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APPLICATION OF CLAY MINERALOGY IN CERAMIC PRACTICE

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Abstract: The chemical-mineralogical characteristics of the main types of clays used in production of traditional Bohemian ceramics in small workshops of Keramo-Praha cooperative have been collected.
For firing, a maximum temperature (1150 - 1160 °C) can be reached in current furnaces. It may be easy to deduce that for manufacture of vitrified "red" stoneware and ceramics are the most appropriate clays from locality Ledce-Žilov, Kačírov or Lhota u Dobřan and for "white" stoneware those illite–kaolinite clays quarried from Kyšice, Kopanina or Tvršice. The most suitable clays for production of ceramics seem to be those from Tvršice labeled as Stc.

Key words: ceramics, clays, raw materials.

Introduction

In practice, ceramic masses, pastes and mixes prepared and used in manufacturing are composed mostly as mixtures of four - six clays by a method of trial and error without any independent knowledge of their chemistry, mineralogy or technological parameters. This is negatively displayed in the variable quality (high shrinkage, high porosity, low mechanical properties) of manufactured products which is improved by prolonged or repeated firing and glazing.

For preliminary control of the optional composition of masses a method of Fabbri & Fiori (1985) and/or calculation of normative minerals can be recommened. From both these methods the most suitable clays or their optimal mixtures can be easily chosen.

Clays as the basic raw materials for many traditional ceramic products manufactured in Central Bohemia influence not only their aesthetic characteristics but also their mechanical strength, porosity and frost resistance. Although these clays have been used for many decades, their chemical and mineralogical composition or structural parameters, which may vary within a wide range, are not sufficiently known. Based on the data from literature on this topic a little attention is also paid to the technological side of processing or manufacturing (Pospíšil & Kollert et al. 1981).

The purpose of this paper is thus:
1 - to collect and give more information about the chemical-mineralogical composition of clays used for traditional production;
2 - to point out again methods of normative calculations of the mineral composition from chemical analyses;
3 - to call attention to the method of Fabbri & Fiori (1985) of preliminary control of appropriate composition of mixes for given conditions of firing and
4 - to choose the most suitable clays and complementary materials for basic types of ceramic mixes.

Information about geology, stratigraphy or depositional conditions at individual localities or the technological and structural characteristics of clays are not within the scope of this paper but can be found elsewhere in Kužvart (1977).

As for the colour of ceramic bodies produced traditionally in small manufactures, it is essentially of two types; "red" colour or "white" one. Actually, products can be also reddish brown or dark brown and yellow, pale, pink or grey. Nowadays coloured ceramic products can be obtained also by using various pigments in the "white" as well as in the "red" body composition.

Clays and complementary raw materials

The colour of a ceramic body depends mainly on the clay utilized. For the "red" ceramics illite/chlorite - montmorillonite/ - kaolinite illite - kaolinite clay with higher iron oxide content (6 - 8 %) have been utilized. For the "white" one a wide range of illite-kaolinite or pure kaolinite clays with lower then 1.5 % content of iron are used (Konta 1982; Polák 1972).

Among complementary materials which are used together with the types of clays mentioned, for improving the structural composition of mixtures or adding more fluxes and lowering the temperature of firing pure quartz sands, limestones, feldspars or MnO_2 have been employed. Also waste glass or feldspathic, feldspathoidic rocks may be used (Urban & Wallat 1991; Konta 1982).

Ordinary clays used in the Keramo-Praha cooperative for manufacturing traditional Bohemian ceramics, jars, beer mugs, flower pots, cups, spice sets and plates come from localities Ledce-Žilov, Lhota u Dobřan and Kačírov (red ceramics), and from Nová Ves-Vonšov, Jehnědno, Kyšice, Tvršice, Kopanina, Brník, Vyšehořovice. Also some dressed kaolins from Sedlec, Kadaň or Horní Bříza are used as additives.

Chemical and mineralogical composition

Chemical analyses of clays and complementary raw materials have been collected from various reports, research projects or catalogues published by suppliers of raw materials and they are shown on Tabs. 1 - 3. For depicting the variability of these analyses, the ternary diagram by Fabbri & Fiori (1985) taking into account practically the whole chemical analysis has been applied.

Table 1a: Average chemical composition of clays for manufacture of the "red" stoneware and ceramics.

Locality	Ledce-Žilov	Lhota u Dobřan	Kačírov
No.anal.	25	18	2
	$\bar{x}$	$\bar{x}$	$\bar{x}$
SiO_2	59.34	56.22	59.08
TiO_2	1.12	1.25	0.75
Al_2O_3	19.42	20.44	21.13
Fe_2O_3	8.78	8.82	7.63
FeO	0.27	0.35	–
MgO	1.14	1.26	0.93
CaO	0.35	0.35	0.13
Na_2O	0.17	0.26	0.15
K_2O	2.96	2.60	4.35
L.i.	5.73	7.98	6.12

Table 1b: Recalculation of chemical analyses into "normative" minerals by the method of Avidon (1976), Šrámek (1982) and basic technological characteristics.

Locality	Ledce-Žilov	Lhota u Dobřan	Kačírov
kaolinite	22.6%	27.3%	20.0%
illite/musc.	27.6%	25.4%	32.3%
quartz	28.0%	24.5%	22.3%
K-feldsp+plgs	9.1%	9.9%	16.2%
other miner.	12.7%	12.9%	9.2%
Total	100.0%	100.0%	100.0%
temp. of sint. °C	1180-1250	over1180	1200
temp. of f. def.	"	1200	1250
shrink. by f. %	8.8	–	–
t. shrink. %	11.2-13.2	–	12-15

Table 2a: The chemical composition of selected clays used for the production of "white" stoneware and ceramics.

Locality	Kyšice			Tvršice		Kopanina	Brník
Label	Kyb.	Kyf.	Kyš.	Tvr.	Stc.	Kop.	Wspec.
SiO_2	59.15	68.90	69.31	54.2	68.3	61.26	41.61
TiO_2	1.25	1.37	1.42	1.7	1.5	1.08	1.54
Al_2O_3	25.07	19.39	19.23	27.0	18.0	23.12	36.80
Fe_2O_3	1.33	1.15	1.18	2.7	2.1	2.22	1.35
MgO	0.48	0.39	0.36	1.2	1.0	0.47	0.20
CaO	0.42	0.35	0.34	1.1	0.8	0.29	0.17
Na_2O	0.06	0.10	0.08	0.1	0.1	0.12	0.10
K_2O	1.16	1.12	1.12	1.5	1.2	0.76	0.56
L.i.	10.19	6.44	6.25	10.5	7.0	9.88	17.67

Table 2b: Contents of normative minerals in selected clays for "white" stoneware and ceramics.

Locality	Kyšice			Tvršice		Kopanina	Brník
Minerals	Kyb.	Kyf.	Kyš.	Tvr.	Stc.	Kop.	Wspec.
kaolinite	54.4	39.3	38.4	40.9	34.0	52.5	83.5
ill./musc.	9.7	10.2	10.1	16.6	12.9	7.6	5.0
quartz	27.0	43.0	43.8	32.0	43.7	32.3	0.0
K-felds+plgs	4.0	4.2	4.0	6.0	4.2	3.3	2.8
other miner.	4.9	3.3	3.7	5.4	5.2	4.3	9.7
Total	100.0	100.0	100.0	99.9	100.0	100.0	100.0
temp. of sint. °C	1260	1260	1260	1170	1130	–	–
temp. of f. def. °C	1580	1580	1580	1540	1500	–	1700
shrink. by f. %	12.4	7.8	7.4	10.0	4.3	–	10.3
t. shrink. %	22.6	13.6	12.2	21.1	14.6	–	14.7

Table 3: The chemical composition of complementary raw materials used for the modification of ceramic mixtures.

	1	2	3	4	5
	nepheline phonolite	waste glass	feldspar	quartz sand	quartz sand
Loc.	Železnický vrch	Karlovy Vary	Poběžovice	Střeleč	Provodín
SiO_2	57.90	75.0	74.01	98.10	98.74
TiO_2	0.15	–	0.16	0.10	0.048
Al_2O_3	19.80	–	14.35	0.85	0.61
Fe_2O_3	2.14	–	0.14	0.11	0.084
MgO	0.12	–	0.28	0.06	0.01
CaO	0.65	6.0	0.62	0.03	0.02
Na_2O	8.60	8.0	3.62	0.03	tr.
K_2O	6.90	10.0	5.93	0.06	tr.
L.i.	3.44	–	0.28	0.34	0.18

1 - The catalogue of the ceramic works Most; 2 - oral inform. from the "Moser" glass works; 3 - Obst (1987 - according to normative mineral calculation the composition is: K-feldspar 35.0 %, plagioclase 31.9 %, quartz 27.8 %, kaolinite 3.5 % and other minerals 1.7 %); 4 - Procházka (1984) anal. No. 69; 5 - Procházka & Čtyroký (1968 in Kužvart 1977).

Abbreviations:

1 - L.i. - loss of ignition;
2 - temp. of sint. - temperature of sintering °C;
3 - temp. of f. def. - temperature of fire deformation °C;
4 - shrink. by f. % - shrinkage by fire %;
5 - total shrink. - total shrinkage %;
plgs - plagioclase.

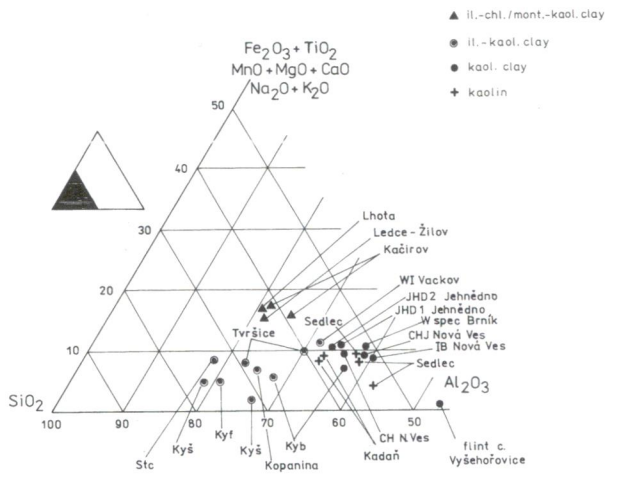

Fig. 1. Composition fields of clays and dressed kaolin used for the manufacture of traditional Bohemian stoneware ceramics projected in the ternary diagrams SiO_2-Al_2O_3-other oxids.

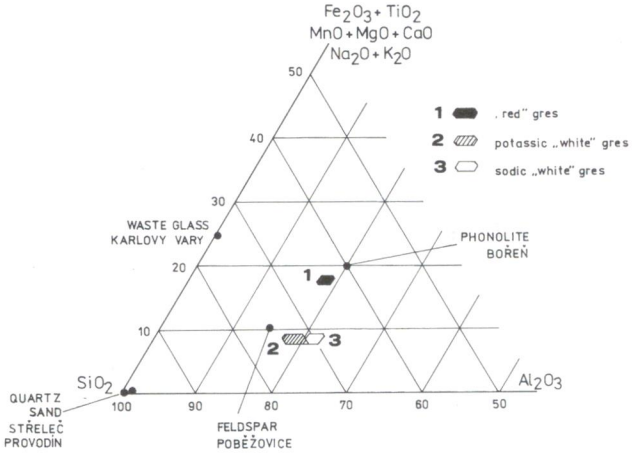

Fig. 2. Compositional fields of the "red" (1) and "white" (2, 3) gres and experimental points of complementary raw materials.

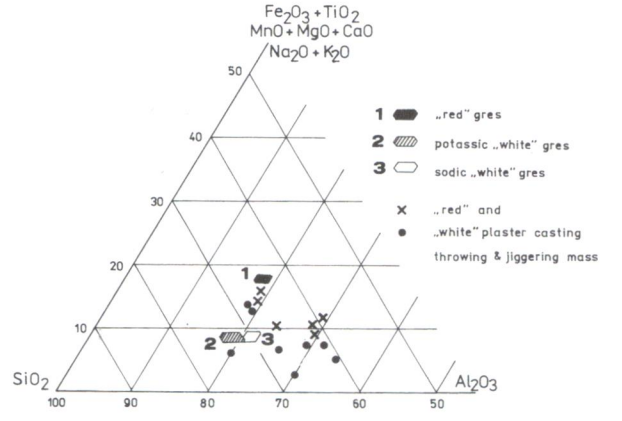

Fig. 3. Compositional field for the "red" (1) "white" potassic (2) or sodic (3) gres and masses used for manufacture ceramics in the Keramo-Praha cooperative

From Figs. 1 and 2 we can clearly see the compositional variability of clays and complementary materials used in the Keramo-Praha cooperative.

Quantitative data on the mineral composition of clays studied are almost missing and if contents of clayey materials, quartz or feldspars are given, they have been fixed by the method of "rational" analysis, which is tedious and clumsy. Thus a method of recalculation of chemical analyses into normative minerals has been applied (Avidon 1976; Šrámek 1982, 1983) and its further extention in the field of ceramics can be recommended.

Checking and theoretic formulation of bodies for stoneware and ceramics

There is not any universal or theoretic formula for the best or optimal mixture of ceramic body. Pospíšil & Kollert et al. (1984) have mentioned only the composition of material for fine ceramic which should approximate to 50 - 55 % of clayey matter, 20 - 25 % of quartz and the same content of feldspar.

At present the "white" or "red" stoneware bodies have been formed mainly "intuitively" as a mixture of four - six clays and kaolins with one or two "fluxes" by the method of "trial and error" not taking into account either technological parameters of firing furnaces nor the basic parameters of the clays used. This is demonstrated in the high shrinkage during drying and firing or in high porosity and water absorption as well as in low mechanical parameters of the body which advocate the necessity of prolonged or repeated firing and glazing. This also for led to higher costs of the final product.

To check and improve the mineral and structural composition of pastes and masses used in Keramo-Praha, results from studies by Fabbri & Fiori (1985) showing industrially produced "red" and "white" gres tiles have been adopted. In accordance with these results the "white" gres field is divided into "potassic white gres" and "sodic white gres" based on the predominance of the one or the other of the two alkali feldspars used as fluxes.

From Fig. 3 it can be clearly seen that only one or two of the fifteen plaster casting and throwing-jiggering masses used in Keramo-Praha workshops are near these fields of appropriate composition. Most of the used masses show an insufficient amount of silica and/or fluxes which can be easily improved either by adding quartz sand, waste glass or feldspars. Usage of dressed kaolins or pure refractory kaolinite clays in mixes is manifested in the shifting of experimental points of masses to the right hand corner of the diagram.

Conclusions

Bearing in mind that the uppermost temperature for any given furnace is only 1150 - 1160 °C, the base for the preparation of "red" or "white" vitrified stoneware body could be served only by illite - chlorite/montmorillonite - kaolinite or illite - kaolinite clays with a higher content of iron. For the "red" stoneware or ceramics these are clays from Ledce-Žilov, Lhota u Dobřan and Kačírov which might be eventually modified by adding e.g., MnO_2, Fe_2O_3 or nepheline phonolite from Želenický vrch hill.

For "white" stoneware, these are clays from the localities of Kyšice, Kopanina and Tvršice. The most suitable clays not needing any improvement of structural or mineral composition seems to be those from Tvršice labelled as Stc used in the past for the manufacture of sewage pipes. The content of these normative minerals represents the most suitable composition for the mass production of "white" stoneware and ceramics.

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