Photo 2　Trial making sample

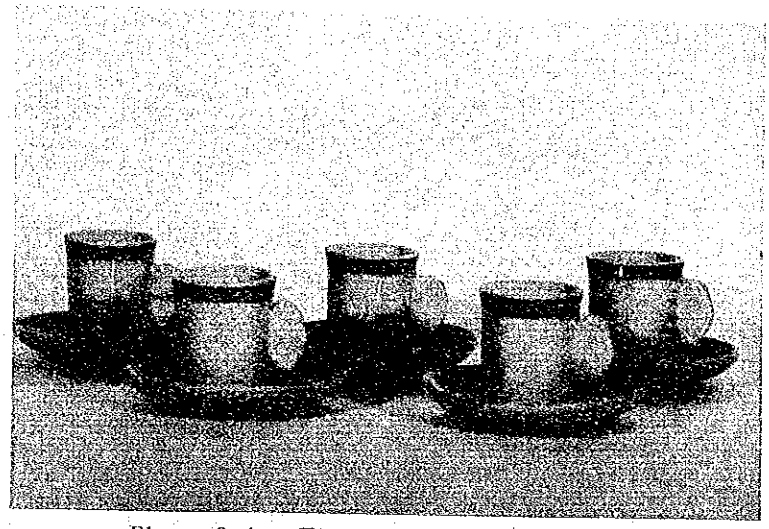

Photo 2-1　Trial making sample

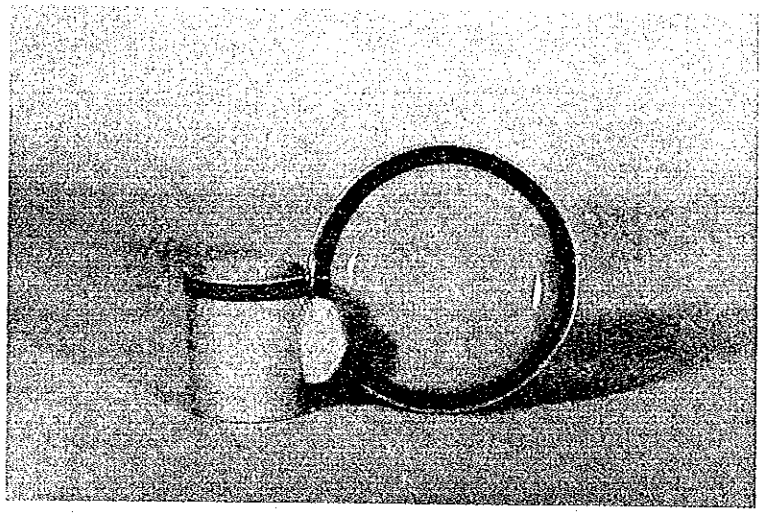

Photo 2-2　Trial making sample

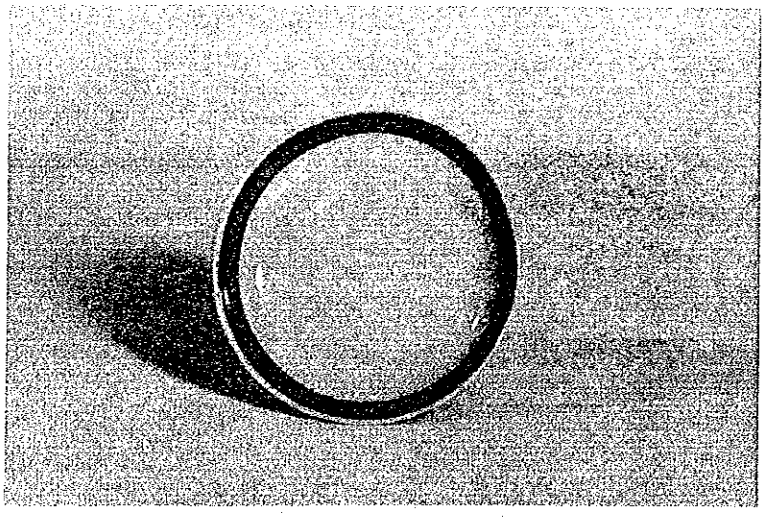

Photo 2-3　Trial making sample

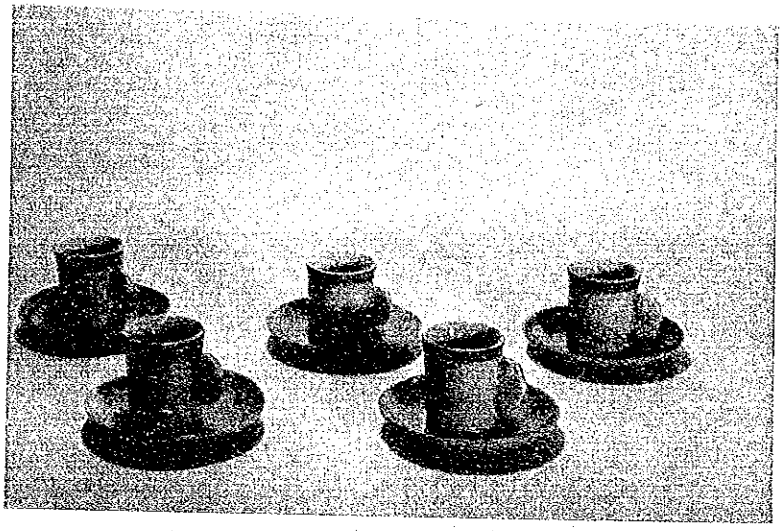

Photo 2-4 Trial making sample

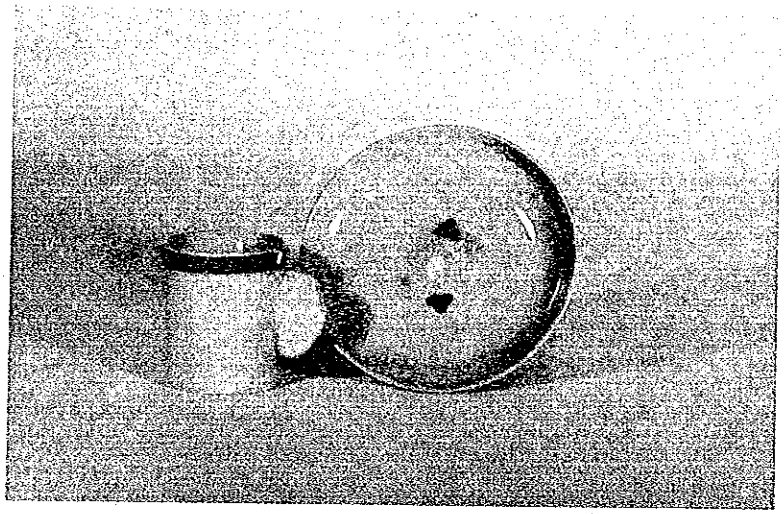

Photo 2-5 Trial making sample

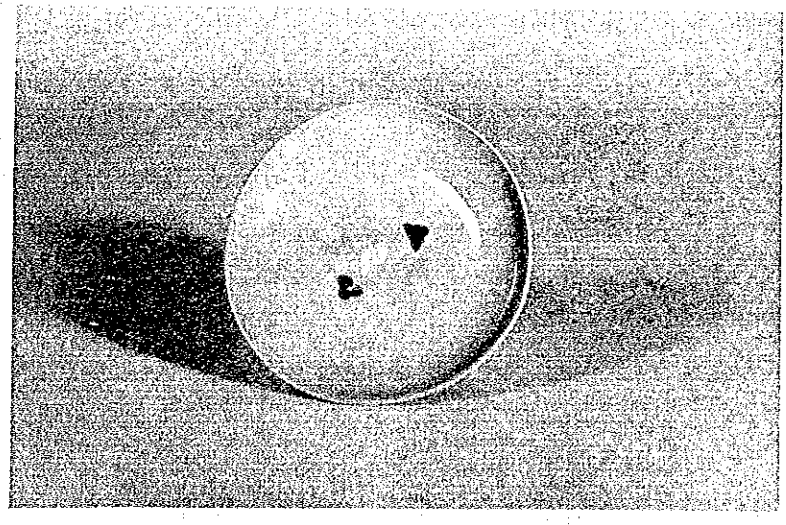

Photo 2-6 Trial making sample

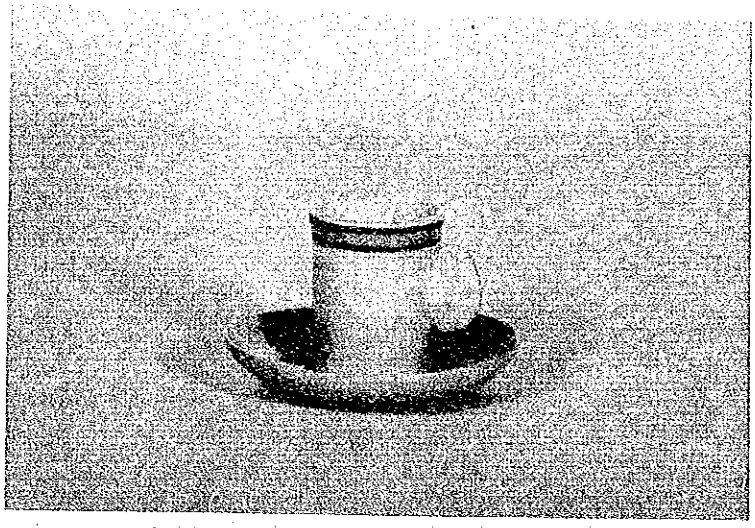

Photo 2-7 Trial making sample

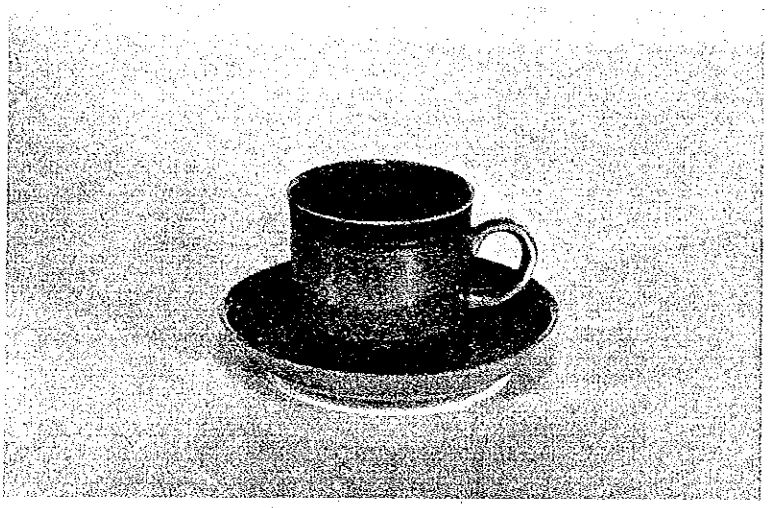

Photo 2-8 Trial making sample

Photo 2-9 Trial making sample

Photo 2-10 Trial making sample

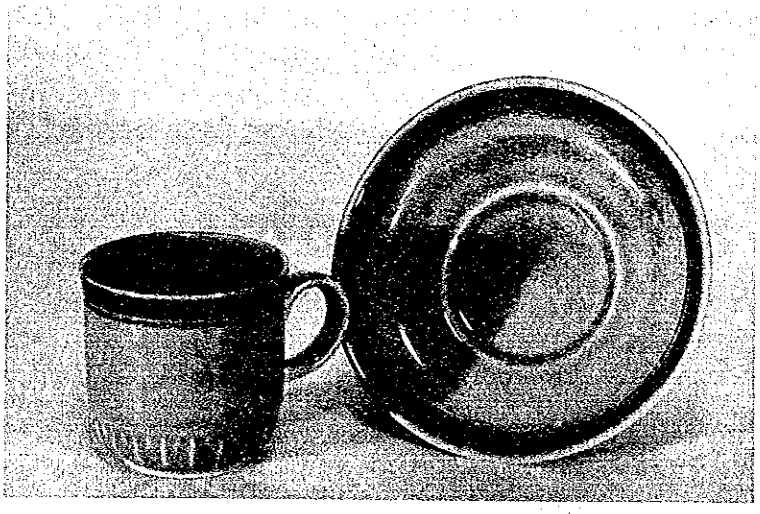

Photo 2-11 Trial making sample

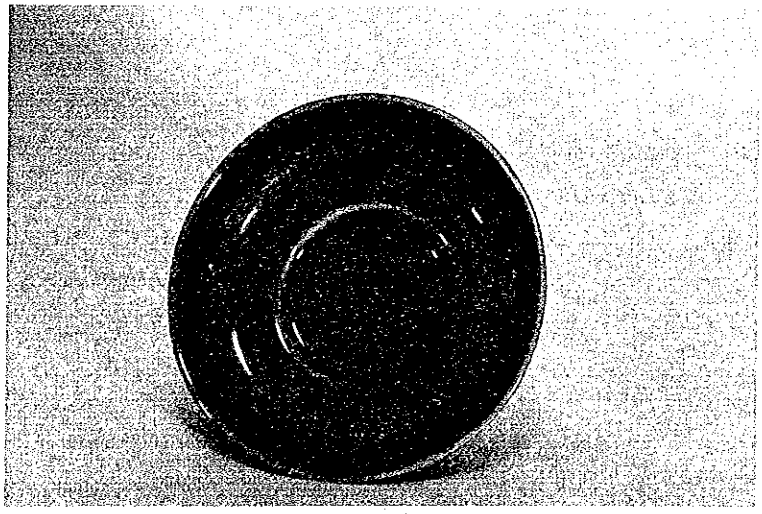

Photo 2-12 Trial making sample

5. Observations

(1) Results of Firing Test of Minerals

1) Feldspar and quartz proved to be of good qualities, containing extremely small amounts of impurities, and the best suited to be used as raw materials for making chinaware.
2) Clay showed many spots after reduction firing, and therefore, it is not good suited for porcelain or white earthenware to be manufactured by the reduction firing. As a result of the oxidation firing, however, it showed color without the spots, and therefore, it is possible to be used as the raw material for making coloured stoneware or semi-porcelain.
3) Kaolin showed good coloring performances in both reduction and oxidation firing processes, proving that it can be used both for white and coloured chinawares.
4) Magnesite was somewhat inferior in white-coloring performance, but it is considered possible to be used for making composite cordierite which is to be used for kiln furnitures like sagger and shelving slab.
5) Limestone (LK-3) is able to be used as ceramic raw material.
6) Limestone (H-5) is also able to be used as ceramic raw material.
7) Dolomite is not suitable for ceramic raw material because of colouring.
8) Corundum did not color white, but it can be used in place of alumina for making kiln furnitures.
9) Kyanite did not color white, but it is possible to be utilized in place of silimanite and andalusite for making refractories.
10) Weathered Clay could be considered possible to be utilized in place of felsite, but it is difficult to eliminate garnet content.
11) Gneiss might be considered possible to be utilized in place of felsite, but it is difficult to eliminate garnet content.
12) Gypsum: After firing, gypsum was added with water and underwent the hardening test, but it did not become Plaster of Paris and color was not white. And therefore, it cannot be used as the raw material of Plaster of Paris.
13) Graphite left many residuals and therefore cannot be used even as a refractory material.

(2) Results of Refractoriness Test

1) While Refractoriness of Tona clay is SK 31 and is somewhat lower than that of Japanese ball clay, it is not so inferior in apparent tint and is found to be homogeneous clay.
2) 'Little Tona' has higher refractoriness and is kaolinic clay.
3) Usangi clay's refractoriness is as low as SK 31, but its good-quality part has higher refractoriness, somewhat higher than that of Tona clay.
4) Pugu kaolin has refractoriness of SK 34, and this is equal to that of Grade 2 kaolin in Japan.
5) Considering the fact that the clay with refractoriness of SK 32 are usually employed for making stoneware, and observing the coloring performances (tints) by firing test and chemical compositions, Tona and Usangi clays are assumed to be utilized for making stoneware.

(3) Results of Grain Size Analysis

1) Tona clay is considered to be a coarse clay composed mainly of coarse grains over 500 microns. The grains smaller than 200 microns were felt non-plastic by finger tips.
2) Usangi clay has less coarse grains than Tona clay, and all the grains smaller than 200 microns were felt to be sticky by finger tips.
3) In elutriation of crude clay, recovery rate of Usangi clay seems to be higher than that of Tona clay.
4) The recovery rates of Usangi and Tona clays below 44 μ, which are 46 % and 31 %, respectively, are deemed to be similar to that of Gairome clay produced in Japan.

(4) Results of Chemical Analysis

1) Tona and Usangi clays have high contents of iron oxide and titanium oxide, therefore, these clays are not suitable for making procelain and white earthenware which require whiteness in colour.
2) Even after elutriation of Tona and Usangi clays the contents of iron oxide and titanium oxide were not reduced and coloring of white tint was not observed.
3) Pugu kaolin has less contents of iron oxide and titanium oxide, and total percentage of the two components is less than 1 %. And, since its coloring performance in firing process was fairly satisfactory, it can be used for making whiter stoneware.
4) Kihurio feldspar showed an analytical value similar to that of Indian feldspar. The impurities seems to be less and it is composed mainly of potassium feldspar with a small amount of soda feldspar. Therefore, it is suitable for making any sort of chinaware.

(5) Results of X-ray Diffraction

1) Pugu kaolin is composed of kaolin and quartz. While this is assumed to contain sericite and halloysite from its stickiness, it was unable to be confirmed from the result of this test.
2) Tona and Usangi clays are assumed to contain gibbsite ($Al_2O_3 \cdot 3H_2O$), which belongs to a category of alumina hydroxide mineral, in addition to kaolinite and quartz, and this is considered to be one of the factors which cause its refractoriness to become relatively high.
3) Corundum proved not to contain any impurity, and therefore, this mineral is able to be used in place of alumina.
4) Kyanite, which proved to contain no impurity, can be used as a high alumina raw material.
5) Magnesite proved to be free from impurities, and therefore, this mineral is able to be used as a raw material for making kiln furniture and composite cordierite.
6) Limestone (H-5) proved to be composed of limestone and a small quantity of dolomite, and it became white after firing, and therefore, this mineral can serve as ceramic raw material.
7) Limestone (LK-3), although this is composed of limestone and a small quantity of unknown mineral, proved to become white after firing and therefore can be used as ceramic raw material.

8) Dolomite powder proved to be composed of dolomite and unknown minerals, and since this mineral failed to become white when fired, it is not supposed to be used as ceramic raw material.
9) Gypsum is composed of gypsum and unknown minerals, and as this mineral is unable to color white by being fired, it is unable to be used as the raw material for Plaster of Paris.
10) Graphite is composed of graphite and unknown minerals. As many residuals were left after firing, this cannot be used as a raw material.

(6) **Results of Viscosity Test**

1) Usangi clay is considered to have plasticity. Further, as it is expected to increase the viscosity by elutriation, it should be able to be used as plastic clay.
2) Pugu kaolin proved not to be as plastic as Usangi clay, but it has enough plasticity as Kaolin and can be used as ceramic raw material.
3) Tona clay, because of its low plasticity, cannot be used as plastic raw material. And therefore, it may be necessary for this clay to be used by mixing with other plastic clays.

(7) **Observations of Raw Materials as a Whole**

By conducting a variety of tests on feldspar, clay and kaolin to be used as ceramic-making raw materials, the following matters were clarified:

1) Feldspar

This mineral is judged possible to be used as a raw material for body from its chemical composition, transparency after firing and distribution of impurities. Further, it may also be used as a raw material for glaze if selected carefully.

2) Clay

- o Both Usangi and Tona clays contain more than 3.0 % in total of Fe_2O_3 and TiO_2, and therefore, the firing resulted in not white but colors tint.
- o Both Usangi and Tona clays are composed mainly of kaolinite, and Usangi clay proved to contain halloysite, too.
- o Usangi clay proved to have plasticity.
- o Both Usangi and Tona clays proved to have refractoriness of SK 31, which is rather low.
- o Both Usangi and Tona clays had good contents of medium and fine grains of below 200 mesh. In order to obtain better plasticity, however, better elutriation to obtain finer particles than 44 μ (325 mesh) shall be conducted.

3) Pugu Kaolin

- o Refractoriness was SK 34, and the fired color was slightly light yellow.
- o Contents of Fe_2O_3 and TiO_2 were less than 1.0 % in total.
- o This was plastic as Kaolin.
- o The kaolin was composed of a high-crystallinity kaolinite.

It is assumed from these results that if a tableware is manufactured by using feldspar, clay and kaolin at an appropriate ratio, the product to be manufactured by maximum utilization of the aforementioned clay would be a colored stoneware. It may be possible to increase the whiteness of stoneware, by reducing the batch ratio of Tona clay and increasing that of

Pugu Kaolin. In order to produce the porcelain or semi-porcelain, the white-coloring clay such as elutriated Gairome clay or Kibushi clay shall be imported.

(8) **Results of Preliminary Trial Production Test**

The trial products were all small in size because the raw material samples available were very limited in quantities. Usangi and Tona clay, Tona clay in particular, are almost non-plastic clays, and therefore, these clays are considered possible to be utilized for forming of objects of limited sizes. In other words, it would be difficult for these clays to be used for making large-size bowl, soup dish (8 inches or more), and tea pot, etc., which are used in a hotel, without mixing with highly plastic clay to be imported from foreign countries.

(9) **Commercial Production Test**

1) Appearance :
The products were found to be free from waving and pinhole, gloss of glaze was excellent, and the body and glaze were well matched.

2) Distortion :
While a distortion was observed on a dish, this is considered to have been unavoidable, because the body was kneaded by hands as it was available in small quantity. In the actual manufacturing process on the production basis, however, the body is sufficiently kneaded by a vacuum pugg mill, and then shaped by a forming machine, and therefore, it is considered possible to prevent a product from such a distortion.

3) Hair cracks :
The hair cracks are caused by difference in thermal expansion rates between body and glaze. In this test, the crazing occurred both on cups and saucers. This is due to the fact that in preparation of the body, it was ground to a grain size equal to that of the body of stoneware being manufactured in Japan, and because of so coarsely ground grains, the free silica which are existing much more in Tanganian clays became abnormally expanded while being cooled in firing process. And therefore, it is considered possible to prevent occurrence of such a hair crack by grinding the body into finer grain size, and also by adjusting the glaze so as to make it match the body.

4) Glaze :
The trial products were made both by transparent glaze and opaque glaze. Though the transparent one looks more attractive than the opaque one according to the Japanese taste, the actual selection shall be made based on the taste of Tanzanian people.

5) Design :
The trial products were made by adopting simple lined pattern and flower-arranged pattern. The simple lined pattern with transparent glaze looks more attractive than the flower-arranged pattern.

6) Shrinkage Rate :
While shrinkage rate of the test bodies proved to be a little higher (approx. 2 %) than that of the body of Japan's stoneware, it should be possible to make adjustment by changing dimensions of the mold. It shall be noted, however, that the more the shrinkage, the more the chance of drying crack.

6. Summary

Surveys were made to search for ceramic raw materials in the areas centering the Kilimanjaro Region, Republic of Tanzania, and a series of basic tests were conducted by using samples collected in these areas.

As a result of a series of fundamental tests, items of products were selected based on the characteristics and properties of local raw materials. And preliminary trial production test and commercial production test were experimented on tablewares. As a result, it clarified that it is possible for these raw materials to be used for producing colored stoneware. Unfortunately, the hair cracks occurred on the cups and saucers. As for this hair crack problem, although the re-examination for seeking the preventing measures was unable to be conducted due to insufficiency of available raw materials, it would be possible to solve the problem by making appropriate adjustments on batching of raw materials, grain size of body and other manufacturing conditions at the time of the actual production in the future.

It shall also be noted that because of availability of the raw materials in a limited quantity the products for this test had to be made in small sizes such as coffee cups and saucers, and therefore, the trial products were successfully made by using Tanzanian raw materials only, but such problems as bending or distortion may occur when large-size dishes of 8″ in diameter or larger were manufactured by using only local raw materials. As for this foreseeable problem in the future, it may be possible to solve it by adding the improted raw materials.

Under the above circumstances, it is advisable to start with small-size products of tablewares in the beginning and try to make larger-size products on step-by-step basis. In case the large size products could not be made only by local raw materials, then the improted materials shall be added in proper ratio. Thus, it may be possible, to solve problems on manufacturing process and quality of the products.

7. Appendix

The equipments used for the tests on the raw materials and the trial production test are shown in Photos 3.1 thru 3.6.

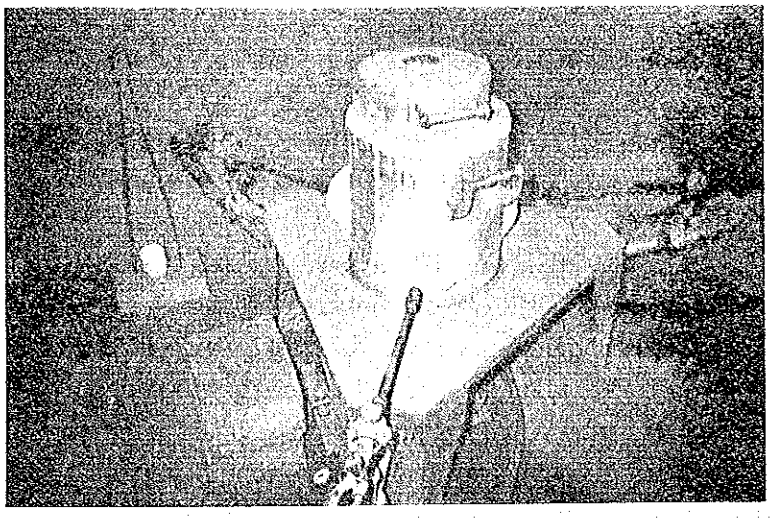

Photo 3-1 Refractoriness testing furnace

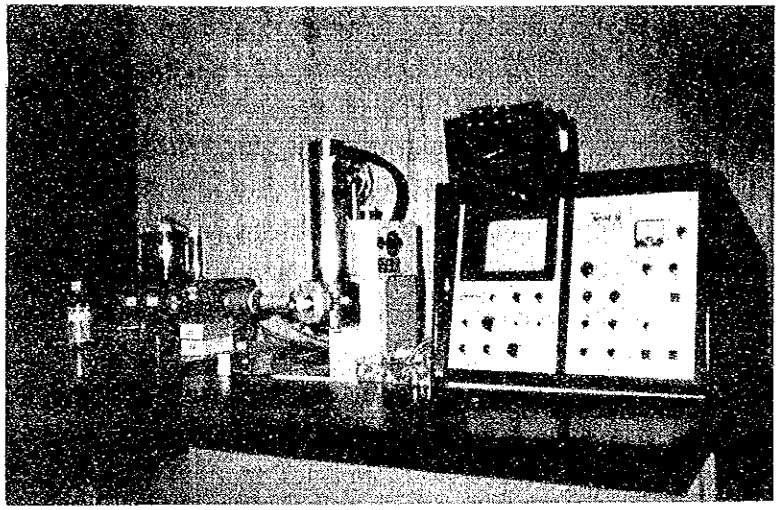

Photo 3-2 Electron microscope

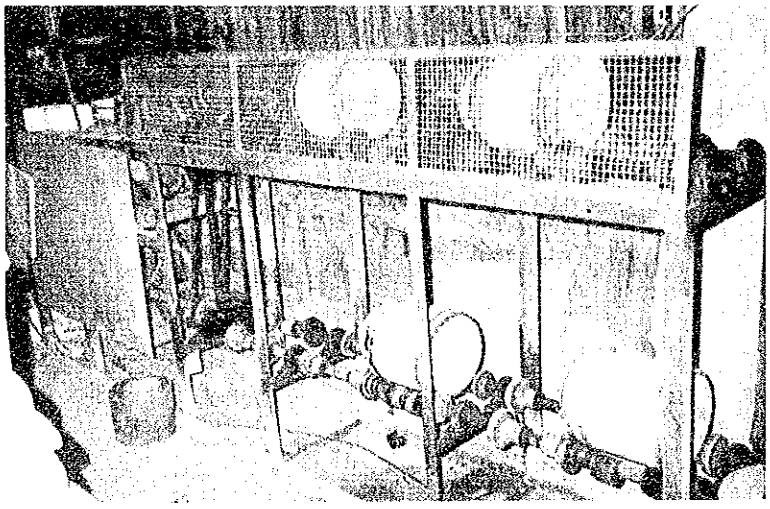

Photo 3-3 Pot mill

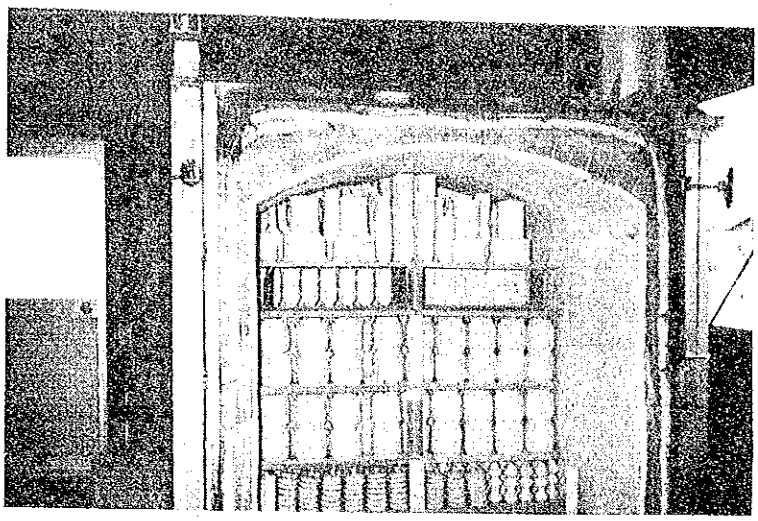

Photo 3-4 Biscuit kiln

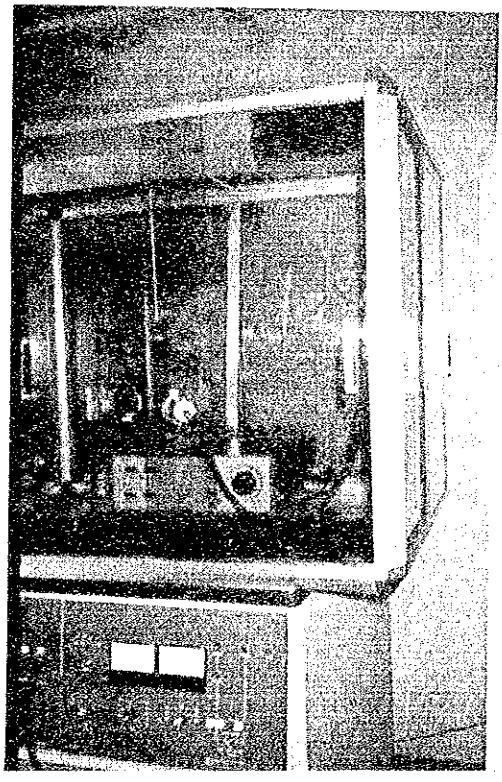

Photo 3-5 X-ray diffraction analyser

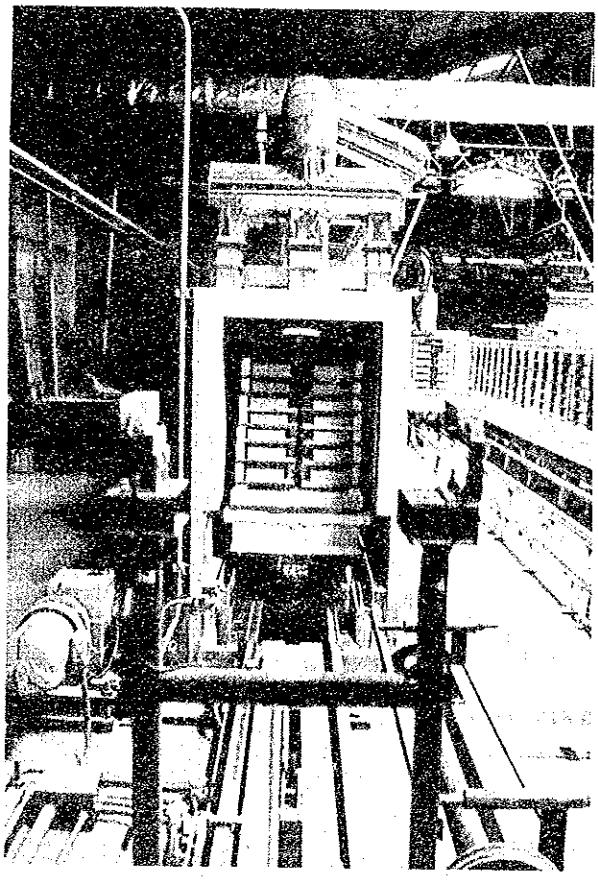

Photo 3-6 Glost kiln

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