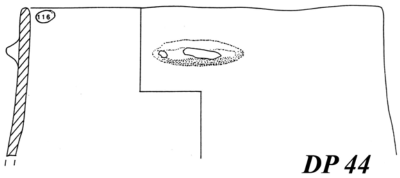
DP 41



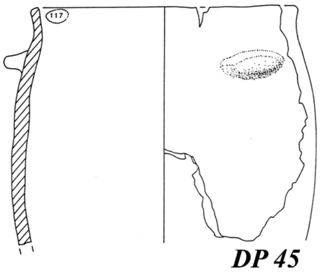
DP 42



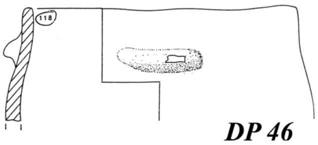
DP 43



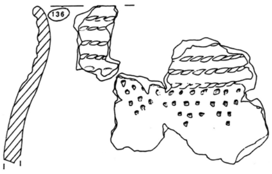
DP 44



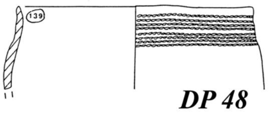
DP 45



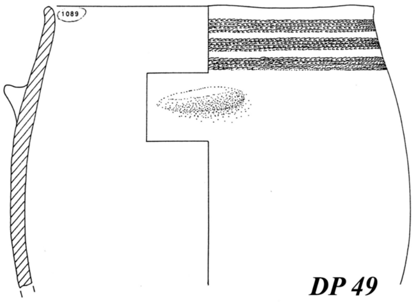
DP 46



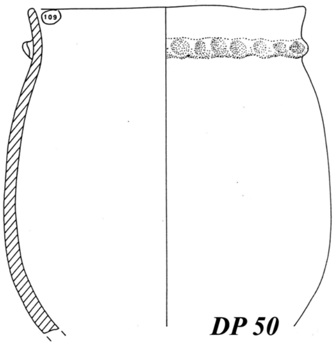
DP 47



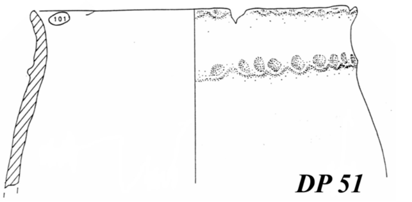
DP 48



DP 49

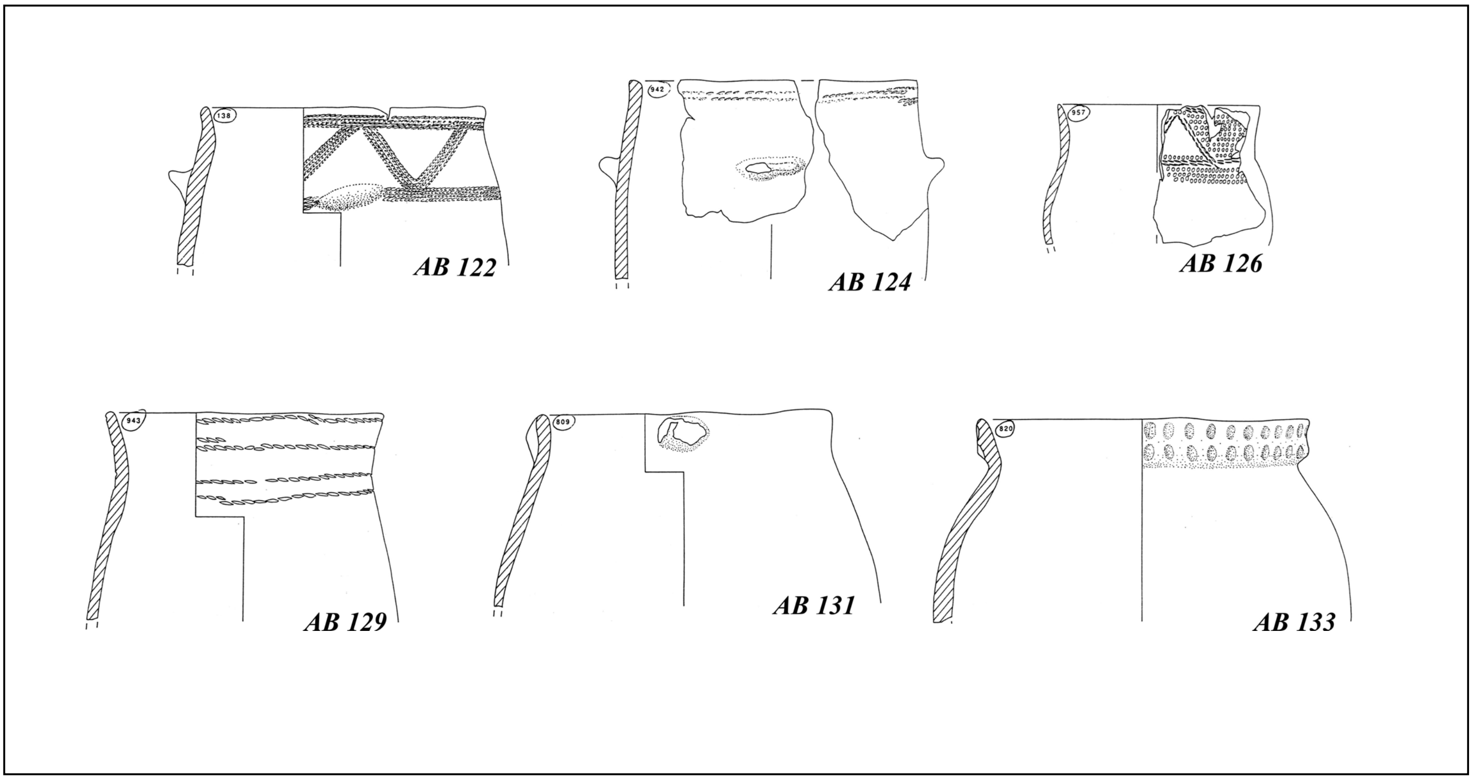


DP 50

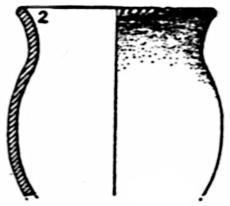


DP 51

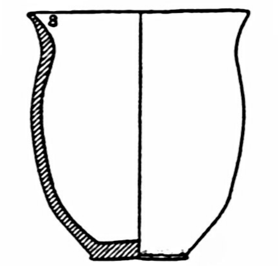
Drawns by F. GILIGNY (1993). Scale 1:6. *DPxx: DI PIERRO samples*



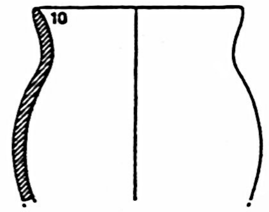
Drawns by F. GILIGNY (1993). Scale 1:6. *ABxx: A. BENGHEZAL samples*



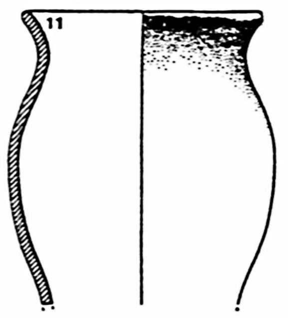
DP 100



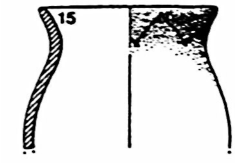
DP 101



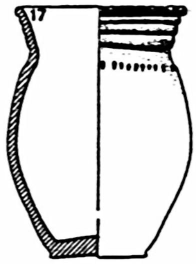
DP 102



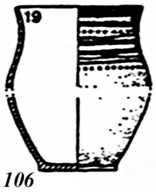
DP 103



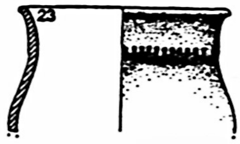
DP 104



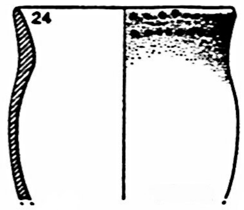
DP 105



DP 106

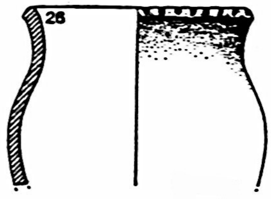


DP 107

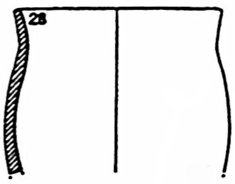


DP 108

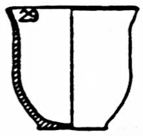
DP 109



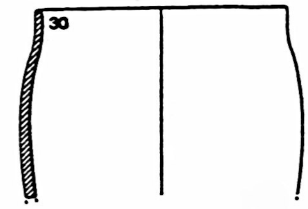
DP 110



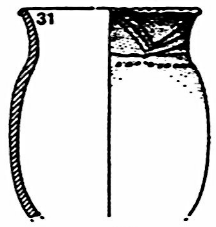
DP 111



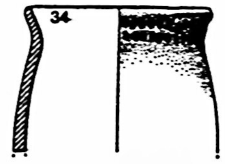
DP 112



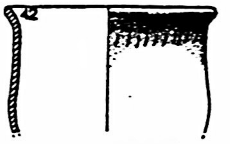
DP 113



DP 114

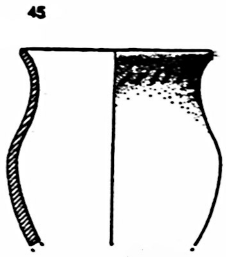


DP 115

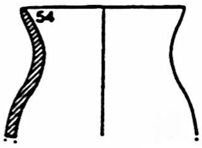


DP 116

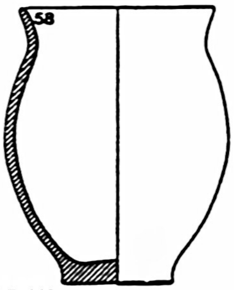
Drawns by R. MICHEL (2002): Scale 1:8 *DPxx: DI PIERRO samples*



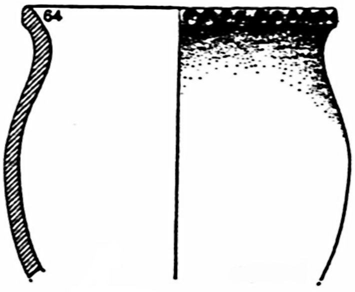
DP 117



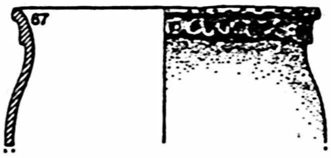
DP 118



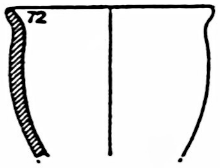
DP 119



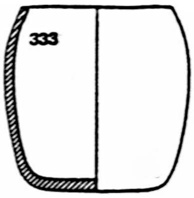
DP 120



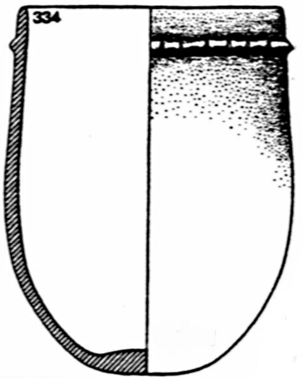
DP 121



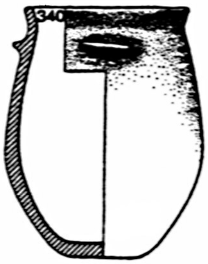
DP 122



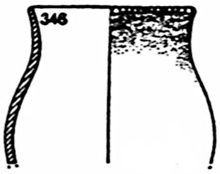
DP 124



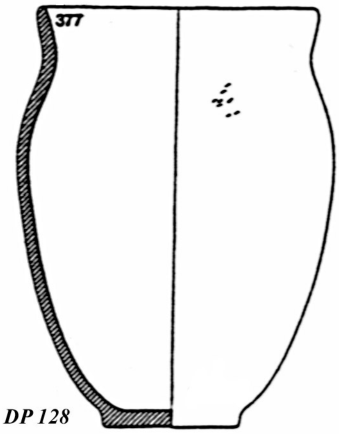
DP 125



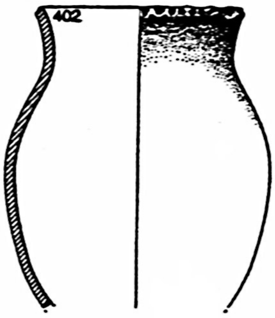
DP 126



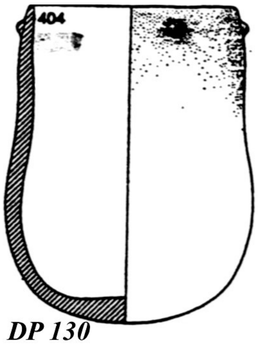
DP 127



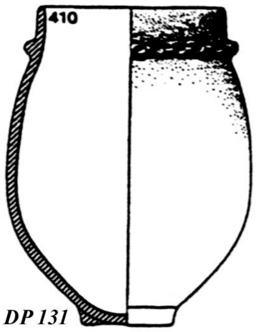
DP 128



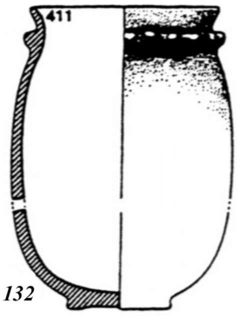
DP 129



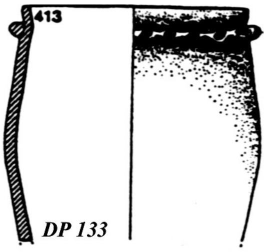
DP 130



DP 131



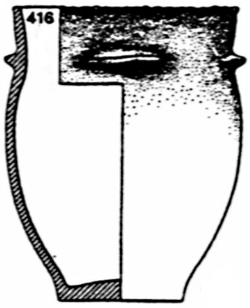
DP 132



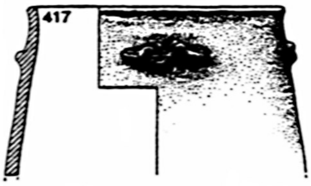
DP 133

Drawns by R. MICHEL (2002): Scale 1:8

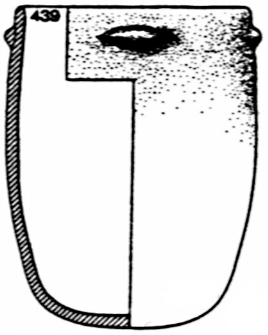
DPxx: DI PIERRO samples



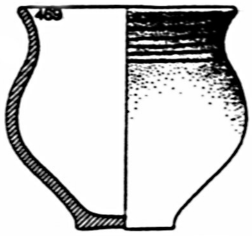
DP 134



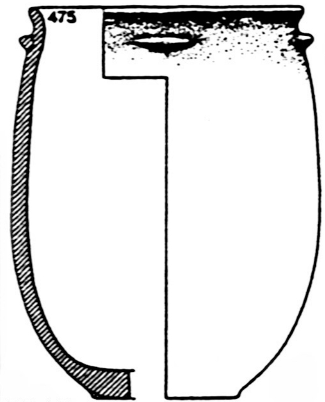
DP 135



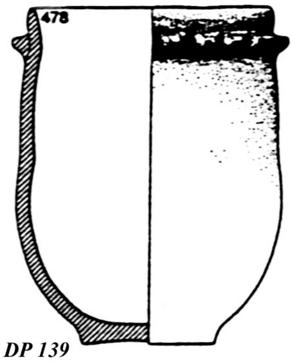
DP 136



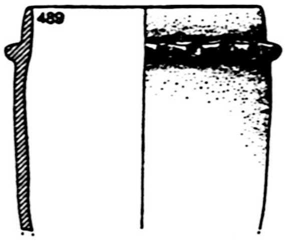
DP 137



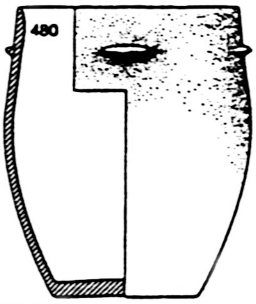
DP 138



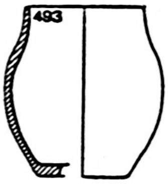
DP 139



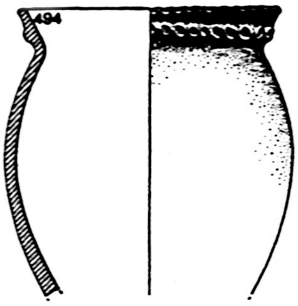
DP 140



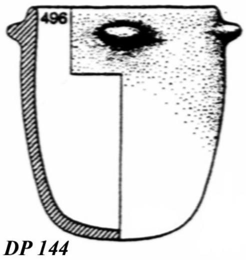
DP 141



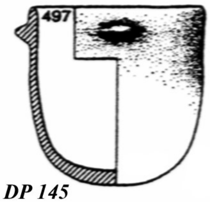
DP 142



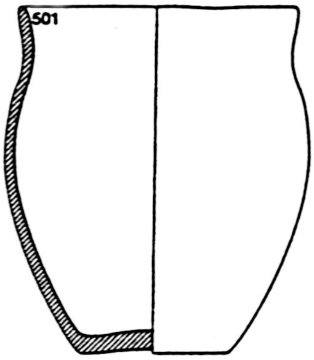
DP 143



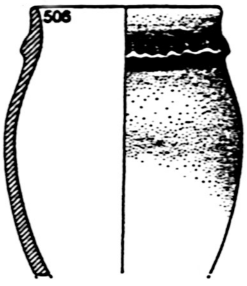
DP 144



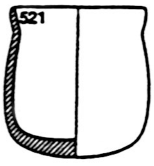
DP 145



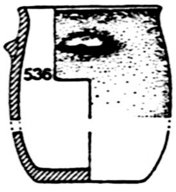
DP 146



DP 147

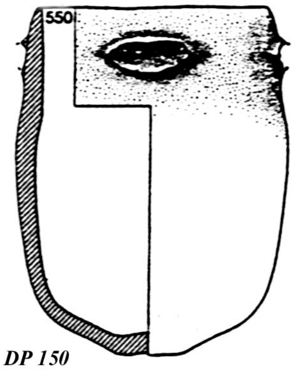


DP 148

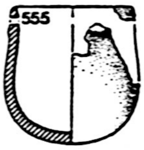


DP 149

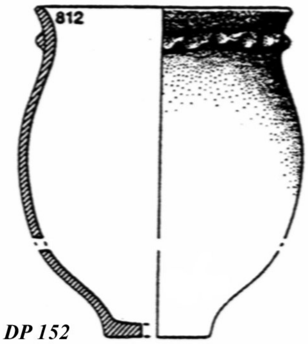
Drawns by R. MICHEL (2002): Scale 1:8 *DPxx: DI PIERRO samples*



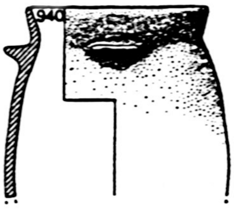
DP 150



DP 151



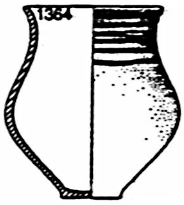
DP 152



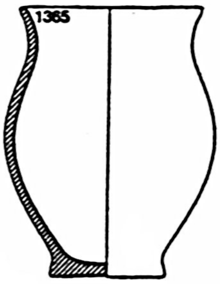
DP 153

DP 154

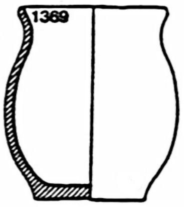
DP 155



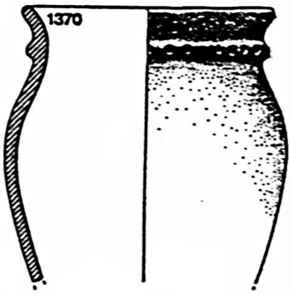
DP 156



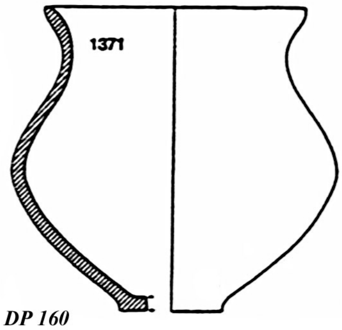
DP 157



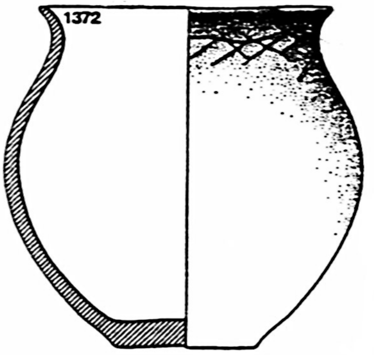
DP 158



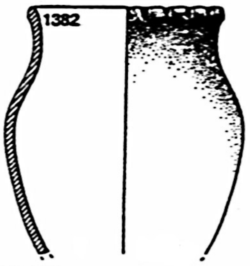
DP 159



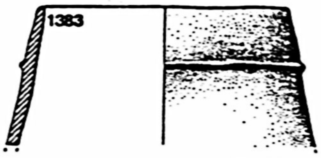
DP 160



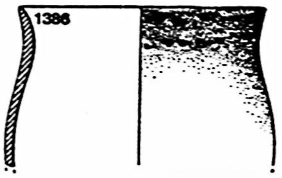
DP 161



DP 162

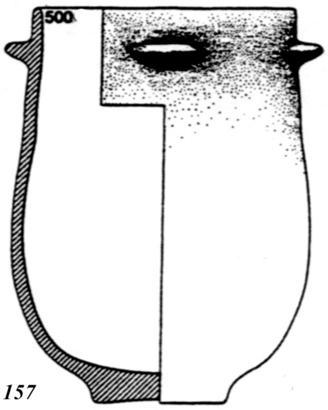


DP 163

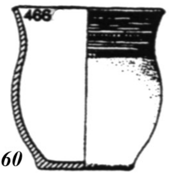


DP 164

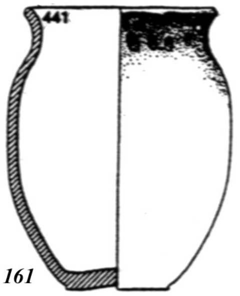
Drawns by R. MICHEL (2002): Scale 1:8 *DPxx: DI PIERRO samples*



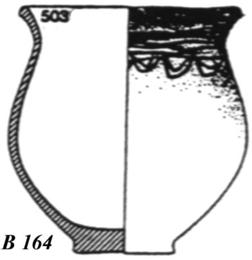
AB 157



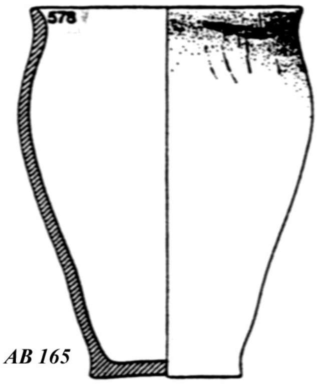
AB 160



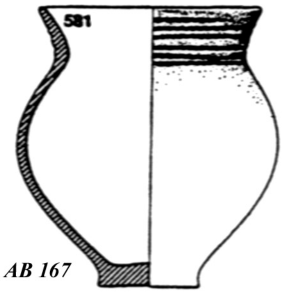
AB 161



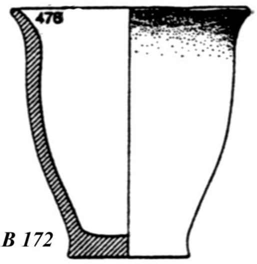
AB 164



AB 165

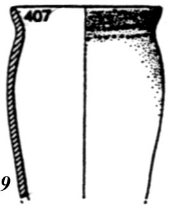


AB 167

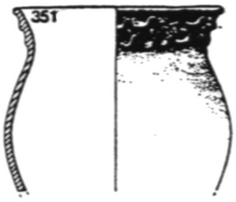


AB 172

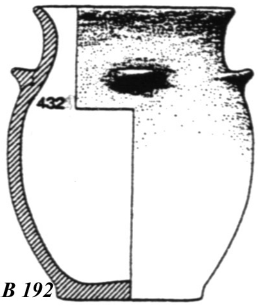
AB 180



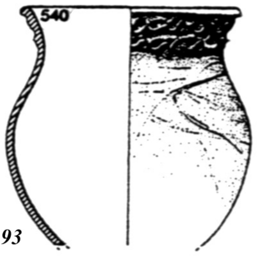
AB 189



AB 191



AB 192



AB 193

Drawns by R. MICHEL (2002): Scale 1:8

ABxx: A. BENGHEZAL samples

Analysis	**specimen**	**XRD detected minerals**	**Petrographic observations (thin section)**							
			matrix			**temper**				
			color	composition	n.a.p.i.	quantity	lenght max	composition I	composition II	particularities
						vol%	mm			
DP 1 - 4	potsherd	qtz, kf, plg, ill, chl	brown-yellowish	silicate	poor	15 - 20	5	granite		clay pellets
DP 5	potsherd	qtz, kf, plg, ill, chl, cal	yellow	calco-silicate	poor	15	5	granite		
DP 6	potsherd	qtz, kf, plg, ill, cal	yellow-brownish	silicate	rich	20	2.5	granite		
DP 7	potsherd	qtz, kf, plg, ill, cal	brown	calco-silicate	poor	10	3	granite		
DP 8	potsherd	qtz, kf, plg, ill	brown-orange	silicate	sandy	10	3	granite		
DP 9	potsherd	qtz, kf, plg, ill, chl, cal	brown-dark orange	calco-silicate	poor	20 - 25	4	granite		
DP 10	potsherd	qtz, kf, plg, ill, cal	brown-dark orange	calco-silicate	sandy	10	1.5	granite	marl & limestone	
DP 11	potsherd	qtz, kf, plg, ill	beige	silicate	poor	15	7.5	granite		clay pellets
DP 12	potsherd	qtz, kf, plg, ill, chl	brown	silicate	sandy	15	3.5	granite		big clay pellets
DP 13	potsherd	qtz, plg, ill, chl	brown	silicate	sandy	15	2	granite		
DP 14	potsherd	qtz, kf, plg, ill, chl	brown	silicate	poor	15 - 20	9	granite		red clay pellets
DP 15	potsherd	qtz, kf, plg, ill, chl, cal	brown	calco-silicate	poor	20	7	granite	limestone	
DP 16	potsherd	qtz, kf, plg, ill, chl	dark brown	silicate	rich	20 - 25	3	granite		clay pellets
DP 17	potsherd	qtz, kf, plg, ill, cal	brown	calco-silicate	poor	10	3	granite	limestone	clay pellets
DP 19	potsherd	qtz, kf, plg, ill, chl, cal	bright brown	silicate	sandy	20 - 25	4.5	granite	marl	clay pellets
DP 20	potsherd	qtz, kf, plg, ill, chl, cal	dark brown	calco-silicate	poor	20	4.5	granite	limestone	
DP 21	potsherd	qtz, kf, plg, ill, chl, cal	bright brown	silicate	sandy	15 - 20	4	granite	marl	clay pellets
DP 22	potsherd	qtz, kf, plg, ill, chl	dark brown	silicate	rich	20	7	granite		red clay pellets
DP 23	potsherd	qtz, kf, plg, ill, chl	dark brown	silicate	rich	20 - 25	7	granite		
DP 24	potsherd	qtz, kf, plg, ill, chl	brown	silicate	rich	20	7	granite		
DP 25	potsherd	qtz, kf, plg, ill, chl	dark brown to red	silicate	poor	25 - 30	4	granite		
DP 26	potsherd	qtz, kf, plg, ill	beige	silicate	poor	25 - 30	7.5	granite		red clay pellets
DP 27	potsherd	qtz, kf, plg, ill	brown to beige	silicate	rich	15	3	granite	sandstone & marl	rare clay pellets
DP 28	potsherd	qtz, kf, plg, ill, chl, cal	brown to beige	calco-silicate	poor	15 - 20	5	granite	limestone	
DP 29	potsherd	qtz, kf, plg, ill, cal	dark brown	calco-silicate	rich	20	6	granite		
DP 30	potsherd	qtz, kf, plg, ill, chl, cal	dark brown	calco-silicate	poor	20	4.5	granite	limestone	
DP 31	potsherd	qtz, kf, plg, ill, chl	orange - brown	silicate	sandy	15	5	granite	sandstone	
DP 32	potsherd	qtz, kf, plg, ill, chl	brown	silicate	rich	15	6	granite		
DP 33	potsherd	qtz, kf, plg, ill,	dark brown	silicate	poor	15	7.5	granite		
DP 34	potsherd	qtz, kf, plg, ill	beige	silicate	poor	15	4.5	granite		
DP 35	potsherd	qtz, kf, plg, ill, chl, cal	brown to orange	silicate	poor	15 - 20	6	granite	limestone	ARF
DP 36	potsherd	qtz, kf, plg, ill, chl	dark beige	silicate	rich	15	4	granite		

Annex III - Mineralogical (XRD) and petrographic (optical) compositions of ceramics and clays. n.a.p.i.=natural a-plastic inclusions. qtz=quartz, kf=alkali-feldspar, plg=plagioclase, chl=chlorite, cal=calcite. ARF=Argill. Rock Fragments.

Analysis	**specimen**	**XRD detected minerals**	**Petrographic observations (thin section)**							
			matrix			**temper**				
			color	composition	n.a.p.i.	quantity	lenght max	composition I	composition II	particularities
						vol%	mm			
DP 37	potsherd	qtz, kf, plg, ill	dark brown	silicate	rich	20 - 25	4.5	granite		
DP 38	potsherd	qtz, kf, plg, ill	dark brown	silicate	rich	20 - 25	5.5	granite		
DP 39	potsherd	qtz, kf, plg, ill, chl	dark brown	silicate	rich	20	4.5	granite		
DP 40	potsherd	qtz, kf, plg, ill	brown	silicate	sandy	20 - 25	6	granite		
DP 41	potsherd	qtz, kf, plg, ill	brown	silicate	rich	15	6.5	granite		
DP 42	potsherd	qtz, kf, plg, ill	black	silicate	rich	30 - 35	3	granite	marl	
DP 43	potsherd	qtz, kf, plg, ill, chl	beige to brown	silicate	rich	15	6	granite		clay pellets
DP 44	potsherd	qtz, kf, plg, ill, chl	beige to brown	silicate	rich	15	4.5	granite		
DP 45	potsherd	qtz, kf, plg, ill, chl	beige to brown	silicate	rich	15	4.5	granite		
DP 46	potsherd	qtz, kf, plg, ill, chl	brown	silicate	rich	10	3	granite		
DP 47	potsherd	qtz, kf, plg, ill, cal	brown to black	calco-silicate	rich	15	4.5	granite		yello clay pellets
DP 48	potsherd	qtz, kf, plg, ill, cal	brown	calco-silicate	sandy	15	3	granite		
DP 49	potsherd	qtz, kf, plg, ill, cal	brown to beige	calco-silicate	rich	15 - 20	4	granite		
DP 50	potsherd	qtz, kf, plg, ill, chl, cal	brown to orange	calco-silicate	poor	10	6	granite	marl	clay pellets
DP 51	potsherd	qtz, kf, plg, ill, cal	brown	calco-silicate	sandy	15	5	granite		clay pellets
DP 52	cob	qtz, cal, ill, plg, kf	beige - reddish - brown	calcareous to silicate	very rich					pellets of marl and clay
DP 53	cob	qtz, cal, ill, plg, kf	brown - beige	calcareous	very rich	5	4.5	micaschist	marl	
DP 54	cob	qtz, cal, ill, plg, kf	dark brown	calcareous	very rich					
DP 55	cob	qtz, cal, ill, plg, kf	beige - dark brown	calcareous	very rich					
DP 56	cob	qtz, cal, ill, plg, kf	beige - dark brown	calcareous	very rich					
DP 57	cob	qtz, cal, ill, plg, kf	brown	calcareous	very rich					clay pellets
DP 58	cob	qtz, cal, ill, plg, kf	brown	calcareous	very rich					
DP 59	cob	qtz, cal, ill, plg, kf	brown to opaque	calcareous	very rich					
DP 60	cob	qtz, cal, ill, plg, kf	brown to opaque	calcareous	very rich					
DP 61	cob	qtz, cal, ill, plg, kf	beige - brown -black	calcareous	very rich					
DP 62	cob	qtz, cal, ill, plg, kf	brown - orange - beige	calcareous to silicate	very rich					
DP 63	cob	qtz, cal, ill, plg, kf	brown - orange - beige	calcareous to silicate	very rich					
DP 64	cob	qtz, cal, ill, plg, kf	redish - brown	calacareous	very rich					
DP 65	cob	qtz, cal, ill, plg, kf, chl	redish - brown	calacareous	very rich					
DP 66	loom weight	qtz, cal, ill, plg, kf	beige to brown	calcareous	very rich					
DP 67	loom weight	qtz, cal, ill, plg, kf	beige to brown	calcareous	very rich	10		charcoal		
DP 68	loom weight	qtz, cal, ill, plg, kf, chl	beige to brown	calcareous	very rich	10		charcoal		

Annex III - Mineralogical (XRD) and petrographic (optical) compositions of ceramics and clays. n.a.p.i.=natural a-plastic inclusions. qtz=quartz, kf=alkali-feldspar, plg=plagioclase, chl=chlorite, cal=calcite. ARF=Argill. Rock Fragments.

Analysis	**specimen**	**XRD detected minerals**	**Petrographic observations (thin section)**							
			matrix			**temper**				
			color	composition	n.a.p.i.	quantity	lenght max	composition I	composition II	particularities
						vol%	mm			
DP 69	loom weight	qtz, cal, ill, plg, kf	beige to brown	calcareous	very rich					
DP 70	loom weight	qtz, cal, ill, plg, kf	beige to brown	calcareous	very rich	10		charcoal		
DP 71	loom weight	qtz, kf, plg, ill, chl	beige	silicate	very rich					
DP 72	loom weight	qtz, kf, plg, ill, cal	brown to red	silicate	very rich					
DP 73	clay	qtz, cal, ill, chl, plg, kf		calcareous	very rich					
DP 74	clay	qtz, cal, plg, kf, ill, chl		silicate	very rich					
DP 75	clay	qtz, kf, plg, ill, chl		silicate	very rich					
DP 76	clay	qtz, cal, plg, ill		calcareous	very rich					
DP 77	clay	qtz, plg, ill, chl, cal, kf		silicate	very rich					
DP 88	clay	qtz, cal, plg, ill, chl		calcareous	very rich					
DP 89	clay	qtz, cal, plg, ill, chl, kf		calcareous	very rich					
DP 90	clay	qtz, kf, plg, ill, chl		silicate	very rich					
DP 91	clay	qtz, cal, kf, plg, ill, chl		calcareous	very rich					
DP 92	clay	qtz, kf, plg, ill, chl		silicate	very rich					
DP 93	clay	qtz, kf, plg, ill, chl		silicate	very rich					
DP 94	clay	qtz, kf, plg, ill, chl		silicate	very rich					
DP 100	potsherd	qtz, kf, plg, ill, cal	brown to reddish	calco-silicate	sandy	25 - 30	3.5	granite		
DP 101	potsherd	qtz, kf, plg, ill, cal	reddish to brown	calco-silicate	rich	15	6	granite	oolitic limestone	
DP 102	potsherd	qtz, kf, plg, cal, ill	brown to beige	calco-silicate	rich	15	3.5	granite	oolitic limestone	
DP 103	potsherd	qtz, kf, plg, ill, cal	red to dark brown	silicate	poor	25	4	granite		
DP 104	potsherd	qtz, kf, plg, ill, cal	reddish to brown	calco-silicate	rich	20	5.5	granite		
DP 105	potsherd	qtz, kf, plg, cal, ill	dark brown	calco-silicate	sandy	10	3	granite	marl	red clay pellets
DP 106	potsherd	qtz, kf, plg, ill	dark brown	silicate	very rich					matrix optically isotrope
DP 107	potsherd	qtz, kf, plg, ill, chl	dark brown	silicate	very rich	15	3.5	granite	limestone & marl	matrix optically isotrope
DP 108	potsherd	qtz, kf, plg, ill, cal	reddish to brown	calco-silicate	rich	15 - 20	5	granite		
DP 109	potsherd	qtz, kf, plg, cal, ill	dark brown	calco-silicate	very rich	10	6.5	granite	marl	
DP 110	potsherd	qtz, kf, plg, ill, cal	reddish to brown	calco-silicate	sandy	10	6	granite		
DP 111	potsherd	qtz, kf, plg, cal, ill	reddish to brown	calco-silicate	rich	15	4.5	granite		
DP 112	potsherd	qtz, kf, plg, cal, ill	brown	calco-silicate	rich	10	7.5	granite	limestone	
DP 113	potsherd	qtz, kf, plg, ill, cal	red to dark brown	calco-silicate	rich	25 - 30	5	granite		charcoal
DP 114	potsherd	qtz, kf, plg, cal, ill	red to dark brown	calco-silicate	rich	10	3.5	granite		
DP 115	potsherd	qtz, kf, plg, ill, cal	brown	calco-silicate	rich	15 - 20	3	granite		

Annex III - Mineralogical (XRD) and petrographic (optical) compositions of ceramics and clays. n.a.p.i.=natural a-plastic inclusions. qtz=quartz, kf=alkali-feldspar, plg=plagioclase, chl=chlorite, cal=calcite. ARF=Argill. Rock Fragments.

Analysis	specimen	XRD detected minerals	Petrographic observations (thin section)							
			matrix			temper				
			color	composition	n.a.p.i.	quantity	lenght max	composition I	composition II	particularities
						vol%	mm			
DP 116	potsherd	qtz, kf, plg, cal, ill	dark brown	calco-silicate	rich	15	2.5	granite		
DP 117	potsherd	qtz, kf, plg, cal, ill	brown	calco-silicate	rich	15	6	granite		
DP 118	potsherd	qtz, kf, plg, cal, ill	dark brown	calco-silicate	poor	25 - 30	5	granite		
DP 119	potsherd	qtz, kf, plg, ill, cal	red brown	calco-silicate	poor	15	3	granite		oolits, opaques
DP 120	potsherd	qtz, kf, plg, ill, cal	reddish to brown	calco-silicate	poor	25 - 30	7	granite		
DP 121	potsherd	qtz, kf, plg, cal, ill, chl	reddish to brown	calco-silicate	poor	10	3	granite		ARF
DP 122	potsherd	qtz, kf, plg, ill, cal	reddish to brown	calco-silicate	sandy	20 - 25	4	granite		black pellets
DP 124	potsherd	qtz, kf, plg, ill, cal	black	silicate	rich	15	3	granite		matrix optically isotrope
DP 125	potsherd	qtz, kf, cal, plg, ill,	brown	calco-silicate	rich	20	3.5	granite		
DP 126	potsherd	qtz, kf, plg, cal, ill,	brown	calco-silicate	rich	15 -20	4	granite		
DP 127	potsherd	qtz, kf, plg, cal, ill,	brown	calco-silicate	rich	20 - 25	2.5	granite		
DP 128	potsherd	qtz, kf, plg, cal, ill,	brown	calco-silicate	poor	25 - 30	7.5	granite		pellets of carbonates
DP 129	potsherd	qtz, kf, plg, ill, cal	brown	calco-silicate	sandy	20	7	granite		pellets of carbonates
DP 130	potsherd	qtz, kf, plg,	brown to grey	calco-silicate	rich	15	7	granite		matrix optically isotrope
DP 131	potsherd	qtz, kf, plg, cal, ill	brown	calco-silicate	rich	25 - 30	5	granite		matrix optically isotrope
DP 132	potsherd	qtz, kf, plg, cal, ill	brown	calco-silicate	rich	25 - 30	4	granite		oolitic carbonate pellets
DP 133	potsherd	qtz, kf, plg, cal, ill	red to dark brown	calco-silicate	rich	15	3	granite		
DP 134	potsherd	qtz, kf, plg, ill, cal	brown to red	calco-silicate	poor	10	3	granite		pellets of marl
DP 135	potsherd	qtz, kf, plg, ill, cal	brown to red	calco-silicate	sandy	15 - 20	7	granite	limestone	
DP 136	potsherd	qtz, kf, plg, ill,	brown	silicate	rich	25 - 30	7	granite		red clays pellets
DP 137	potsherd	qtz, kf, plg, ill, chl, cal	brown	calco-silicate	rich	25 - 30	7	granite		
DP 138	potsherd	qtz, kf, plg, ill, cal	reddish to brown	calco-silicate	rich	20	6	granite		
DP 139	potsherd	qtz, kf, plg, cal, ill, chl	reddish to brown	calco-silicate	rich	20 - 25	5	granite	oolitic limestone	
DP 140	potsherd	qtz, kf, plg, ill, cal	brown	calco-silicate	rich	15 - 20	4	granite		matrix optically isotrope
DP 141	potsherd	qtz, kf, plg, ill	brown	silicate	poor	15	3	granite	calcite	
DP 142	potsherd	qtz, kf, plg, cal, ill	brown	calco-silicate	very rich		1.5	granite		
DP 143	potsherd	qtz, kf, plg, cal, ill	red to dark brown	calco-silicate	rich	10	3.5	granite		
DP 144	potsherd	qtz, kf, plg, ill, cal	dark brown	calco-silicate	rich	15	5	granite	limestone	
DP 145	potsherd	qtz, kf, plg, ill, cal	brown	silicate	rich	15	4.5	granite		matrix optically isotrope
DP 146	potsherd	qtz, kf, plg, ill	red	silicate	poor	15	5.5	granite		
DP 147	potsherd	qtz, kf, plg, ill, cal	red to dark brown	calco-silicate	rich	15	6	granite		
DP 148	potsherd	qtz, kf, plg, ill, cal	brown	calco-silicate	rich	20 - 25	4	granite		matrix optically isotrope

Annex III - Mineralogical (XRD) and petrographic (optical) compositions of ceramics and clays. n.a.p.i.=natural a-plastic inclusions. qtz=quartz, kf=alkali-feldspar, plg=plagioclase, chl=chlorite, cal=calcite. ARF=Argill. Rock Fragments.

Analysis	**specimen**	**XRD detected minerals**	**Petrographic observations (thin section)**							
			matrix			**temper**				
			color	composition	n.a.p.i.	quantity	lenght max	composition I	composition II	particularities
						vol%	mm			
DP 149	potsherd	qtz, kf, plg, ill, cal	red to dark brown	calco-silicate	rich	15	3	granite		
DP 150	potsherd	qtz, kf, plg, cal, ill, chl	brown	calco-silicate	rich	15	7	granite		
DP 151	potsherd	qtz, cal, kf, plg, ill, chl	brown	calcareous	rich	15	2.5	granite		fossiliferous
DP 152	potsherd	qtz, kf, plg, ill	dark brown	silicate	rich	15	3	granite		
DP 153	potsherd	qtz, kf, plg, ill, cal	dark reddish to brown	calco-silicate	rich	15 - 20	3.5	granite	limestone	matrix optically isotrope
DP 154	potsherd	qtz, kf, plg, ill	brown	silicate	sandy	10	2.5	granite		matrix optically isotrope
DP 155	potsherd	qtz, kf, plg, cal, ill	red	calco-silicate	rich	20	6	granite		
DP 156	potsherd	qtz, kf, plg, ill, chl	brown	silicate	rich					temper-less
DP 157	potsherd	qtz, kf, plg, ill, cal	red	calco-silicate	sandy	20	5	granite		
DP 158	potsherd	qtz, kf, plg, cal, ill	red	calco-silicate	poor	15 - 20	5	granite		carbonate pellets
DP 159	potsherd	qtz, kf, plg, ill, cal	dark brown	calco-silicate	poor	20	5	granite		
DP 160	potsherd	qtz, kf, plg, ill, cal	light brown	calco-silicate	rich	10	3.5	granite	limestone	
DP 161	potsherd	qtz, kf, plg, ill, cal	red	calco-silicate	rich	20 - 25	5	granite		
DP 162	potsherd	qtz, kf, plg, ill, cal	brown	calco-silicate	sandy	15	4.5	granite		matrix optically isotrope
DP 163	potsherd	qtz, kf, plg, ill	light brown	silicate	poor	15	3.5	granite		
DP 164	potsherd	qtz, kf, plg, ill, chl	black	silicate	rich	15	4	granite		matrix optically isotrope

Annex III - Mineralogical (XRD) and petrographic (optical) compositions of ceramics and clays. n.a.p.i.=natural a-plastic inclusions. qtz=quartz, kf=alkali-feldspar, plg=plagioclase, chl=chlorite, cal=calcite. ARF=Argill. Rock Fragments.

Annex IV

Curriculum Vitae

(28.02.2003)

First and Family Name: **Simonpietro DI PIERRO**
Place and date of birth: Torino (ITALY), 05/12/1969
Nationality: Italian
Address: R.te du Pafuet 112, 1729 Bonnefontaine, (FR), Switzerland.
Via Bionaz 8, 10142 Torino Italy.
e-mail: simonpietro.dipierro@yahoo.com

EDUCATION:

11 October 2002
PhD thesis in Mineralogy, Archaeometry. Institute of Mineralogy and Petrography, University of Fribourg, Switzerland.
Title "*Domestic production versus pottery exchange during the Final Neolithic: characterization of the Auvernier-cordé ceramics from the Portalban and St. Blaise settlements, Western Switzerland*", 128 pp.

24 November 1997
Graduate in Geological Sciences, applied petrography, Turin University (105/110).
Title: "*Geologic-petrographic study of the "Green Marble Alpi Cesana" and petrographic comparison with similar ophicarbonatic rocks coming from abroad*", 140 pp. 2 Vol. Geological Map (1:10.000) and CD-Rom attached.

WORKING EXPERIENCES:

February 1999 – up to present
Assistant at the Institute of Mineralogy and Petrography. University of Fribourg. Switzerland.

November 1988 – January 1999
Administrative employee - **Budget officer** c/o Budget & Control Section - Finance Depart., International Training Centre of the ILO, United Nations specialised agency, Turin.

PUBLICATIONS:

Di Pierro S., Fiora L. (1998) - Caratterizzazione petrografica dell'oficalcite "Verde Cesana" e di potenziali rocce oficarbonatiche sostitutive. *Atti della V giornata Archeometrica, Bari 19-21 febbraio 1998*. p. 99-108.

Fiora L., **Di Pierro S**., Gallo M. (1998) - Il "Verde Alpi Cesana" nel panorama delle pietre storiche dell'architettura piemontese". *Marmi Graniti Pietre*, p.36-40.

Fiora L., **Di Pierro S**. (1998) - Marmi Verdi (parte I) - *L'Informatore del Marmista* n.437, maggio 1998, p.16-31.

Fiora L., **Di Pierro S**. (1998) - Marmi Verdi (parte II) - *L'informatore del Marmista* n.438, giugno 1998, p.6-10.

Di Pierro, **S**., 2002a, *Ceramic production technology and provenance during Final Neolithic : the Portalban settlement, Neuchâtel Lake, Switzerland.* Proceedings of the "4e Colloque d'Archéometrie", La Rochelle, France, 24 - 28 April 2001, *Revue d'Archéometrie*. In press.

Di Pierro, **S**., 2002b, *Matrix-temper separation of Neolithic ceramics ; an experimental approach to characterise the original raw materials.* In: Proceedings of the 6th European Meeting on Ancient Ceramics EMAC '01, Ceramic in the Society, Fribourg, Switzerland, 3-6 October 2001. In press.

Di Pierro, **S**., Michel, R. & Martineau, R., 2002, *Matériau et types céramique à St. Blaise (Néolithique Suisse) Poterie exogène et production locale.* Proceedings of the XIVth Congress of the U.I.S.P.P.,Liège, Belgium, 2 – 8 September 2001. *British Archaeological Report*. In press.

Di Pierro, S., Gnos, E., Grobety, B.H., Armbruster, T., Bernasconi, S. & Ulmer, P., 2003, *Rock-forming moissanite (natural α-silicon carbide).* American Mineralogist. Submitted.

LANGUAGE SKILLS:

English: fluency:
UNESCO **Proficiency** Certificate, Paris 02.09.1997.

French: fluency
UNESCO **Proficiency** Certificate, Paris 01.09.1993

German: basic knowledge.

OTHER SKILLS: Computer literacy