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SOCIALIST ETHIOPIA

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ASSISTANCE TO EELPA IN CERAMIC TECHNOLOGY

POLYTECHNA
PRAGUE

RESEARCH INSTITUTE
FOR CERAMICS, PILSEN

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1. ABSTRACT

The results of the chemical analyses and mineralogical analyses of the fifteen Ethiopian raw materials samples completed by technological tests orientated on the possibility of beneficiation are given. There were distinguished raw materials of extraordinary quality and raw materials for less demanding ceramic applications. Further research of possibility of the selected raw materials beneficiation is recommended according to the conclusions of consultation with Ethiopian experts.

2. TABLE OF CONTENTS

3. INTRODUCTION

To the Research Institute of Ceramics / RIC /, Pilsen,division Karlovy Vary,the fifteen samples of non-metallic raw materials were delivered in double chests from Ethiopia,weighting 270 kg altogether.

The samples were identificated /at the attendance of the experts from Ethiopian Electric Light and Power Authority,Addis Ababa/,inserted into the central evidence of RIC laboratories and analysed in chemical and mineralogical way.

The summary of the samples,their identification and delivered quantity is put down in Table 1. Among the samples the raw materials acceptable for the production of electrically warmed heating plates were chosen,dressed and passed to Keramo Co-operative,Prague,to further pilot tests.

This work is introductory study defining quality and usability of the submitted samples of Ethiopian raw materials.The consultation with Ethiopian experts ought to be realised during the successive stage,in which would be decided to which raw materials to give more attention and would be solved technico-economical questions of their exploatation,beneficiation and the possibilities of their industrial applications in the harmony with the requirements of national economy.

4. FINDINGS AND RECOMMENDATIONS

The results of chemical and mineralogical analyses of the fifteen Ethiopian non-metallic raw material samples are introduced in this report. Reached experimental data are interpreted from the point of view of the possibility of beneficiation of evaluated raw materials and the usability of the upgraded products in more pretentious industrial applications.

4.01. The samples of limestone /1161.85/, quartz /1163.85/, feldspar /1166.85 and 1175.85/, diatomite /1170.85/ and talc /1173.85/ represent the high quality raw materials to the most demanding industrial applications. In the following stage it is necessary to verify the size of geological reserves of these raw materials, to state the conditions of their exploatation and to carry out the pilot tests of their beneficiation / first of all the tests of crushing and milling/, as well as the pilot production tests of their usability in concrete ceramic and other applications.

4.02. The samples of limestone /1162.85/, raw kaolins /1164.85, 1165.85, 1167.85 and 1168.85/, washed kaolin /1174.85/, quarzite /1169.85, clay /1171.85/ and sand /1172.85/ have a low quality and it is necessary to carry out further investigations of their beneficiation and upgrading to products for more demanding industrial applications.

4.03 The results of chemical and mineralogical analyses as wall as the results of orientation of beneficiation tests is possible to summarize to the following points:

4.03.1 From the evaluated samples of limestone/1161.85 Cup Factory, 1162.85 Glass Factory/ the sample 1161.85 is an exellent raw material with 87 % of calcite, 6.8 % of dolomite and only 0.1 % of the oxides of chromatogenous elements, usable in all ceramic applications, in the production of ceramic bodies and glazes.

4.03.2 The sample of quartz/1163.85 Kenticha/ is the raw material with 98.4 % of silicon dioxide and 0.1 % of chromatogenous contaminations; after crushing and milling it is applicable in the great number of ceramic and glass productions.

4.03.3 The two evaluated samples of feldspar/1166.85 Kenticha,1175.85 Hazare/ are of an excellent quality; the sample 1166.85 contains 99 % of feldspar components and only 0.1 % of titanium and ferric impurities; it is the raw material for the most demanding ceramic applications,and it is also usable in the production of glass and ceramic colours; the sample 1175.85 contains 78.3 % of feldspar components and 0.2 % of titanium and ferric contaminations; it is a high quality raw material for production of ceramic bodies and glazes.

4.03.4 There were evaluated four samples of the kaolin sands / raw kaolins / : 1164.85 Mucarsa,1165.85 Bombawoha, 1167.85 without giving the locality and 1168.85 Kibre Mengist with this results :

a/ from the sample 1164.85 was separated in laboratory only 14 % of washed kaolin /grain size fraction less than 20/um /,which contains 27 % Al_2O_3 and 2.2 % TiO_2 + Fe_2O_3; the product is low quality raw material for the production of coloured ceramics

b/ from the sample 1165.85 was classified 46.2 % of washed kaolin and it contains 34 % Al_2O_3 and 1.1 % TiO_2 + Fe_2O_3 ; the product of beneficiation has characteristics of the raw material for the production of white body fine utility ceramics and building ceramics

c/ from th sample 1167.85 was classified 18.3 % of washed kaolin with 31.4 % Al_2O_3 and 2.7 % TiO_2 + Fe_2O_3; this product of classifying has low quality and it is suitable only for the production of coloured building ceramics d/ from the sample 1168.85 was separated 21.3 % of washed kaolin with 30.2 % Al_2O_3 and 2.6 % TiO_2 + Fe_2O_3 ; this product is analogous to the preceding product and it isusable only in the production of coloured building ceramics

4.03.5 The sample of quarzite from the Kecha locality /1169.85/ contains 90 % of silicon dioxide and 2.7 % of oxides of chromatogenous elements; after crushing and milling this raw material would be suitable for applications as a grog in the production of all kinds of building ceramics.

4.03.6 The sample 1170.85 is diatomite /Adami Tulu / with almost 85 % of opal and with less than 3 % of clay alterations; it is exceptionally high quality raw material, suitable for production of lightware building material and heat insulations.

4.03.7 The sample 1171.85 is sandy clay, taken in Cup Factory; it contains only 17 % of kaolinite and 8 % of schist silicates, but 12.7 % of the oxides of chromatogenous elements; it has low plasticity and brown-red colour after firing; it is applicable in the production of coloured building ceramics / floor tiles, stoneware pipes /.

4.03.8 The sample 1172.85 is fine quartz sand, taken in Glass Factory; it contains 94 % SiO_2 and 0.3 % Fe_2O_3; by classifying the glass fraction /from 0.1 to 1.0 mm / with the yield 76 % and by effective attrition the content of SiO_2 increases to 97 % and the content of Fe_2O_3 subsides to 0.09 %; the beneficiated product is usable only for the production of bottle glass .

4.03.9 The sample 1173.85 is talc from the Shakiso locality; it contains 95 % of talc and it is a high-quality raw material for various applications / production of steatite ceramics for electrotechnics,production of refractory cordierite bodies etc./.

4.03.10 The sample 1174.85 is washed kaolin,produced in Ethiopia from the raw material Mucarsa; it contains 29.8 % Al_2O_3, 1.08 % TiO_2 and 1.23 % Fe_2O_3 ; it has mean bending strength,unsuitable rheological properties,low plasticity and being coloured after firing; it is usable in the production of coloured utility ceramics and building ceramics.

4.04. The samples of quartz /1163.85/,feldspar/1166.85/, talc/1173.85/ and washed kaolin/1174.85/ were selected from the collection of Ethiopian raw materials to the production of heating plates.These raw materials were dressed and sent to Keramo-Co-operative,Prague,for pilot tests.The possibility of production of heating plates was proved by means of definite technology,as it is described in Annex No.2 of this report.

4.05 With regard to reached results it is possible for further research of evaluated collection of Ethiopian non-metallic raw materials to recommended :

4.05.1 To consult with Ethiopian experts the results of this report and to solve the technico-economic questions of mining and beneficiation of chosen raw materials.

4.05.2 From the collection of evaluated non-metallic raw material samples to devote more attention to :

a/ technology of dry dressing /crushing and milling/of quartz /Kenticha/ and feldspars/Kenticha,Hazare/;

b/ the optimalization of the technology of classifying and of the higher steps of upgrading of raw kaolin Bombawoha type;

c/ the veryfying of the filtration and adsorption properties of diatomite earth/Adami Tulu/ ;

d/ sand from the Glass Factory, the possibility of its beneficiation to the product for more demanding glass production /sheet glass/;

e/ optimalization of classifying and the higher steps of upgrading of the Mucarsa kaolin type.

4.05.3 By detailed beneficiation and technological tests to verify the applicability of evaluated starting raw materials and upgraded products at industrial applications in accordance with demands of Ethiopian side.

5. EVALUATION OF ETHIOPIAN RAW MATERIALS

5.1. Methods

The samples of delivered raw materials were at first evaluated in a macroscopic way/ contingently in a microscopic way and by further simple methods/ from the point of view of mineral composition and petrological structure. Further there were analysed chemically by the methods of classical wet analysis/ by gravimetric,titrimetric and photometric methods/,combined with the method of absorption spectrophotometry/AAS 403,Perkin-Elmer,USA/.Mineralogical analyses were executed by the X-ray method and by the thermal methods.To the X-ray analyses the X-ray goniometer /HZG 4 B,Zeiss,GDR/ was used with Cu radiation,Ni filter and the shift of an arm 1^{o}.Thermal analyses,i.e.differential and gravimetric thermal analyses,were realized by means of derivatographic method/Q-1500 D,MOM,Hungary/ from the 400 mg of weighed samples and the heating rate $10^{o}C.min^{-1}$.To the verification of the minerallcomposition of some samples also the method of infra-red spectroscopy/Specord 75,Zeiss, GDR/ was used; there were written down and evaluated spectrums of samples preparated by pressing with potassium bromide.

Chosen samples were also evaluated technologically. The grain size distribution of more coarse fractions were ascertained by sieve analyses,more fine fractions by sedimentometric method / Sedigraph 5000,Micromeritics,USA /. The temperatures of the characteristic data of the samples were determined by high-microscopic method / II-A-P,Leitz, West Germany /.

The samples of raw kaolins and sands were / of orientation / evaluated in laboratory from the point of view of the possibility of their beneficiation / according to the procedures of Czechoslovak state standards / .

5.2. Results

5.2.01 <u>Limestone</u> from Cup Factory / the sample 1161.85/

5.2.01.1 Results of tests

The analysed sample is sericite-sandy calcite, which is not usable, with respect to increased contaminations, in more demanding industrial applications. Its composition and texture corresponds to the applications in the production of white body building ceramics / wall tiles, floor tiles /.

5.2.01.2 Laboratory investigation

This sample was declared as kaolinite sand / Cup Fyctory / but by mineralogical-petrological analysis it was determined that it is limestone. It is white-gray, very fine grained rock, with dilapidates to silty crushed material.

The chemical composition is given in Table 2. The sample contains the high concentration of calcium oxide, relatively high quantity of silicon dioxide, increased amount of aluminium oxide and oxides of chromatogenous elements / 0.26 % TiO_2 and 0.89 % Fe_2O_3 /, low concentration of magnesium oxide and negligible quantity of sodium oxide.

On the X-ray pattern of the sample are very intensive reflections of calcite / except d=0.303 nm the whole reflection spectrum / and the intensive reflections of quartz / largely d=0.426 nm and d=0.334 / ; in the sphere of lower angles 2Θ at d=1.0 nm there is the reflection of micaceous mineral, whose asymmetry testifies to significant degradation / to the deficit of K_2O and the detriment of H_2O /, consequently about the presence of illite.

The curve of differential thermal analysis contains shallow endothermal deviation with a peak at

115°C , corresponding to the release of molecular water from micaceous mineral, the diffusive endothermal deviation at 560°C , illustrating the release of structural water from micaceous mineral and the big endothermal deviation of the dissociation of calcite at 870°C.

The curve of gravimetric thermal analysis contains, in harmony with the preceding curve, dehydrating, dehydroxylating and dissociation steps, which coincidate each other.

On the basis of carried out analyses it is possible to determinate approximate mineral composition of this sample / Table 3. /.

5.2.02 Limestone from Glass Factory /the sample 1162.85 /

5.2.02.1 Results of tests

This sample is crystalline limestone with a low contamination and after mechanical dressing / crushing and milling / it is usable in all ceramic applications, in the production of ceramic bodies and glazes.

5.2.02.2 Laboratory investigation

The sample was denominated as a dolomite, taken in Glass Factory. Chemically and mineralogically it was proved, that the sample largely contains calcite and only quite reduced quantity of dolomite. The rock has light gray, partially green colour, it is coarse crystalline, compact. It is created from rhombohedral crystals with glassy lustre.

The results of chemical analysis are given in Table 2. The sample contains the high concentration of calcium oxide and the increase concentration of magnesium oxide as well as of silicon dioxide; the content of other oxides is exceptionally low; the oxides of chromatogenous elements are only 0.07 %.

The X-ray pattern of the sample is very simple, it contains the complete spectrum of calcite / with dominating reflection d=0.303 nm and with prominent reflections at d=0.250 nm, d=0.228 nm and d=0.209 nm / and diffusive reflections at d=0.289 nm /dolomite/ and d=1.0 nm /micaceous mineral/.

On the curve of differential thermal analysis is very intensive asymmetric endothermal deviation with a peak at 895 ^{o}C, corresponding to the dissociation of calcite.On the curve of gravimetric thermal analysis is only one dissociation step / at a temperature range from 785 to 905 ^{o}C / in which the loss of the mass of sample is 43.1 %.

Approximate mineral composition of the sample 1162.85 is listed in Table 3.

5.2.03 Quartz from Kenticha / the sample 1163.85 /

5.2.03.1 Results of tests

The sample is very pure vein quartz,which is, after crushing and milling,possible to use in the great number of ceramic and glass applications.With respect to superficial contaminations it is possible to presume, that by simple washing of crushed material a raw material for more demanding industrial applications would be disposal.The sample was chosen together with other raw materials for pilot production tests in the Co-operation Keramo, Prague, where it was sent after crushing below 1 cm.

5.2.03.2 Laboratory investigation

The sample is denominated as quartz from Kenticha locality.It is represented by milk-white turbid rock. On the fractures of massive fragments it is possible to find sporadic contaminations of oxides and hydroxides ferric pigments.

The results of chemical analysis is given in Table 2.The raw material has a high concentration of silicon dioxide / 99.1 % /,mildly increased content of aluminium oxide / 0.6 % / and a very low quantity of other oxides ; it is significant that there are only 0.07 % of oxides of chromatogenous elements / TiO_2 + Fe_2O_3 /.

By mineralogical analyses / X-ray and thermal methods / it is possible to prove only quartz in the sample. By microscopic way it was in the fractures of fragments of the sample determinated the pigmentation by ferric hydroxides of the geothite type in a mixture with clay alterations.

It is possible tocompute the theoretical mineral composition of the sample / Table 3. / according to reached analytical data.

5.2.04. Sand from Mucarsa / the sample 1164.85 /

5.2.04.1 Results of tests

The evaluated sample contains a very low quantity of clay fractions / below 20 μm /, which has not parameters of washed kaolinfor more demanding industrial applications.This raw material is not possible to recommend for exploitation and beneficiation to the standard washed ceramic kaolin.It will be effective to verify Mucarsa deposit area with the aim to gain the raw material richer in washing and with higher chemical purity.

5.2.04.2 Laboratory investigation

The sample was denominated as raw kaolin from Mucarsa locality.It is light grey,fine grained sedimentary rock.It has low step of strain hardness,easily dilapidates. It contains the quartz grains of clastic origin, which bear the characters of longer transport, and clay fraction, which cements the grains of sand and silt.From the petrological point of view the sample is sand quite sandstone.

The result of chemical analysis of this sample is shown in Table 2.The sample contains predominant silicon dioxide / about 93 % /, the low concentration of aluminium oxides / less than 4.5 % / as well as of oxides of chromatogenous elements / 0.29 % TiO_2 and 0.38 % Fe_2O_3 / and quite negligible content of the alkaline earth metals and oxides of alkaline metals.

On the X-ray pattern of the sample quite predominante reflections of quartz ; except the most intensive lines d=0.426 nm and d=0.334 nm the complete reflections spectrum of this mineral is present.There are the shallow reflections of the clay mineral of kaolinite type / at d=0.715 nm and d=0.358 nm / and of fully degradated dioctahedric mica contingently of interstratification of illite-montmorillonite / to the lower angles 2 Θ asymmetric reflection at d=1.0 nm /.Except mentioned minerals there were not found any other crystalline phases in the sample.

The curves of thermal analyses have low value of identification.On the curve of differential thermal analysis is the endothermal deviation of the modification transformation quartz at the temperature 573 ^{o}C, and at temperatures 110 ^{o}C and 550 ^{o}C are shallowly indicated endothermal deviations corresponding to the dehydration of schist-silicates present in the sample.The curve of gravimetric thermal analysis contains the only inexpressive step,which illustrates the reduction of the mass of the sample about 2 %.

From the results of chemical, X-ray and thermal analyses it is possible to determine approximate mineral composition of this sample / Table 3. /.

The results of laboratory classifying on the limit 20 μm , i.e. to washed kaolin, correspondens to the above date :

above	63 μm	/ sand /	67.6 %
20 -	63 μm	/ silt /	18.3 %
below	20 μm	/ clay /	14.1 %

By classifying it is possible to gain only less than 15 % of clay fraction ; the raw material is very low grade in washing.Contaminations / 1.04 % TiO_2 and 1.17 % Fe_2O_3 / along with fine quartz and schist silicates pass to clay fraction.The quality of this clay fraction / 27 % Al_2O_3 / is from the ceramic point of view very low.

5.2.05. <u>Raw kaolin</u> from Bombawoha / the sample 1165.85/

5.2.05.1. Results of tests

The raw material,represented by the sample 1165.85 /Bombawoha/ it is possible to beneficate to the clay product for the great number of ceramic industrial applications /utility ceramics,white body building ceramics/. It is possible to recommend the execution of the pilot test of classifying,detailed evaluation of the beneficiated products and the tests of practical applications.

5.2.05.2 Laboratory investigation

The sample is white,sporadicly slightly rose, fine grained,soft,cohesioless rock with an increased fraction of clay material.It contains differently large grains of quartz and sporadic little leaves of light mica.From the petrological point of view it is kaolinitically alterated aplite.

The chemical analysis of the sample is given in Table 2.The sample contains the increased concentration of silicon dioxide /65 % /,aluminium oxide/23.5 %/and potassium oxide/1.6 %/; the relatively low quatity of the oxides of chromatogenous elements/0.1 % TiO_2 and 0.6 % Fe_2O_3/and negligible quatity of oxides of alkaline earth metals and sodium oxide.

The X-ray pattern of the sample 1165.85 contains from the reflections of non-clay minerals very intensive reflections of quartz /d=0.426 nm, d=0.334 nm and further/, and meanly intensive reflections of feldspar /d=0.324 nm/, gibbsite /d=0.482 nm/ and sericite /d=1.0 nm/.From clay minerals there were identificated only kaolinite according to the reflections d=0.715 nm, d=0.448 nm and d=0.358 nm.

On the curve of differential thermal analysis there is a shallow deviation at 105 ^{o}c/kaolinite dehydration/, inexpressive endothermal deviation at 295 ^{o}C/dehydroxylation of gibbsite/, more intensive endothermal deviation at 565 ^{o}C

/dehydroxylation of kaolinite/ and diffusive exothermal deviation at 970 °C / formation of a new phases from the products of dehydroxylation of kaolinite/.

Endothermal reactions coincidate each other and therefore there is essentially one step of the loss of the mass on the curve of gravimetric thermal analysis /around 9.1 % / with inexpressive changes of line slope at ranges of temperatures about 150 °C, 300 °C and 550 °C.

The approximate mineral composition of this sample is listed in Table 3.

At the further it was executed the laboratory washing by removal of sandy fraction by sieving and by sedimentation on the limit 20 μm :

above 63 μm	/ sand /	36.4 %
20 - 63 μm	/ silt /	17.4 %
below 20 μm	/ clay /	46.2 %

The sample is consequently rich in washing. The clay fraction /washed kaolin/ contains 34.37 % of aluminium oxide, 0.12 % of titanium dioxide and 0.97 % of ferric oxide.From the mineralogical point of view 66.5 % of kaolinite,the higher amount of gibbsite /11.2 %/, the lower quantity of micaceous mineral /6.5 %/ and only 1.1 % of oxides of chromatogenous elements passed to washed kaolin.

5.2.06. <u>Feldspar</u> from Kenticha /the sample 1166.85 /

5.2.06.1. Results of tests

The sample represents extra-ordinary high-quality raw material for the most demanding ceramic applications, at first for the production of glazes and ceramic colours.The sample /after crushing/ was passed to Keramo Co-operation,Prague,to the pilot production tests.

5.2.06.2 Laboratory investigation

The sample was denominated as white feldspar from Kenticha locality.It is light gray,compact,block feldspar without symptoms of alteration.There were not found more frequent contaminating additions in the fragments ; there are only sporadic flakes of light mica and rusty brown smudges along fissure cracks.

The chemical analysis of the feldspar is given in Table 2.The sample contains the high quantity of alkaline oxides/ 2.2 % Na_2O and 13.5 % K_2O / and quite negligible amount of other oxides.Titanium dioxide was not found by used analytic method,and the ferric oxide is present in the sample only 0.04 %.

On the X-ray pattern predominate the reflections of feldspars.The most intensive reflections are of the potassium feldspar of microcline type,subordinately the reflections of calcium-sodium plagioklase of andesine type are present;reflections of quartz are not developed and reflections of micaceous mineral are problematic /convex course of the reading background at lower angles 2 θ /.With regard to the composition of the sample/the absence of alteration products /the sample was not evaluated by thermal analysis.

The normative mineral composition computed from the results of chemical and mineralogical analysis is listed in Table 3.

The sample is very pure feldspar practically without contaminations.By means of high-temperature microscopic analysis the temperatures of characteristic data were determined.The end of sintering /the sample begining to soft/ is in1230 ^{o}C and the starting point of melting is at the temperature 1360^{o}C; it accords with the relative abundance of potassium and calcium-sodium components / 4 : 2 /.

5.2.07. Raw kaolin from unknown locality /the sample 1167.85 /

5.2.07.1 Results of tests

The results of classifying is not satisfactory: the yield of washing on the limit 20 μm is only meanly rich and obtained washed kaolin has low qua-lity for upgrading of a product for more demanding ceramic applications. It would be necessary to use the higher steps of beneficiation /for example the high intensity magnetic separation/. At the raw material of this type it is necessary to solve technico-economical conditions of mining and upgrading, as well as the possibility of the practical utilization of gained products.

5.2.07.2 Laboratory investigation

The sample was declared as raw kaolin. It is white gray, fine grained, dilapidating, kaolinitically alterated rock. In the macroscopic way it is possible to distiquish the considerable quantity of fine quartz and micaceous mineral in the sample. From the petrological point of view it is silty-clayey sand.

The results of chemical analysis is given in Table 2. The sample contains the significant quantity of aluminium oxide /nearly 19 % / and potassium oxide /nearly 3 %/, relatively low content of the oxides of chromatogenous elements /0.12 % TiO_2 and 0.90 % Fe_2O_3 / and negligible content of other oxides.

On the X-ray pattern of the sample prevail the reflections of quartz /d=0.426 nm, d=0.334 nm and all the other lines of reflaction spectrum/; there are significant reflections of micaceous mineral of sericite type/d=0.324 nm /. From the reflections of clay minerals there are developed low intensive reflections of kaolinite/d=0.715 nm, d=0.448 nm and d=0.358 nm/ and diffusive lines of interstratification of illite-montmorillonite /d=1.2 nm /with the prevalence of montmorillonite component.

The curve of differential thermal analysis contains inexpressive endothermal deviations of dehydration /at 110 °C/ and of dehydroxylation /at 570 °C / and diffusive exothermal deviation of the crystallization of new phases /at 980 ^{o}C/.There are two steps of the loss of the sample mass,the dehydrating / from 20 to 240 ^{o}C / and the dehydroxylating/from 410 to 790 ^{o}C/ on the curve of gravimetric thermal analysis ; at first the loss of the mass is 2.3 % , at second 4.0 % .

The mineral composition computed from the results of chemical and mineralogical analysis is listed in Table 3.

5.2.08. Raw kaolin from Kibre Mengist locality/the sample 1168.85/

5.2.08.1. Results of tests

The results of classifying is satisfactory; the yield of washing on the limit 20 μm is 21.3 %, and this product /washed kaolin/ contains 30.2 % of aluminium oxide but increased quantity of oxides of chromatogenous elements /0.93 % TiO_2 and 1.70 % Fe_2O_3/. Likewise in the preceding case also this product of classifying has the parameters of the raw material for less demanding ceramic application /for the production of colored building ceramics/.It is necessary to curry out further tests/ to optimalize of the beneficiation /and after consultation with Ethiopian side to consider the serviceability of beneficiation and application of the raw material,represented by this sample.

5.2.08.2. Laboratory investigation

At the delivery,the sample was denominated as the kaolinite raw material from the Kibre Mengist locality. The raw material is strongly alterated,dilapidating and it is probably different,mean-grained petrological type of raw material,represented by the preceding sample.

The chemical composition of the sample is listed in the Table 2.The increased contents of aluminium oxide and higher concentration of potassium oxide and oxides of chromatogenous elements, in harmony with the chemism of the sample 1167.85 are characteristic for this sample. Also the results of mineralogical / i.e. X-ray and thermal / analyses are analogous to the preceding sample.The approximative mineral composition is listed in the Table 3.

5.2.09. Sandstone from Kecha /the sample 1169.85 /

5.2.09.1. Results of tests

With regard to the low contents of contaminations it is possible to use the raw material of the sample 1169.85 type after crushing and milling as a grog for the production of the building ceramics of all types.It is not suitable for the production of the glass melting sands.

5.2.09.2. Laboratory investigation

The sample was denominated as sandstone from the Kecha locality.It is light gray,fine-grained,strongly consolidated.Except quartz it is possible to distinguish in it the feldspar.The quartz grains are cemented by siliceous cement.From the petrological point of view the sample 1169.85 is quartzite.

The results of chemical analyses of evaluated sample is listed in the Table 2.There are presented the high concentration of silicon dioxide / nearly 95 % / and increase quantity of aluminium oxide / above 2 % / and of potassium oxide / almost 1 % /; the concentration of the other oxides including the oxides of chromatogenous elements, is low.

On the X-ray pattern of the sample are practically only the reflections of quartz / the whole reflection spectrum / and of feldspar / little intensive reflection at d=0.324 nm /. The presence of clay alterations was not proved by X-ray method / the absence of reflection at lower angles 2 Θ /.The termal analyses of the sample were not executed with respect to the absence of thermally active components.

After the results of chemical and X-ray analyses it is possible to determine approximative mineral composition of evaluated sample, listed in Table 3.

5.2.10. Diatomite from Adami Tulu /the sample 1170.85 /

5.2.10.1. Results of tests

The sample is diatomite with high contents of utility components, opal / almost 85 % / which is only from little part recrystallized ; the contamination by clay fraction is enormously low.

The raw material has from the point of view of chemical composition, of the presence of mineral modes and of the structure an excellent parameters for application in production of ligh-ware building materials and heat insulating materials. With respect to microstructure / the presence of the increased quantity of the fragments of diatomaceous skeletons / it will be necessary by further practical tests to evaluate the raw material from the point of view of its usability for filter and adsorbing materials.

5.2.10.2. Laboratory investigation

The sample was denominated as a diatomite from Adami Tulu locality. The raw material is purely white, porous, very light, and it is not possible to find in it by a macroscopic way any contaminating foreign admixtures.

The results of chemical analyses is given in the Table 2. The sample contains the high per cent of silicon dioxide / 90 % /, the mildly increased contents of aluminium oxide/ less than 1.5 % / as well as the sodium oxide / about 1 % / and relatively low contents of the other oxides.

On the X-ray pattern there is the outstanding camber of reading background at the angle ranges from 5 to 10^{o} 2 Θ and from 20 to 25^{o} 2 Θ, characteristic of the presence of glass phase. There are the diffusive reflections of micaceous mineral of illite type / d=1.0 nm / and interstratification illite-montmorillonite / d=1.2 nm /, at a range of higher angles are few intensive,sharp reflections of quartz / d=0.334 nm / and of feldspar / d=0.324 nm /.

On the curve of differential thermal analysis there is in the range of low temperature shallow endothermal deviation of dehydroxylation of all components of the sample with a peak at 110 °C.Then the curve slips parallelly with the temperature axis.The curve of gravimetric thermal analysis is characteristic of one step of the mass loss : at lower temperatures, to 320 °C,the mass of the sample decreases significantly / by 4.8 % /and at higher temperatures,from 320 to 1000 °C,less significantly / by 1.7 % /.The losses of mass correspond to the spontaneous dehydration of amorphous phases of silicon dioxide at lower temperatures and to the remanent dehydration of this phase as well as to dehydroxylation of alterations at higher temperatures.Therefore the curve of gravimetric thermal analysis is not even at higher temperature parallel with a temperature axis.

By scanning electron microscopy there were found the anisometric tests of diatomaceous in the sample with very richly broken surface.Besides the whole tests and their fragments it is possible to find the little crystals of feldspar and agglomerates of very fine flakes of clay minerals.The inside and outside surface in the tests of diatomaceous,as well as of their fragments,are quite insignificantly contaminated by alterations.After reached experimental data it is possible to determine approximative mineral composition of the evaluated sample of diatomite, listed in Table 3.

5.2.11. Clay from Cup Factory / the sample 1171.85 /

5.2.11.1. Results of tests

The evaluated sample is a kaolinite clay with high contents of sand fractions / 28.4 % particles above 63 μm /.After mixing with water it forms plastic body,which is hard after drying, but it has texture failed by the number of cracks.After firing at oxidizing atmosphere to 1250 °C it is sintered and has brown-red colour.The raw material of this quality is suitable for the production of coloured building ceramics after firing /tiles,clay pipes etc./.

5.2.11.2. Laboratory investigation

The sample is denominated as a clay,taken in Cup Factory.It is brown gray,finely fragmental quite cloddy rock,with fraquent wholes different in colour and structure.

The results of chemical analysis is listed in the Table 2.The sample contains only little quantity of aluminium oxide / less than 7 % / and considerable concentration of the oxides of chromatogenous elements / 1.9 % TiO_2 and 10.8 % Fe_2O_3/ ; contents of calcium oxide / 1.9 % / and potassium oxide / 1 % / is mildly increased.

On the X-ray pattern of the sample are very intensive reflections of quartz / d=0.426 nm and d=0.334 nm /, meanly intensive reflections of calcite / d=0.303 nm / and few intensive reflections of clay minerals : kaolinite / d=0.715 and d=0.358 nm / and of interstratification illite-montmorillonite / d=1.2 nm /.

The curve of differential thermal analysis contains the wide and the shallow endothermal deviation of dehydration of schist-silicates / at 110 °C /, elongated and irregulary zoned exothermal deviation of oxidative processes / with a peak at 350 °C /,the shallow and inexpressive endothermal deviation of dehydroxylation of schist-silicates / at 555 °C / and diffusive exothermal deviation of crystallization of new phases at 935 °C.

On the basis of the results of analyses it is possible to determine only a rough approximation of the mineral composition of evaluated sample/ in Table 3 /.

5.2.12. Sand from Glass Factory / the sample 1172.85 /

5.2.12.1. Results of tests

The analysed sample is fine quartz sand which is not usable according to its chemical composition in more demanding industrial applications. A beneficiated product was obtained by classifying to the glass fraction and effective attrition ; this product is usable only in the production of bottle glass.

5.2.12.2. Laboratory investigation

The sample was denominated as sand from Glass Factory. It is very fine grained and has a yellow-white colour. The sand contains contaminations of oxide and hydroxide ferric pigment beside milk-white grains of quartz.

The results of chemical analysis of this sample are given in Table 2. The raw material contains 94.02 % of silicon dioxide only, and the increased amount of aluminium oxide / 3.16 % / and potassium oxide / 1.12 % /. The content of chromatogenous impurities is relative high / 0.24 % TiO_2 and 0.30 Fe_2O_3 /.

The grain size distribution of original sample is shown in Table 4. The yield of glass fraction, i.e. from 0.1 to 1.0 mm, is high - 76 %. This fraction was beneficiated by means of effective attrition. The content of silicon dioxide increases to 97 % and the content of ferric oxide decreases to 0.09 % .

Only quartz was determined by X-ray method in the sample ; except the most intensive reflections d=0.426 nm and d=0.334 nm the compute X-ray spectrum of this mineral is present.

The thermal analysis has low value to identification of mineral composition of this sample. The endothermal deviation of the modification transformation / 573 °C / is present on the curve of differential thermal analysis. The curve of gravimetric thermal analysis is practically parallel to temperature axis, only a low step illustrates the dehydration of clay alterations in the temperature area from 20 to 205 °C.

The theoretical mineral composition is possible to compute according to reached analytic data / Table 3 /.

5.2.13. <u>Talc</u> from Shakiso / the sample 1173.85 /

5.2.13.1. Results of tests

The sample represents a high quality raw material for most demanding ceramic applications.It is suitable for production of special steatite ceramics for electrotechnical industry,for the production of refractory materials on the basis of cordierite.The sample was after crushing passed / together with the other samples,given in Annex 2. / to Keramo Co-operative,Prague,to the pilot tests of the production of heating plates - mitad.

5.2.13.2. Laboratory investigation

The sample was denominated as a talc from the Shakiso locality.It is gray green,compact rock with outstanding parallel arrangement of fine flaky mineral components.

The results of the chemical analysis of the sample is given in Table 2.It contains outstanding quantity of magnesium oxide / nearly 34 % / and increased concentration of ferric oxide / 4.5 % / ; concentration of the other oxides is very low.

On the X-ray pattern of the sample the reflections of talc / d=0.935 nm, d=0.459 nm, d=0.312 nm etc./ prevail. Further there are developed the reflections of smektite / d=1.45 nm, d=0.708 nm, d=0.356 nm / ; on the X-ray pattern of the orientated and ethylene glycolated preparation of the sample the reflection d=1.45 nm does not expand,it stays in the primary position ; the only smektite of the sample is then the clay mineral of chlorite type.Further there was identificated the dolomite / d=0.289 nm /,but it is present only in low quantity.

On the curve of differential thermal analysis there is one deep asymmetrical endothermal deviation with a peak at 920 °C, which corresponds to the dehydroxylation of talc.The curve of gravimetric thermal analysis illustrates the leakage of hydroxyl water from the lattice of talc in the temperature range from 850 to 1000 °C / the loss of the mass is here 4.5 % /.

From the experimental data it is possible to determine approximative mineral composition of the evaluated sample,as listed in Table 3.

5.2.14. Washed kaolin from Mukarsa / the sample 1174.85 /

5.2.14.1. Results of tests

From the results of analyses and tests it is evident,that the sample of washed kaolin represents the raw material of worse quality for less demanding ceramic applications.It is usable in the production of coloured utility and building ceramics after firing.At the consultation with Ethiopian side it is necessary to decide,if it will be purposively to continue testing this raw material,especially in solving of optimalization of beneficiating process and application of the higher steps of upgrading with aim to gain the product for more demanding ceramic production.

5.2.14.2. Laboratory investigation

The sample was denominated as washed kaolin from Mukarsa locality.It was delivered in a large lumps.

In the Table 2 the result ofchemical analysis of this sample is given.It contains less than 30 % of aluminium oxide and mildly above 1 % of titanium dioxide as well as of ferric oxide.The concentration of the other oxides is very low.

By the X-ray method it is possible to identify in the sample the prevailing kaolinite / after reflections d=0.715 nm, d=0.448 nm and d=0.358 nm it is pseudomonoclinical kaolinite with the low degree of crystallinity / and a quartz considerably contained / after intensive reflections d=0.426 nm and d=0.334 nm /.In the range of lower angles 2 Θ any reflections of clay minerals are not present on a X-ray pattern ; only schist-silicate of the sample is then kaolinite.There are intensive,sharp reflections at d=0.570 nm, d=0.496 nm and d=0.298 nm,which appertain to alunite.Any other reflections were not identificated on the X-ray pattern of the sample.

The curve of differential thermal analysis bears out the results of X-ray analysis.There are endothermal deviations of dehydration of kaolinite / 105 ^{o}C /, of dehydroxylation of alunite and of kaolinite / from 560 to 590 ^{o}C/ and exothermal reaction of the formation of new phases / 975 ^{o}C / on her.The curve of gravimetric thermal analysis illustrates the dehydration and dehydroxylation reactions of kaolinite and alunite,which coincidate each other.It is essentially one degree of the loss of mass / by 12.4 % /.

After reached data it is possible to determine the directive mineral composition of the sample of washed kaolin,as listed in Table 3.

In a further the technological properties of the sample were searched into of orientation.The evaluated kaolin has a low bending strength after drying / 0.83 MPa/, it is uneasily flowable / the consequence of the presence of free SO_4^{2-} from alunite,it has standard changes in length by drying and firing and it has dark being colour after firing to 1250 and 1400 ^{o}C.

5.2.15. Feldspar from Hazare / the sample 1175.85 /

5.2.15.1. Results of tests

The sample consequently contains 78.3 % of feldspar.The temperatures of its characteristic data correspond to potassium feldspar raw material / the starting point of softening is at 1260 ^{o}C,the starting point of melting at 1380 °C /.The sample is the high-quality raw material,which would be after crushing and milling usable in the production of ceramic bodies and glazes.

5.2.15.2 Laboratory investigation

The sample was denominated as feldspar rose from Hazare locality.The rock is dark rose,fresh and compact.Besides the feldspar it is possible to differentiate the quartz by the macroscopic way,which forms the irregular little veins and graphitical intergrowths with feldspar. The light mica is present in quite secondary quantity.

The chemical analysis of this sample is put down in the Table 2.The sample contains high per cent of potassium oxide /10.7 %/,the increased per cent of sodium oxide / 1.8 % / as well as of aluminium oxide / 15 % /. The oxides of chromatogenous elements are present only in very low quantity / 0.08 % TiO_2 and 0.14 % Fe_2O_3/ as well as the oxides of alkaline earth metals.

By X-ray method it is possible to identify in the sample only feldspar and quartz.The thermal analyses of the sample were not performed with regard to the presence of only low quantity of alteration products.

The normative mineral composition of the sample is possible to compute from chemical analysis,as presented in Table 3.

6. FINAL NOTE

In the presented work the large collection of various samples of non-metallic raw materials from Ethiopia is evaluated.

There were not any documentations at disposal about the results of the evaluation of chosen raw materials by Ethiopian side.Then it was necessary to carry out basic chemical and mineralogical determinations and experimental data, completed by beneficiation and technologic tests of orientation, to interprete from the point of view of possibility of industrial application of evaluated raw materials.

Then in this sense,this report is the introductory study,which must be consult with Ethiopian experts in details and after conclusions of such a consultation the aim of further work ought to be fixed.

The main attention in principal should be given to the research of the possibility of beneficiation and application of designated raw material in industrial scale.

7. ANNEXES

Annex No.1
The Summary of Results in Tables

Annex No.2
Pilot tests of the Raw Materials from Ethiopia in Keramo Co-operative, Prague

Annex No.1

The Summary of Results in Tables

Table 1.

List of the samples of Ethiopian Raw Materials

Number	Raw Material	Locality	Weight in kg
1161.85	limestone	Cup Factory	0.5
1162.85	limestone	Glass Factory	1.5
1163.85	quartz	Kenticha	8.0
1164.85	sand	Mucarsa	60.0
1165.85	raw kaolin	Bombawoha	8.0
1166.85	feldspar	Kenticha	7.0
1167.85	raw kaolin	unknown locality	5.0
1168.85	raw kaolin	Kibre Mengist	12.0
1169.85	sandstone	Kecha	8.0
1170.85	diatomite	Adami Tulu	8.0
1171.85	clay	Cup Factory	7.0
1172.85	sand	Glass Factory	7.0
1173.85	talc	Shakiso	16.0
1174.85	washed kaolin	Mukarsa	10.0
1175.85	feldspar	Hazare	0.2

Table 2

Chemical analyses of the samples

in %	1161.85	1162.85	1163.85	1164.85	1165.85
L.O.I.	31.52	43.06	0.04	1.94	8.75
SiO_2	20.52	3.61	99.12	92.75	65.11
TiO_2	0.26	0.01	0.04	0.38	0.08
Al_2O_3	4.61	0.52	0.61	4.48	23.45
Fe_2O_3	0.89	0.06	0.03	0.29	0.59
MgO	0.74	1.49	0.02	0.03	0.09
CaO	39.96	51.03	0.05	0.05	0.21
Na_2O	0.08	0.04	0.04	0.03	0.08
K_2O	1.42	0.18	0.05	0.05	1.64

Table 3

Mineralogical composition of the sample

in %	1161.85	1162.85	1163.85	1164.85	1165.85
clay min.	-	-	1.1	11.3	35.8
mica min.	12.0	1.5	0.4	-	9.3
feldspar	-	-	-	-	4.9
alunite	-	-	-	-	-
gibbsite	-	-	-	-	7.1
calcite	71.3	87.4	-	-	-
dolomite	3.4	6.8	-	-	-
talc	-	-	-	-	-
opal	-	-	-	-	-
quartz	12.1	4.2	98.4	88.0	42.2
Ti,Fe ox.	1.2	0.1	0.1	0.7	0.7
raw material	lime stone	lime stone	quartz Kenticha	sand Mucarsa	raw kaolin Bombawoha

Table 2 - continuation 1

Chemical analyses of the samples

in %	1166.85	1167.85	1168.85	1169.85	1170.85
L.O.I.	0.43	5.28	6.84	1.47	4.59
SiO_2	66.12	71.70	70.62	94.41	90.41
TiO_2	-	0.12	0.11	0.38	0.14
Al_2O_3	17.50	18.81	19.12	2.12	1.42
Fe_2O_3	0.04	0.90	0.97	0.38	0.66
MgO	0.10	0.16	0.13	0.03	0.68
CaO	0.11	0.07	0.36	0.16	0.71
Na_2O	2.20	0.12	0.12	0.07	1.08
K_2O	13.50	2.84	1.73	0.98	0.31

Table 3 - continuation 1

Mineralogical composition of the sample

in %	1166.85	1167.85	1168.85	1169.85	1170.85
clay mineral	-	32.1	47.0	2.7	2.8
mica mineral	-	16.3	2.4	-	-
feldspar	99.0	5.0	3.4	5.8	4.5
alunite	-	-	-	-	-
gibbsite	-	-	-	-	-
calcite	-	-	-	-	-
dolomite	-	-	-	-	-
talc	-	-	-	-	-
opal	-	-	-	-	83.9
quartz	0.9	45.1	46.1	90.7	8.0
Ti,Fe oxides	0.1	1.0	1.1	0.8	0.8
raw material	feldspar Kenticha	raw kaolin unknown locality	raw kaolin Kibre Mengist	sand stone Kecha	diatomite Adami Tulu

Table 2 - continuation 2

Chemical analyses of the samples

in %	1171.85	1172.85	1173.85	1174.85	1175.85
L.O.I.	10.92	0.78	5.51	11.38	0.74
SiO_2	65.68	94.02	54.85	55.65	71.32
TiO_2	1.88	0.24	0.14	1.08	0.08
Al_2O_3	6.86	3.16	0.80	29.83	15.06
Fe_2O_3	10.81	0.30	4.53	1.23	0.14
MgO	0.75	0.09	33.50	0.20	0.10
CaO	1.90	0.23	0.55	0.33	0.07
Na_2O	0.23	0.06	0.04	0.07	1.76
K_2O	0.97	1.12	0.08	0.23	10.73

Table 3 - continuation 2

Mineralogical composition of the sample

in %	1171.85	1172.85	1173.85	1174.85	1175.85
clay mineral	25.6	4.4	2.9	73.6	1.4
mica mineral	-	-	-	-	-
feldspar	-	7.7	-	-	78.3
alunite	-	-	-	2.0	-
gibbsite	-	-	-	-	-
calcite	3.4	-	-	-	-
dolomite	-	-	1.8	-	-
talc	-	-	95.3	-	-
opal	-	-	-	-	-
quartz	58.3	87.4	-	22.1	20.1
Ti,Fe oxides	12.7	0.5	-	2.3	0.2
raw material	clay	sand	talc Shakiso	washed kaolin Mukarsa	feldspar Hazare

Table 4

Grain size distribution of the sample of sand

mm	1172.85 weigh in %
above 1.0	0.0
0.5 - 1.0	3.6
0.3 - 0.5	2.2
0.2 - 0.3	12.8
0.1 - 0.2	57.6
below 0.1	23.8

Annex No.2

Pilot tests of the raw materials from Ethiopia in KERAMO Co-operative - Prague

1. Selection of the raw materials

For the EELPA purposes the following raw materials were selected from the Ethiopian samples according to the cooperation with Research Institute for Ceramics,Pilsen.

Due to the chemical analyses the work was done with samples :

1163.85	quartz Kenticha
1166.85	feldspar Kenticha
1173.85	talc Shakiso
1174.85	washed kaolin Mukarsa

Calculated composition of ceramic stuff regarding the chemical analyses :

talc	55 %	
kaolin	30 %	+/
feldspar	10 %	
$CaCO_3$	5 %	

+/ using the " washed kaolin " from Mukarsa area containing 22.1 % of quartz

The raw material were obtained well crushed from Research Institute for Ceramics,Pilsen-Karlovy Vary Division.

Composition of raw materials were milled in drum-mill during 7 hours.

Proportion :	stuff composition	1
	water	1
	milling elements	1

After milling the stuff was dewatered using plaster moulds. The plastic material was enveloped by plastic cover during 24 hours and later one hand formed to the plaster mould specialy designed for the " m i t a d " production.

2. Forming

The work has started by the preparation of plaster model of " mitad ",forming mould devided into 2 pieces were taken out from the model as follow:

the future baking plate with bottom grooves for heating elements and support plate.The design of the forming mould was allready made for future technology of jiggering.

The available jigger at KERAMO Co-operative was too small for the diametre of 660 mm / plaster mould / and for the tests the hand-forming was used.

Plaster mould,the grooves and inside surface was covered with layer of micro-milled talc to eliminated fast drying and crackeling.

Plastic material of ceramic stuff was applicated into the mould,plasticity was very good,drying and de-watering in plaster mould over layer of talc without any problems.

Drying up to the residual moisture in normal work-shop condition without any air humidity control or regu-lation-during 3 days.

Also the testing bricklets were made from the same composition of the raw materials with results :

drying shrinkage	5 %
firing shrinkage	3 %
open porosity	2 %
el.insulation resistance	
tested with 500 V	50 kOhms min.
firing in electric kiln	1185 °C
colour	light-brown

Due to the wish of Ethiopian technicians four bricklets were tested with the glase to get the similar colour of surface as a standart ethiopian production :

/ 1/ red-clay from Kechene directly applicated over green ceramic body

/ 2 / red-clay from Kechene 50 % and 50 % of ceramic glase ZP 6448 /Czechoslovakia/ over green body

/ 3 / red-clay from Kechene 47.0 %,3 % of MnO_2 and 50 % of ceramic glase ZP 6448

/ 4 / red-clay from Kechene 50 % and 50 % of ZP 6448 over biscuit body / 900 °C /

3. Discussion of results

As it is shown above the pilot tests of the composition of ceramic raw materials of Ethiopian samples,are fully suitable for the production of heaters,including diameter of 600 mm for " m i t a đ ".

New design of "mitad" was followed with the new calculation of heating elements and new distribution round the heated plane.Electrical in-put was calculated on 1.8 kW / calculation of the heating elements and distribution of coliled wire tekes part of final report of the Ethiopian technicians /.

Special wish of Ethiopians with the glase application over ceramic body takes part of tests, but the "mitad" use, could be taken as periodicaly heated and recooled ceramic body.For the reason of crackeling was recommanded to colour directly the ceramic composition of raw materials with clay from Kechene or Legedadi area.The ceramic glase ZP 6448 was selected as a resistant glase of thermal-shock.Keramo Co-operative use the glase for production of baked moulds for different types of cakes.The long term experiance is very good and the glase is lead free.

sample / 1 /	disproportion in shrinkage of red-clay and ceramic body	... not suitable
sample / 2 /	good surface and colour	...... very good
sample / 3 /	good,but dark brown colour	.... good
sample / 4 /	similar to No/2/	...... very good

4. Conclusion

Ethiopian raw materials selected by Research Institute for Ceramics,Pilsen,are fully suitable for EELPA purposes - electricaly heated hot-plates.

All other use of raw materials is possible -excelent quality of feldspar and quartz / see the chemical analyses/. Good quality of kaolin,if there is good washing-plant at Mukarsa station,also production of table-ware is reasonable.

The final report of the Ethiopian technicians contains detailed information but for the reason of weight was impossible to take the mould and "mitad" model from Prague to Addis Ababa.Both plaster items are stored at Keramo Co-operative as a part of project SI/ETH/85/801 and any time are available for next use.