SURVEY AND TEST REPORT
ON
CERAMIC RAW MATERIALS
IN CONNECTION WITH
KILIMANJARO INDUSTRIAL DEVELOPMENT CENTER
THE UNITED REPUBLIC OF TANZANIA

March 1984

Japan International Cooperation Agency
(J I C A)

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Preface

Japan International Cooperation Agency dispatched Dr. Mitsuyoshi Ueno and Mr. Shozo Adachi to Tanzania as short term experts for the survey of ceramic raw materials for two months from November 25, 1982 to January 25, 1983, with the objective of collecting data for planning the technical cooperation program in the ceramic field of the Kilimanjaro Industrial Development Center (KIDC).

The two experts carried out the geological survey and sampling of the ceramic raw materials centering on Same district in Kilimanjaro Region. Meanwhile, the surveys were also made in neighboring Arusha Region and suburban area of Dar-es-Salaam, the capital of this country. Further, the mineral specimens which were brought back to Japan by the experts were tested by an authorized testing laboratory for clarification of their utilization as the ceramic raw materials.

This report was prepared for the presentation of results of the field survey in Tanzania and the laboratory tests in Japan.

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Director,
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Fig. 1 Map of The United Republic of Tanzania

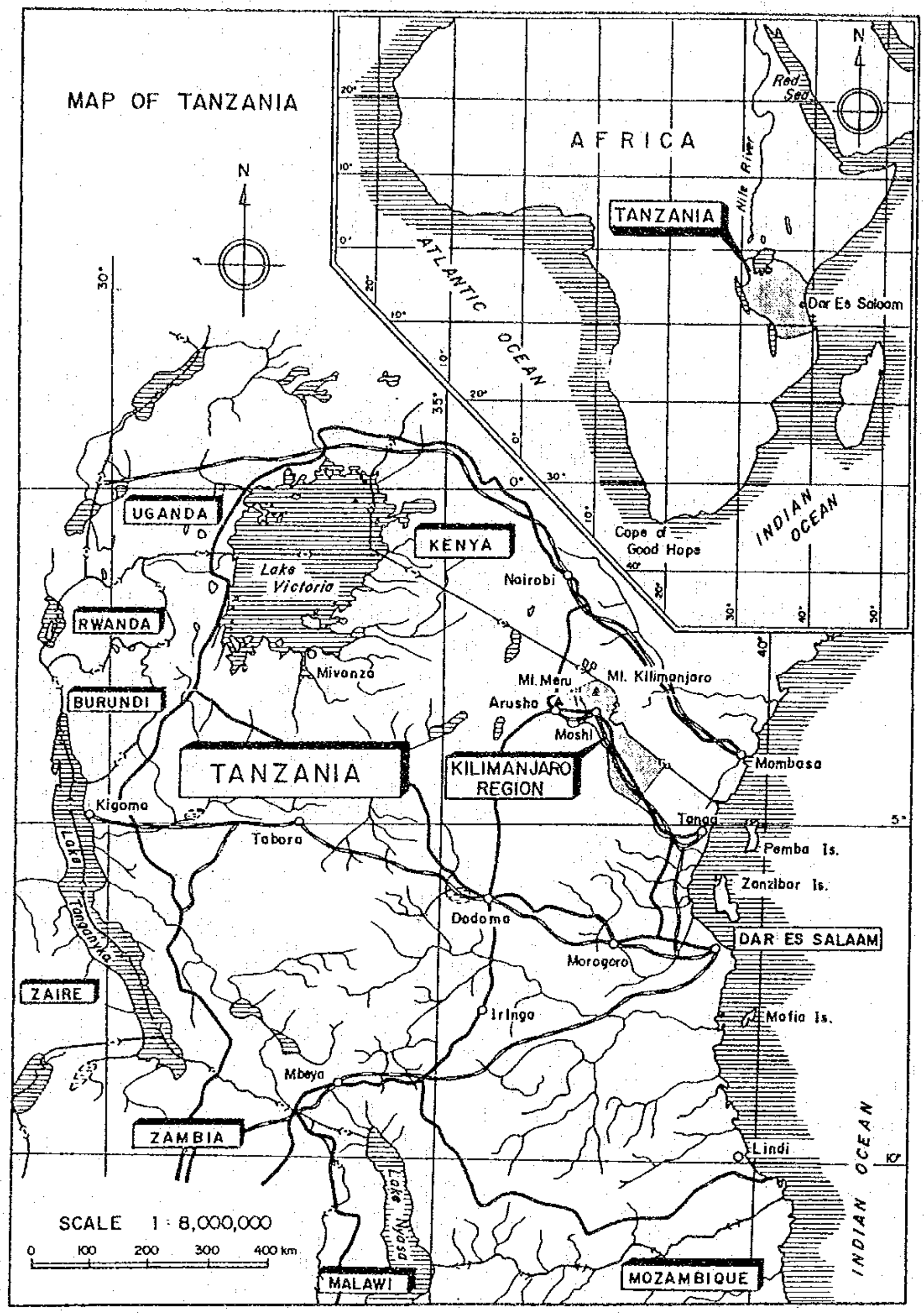
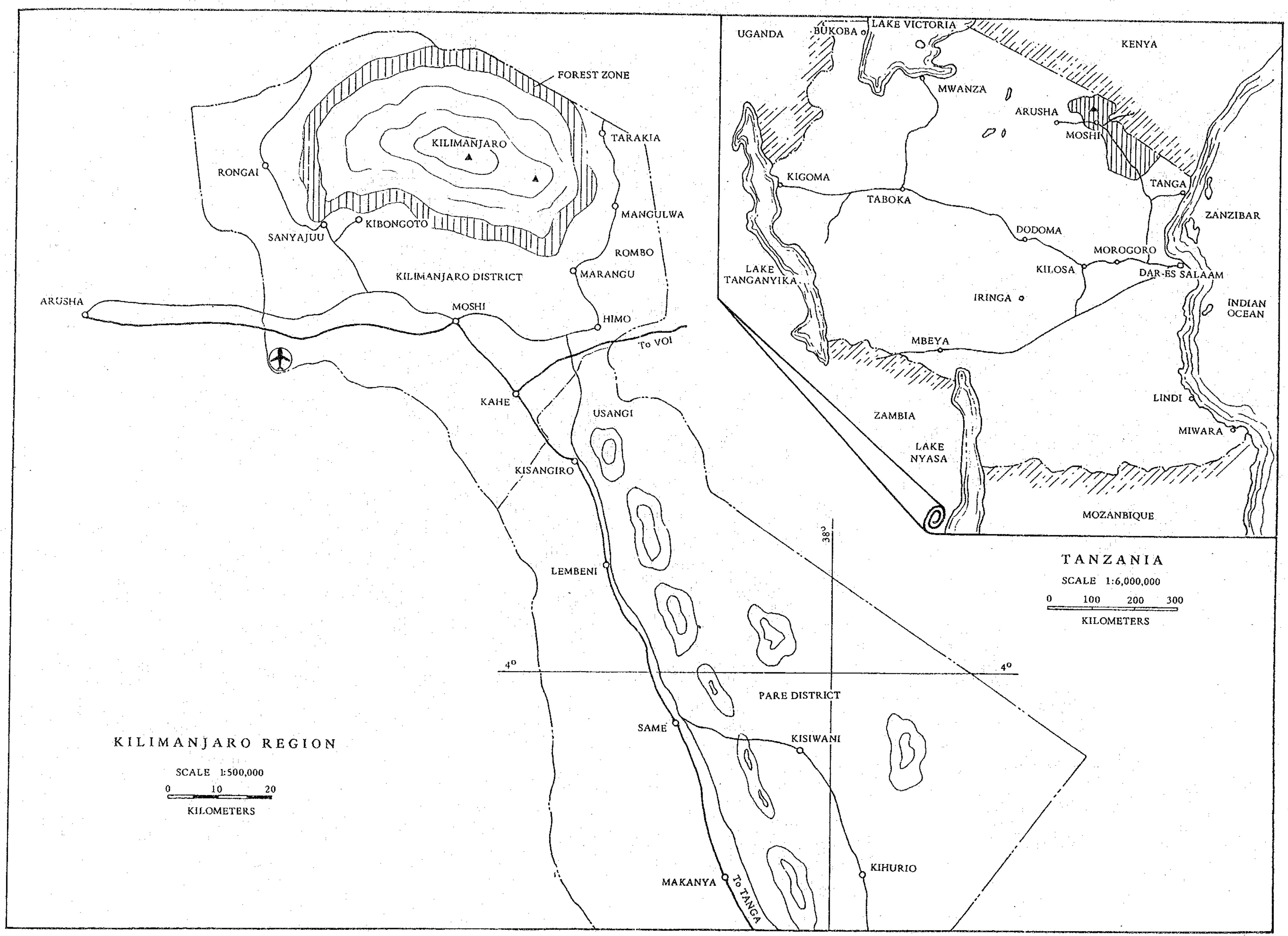


Fig. 2 Map of Kilimanjaro Region



Contents

List of Figure, Table, Chart and Photo

Part I.
Result of Field Survey in Tanzania

Introduction

With respect to the ceramic industry in Tanzania, there are no remarkable productions of chinaware and refractories, with exception of small quantities of cement and glassware. When it comes to a question of mineral resources of Tanzania, however, the Kilimanjaro Region is regarded as one of the regions abundant in deposits of non-metallic minerals such as pegmatite, gypsum, magnesite, etc.

While the ceramic department of the Kilimanjaro Industrial Development Center (KIDC) is producing redbricks, roofing tiles and clay pipes at the moment, the actual situation with respect to supply of raw material is still left unclarified. And therefore, this survey of ceramic raw materials in Kilimanjaro Region was designed to provide basic data for the ceramic industry for further development in the future by making good uses of these resources.

In order to achieve the objectives of this survey, Dr. Mitsuyoshi Ueno conducted the geological survey, particularly for investigating the features of various deposits, and estimating the reserves of the deposits. On the other hand, Mr. Shozo Adachi was engaged in checking the quality of raw materials in the field and also in conducting the trial production test by using the samples collected.

The dispatched period was 2 months, from November 25, 1982 to January 25, 1983, including number of days for travelling to and fro between Japan and Tanzania. During this period, the surveys were made on as many deposits as practically possible. However, having had to spend many days particularly for locating and scrutinizing good-quality Kaolinic clay and the difficulties of conducting surveys under poor road conditions and in steep hills, the survey team was restrained from conducting detailed studies of all kinds of the deposits. And yet, it was lucky for the survey team to have been able to carry out during the survey period a series of studies not only of the main raw materials but also of the subsidiary materials and other industrial raw materials such as magnesite, gypsum, dolomite, etc.

In view of the fact that there were only few literatures and reports concerning the mineral resources in these regions and the locally available information were somewhat inaccurate, the utmost appreciations are herein expressed by the survey team, to all who are concerned of KIDC and also to the officials of Tanzania who extended positive cooperation and support to the team.

1. Geographical Environment of Kilimanjaro Region

Tanzania is situated in East Africa and facing the Indian Ocean. It borders on Kenya and Uganda in the north, Zaire and Zambia in the west and Mozambique and Malawi in the south. The total area of this country is approximately 939,703 square kilometers and the population is about 15 millions. Kilimanjaro Region, one of the 17 administrative Regions, is extending 230 kilometers from northwest to southeast, with Kilimanjaro Volcano, the highest mountain in Africa (the highest altitude of Kibo Peak is 5,895 meters) in the North, and Pare-Usambara Mountain system in the South-East. Extending on the west of this mountain system is Masai Steppe with heights ranging from 650 meters to 850 meters above sea level. A part of this steppe is a dry land being nearly desert. Numerous rivers flowing radially from the Kilimanjaro accelerate weathering of volcanic rocks. And, as fertile soil is sedimented in a thick layer at the foot of the mountain being 1,000 – 2,000 meters in altitude, this area has a high density of agricultural population.

While most of these rivers in this region peter out after running into the plains, Ruvu (Pangani) River and Kikuletwa River gather water from the upper streams and keep flowing even in the dry season. The both rivers join together at a point, approximately 38 kilometers south of Moshi City, forming a large artificial lake called 'Nyumba Ya Nungu' extending about 6 kilometers from north to south.

The water system from the dam discharge, that is to become Panganior River, turns around and flows southward in the neighborhood of Mkomazi at the southern tip of South Pare mountain system forming the largest water system in this region. The rainfall in this region seems to be in proportion to the scale of the mountains, and the annual rainfal in the mountainous area over 1,600 meters above sea level, with a radius of about 25 kilometers centering the Kilimanjaro, is said to be more than 2,000 millimeters. Because of sufficient water supplies in the areas between Gonja and Khurio at the foot of the mountain on the east side of South Pare mountain system, rice field farming is operated by taking advantage of the irrigation system. The waterways on the west side of Pare mountain system are short in general, and many flows in the precipitous ravines peter out in the debris deposits at the foot of the mountain. (Refer to Figures 1, 2, 3 and 4.)

2. General Geology

The surveys were conducted in an area extending over about 150 kilometers from east to west and stretching about 200 kilometers from south to north including the districts having District Development Directors, such as Moshi, Same, Mwanga, Mkomazi, Sanya, Mkuu, etc. Topography and geology of this area are roughly classified into volcanic zone, pre-Cambrian metamorphic rocks zone and plain zone. The pre-Cambrian metamorphic rocks widely spread under the topsoil in Masai Steppe, and the surface is covered by sandy deposits of weathered volcanic rocks or metamorphic rocks to a thickness ranging from 1.5 meters to 3 meters. The area having topsoil composed of alkaline lava and debris is particularly suitable for farming.

(1) **Pre-Cambrian Metamorphic Rocks**

The pre-Cambrian metamorphic rocks in this district are composed of a variety of gneiss and crystalline schist which were metamorphosed from sedimentary rocks and volcanic rocks. And these deposits belong to the metamorphic-rock zone located in the southern part of the shield land on the northeast side of the African Continent. The distribution of this metamorphic rocks is based on the sediments in the Great Syncline which extends from Masai Steppe to Lake Victoria, Kenya and Mozambique. And, in Tanzania, the metamorphic rocks in the western district is called 'Nyanza System' and those in the eastern district is referred to as 'Usagaran System Rocks'. Many of these rocks are accompanied by pegmatite deposits.

The pre-Cambrian metamorphic rocks are accumulated beds of gneiss, crystalline schist, quartzite, etc. And limestone bed and dolomitic limestone bed are caught between the accumulated beds.

In Pare mountain system, the main rocks are gneisses, composing of biotite gneiss, amphibolite gneiss, biotite-garnet gneiss, felsite gneiss, graphite schist, granulite, quartzite, etc., showing the N20° – 45°W strike and the 15° – 40°NE dip. The general structure of these metamorphic rocks is a monocline structure with the NWN–SES strike and the NE dip, and faults are developed in the directions of NWN–SES or N60°W. In the Pare mountain systems, there is a granulite facies which is developed in the Northeast African mountain-forming zone, and this is exposed in many locations, forming the mother rock of the surface weathered kaolin.

The granulite facies in this district is composed of pyroxene granulite, amphibolite granulite and garnet granulite. In particular, the garnet granulite is a noteworthy resource because its felsite portion can be used for making chinaware and the garnet portion for grinding material.

While a deposite of quartzite is often accompanied by kyanite, silimanite, garnet, hematite, etc., large-scale deposits have not yet been discovered.

(2) **Volcanic Rocks**

Mt. Kilimanjaro is the biggest volcano in Africa which erupted alkaline lava and debris. Since the end of Tertiary period it has been allowing numerous volume of erupted materials to flow out onto the pre-Cambrian metamorphic rocks. Mt. Kilimanjaro is a double conical volcano consisting of three volcanoes including Kibo in the center, Mawenzi in the east and Shira in the west. The volcano allowed a large volume of basalt to flow out widely on its bottom, and during the period from the Pleistocene to Diluvial Epoch (Approximately 1.5 million years ago) it erupted nepheline basalt, trachytic andesite, trachyte, amphibolite and tuff. Beside the above, there are many large and small volcanoes on the NW–SE line, and their respective crater cones are spread over the foot of the Kilimanjaro and the Masai Steppe. It was observed during the field survey that in such districts as Moshi, Sanya and Rombo where these volcanic rocks are widely distributed, porous basalt and clastic rock have been turned into lateritic soil through the weathering and the sedimenting which took place a long period. And, in the low-level land having much rainfall and in the basins of flood-causing rivers, the topsoil has been turned into clayish soil, and this is now being used as a raw material for making red bricks.

(3) Intruded Rocks

While a large-scale bed of intruded rocks has not yet been discovered in Pare mountain system, a variety of basic rocks such as metamorphic pyroxene, zunite, peridotite, metamorphic gabbro, garnet amphibolite, etc. were observed to have intruded in many places. Although major acidic intruded rocks were not observed during the field survey except that granitic diorite exposed as long as approx. 100 meters in the excavated section of a newly constructed road in Ndambwe on the west of South Pare mountain system, pegmatite is observed in a large quantity in Pare and Usambara mountain systems. Out of the basic intruded rocks in this area, serpentinized peridotite and magnesite deposites are closely related to each other with respect to the origin of formation, and mass of granite being the origin of pegmatite is considered to be located in the deep underground.

The trachytic dike in the Kilimanjaro volcanic zone is that of the end of Pleistocene. As the post-volcanic action such as hot spring was not so active, it seems to be extremely difficult to discover deposits of China stone and Kaolin in this area.

3. Survey of Mineral Resources for Ceramic Raw Materials

It was reported in literatures that there are not only clay, quartz and feldspar which are the main raw materials for chinaware, but also carbonate minerals such as dolomite, magnesite and calcite, and also silimanite, corundum, etc. which are used as raw materials for special refractories. There are other minerals such as gypsum, graphite, garnet, talc, etc. too in this area. The utmost effort was made by the survey team in searching for various mineral resources as the exploitation of these resources are considered to make a contribution to the industrial development of Tanzania. This report is to be made for the ceramic raw materials, the subsidiary raw materials and the industrial raw materials, respectively.

(1) Kaolin and Clay

Existence of a large-scale deposit of kaolin and clay of good quality has not been known in this area. Production of small quantity of kaolin is being done by Tanzanian Magnesite Mining Co. A chinaware manufacturer named Sheriff Dewji & Sons Ltd. in Arusha is being engaged in a small-scale production of chinaware by using Pugu Hill kaolin in Dar-es-Salaam. Since availability of white kaolin is most preferable for local chinaware manufacturers, the survey team concentrated its efforts on exploration of the kaolin deposit. The survey mission, however, encountered with many difficulties because appropriate reports on kaolin were not available, locally obtainable information was unclear and unreliable, the survey site was far from the base camp and the team members had to travel a long distance passing through steep mountain roads. From the result of this survey, the kaolinic clay available in this area is classified as follows:

- (i) Residual kaolin by weathering of granulite
- (ii) River basin sedimentary clay
- (iii) Lake-area sedimentary clay
- (iv) Clay by weathering of pegmatite

(i) Residual Kaolin by weathering of Granulite :

Biotite gneiss and pyroxene-amphibolite gneiss in Pare mountain system were observed to have been weathered and kaolinized, but from the view point of quality, the kaolin by surface weathering of granulite is better. Many outcrops of kaolin of this kind are seen mostly on the central highlands of North Pare mountain system and also in the excavated section of the bus-travelling highway connecting Mwanga City, where D.D.D is located, to Rombani and Kigare by way of Kikweni Pass. The kaolinization can easily develops on a hill land and also on the both sides of a small swamp on a gently sloping ground, and white kaolin portion is ranging from several meters to 30 meters at the most. For instance, utilization test of samples collected from a kaolinized zone in the neighborhood of Kikweni Pass showed a good result, and the specimen sieved below 200 mesh also underwent an X-ray diffraction test and the result showed that kaolinite content was approximately 90 %, feldspar a few % and fine quartz about 10 %. At the place where granulite was displaced by kaolin, some portions of the topsoil have been turned into brownish by content of iron hydroxide, and it is hard to mine snow white kaolin ore in a large quantity in such a place.

As quartz and feldspar of granulite origin are contained in kaolin zone of this kind, elutriation is required for obtaining high-grade white kaolin. And, net recovery rate of the elutriation is approximately 30 % of volume of crude ore.

If exploration for kaolin of this kind is conducted in the future, it is advisable to do it selectively on the peneplanation-progressed slope in the highland of Pare mountain system where granulite facies spreads widely.

(ii) River Basin Sedimentary Clay :

Brownish sedimentary clay beds are often observed to have been formed along water systems in high hilly areas in Pare mountain system. These beds were formed by sedimentation of earth and sand either in the original place or in the neighboring areas and streamed down. The viscosity of this clay is relatively high. There is a typical place of such a clay in the east of South Pare mountain system: A motorway is traversing on a steep mountain linking Mpirani to Bombo, Ndwng and Kiburo ; Gema River is flowing in the neighborhood of Kanza located along this motorway ; and in the basin of Yongoma River which is an upper stream of Gema river, there is a deposit of brownish clay. The clay bed becomes broader in the plain where the river bends, and at the point of this survey (1,030 meters above sea level) it spreads to the plains on the both side of the river in the range of 10 – 20 meters in width and 1.5 – 2.5 meters in thickness. The deposit of this clay in the area of the survey alone is estimated at approximately 10,000 tons. A long river basin in the central mountainous area of South Pare mountain system is regarded as a promising area of the deposit of sedimentary clay. However, since there is no one who utilize it, this clay has no value at the moment. The boring by hand auger was conducted in a place between a bus-running highway and a primary school compound in Kifu district of North Pare mountain system. It, however, turned out to be of no utility value because it proved to be of only 40 – 50 centimeter in thickness on the granulite bed.

Another survey was conducted for a brownish sedimentary clay spreading in the low-level zones surrounding an artificial dam (for irrigation use) located in the neighborhood of the aforementioned outcrop. This clay bed had a depth of 3 – 5 meters, and a total deposit of two places were estimated at approximately 15,000 tons. This is fine-grain mud-like clay of high viscosity and composed mainly of halloysite. A result of firing test of the specimen clarified that this clay is able to be used for making shamotte firebricks. The artificial dam was constructed in 1964 to stop flow of a river of the upper stream of Kidoro River. This clay bed around the dam proved to be same as the river sedimentary deposit.

Since Moshi district has insufficient supply of clay for making good-quality bricks, it may be worthwhile to consider to utilize this clay by transporting it to that city.

(iii) Lake-Area Sedimentary Clay :

In this district, lake-area sedimentary clay is regarded as the largest clay source.

The lake-area sedimentary clay was deformed from sedimentary deposit in a swamp or lake which was immersed in water at all times. Considering the fact that the clay deposit of this kind is hard to be formed in the volcanic rocks area of the Kilimanjaro or in a dry plain area, the survey was concentrated in the area of Pare mountain system where metamorphic rock zones spread around. Surveys were first made to locate possible clay deposits in basin-like lands, plains where flows join, low-level forests in the neighborhood of Ndanbwe on the west of North Pare mountain system, and other low-level lands in the neighborhood of Mbono on the southern tip, etc. referring to the maps of a scale of 1 to 50,000, then the boring operations were conducted. The result, however, did not discover any kaolinic clay deposit in these areas. Meanwhile, Kigare (generally called 'Usangi') deposit and Lake Tona deposit were found to be hopeful, and therefore, close studies were made on these deposits.

Kigare Clay Deposit : (Refer to Fig. 5)

The area in the south of the low land (1,260 – 1,280 meters above sea level), approximately 12 kilometers east-south-east of Mwanga, is a wet land containing swamps. The wet land, located on the south of the campus of the Junior College of Education, stretches in a shape of a belt of 75 – 120 meters in width and 240 kilometer in length in the direction of NW–SE. Presence of a clay bed with a depth of more than 3 meters was confirmed in this wet land. And, it is possible to estimate depth of a bed up to 4 meters. The clay is highly viscous slime-like clay of gray or dark gray color and contains a small amount of humus. It is clarified from X-ray diffraction of some specimens that the clay is composed mainly of such minerals as low-crystallinity kaolinite or halloysite and anauxite with a small content of quartz. There is no firmly established crystallographical theory on anauxite at the moment. And, there are several theories stating that a kaolinite crystal contains some tetrahedral lattice of Si-O, and that silicagel might be contained in kaolinite crystal. Anyway, the Kigare clay is ultra-fine colloidal clay and hard to be refined by elutriation. It, however, proved to be possible for this clay (refractoriness : SK 31^+ ; tint resulting from firing test : light gray) to be used as plastic clay for chinaware. A result of chemical analysis of the clay is shown in the following table.

(Table 1) Chemical Analysis of Kigare Clay

Chemical Composition wt % \ Specimen	Compounds of 3 Specimens	Clay Recovered from Elutriation
SiO_2	56.9	48.2
TiO_2	2.67	2.51
Al_2O_3	24.3	27.4
Fe_2O_3	3.10	2.99
CaO	0.06	0.09
MgO	0.13	0.17
Na_2O	tr	tr
K_2O	0.17	0.21
Iglpss	13.2	18.2
Total	100.53	99.77
Refractoriness	$SK31^+$	

Analysis: Mino Ceramic K.K. Research Lab.

On the basis of a map drawn to a scale 1/2,000 and a result of boring test, the deposit is calculated as follows:

Estimated Deposit : Approx. 53,000 tons

Expected Deposit : Approx. 70,000 tons

While the ore bed is favorably located from the standpoint of exploitation, if open-air mining were employed for the mud-like clay, a special collecting method may have to be devised.

Lake Tona Clay Deposit (Refer to Fig. 6) :

The Lake Tona is approximately 6 kilometers (in terms of direct distance) southwest of Kisiwani, located on a highland (approx. 1,800 meters above sea level) in the east of the center of South Pare mountain system. The mud-like kalinic clay is deposited all over the west side of Lake Tona, and the deposit-distributed area extends approximately 330 meters from south to north and 120 – 200 meters from east to west. While the water depth is only 40 – 50 centimeters, since about 60 % of the total area of the deposit is submerged in this lake and turned into a swampy land, it is not possible for people to walk around this area. With respect to the stratigraphic formation of the clay bed, as shown in Fig. 6, the surface is covered with top soil to a thickness of 30 centimeters – 1 meter, and there is gray – dark gray clay bed underneath. Though it was not possible to confirm thickness of the clay bed further than 4 meters, but it is estimated to be as thick as 10 meters at the deepest portion. On the east side of the lake where the deposit is submerged in the water at all times, the clay bed tends to become thinner because of sedimentation of dark humus underwater. The white clay which is seen on the northeastern tip of the deposit was originally formed as gray clay, but after the formation it was discolored by fresh water and subterranean water, and therefore, it has the same mineral composition as those of other clays. The mud-like clay is viscous and proved to be of the same kind as Kigare clay, and in 4 specimens of the clay, anauxite was found.

The crude clay was containing quartz to the extent of about 40 %. X-ray diffraction test of the specimen resulted in clarifying that the clay is composed of such minerals as kaolinite, anauxite, and also small amounts of fine-grain quartz and non-decomposed feldspar. And, it contains montmorillonite in some case. In general, the large portion of composition of the white clay is occupied by high-crystallinity kaolinite and quartz, and its anauxite content is extremely small. Shown in the following table are results of analysis of the mixture clay of core specimens from boring on several locations and the refined clay by elutriation.

(Table 2) Chemical Analysis of Tona Clay

Composition \ Specimen	Mixture of Crude Clay	Refined Clay by Elutriation
SiO_2 WT%	59.9	43.4
TiO_2	1.99	2.43
Al_2O_3	21.7	30.2
Fe_2O_3	1.73	1.98
CaO	0.01	0.07
MgO	0.16	0.27
Na_2O	tr	tr
K_2O	0.18	0.23
Ig. loss	14.1	21.4
Total	99.77	99.98
Refractoriness	$SK31^+$	

Analysis: Research Laboratory of Mino Ceramic K.K.

While the total deposit was estimated at approximately 460,000 tons on the basis of a map drawn on a scale of 1 to 2,000 and the result of a series of boring, the clay bed of approximately 185,000 tons, which is located on the west side of the lake where mining operations can be easily done except those in the lake's stagnant area, is readily available for exploitation.
The cause of sedimentation of this deposit and nature of crude clay are very similar to those of Kigare clay and suitable for being used as plastic clay raw material for making colored chinaware. While this deposit is large in quantity, there are several problems to be solved for materialization of the mining operations, that is, (1) Availability of transportation system for steep mountainous area extending approximately 3.5 kilometers from the mine site to the truck-running road; (2) Repair of 14-kilometer road linking from depot to Kisiwani; and (3) Safety mining operation in the clay deposited area and also prevention of desolation of the mining field.

The contents of clay minerals below 44 μ in Kigare clay and Tona clay are more than 40 % and 30 %, respectively. Further, it is estimated from the electron microscopic photography of the clay minerals that Kigare clay is composed of a mixture of kaolinite and halloysite, and Tona clay is composed mainly of kaolinite.

(Table 3) Particle Size Analysis of Kaolinic Clay

Particle Size (μ)	Contents (%)	
	Kigare Clay	Tona Clay
> 3,360	0.25	0.50
3,360 – 2,000	1.00	0.50
2,000 – 1,000	3.00	6.75
1,000 – 500	9.00	14.0
500 – 149	19.50	24.6
149 – 74	16.50	16.0
74 – 44	4.50	6.0
< 44	46.25	31.65
Total	100.0	100.00

(iv) Clay by Weathering of Pegmatite

A large quantity of intruded pegmatite is observed in Pare mountain system and the surface portion of this bed is partly kaolinized. This white kaolinitic clay is a valuable mineral as a raw material for white-color chinaware, but the original rocks (pegmatite) are all small in size. The outcrops confirmed during the survey include that of road side pegmatite located in the areas of Lomboni and Totola in the center of North Pare mountain system, and that of pegmatite lying in the area approximately 8.7 kilometers (in terms of direct distance) southeast of Hedaru, in the mountainous area in the west of South Pare mountain system. The vein width of the former ranges from 1.2 meters to 1.5 meters and that of the latter from 0.2 meters to 0.4 meters, and it seems to be difficult to mine these veins. The clay of this kind is composed mainly of high-crystallinity kaolinite and also contains a small amount of quartz. Presently, Tanzania Magnesite Mining Company is mining a small quantity of kaolin for the purpose of producing Clay. As deposit of kaolin of this kind is small, it would become costly if mining is done in a large scale.

(2) Pugu Hill Kaolin Deposit

The survey team had an opportunity to conduct a quick survey of Pugu Hill kaolin deposit in Dar-es-Salaam when they visited there on their way back to Japan after completion of the survey in Kilimanjaro Region. This extra survey was made in compliance with a request of the director of KIDC, and JICA Resident Representative accompanied the survey team all the way to the mine site.

This kaolin deposit is located in Kisarawe, approx. 27 kilometers (in terms of direct distance) from Dar-es-Salaam, and occupies a part of Pugu Hill stretching long in the direction NEN–SWS.

Distributed in this area are marine sedimentary sandstone, siltite, limestone and conglomerate. And, kaolinized sandstone bed was originally a sediment of Miocene, lower Tertiary. It is stated in literatures that this sandy kaolin bed stretches N10°–30°W, gently inclines 5° – 10° to the west and extends as long as approximately 10 kilometers. It contains biotite felsic sandstone. Of all the kaolin ores producible in the neighborhood, the presently operating mine is of the best quality, and the bed is exposed as long as 2 kilometers to the clay elutriation plant. The ore is presently mined from open-air cut and underground pit. In open cut of about 300 meters in length bulldozers are working. The ore is composed of 30 – 50 % of kaolin and granular quartz, and it has small amounts of impurities and ferrous content.

Typical kaolin refined by the elutriation is composed of high-crystallinity kaolinite (approx. 85 %), fine quartz (about 10 %) and hydro mica (approx. 5 %).

The reserve is roughly estimated at 10 million tons, and this figure is very much close to 11.25 million tons estimated by an Austrian technical consultant company in 1981.

The mine operator is provided with a cableway transportation system, and the ore is separated into refined kaolin and silica sand at the elutriation plant.

Annual production capacity of this elutriation plant is approx. 4,000 tons.

The products of this elutriation plant are to be used for the following applications, and shipments and productions are said to be adjusted in accordance with demands:

Kaolin : Paint, rubber filler and chinaware
Silica Sand : Glass (Grain size : 0.2 – 1.5 mm)

Pugu Hill kaolin deposit is large in scale, and the ore is good suited for chinaware making. As this mine has such advantages that mining in a large quantity is possible and that it is only a distance of about 3 kilometers to the railway station at Pugu, it would become a main supply source to the ceramic industry in Tanzania in the future. A result of fluorescent X-rays analysis of the elutriated kaolin is as shown in the following:

SiO_2 : 50.2, TiO_2 : 0.67, Al_2O_3 : 35.4, Fe_2O_3 : 0.15, CaO : tr, MgO : tr,
NaO : tr, K_2O : 0.17, Ig.loss : 12.7

(3) **Feldspar and Quartz Resources**

In Pare mountain system and Usambara mountain system, formation of pegmatite is remarkable in spite of the fact that there are few granitic intruded rocks. As shown in a deposit distribution map, many places of pegmatite are known for mining large-size mica, but feldspar and silica are left untouched in many places. In the area of Pare mountain system, too, vein-like, or tubular or lens-like pegmatite beds are formed by intruding metamorphic rocks. Particularly, in the hill area in the neighborhood of Kihurio on the east of South Pare mountain system, many small-scale pegmatite beds intrude in parallel with strata.

In fact, the distribution density of pegmatite is so high that a new bed was discovered in the excavated section of newly constructed road in Pare mountain system. The pegmatite deposited in this area, however, is generally small in scale with an estimated deposit ranging from several hundreds tons to 2,000 tons. And, it may be said that the pegmatite is characterized by small contents of rare element minerals and gem stones other than large-size biotite, white mica and garnet.

The feldspar and quartz are the major minerals constituting the pegmatite. And, good-quality pink feldspar (orthoclase and microcline), soda feldspar and high-grade quartz for optical glass are often observed. Though there are too many places for survey of pegmatite, some examples are shown in Table 4.

(Table 4) Status and Scale of Pegmatite

Place of Production	Status and Scale	Mineral Composition	Reserve (estimated)
Approx. 1 km west of TMM office in Chambogo	Tubular, approx. 25°ES, 5 – 8 m wide, 0.5 – 1 m thick	Feldspar – 60 %, quartz – 40 %	2,300 tons
Kihurio district, A Deposit	Expand-and-contract vein-like form extending N38°W, vertical – inclines to 80°E	Feldspar – abt. 50 %, quartz – abt. 50 %, mica – a few %	2,400 tons
Kihurio district, B Deposit	Lens-like form extending N25°W, inclines about 70°NE	Potash feldspar – abt. 35 %, soda feldspar – abt. 20 %, quartz – abt. 45 %	2,500 tons
Kihurio district, C Deposit	Vein-like form extending N10°W	Feldspar – abt. 55 %, quartz – abt. 45 %, biotite – a few %	1,300 tons
East side of new road, about 8 km southeast of Hedaru	Flattened lens-like form, about 5 m thick, extending N70°W, falls 25°SW	Feldspar – abt. 45 %, quartz – abt. 55 %, mica and garnet – a few %	1,800 tons (Remaining deposit)
On the west side of the foot of Mount Monire, about 300 m to the state highway	Expand-and-contract vein-like form extending N70°E, inclines 75°NW	Feldspar – abt. 60 %, quartz – abt. 40 %, garnet – fairy big in quantity	2,000 tons
About 3.5 km north of the center between Lomboni and Usangi, 1,310 m from the sea level	Vein-like form extending N18°E, inclines about 40°SE, partly kaolinized	Feldspar – abt. 65 %, quartz – abt. 35 %	1,000 tons

4. Mineral Resources for Ceramics' Subsidiary Raw Materials and Other Industries' Raw Materials

(1) Magnesite Deposit

In Tanzania there are magnesite deposits resulted from chemical sedimentation (Gelai Deposit at the east end of Lake Natron) and igneous magnesite deposits resulted from intrusion of ultrabasic rocks. Magnesite is listed as one of the export items of this country.

The famous magnesite deposit in Pare mountain system belongs to the latter and lies underneath a small hill about 11 kilometers (in terms of direct distance) southeast of Same. This deposit has long been operated after having been developed by Chambogo Mine of

Tanzania Magnesite Mining Company, known as the major miner of magnesite in Tanzania. This deposit is composed of slim and net-like magnesite veins formed on the top of serpentinized olivine intruding pre-Cambrian metamorphic rock. All the venins range from 2 centimeters to 15 centimeters in thickness, but this deposit is so large as the mineralized zone extends approximately 700 meters from south to north and about 80 meters from east to west, and the depth is confirmed to be 110 meters at the deepest portion by boring. In the area near the open-air mining yard extending approximately 150 meters, even a lump of magnesite having 50 cm dia. can be observed. Talc vein and magnesium chlorite vein develop, and serpentine-like olivine is exposed. This deposit is said to be estimated at more than 10,000 tons.

The magnesite ore is in snow white lumpy form and contains an extremely small amount of impurities. A result of X-ray diffraction test of a specimen clarified that it contains more than 93 % of magnesite and a trace of chlorite and unconsolidated minerals (carbon silicate minerals). Shown in the following table (Table 5) is a comparison of chemical analysis between Tanzanian and other countries' magnesite ores.

Composition / Place of Production	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Ig. loss	Insoluble (Acid)
Chambogo*		0.5		0.8	46.4	51.1	1.3
Austria	1.45	0.03	3.35	1.68	42.43	50.41	
Manchuria (Daissekkyo)	2.98	0.40	0.32	0.72	44.89	50.72	

* J.F. Harris : Summary of the Geology of TANGANYIKA : 1981

The standard for impurities contained in the magnesite to be exported from this mine is to be as follows (wt%) :

SiO_2 : 4.0, Al_2O_3 : 0.25, CaO : 1.5, SO_3 : 0.02, Fe_2O_3 : 0.1

Depending on an information from a teacher of Kadingari primary school, a survey was conducted in the mountainous area in the east of North Pare mountain system, and a magnesite deposit was discovered. This deposit is exposed on a cliff (approx. 1,100 meters above sea level) adjacent to a motorway linking Kadingari to Butu. Slim and net-like magnesite veins develop in biotite gneiss, and the mineralized zone was confirmed to be extending approximately 25 meters on both sides of a small stream. As the mineralized zone is somewhat turned into clay, hand-picking selection can be easily done. A specimen of creamy white magnesite is composed of magnesite (abt. 90 %), chlorite and montmorillonite (abt. 10 % in total), and this is because clay was mixed up with the specimen when being sampled. Since olivine is not seen in this bed, there is a possibility of becoming a large deposit when the bottom section is confirmed. Some more potential deposits are expected to be discovered in Pare mountain system where there are many ultrabasic intruded rocks. Magnesite is a mineral resource for industrial use like, magnesia brick, metallic magnesia, etc., and particularly high-quality magnesite ore is potential for exporting to industrialized countries.

(2) **Gypsum Deposit**

In the plain zone of Kilimanjaro Region, gypsum deposits are found in the area where salt water lakes had run dry. The deposit of this kind was formed by chemical sedimentation of gypsum contained in sea water, and it tends to spread near the surface of the earth. Gypsum is mainly shipped to Portland cement plants, but gypsum of good quality is an important resource for making Plaster of Paris for the use of plaster mould of chinaware. The survey was conducted, therefore, for locating gypsum ores and also for studying the quality. Two mines of gypsum are operating in a deposit located in the flat area approximately 10 kilometers north of Mkomazi and also in another deposit spreading on the west side of the point approximately 14 kilometers west of Makanya. The former deposit, however, was not surveyed as it was with a large content of clay and sand. The latter deposit (west of Makanya) is covered by a topsoil bed, and a gypsum bed of 0.3 – 2 meters in thickness extends approximately 5 kilometers from east to west and approximately 400 meters from south to north. The gypsum bed is composed not only of fine and homogeneous gypsum but also of porous gypsum containing clay in many portions, and the bottom side of the bed is composed of lumpy gypsum. As the ore is more or less covered by clay, it can not be removed by hand. X-ray diffraction of a specimen of fine lumpy gypsum shows that it contains, other than gypsum, 30 or 40 % of quartz, halloysite-like clay mineral and feldspar.

In Africa the gypsum deposited in the salt water lake area is called 'gypsite'. As a result of utilizing test, gypsite proved not to be suitable for making plaster of Paris because of its contents of quartz and impurities.

(3) **Limestone and Dolomite Resources**

An abundance of limestone and dolomite are deposited in the areas where surveys were made. In Masai steppe zone, in particular, bed-state and lens-like limestones are formed in metamorphic rocks in the area between the railway and Ruvu River on the west of Pare mountain system. Further, in Lelatema mountain system extending in a crescent shape from the point approximately 74 kilometers southwest of Moshi, tremendously large-scale metamorphic limestone beds are exposed with dolomite beds caught between them. The limestone exposed on the river bed of Sanya about 21 kilometers southwest of Moshi is micro crystalline dolomitic limestone, and that exposed in the neighborhood of Nyumba Ya Mungu Dam Power Station is composed of aragonite and dolomite. And both limestones are in a position to be mined as dolomite ore. In the area about 23 kilometers west of Makanya, large-crystal limestone (conglomerate of calcite) are exposed in several places, and those limestone and dolomite exposed in the plain form gently-sloping hills while bearing years and years of weathering. The crystalline limestone is also known to be produced in the mountainous area in the neighborhood of Bendela. Thus, Kilimanjaro Region is a promising land for production of limestone and dolomite. Good-quality crystalline limestone is used for manufacturing soda ash, carbide, glass and chemical products, etc. Dolomite containing 20 % or more of MgO is used for refractories for steel, sheet glass, and dolomite body and glaze of chinaware, etc.

(4) **Kyanite and Silimanite**

Kyanite and silimanite are polymorphic minerals shown by a molecular formula of Al_2SiO_5 and used for special high-alumina sagger and furnace refractories for steel industry. In the high-pressure metamorphic rock zone of Archaezoic era distributed in the entire area of Tanzania, kyanite and silimanite are formed in crystalline schist and gneiss.

These minerals are said to be produced in a large quantity in the mountain systems of Pare and Usanbara. In Pare mountain system the minerals are produced in such areas as (1) Chankuku, about 2 kilometers east of Hedaru and (2) Uguruwa Hill, about 16 kilometers north of Mkomazi, etc. In the case of (1), kyanite is collected from small lumps contained in kyanite schist or from rolling stones containing kyanite in band structure, and in the case of (2), band-state kyanite ore is mined from kyanite-quartz schist exposed on the hilly area. In general, the ores in these areas are of low grade containing quartz, mica, garnet and silimanite, but this gneiss is said to extend as long as approx. 4 kilometers. In the area of Kwa Kiholo about 16 kilometers northeast of Mkomazi in the north of Usanbara mountain system, a kyanite mining yard is located on a slope approx. 1,100 meters above sea level. A kyanite-containing felsite gneiss bed is formed to a thickness of 10 – 40 centimeters alternately with biotite-garnet gneiss bed, and kyanite is exploited from the felsite gneiss. Selection of ores is done in such a manner as to hammer the portion where blue kyanite and silimanite are concentrated. As kyanite is formed in a thin lens-like form having a length of about 30 centimeters, it is difficult to get kyanite of good quality in a large quantity.

(5) **Other Mineral Resources**

(i) Garnet

Many of metamorphic rocks in Pare mountain system contain garnet ensuring an abundant supply source, and drift sand sedimentary garnet deposits are formed in the entire area of Masai Steppe. Garnet is mined from topsoil in such areas as Kichaa Hill approx. 11 kilometers west of Same, Lolobukio about 13 kilometers west of Same, Buiko roughly 24 kilometers southwest of Mkomazi, etc. In general, a garnet-containing topsoil bed is thinner than 1 meter and distributed irregularly. Crystals of almandine ($Fe_2Al_2Si_3O_{12}$), pyralspite $(Fe, Mg, Mn)_3Al_2Si_3O_{12}$, etc. range from 0.5 millimeters to 3 millimeters in diameter, but garnet as gem stone is rarely available.

(ii) Miscellaneous Clays

KIDC is now making good use of the topsoil of Holocene epoch, Quaternary-period alluvium, as the main raw material for making red bricks. In the low-level zone and the foothills surrounding the Kilimanjaro, alkaline lava and clastic rocks which had been erupted from the volcano deposited on the surface of the earth to form a lateritic soil. And this soil covers a part of volcanic rocks and pre-Cambrian metamorphic rocks as a topsoil bed ranging from 1.5 meters to 3 meters in thickness. This topsoil deposited in low-level land and river-eroded basin became clay-like soil beds. In such areas as the both sides of the railways near Mobogeni about 3 – 6 kilometers south of Moshi, the south side of Sanya Chini Railway Station and the basins of Sanya River, viscous brownish topsoil is distributed extending over approx. 4 kilometers, and local people in this area uses this topsoil for making bricks for housing.

In general, the clay of this kind has a large quantity of un-decomposed plagioclase, glassy substance and ferrous content, hence its refractoriness is low. Thus, it is not suitable for making brick & tiles of good quality. While the deposit is roughly estimated at 200 million tons in the above district alone, as being utilized as a farming land, too, the mining of this topsoil has to be done with care. If more viscous brownish clay is required in the future, it is desireable to utilize those clay from wet land in lake area and swamp.

Table 6 shows the chemical compositions of basalt, mother rock of the topsoil in Kilimanjaro, and major basalts in the world.

(Table 6) Chemical Compositions of Basalts

Composition ,wt%	1	2	3	4 (Norm value of specimen No. 1)	
SiO_2	44.4	46.4	47.0	or	7.8
TiO_3	3.3	2.5	3.0	ab	17.3
Al_2O_3	14.2	15.4	14.9	an	22.0
Fe_2O_3	4.6	3.2	3.1	ne	3.7
FeO	8.8	8.5	8.8	di	23.0
MnO	0.2	0.2	0.15	ol	10.4
MgO	7.3	7.0	6.9		
CaO	11.0	10.7	11.0	il	6.2
Na_2O	2.9	3.2	2.9	ap	1.6
K_2O	1.3	1.6	1.2	Mafics	47.9
P_2O_5	0.7	0.5	0.45		
H_2O_+	1.4	0.9	0.7		
Total	100	100	100		
ΣFeO	12.9	11.4	11.6		

1 : Average values of 5 specimens of peridotite basalt, and 25 specimens of trachytic basalt, sampled in Amboeli area, Mt. Kilimanjaro.

2 : Average values of 84 specimens of basalts sampled in the inner land of African continent.

3 : Average values of 61 specimens of alkaline basalt sampled in the Indian Ocean.

Table 6 indicates that basaltic soil contains iron, titanium, potassium and magnesium in larger quantity than acidic rocks, therefore, it is hard to be turned into kaolinic clay by weathering only. Column 4 shows the mineral components (Norm value) of Kilimanjaro basalt.

(iii) Corundum

Corundum (Al_2O_3) is one of the outstanding minerals producible in this district. A corundum bed is found in the area of the south slope of a mountain (about 1,100 meters above sea level) about 12 kilometers south-southeast of Same, and it is scattered in the thin topsoil bed. Tanzania Magnesite Mining Company explored and discovered an outcrop of biotite schist containing corundum, and this company is now mining corundum both from sedimentary deposit and mother rock. Corundum contained in the topsoil has such colors as light gray, grayish pink, bluish gray, etc., and its major axis ranges from 0.5 to 2 centimeters, but corundum phenocrystically contained in mother rock is light gray and has the major axis of less than 0.5 centimeters. The corundum producible in this area has no tint suitable for gem stone with little exception, but as the bed is ditributed in wide area, it can be a supply source of grinding media and special refractories (additive of calcined kyanite). The field survey was conducted by a special arrangement of Mr. Anderson, a geologist Tanzania Magnesite Mining Company, to whom the survey team is deeply indebted.

(6) **Unutilized Rock Resources (Granulite)**

As explained earlier, granulite facies is widely distributed in metamorphic rocks in Pare mountain system. Of this facies, garnet granulite, in particular, is composed mainly of potassium feldspar, soda feldspar and quartz of almost equal grain size, having a granular structure. Grain sizes of all minerals range from 0.5 to 1.5 millimeters in diameter, and if garnet impurities were eliminated, this granulite can be satisfactorily utilized as a raw material for making white-color chinaware. Above all, the rock of this kind is exposed on gently-sloping land in Muheza district, about 2.3 kilometers east of Mwanga and approx. 7 kilometers north-northeast of Makanya Railway Station, and this rock is weathered to such an extent as to be easily crushed. This rock is composed of such minerals as about 43 % of quartz, 26 % of potassium feldspar, 24 % of soda feldspar and 7 % of garnet, and if garnet could be recovered by the gravity and magnetic force screening methods, it may be used as grinding media, and thus the Granulite is expected to become as one of the multipurpose rocks.

5. Situation of Mining Industry in Kilimanjaro Region

The mineral products of Tanzania consist mainly of diamond, gold, tin, lead, mica, etc., and also of small quantities of garnet, magnesite and graphite. As for the mineral resources for the domestic demands, limestone and gypsum for Portland cement, bentonite, kaolin, quartz, feldspar and sepiolite (for making pipes) are mined. Of these mineral products, magnesite, gypsum, feldspar, quartz and garnet are produced in Kilimanjaro Region, but those establishments which are engaged in the exploitation are all small in scale except Tanzania Magnesite Mining Company. The list of mining establishments in Kilimanjaro Region is shown below.

Company Name	Location of Mine	Kinds of Minerals
TANZANIA Magnesite Mining Co., Ltd.	Chambogo, Same P.O. Box 63 Tel : 94	Magnesite, Limestone, Feldspar, Quartz, Kaolin, Dolomite and Corundum
Lekitojo Mining Partners	Makanya Same	Gypsum
Latena Mine	P.O. Box 1859 Moshi	
Kateri Mine Company Ltd.	P.O. Box 63 Same	Gypsum and Limestone
Makanya Gypsum Co., Ltd.	Makanya	Gypsum

Exploitation of mine in Tanzania is restricted by the following mining rules:

(1) General Prospecting Right

(2) Exclusive Prospecting Right

(3) Mining Right

(4) Mining Concession Transfer Claiming Right

Further, mining and shipping of ores are controlled by Tanzania Mining Corporation (generally called STAMICO). As shipments from small-scale mines are made in compliance with irregular demands, it is said to be difficult to take statistics of the tonnage on the monthly basis. Only Chambogo mine of Tanzania Magnesite Mining Company is provided with a simple clay plant in the mining premises for making clays of magnesite, dolomite, kaolin and limestone.

6. Problems on Exploitation and Utilization of Mineral Resources

Pare mountain system has abundant deposits of feldspar, quartz and magnesite. Dolomite and limestone deposited in the area of Masai Steppe are also producible in good quality. It is considered that the most serious problems Tanzania has to solve are how to mine these mineral resources economically and how to transport them to consuming plants or to shipping ports at a low cost.

As many of the deposits are located in the mountainous area, transportation of ore has to depend largely on laborers. The materials required for mining operations are not readily available. And, exploitation by low mining technology has been keeping the mining productivity extremely low. Availability of transporting road from mine to depot is to become a prerequisite to successful exploitation of a mine. Even existing roads have many hazardous places. Traffic is suspended frequently, and driving on a poorly maintained road is to cause an automobile to get worn out remarkably.

The lowest cost in Tanzania is the official rate of labor cost, and a daily wage of a labor was said to be 15 – 20 shillings at the time of the survey. Even then, according to a highly reliable source, prices of ores per ton ex-mine are said to be as follows:

Feldspar (hand-picked) : Approx. 1,000 shillings

Magnesite ($MgCO_3$: 95 % or more) : Approx. 3,000 shillings

When these prices are converted to U.S. dollar at an official rate (1 U.S. dollar is equal to 95 shillings), feldspar is to become US$105.20 and magnesite US$315.80. These prices are far high from internationally prevailing rates. Considering the fact that Tanzania is presently suffering from shortage of all kinds of materials, and that prices of the materials are tending to go up remarkably, the ceramic industry of this country seems to hold many problems to be solved.

7. Conclusion

In Pare mountain system in Kilimanjaro Region, numerous pegmatite beds intrude the pre-Cambrian metamorphic rocks causing this land to become a promising supply source of feldspar and quartz of good quality. And, there are abundant deposits of limestone and dolomite in a plain area on the west of Pare mountain system.

The deposit-finding survey of this time resulted in failure to discover any source of kaolin of good quality. From geological structure of Pare mountain system and the plain area on the foot thereof and also cause of formation of the deposit thereunder, it is judged that this region is not in an environment to allow a large kaolin bed to be formed. On the other hand, however, there are grayish clay deposits in two places, that is, one in Kigare District in North Pare mountain system, and the other on the Lake side of Tona in South Pare mountain system. And, deposits of hundreds of thousands tons in total were confirmed by boring operations.

The both deposits are sedimentary deposits lying underneath the low-level land or wet land in the mountainous areas. The clay is composed of grayish and fine kaolinite and halloysite, and containing anauxite. It is mud-like plastic clay, and can be used for making chinaware. But it has grayish tint after firing.

The major problem left unsolved is in connection with supply of Kaolin as one of the main raw materials in order to make white chinawares.

Fortunately, there is a large kaolin deposit on Pugu Hill, approximately 27 kilometers west of Dar-es-Salaam. Considering the fact that this deposit is capable of supplying good-quality kaolin, it is recommendable to make good use of this resource for making white chinawares.

Magnesite, the main mineral resource in this Region, is now being mined and shipped from Chambogo Mine. It is supplying calcite, too.

There are other mineral resources such as kyanite, dolomite and corundum, etc., which are used as raw materials for refractories, in this region. Since deposits of these minerals are inconveniently located, it is difficult to transport the ores in large quantity. In fact, the poor condition of transportation restrains various deposits from exploitation.

In Tanzania, the ceramic industry is still under the cradle stage. Except the traditional potters who are making Terra-cotta pitchers, etc., there is no pottery plant who is applying the modern technology at all in Kilimanjaro Region. Under the above circumstances, it is recommendable for KIDC to set up a ceramic research laboratory cum pilot plant who can provide local people with the opportunity of training on the ceramic engineering technology. Thus, the modern ceramic technology could be established in the region.

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1 : 125,000 Geological Map of "Hedaru" ;
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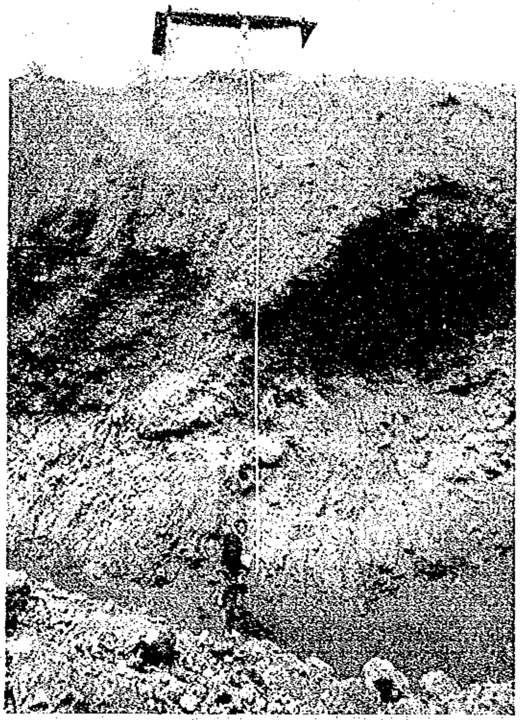
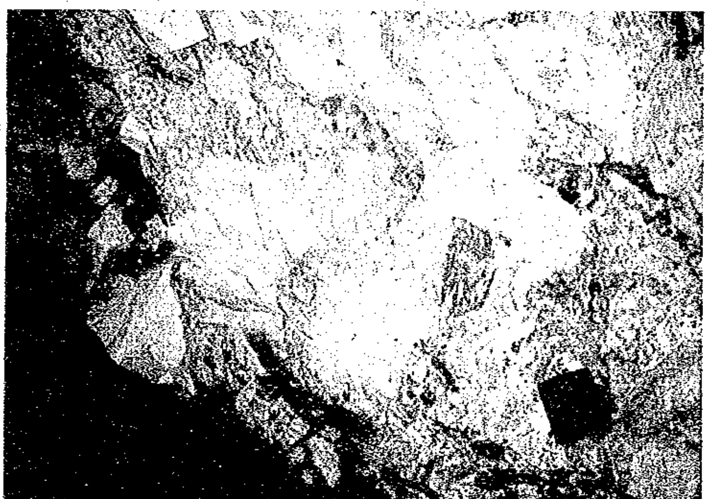
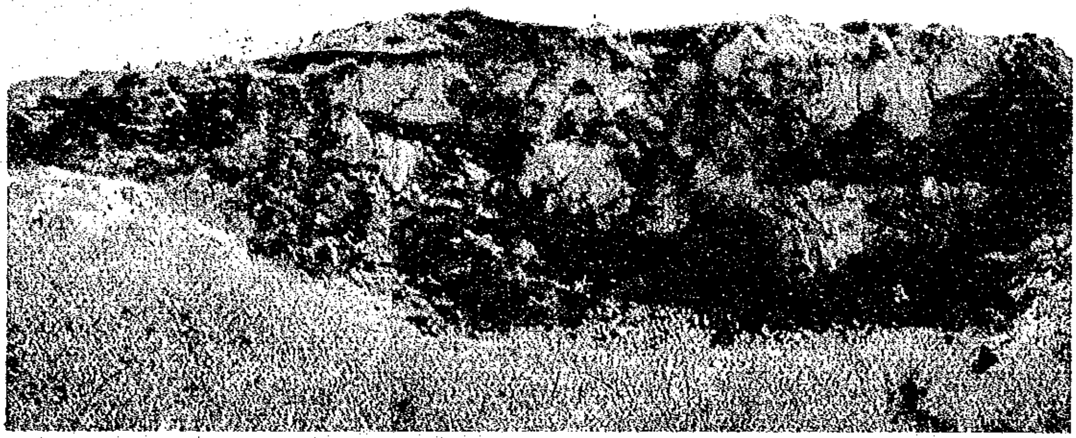


1 The strata of a river bank, near to Moshi.
The lower zone : Basaltic breccia.
The upper zone : Basaltic topsoil.
This topsoil is being utilized by local people as red brick material.

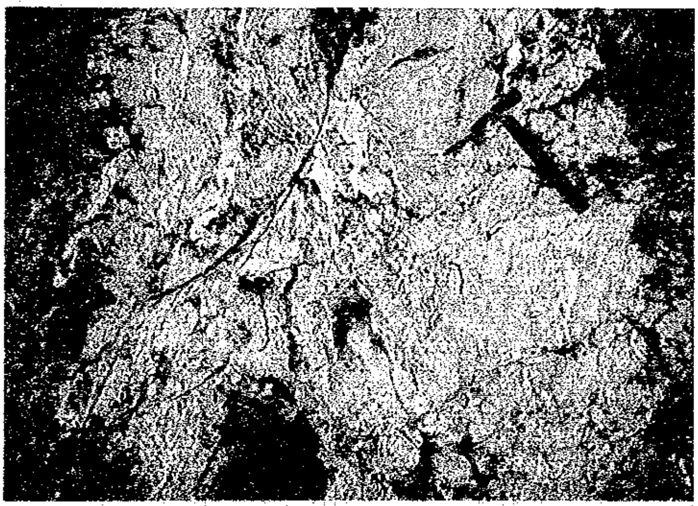
2 Red brick kiln, near to Kifura village.
Raw bricks made of topsoil along Rivu river are loaded in a shape of brick kiln. Three fire boxes are observed.
In this particular case, however, the "Kiln" is nearing a ruin, due to long term weathering.

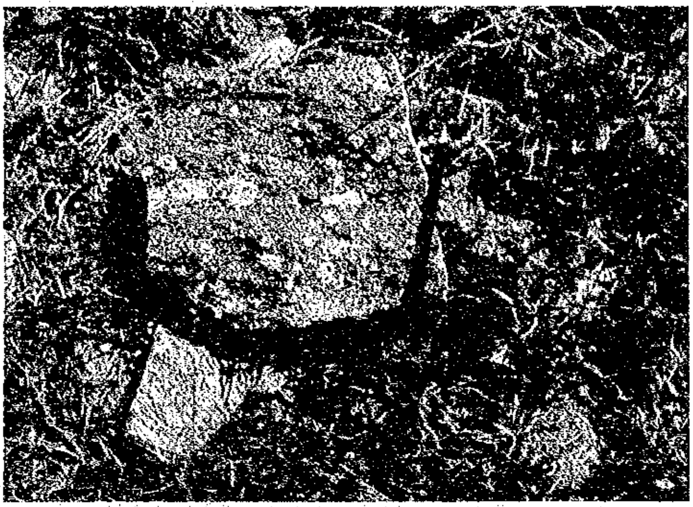


3 The Pegmatite exposed at the entrance of a pit hole.
Sharp white portions are the composits of Feldspar.
Big crystals of Biotite and Muscovite are observed beneath the field note.


4 The open pit of Chambogo Magnesite deposit.
This mine is the biggest one in the Region, operated by Tanzania Magnesite Mining Co.


5 Outcrop of Magnesite;
east side of a valley in Kadingari area
(North Pare mountain system).

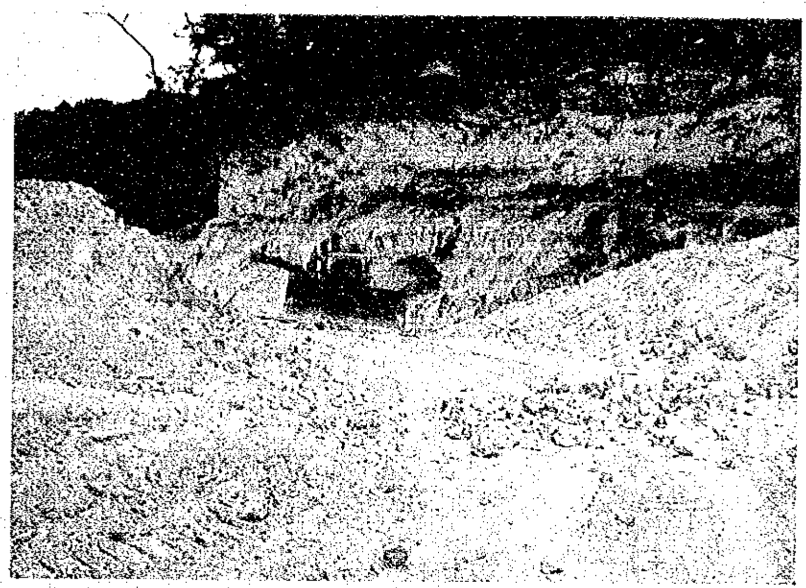

6 Outcrop of Magnesite; west side in Karingar area.
Vein like or thread like developed white portions are
the Magnesite.



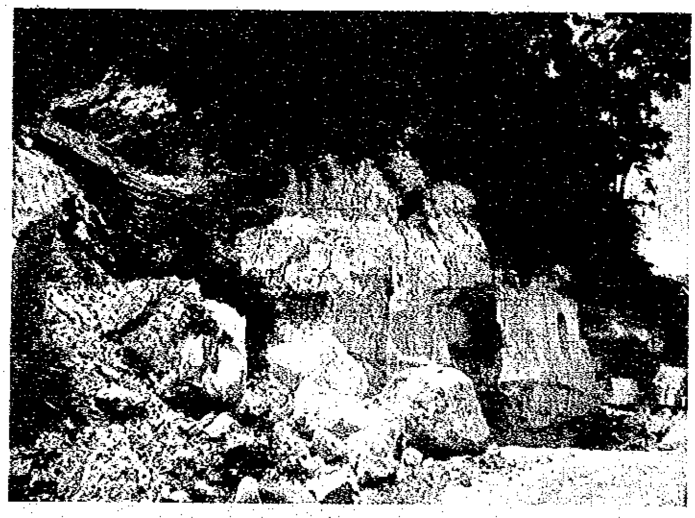
7 Corundum bearing Biotite Schist.
This corundum does not deserve the gem stone, because of gray tint and non-transparency.

8 Pre-Cambrian Gneiss, near to Kwakiholo in northwestern Usambara mountain system.
The Gneiss forms a long range strata along the cliff. In the middle, there is a Kyanite mine.

9 Kyanite is contained in biotite less gneiss, i.e., quartz gneiss.
It is co-existing with Sillimanite, and the hammer shows the Kyanite rich portion, which is 40 – 60 cm thick.



10 Open-cut mining of Pugu Kaolin.
Kaolin ores are collected by a bulldozer and sent to the elutriation plant. There were about 15 workers.



11 The mining of Pugu Kaolin is being done both in open-cut as well as in levels.
The kaolin is derived from the feldspar in Pugu sand stone.

12 The Elutriation Plant of Pugu Kaolin (STAMICO).
The plant was nicely maintained by three engineers.
The photography owes to STAMICO for their special favour.

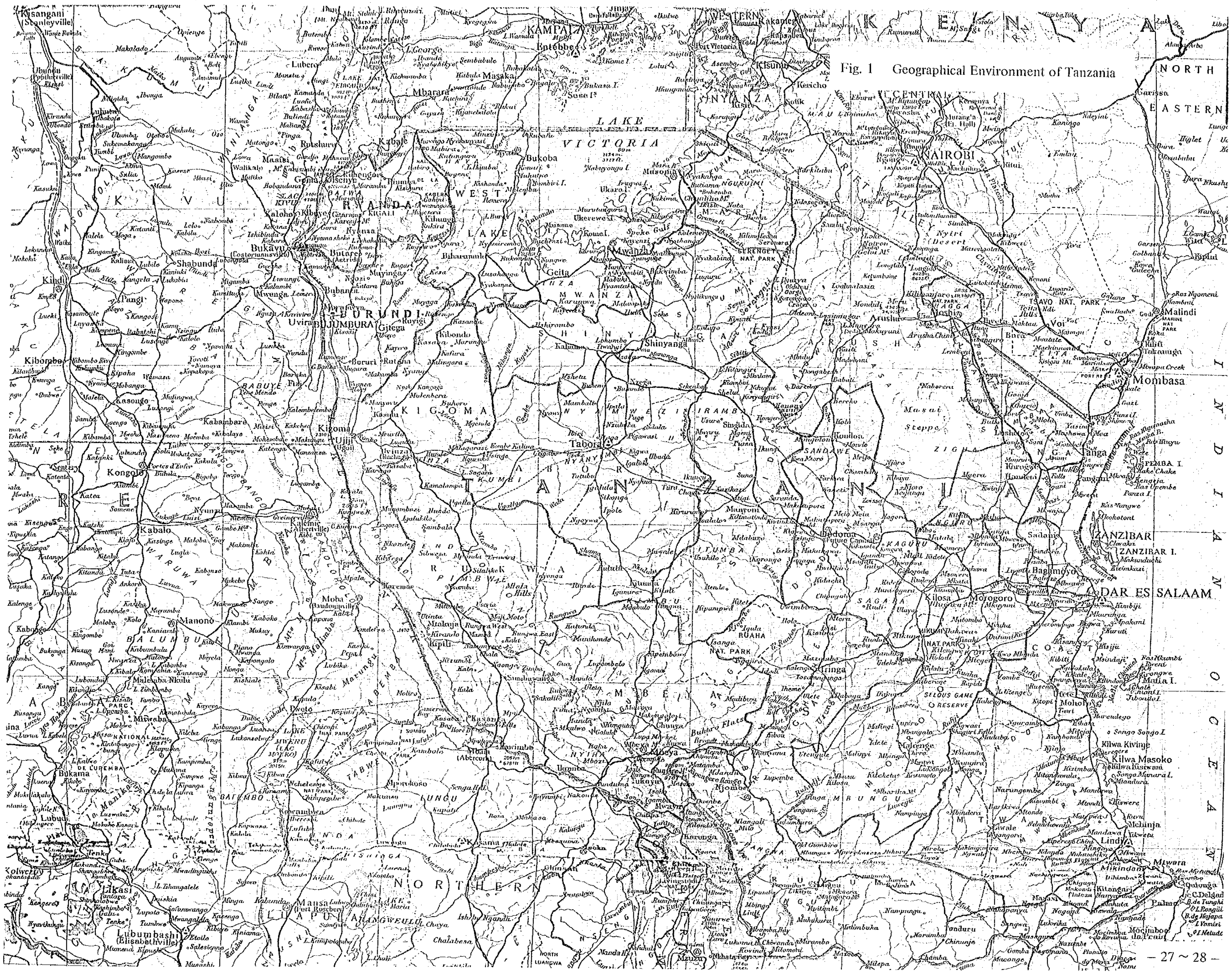
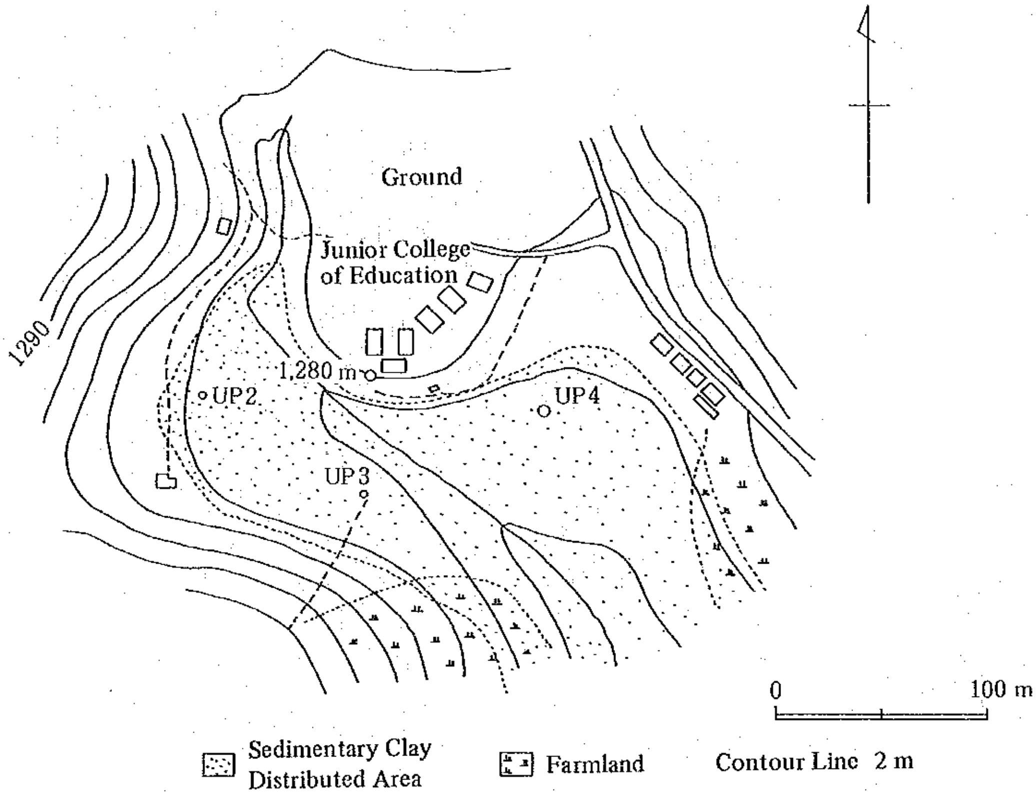
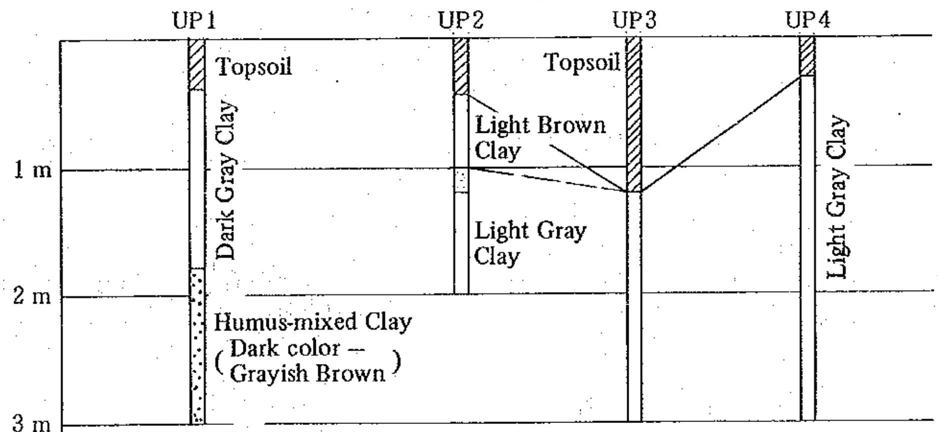


Fig. 1 Geographical Environment of Tanzania

Fig. 2 Concept of Clay Deposit under Wet Land in Kigare District

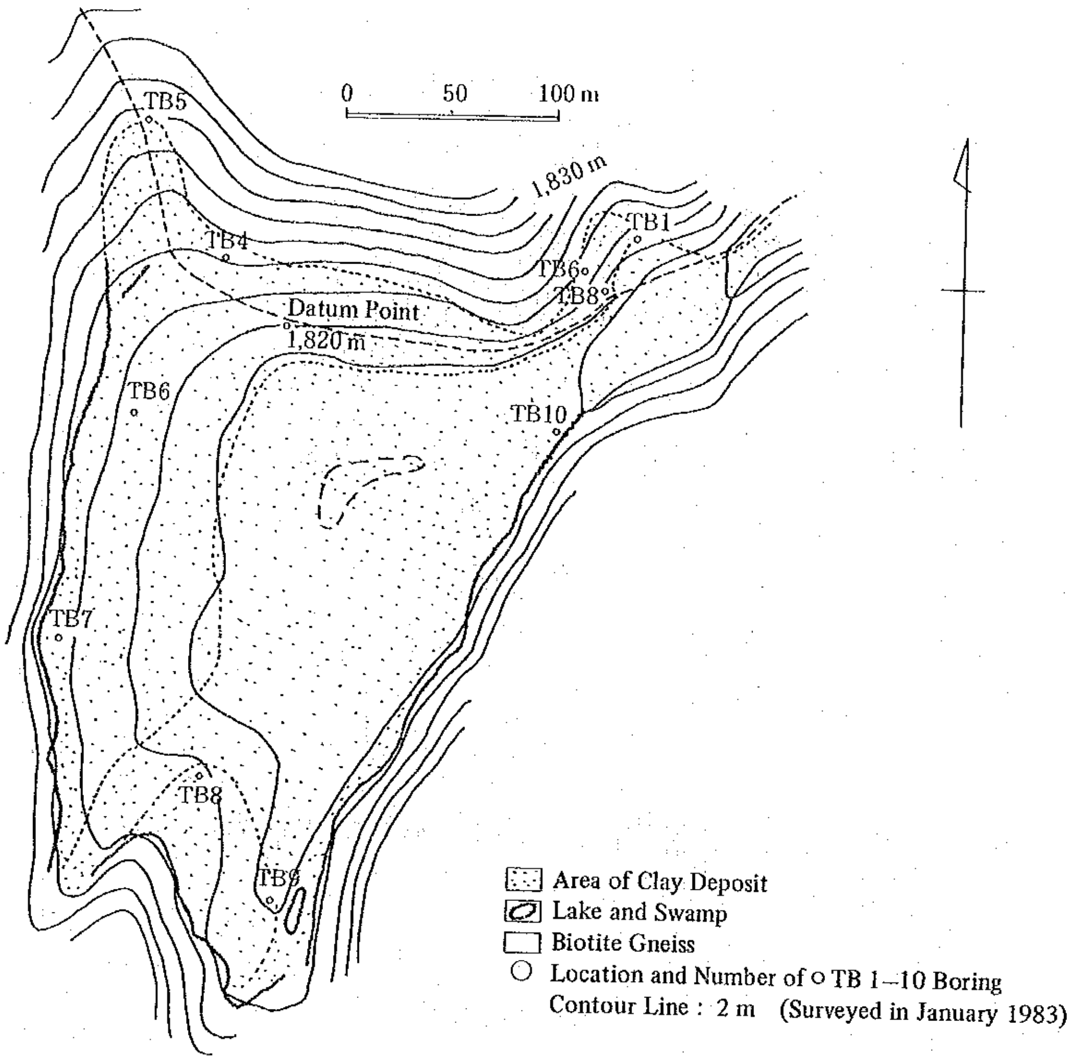


Columnar Chart by Boring Cores

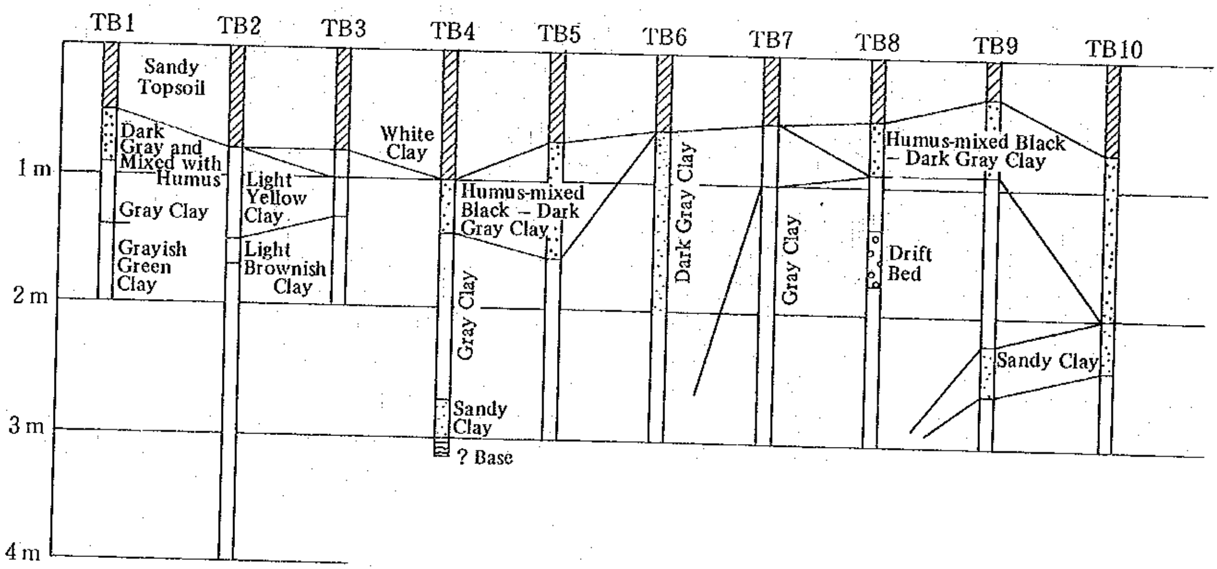


UPI : Boring conducted in the wet land in Kironge District, approx. 0.7 kilometers southeast of the Junior College of Education

Fig. 3 Concept of Sedimentary Clay Deposit in Lake Tona



Columnar Chart of Clay Bed by Boring Core



Part II.
Result of Raw Material Test and Trial Production Test

1. Specimens Tested

18 kinds of specimens were used for this test as shown in Table 1.

Table 1 Sample

	Raw Material	Place of Production	Remarks
1	Average Sample of Tona Clay	Swampy area in South Pare mountain system ; 2-and-half-hour drive from Same to Manka (a village) ; 2-hour walk from Manka ; 1,800 meters above sea level.	Boring at 7 locations, TP-3 thru TP-9, and specimens were sampled uniformly.
2	Good-appearance Part of Tona Clay	Same as 1. above	Specimens were sampled at the boring point (TP-6A).
3	White-color Part of Tona Clay	Same as 1. above	Specimens were sampled at the boring point (TP-10A)
4	Little Tona Clay	A ditch-like small swamp adjacent to the afore-mentioned swampy area ; 1,800 meters above sea level.	Specimens were sampled at TP-8A, a boring position.
5	Average Sample of Usangi Clay (Kigare Clay)	A swampy area in Usangi (village) ; North Pare mountain system ; 1,265 meters above sea level.	Specimens were sampled uniformly, boring at 3 locations, UP-2, -3, -4.
6	Good-appearance Part of Usangi Clay	Same as 5. above	Specimens were sampled at UP-3B, a boring position.
7	Pugu Kaolin	A hilly area, 34 kilometers west of Dar-es-Salaam ; 130 meters above sea level.	Kaolin was refined at site.
8	Weathered Clay	Between Muangakikuwani Peak in North Pare mountain system.	Half-weathered zone of gneiss. Sampling Mark U-8

	Raw Material	Place of Production	Remarks
9	Gneiss	Between Muangakikuwani Peak in North Pare mountain system	Garnet-containing granulitic gneiss. Sampling Mark U-21.
10	Kihurio Feldspar and Kihurio Quartz	A hilly area extending in Kihurio (village) in South Pare mountain system ; approx. 800 meters above sea level.	Pegmatite deposit. Formerly, mica was mined here.
11	Corundum	Untrodden area near Chambogo (village) in South Pare mountain system.	Guided by Mr. Anderson.
12	Magnesite	Sampling at Tanganyika Magnesite Mine in South Pare mountain system.	13-kilometer drive from Same.
13	Crystalline Limestone	A plain being 20 kilometers west of Makanya ; 620 meters above sea level.	Accompanied by a guide of Kekitojo Mining. Sampling Mark LK-3.
14	Limestone	An outcrop projecting from river bed on the plain, southern part of the high district.	Lens-like limestone in sedimentary rock. Sampling Mark H-5
15	Dolomite		Powdery sample obtained from Mr. Anderson
16	Gypsum	One of more than one hundred mines located on the plain, 14 kilometers west of Makanya.	Mining right held by Mr. Abraham.
17	Graphite		The specimen having been brought into K.I.D.C.
18	Kyanite	Sampled at the foot of Usambara mountain system, Tanga Region.	Mining has been stopped since 1966.

2. Raw Material Test

(1) Firing Test

Firing test is the most fundamental and quickest way of determining acceptability of a specimen as a ceramic raw material. By firing the specimen, various informations as follows are obtained: change in color, presence of impurities, expansion and shrinkage, and sintering character. And this test was conducted for all the raw materials. When testing, the raw materials were classified into main raw materials (for body) and subsidiary raw materials (for glaze and sagger).

(i) Specimens

The tests were conducted on crude clay or crude ore and elutriated kaolin.

(ii) Firing

Conditions of Reduction Firing : 1,350°C x 60 minutes

Conditions of Oxidation Firing : 1,250°C x 60 minutes

Samples were filled in sagger and fired in a tunnel kiln.

(iii) Results

1) Main Raw Materials

Results of firing of the main raw materials are shown in Table 2.

Table 2 Result of firing test for main raw materials

Specimen	Lively Look	Firing Test			
		Firing	Coloring by Firing	Impurities and Distribution thereof	Sintering by Firing
Average of Tona Clay	Grayish Brown	Reduction	Reddish Brown, Partly Light Yellow	Many iron spots	Sintering was satisfactory. Some were broken by finger nail, and some were not.
		Oxidation	Light Yellow	Small spots were observed	Sintering was satisfactory. None of the specimen was broken by finger nail.
Good-appearance Part	Grayish Brown	Reduction	Reddish Brown	Same as Average Section's.	Same as Average Sample's.
		and Oxidation	and Light Yellow	〃	〃

Specimen	Lively Look	Firing Test			
		Firing	Coloring by Firing	Impurities and Distribution thereof	Sintering by Firing
Average Sample of Elutriated Clay	Brownish Gray	Reduction and Oxidation	Reddish Brown and Light Yellow	No impurity was observed	Same as Average Sample's
White-color Part of Tona Clay	Light Yellowish White	Oxidation	Light Color	Black spots and iron spots were partly observed	Sintering was not satisfactory. Specimen was broken by finger nail.
Little Tona Clay	Yellowish Brown	Oxidation	Yellow	No impurity was observed	Sintering was not satisfactory. Specimen was broken by finger nail.
Average Sample of Usangi Clay (Kigare Clay)	Dark Brownish Gray – Gray	Reduction	Earthen Colour or Light Brown	Many large and small iron spots were observed.	Sintering was satisfactory. Specimen was not broken by finger nail.
		Oxidation	Light Brown	Neither impurity nor spot was observed.	Same as the above
Good-appearance Part of Usangi Clay	Dark Gray and Light Gray	Reduction	Earthen Colour	Many large and small iron spots were observed	Sintering was satisfactory. Specimen was not broken by finger nail.
		Oxidation	Light Brown	Neither impurity nor spot was observed	Same as the above

<table>
<tr><th rowspan="2">Specimen</th><th rowspan="2">Lively Look</th><th colspan="4">Firing Test</th></tr>
<tr><th>Firing</th><th>Coloring by Firing</th><th>Impurities and Distribution thereof</th><th>Sintering by Firing</th></tr>
<tr><td>Elutriated Clay of Usangi's</td><td>Dark Grey</td><td>Reduction

and
Oxidation</td><td colspan="2">Same as
Usangi Average Sample's
and
Same as
Usangi Average Sample's</td><td></td></tr>
<tr><td>Pugu Kaolin</td><td>Light Yellow</td><td>Reduction</td><td>Light Yellow</td><td>Neither impurity nor spot was observed.</td><td>Sintering was not satisfactory.
Specimen was broken by finger nail.</td></tr>
<tr><td rowspan="2">Kihurio Feldspar</td><td>White</td><td>Reduction</td><td>–</td><td>An extremely small number of fine black spots were observed.</td><td>Clear, and partly opaque.</td></tr>
<tr><td>Red</td><td>Reduction</td><td>–</td><td>Same as above</td><td>Clear.</td></tr>
<tr><td>Kihurio Quartz</td><td>Clear</td><td>Reduction</td><td>–</td><td>No impurity was observed</td><td>Clear, and partly half opaque.</td></tr>
</table>

2) Firing Test of Subsidiary Raw Materials

(1) Magnesite

Crude Ore is a lumpy form measuring less than 60 millimeters, and its surface is light brown – gray, but its broken surface is white.

Result of firing at 1,350°C (Reduction Flame) :

The surface was turned into light brown, and the broken surface remained white.

(2) Limestone (LK3)

Crude Ore is composed of white crystalline limestone (calcite).

Result of firing at 1,350°C (Reduction Flame) :

The color remained white.

(3) Dolomite (Powdery)

Crude Ore is white powdery material passing 80 mesh.

Result of firing at 1,350°C (Reduction Flame) :

The color was turned into dark brown.

(4) Corundum

Crude Ore is a hexagonal-columnar crystal (10 – 30 millimeters) having color between light brownish green and dark green.

Firing at 1,250°C (Oxidation Flame) resulted in changing the color to light green, and partly light brown.

(5) Kyanite

Crude Ore is composed of small lumps (40 – 60 millimeters) which are conglomeration of light-blue radial crystals.

Result of firing at 1,250°C (Oxidation Flame) :

The color was still light and pale blue, but small brown spots were scattered on the surface.

(6) Gypsum

Crude Ore is an earth-like lump of light brown.

Result of firing at 200°C (Oxidation Flame) :

The color was turned into earth-like color.

(7) Weathered Clay

Crude Clay shows a mixed color of light purple, reddish tint, brownish tint and white, and it is so brittle as to be easily broken by finger nail.

Result of firing at 1,250°C (Oxidation Flame) :

Lime content was turned into rose pink and other contents to white. Brown spots were observed partly indicating that garnet was oxidized.

(8) Gneiss

Crude Rock is a light brown lump of gneiss containing garnet.

Result of firing at 1,250°C (Oxidation Flame) :

Garnet was scattered as light brown – black spots.

Feldspar turned into a clear glass. The color became rose red color as a whole.

(9) Limestone (H-5)

Crude Ore is gray and composed of fine crystalline limestone.

Result of firing at 1,350°C (Reduction Flame) :

The color turned into white.

(10) Graphite

Crude Ore is glossy black flake (measuring 30 – 50 millimeters), and it has partly light brownish tint.

Result of firing at 1,350°C (Reduction Flame) :

It turned into a dark brown glass-like material having much residual.

(2) **Refractoriness**

(i) Specimen

The refractoriness tests were made on the main raw materials, that is, Tona, Usangi Clays and Pugu Kaolin. Specimens of Tona and Usangi clays were prepared by drying, grinding into specified grain size and removing ferrous content. Specimen of Pugu kaolin was prepared only by drying.

(ii) Measurement

By preparing a testing cone in conformity with JIS R2201, the specimens were fired under the specified temperature-raising curve, and their respective refractoriness were measured. An LPG-firing refractoriness testing furnace was used for these tests.

(iii) Results

Results of the measurements are as shown in Table 3.

Table 3 Result of refractoriness test

SAMPLE	REFRACTORINESS (SK)
TONA Clay	
Average Sample	31^+
Good-appearance Part	31^+
White Part	31^-
Little TONA Clay	34^-
USANGI Clay	
Average Section	31^+
Good-appearance Section	32^-
PUGU Kaolin	34

(3) **Grain Size Analysis**

(i) Raw Materials :

Usangi and Tona Clays

(ii) Test :

The raw material was dried and reduced for preparation of a specimen, and water was added to turn into slurry state, and then, analysis was made by wet process.

(iii) Result :

Results of Analysis are shown in Tables 4 and 5, and also in Figures 3 and 4.

Table 4 Result of grain analysis

USANGI Clay

Mesh (μ)	(g)	(%)
>3360	0.5	0.25
3360 ~ 2000	2.0	1.00
2000 ~ 1000	6.0	3.00
1000 ~ 500	18.0	9.00
500 ~ 149	39.0	19.50
149 ~ 74	33.0	16.50
74 ~ 44	9.0	4.50
<44	92.5	46.25
Total	200.0	100.00

Table 5 Result of grain analysis

TONA Clay

Mesh (μ)	(g)	(%)
>3360	1.0	0.50
3360 ~ 2000	1.0	0.50
2000 ~ 1000	13.5	6.75
1000 ~ 500	28.0	14.0
500 ~ 149	49.2	24.6
149 ~ 74	32.0	16.0
74 ~ 44	12.0	6.0
<44	63.3	31.65
Total	200.0	100.00

Fig. 3 Grain distribution of USANGI Clay

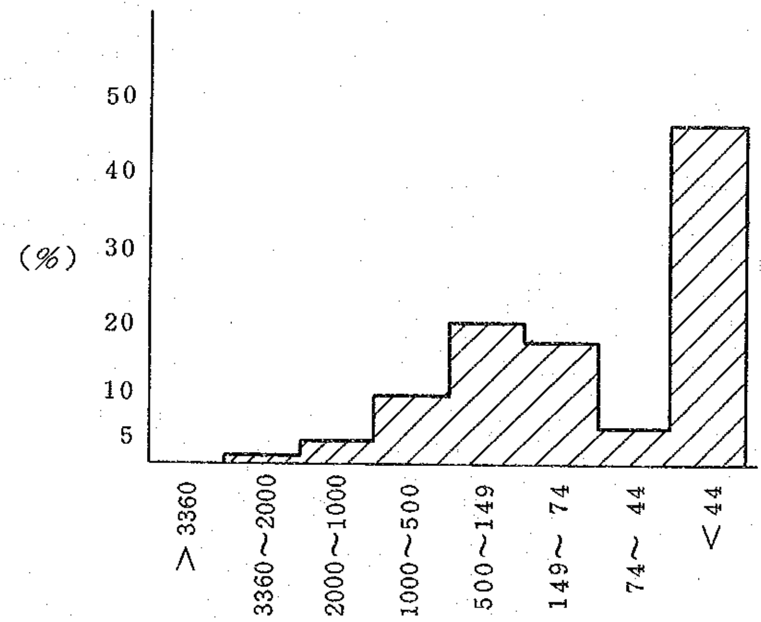
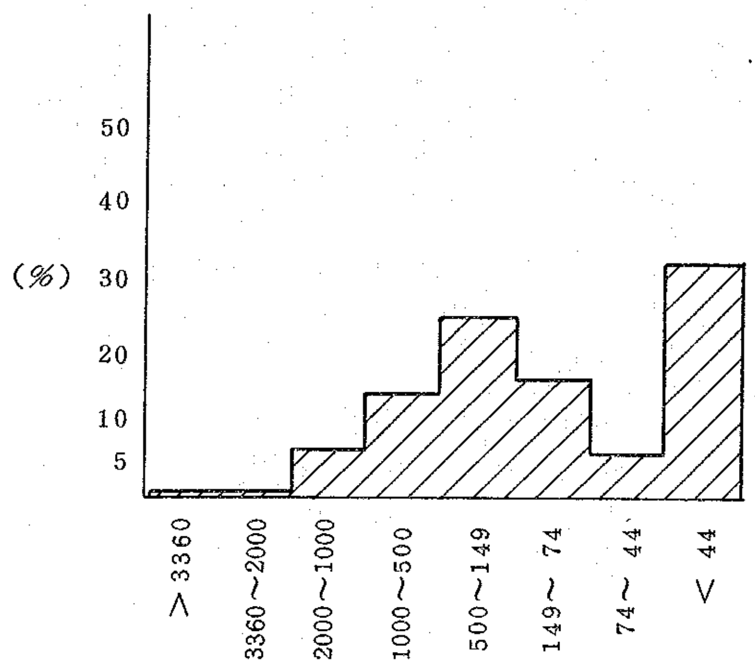


Fig. 4 Grain distribution of TONA Clay



(4) **Chemical Analysis**

(i) Specimen :

The specimens of crud clay, elutriated clay, kaolin and feldspar, which are the indispensable main raw materials for making chinaware, were prepared in such a manner that all the minerals were dried and screened by 200-mesh vibration mill (100 % pass).

(ii) Measurement :

Each specimen, after measurement of ignition loss, was put into a platinum crucible, supplied with flux and melted in an electric furnace to prepare glass beads. And then, the beads and the reference specimen were set to a fluorescent X-ray Analyses, and analytical values of all the elements were sought from the strength ratio and the working curve.

(iii) Result :

The analytical results are shown in Table 6.

Table 6 Result of chemical analysis

	SiO_2	Al_2O_3	Fe_2O_3	TiO_2	CaO	MgO	K_2O	Na_2O	Ig.loss	Total
Tona Clay	59.9 69.7	21.7 25.3	1.73 2.01	1.99 2.32	0.01 0.01	0.16 0.19	0.18 0.21	tr tr	14.1 —	99.77 99.74
Elutriated Tona Clay	43.4 55.2	30.2 38.4	1.98 2.52	2.43 3.09	0.07 0.09	0.27 0.34	0.23 0.29	tr tr	21.4 —	99.98 99.93
Usangi Clay	56.9 65.5	24.3 28.0	3.10 3.57	2.67 3.08	0.06 0.07	0.13 0.15	0.17 0.20	tr tr	13.2 —	100.53 100.57
Elutriated Usangi Clay	48.2 58.9	27.4 33.5	2.99 3.66	2.51 3.07	0.09 0.11	0.17 0.21	0.21 0.26	tr tr	18.2 —	99.77 99.71
Pugu Kaolin	50.2 57.5	35.4 40.6	0.15 0.17	0.67 0.77	tr tr	tr tr	0.17 0.20	tr tr	12.7 —	99.29 99.24
Kihurio Feldspar	65.5	18.9	0.09	0.01	0.25	0.20	12.24	2.36	0.37	99.94

Notes : The lower figures are analytical values of glass beads.
And, the upper figures are converted values after measurements of ignition losses.