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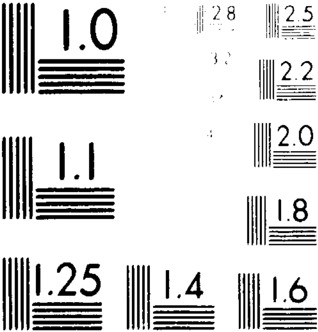
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ASSISTANCE IN THE ESTABLISHMENT OF CLAY PRODUCTS MANUFACTURE

SI/TTP/79/801

TRUST TERRITORY OF THE PACIFIC ISLANDS

Technical report: Potential for local ceramic industry

Prepared for the Government of
the Trust Territory of the Pacific Islands
by the United Nations Industrial Development Organization,
acting as executing agency for the United Nations Development Programme

Based on the work of Miska F. Petersham,
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United Nations Industrial Development Organization
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Explanatory notes

A comma (,) is used to distinguish thousands and millions.

A full stop (.) is used to indicate decimals.

References to dollars ($) are to United States dollars, unless otherwise stated.

The following abbreviation is used in this report:

TTPI	Trust Territory of the Pacific Islands

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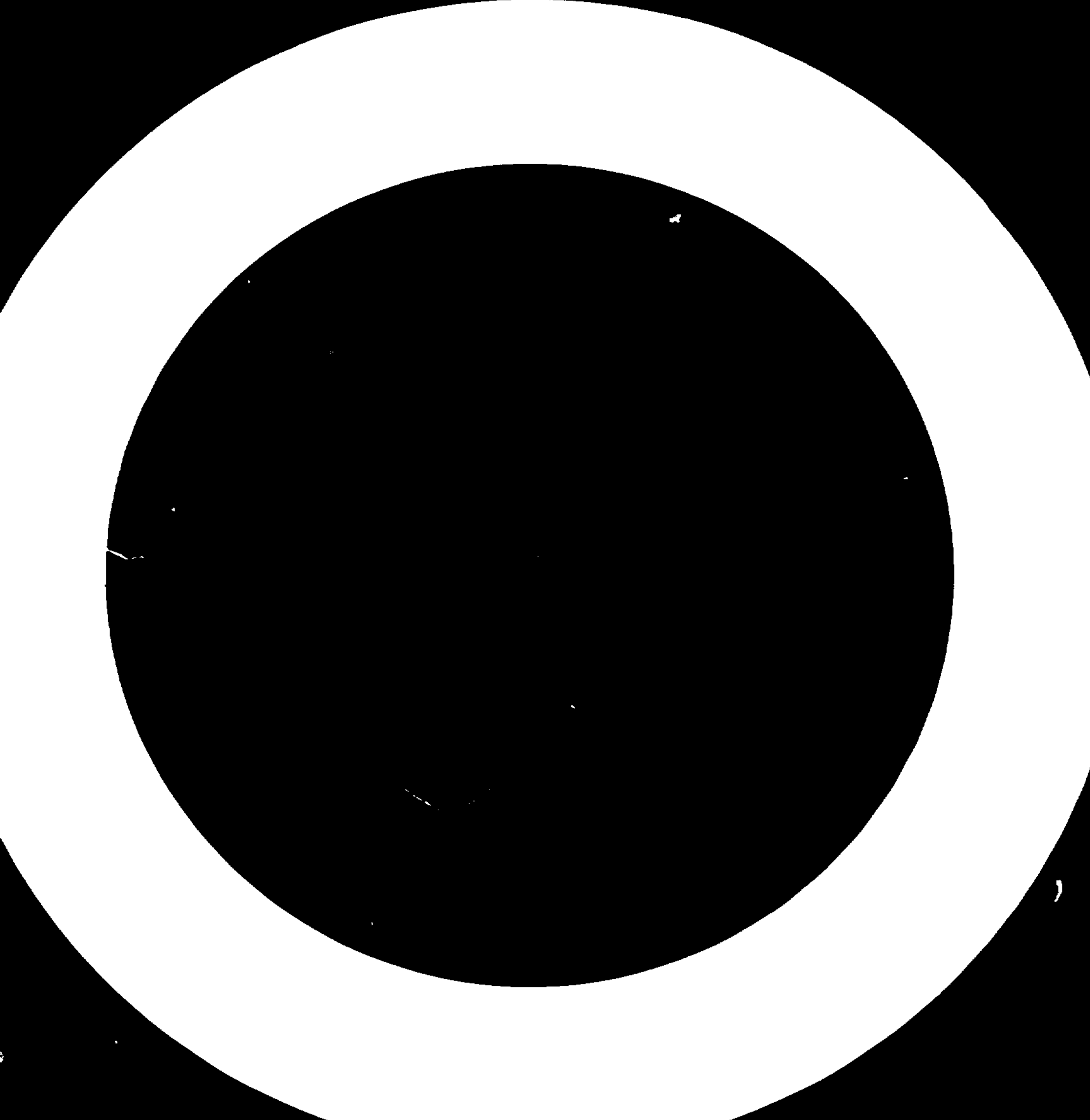
ABSTRACT

The project entitled "Assistance in the establishment of clay products manufacture" (SI/TTP/79/801) arose from a request submitted by the Government of the Trust Territory of the Pacific Islands in June 1979 and approved by the United Nations Development Programme in July 1979. The six-weeks mission covered by this report, which corresponds to phase II of the project, took place in April-May 1980. The specific duties of the expert were as follows:

(a) To procure necessary testing materials and put existing testing facilities in working order;

(b) To carry out a series of tests designed to characterize a range of previously sampled local raw materials;

(c) To carry out a series of shaping and firing trials covering structural clay products and pottery, with a view to identifying technically feasible production technologies.



CONTENTS

INTRODUCTION

The Trust Territory of the Pacific Islands (TTPI) consists of over 2,000 islands covering about 1,300 km^2 of land area distributed over approximately 7,500,000 km^2 of ocean. However, only 84 of the islands are inhabited by a total population estimated at 120,000 in 1978. Most live in the districts of Palau, Yap, Truk and Ponape. The capital is located in Saipan, in the Mariana Islands.

The use of local building materials, including bricks, may become a matter of primary concern with the termination of the trusteeship announced by the United States of America for the near future. The production of pottery for sale to the increasing number of tourists and a local manufacture of ceramic filters represent some of the very few possibilities for industrial development in the Territory. On those grounds, the Government of the Territory requested the co-operation of UNIDO in the investigation of the potential for a local ceramic industry. The project entitled "Assistance in the establishment of clay products manufacture" (SI/TTP/79/801) arose from that request.

The development objective of the project is to promote indigenous industrial activity based on local raw materials. The immediate objectives are:

(a) To identify suitable resources of local clay which could sustain local manufacture of clay products;

(b) To develop the most suitable technologies for local clay products manufacturing units and to assess their feasibility;

(c) To evaluate the overall potential for the development of clay-based industries in the Territory.

The project was divided into three phases. During the first phase a field geologist studied the data on clay deposits, carried out a geological survey and collected samples for laboratory testing. The second phase was to consist in the laboratory analysis of samples. In the third phase a ceramic technologist will study the findings and recommendations of the previous phases, assess the local market for structural clay products and other clay-based items, and prepare prefeasibility studies for production units of appropriate size and technology.

Based on the recommendation of the expert assigned to phase I of the project, phase II was changed from a laboratory to a field test. A ceramic testing expert was therefore needed to test clays from Palau, Truk and Yap and help identify technically feasible production technologies for those areas.

The testing was to be carried out in Koror, Palau. The specific duties of the ceramic testing expert were as follows:

(a) To procure the necessary testing materials and put in working order the existing testing facility and kiln in Palau;

(b) To carry out a series of tests designed to characterize a range of local raw materials sampled by the UNIDO geologist;

(c) To carry out a series of shaping and firing trials covering structural clay products as well as pottery with a view to identifying technically feasible product technologies;

(d) To produce a report presenting findings and recommendations.

A. Summary of previous general findings and proposed follow-up action

Truk is the only one of the three areas with no identifiable historic ceramic activity. Traditional pots were still being produced on Palau in 1912. A report preserved by the Palau Museum on a mission to Palau in that year describes the local making of pottery in some detail. The Museum has a few shards and some old pots are still to be found in remote villages. Pots were made on Yap in the past but information at present is scanty. The observer from Yap to the mission suggests that a few older people might remember the pottery-making skills that have fallen into disuse. From a general knowledge of the area, the shards seen, and the descriptions given, the pots from both Palau and Yap, with coil, paddle and anvil shapes, were utilitarian and brush-fired at approximately 700°-$800^{\circ}C$. Such low-temperature firing of typical high-silica tropical clays makes a soft but very heat-resistant pot ideally suited for use on an open fire. As in other parts of the world, the tradition probably died out as a result of the introduction of tinware and plastic.

Craftsmen from Japan made good-quality brick and salt-glazed roof tiles on Palau before the Second World War. Stoneware and salt-glazed ware were recently made by producers from the United States of America at two locations in Palau. All those products were made wholly or in large part from local clays.

Samples of eight clays from Palau were sent to the United States of America for testing, the results of which will be summarized later in this report. A UNIDO expert also produced a report on the geology of the clays of Palau, Truk and Yap during phase I of the project. All the proceeding information will be used as the basis for testing the Palau clays. Since no previous testing has occurred for Truk and Yap, a more general and basic series of tests was first undertaken.

Based on the findings and recommendations of phase II of the UNIDO project, a ceramics production expert will be sent to Micronesia for phase III of the project. His duties will be to analyse local markets for various types of products, to prepare feasibility studies for appropriate production units, and to assess levels of technology, investments, operating costs etc.

The main development objective of the project is to promote indigenous industrial activity based on local raw materials.

I. BACKGROUND INFORMATION ON CERAMICS MANUFACTURING

A. Relationship of clay type to product

There are many countries in the world today that produce and export highly sophisticated whiteware, both porcelain and fine china. The industry is based on high levels of technology, sources of high-quality raw materials, sophisticated marketing and excellence of design. It is almost impossible for a developing country to produce competitive ware for this market even if raw materials are available, unless a history of some related type of ceramic production is a part of the culture. It is necessary to have quantities of good quality kaolin, felspar, and silica to produce ware of this type. Kaolin, the only one of those materials found in Micronesia, is generally poorly structured with serious iron contamination. Commercial ceramics production also includes a wide range of items from quality giftware to stoneware, hotel china etc. The market is larger, but there are correspondingly more producers. The level of technology is more varied, while the design and marketing aspects are largely comparable. The producers range from full-scale factories to individual craftsmen, hence there is wide variation in the kinds of raw materials used. The materials need not be highly refined, but must still be of sufficient quality to produce handsome durable objects. Micronesia has clays that could be used to produce for this market, but some imports would be necessary to achieve the desired quality level.

There is a large amount of ceramics production throughout the world for local markets. It is primarily utilitarian and generally done with low-temperature clays. Some of the objects are very handsome, but their appeal is usually local and not necessarily adaptable to an export market. The items are often quite fragile because of the low-temperature clay, and therefore do not travel easily. Almost any common surface alluvial clay may be used. Clay of this type may be found on both Yap and Palau. With the exception of such items as flower pots for local consumption, any attempt to revive a historical tradition seems unfeasible.

The building materials market is dominated by a few large producers of technically sophisticated high-quality products. In many developing countries, hand production of brick, tiles etc. is still carried on, but it is only feasible where labour is relatively cheap and costs can be kept below those of imported materials. Good-quality clays are required for more technically sophisticated wares, but there is a much wider quality tolerance than for hollow-ware production.

For less sophisticated products, many clays can be used, the only requirement being a labour force and a market.

In Micronesia the amount of rainfall is an important factor to be taken into account, because it will require the construction of buildings and more sophisticated drying and firing capabilities. In a dry climate, such as that of Pakistan and Iran, bricks are made and fired in the open. Usable clays are available in Micronesia, but a marketing survey must be made to ensure their profitable utilization.

B. Possible product market relationship

Based on observation, experience in Fiji, past reports and information from local people, a few tentative conclusions can be drawn. The conclusions, which should in no way prejudice phase III, may provide an additional basis on which to formulate the final recommendations. Any product made must have some export potential, even if only within Micronesia. The most likely markets would be hotels and the islands of Guam and Saipan. Shipping must therefore be considered an integral part of design and cost analysis. A considerable period of training will also be needed to develop the necessary skills and expertise. Moreover, since the market is highly competitive, excellent and original designs with a distinct Micronesian character will be necessary. Another major concern is lack of motivation, which seems to be part of the reason why the previous pottery projects were abandoned. Serious attempts must therefore be made to find sufficiently motivated persons and change some traditional patterns of thinking. It will be difficult and time-consuming but necessary if there is to be any chance of success. Local clays are adequate but have limitations when used to make commercial products. For example, none of them can be used as a casting body, which is one way of reproducing items without long training periods. Clay is the only raw material available. The type of ware therefore dictates the kind and amount of material imports necessary. The type of clay, scarcity of trained and motivated people, and lack of other raw materials will to a large extent dictate the type of ceramic production that is possible.

II. THE KOROR POTTERY PLANT

A. Condition on 9 April 1980

The Koror pottery plant was found in the following state in April 1980 after more than two years of non-use. The shed had been completely vandalized. Two oil-fired kilns and one electric kiln had been destroyed. All clay and glaze materials had been dumped on the ground or taken. Labels have been removed from the few bins containing materials, making identification without a testing programme impossible. The roof is damaged and full of holes, and wire security screens are torn.

A survey of the premises also produced the following observations:

(a) Five pottery wheels were still in the building;

(b) One randal wheel slightly damaged but usable;

(c) Two kick wheels made from a kit were in satisfactory condition;

(d) Two kick wheels made from a kit were damaged;

(e) One new electric kiln measuring approximately 6 cu ft was in working condition;

(f) Two work benches were shaky but usable;

(g) One small set of shelves were in satisfactory condition;

(h) One material bin was damaged;

(i) Two damaged sinks;

(j) Two electric wheels were found but not checked;

(k) The motors of a pug mill and a jaw crusher were missing;

(l) There were two oil burners, one in satisfactory condition, the other damaged;

(m) Four motors for wheels were in satisfactory condition.

Work on securing the building began just prior to the mission covered by this report.

B. Work done to make the pottery operational

A small padlocked room was constructed on approximately one fourth of the area of the concrete floor. Security screens were repaired and a front door with a lock was put up. A water line and electric lighting and outlets were soon installed. A frame was built for a small electric test kiln completed with materials brought from Suva. Broken kilns were dismantled and good bricks salvaged. The following were found to be in good condition: 936 insulating bricks, 400 clipper fire bricks, and 28 clipper arch fire bricks. Another 450 bricks were in fair condition, and there were 19 silicon carbide shelves measuring

5.5 m x 5.5 m and 9 measuring 6.1 m x 2.7 m in usable condition. Many other damaged bricks would still have some use in kiln construction.

Several broken kiln shelves and a number of shelf supports were in poor condition. A brick stack approximately 5.5 m high was left standing to accommodate the new kiln of approximately 9 cu ft that was constructed using some of the good clipper bricks and insulated with the insulating bricks. Broken and damaged bricks were used wherever possible, and the roof over the kiln was repaired. A small laboratory was set up in the locked room with gram scales, mortar and pestle, measuring cup, pans, screens, small plaster moulds, sodium silicate and other testing equipment.

C. Condition on completion of the mission

The shed was relatively secure, although an agile person could crawl in through holes in the roof. There were many small leaks and some large ones in the roof. If a full-scale operation were to be conducted, extensive roof repairs would be necessary. During heavy rains, the uncemented portion was covered with over 2.5 cm of water and the cement area was occasionally wet. Much of the water seeped in from high ground north-west of the shed. The electricity supply was sufficient for the testing programme but totally inadequate for any more extensive use. There were three operating kilns, one small electric test kiln built by the mission, one large electric commercial unit and one oil-fired downdraft unit. Water was available from a faucet outside the building and three working kick wheels and motors were kept in storage. Laboratory material was packed and delivered to the Government for storage.

Available laboratory equipment

Contributed by UNIDO

1 electric test kiln (metal frame made in Palau)
1 pyrometer with thermocouple
1 15.2 cm mortar and pestle
1 laboratory balance
2 screen rims
3 screen inserts of 60 mm, 120 mm and 200 mm
1 box of assorted ceramic cones
2 plaster test moulds
1 500 ml can of N brand sodium silicate
1 10.1 cm steel die

Contributed by the TTPI

1 frame for test kiln
1 hammer
1 chisel
1 pair of work gloves
1 pair of pliers
1 screwdriver
1 magnifying glass
1 measuring cup
1 covered pail
2 plastic pails
4 plastic pans
1 eyedropper
2 20-mesh screens
2 slop-moulds for bricks
1 catenary arch mould

Some difficulties were caused by the lack of electricity until the last two weeks. The major problem, however, was the inability to dry clays and finished samples. The rainy season was just beginning, which meant some rainfall every day. Having been stored in sealed plastic bags, the sample clays were wet when opened. It would have been very helpful if they could have been pre-dried prior to the mission.

III. SUMMARY OF RELATED TECHNICAL INFORMATION

A. Palau

An abstract of Micronesian minerals lists Airai clay formations distributed over numerous scattered areas of south Babelthuap near Karamado bay. Firms from Japan have mined clay at Ngerasech and 0.8 km north of Oikul. The clay of Ngerasech is composed of relatively fine kaolin, and from 1939 to 1942 over 250,000 bricks, pipes, tiles and pots were produced there. It has been estimated that 23,000-t deposits of white clay exist north of Oikul.

A mineral geology report lists the following three clay types: a weathered volcanic tuff, sedimentary clay with lignite, and the alluvium. A large amount of weathered volcanic tuff of slightly plastic reddish to yellow clay is well distributed on Babelthuap. It is predominately lateritic or bauxitic material that is not usable alone but may have some use as an additive or slip material.

Sedimentary clay with lignite is located in the districts of Airai, Oikul, Aimeliik and Ngatpang, and on the island of Ngerasech. It is of two types, one consisting of red soils over grey clays, and the other of yellow soils over grey clays.

The alluvium occurs in the flood plains of various rivers in the districts of Airai, Aimeliik, and Ngatpang. It is a possible source of clay depending on the difficulties encountered with the high water table during extraction.

Historical pottery production

Pots were made at Ngerasech and Ngatpang as late as 1912. The process was described in a report of a mission to Palau in that year. The report is preserved at the Palau Museum and the clay used would seem to be the alluvium or what potters refer to as common surface clay. Production by firms from Japan at Ngerasech and observation of the brick seem to suggest that the kaolin was used without refinement or additions. The bricks are soft white to pink and quite porous, with a significant quantity of foreign bodies. Pots have also been made in Koror and at Ngersuul using some or all local clay.

Viteralli report, 1977

The Viteralli report describes pottery production using a grey clay (probably the middle Airai clay) mixed with other local (Ngerasech) or imported clays. They were fired at C/7-8 producing both regular stoneware and some salt glazed ware. The field notes are unfortunately not precise enough to locate the clay actually used. Clays from the same geological formation may have drastically different working and firing properties within a few feet of each other. Precise localization is therefore essential.

Alfred report

The Alfred tests involved eight clays, three of which were found suitable for throwing and two for structural clay products, while the remaining three were of less value. The samples were taken from a wide variety of locations.

Hill report

Various clays from the Airai formation were sampled, and attempts were also made, without success, to obtain a sample from the Ngersuul pottery. No samples were taken of the weathered volcanic material because it was not considered to be of ceramic quality. It was concluded that the Airai formation contains three clay horizons, which are described below.

Type A, the top layer, consists of a greenish-white and -red mottled clay. Sample P1-031279A1 was taken from the side of the road approaching the airport at the top of a large erosion scar. Sample P2-031279B1, the top layer of an abandoned pit, lies across the road about 30 m nearer the airport. The clays look similar but have different working qualities. The deposit is estimated to amount to 50,000 m^3 at the airport and a probably similar clay deposit of 23,000 t has been reported near Oikul. It is to be noted that since clays differ markedly in working properties, an actual sampling from several locations in any particular deposit should be made before any large-scale use of the material is considered.

Type B is the middle layer consisting of a grey clay underneath the lignite bed. It is possible that this is the grey plastic clay referred to in the Viteralli report. Approximately 100,000 m^3 would be accessible after removing the top clay and the lignite. Sample P3-031279A2 was taken from the middle level of the erosion scar.

Type C, sample P5-031279A3, the lowest layer exposed in the erosion scar, is a residual rather than sedimentary grey clay weathered green. It would be difficult to mine it in quantity unless the other clays were removed.

A soil survey is currently being conducted in Micronesia. It represents a considerable refinement and enlargement of previous work. Information will be published in the near future and sent to the TTPI Economic Development office in Saipan. It will help to determine the long-scale use of the material in the Airai clay formation, previously estimated to cover 1,619 ha.

B. Truk

A report entitled "Micronesia Minerals, an Abstract", published in 1971 by the division of Lands and Surveys, does not refer to clay. However, another report, known as the Military Geology Report, lists two main clay formations consisting of residual weathered material from the volcanic rock. The one referred to as Truk stony clay is the most common soil on Moen and Dublon. There is no record of pottery-making or any historical use of clays on Truk.

A readily accessible yellowish brown clay, sample 071279A, covers 23 per cent of the upland on Moen and Dublon. A deposit of reddish-brown stony clay, sample 071279B, between 30 cm and 9 m thick covers 90 per cent of the area of Moen and Dublon.

C. Yap

Although the publication "Micronesia Minerals, an Abstract" makes no reference to clay, the Military Geology Report lists two general clay formations, the weathered surfaces of Tomil volcanic clay and Yap green schist. Historically, pottery was made at Gitam, Ngal and Gachlau in all probability using the weathered schist which is the clay most suitable for working by hand. Some of the older people may still know the traditional skills.

The Hill report lists three clays of different origins. One is the fairly accessible weathered surface of the Yap green schist, which is 55 cm thick with 20 cm of overburden. It is located at Dolefebinau from Derikan in the west to Gitam in the east. Samples 261179C(Y3) and 271179A(Y4) consisted of such clay.

The second type is reddish-brown mottled clay, the weathered surface of the Tomil volcanics formation located north of Gachlau near Derikan. Samples 261179B(Y2) and 261179A(Y1) consisted of that clay. The third type is medium brown clay situated near Maki and Murra about 10 k from the other two clays. It provided sample 271179B(Y5).

IV. FIELD WORK

A. Testing procedures

Since no previous testing had been done on Truk and Yap clays, it was originally decided to begin with a series of more general tests. Because of the late installation of electricity, the drying problem and the difficulty of determining exactly which Palau clays were referred to in earlier reports, the same procedure was undertaken for all the clays. Normally, some previous determination of suitability by firing test bars would have preceded any other tests.

A part of each clay was spread out to dry on flat boards exposed to the sun. Some unrefined test bars were made with any clay which seemed free enough from foreign matter, and in two cases a small piece was tried on the wheel. The brick tests were carried out without any knowledge of firing characteristics. Unrefined clay and some water was mixed and allowed to stand for four days. The mixture was then poured into the mould on an earthen floor. When the dried clays were available, the following procedure was used. A portion of each was weighed, slaked and screened through three mesh sizes. The screenings were dried, examined and weighed to determine their percentage of the whole. The bulk of the clay was dry-crushed and screened through a 20-mesh screen. A smaller portion was screened through a 60-mesh screen. The 60-mesh material was used for casting tests and to make test bars. The rest of the coarsely screened clay was apportioned between the throwing tests and the tile tests. Test bars were made from the clay for each throwing test, because some were blends or contained grog. All the test bars and some of the trial pieces were biscuit-fired at 1,000°C. While firing tests at various temperatures were done on the test bars, the remainder of the pieces were bisqued.

B. Testing results

Palau

Sample P1-031279A1 was a greenish-white and -red mottled sedimentary clay taken from the top level of the Airai formation in an erosion scar. The clay had very poor body and low plasticity but became quite hard at 1,300°C. It would probably take a somewhat higher temperature to reach maturity. Although the clay worked well in the slop brick test, it required screening because the large iron nodules, though few, were of a size to disrupt areas of the brick surface. It would not be usable for casting or forming methods requiring plasticity. One brick was made. See annex for details.

Sample P2-031278B1 was from the same geological formation as sample P1 and of similar appearance. It had poor body but a higher plasticity than sample P1. It could be thrown but did not stretch and slump easily. It fired to 1,300°C without deformation, with 31 per cent shrinkage and no absorption. It may be used for bricks and worked well for pressed tiles, but a more plastic addition would be necessary for good throwing. Two bricks, three tiles and two pieces of hollow-ware were made. See annex for details.

Sample P3-031279A2 was taken from the middle level of the erosion scar. A grey sedimentary plastic clay, it is free from foreign material and has a good body. It matures at 1,250°C with 24 per cent shrinkage and no absorption. Two bricks were made, one using 50 per cent of sample P1 and the other using an addition of grog. The bricks were satisfactory, but both would be better if they were sand-moulded or extruded. The clay pressed well for tiles and threw well both alone and with a 50 per cent addition of sample P2. Two bricks, three tiles, 11 pots based on sample P3 with grog and four pots based on samples P3 and P2 were made. The mixture of samples P3 and P2 threw well but was more tender in the kiln than either clay alone. See annex for details.

Sample P4, a dark grey sedimentary clay from the middle level of the Airai formation, is a clay of pleasing texture with good plasticity and body. It comes from the same geological formation as sample P3 but is quite different in its working properties. It matures at 1,200°C with a shrinkage of 19 per cent and absorption of 1 per cent. The clay was suitable for both pressed tiles and throwing and could be easily used for extrusion. There was some warping of the tiles, but everything else dried well.

Three tiles were pressed and eight pieces thrown. A mixture of sample P4 with 50 per cent of sample P1 threw very well but tended somewhat to slump in shallow forms. 18 pieces were made. See annex for details.

Sample P5-031279A3, a green residual clay at the bottom of the Airai formation with a poor body and low plasticity, also came from the erosion scar. It had a maturing temperature of 1,250°C with a 25 per cent shrinkage and no absorption. It would be difficult to use because of its location at the bottom of the erosion scar. Since the properties were not essentially different from those of other clays, no further tests were conducted. See annex for details.

A salt glaze test at a temperature equivalent to pyrometric cone 7-8 was originally scheduled for the Palau clays, but could not be carried out because of difficulties with the oil-burner control and the frequent power failures.

A high-temperature test on the thrown pots also had to be abandoned because of the low voltage. The 220-V line never went higher than 180 V, which kept the top temperature of the kiln under 1,100°C.

Completion of the tests was not deemed essential to the success of the mission. In Koror there exist many samples of pots made from clays fired at stoneware temperature with both salt and regular glaze. The results are quite good and show no problem with body or glaze at such temperatures.

Truk

Sample TI-071279A, a yellowish-brown residual clay from weathered volcanic material, was taken from a road cutting in Edinup. It has very low plasticity and body, but is quite strong when fired. At 1,300°C it has a shrinkage of 25 per cent and an absorption of 10 per cent, which indicates it could be fired at a somewhat higher temperature. It can be used to make satisfactory bricks, but would not be usable for more complex forms or for hollow-ware. One brick was made. See annex for details.

Sample T2-071279B from Sabau is a reddish-brown residual clay weathered from volcanic material. Like sample T1, it has very poor body and low plasticity but becomes quite dense and hard after firing. It matures at 1,200°C, with 35 per cent shrinkage and 2 per cent absorption, makes satisfactory bricks but would be unusable for complex shapes on hollow-ware. One brick was made. See annex for details.

Yap

Sample Y1-261179A from Gachlau is a reddish-brown residual clay weathered from the surface of the Tamil volcanics formation. It has very poor plasticity and body, but becomes hard after firing. The maturing temperature is 1,300°C, with 28 per cent shrinkage and less than 1 per cent absorption. It is suitable for bricks but not usable for more complex shapes or hollow-ware. Two bricks were made. See annex for details.

Sample Y2-261179B from Derikan is a reddish-brown residual clay from the weathered surface of the Tamil volcanics formation. It has poor body and low plasticity but is marginally better than sample Y1. It matures at 1,300°C, with a 27.5 per cent shrinkage and 1 per cent absorption. It was one of the best clays tested for slop-moulding but would be unusable for more complex shapes or hollow-ware. One brick was made. See annex for details.

Sample Y3-261179C from Dinay and Gitam is a yellowish-brown clay weathered from the surface of green schist. It has been traditionally used to make pots in Gitam. The clay has plasticity and body, seems to be easy to handle and matures at 1,125° C, with a shrinkage of 19 per cent and less than 1 per cent absorption. It tends to warp but works well for pressed tiles and throws well. One brick was made with sample Y3 and 50 per cent of sample Y1. Two tiles and three thrown pieces were made. See annex for details.

Sample Y4-271179A from Nummung is a yellowish-brown clay weathered from the surface of green schist. It has fair plasticity and good body, is easy to handle and involves no problems of drying or firing. It presses and throws well and matures at 1,125°C, with 16 per cent shrinkage and 4 per cent absorption. One tile and two thrown pieces were made. A blend of sample Y4 with 50 per cent of sample Y2 threw very well and matured at 1,150°C, with 17 per cent shrinkage and 7 per cent absorption. Five thrown pieces were made. Cracking occurred in glaze-firing. See annex for details.

Sample Y5-271179B from Maki and Murra is a medium-brown clay with good body and fair plasticity. It matures at 1,100°C, with 18 per cent shrinkage and 1.5 per cent absorption, and throws rather poorly with a tendency for edges to crack. There was a severe warping and cracking problem during the bisque firing. It is a poor clay for hollow-ware, but the tile pressed well, and small pressed tiles might prove satisfactory since tile quality was good. One tile and three thrown pieces, two of which cracked in bisque fire, were made. See annex for details.

Sample Y6-271179C came from Ngal. There was only a very small sample and no information was available. Hence only the basic test could be carried out. It has reportedly been used to make traditional pots. The clay has good body and plasticity, and there was no trouble in drying or firing the sample bars. It matures at 1,200°C, with a 25 per cent shrinkage and 0.5 per cent absorption. It appears to offer good results for throwing, pressing or extrusion.

C. Additional data

It should be noted that test results such as the above may be misleading. They provide considerable data about the particular area tested, but should be viewed cautiously when dealing in generalities.

"Natural deposits of clay are usually if not always variable in quality and hand-picking is often necessary." 1/ In order to achieve really accurate results, a complex system of sampling such as "quartering" or blending a variety of samples must be used. Sampling is defined as "the art of extracting from a large bulk of material a small portion which shall properly represent the whole." 2/ As an example of the problems that may be encountered, samples P1 and P2 come from the same geological formation within a few hundred feet of each other and appear quite similar. In practice, however, sample P1 worked well for slop-moulding of bricks, poorly for tile and not at all for throwing. On the other hand, sample P2 worked satisfactorily for brick, well for tile, and fairly well for throwing. There is a significant difference in plasticity, firing, temperature, shrinkage and absorption. The clay at Ngerasech is reportedly of the same geological formation, but old brick and tile made there seem quite different in physical properties. That is not a major problem in small-scale operations using primarily hand methods, since production is slow enough to allow for variations in quality. In a larger more mechanized operation, however, an inaccurate analysis of total reserves must be established to enable the operation to be continuous rather than having to close periodically while searching for material of comparable quality. The testing need not be sophisticated, but must meet the criteria of proper sampling.

The problem of variable quality in clay deposits tends to be exacerbated in tropical climates where there has been volcanic activity. It also seems to be worse in geographically isolated areas such as islands. Under those conditions, the forces that alter rocks to clays are more rapid and localized, while the mixing forces that exist in temperate climates, such as glaciers, do not exist. Such a combination of circumstances can mean significant physical differences within small areas of a clay deposit.

Very little work has been done on the practical use of volcanic and tropical clays. They have been used historically but generally at a rather primitive technical level. In areas of the world such as New Zealand, where both temperate and tropical clays are present, the more difficult to use tropical varieties are seldom actually used. It is difficult if not impossible to use the yardstick of traditional clay theory when trying to categorize tropical clays. Standard

1/ Cardew, Pioneer Pottery (New York, 1969) p. 259.

2/ J. W. Mellor, Quantative Inorganic Analysis (London, 1913) p. 127.

earthenware, ball clay, stoneware etc. was worked out for temperate clays. Moreover, no literature on tropical clays exists, except for casual references in various books.

Tropical clays have been found to do all the things a clay should do, and also some things that traditional theory tells us a clay should not do. Once the properties and peculiarities are known they can be used successfully, but it requires a certain maturity and flexibility to use them without previous knowledge.

Generally speaking, after experience in Fiji with 60 clays, including chemical and mineralogical analysis of 11 clays, and based on a variety of information from New Zealand, New Guinea and Micronesia, the following conclusions seem reasonable. Much more data is necessary for any positive statement on tropical clay qualities.

An extensive shrinkage seems to be normal, 20-25 per cent on average, and occasionally over 30 per cent. This is true for all types of tropical clays found. The alluvial or common red clay comes as close to being similar to temperate earthenware as any, but even here there are differences. The maturing temperatures, even for the red clays, are high, often reaching 1,300°C with no deformation. The clays are usually very tender and in bisque firing have to be stacked individually and fired extremely slowly. They often have high rates of absorption up to the deformation point. There are major differences between geographical areas, but they generally fall within the tropical pattern.

The properties of tropical clays are complex and variable. They contain a high proportion of free silica in an ultra-fine form and clay minerals such as montmorillanite, which do not occur in large amounts in more temperate clays. It is therefore difficult to categorize a particular clay until sufficient work is done to understand its properties. In general, temperate clays are more alike than not. A Kentucky ball clay therefore is close in quality to an English one and its properties can be fairly well predicted. That is not true in the case of tropical clays, and each must be investigated individually. Tests such as those described in this report are necessary to determine the probable uses of the various clay deposits. It should, however, be understood that the deposits are quite variable in their physical qualities and that certain difficulties and peculiarities will affect production methods and prospects.

D. Trip to a brick factory

A trip to Ngerasech Island, which was the site of a Japanese bricks factory during the period 1939-1942, was very rewarding. Enough was left to give a fairly clear picture of the operation. The factory is interesting because the products were of quite good quality and the operation was labour-intensive and not highly mechanized. In fact, it would not be difficult to set up a similar operation if the market report warrants it.

The clay is from the Airai formation top layer and looks very similar to samples P1 and P2. It may well be a purer type of kaolin, since the resulting pieces are white to light pink and free from major inclusions. There is no evidence of refining before use. Only a small amount of clay from the adjacent pit was used, since the plant operated for only three years. A small rail line ran from the plant next to the pit down to the river, thus serving as a means of bringing raw clay up and finished products down. The clay was mulled in a belt- and pulley-operated mix muller of approximately 12.7 cm in diameter. After mulling it was fed into one of four large verticle pug mills that are also belt- and pulley-operated. The mills extruded either bricks, pipes or blanks for the tile press. The press was a hand-operated screw press with metal dies requiring several men for its operation. That part of the works was probably under a shed since no building remains are evident. The firing was done with wood and lignite from the clay pit in a series of kilns connected to one central stack. Tiles and pipes were given a light salting to seal the surface. The results are quite handsome and durable though softer than much of what is now produced commercially.

The craftsman was a potter from Okinawa, and it can be assumed that much of the labour was local. An operation of that type could produce a large amount of material for a comparatively low original investment.

E. Pottery at Ngersuul

The pottery at Ngersuul is in fairly good condition but will deteriorate very quickly if not used. The land, buildings and equipment are the property of one extended family. The facility would require repair and maintenance but is reasonably well equipped. Little would have to be added, except for essential raw materials. The family is very anxious to put the facility to use and have in fact established new homes nearby in order to do so. They will need a trained potter and some financial assistance for at least two or three years. The co-operation of UNIDO would be useful in that respect. The main requirement would be the recruitment of a person qualified to deal with production problems. If someone were found willing to live, work and teach under the existing conditions, back-up funding of approximately $15,000 per year would be required to cover salaries, materials, transport etc. It is unrealistic to expect much income for the first two years, although some should be generated in the second year. The presence of silica sand on one of the Yap Islands was mentioned in casual conversation. The possibility should be investigated because it could prove very useful in any ceramic project undertaken.

V. CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

Palau

Bricks

Bricks could be made by several methods, each of which would give satisfactory results. Sample P1 worked well but needed screening; sample P2 had some cracking problems, as in the case of the combination of samples P2 and and P3; sample P3 and grog worked well; samples P2 and P3 or the combination worked well for sand moulding and extrusion. The best results were achieved by using sample P1 screened or sample P3 with grog. The clay used at Ngerasech is of proven value.

Casting

None of the clays tested was suitable for casting.

Tile

Samples P2, P3 and P4 all pressed well and made adequate tiles; sample P1 lacked body and cracked before releasing; samples P3 and P4 had some tendency to warp, but that can be corrected with the addition of sand or grog and careful drying. The best results seemed to be achieved with samples P2 and P4.

Throwing

Samples P3 and P4 were the best throwing clays and worked well with the addition of 10 per cent of grog. Two blends were tried, one of samples P1 and P4, which threw well but shallow forms tended to slump, another of samples P2 and P3, which threw well but proved to be tender in firing. There should be no problem achieving an excellent throwing body after a little experimentation. The clays were successfully salt-fired, which gives an added advantage by eliminating the cost of one firing.

Truk

Bricks

It would be possible to make bricks from both types of clay, but sample T2 seems slightly better with less surface cracking and more body. Neither clay would work for complex shapes and the brick process would have to be a simple one, but usable bricks of a medium quality could be made.

Casting

Neither clay was suitable for casting.

Tile

Clays cracked on release would not make good tile.

Throwing

The clays tested were not suitable for throwing.

Yap

Bricks

Sample Y2 produced satisfactory bricks, but there were problems with sample Y1, with surface cracks that started in drying and became worse during firing. A combination of sample Y2 with one of the more plastic clays, such as samples Y3, Y4 or Y6, works well for sand-moulding or extrusion. Some brittleness was noted in the blend of samples Y3 and Y1, but control of proportions should overcome that problem.

Casting

None of the clays was suitable for casting.

Tiles

The more plastic clays worked best, but there was some warping. The addition of grog or sand and careful drying should correct that problem. Sample Y5, which was troublesome in other respects, pressed very well. Samples Y3, Y4 or Y6 made adequate terra cotta tiles, and little difference was noted between the three clays in the test.

Throwing

Sample Y5 threw well but showed serious warping and cracking in firing. Samples Y3 and Y4 both threw well and involved no drying or firing problems. The blend of samples Y2 and Y4 threw best. With the exception of sample Y5, the other plastic clays alone or in a blend work quite well for thrown ware. The blend of samples Y2 and Y4 cracked badly in the final glaze test.

B. Recommendations

Palau

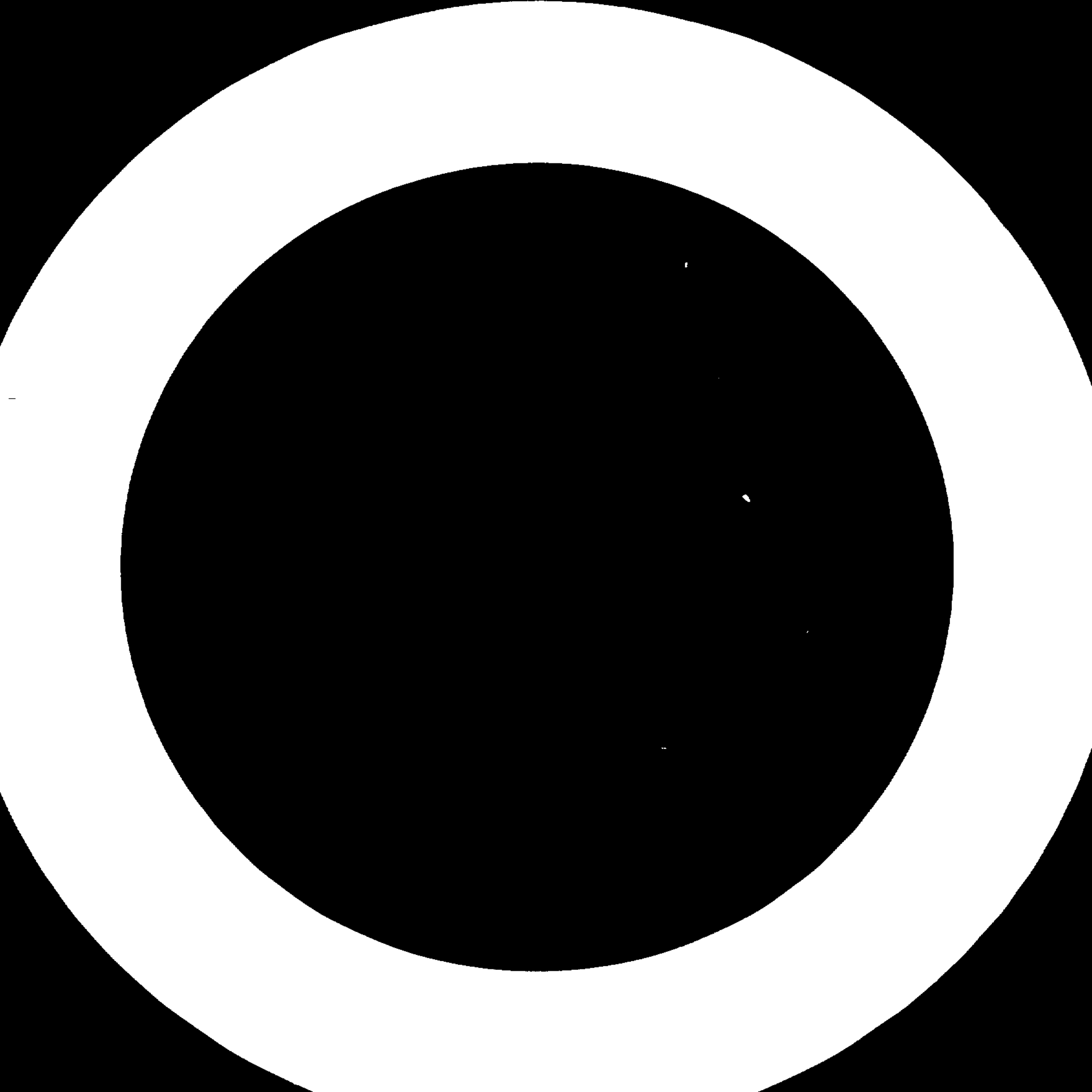
Clays suitable for structural clay products or hollow-ware exist on Palau. Their quality is good to fair and they are quite plentiful. There is, however, a very serious problem of motivation. For example, two potteries existed for several years with people trained, pieces sold and money and time invested in them. When the outside influences left, those enterprises soon collapsed. It would be unwise to undertake any further effort unless some individual or local group (not Government) indicates a willingness to put money and labour into the project. A small production unit suitable for the needs of Palau would require several years of intensive personnel training. A small pottery demands skills, a willingness to learn and much hard physical work. As a first step, the best course of action at present would be to seek a volunteer trainee or establish direct contract with a young potter. In the case of structural ceramics, a slightly larger investment would be needed, but the training would be shorter and less intensive.

Truk

Truk presents a different problem because the skill level required for making only brick can be readily learned and is in effect just a job and not a lifetime commitment. Bricks can be made from Truk clays. The major need is therefore a local entrepreneur willing to invest and a determination of market potential. Some training and supervision would be necessary, but a year should be sufficient.

Yap

There are clays on Yap suitable for making both structural ware and hollow-ware, but their properties are quite different from those of Palau clays. Products made on Yap would therefore differ in quality from those of Palau, and would not directly compete with them. The Yap representative associated with the mission expressed interest in establishing a small workshop. It might therefore be useful to investigate the possibility of sending him on a short-term training mission abroad and assisting in the establishment of the workshop.



Annex

CLAY FIELD TEST RESULTS

A. Palau

Location: Palau; top layer erosion scar: right side of road going toward airport.

Sample identification numbers used in this and other reports [a]:

Petersham P1 Hill 0312779A1

Alfred ______ Vitarelli ______

Clay type: sedimentary

Colour: unfired, greenish, white, red; fired, tan

Body: poor; dry screened through 60 mesh

Plasticity: low

Green strength: low, 1,300°C limit of test equipment

Dry strength: fair

Fired strength: good

Maturity temperature, 1,300°C; total shrinkage, 27%; absorption, 5%

Shrinkage: plastic to dry, 15%; dry to 1,000°C, 3%; 1,000°C to maturity: 9%

Firing data	1,000°C	1,125°C	1,160°C	1,250°C	1,300°C
Colour	Light pink	Light pink	Light pink	Light tan	Tan
Total shrinkage	18%	18%	18%	27%	27%
Absorption	24%	21.5%	24%	7.5%	5%
Ring	Fair	Fair	Fair	Satisfactory	Good
Hardness	Soft	Medium hard	Medium hard	Medium hard	Hard

Gross materials analysis

20 mesh: 1.5%, tubular brown and lavender nodules up to 12.7 mm long, none crystalline white

60 mesh: 1.5%, white, lavender and brown, none crystalline

120 mesh: 1%, white, lavender and brown, none crystalline

Total: 4

Casting test

Clay dry-screened through 60 mesh, N brand sodium silicate deflocculant

Results: not usable

No pieces made

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a/ The reports are identified by the names of their authors.

Brick test

The clay was mixed with water and aged in a plastic bag for four days.

Method: set in a brick-wood slop-mould on an earthern floor

Moulding: pulled well

Drying: moved to side in three hours; hard but cracked over foreign material

Firing: fired satisfactorily at 1,000°C, soft, no further cracking; unable to go higher than 1,070°C because of low voltage

One piece made, of approximately the same hardness as old bricks but pinker, cracked over foreign material.

Tile test

Tile press made from 1.5 t automobile jack, iron frame and 11.4 cm steel die

Pressure: approximately 1 t

Lubricant: engine oil

Clay dried, crushed, screened (20 mesh)

Formula by volume: 1,000 ml clay, 250 ml water

Moulding: poor release, fragility of body, cracked

Two pieces made, both cracked on release

Throwing test

Clay dried, crushed, screened (20 mesh) and rewet to plastic consistency. Wedged and bagged for 2-4 days.

Because of the onset of the rainy season, there was no possibility of slaking, blunging, screening, redrying and aging in time to complete the mission. Therefore the less satisfactory method was chosen, knowing that results would show in most cases a lower degree of plasticity and workability. That fact should be taken into account when evaluating the throwing results.

Additions: base clay not suitable

Location: Palau, top layer of old pit left of road going toward airport, geologically the same as P1.

Sample identification number: Petersham P2 Hill 031279B1
Alfred ______ Vitarelli ______

Clay type:	sedimentary
Colour:	unfired, greenish, white, red; fired, light
Body:	poor to fair, dry-screened through 60 mesh, 12.5% shrinkage
Plasticity:	semi-plastic
Green strength:	low
Dry strength:	fair
Fired strength:	excellent

Maturity temperatuer, 1,300°C; total shrinkage, 31%; no absorption

Shrinkage: plastic to dry, 15%; dry to 1,000°C, 6%; 1,000°C to maturity, 11%

Firing data	1,000°C	1,125°C	1,160°C	1,250°C	1,300°C
Colour	Light buff	Light buff	Light buff	Light buff	Tan
Total shrinkage	20%	21%	22%	31%	31%
Absorption	24%	21%	20%	0	0
Ring	Fair	Fair	Fair	Good	Excellent
Hardness	Medium soft	Medium hard	Medium hard	Hard	Hard

Gross materials analysis

20 mesh: 1%, lavender nodules up to 12.7 mm in diameter
60 mesh: 1%, few white fragments
120 mesh: negligible, lavender nodules and fragments
Total: 2%

Casting test

Clay dry-screened through 60 mesh, N brand sodium silicate deflocculant

Results: not usable

No pieces made

Brick test

The clay was mixed with water and aged in a plastic bag for four days

Method: set in a brick-wood slop-mould on an earthen floor

Moulding: pulled well, but slow to become firm; turned after 12 h

Drying: first sample cracked, dry chopped grass added to second, hard, very few surfaces cracked

Firing: satisfactory at 1,000°C, soft, unable to go higher than 1,070°C because of low voltage, harder than P1, but some surface cracking

Two pieces made

Tile test

Tile press made from 1.5 t automobile jack, iron frame and 11.4 cm steel die

Pressure: approximately 1 t

Lubricant: engine oil

Clay dried, crushed and screened (20 mesh)

Formula by volume: 1,000 ml clay, 250 ml water

Moulding: pressed and released well

Drying: slight warpage

Firing: biscuit satisfactory

Three pieces made

Throwing test

Clay dried, crushed, screened (20 mesh) and rewet to plastic consistency; wedged and bagged for 2-4 days.

Because of the onset of the rainy season there was no possibility of slaking, blunging, screening, redrying and aging in time to complete the mission. Therefore the less satisfactory method was chosen knowing that results would show in most cases a lower degree of plasticity and workability. That fact should be taken into account when evaluating the throwing results.

Additions: base clay, P2 with no screening

Throwing: done on food-powered randal wheel, throws fairly well, edge cracks when opened, not much body

Drying: 12.5% unscreened, satisfactory

Firing: satisfactory

Two unrefined cups made

Location: Palau, erosion scar, middle level, right of the road to the airport, geologically the same as sample P4

Sample identification number: Petersham P3 Hill 031279A2
Alfred 6 Pal F1 Vitarelli ____

Clay type: sedimentary
Colour: unfired, grey; fired, yellowish grey
Body: good, dry screened through 60 mesh
Plasticity: good
Green strength: good, except for screen residue
Dry strength: good
Fired strength: excellent

Maturity temperature, 1,250°C; total shrinkage, 24%; no absorption

Shrinkage: plastic to dry, 12.5%; dry to 1,000°C, 3.5%; 1,000°C to maturity, 8%

Firing data	1,000°C	1,125°C	1,160°C	1,250°C	1,300°C
Colour	Light buff	Light buff	Light buff	Yellowish grey	
Total shrinkage	16%	17%	17%	24%	25%
Absorption	18%	17%	17%	0	0
Ring	Fair	Fair	Good	Excellent	Excellent
Hardness	Medium hard	Medium hard	Medium hard	Very hard,	Very hard,
Other				Slightly warped	Warped

Gross materials analysis

20 mesh: 0%
60 mesh: 6.6%, grey pieces like the clay
120 mesh: 3.5%, grey pieces like the clay
Total: 10.1%, no crystalline structure, felspar or silica apparent

Casting test

Clay dry-screened through 60 mesh, N brand sodium silicate deflocculant

Results: not suitable

No pieces made

Brick test

The clay was mixed with water and aged in a plastic bag for four days

Method: set in a brick-wood slop-mould on an earthen floor

Moulding: both slumped when form-pulled

Drying: both very slow, not turnable in less than 24 h, some cracks, both hard when dry

Firing: both satisfactory but soft at 1,000°C, unable to go higher than 1,070°C because of low voltage

Pieces made: PB3, semi-hard with some cracks; PB4, slight ring, no cracks, would work best in sand mould

Tile test

Tile press made from 1.5 t automobile jack, iron frame 11.4 cm steel die

Pressure: approximately 1 t

Lubricant: engine oil

Clay dried, crushed and screened (20 mesh)

Formula by volume: 1,000 ml clay, 250 ml water

Moulding: pressed and released well

Drying: one warped badly, two warped slightly

Firing: one slight crack, possibly due to release

Three pieces made

Throwing test

Clay dried, crushed, screened (20 mesh) and rewet to plastic consistency; wedged and bagged for 2-4 days.

Because of the onset of the rainy season there was no possibility of slaking, blunging, screening, redrying and aging in time to complete the mission. Therefore the less satisfactory method was chosen knowing that results would show in most cases a lower degree of plasticity and workability. That fact should be taken into account when evaluating the throwing results.

Additions: base clay, P3; grog, 10%, made by pounding shards found at the pottery, coarse screening and removing dust with 120 mesh screen;

Throwing: done on foot-powered randal wheel, throws fairly well

Drying: no problem

Firing: biscuit satisfactory

Pieces made: two ashtrays, three cups, three bowls, two pitchers and one covered jar

Comments: ashtrays survived stacking

Additions: base clay, P3; other clay, P2 50%

Matures at 1,250°C; total shrinkage, 26%; no absorption

Throwing: done on foot-powered randal wheel, throws well

Drying: no problem

Firing: one bowl edge cracks in stacking, one candlestick bottom cracks

Pieces made: two lanterns, one candlestick and one bowl

Comments: biscuit bowl cracked, stacked underneath; clay seems difficult to work and fragile

Location: Palau, visible from first erosion scar, middle level under lignite bed, right side of road across small valley.

Sample identification number: Petersham P4 Hill ______
Alfred 8 Pal F3 Vitarelli ______

Clay type: sedimentary

Colour: unfired, dark grey; fired, yellowish grey

Body: good, dry screened through 60 mesh

Plasticity: good

Green strength: excellent
Dry strength: excellent
Fired strength: excellent
} Several discrepancies, but fairly close to Alfred results

Maturity temperature: 1,200°C; total shrinkage, 19%; absorption, 1%

Shrinkage: plastic to dry, 11%; dry to 1,000°C, 4%; 1,000°C to maturity, 4%

Firing data	1,000°C	1,125°C	1,160°C	1,250°C	1,300°C
Colour	Tan grey	Light tan	Light tan	Tan to brown	Brown
Total shrinkage	15%	13%	16%	20%	22.5%
Absorption	19%	16.5%	16%	0	0
Ring	Good	Good	Good	Good	Excellent
Hardness	Medium hard	Medium hard	Hard	Very hard	Very hard
Other				Brittle, grey	Small bloat

Gross materials analysis

20 mesh: 0%

60 mesh: 4.2%, seems to be same material as clay

120 mesh: 3.2%, no apparent silica or felspar

Total: 7.4%

Casting test

Clay dry-screened through 60 mesh, N brand sodium silicate deflocculant

Results: not usable

No pieces made

Brick test

No brick test carried out because of high plasticity of clay

Clay was mixed with water and aged in a plastic bag for four days

Method: set in a brick-wood slop-mould on an earthen floor

No pieces made

Tile test

Tile press made from 1.5 t automobile jack, iron frame and 11.4 cm steel die

Pressure: approximately 1 t

Lubricant: engine oil

Clay dried, crushed and screened (20 mesh)

Formula by volume: 1,000 ml clay, 250 ml water

Moulding: pressed and released well

Drying: two warped badly, one warped slightly

Firing: small surface crack on piece at bottom of stack

Three pieces made

Throwing test

Clay dried, crushed, screened (20 mesh) and rewet to plastic consistency: wedged and bagged for 2-4 days.

Because of the onset of the rainy season there was no possibility of slaking, blunging, screening, redrying and aging in time to complete the mission. Therefore the less satisfactory method was chosen knowing that results would show in most cases a lower degree of plasticity and workability. That fact should be taken into account when evaluating the throwing results.

Additions: base clay, P4; grog, 15%, made by pounding shards found at the pottery, coarse screening and removing dust with 120 mesh screen

Throwing: done on foot-powered randal wheel, throws fairly well, some cracks on stretching

Drying: 10%, no problem

Firing: biscuit satisfactory

Pieces made: two ashtrays, four bowls, one pitcher and one candlestick

Comments: ashtrays survived stacking

Additions: base clay, P4; other clay, P1, 50%

Throwing: done on foot-powered randal wheel, throws well but not much body, shallow forms tend to crack and slump

Firing: one bowl bottom cracked because of trimming too thin

Pieces made: four bowls, three bottles, two pitchers, two ashtrays

P6, mature at 1,250°C	P7, mature at 1,250°C	No pots made
Total shrinkage 23%	Total shrinkage 25%	
No absorption	No absorption	
Fair plasticity for body	Good plasticity	
	Good body	

Location: Palau, bottom layer erosion scar, right side of road to airport

Sample identification number Petersham P5 Hill 031279A3

Alfred ______ Vitarelli ______

Clay type:	residual
Colour:	unfired, green; fired, yellowish brown
Body:	poor, dry screened through 60 mesh
Plasticity:	poor
Green strength:	low
Dry strength:	fair
Fired strength:	excellent

Maturity temperature, 1,250°C; total shrinkage 25%; no absorption

Shrinkage: plastic to dry, 12.5%; dry to 1,000°C, 5%; 1,000°C to maturity, 7.5%

Firing data	1,000°C	1,125°C	1,160°C	1,250°C	1,300°C
Colour	Light buff	Light buff	Light buff	Yellowish brown	Yellowish tan
Total shrinkage	17.5%	17.9%	17.5%	25%	26%
Absorption	18%	17%	16.5%	0	0
Ring	Good	Good	Good	Good	Excellent
Hardness	Medium hard	Medium hard	Medium hard	Hard	Very hard

Gross materials analysis

20 mesh: 0.5%, few brown stones 3.17 mm in diameter

60 mesh: 1%

120 mesh: 0.5%

Total: 2%

Casting test

Clay dry-screened through 60 mesh, N brand sodium silicate deflocculant

Results: not usable

No pieces made

No further tests carried out because of relative difficulty of obtaining clay and lack of suitable properties.

B. Truk

Location: Truk

Sample identification number: Petersham T1 Hill 071279A
Alfred ______ Vitarelli ______

Clay type: residual
Colour: unfired, yellowish brown; fired, dark reddish brown
Body: none, dry screened through 60 mesh
Plasticity: none
Green strength: low
Dry strength: low
Fired strength: good

Maturity temperature, 1,300°C; total shrinkage, 25%; absorption, 10%

Shrinkage: plastic to dry, 10%; dry to 1,000°C, 6%; 1,000°C to maturity, 9%

Firing data	1,000°C	1,125°C	1,160°C	1,250°C	1,300°C
Colour	Red	Dark red	Dark red	Reddish brown	Dark reddish brown
Total shrinkage	16%	20%	23%	25%	25%
Absorption	27%	19%	15%	12%	10%
Ring	Some	Good	Good	Good	Good
Hardness	Medium soft	Hard	Hard	Hard	Hard

Gross materials analysis

20 mesh: 0%
60 mesh: 7.4%, brown rock fragments
120 mesh: 1.5%, brown rock fragments, no apparent silica or felspar
Total: 9%

Casting test

Clay dry-screened through 60 mesh, N brand sodium silicate deflocculant

Results: will not deflocculate

No pieces made

Brick test

The clay was mixed with water and aged in a plastic bag for four days

Method: set in a brick-wood slop-mould on an earthen floor

Moulding: slight slumping when form-pulled, stiffer mix would be correct, turned after 12 hours

Drying: some surface cracks, reasonably strong

Firing: satisfactory but soft at 1,000°C, unable to go higher than 1,070°C because of low voltage; fair strength, should be satisfactory if fired higher

One brick made

Tile test

Tile press made from 1.5 t automobile jack, iron frame and 11.4 cm steel die

Pressure: approximately 1 t

Lubricant: engine oil

Clay dried, crushed and screened (20 mesh)

Formula by volume: 1,000 ml clay, 250 ml water

Moulding: broken on release, not enough body for die used

No pieces made

Throwing test

Clay dried, crushed, screened (20 mesh) and rewet to plastic consistency. Wedged and bagged for 2-4 days.

Because of the onset of the rainy season, there was no possibility of slaking, blunging, screening, redrying and aging in time to complete the mission. Therefore the less satisfactory method was chosen knowing that results would show in most cases a lower degree of plasticity and workability. That fact should be taken into account when evaluating the throwing results.

Location: Truk Sabau

Sample identification number: Petersham T2 Hill 071279B

Alfred ______ Vitarelli ______

Clay type: residual

Colour: unfired, reddish brown; fired, dark reddish brown

Body: poor, dry screened through 60 mesh

Plasticity: poor

Green strength: low

Dry strength: fair

Fired strength: good

Maturity temperature, 1,200°C; total shrinkage, 35%; absorption, 2%

Shrinkage: plastic to dry, 16%; dry to 1,000°C, 7%; 1,000°C to maturity, 12%

Firing data	1,000°C	1,125°C	1,160°C	1,250°C	1,300°C
Colour	Dark red	Reddish brown	Reddish brown	Dark reddish brown	Dark reddish brown
Total shrinkage	23%	32%	32.5%	33.5%	34%
Absorption	21%	2%	3%	1%	½%
Ring	Fair	Good	Good	Good	Excellent
Hardness	Medium soft	Hard	Hard	Hard	Hard
Other				Brittle	Slight warping

Gross materials analysis

20 mesh: 1%, a few small stones

60 mesh: 0%, negligible

120 mesh: 0%, negligible, settled quickly even after passing

Casting test

Clay dry-screened through 60 mesh, N brand sodium silicate deflocculant

Results: not usable

No pieces made

Throwing: done on foot-powered randal wheel; not suitable for throwing

Brick test

Clay was mixed with water and aged in a plastic bag for four days

Method: set in a brick-wood slop-mould on an earthen floor.

Moulding: some slumping, turned after 12 hours

Drying: satisfactory, strong enough

Firing: satisfactory at 1,000°C but soft, unable to go higher than 1,070°C because of low voltage

Tile test

Tile press made from 1.5 t automobile jack, iron frame and 11.4 cm steel die.

Pressure: approximately 1 t

Lubricant: engine oil

Clay dried, crushed and screened (20 mesh)

Formula by volume: 1,000 ml clay, 250 ml water

Moulding: broke on release, not enough body for die used

No pieces made

Throwing test

Clay dried, crushed, screened (20 mesh) and rewet to plastic consistency; wedged and bagged for 2-4 days.

Because of the onset of the rainy season there was no possibility of slaking, blunging, screening, redrying and aging in time to complete the mission. Therefore the less satisfactory method was chosen knowing that results would show in most cases a lower degree of plasticity and workability. That fact should be taken into account when evaluating the throwing results.

Throwing: done on foot-powered randal wheel, not suitable for throwing

C. Yap

Location: Yap Gachlau; weathered surface, Tomil volcanic clay, same geological formation as sample Y2

Sample identification number: Petersham Y1 Hill 261179A
Alfred ____ Vitarelli ____

Clay type: residual
Colour: unfired, reddish brown; fired, dark reddish brown
Body: poor, dry screened through 60 mesh
Plasticity: poor
Green strength: low
Dry strength: low to fair
Fired strength: good

Maturity temperature, 1,300°C: total shrinkage, 28%; absorption, under 1%

Shrinkage: plastic to dry, 12.5%; dry to 1,000°C, 5.5%; 1,000°C to maturity, 10%

Firing data	1,000°C	1,125°C	1,160°C	1,250°C	1,300°C
Colour	Orange	Orange red	Red	Reddish brown	Dark reddish brown
Total shrinkage	18%	20%	22%	27.5%	28%
Absorption	24%	17%	13%	1%	0.8%
Ring	Fair	Good	Good	Good	Excellent
Hardness	Medium hard	Hard	Hard	Hard	Hard

Gross materials analysis

20 mesh: negligible
60 mesh: negligible, few small fragments of reddish stone
120 mesh: 0.5%, small dark rock fragments, no apparent silica or felspar
Total: 0.5%

Casting test

Clay dry-screened through 60 mesh, N brand sodium silicate deflocculant

Results: not suitable

No pieces made

Brick test

Clay was mixed with water and aged in a plastic bag for four days

Method: set in a brick-wood slop-mould on an earthen floor

Moulding: pulled well

Drying: first piece cracked after two hours; second piece dried satisfactorily, turned after eight hours; hard with some surface cracks

Firing: satisfactory at 1,000°C but soft, unable to go higher than 1,070°C because of low voltage

Pieces made: one cracked, another small semi-hard piece with surface cracks, some dry chopped grass added

Tile test

Tile press made from 1.5 t automobile jack, iron frame and 11.4 cm steel die.

Pressure: approximately 1 t

Lubricant: engine oil

Clay dried, crushed and screened (20 mesh)

Formula by volume: first test, 1,000 ml clay, 250 ml water; second test, 1,050 ml clay, 250 ml water

Moulding: cracked on release

Two pieces made, both cracked on release

Throwing test

Clay dried, crushed, screened (20 mesh) and rewet to plastic consistency; wedged and bagged for 2-4 days.

Because of the onset of the rainy season there was no possibility of slaking, blunging, screening, redrying and aging in time to complete the mission. Therefore the less satisfactory method was chosen knowing that results would show in most cases a lower degree of plasticity and workability. That fact should be taken into account when evaluating the throwing results.

Throwing: done on foot-powered randal wheel, not suitable

No pieces made

Location: Yap Derikan, same geological formation as Y1

Sample identification number: Petersham Y2 Hill 261179B
Alfred ______ Vitarelli ______

Clay type:	residual
Colour:	unfired, reddish brown; fired, dark reddish brown
Body:	poor, dry screened through 60 mesh
Plasticity:	poor, but better than Y1
Green strength:	fair
Dry strength:	fair
Fired strength:	good

Maturity temperature, 1,300°C; total shrinkage, 27.5%; absorption, 1%

Shrinkage: plastic to dry, 11.5%; dry to 1,000°C, 4.5%; 1,000°C to maturity, 11.5%

Firing data	1,000°C	1,125°C	1,160°C	1,250°C	1,300°C
Colour	Orange	Orange red	Orange red	Reddish brown	Dark reddish brown
Total shrinkage	16%	17.59%	18%	23.5%	27.5%
Absorption	26%	21%	12%	7.5%	1%
Ring	Fair	Fair to good	Fair to good	Good	Good to excellent
Hardness	Medium hard	Hard	Hard	Hard	Hard

Gross materials analysis

20 mesh: 0.5%, yellow red fragments
60 mesh: 1.5%, yellow red fragments
120 mesh: 1%, yellow red fragments
Total: 3%, no apparent silica felspar

Casting test

Clay dry-screened through 60 mesh, N brand sodium silicate deflocculant

Results: seemed to deflocculate but thickened on standing and cracked in mould (not usable)

Two pieces made, both cracked in mould

Brick test

Clay was mixed with water and aged in a plastic bag for four days

Method: set in a brick-wood slop-mould on an earthen floor

Moulding: pulled well

Drying: able to turn after three hours, hard, few surface cracks

Firing: fired satisfactorily to 1,000°C but somewhat soft, unable to go higher than 1,070°C because of low voltage, semi-hard, no additional cracks

Tile test

Tile press made from 1.5 t automobile jack, iron frame and 11.4 cm steel die

Pressure: approximately 1 t

Lubricant: engine oil

Clay dried, crushed and screened (20 mesh)

Formula by volume: first test, 1,000 ml clay, 300 ml water; second test, 1,000 ml clay, 250 ml water

Moulding: both pieces cracked on release

Two pieces made, production possible but not without difficulties

Throwing test

Clay dried, crushed, screened (20 mesh) and rewet to plastic consistency; wedged and bagged for 2-4 days.

Because of the onset of the rainy season there was no possibility of slaking, blunging, screening, redrying and aging in time to complete the mission. Therefore the less satisfactory method was chosen knowing that results would show in most cases a lower degree of plasticity and workability. That fact should be taken into account when evaluating the throwing results.

Throwing: done on foot-powered randal wheel, not suitable

Location: Yap Dinay and Gitam, weathered surface of green schist, geologically the same as sample Y4

Sample identification number: Petersham Y3 Hill 261179C
Alfred ______ Vitarelli ______

Clay type: residual, used to make traditional pots in Gitam

Colour: unfired, yellowish brown; fired, reddish brown

Body: good, dry screened through 60 mesh

Plasticity: good

Green strength: good

Dry strength: excellent

Fired strength: good

Maturity temperature, 1,125°C; total shrinkage, 19%; absorption, less than 1%

Shrinkage: plastic to dry, 12.5%; dry to 1,000°C, 4%; 1,000°C to maturity, 2.5%

Firing data	1,000°C	1,100°C	1,125°C	1,160°C
Colour	Red	Reddish brown	Reddish brown	Reddish brown
Total shrinkage	16.5%	18%	19%	18%
Absorption	4%	7%	0.7%	
Ring	Good	Good	Good	Good
Hardness	Hard	Hard	Hard	Hard
Other			Slight sheen	Bloating

Gross materials analysis

20 mesh: 3%, black, grey and yellow fragments up to 12.7 mm, no crystalline structure

60 mesh: 1%, same as above but smaller, yellowish grey regular size

120 mesh: 0.5%

Total: 4.5%

Casting test

Clay dry-screened through 60 mesh, N brand sodium silicate deflocculant

Results: not suitable, did not deflocculate

No pieces made

Brick test

Clay was mixed with water and aged in a plastic bag for four days

Method: set in a brick-wood slop-mould on an earthen floor

Moulding: clay sticky but form pulled

Drying: turned after three hours, hard

Firing: fired satisfactorily at 1,000°C, medium hard, unable to go higher than 1,070°C because of low voltage

Tile test

Tile press made from 1.5 t automobile jack, iron frame and 11.4 cm steel die

Pressure: approximately 1 t

Lubricant: engine oil

Clay dried, crushed and screened (20 mesh)

Formula by volume: 1,000 ml clay, 250 ml water

Moulding: released well

Drying: one piece warped slightly, another badly

Firing: biscuit satisfactory at 1,000°C

Two pieces made, both brittle

Throwing test

Clay dried, crushed, screened (20 mesh) and rewet to plastic consistency; wedged and bagged for 2-4 days.

Because of the onset of the rainy season there was no possibility of slaking, blunging, screening, redrying and aging in time to complete the mission. Therefore the less satisfactory method was chosen knowing that results would show in most cases a lower degree of plasticity and workability. That fact should be taken into account when evaluating the throwing results.

Additions: base clay, Y3; grog, 10%, made by pounding shards found at the pottery, coarse screening and removing dust with 120 mesh screen

Throwing: done on foot-powered randal wheel, throws well

Drying: no problem

Firing: biscuit satisfactory, glazed at 1,060°C

Pieces made: one bowl, one cup and one pitcher

It was not possible to achieve a temperature higher than 1,060°C for the glaze test because of low voltage.

Location Yap near Numming, geologically the same formation as Y3

Sample identification number: Petersham Y4 Hill 271179A

Alfred ______ Vitarelli ______

Clay type: residual

Colour: unfired, yellowish brown; fired, reddish brown

Body: good, dry screened through 60 mesh

Plasticity: fair

Green strength: good

Dry strength: excellent

Fired strength: good

Maturity temperature, 1,125°C; total shrinkage, 16%; absorption, 4%

Shrinkage: plastic to dry, 10%; dry to 1,000°C, 4%; 1,000°C to maturity, 6%

Firing data	1,000°C	1,100°C	1,125°C	1,160°C
Colour	Red	Red	Reddish brown	
Total shrinkage	14%	12.5%	16%	20%
Absorption	9	4	4	
Ring	Good	Good	Good	Good
Hardness	Hard	Hard	Hard	
Other				Brittle, slumped and bloated

Gross materials analysis

20 mesh: 11%, pieces of green schist with black fragments and brown nodules of iron up to 12.7 mm in diameter

60 mesh: 3%

120 mesh: 2.2%, same general mix

Total: 17.5%

Casting test

Clay dry screened through 60 mesh, N brand sodium silicate deflocculant

Results: not suitable, will not deflocculate

No pieces made

Brick test

No brick test conducted because of high plasticity of clay

Clay was mixed with water and aged in a plastic bag for four days

Method: set in a brick-wood slop-mould on an earthen floor

No pieces made

Tile test

Tile press made from 1.5 t automobile jack, iron frame and 11.4 cm steel die

Pressure: approximately 1 t

Lubricant: engine oil

Clay dried, crushed and screened (20 mesh)

Formula by volume: 1,000 ml clay, 250 ml water

Moulding: pressed and released well

Drying: slight warping

Firing: biscuit satisfactory at 1,000°C

One piece made

Throwing test

Clay dried, crushed, screened (20 mesh) and rewet to plastic consistency; wedged and bagged for 2-4 days.

Because of the onset of the rainy season there was no possibility of slaking, blunging, screening, redrying and aging in time to complete the mission. Therefore the less satisfactory method was chosen knowing that results would show in most cases a lower degree of plasticity and workability. That fact should be taken into account when evaluating the throwing results.

Additions: base clay, Y4; grog, 10%, made by pounding shards found at the pottery, coarse screening and removing dust with 120 mesh screen

Throwing: done on foot-powered randal wheel, throws well

Drying: satisfactory

Firing: biscuit and glaze satisfactory

Pieces made: two bowls

It was not possible to achieve a temperature higher than 1,060°C because of low voltage.

Additions: base clay, Y4, maturing temperature, 1,150°C; other clay, 50% Y2

Throwing: done on foot-powered randal wheel, throws very well

Drying: satisfactory

Firing: biscuit satisfactory, glaze cracked

Pieces made: two bowls, one ashtray, one pitcher and one cup

Shrinkage	1,000°C	1,125°C	1,160°C	1,250°C
	13%	17%	17%	
Absorption	17%	7%	7%	Bloated and slumped

Of the three items tested in a glaze kiln, one bowl, one cup and one ashtray, the bowl and cup cracked badly. The cracks occurred during cooling and were probably caused by contraction of the glaze.

Location: Yap, Maki and Murru

Sample identification number: Petersham Y5 Hill 271179B
Alfred ______ Vitarelli ______

Colour: unfired, medium brown; fired, reddish brown
Body: good, dry screened through 60 mesh
Plasticity: fair
Green strength: good
Dry strength: fair to good
Fired strength: fair

Maturity temperature, 1,100°C; total shrinkage, 18%; absorption 1.5%

Shrinkage: plastic to dry, 12.5%; dry to 1,000°C, 5.5%; 1,000°C to maturity, 0%

Firing data	1,000°C	1,100°C	1,125°C	1,160°C
Colour	Red	Reddish brown	Reddish brown	Reddish brown
Total shrinkage	18%	18%	20%	20%
Absorption	6%	1.5%	1%	0%
Ring	Good	Good	Good	Good
Hardness	Hard	Hard	Hard	Brittle
Other	Warped badly		Brittle	

Gross materials analysis

20 mesh: 3.5%, largest diameter, 6.35 mm, mostly iron nodules, few particles of possibly quartz and black crystalline

60 mesh: 3.5%, same general mix but more quartz

120 mesh: 1%, same general mix but more quartz and black crystals
Total: 8%

Casting test

Clay dry-screened through 60 mesh, N brand sodium silicate deflocculant

Results: not suitable

No pieces made

Brick test

No brick test made because of high plasticity

Clay was mixed with water and aged in a plastic bag for four days

Method: set in a brick-wood slop-mould on an earthen floor

No pieces made

Tile test

Tile press made from 1.5 t automobile jack, iron frame and 11.4 cm steel die

Pressure: approximately 1 t

Lubricant: engine oil

Clay dried, crushed and screened (20 mesh)

Formula by volume: 1,000 ml clay, 250 ml water

Moulding: pressed and released well

Drying: very slight warping

Firing: biscuit satisfactory at 1,000°C

Throwing test

Clay dried, crushed, screened (20 mesh) and rewet to plastic consistency; wedged and bagged for 2-4 days.

Because of the onset of the rainy season there was no possibility of slaking, blunging, screening, redrying and aging in time to complete the mission. Therefore the less satisfactory method was chosen knowing that results would show in most cases a lower degree of plasticity and workability. That fact should be taken into account when evaluating the throwing results.

Additions: base clay, Y5; grog, 10%, made by pounding shards found at the pottery, coarse screening and removing dust with 120 mesh screen

Throwing: done on foot-powered randal wheel, does not throw well, edge cracks

Drying: 11%, some warping

Firing: one candlestick cracked at bottom, cup cracked at bottom and warped

Pieces made: one bowl, one candlestick and one cup

The clay has a tendency to crack and warp. It could be used but seems to be a problem clay. If used, samples should be extensively tested. Its best use would be in small pressed tiles.

Location: Yap Ngaf

Sample identification number	Petersham	Y6	Hill	271179C
	Alfred		Vitarelli	

Colour: unfired, brown; fired, reddish brown

Body: good, dry-screened through 60 mesh

Plasticity: good

Green strength: good

Dry strength: good

Fired strength: good

Maturity temperature, 1,200°C; total shrinkage, 25%; absorption, 0.5%

Shrinkage: plastic to dry, 13%; dry to 1,000°C, 5%; 1,000°C to maturity, 7%

Firing data	1,000°C	1,125°C	1,160°C	1,250°C
Colour	Orange	Reddish brown	Reddish brown	Dark reddish brown
Total shrinkage	18%	22.5%	23%	24%
Absorption	18%	5%	4%	0
Ring	Good	Good	Good	Good
Hardness	Fairly hard	Hard	Hard	Hard
Other				Started to bloat

Gross materials analysis

20 mesh: 7.5%, brown and black nodules up to 12.7 mm in diameter

60 mesh: 1%, brown and some white crystalline nodules

120 mesh: 0.5%, brown and white

Total: 9%

Sample too small to do more than basic tests

Casting test

Clay dry-screened through 60 mesh, N brand sodium silicate deflocculant